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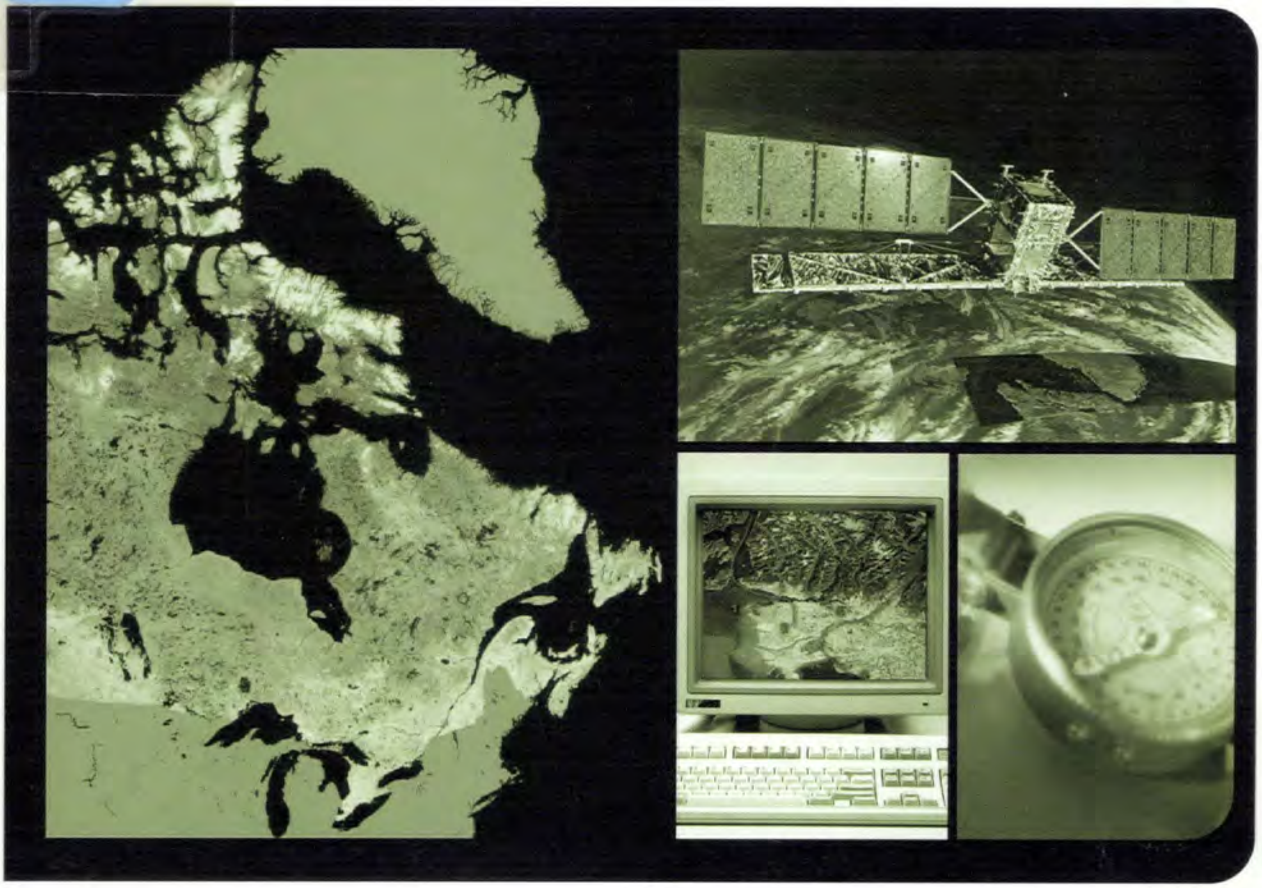
Geomatics Industry Association of Canada / L'Association Canadienne des Entreprises de Géomatique

> TECHNOLOGY ROADMAP



>> Geomatics

SPECIAL REPORT

Canada

Geomatics

Technology Roadmap:

Special Report

Government of Canada

Canadian Institute of Geomatics

Geomatics Industry Association of Canada

November 1998

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FOREWORD

The Canadian geomatics industry is once again entering an exciting period of rapid growth that promises great benefits to firms that can identify future markets and seize the prime opportunities they offer.

Innovation is the key to success in constantly evolving market situations. The Geomatics Technology Roadmap is an outstanding first step toward ensuring that appropriate and critical technologies are developed. This in turn will drive the creation of new applications and required solutions to business problems that will allow Canada and Canadian companies to effectively capture new and expanding markets.

This Geomatics Technology Roadmap presents an exceptional means for charting future market direction, technological innovation, research and development and technology transfer, technological forecasting, and the strategic choices that need to be made in the geomatics industry. It highlights the driving forces of technology development and presents valuable tools for assessing the direction of the technological improvement within geomatics and related industry sectors that rely upon the use of geospatially referenced data.

Another key to success in the evolving marketplace is the formation of dynamic partnerships among public and private sector organizations. These partnerships were critical to the development of the Geomatics Technology Roadmap and will be equally crucial to its evergreening. Through the continued addition of valuable information and dialogue between stakeholders, an evergreen roadmap will be important in setting policy and planning objectives for both industry and government.

By successfully completing this first edition of the Geomatics Technology Roadmap we have already achieved a more collaborative working relationship among partners in both industry and government, and with innovators in the academic community. Ultimately, we hope that our partnering efforts will result in a more coordinated and productive geomatics industry sector.

We would like to acknowledge the full support of the Geomatics Industry Association of Canada, the Canadian Institute of Geomatics, all persons involved in the regional roadmap consultations, and the Technology Roadmap Steering Committee for making this Geomatics Technology Roadmap possible.

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INTRODUCTION

Vision

To help make the Canadian geomatics sector the world's preferred source of supply for its geomatics-related needs.

Purpose

The Technology Roadmap (TRM) initiative is a consultative process designed to assist the geomatics industry, its associations, government and academia jointly to identify the market segments that will be the source of the geomatics industry's growth in the next five to ten years, and to identify the critical technologies required to produce the goods and services demanded by these markets. This document will serve as a base discussion paper for developing a set of recommended actions to ensure that the Canadian geomatics industry is technologically prepared to address future market demands.

Goal

To provide public and private sector decision makers with information about industry views on future market-driven technology needs and to facilitate related investment, training and policy decisions as well as to guide the industry's new research agenda.

Background

In mid-1997, Industry Canada released its Sector Competitiveness Frameworks study on *Geomatics: Part 1 – Overview and Prospects* (Ottawa: Industry Canada, 1997). *Part 2 – Framework for Action* in the same series is scheduled for completion in the coming months. These documents provide an overview of the industry in terms of trade, technology, investment, human resources and sustainable development. They focus on opportunities, both domestic and international, as well as on challenges facing the sector. The critical importance of technology-related issues to this industry became evident early on in the development of these documents. At this time, the feasibility of a Technology Roadmap for the industry was investigated.

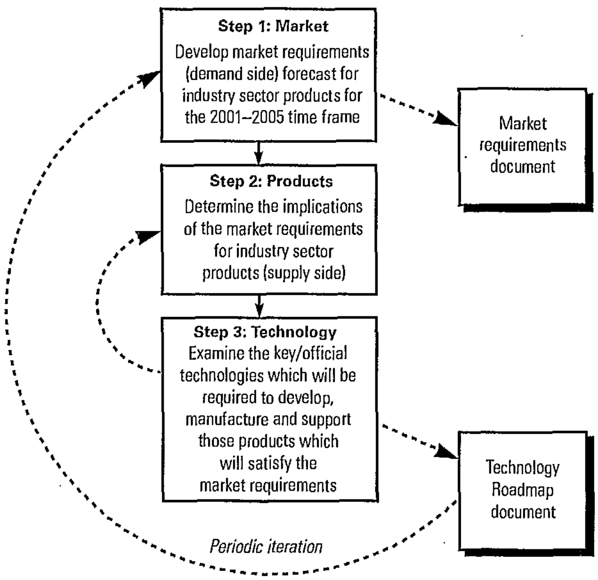
Drawing on the experience gained from the process of writing the Sector Competitiveness Frameworks and on advice from a steering committee, which was headed by Dr. John McLaughlin of the University of New Brunswick and which comprised industry stakeholders from the private sector, government and academia (see Appendix A for a list of steering committee participants), Industry Canada began to work on development of a TRM process for the geomatics industry in the summer of 1997. In cooperation with the Geomatics Industry Association of Canada and Geomatics Canada, a series of consultations were held in Vancouver, Calgary, Regina, Winnipeg, Toronto, Ottawa, Montreal and Halifax during the fall of 1997, which involved more than 100 sector representatives (see Appendix B for a list of workgroup participants). The goal of these consultations was to gain an understanding of what the stakeholders believed to be the industry's key future markets and critical technologies and to capture the sector's perspective on this industry-led, government-facilitated document. The production of this document represents the successful completion of this goal.

The TRM is based on geomatics industry-specific information and, in today's evolving, highly competitive environment in which "domestic" markets have been replaced by "global" markets, this information changes continuously. Accordingly, the TRM concept involves an ongoing, iterative process, characterized by increasing industry involvement and commitment with information that is continuously updated and by criteria for decision making that are scrutinized and revisited.

METHODOLOGY

The Technology Roadmap process consists of three basic steps. First, the industry's market requirements are determined. Second, the impact of these requirements on the sector's products and services is considered, particularly in relation to opportunities to innovate. Third, this information is used to determine what are and will be the critical technologies needed to address identified market requirements. In order to gain the maximum benefit from this process, the TRM must be kept "evergreen" through periodic review, not only of the industry's market requirements but also of the impact of technological advances on the sector's goods and services. Figure 1 presents a graphical representation of the process, which is very much an iterative/interactive one.

Figure 1 – Technology Roadmap: Major Steps



In an effort to analyze this issue set in a realistic context, a technology scanning approach was used. The technology scanning schema used here is an adaptation of the one developed in the late 1960s by Gene R. Simons to design a research and development (R&D) priority program for the State of Connecticut. The process is based on a grid in which a number of problems or goals are identified and arrayed against a number of solutions or actions designed to address the goals and problems listed. Participants are first asked to rank each problem based on their perception of that problem's importance, and then to evaluate the effectiveness of each solution in addressing the problems identified in the earlier steps. Table 1 lists the markets and technologies identified during the consultations in a preliminary order of importance and effectiveness. Note that there is no direct correlation between a specific market and technology listed. See Appendix C for more detail.

Table 1 – Preliminary Order of Importance/Effectiveness

Markets	Technologies
Natural resources	Navigation and positioning
Environment	High-resolution sensing
Property	Image analysis
Infrastructure	Geographic information systems
Health	Data visualization
Emergency preparedness and defence	Database management
Business geographics	Communication and distribution
Education and entertainment	Geospatial data and infrastructure
Society/consumer	User applications and solutions
	Miniaturization
	Embedded technologies

MAJOR TRENDS

Since the Second World War, the Canadian geomatics[1] industry has developed into a knowledge-based industry that depends more and more on sophisticated computer-based technology and software and on a growing professional work force. This work force is becoming transformed from one that was engaged in relatively labour-intensive activities such as map and chart making and legal boundary surveying to one that is more knowledge-intensive. This growth was brought on, most obviously, by new technological developments and by the transition from a Cold War to a peacetime economy.

The industry is evolving rapidly as firms shift from the more traditional activities like surveying, mapping or photogrammetry to activities based on new technology such as image enhancement software and systems development. While traditional activities are still dominant at present, new activities, usually associated with the emerging knowledge-based economy, are becoming more important. Land reform, the environment and the development of national information infrastructures are some of the global issues fuelling these trends. Technological change is also blurring industry boundaries and is giving rise to hybrid firms that are situated in more than one industry sector. Users and suppliers appear and develop both within and outside the sector as currently measured.

The technology of the geomatics industry is now becoming more user friendly. The sophistication of new data-gathering technologies and geographic information systems (GIS) technologies and their increasing ease of use are allowing former clients of geomatics firms to themselves become developers of spatial data applications. Until recently, the software used in the geomatics industry was expensive and required costly hardware. Use of this technology was normally restricted to individuals who had completed extensive training programs. Consequently, this technology tended to be within the industry or within specialized units of a large corporate/institutional structure, where it was efficient to allocate personnel and resources to its use. The advent of simple desktop systems has significantly lowered the barriers to entry.

These technological advances and the completion of major data collection programs have highlighted the need for an infrastructure that will facilitate data access and distribution. Once such an infrastructure is in place, recent developments in interactive mapping on the Internet will become fully functional. Interactive mapping sites allow users to select and download/upload map graphics and data using a simple query language. Scheduled developments in interactive mapping will soon permit users to perform sophisticated spatial analysis on the centralized sites using free software plug-ins.

This combination of powerful, web-based software and easy access to centralized map/data information will ensure widespread future use of geomatics goods and services by non-traditional users. Interactive analyses on the web will be a major factor in the development of geomatics in many sectors. As more non-geomatics specialists experiment with this technology, they will encourage the development of new innovations by geomatics specialists. This is already occurring with the increased use of Internet-based interactive mapping. Users of geomatics on the Information Highway are demanding new capabilities from the technology.

The transition from Cold War diplomacy to the peacetime economy has had, and will continue to have, a profound effect on the geomatics industry. The military and intelligence

[1] Geomatics is a generic term that covers the discipline of surveying (geodetic, cadastral, engineering and marine) and includes the global positioning system (GPS), mapping (photogrammetry, radargrammetry, cartography, automated mapping/facilities management and charting), remote sensing (data acquisition and application), and the creation and maintenance of spatial or geographic information systems. See Industry Canada, *Geomatics: Part 1 – Overview and Prospects*, Sector Competitiveness Frameworks (Ottawa: Industry Canada, 1997) for more information.

sectors were major drivers of the geomatics industry, with many technologies originally developed for these sectors having been subsequently disseminated for use in the civilian economy. The satellite-based global positioning system (GPS) is an excellent example of this type of technology transfer. The post-Cold War period, however, has seen a significant decline in the military and intelligence community's spending, and it can be expected that technology transfer from these sectors to the civilian sector will also be curtailed.

The evolution of a new world order has also changed the requirements of the military and intelligence sectors. During the Cold War, the parties involved were easily identifiable (e.g. the United States vs. the USSR) and relatively stable in terms of composition and geographic location. This, for the most part, is no longer the situation. Today's military and intelligence forces not only must react quickly to less discernible and changing "hot spots," which may not necessarily comply with traditional geographic areas of observation, but also they must learn to cooperate with a mixture of national partners such as the participants in the continuously changing group of coalition forces. These developments have created a new set of dynamic geomatics requirements such as:

- high-speed data collection, analysis and distribution
- the ability to look at smaller pieces of the world in greater detail
- a greater standardization of products and processes
- highly integrated systems.

The Mapping Science Committee of the National Research Council in the United States held a workshop in 1996, in part, to identify forces affecting the future of spatial data users and applications. Participants included representatives from all major sectors of spatial data activity in government, academia and private industry. They identified five principal forces that should motivate spatial data collection and use in the future:

- **Synergy of information, technology and access:** Technology convergence and development will continue to have significant effects on spatial data activities in the near future. In the longer term, however, information needs and a greater access to information will drive further technological developments.
- **Expanding global interdependence:** The increasingly global nature of commercial and other economic activities will drive a globalization of spatial information.
- **Increasing emphasis on sustainability:** The concept of sustainable growth involving environmental awareness, economic prosperity, and social equity and well-being will play a very large role.
- **Emergence of community-based governance:** Readily accessible systems that integrate information from a wide range of sources will facilitate greater involvement in governance; in other words, they will enable more participatory governance.
- **The individual:** As spatial information becomes more readily accessible, current conventions related to an individual's health, personal rights, privacy, quality of life and recreation will change.[2]

The knowledge-based economy is continually changing its requirements: new technologies are developed every day and existing ones are being applied in an ever-increasing number of ways. The challenge for firms in any field, but especially in the geomatics sector, is to stay on top of these changes and to position themselves not only to nurture existing markets but also to develop new, non-traditional markets.

[2] United States, National Research Council, *The Future of Spatial Data and Society: Summary of a Workshop* (Washington, DC: NRC, 1997).

MARKETS

The first step in the Technology Roadmap process is to develop a consensus among industry stakeholders on what markets are critical to the future growth of the Canadian geomatics industry. The consultation meeting participants identified nine market areas, ranging from traditional geomatics markets to markets that only now are beginning to apply geomatics applications. The markets identified were: natural resources, environment, property, infrastructure, health, emergency preparedness and defence, business geographics, education and entertainment, and the society/consumer market.

1 Natural Resources

The natural resources market includes fishing, forestry, agriculture and mining industries. These industries market goods derived from the Earth and its waters. As such, the principles of conservation and environmental management are playing increasingly important roles in all basic business functions within each of these sectors, including planning, management, monitoring, administration, operations and inventory. For this reason, natural resources and the environment (addressed in the next section) are often seen as an integrated market area.

Taking an integrated or system approach to these disciplines leads to the need for powerful tools for data collection, analysis and management and ultimately decision making. There are two models for delivering products and services to these sectors. One is the straight service approach that provides what the end user wants. A second is the system approach, which builds on functionality for users to conduct their business activities with the help of technology.

One area that offers substantial potential growth is decision support systems or modelling. These systems involve the use and development of complex spatio-temporal data sets and intricate mathematical models, and the presentation of their results in an obvious and straightforward way. It is the time component that is important here and that allows for complex analysis of "what if" scenarios. Given that experimentation on the natural environment is not acceptable, these systems offer decision makers a cost-effective and accurate alternative for understanding how their operations involving natural resource extraction or use will affect the environment.

Principles of sustainability, biodiversity protection and others are increasing demands for more and better data. High-resolution imaging technologies, high-precision GPS and integration of GPS, GIS and remote sensing technologies certainly will continue to be at the centre of developments in this area. Increasing in importance also is the requirement to maintain up-to-date databases, which derives from increased monitoring activities.

An area of increasing interest is exploration of other planets and the Earth's moon for natural resources. Recent images have already revealed ice on the moon and iron on Mars. Furthermore, in the next five years, more than 15 satellites will be launched to capture and transmit images of most of the planets in the solar system back to Earth. Many of the requirements of scientists examining images from other planets are similar to those needed for monitoring images of the Earth. It is therefore expected that there will be growing overlap between the communities studying Earth-based imagery and scientists analyzing images of our solar system. The promise of hyperspectral image analysis lies in vastly improved information regarding land cover.

With the significant decrease in remote sensing data costs predicted after the launch of Landsat 7, the more user-friendly software interfaces, the new data fields and an increase in the number of computer-literate people in strategic positions, the natural resources markets for geomatics should continue to expand in the future.

2 Environment

The environmental market for geomatics goods and services is related to a wide range of pollution prevention, environmental conservation, control, protection, remediation and enhancement technologies, processes, products and services. The Canadian environmental industry, which is both a user and provider of these goods and services, includes approximately 4 500 small and medium-sized firms and employs about 150 000 people in both public and private organizations.[3] These organizations have expertise in wastewater treatment, environmental monitoring and instrumentation and, by working with other industries such as resource processing and steel production, have developed the ability to produce unique solutions to industry-specific environmental problems.

Environmental goods and services provided in Canada in 1995 totalled US$16.748 billion. While the Canadian market is maturing, the global industry is growing dramatically and is predicted to double between 1994 and 2000 to approximately US$600 billion. The United States, western Europe and Japan are the three largest markets in this intensely competitive industry.[4] Latin America, Southeast Asia (Indonesia, Malaysia, Singapore and Thailand in particular), India, China and eastern Europe have been identified as offering excellent opportunities for future growth. As these economies continue to develop, environmental management will become an increasingly important issue. Continued support by international financial institutions for environmental projects will help develop these markets.

Environmental reporting is increasing in importance in part because of the growing recognition of the importance of environmental management. The Kyoto commitments, for example, require nations to report on the state of the environment in their countries. In the Canadian case, this requires individual firms to report to regional groups, which report to provincial groups, which in turn report to federal agencies. This chain of reporting offers substantial opportunity for the sale of geomatics goods and services.

The complexity of environmental issues demands the collection, analysis and presentation of massive quantities of data, and the mathematical modelling of multifarious processes, usually over time. Geomatics technologies are ideally suited to this area. GPS, for example, offers an excellent tool to monitor society's impact on the environment. It can be used to track the movement of everything from icebergs to polar bears, and offers exciting opportunities in the area of weather forecasting. Remote sensing technologies and GIS, which are ideally suited for handling such data sets, and many other geomatics technologies are regularly being employed in many environmental applications.

Canada's environmental and geomatics industries are very highly regarded around the world. By working together, they can take advantage of the increasing global recognition of the importance of environmental management.

3 Property

In terms of geomatics goods and services, the property market includes the building and maintenance of property infrastructures, which involve systems for survey, registry and assessment. Other activities include surveying and mapping in support of land development and providing information in support of property-related transactions such as conveyancing, mortgaging, valuing and environmental assessing.

[3] Industry Canada, Canadian Environment Industry, Canadian International Business Strategy, 1998–99 (http://strategis.ic.gc.ca/SSG/ea01258e.html).

[4] Ibid.

With the exception of Aboriginal lands, Canada's cadastral system, the property infrastructure described above, is largely already in place. The current challenge is mostly related to automating, re-engineering and integrating this infrastructure. At present, a number of jurisdictions are addressing this challenge, and the activity is expected to increase in importance and to grow over the next three to five years.

There has been a renewed focus on the role of property in economic development, and this has led to a number of property infrastructure projects in developing countries (also known as land reform, land titling, property formalization, etc.). This area will continue to grow for the foreseeable future, although the competition for work is also growing dramatically. There are also growth opportunities in more developed countries in municipal and local governments and cadastral record areas similar to the needs identified above in Canada.

For Canadian geomatics firms to be successful internationally in this market segment, they will need to form partnerships with government property registration agencies, information technology firms, project management companies, and companies in other property-related professions (e.g. real estate lawyers, appraisers, etc.). This need for forming partnerships has been discussed in the past, but to date there has been little action.

Land development work peaked some time ago in Canada, although there are and will continue to be brief flurries of activity across the country. These activities were traditionally the mainstay for the land surveying profession; however, survey firms have been struggling to develop a business model less dependent on these activities for some time. Canadian firms, unless they are part of build-and-operate consortia, find it exceedingly difficult to export these services because of strong local capacities.

The business of providing information in support of property transactions is also changing from its more traditional ways. Traditional conveyancing and mortgaging work is diminishing for a variety of market, economic and technical reasons; however, opportunities to provide new services such as environmental assessment are gradually increasing. Unless the industry can successfully introduce new business models, it can expect very little growth in this area. It needs to go beyond simply providing information to assuming more responsibilities through variations on an insurance model, for example. The two forces appear to cancel one another out. Even if business as a whole shrinks, however, there are significant opportunities in the future by using new techniques to make it more professional and remunerative. Assuming the industry can develop these new business models, there will also be significant opportunities in this area abroad both in developed and developing countries.

In general, it will become increasingly important to be able to work in an on-line world, conversant both with the latest developments for accessing and analyzing property-related information and with the world of electronic commerce. More important than technology per se, however, will be an in-depth understanding of areas such as cost/benefit and risk management and the capacity to quickly incorporate them into new geomatics business models.

4 Infrastructure (Engineering, Construction, Transportation and Utilities)

The infrastructure market for geomatics goods and services includes engineering, construction, transportation and utilities industries. This sector supports both business and non-business activities in a country through the design, engineering, construction and maintenance of capital projects and the provision of ground, air, water and space transport services, telecommunications, and water and energy supplies. The use of geomatics technologies in this area not only facilitates the efficient, cost-effective and environmentally responsible development and operation of these activities but also may preclude the need for the more costly expansion of the infrastructures. As such, the geomatics industry will play an increasingly important role in the infrastructure market.

The construction sector is responsible for building the facilities and supportive infrastructure necessary for a nation to produce wealth and shelter its citizens. Some geomatics-related activities include land planning and development, design, location selection, impact assessments, surveying, mapping and other associated municipal activities such as urban planning and development. In recent years, the construction sector has experienced lacklustre growth in Canada, which is causing it to look to foreign markets for its further growth.

Utilities, hydro grids, pipelines, communications systems and so on must monitor, maintain, accurately locate and coordinate extensive amounts of expensive, geographically dispersed capital stocks. In order to do so effectively and in light of deregulation and the new competition it brings, utilities are and will be demanding an increasing amount of geomatics goods and services to help them manage their operations. As newly developing economies expand the reach and capacity of their utilities, they too will be demanding more of these goods and services.

Automated mapping and facilities management (AM/FM) systems and supervisory control and data acquisition (SCADA) systems are two areas that have been growing in importance in the infrastructure market and that are particularly applicable to the utilities sector. AM/FM systems automate mapping processes and help manage facilities, while SCADA systems collect real-time data from remote locations, process and analyze these data, and in turn help control equipment. Other areas that have been growing in importance are field information management systems, environmental impact studies and flow analyses. GPS is another area that is having a major impact on the utilities market. The ability of GPS receivers to synchronize themselves to atomic clocks on satellites is proving to be a boon to the wireless communications industry.

There is currently in process a Technology Roadmap on electric power that will be of interest to the geomatics industry. It will focus on four issues: asset optimization, intelligent power system delivery, end-use efficiency and convergence, and small-scale generation and renewables.

In combination with advanced computing and communication technologies, geomatics technologies are dramatically improving the efficiency and environmental cleanliness of all modes of transportation and commodity exchange. Intelligent transportation systems (ITS), for example, are revolutionizing the way transportation-related issues such as congestion, safety and logistical optimization are being handled. ITS can be applied in areas ranging from travel planning, adaptive traffic control, real-time traffic information, public transit operations, commercial vehicle operations, fleet management and emergency vehicle routing to, in the future, automated vehicle control systems.

The ITS market is developing into a multibillion-dollar global market in which opportunities for Canadian geomatics firms are expanding rapidly. A recent joint study carried out by Industry Canada and Transport Canada forecasts the world market for ITS technologies, a significant proportion of which are geomatics-related, to reach US$66 billion in 2011.

The potential Canadian share of this market is estimated to be in the order of US$4.8 billion.[5] Access to geospatial information will play an essential role in the development of these market opportunities. Japan, Europe and the United States are currently the leaders in the development and deployment of ITS and, as emerging industrial nations' transportation systems become more congested, their markets will become very important as well.

Currently, Canada offers a wide range of niche products and solutions in all areas of ITS as firms with expertise in navigation and positioning, remote sensing, distribution and communications are teaming up in order to tap into this growing market. In order to be able to compete globally and to expand the market domestically, it is important that:

- partnerships continue in order to provide full ITS packages/solutions and not merely components
- navigable map databases be interactively developed and conform to recognized standards.

5 Health

As the geomatics industry has evolved, there has been limited involvement between it and the health care sector. Where links have been made, they have been concerned with the location of facilities (i.e. clinics, ambulance stations and practitioners' offices) and the routing of emergency service vehicles. The growth of geomatics in this area has been hampered by limitations on the data, technology constraints, lack of training and education, and the structure of the health care sector. These constraints are interrelated and, taken together, have resulted in limited use of geospatial data in the health care sector. However, both the geomatics industry and the health care sector are undergoing major changes.

With geomatics expertise residing in highly specialized units, there have been few opportunities for interaction between these experts and experts in the health care sector. As a result, awareness and appreciation of the potential usefulness of geospatial data in the health care sector have been limited. Furthermore, even where there was an awareness of the technology, it was sometimes discounted because of the presumed high costs associated with its use. With geomatics expertise residing where it does, there is an increasing need for cross-talk and cross-training between these sectors.

Geomatics is evolving from an expensive, highly specialized technology to a widely distributed, desktop technology. At the same time, the health care sector is moving toward a more integrated model. The two industries should be converging upon a model of shared access and coordinated information at the desktop level. Furthermore, the data, technology, education and organizational trends have begun to align themselves, opening the door to greater incorporation of geomatics-related goods and services in the health care sector. There are still, however, many areas where the Canadian geomatics industry, in cooperation with experts in the health care sector, needs to take action to enable the use of geospatial data for health care planners, providers and users.

Geospatial data provide the health care sector with a new subdiscipline for collecting, storing, retrieving and analyzing health care data. To take advantage of this subdiscipline, the geomatics and health data must be coordinated across the organizations, institutions and individual providers in the community. A coordinated data infrastructure supports:

- human resources planning
- facilities planning and optimized service delivery
- epidemiological studies

[5] Industry Canada, "Strategy for Developing an ITS Industrial Base in Canada" (http://silicon.sim.qc.ca/its_const/t-main.html).

- informed decision making by users and providers
- proactive and preventive health care
- emergency preparedness
- health imaging techniques development.

The health care sector is an important market because a large percentage of the Canadian gross domestic product is spent on health care and associated products. Emerging market opportunities include medical data sets distributed on secure Intranets to regional and local medical offices. These new data sets will include graphics such as maps, used to depict disease pattern analysis and the location of potential health hazards. Since health care is provided by a large number of public and private agencies, there are many opportunities for an integrated, geomatics approach. Canadians are world leaders in the fields of geomatics and health care. By combining the efforts of these two sectors, Canadian expertise in both fields will be enhanced, and export performance in both fields will be improved.

There is currently a Technology Roadmap on medical imaging in process. It is focussing on how Canadian information technology and telecommunications strengths can be brought to bear in increasing Canadian value-added in medical imaging.

6 Emergency Preparedness and Defence

Emergency Response and Disaster Relief

As demonstrated by the 1997 Manitoba floods and the eastern Ontario/Quebec ice storm in early 1998, emergency response operations require geomatics technologies and database information to support relief efforts. Both natural and human disasters such as floods, tornadoes, storms, oil spills and the release of poisonous gases require timely, accurate and supporting geomatics information for relief operations, logistics of supply, national search and rescue capabilities, prediction modelling and environmental monitoring associated with these disasters.

Emergency response and disaster relief are the primary obligations of the Department of National Defence, which must be capable of mounting effective responses to emerging situations. In cooperation with local officials, other government agencies and a host of other organizations, the Department of National Defence must mobilize operational efforts within 24 hours, 365 days a year, and must be able to sustain relief efforts for as long as is necessary.

Current and future geomatics technologies used for emergency response and disaster relief efforts include integrated information systems, precision and mobile GPS, sophisticated planning and prediction modelling, wireless dissemination and multi-purpose operational support systems. As future disasters emerge and as relief efforts are mobilized, geomatics technologies will be required more and more to accelerate the planning and response activities. Technologies that provide ease of access and integration will be important, as will on-line access to information sources through integrated infrastructure shared between the private and public sectors. Timely access and rapid dissemination are key variables to aid relief efforts. Information distribution must also support differentiated views of supporting geomatics information, along with the tool kits to use wireless and remote communications to disseminate critical information to users in the field and in planning and coordination centres.

Military and Defence

The military geomatics market offers some of the greatest potential for new applications and integrated geomatics technology and systems. The military geomatics market has traditionally been one of the larger consumers of geomatics technology, information and related services, although most production activity so far has been conducted in-house. This is now changing, as organizations such as Canada's Department of National Defence and the U.S. National Imaging and Mapping Agency are increasingly contracting out work to the private sector. As we move toward the millennium, the military market remains large and strong, with an emphasis on maintaining global capabilities that enable the mobilization of operations over land, sea and air.

Overall, the military geomatics market spans a range of different requirements. Military geomatics systems and technology requirements are diffuse, vary greatly and tend to be user driven. The nature of the market has moved from customized large-scale developments to commercial-off-the-shelf (COTS) products. Similarly, the pace of technological development and changing operational environments have resulted in a change in requirements toward flexible components, interoperability, standardized tool kits and data, and integrated systems development.

Future market opportunities for geomatics technologies in this sector are numerous. Key areas include advanced communications and secure networking to meet demands for on-line, just-in-time delivery of information and decision support capabilities. Development of experimental, soon-to-be-operational mobile warrior and integrated systems for in-field application continues to dominate research and early pilot phases. These and other technology areas such as advanced guidance, high-resolution imagery, operational picture and precise location determination remain critical areas for geomatics technologies, often within larger operational command and control systems.

As ever, military systems require well-supported access to geographic information. These requirements fuel an ever-expanding demand for innovative geospatial information discovery, access, integration and management tools to support the provision of responsive, accurate and timely global geospatial information systems. Delivery of this information is moving from internally produced, discrete hard copy products toward interoperable, seamless, on-line delivery of services via national and global infrastructures, in essence, mobilizing technology to support the delivery, storage and accessibility of information from within and outside military sources.

This shift in requirements has resulted in many new market opportunities. An emerging focus is toward flexibility, data integration and tools for seamless management of disparate data sources. Following development of systems and infrastructure is demand for software that enables assessment of data quality, unique data elements and properties, and support for "just-in-time" delivery. Standardization and harmonization within international standards frameworks are important drivers, as the military community works in a global theatre and in cooperation between nations and internally — among different agencies — resulting in even larger opportunities for technology and product penetration. In some instances, access to military geomatics markets within Canada and across the globe can require security clearances.

7 Business Geographics

The business market includes applications in commercial sectors such as shipping, banking, retail sales, food services, real estate and insurance, and also in vehicle navigation and routing. There has been a clearly identified shift in the mapping/GIS business opportunities away from traditional surveying and mapping data capture to the outsourcing of data services. Large organizations with legacy databases are now asking the surveying and mapping providers to offer "value-added" services — where their legacy non-graphic databases are joined with their graphics, delivered by a data capture firm, to produce intelligent business analysis of their day-to-day operations.

This trend will continue, and many organizations will find themselves moving from the existing traditional data capture model to a new and more lucrative business geomatics model. In addition, the traditional business geographics market now has expanded to encompass this new and more lucrative market.

The traditional business geographics market addresses the needs of the commercial business sector for business demographic and geographic market trend analysis, while the new business geomatics market encompasses non-traditional GIS analysis in market segments such as health and welfare. Medical and social market analysis are but two of the new business market areas being addressed by GIS under the business geomatics label. Health and other emerging business market segments are dealt with separately in other the sections of this report.

The new business geomatics consumer is any professional or businessperson who makes business decisions. While these individuals have always had the responsibility to make these decisions, they have traditionally lacked access either to the data, in a presentable or manageable manner, or to the appropriate technology that allows them to share the data. Existing technologies such as desktop PCs and server centric terminals/PCs were limiting, not only in the cost and support of the infrastructure but also in these environments' inabilites to share vast amounts of data on different systems and in different software programs. All this has changed with corporate Intranet/Internet server environments and standards established in server software.

The market today includes any organization with large data sets that wishes to share those data on a corporate Intranet. In addition, the market is also the family household, and their desktop personal computer, which offers both a marketing and sales opportunity for that large corporate database through the use of the Internet.

Many organizations such as education, health, insurance and banking firms have used the corporate Intranet well. These organizations and many more are now offering or are being mandated to share their non-confidential data sets with other organizations as well as with the general public.

The largest single market is the private sector household. Private households are also becoming global offices. Telecommunications infrastructure is beginning to reflect this. As bandwidth and quality of communication increase, so will the volume and quality of the digital data being "served" up by individual communications nodes. Other examples of potential market opportunities in the household market include the sale of traditional information such as demographic statistics, digital mapping data sets and tourism reservations.

The market for organizations to provide the goods and services necessary to provide "intelligent" and easily accessed data will grow rapidly over the next five years. Budget cuts in industry will dictate a more economical way of sharing and analyzing accumulated data. Many large organizations have given up on the cost of supporting an infrastructure requiring both physical and human resources. Outsourcing of both the data management and analysis as well as the "management" of the entire physical plant operation is becoming very attractive.

Companies familiar with handling databases, both graphic and non-graphic, will have excellent opportunities to service these new market areas.

Companies currently managing and manipulating digital map and non-graphic databases are now providing services for organizations not familiar with the graphic presentation of data in a geographic context. These new business opportunities are offering challenging and rewarding experiences for companies previously confined to the traditional mapping/GIS business model. The expression "a picture is worth a thousand words" is proving that the value of presenting previously proprietary non-graphic data in a public forum on a graphic backdrop is both effective and exciting. The analysis now available using the previously "graphically static" databases is very impressive.

Entirely new approaches are being used to distribute and display these data sets by marrying the legacy databases, graphic and non-graphic, with the companies which produced them. The technology is Intranet/Internet software. The products necessary to "explode" this market include access to digital mapping, national, provincial, regional and local data sets, interoperable software and the associated non-graphic databases.

8 Education and Entertainment

The convergence of technologies and applications in the mapping sciences has led to geographic information processing being used on the development of a much wider range of products. As mentioned, traditional geomatics has concentrated on applications in environment, natural resources, infrastructure, cadastre and defence. More recently, business applications, vehicle navigation systems and health applications have increased in importance.

Education and entertainment, especially the latter, are the most recent and promising markets for geomatics. Already a number of Canadian firms such as IQ Media of Toronto and Morgan Media Inc. of Vancouver are moving into this extremely lucrative area. The technologies involved are interactive multimedia tools. These are quite often geographically based. An excellent example of this is the Canadian Geographic Explorer CD-ROM produced by IQ Media in association with Canadian Geographic and other industry partners such as PCI Enterprises and RADARSAT International. This field has come to be known as "edutainment" and is one of the fastest-growing areas of business in the multimedia sector.

An obvious market is the K-12 school segment both in Canada and abroad, especially for hybrid CD-ROM/web products. "Edutainment" products can be tied into Internet-based networks such as SchoolNet **(http://www.schoolnet.ca/)** in Canada and a number of similar networks being developed in countries such as the United Kingdom, the United States and Malaysia. There is potential for the inclusion of geomatics content on these networks in CD-ROM format.

Just as the Gulf War was the first full-scale geomatics war, it can be argued that the pure edutainment and games applications mark the first full-scale geomatics attack on the mass market for technologies such as data visualization. Canadian companies can enter the market either as individual producers or, more likely, as joint venture partners with educational software and multimedia producers. Many of the existing games are utilizing GIS technology on a variety of different scales but few, if any, geomatics companies as yet have seen the potential of this growing market.

The demand for good quality geospatial products for formal education as well as entertainment is worldwide and is not confined to North America and western Europe. Special opportunities exist for Canadian firms in Latin America and in selected countries in the Middle East, Africa and Asia, especially countries such as Malaysia that have a specific policy to create "smart schools." The map as an organizing concept for educational information on a wide range of topics can be introduced as computer-based school networks emerge, and Canadian geomatics companies can be there from the beginning to provide the building blocks and frameworks for such emerging systems. Many nations are devoting considerable resources to new means of mass education in distance learning or computer-based formats.

The entertainment segment of the "edutainment" market is probably larger but much less focussed than the educational segment and is more difficult for Canadian geomatics firms to penetrate even in joint ventures or partnerships. This market tends to be concentrated in the more affluent countries around the world.

9 Society/Consumer

The consumer market for geomatics products and services is still in its infancy as we approach the end of the 20th century, but it appears to be infinite, governed only by our ability to organize knowledge. This market currently consists of individuals whose primary use of geographical information is for such purposes as travel planning and navigation in both land and water vehicles and for outdoor recreational activities such as hiking, camping and hunting. These kinds of demands have traditionally been met through the use of paper map and atlas products and less frequently through the use of aerial photography or satellite image products.

Advances in two key technologies, GPS and GIS, combined with other technological developments in data storage and communications (especially the Internet) and computer visualization, make possible a broad range of new geomatics applications. For example, consumers now have access to mass-produced, hand-held GPS receivers that are being used for a variety of recreational activities. Basic desktop mapping and GIS functionality are being bundled with off-the-shelf office management software, providing consumers with the capability to manage and use all kinds of information in a geographic context.

An area that has been identified as having substantial growth potential is value-added distribution. This is the process of collecting diverse sets of data from disparate sources for sale to niche markets. These thematic data sets could be distributed by the Internet or on CD-ROM. One example would be to bring together data on navigable waterways, roads, fish stocks, campsites and water depths and then selling this package to fishermen or fisherwomen.

Within the next five years, other applications of geomatics technology for the consumer market will include Yellow Pages searches by geographic parameters, and travel and play in three-dimensional virtual reality based on geography. Given the scope of daily activities that are location-dependent, applications for the integration of geography with other types of information are limited only by the imagination. Constraints on the rate of development of the society/consumer market segment in Canada include the limited amount of up-to-date geographical information publicly available, restrictions on its access and the small size of the present-day consumer market.

Given these constraints, the Canadian industry is at a competitive disadvantage in this arena relative to the geomatics industry in the United States. U.S. competitors have the dual advantages of a much larger and more mature consumer market for geomatics goods and services, and relatively easy access to the public sector data upon which many of the consumer applications are built. This concern is being partially addressed through the Canadian Geospatial Data Infrastructure (CGDI) project, a national initiative to increase access to and use of government data for new business development.

TECHNOLOGIES

Once key markets were identified and their characteristics discussed, the steering committee and the working groups identified technologies that are seen as being critical to the industry's ability to address these markets over the next three to five years. The technology scanning schema was then used to examine how effective the technologies are in doing so. There were questions raised as to whether or not the "technologies" listed are in fact technologies at all, but rather are end products developed as a result of the application of various technologies or existing technologies already delivered in a different "package." There were also questions raised about the characteristics or definitions of the technological and market categories that appeared on the scanning grid.

It was concluded that the geomatics industry is an excellent example of a knowledge-based industry where its products and services directly represent a technology or its application. This is an industry where products and services either are the application of existing technologies or are existing technologies in new forms and can be considered in their own right. As such, all of the technologies listed were considered to be valid.

In the final analysis, the working groups redesigned, identified and discussed 11 technology areas, which were then approved by the steering committee. They included navigation and positioning, high-resolution sensing, image analysis, geographic information systems, data visualization, database management, communications and distribution, geospatial data and its infrastructure, user applications and solutions, miniaturization, and embedded technologies. Each one is discussed in greater detail in the following sections.

1 Navigation and Positioning

The principal navigation and positioning technologies in use today are the GPS, inertial navigation systems (INS), radio-navigation systems such as differential GPS, beacons, satellite wide-area systems and local radio links; cellular triangulation, vehicle wheel sensors and other heading sensors and dead-reckoning systems.

By far, the largest growth area is GPS and its applications, the markets for which are estimated in total to be in the order of US$8.5 billion by the year 2000 and US$16 billion by the year 2006. Recent developments in GPS technologies include the incorporation of the Russian GLONASS system and, as the constellations are established, networks of low Earth orbit satellites.

Applications of navigation and positioning technologies are extensive, involving almost anything that requires positioning information. Application areas include:

- surveying: geographic location and data analysis including high-resolution asset location mapping
- GIS: geographic location, data analysis and presentation for asset management
- vehicle navigation: installed in anything from commercial passenger cars to tanks
- emergency location systems: typically installed in cars, in call-911 and in telecommunications devices made to pass on precise location data
- airborne crop spraying: field positioning devices
- marine navigation systems: from commercial fish finders to redundant systems on oil tankers
- marine docking systems: centimetre level, short range systems for ferries and cargo vessels

- aircraft navigation systems: from simple, en route systems in light aircraft to full CAT III landing systems
- aircraft CFIT (controlled flight into terrain) avoidance systems: which match aircraft position to three-dimensional maps and warn crews of dangerous approaches to terrain
- aerial survey systems: measuring and recording data from the air
- hand-held personal navigators: from recreational use to search-and-rescue operations
- wide area navigation systems: land-based, fixed data gathering and analysis systems to improve accuracy and integrity of the basic GPS system
- robotic vehicles: mining ore extractors, helicopter surveillance, dangerous area surveillance, security surveillance
- weapons training pods: attack aircraft weapons training systems
- golf "guidance" systems: cart-mounted measurement systems that provide yardage and situation awareness
- cell site timing coordination receivers.

With the type of market growth forecast for this industry, it is important for the Canadian industry to become more geomatics capable, literate and able, and to invest in geomatics core technologies and applications. It must do this more intensely; otherwise the competition (who also read the forecasts) will capture most of the growth in the market. The competition (Trimble, Orbcom, Ashtech/Magellan, Leica, Rockwell, etc.) have huge R&D and marketing budgets. Canadian geomatics firms will become increasingly less competitive without a serious, practical investment program. Most of these organizations have significant military business that supports their commercial program investments at present, but new sources of funding for R&D and marketing are required.

2 High-resolution Sensing

The two broad categories of high-resolution sensing — airborne and satellite — can be differentiated in many ways: by type of sensor, end user, etc. Understanding the differences and similarities of airborne and satellite remote sensing is one fundamental step in realizing the business opportunities.

Airborne remote sensing has been characterized as follows: extremely flexible and broad range of high-resolution data enabling mapping at scales of better than 1:1000; black-and-white and colour photography, mono and stereo; high-resolution multispectral and radar digital imagery; virtually 100 percent commercial ownership; flexible, responsive delivery options to meet individual clients' needs; small volumes of speculative acquisitions; and inventories of actual physical data. Alternatively, satellite remote sensing has exhibited the following characteristics: commercially available resolutions have been typically 10 m (8 m for RADARSAT I), enabling mapping of up to 1:50 000 scale; digital panchromatic and multispectral sensors; virtually 100 percent government ownership or financing in most instances; a variety of acquisition schemes ranging from continuous acquisition, contracted acquisitions and on speculation of future needs; data/information delivery of four hours in some cases; contracted acquisitions available for subsequent sale from archive to other clients; and electronic access to catalogues of data.

Civilian satellite remote sensing has offered lower resolutions than its military counterpart, which is reflected in its use for meteorological, environmental and certain civilian mapping scales applications. High-resolution satellite remote sensing has been restricted to military applications by the NATO nations, China, Russia and emerging space nations such as Israel and India.

This situation changed when the American government declared its intention to license U.S. companies to provide high-resolution imagery from satellites. This announcement was greeted with the application by several American companies for licences and by other national governments and companies announcing their intentions to provide similar data. A listing of major participants and their current status is summarized in Table 2.

Despite relatively small government remote sensing budgets, Canada is well respected internationally and has enjoyed considerable export success. There are, however, still many emerging opportunities here in North America and in the emerging economies of Latin America, Asia and eastern Europe. For example, using Canada's international position, reputation and geomatics capabilities, organizations can provide, for a fee, independent, verifiable, legally defendable, geomatics data, information and services to provide non-partisan treaty and agreement verification.

The availability and cost of computing power, data storage, communications, new display and interaction technology are revolutionizing business. The Canadian geomatics sectors, both government and industry, to date have been primarily science and resource oriented. An informed, growing, computer-literate, globally aware population will have a virtually insatiable demand for spatial, readily available, accessible, and cheap, consumer-oriented information systems and products. Of particular interest is hyperspectral remote sensing. A hyperspectral image provides a richer set of data than black-and-white or traditional multispectral imagery. It accomplishes this through the acquisition of hundreds of spectral channels for a particular image (as opposed to one channel for black and white, and three to six channels for multispectral).

Table 2 – Developments in Satellite Remote Sensing

Program	Launch Date	Features	Status
EarlyBird EarthWatch Inc., U.S.	December 1997	3 m black and white, 5 m multispectral	Satellite command and control was lost the week after a successful launch
Quickbird EarthWatch Inc., U.S.	1999	1 m black and white	Satellite on schedule after a corporate reorganization
IKONOS I Space-Imaging EOSAT, U.S.	June 1997	1 m black and white, 5 m multispectral	Launch date slips regularly but delays may be due to launch vehicle rather than satellite
SPIN-2 Aerial Images, U.S. SOVINFORMSPUTNIK, Russia	February 1998	2 m black and white from scanned photos	Satellite launched in early February; onboard camera film limits mission lifetime to months
OrbView-3 OrbImage, U.S.	1999	1 m black and white, 4 m multispectral	Funding in place and USAF committed funds to OrbView-4
RADARSAT II Canadian Space Agency	2001	5 m C band SAR	On schedule

GIS software companies are adding business-oriented functionality, and the traditional business tools vendors are adding spatial functionality. As geomatics-oriented applications continue to penetrate these markets, business opportunities will be created for the supply of remote sensing-based services and products. One interesting application is precision farming using remote sensing in conjunction with other data sets to estimate yields and manage agricultural practices such as herbicide and fertilizer application.

While Canadian organizations are well positioned to capitalize on these opportunities, there still exist many obstacles:

- **Market access and abilities:** The relatively small size of Canadian firms makes international market penetration difficult.
- **Centralized data distribution models:** Increasingly, satellite imagery recorded anywhere in the world is stored on large, solid-state memories and is down-linked to a single reception and processing site for subsequent distribution. This results in limited opportunities for data acquisition, processing, cataloguing, archiving, distribution systems and related commercial off-the-shelf software.
- **Restrictive market allocations:** Satellite owners are moving to a licensing model whereby major markets are either kept by the satellite owner or assigned to a distributor who is also a co-investor in the program, with the result that Canadian companies are being prevented from entering these particular, often lucrative market segments.
- **End-to-end offering:** Many new satellite owner operators are offering value-added services and, given their ability to control the "cost" of the data, this places companies not associated in some way with the satellite owner and access to preferential image pricing at a disadvantage.
- **Multidisciplinary skills required:** Remote sensing requires a broad multidisciplinary skill set, and this requirement can be expected to increase as new markets are addressed, which often leads to an inability for any one single company to effectively address these markets.

3 Image Analysis

Image analysis technologies are undergoing a number of changes. The major trend will be to see the expansion of image analysis technology from the exclusive domain of the highly educated remote sensing professional to the desktop of significant numbers of new professional and other users, as a result of a number of contributing factors. First, the continued drop in the price of PC hardware combined with a substantial increase in power, memory, storage capabilities and graphics speed makes sophisticated image analysis feasible for the first time on the desktop. Also, the planned launch of high-resolution commercial satellites will bring image analysis technology into many new markets including infrastructure, property management, health and insurance.

Certainly, the technology will need to prove itself to these new markets; however, industry watchers believe that over a five-year time horizon, high-resolution satellite data will prove to be an invaluable asset to many new markets. With commercial sensors competing with government satellites, the price of data should drop over the next five years, increasing the cost effectiveness of image analysis operations.

Again, one of the greatest difficulties the image analysis and GIS markets have faced is data distribution. The Internet promises to solve many of these problems. Of course, the current bandwidths support only limited data distribution. However, this will certainly change over the next three to five years, and a vast amount of remotely sensed GIS and map data will be available over the Internet. Wide distribution and lowered costs will benefit this industry.

Finally, the maturation of the image analysis technology is being characterized by the development of vertical markets. Users in fields as diverse as forestry, agriculture, geology and defence are demanding application-specific solutions. This is a healthy sign; these vertical markets are often profitable. Over the next few years, non-scientific users in these fields will be the main driving force in demanding integrated remote sensing/GIS/mapping solutions rather than technologies.

These trends will afford the Canadian geomatics industry many opportunities. However, in order to take advantage of these opportunities, the industry must invest heavily in market research and alliances between data providers and complementary technology providers.

An important trend over the next three to five years will be the growing commercialization of image analysis technology. However, it is essential to maintain strong industry/government alliances and programs. Government policies will continue to be the main driving force behind the industry. It has been said that one of the Canadian geomatics industry's strengths is the unique and powerful cooperation between the geomatics private sector and governments.

4 Geographic Information Systems

Geographic information systems (GIS) deal with the storage, management, retrieval, conversion, analysis, modelling and display of spatially related data in a systematic way.[6] In a sense, GIS software is the conduit through which complex data collected using an array of highly advanced technologies are massaged into a more easily comprehensible, user-friendly, interactive form, again using advanced technologies. These systems have been applied across all markets to some extent or another.

GIS software is potentially applicable in nearly any situation that calls for decisions involving a spatial component. In other words, GIS can be a useful tool in situations as diverse as choosing an appropriate site for a movie rental store in a metropolitan area to determining the environmental impact of establishing an above-ground pipeline in the Arctic. It is impossible to list here all the possible applications of GIS, as they are practically limitless. As computer power grows, enabling the use of more complex models and the more efficient incorporation of a time component in analysis, the more this will be true.

Advances in computer software and hardware, increased familiarity with the power and applicability of GIS and its related technologies, and a greater breadth of accessible data have driven the growth in demand for GIS and will continue to do so in the future. Throughout the knowledge-based economy, both software and hardware have become much more powerful and simple to use while becoming less expensive. Clients in all markets are now comfortable with computers and have access to the necessary equipment to run even complex GIS packages. Furthermore, not only has a greater range of geospatial data become more readily available but also non-traditional data such as those found in the social sciences have become more extensively geo-referenced.

Increasingly, clients are seeking information systems that do not require a whole range of independent technologies and knowledge bases. Rather, they are seeking a system that renders the technological distinctions invisible. To give an analogy, Microsoft Office components are not integrated; they are merely compatible. So integration is a market

[6] Bruce E. Davis, *GIS: A Visual Approach* (Santa Fe, NM: Onward Press, 1996), p. 23.

pull in geomatics. GIS is particularly affected by this trend, as it depends on a vast array of these factors to deliver its final outputs.

5 Data Visualization

Simply put, geomatics-related data visualization technologies are tools that facilitate the understanding of complex data sets, models and issues that have a spatial component. They include everything from their most simplest form — paper maps — to a wide range of computer hardware and software. While these represent a broad spectrum of complexity, these media are linked by their purpose of presenting geospatial data from different perspectives. Recently, however, data visualization has been driven by advances in modern computer and display technology.

As geographic information systems become more flexible, powerful and sophisticated and more closely integrated with modelling software, the interface between the GIS and the user needs to become more interactive and complex. There is also a push for the broader application of data visualization technologies in non-traditional areas. As such, it is important for future data visualization technologies to present data as richly, realistically and interactively as possible. Humans have a tendency to ignore stimuli if they contradict their perception of the real world. This suggests that the more realistically and richly data are presented, the more useful and effective they become.

Tempering the use of increased realism is the use of more abstract stimuli in data visualization to broaden the use of data visualization techniques. For example, the use of abstract graphics to represent the distribution of non-visual patterns or phenomena such as the spread of disease, demographics and election results or to describe processes is becoming more popular and is seen as a way of expanding geomatics markets to include non-traditional consumers such as those in the social sciences.

The level of interactivity in visualization tools varies greatly. While less interactive methods like paper maps are useful in presenting straightforward thoughts and information, the trend toward the analysis of complex and diverse data sets demands an increasing level of interactivity between the user and the data. Applications that facilitate the dynamic analysis of complex issues or "what-if" scenarios are in demand everywhere, including resource and environmental management, market analysis and urban planning. These often involve comprehensive data sets, complicated models and the use of a digitized and interactive time component.

New visualization technologies are being developed as quickly as computing abilities allow. Some examples that show promise are interactive stereographic displays, which facilitate the presentation of three-dimensional data, and computer-generated movies. Also, more dynamic modelling tools within the GIS environment, such as high-capacity video disks that allow for highly realistic and interactive analysis of issues, are being developed every day.

While present communications and computer processing power limit the effectiveness of real-time data collection, analysis and presentation, rapid improvements in these areas will soon allow for the widespread application of real-time visualization of complex data sets in areas ranging from environmental monitoring to fleet management.

The power of effective data visualization techniques cannot be argued, and any innovative developments that increase the power of these techniques will be met with very favourably. The incorporation of more than visual stimuli is one area that is gaining momentum. This can include anything from adding sound to traditional video displays to exciting new areas like virtual reality. Virtual reality is the next step for data visualization. Not only does it allow for the very realistic presentation of information, but also it has the potential to do so in a quite realistic manner. As the equipment needed for virtual reality becomes smaller, less expensive and of higher quality, the application of these technologies will be seriously investigated for use in the presentation of spatial data.[7]

A great deal of Canada's competitive advantage in the geomatics sector has been based historically on the collection and processing of geospatial data. As market demand for sophisticated value-added applications accelerates, these traditional strengths are no longer enough to sustain the growth of the Canadian industry. Furthermore, in order for the industry to expand its markets to non-traditional applications such as epidemiology and the social sciences, the ability to combine and present geospatial data with data from these fields is indispensable.

6 Database Management

Database management systems (DBMS) are specialized pieces of software that provide functionality for storing, updating and retrieving information and generally provide mechanisms for maintaining the integrity of stored information, managing security and user access, recovering information after the system fails, and accessing database functionality from within an application written in a third-generation language such as COBOL, C or JAVA.[8]

Great advances have been made in the area of DBMS over the past decade. Early systems were hierarchical in nature, but relational systems have become the standard recently. With the emergence of object-oriented programming languages, object-oriented systems are becoming increasingly important to data storage. Constant developments in areas such as structured query languages, most recently SQL3, have been a driving force in these changes and are fuelling a shift away from purely relational systems. The newest structure being developed and gaining in popularity is object-relational in form.[9]

Due to be released in 1999, the proposed ANSI SQL3 standard will describe an object-relational model in detail. Object-relational systems offer many new, beneficial features including columns of tables that can contain "composite" types and collections of multiple values; columns that can be Abstract Data Types, satellite pictures in searchable bitmap form, for example; and a new "ref" data type, which allows for the reference of a row of one table from a column of another table in an absolute way. There are still a number of issues related to object-relational design; however, new object-relational database systems will house older relational database system capabilities, making the upgrading of systems less problematic and more cost effective.[10]

Price Waterhouse, in its *Technology Forecast: 1998*, forecasts a number of developments in the area of database management, including:

- Object-relational systems will replace pure relational systems fully within five years.
- Given the shift toward object-relational systems, database design will become crucial to the system development life cycle.
- While parallelism will continue to be important, advanced indexing will be essential to improve query performance in areas such as decision support applications.
- In order to support data warehousing, databases will increasingly be designed to incorporate attributes such as bit-mapped indexes, parallel query execution and multidimensional capabilities.[11]

7 A chapter by A. MacEachren, I. Bishop, J. Dykes, D. Dorling and A. Gatrell, "Introduction to Advances in Visualizing Spatial Data" in *Visualization in Geographic Information Systems*, edited by Hearnshaw and Unwin (New York: Wiley, 1994), pp. 51–59 was very helpful for describing the concepts of realism, interactivity and abstraction as well as for an outlook on developing technologies.

8 Price Waterhouse, *Technology Forecast: 1998* (Menlo Park, CA: Price Waterhouse, 1998), p. 470.

9 Ibid., pp. 470–74.

10 Ibid., pp. 474–75.

11 Ibid., pp. 488–89.

Data warehousing attempts to bring together the best aspects of information centres, decision support systems and executive information systems, creating an integrated enterprise architecture facilitating on-line analytical processing. Essentially, data warehousing establishes a clearinghouse using a structured discipline and strategy that allow for ready access to valuable data.[12] Systems designed to manage infrastructure are expensive to develop and hence must be flexible and sustainable over time.

Vendors have recognized that spatial data should be managed and stored in enterprise databases, not specialty databases, and have begun implementing support for this. However, simply adding spatial indexes into existing DBMS will not ensure a scalable enterprise system. Furthermore, seamless storage of all information in DBMS, without the need for proprietary spatial data management layers, is essential. Much work has yet to be done. Enterprise infrastructure management involves large numbers of users requiring different types of services. Implementations must grow beyond a simple prototype or departmental rollouts within a few departments in order to ensure major process improvements and economies of scale.

A single enterprise system for infrastructure information management must accommodate a variety of business tasks — in many cases already using their own, proven and reliable applications. To reduce risk, preserve investment and maintain user loyalty, replacement is not an option. The technology must provide tools that promote transparent interoperability and not cumbersome translation or data duplication.

The varying nature of large enterprises makes "off-the-shelf, one-size-fits-all" products impossible. Application frameworks will provide reliable, rapidly customized or created solutions. Technologies must leverage existing and commercial best-of-breed tools and standards, promote reuse of components and be supported with proven methodologies.

7 Communications and Distribution

A key element to the present and future distribution of geospatial data is the Information Highway, whose use is growing exponentially. The governments of Canada and the United States have already committed billions of dollars to its development. While geospatial information represents only a very small fraction of the data now being transmitted on the Information Highway, it is quickly becoming more prominent, and "cybercartography"[13] will become an important feature on the Information Highway.

Cybercartography is a highly interactive, multimedia method of collecting, processing, analyzing and distributing spatial data using the increasing range of emerging media forms and telecommunications networks such as the Internet and World Wide Web. It will allow cartography to be applied to a much wider range of topics than has traditionally been the case and will open the field to a much wider range of participants. This unifying trend will truly broaden the influence of geomatics in education, policy and decision making, and research in all sectors.

In addition to the Internet, Intranets and Extranets now are being developed by firms and groups of firms to facilitate communications between themselves, their customers and their suppliers. Currently, the main factor restricting the effectiveness of these systems to distribute geospatial information is their limited bandwidth. Furthermore, the cost of establishing high-speed fibre optics systems is currently very high.

It is believed, however, that these will be temporary problems, with less expensive fibre optics systems, wireless communication and greater bandwidths becoming more readily available. Just as Moore's law predicts that the power and complexity of chips will double every 12 to 15 months, some in the industry

[12] Ibid., p. 599.

[13] Term used and described by Dr. D. R. F. Taylor of Carleton University in a keynote speech titled "Maps and Mapping in the Information Era," given at the 18th International Cartographic Association Conference in Stockholm, Sweden, in 1997.

believe this axiom will hold true in terms of communications power. Already, one-terabit communications links have been used to transmit data. Also, Teledesic Corporation is planning to launch 840 low-level satellites beginning in the year 2000. Given that only a small antenna and signal decoders are needed, this new system would greatly enhance communications capabilities around the world. This new system is designed to be Transmission Control Protocol – Internet Protocol (TCP-IP) friendly, thereby expanding the scope of the Information Highway.

8 Geospatial Data and Infrastructure

Geomatics is a discipline dealing with collecting, managing, processing and using geospatial data — data related to the Earth's surface, subsurface, water bodies and the atmosphere. While geospatial data are not what is traditionally considered to be a "technology," the concept embodies a great deal of technology described by a more traditional definition, and its infrastructure taken as technology is a key driver of the transition of this and other related industry sectors to obtain a place in the knowledge-based economy.

The characteristics of the geospatial data set are changing. First and foremost, in order to meet market demands effectively, the capacity for the real-time collection, synthesis and access must exist; data currency is essential. The data should be scaleless, seamless, without artificial boundaries, and linked to a time component that has become critical to many applications, for example, call-911, traffic flow management, routing and delivery, and tidal and marine traffic. Moreover, as technologies become more advanced, geospatial information will be both more readily available and in greater demand.

There will also be a growing trend toward the collection and integration of non-traditional data using secondary reference systems like voting, culture and housing patterns, gender, sales and industry. Furthermore, as geomatics technologies and applications become more globally used, geospatial data will spread to and originate from non-traditional sources such as the voluntary sector, health councils, communities and Aboriginal peoples. However, regardless of what data are collected by whom, unless they are easily and readily accessible, their value diminishes; hence the importance of an exceptional geospatial data infrastructure.

Furthermore, a well-developed national information infrastructure, enabling the dissemination and sharing of valuable, geographically referenced information, and with an ever-increasing audience of businesses, entrepreneurs, students and researchers, and communities (particularly those traditionally disadvantaged by the barriers of geography and time), is widely accepted as an essential asset for any country to maintain and to advance its social and economic well-being. As such, geospatial data and the infrastructure in which they are organized can be considered to be a technology in its own right within the rubric of this Technology Roadmap.

An efficient information infrastructure greatly increases the potential for innovation and for the creation of knowledge and the ideas that are critical to socio-economic development. It can also reduce firms' operating costs and expand their opportunity for developing value-added applications for an increasing number of non-expert users who require simple access to multidimensional data. Some of the essential tools required for an effective information infrastructure include consistent metadata information about geographic databases, catalogues of directory levels to identify different data sets, and directory access to different themes and networks of information (knowledge management).

The revolution caused by the emergence of the knowledge-based economy is transforming all sectors of the economy including everything from primary and secondary resource activities to service industry activity. In support of the transition, the federal government is making information infrastructure accessible to all Canadians through initiatives aimed at "connectedness" among individuals, schools, libraries and businesses, as well as all levels of government. Building on these efforts, a common framework that promotes improved access to the geographic component of the Information Highway will support a knowledge-based economy and stimulate opportunities for the Canadian "geo-info" industry. One major initiative is the proposed Canadian Geospatial Data Infrastructure (CGDI) Initiative.

In advancing this initiative, a range of possible new programs are under consideration to accelerate the development of CGDI: programs that focus on working across governments and with other stakeholders in and beyond the private sector to advance the amount of information accessible through "clearinghouse" systems, the development of data frameworks to ease data integration, advanced technology and application development, and building supportive policies to speed industry growth.

Similar initiatives are also being carried out at different levels, including the intra-organizational and regional. A good example of the latter is the work being done by the Queen's University GIS Lab and others who are in the process of developing and testing a prototype for building spatial data infrastructures at a grass-roots regional level. In doing so, Queen's is developing a model of how partnerships help develop regional infrastructures. A portion of eastern Ontario centring around Kingston was selected as a result of its being a relatively small geographic area, compact and containing a mix of urban and rural environments. Furthermore, there is strong public support and local government cooperation in this region for such a venture following the ice storm of January 1998. The region is plugged into expertise in the federal government, and there are a number of initiatives already in place in eastern Ontario in education, health care delivery, municipal planning and communications infrastructure, which will complement and accelerate the work on this local spatial data infrastructure.

A valuable contribution of this prototype spatial data infrastructure is to develop linkages between infrastructures at various levels. In addition, the knowledge acquired while building and using the eastern Ontario spatial data infrastructure will be valuable at the national, provincial, regional or community levels for exploring and building other spatial data infrastructures. The interactive Internet-based methodology used in this prototype accelerates the knowledge exchange to these other groups.

There are three major benefits of this project:

- The project develops a spatial data infrastructure at the regional level for integration and interoperability at other levels.
- The model will demonstrate the current and potential benefits to a region of building a spatial data infrastructure including a road network enhanced with civic addressing for planning and emergency response, improved ambulance response times, lower cost for developing and maintaining the network, a framework for adding other attribute information, a searchable database for health care delivery, marketing and other economic development initiatives, and a public relations opportunity to demonstrate the forward thinking of the region to potential private/public sector firms considering relocation.

- The model includes the development of various innovative educational initiatives that link together secondary, post-secondary and professional education. This training will be more meaningful because it will use data relevant to the agency/firm/institution involved in the training; student projects in many instances will help populate a broader spatial data infrastructure; and education will be integrated with application development, improving the educational process and strengthening the case for contributing partners to enhance and maintain the regional spatial data infrastructure.

9 User Applications and Solutions

While geomatics core technologies such as GIS and GPS have matured during the 1990s, increasing attention has been focussed on the development of user applications and solutions. This technology segment can be defined as software/hardware solution bundles developed specifically to solve a geospatial information user's problem. The critical challenge in this area is for the technology supplier to gain an in-depth understanding of the user's business environment so that the solution is optimized to address the user's key business issues. Built on top of the core technologies, user applications/solutions are developed using combinations of database management, object-oriented programming and systems integration tools and techniques.

During the next three to five years, these technologies will be a central feature of the geomatics market. Geospatial information users are becoming more sophisticated in their use of, and more demanding of the suppliers of, geomatics products and services. The market is demanding solutions, not technologies, and successful companies will satisfy this demand by freeing clients from having to know about the core technologies. Information solutions on the decision maker's desktop will integrate geospatial data and analysis tools with many other types of data, word processing, spreadsheet, database management and multimedia technologies. Geomatics will move from the science and engineering world into the broader business and consumer marketplace.

A fundamental transformation of the geomatics industry is taking place in response to these market changes. Emphasis is shifting from data collection and processing to technology integration and information packaging. Traditional geomatics firms are retooling to meet these new demands, and new entrants from related disciplines such as engineering, environmental sciences and computer systems are carving out market niches. The strongest competition comes from the United States, where the market has matured more rapidly, fuelled by the availability of free public sector data and a much larger business community. Several U.S. firms have opened offices in Canada to exploit their technology lead in the much smaller but growing Canadian market for user applications/solutions.

10 Miniaturization

Many key elements of geomatics technologies are and will continue to be affected by miniaturization. Miniaturization is characterized by the decreasing size of the technology components. Paradoxically, decreased size of the technology components is often accompanied by increased processing power, technical capacity for performance and a reduction in power consumption. Furthermore, while the initial miniaturization of products is often associated with a higher cost structure, these costs typically decline rapidly with acceptance of product, experience in use, and economies of scale and scope.

For the short term, miniaturization of geomatics technologies has found focus in GPS receivers and communications devices, along with smaller visualization and data input/update approaches. Over time, diffusion will occur but these areas will continue to dominate, offering greater potential for commercial sales. These technologies are also further influenced by the continued convergence of technologies, enabling still greater miniaturization of different tasks within smaller components and technology systems, enabling the unification of required geomatics functions into smaller and smaller technical systems.

The sector perhaps most profoundly affected by the miniaturization of technologies, however, is aerospace. For example, the space industry, due to limited payloads, power supplies and physical space, is willing to pay huge premiums for the smaller, lighter, more power-efficient technologies required for space travel. Geomatics technology components have much to offer in this regard. Similarly, developments in the aeronautics industry such as cruise missile guidance systems are driven by the miniaturization of geomatics technologies.

11 Embedded Technologies

Within the geomatics technology market, tremendous opportunities will be provided through embedded technology. Long considered a highly specialized and highly technical area requiring specialists, geomatics activities are now included in general technical expertise and often in the practical experience of mainstream computing technologies. The prospects of embedded technology offer geomatics technologies further potential to be included in packages appearing on every desktop, embedded within standard operational software suites that will enable geospatial analysis and functionality.

In essence, embedded technology offers the potential for mass marketing of geomatics technology and geospatial functionality. Other possibilities of embedded technologies are afforded through networks such as the World Wide Web and client server applications. These offer potential for mass marketing of geomatics through "embedding" functions into applications and consumer technologies that offer knowledge-based responses. A particular driving force in this domain is transparency to users; that is, users can be delivered a response to a question or problem through the interaction of geospatial information and embedded technology without having detailed knowledge of either geomatics or the embedded technology itself.

More advanced potential of embedded technology is offered through the futuristic potential of palmtop computers, watches and other electronic devices such as control panels for appliances and vehicles. Over time, many of these applications will prove themselves and will offer additional markets and potential for miniaturized, embedded and interrelated geomatics technologies and geospatial information.

THE TECHNOLOGY SCANNING PROCESS

In order to facilitate the formation of a consensus on the key future market requirements that the Canadian geomatics industry must address and on the the critical technologies most needed to address these requirements, the method of technology scanning was used during the series of industry consultations. The concept of technology scanning was developed in the late 1960s by Gene R. Simons, initially to direct the development of an R&D priority program for the State of Connecticut. In short, the technology scanning process provides a structured analytical approach to the analysis of issues that traditionally have been difficult to review. A more elaborate explanation of this technique appears in this document as Appendix C: Technology Scanning in the Geomatics Industry.

1 Methodology

During the consultations, participants were first asked to rank prospective markets for geomatics goods and services in terms of their importance to the future growth of the industry in Canada. The next step was to identify what technologies or groups of technologies exist, are being developed or need to be developed in order to address these markets. The participants were then asked to rank these technologies in terms of their effectiveness in addressing the various markets identified in the earlier step. These results were collected in an evergreen matrix or grid, and then with the use of a simple algorithm were used to derive a measure of the technologies' overall effectiveness or importance to the future growth of the industry.

However, the results and conclusions of this technology scanning process must be looked at cautiously because of the varying and sometimes small sample sizes used in the calculations. The reason for this limitation is twofold. First, during the consultations, the composition of the grid was continuously updated according to the participants' input; that is, new technologies and markets were added. Also, of the more than 50 grids collected, many were only partially complete, reflecting in large part the participants' areas of expertise. Nevertheless, the analysis to date provides a great deal of useful insight not only into which technologies and markets are considered key to the future growth of the industry but also into where the industry's technological efforts might easily bring the greatest results. Further elaboration of the preferences/choices used to enrich the analysis can be obtained through iterative use, once a Virtual Technology Roadmap is in place.

2 Results

In terms of relative importance, the more traditional markets for geomatics goods and services were identified as being most important to the growth of the geomatics industry in the next three to five years. The infrastructure market was selected as the most important, followed closely by the natural resources and environment markets (sometimes dealt with as one market). The mature property market and the now evolving business market were perceived as being of moderate importance. Finally, the complex and perhaps more specialized and evolving defence and emergency preparedness market, and the emerging health and edutainment markets, were considered to be of only relatively minor importance in the medium term. This, in the case of the latter two, may be the result of the relative immaturity of these market segments.

The impact of the level of familiarity with possible geomatics applications in the various sectors may have a bearing on these rankings and needs to be considered. For example, the relatively low ranking of the health and edutainment markets may be attributable in part to the fact that these are relatively new and developing markets and, as such, participants overall were not as fluent in the use and possible applications of geomatics in these areas. This may have led these participants to assign these markets relatively low rankings, despite the fact that the markets actually are growing rapidly and will become of greater importance in the longer term (five to ten years).

Clearly, geospatial data and GIS were considered to be extremely important technologies for addressing solutions in a number of markets. This is not surprising, given the importance of data in analysis and decision making in all perceived markets and given the applicability of GIS to these processes. Other exceptional "matches" include navigation and positioning technologies and the defence and security market, database management and the property market, and user applications and solutions and the society and consumer market. While many of these pairings may seem obvious, this objective approach provides at least some level of analytical confirmation of earlier consultations and subjective observations.

It is interesting to note that some technology categories such as geospatial data and their collection, database management, and communication and distribution are seen to be broadly applicable across all markets, whereas others like embedded technologies, high-resolution sensing, and image analysis are perceived to have particular niches. Also of interest is the fact that some markets — defence and security, for example — seem to be able to draw on many or all of the technologies extensively, while others such as the property and health market draw on only some specific technologies. As was the case when analyzing the markets, the level of familiarity with the technologies can also have an impact on the effectiveness ranking given by the participants to various technologies. Miniaturization and embedded technologies, for example, are relatively abstract and as a result may have been assigned lower values by some contributors.

One of the more important functions of the technology scanning process is its ability to assist planners and policy makers in their resource allocation decisions. Using a simple algorithm that looks at both the relative importance of each market and the effectiveness of the technologies in addressing each market, a measure of the overall ability of individual technologies to address the key markets as a whole is calculated. This measure gives decision makers a sense of where they may be able to get the most "bang for their buck." The Geomatics Technology Roadmap Team will be able to predict better "technology winners" once the grid is more actively used by additional contributors during the Virtual Technology Roadmap stage.

The participants ranked the market-wide effectiveness of the geospatial data, database management, and communication and distribution areas highly. This can be taken to mean that the dawn of the information age, which drives the global demand for large amounts of easily accessible real-time data and extensive communications capabilities throughout the emerging knowledge-based economy, affects the geomatics industry no differently than any other knowledge-based sector. The user applications and solutions area also scored very highly, demonstrating that the knowledge-based economy also brings the use of these data down to a more personal level. Alternatively, miniaturization and embedded technologies were seen as being the least important for future industry growth. A listing of the technologies in terms of their overall effectiveness as determined by the technology scanning process is included in Appendix C.

3 Observations

Despite its weaknesses, this application of Simons's technology scanning process is very insightful and provides a base for analysis of technology-related issues leading toward decision-making choices. This is not to suggest that the concerns expressed by the participants during the consultation process about the limitations of the process are not equally valid. They simply do not affect the attainment of the goal of the process, which was to encourage a structured dialogue about the future technological requirements of the Canadian geomatics industry.

This analysis is a good start at issue identification, which traditionally has been difficult to do. The exercise can, however, be improved with the incorporation of a greater number of completed grids from contributors in order to achieve a more complete sampling of the industry. The feasibility of the development of the particular technologies and the time frame required to do so can also be included in future analytical work.

CONCLUSION

This document provides a snapshot of technology development within the geomatics industry, as developed through an extensive consultation process. It portrays what the industry believes to be those markets that are critical to the growth of the industry in the next three to five years and the technologies that are essential for the industry's ability to address these market needs. Additionally, the technology scanning process helps to develop a picture of the relative importance of these markets and technologies to the future growth of the industry as perceived by the stakeholder sample used at this point in time.

The geomatics industry is a knowledge-based industry, having no bounds or limits at this time and having the possibility to evolve in numerous directions. Technology advancement will in part determine the direction and strength of this evolution over the next few years. As such, it is very difficult to describe how the industry will look at any time in the future with any degree of certainty.

Many industry leaders believe that the use of "print-oriented" policy documents in rapidly changing high-tech industries such as this one are somewhat dysfunctional because of the industry's capacity to change rapidly. This document does provide both a reasonable idea of the industry's market-driven technology issues and a base from which an iterative Technology Roadmap process can proceed. This document can begin to help industry and government proactively plan to effectively respond to market demands, assuming that an on-line document similar in nature will immediately follow.

The technology scanning process provides a structured method of collecting the industry's views. The issue now becomes: How can changing perceptions of the industry registered in these views be incorporated into a format that can assist future planning and decision making? The steering committee has suggested that the Information Highway's ability to draw on resources from across the country be used to feed this effort on a continual basis. This new information exchange medium affords caretakers of the document an opportunity to create a "living" policy document, a "Virtual Technology Roadmap." Not only would this allow parties to update their views on market and technology requirements **as they are changing**, but also it would allow for continuous feedback on the document itself. Perhaps most importantly, however, it would allow for the highly interactive development of a continually adapting action plan for the industry. Initial steps have been taken to investigate the feasibility of a Virtual Technology Roadmap, and every effort should be made to advance this project.

The future of the Canadian geomatics industry is driven by dynamically expanding domestic and international markets, and the convergence of continuously developing technologies all in the light of the emerging knowledge-based economy. In order to ensure the industry's continued success and growth, the development of innovative solutions in an expanding number of areas must be supported. This document and the evolving Virtual Geomatics Technology Roadmap provide a format for a continuing dialogue among industry stakeholders for exploring technology issues and can help guide the innovative activities of Canadian geomatics firms.

APPENDIX A: STEERING COMMITTEE PARTICIPANTS

Neil Anderson
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Neil Anderson is vice president of International Business Development for NDI, which was created to form a public/private sector partnership with the Canadian Hydrographic Service (CHS) primarily to jointly produce, market and distribute Electronic Navigation Charts on international standards. He was the director of R&D for the CHS for 15 years and was one of Canada's representatives to the International Hydrographic Organization. His work experience is truly global and includes sustainable development projects with the Canadian International Development Agency.

Robert J. Batterham
Management Consulting in Geomatics Inc.
Robert J. Batterham is a management consultant specializing in the field of geomatics, in which he has some 30 years of experience working in the private and public sectors in Canada and the United Kingdom. During his career, he has worked extensively in, and with, the geomatics industry and at senior levels in the Canadian federal government as well as with counterpart provincial and other national agencies. He has held office in a number of professional associations including the Pan-American Institute of Geography and History, the Geomatics Industry Association of Canada and the Canadian Institute of Geomatics.

M. Elizabeth Cannon, B.Sc., M.Sc., Ph.D.
Professor, University of Calgary
Dr. M. Elizabeth Cannon is a professor in the Department of Geomatics Engineering at the University of Calgary where she also holds the Natural Sciences and Engineering Research Council of Canada/PetroCanada Chair for Women in Science and Engineering (Prairie Region). She has made major contributions to the field of satellite-based positioning and has received 20 national and international awards for her work. Dr. Cannon has been involved in numerous learned societies and has served as president of the U.S.-based Institute of Navigation (ION) in 1996–97.

Mark Corey
Director General, Geomatics Canada
Mark Corey is the director general of the Mapping Services Branch, Geomatics Canada and is also the chairman of the Federal Inter-Agency Committee on Geomatics. Previous positions include director of the Geodetic Survey Division, director of the Products and Services Division and director of the Strategic Planning Division for Geomatics Canada.

Q. Hugh J. Gwyn, Ph.D.
Professor, Université de Sherbrooke
Dr. Hugh J. Gwyn is a professor in the Département de géographie et télédétection at the Université de Sherbrooke. His research and applications development in geomatics are in radar and optical remote sensing and information systems applied to agriculture and the Earth sciences. He is a member of the Canada Centre for Remote Sensing Advisory Committee on Agriculture and Land Use, and has done numerous studies related to agricultural remote sensing and crop information applications in Canada, North Africa, West Africa, China and South America.

Ed Kennedy, P.Eng.
President, Geomatics Industry Association of Canada (GIAC)
E. A. (Ed) Kennedy is the president of the GIAC, where he directs the operations of this national business organization, which represents the interests of leading GIS, remote sensing, surveying and mapping firms across Canada. Mr. Kennedy has worked in both government and industry sectors, his most recent

position prior to joining GIAC being assistant deputy minister with the Alberta Ministry of Forestry, Lands and Wildlife. Mr. Kennedy is a past president of the Canadian Institute of Geomatics, and has served on a number of advisory boards to government and the academic sector.

Guilio Maffini
Vice President, SHL Vision Solutions
Guilio Maffini is responsible for international sales and marketing for continental Europe and Latin America, and the worldwide Local Governments vertical market for the VISION* Business Unit. VISION* is an enterprise-wide GIS solution for telecommunications companies, utilities and governments. Prior to joining SHL, he co-founded TYDAC Technologies, which developed the GIS software product SPANS. He serves as an editorial advisor to *GIS World*, a leading industry publication, is a member of the Urban and Regional Information Systems Association and the Geospatial Information & Technology Association, and was a member of the Mapping Science Committee of the National Research Council in the United States.

John McLaughlin, Ph.D., P.Eng.
Vice President, Research and International Cooperation, University of New Brunswick
As well as being a professor of land studies, Dr. McLaughlin is a member of the New Brunswick Geographic Information Corporation and a Fellow of the Instituto Libertad Y Democracia in Peru. He is recognized world wide as an authority on land administration; he has held positions with universities around the world, has been an advisor to numerous international organizations including the World Bank, has authored or co-authored more than 200 publications, and has served on the editorial boards of numerous industry publications.

Dr. Robert Moses
President and CEO,
PCI Geomatics Group Inc.
PCI Geomatics Group Inc. has been ranked as one of the top 10 suppliers of geomatics software worldwide and is one of the fastest-growing companies in this arena. Dr. Moses is chairman or co-chairman of a number of organizations including the Minister's National Advisory Board on Earth Sciences, which reports to the Minister of Natural Resources, and CRESTech Ontario Centre of Excellence. He has also participated in a number of other groups, among them the Ministerial Advisory Council on Science and Technology and the Canadian Advisory Committee for Remote Sensing.

APPENDIX B: WORKGROUP PARTICIPANTS

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APPENDIX C: TECHNOLOGY SCANNING IN THE GEOMATICS INDUSTRY

Introduction

In the fall of 1997, the Service Industries and Capital Projects Branch of Industry Canada, in conjunction with the Geomatics Industry Association of Canada and Geomatics Canada, held a series of workshops across Canada to solicit industry input into a Geomatics Sector Competitiveness Framework and Technology Roadmap. The workgroups were organized into two parts. The first gathered feedback on what Industry Canada believed to be the priority issues facing the industry today. Next, with the assistance of a technique called technology scanning, stakeholder's views on markets that will be key to the future growth of the geomatics industry and on technologies critical to the industry's ability to satisfy these markets were collected.

Technology Scanning

The technology scanning schema was developed in the late 1960s by Gene R. Simons initially to develop an R&D priority program for the State of Connecticut. The process is based on a grid on which a number of problems or goals are identified and arrayed against a number of solutions or actions suggested as being able to address the goals or problems listed. Participants are first asked to rank each problem on a scale of 1 to 5 (1 being lowest, 5 being highest) based on their perception of each problem's importance. Next, participants are asked to evaluate the effectiveness of each solution in addressing the problems identified in the earlier steps by assigning them a ranking of 1 to 5 (1 being not effective, 5 being very effective).

This input is then used to calculate an "Importance Factor," which gives an average ranking of the importance of the various markets, and a "Solution Index," which represents the overall effectiveness of each solution in addressing all of the problems as described in the grid. The Solution Index is calculated by adding together each element in a row (the individual effectiveness ratings of the solutions) multiplied by the corresponding problem's importance factor.

The Geomatics Grid

The initial geomatics grid was developed by a gold-plate steering committee comprising government, industry and academic leaders. See Appendix A for a complete list of participants. This grid arrayed what the committee viewed as the markets key to the future growth of the geomatics industry against technologies viewed as being critical to the industry's ability to satisfy these markets. In this case, the markets can be seen as the goals or problems in Simons's structure; that is, supplying these markets is a goal or how to supply these markets can be seen as a problem, and the critical technologies can be seen as solutions that help the Canadian geomatics industry attain its goal of supplying these markets.

The initial grid listed six key future market segments:

- **environment:** applications in environmental monitoring, environmental information systems, environmental impact assessments, etc.
- **natural resources:** applications in agriculture, fisheries, forestry, mining, oil and gas
- **infrastructure:** applications in utility and transportation systems planning, development and maintenance

- **property:** applications in cadastral or property registration systems, land records management and land administration
- **business:** applications in commercial sectors such as shipping, banking, retail sales, food services, real estate and insurance, and in vehicle navigation and routing
- **society/consumer market:** development of new spatial data products and services for the mass market.

There were six critical technologies listed:

- navigation and positioning technologies
- high-resolution sensing technologies
- database management techniques and technologies
- communication and distribution technologies
- data visualization technologies
- user applications/solutions and related technologies.

The workgroups discussed the technologies and markets listed and any additions or deletions that should be made. In order to obtain as comprehensive a review as possible, additional space was provided, and workgroup participants were encouraged to add to the original grids any markets or technologies they deemed important after their discussions. Additionally, revised grids incorporating the additions discussed were developed and distributed in the Ottawa and Toronto workgroups. The most recent grid is included in this appendix.

Three market segments were added to the grid during the consultations:

- **education and training:** applications designed for schools, professional and personal development, and entertainment purposes
- **defence and security:** applications in military, emergency preparedness and related sectors
- **health:** applications in health sectors, including epidemiology, drug tracking, hospital management and imaging.

Five technologies were added:

- image analysis technologies
- miniaturization and its related technologies
- GIS
- embedded technologies
- geospatial data.

Results

The results of the data collection stage must be looked at cautiously, because two factors led to variations in sizes used in the calculations. First, during the consultations, the grid was continuously updated based on the participants' inputs (i.e. new technologies and markets were added). Also, of the more than 50 grids collected, many were only partially completed.

Nevertheless, the analysis provides a great deal of useful insight not only into which technologies and markets are key to the future growth of the industry but also into where the industry's technological efforts might bring the greatest results.

Importance Factor

The Importance Factor is simply the mean of the participants' importance rankings of the markets, 1 being the lowest and 5 being the highest. The infrastructure market, followed closely by the natural resources and environment markets, was identified as being of the greatest importance to the future growth of the industry. The health and edutainment markets, of the markets studied, were deemed to be the least important. Table C-1 presents the numerical results of the importance analysis and gives the Importance Factor of all the markets included in the analysis, as well as the number of responses received.

The impact of the level of familiarity with possible geomatics applications in the various sectors on these rankings should be explored. For example, the relatively low ranking of the health, edutainment, and business/consumer markets may be in part attributable to the fact that these are relatively new and developing markets and, as such, the participants were not as fluent in the possible applications of geomatics in these areas. This may have resulted in their assigning these markets relatively low rankings, despite the fact that they are growing rapidly and will become of greater importance in the longer term.

Technology Effectiveness

Participants were asked to rank each technology from 1 to 5 based on its effectiveness in addressing the various market segments. These figures were then averaged to derive an overall assessment. Table C-2 shows the average responses of the participants and also presents these figures in graphical form: the darker the box the more effective the technology is in addressing the requirements of the corresponding market segment.

Table C-2 reveals that geospatial data and GIS technologies are perceived as being extremely effective in addressing all of the markets listed. Again, it is important to keep in mind that in many cases the sample sizes used in the calculations were quite small and, as a result, the derived estimates may be skewed. Table C-3 shows the number of responses in each sample.

Other exceptional "matches" include: navigation and positioning technologies and the defence and security market; database management and the property market; and user applications and solutions and the society and consumer market. While many of these pairings may seem obvious, this analytical approach provides at least some level of analytical confirmation of earlier consultations and subjective observations.

It is interesting to note that some technology categories such as geospatial data and infrastructure, database management, and communication and distribution seem to be broadly applicable across all markets, while others such as embedded technologies, high-resolution sensing and image analysis are not. Also of interest is the fact that some markets, defence and security, for example, seem to be able to draw on many or all of the technologies extensively, while others such as the education and entertainment market draw on only a few to varying degrees.

Table C-1 – Importance Factor and Number of Responses

Market	Importance Factor	Number of Responses
Infrastructure	4.2	38
Natural resources	4.1	37
Environment	4.0	37
Property	3.9	38
Business	3.7	38
Society/consumer	3.6	37
Defence and security	3.6	26
Health	3.5	20
Education and entertainment	3.3	8

Importance Factor Scale

1 = Low importance
2
3
4
5 = High importance

Table C-2 – Technology Effectiveness Rating

Critical Technologies	Key Future Market Segments: Environment	Natural resources	Infrastructure	Property	Business	Society/ consumer	Defence and security	Health	Education and entertainment
Navigation and positioning	3.5	4.0	4.2	4.2	3.7	3.6	4.4	2.8	2.7
High-resolution sensing	4.1	4.0	3.2	3.1	2.6	2.7	4.2	2.4	2.2
Database management	4.0	3.9	4.2	4.4	4.2	3.8	4.0	3.8	3.3
Communication and distribution	3.5	3.6	3.7	3.9	4.2	4.2	3.8	3.6	3.7
Data visualization	3.8	3.9	3.6	3.4	3.9	3.9	3.7	3.2	2.8
User applications/ solutions	4.0	4.0	4.0	3.8	4.2	4.3	3.6	3.6	3.2
Image analysis	4.0	4.0	3.3	2.8	2.6	2.6	4.2	2.7	2.0
Miniaturization	2.4	2.6	3.3	2.5	3.6	4.2	3.8	3.2	2.7
Embedded technology	2.4	2.8	2.9	2.2	4.0	4.0	3.6	2.7	3.6
Geospatial data and infrastructure	4.4	4.3	4.0	4.3	4.1	3.9	4.5	4.1	3.5
GIS	4.7	4.7	4.7	4.6	4.1	3.3	3.8	2.7	3.0

Effectiveness ranking

0–2.9	3–3.4	3.5–3.9	4–4.2	4.3–5
Low				High

Table C-3 – Technology Effectiveness: Number of Responses

Key Future Market Segments

Critical Technologies	Environment	Natural resources	Infrastructure	Property	Business	Society/ consumer	Defence and security	Health	Education and entertainment
Navigation and positioning	45	46	48	46	47	47	26	24	6
High-resolution sensing	46	47	45	44	44	41	25	24	6
Database management	47	47	49	48	48	45	26	25	6
Communication and distribution	45	46	46	47	47	45	26	24	6
Data visualization	46	46	46	45	46	45	26	24	6
User applications/ solutions	46	46	46	47	48	46	25	23	6
Image analysis	20	20	20	20	20	20	18	14	6
Miniaturization	19	19	19	19	19	19	16	13	3
Embedded technology	18	19	20	19	19	20	16	12	5
Geospatial data and infrastructure	7	7	7	7	7	7	8	7	4
GIS	6	6	7	7	7	7	5	3	3

Solution Index

Perhaps the most important function of the technology scanning process is its ability to assist planners and policy makers in their resource allocation decisions. The Solution Index is a measure of the overall ability of individual technologies to address the key markets as a whole. In other words, the Solution Index gives decision makers a sense of where they can get the most "bang for their buck." Table C-4 shows the Solution Indexes for the technologies examined in order of their overall effectiveness.

The dawn of the information age drives the global demand for large amounts of easily accessible real-time data and extensive communications capabilities throughout the emerging knowledge-based economy. The geomatics industry is no different, as the participants ranked the market-wide effectiveness of the geospatial data, database management, and communication and distribution areas quite highly. The user application and solutions area was also scored very highly, demonstrating the fact that the knowledge-based economy also brings the use of these data down to a more personal level. Alternatively, the concepts of miniaturization and embedded technologies were seen as being the least effective.

General Comments

The composition of the technologies listed in the technology scanning schema was the most broadly discussed issue throughout the consultation process. Many participants intimated that the "technologies" listed were not in fact technologies at all, but instead were end products developed as a result of the application of various technologies. Geospatial data and user applications/solutions were a couple of the categories mentioned.

Also, some of the categories were said to be simply different methods of delivering technologies that were already listed. Miniaturization for example, was seen by some participants as simply the "package" in which a technology is sent. When hand-held GPS systems were introduced as an example of miniaturization, these participants stated that the technology involved was in fact positioning technology, which was already listed.

One issue raised at the outset was that the technology categories used were too diverse, in the sense that some were very broad and some were quite specific. To accommodate these views, the grid was adjusted as much as possible; however, it is acknowledged that this issue continues to exist and, because of the diverse set of technologies found in the geomatics industry, is quite unavoidable.

Table C-4 – Solution Indexes

Critical Technologies	Solution Index
Geospatial data and infrastructure	140
GIS	135
Database management	134
User applications/solutions	131
Communication and distribution	128
Navigation and positioning	125
Data visualization	122
High-resolution sensing	108
Image analysis	107
Miniaturization	105
Embedded technology	105

Conclusion

Despite its weaknesses, this application of Simons's technology scanning process is very insightful and provides a base for analytical analysis of technology-related issues such as resource allocations for R&D. This is not to say that the concerns expressed by the participants are not valid; they simply do not impair the attainment of the goal of the process, which is to encourage a structured dialogue about the future technological requirements of the Canadian geomatics industry.

The geomatics industry is an excellent example of a knowledge-based industry. The essence of its products and services is technology or its application. This is an industry where even products and services that either are the application of existing technologies or are existing technologies in new forms can be considered as knowledge-based or "technologies" in their own right due to the expertise and research required to develop them. As such, all of the technologies listed are valid "solutions" in the Simons technology scanning structure.

Of greater concern are the sometimes small sample sizes used, the difficulty of encouraging participants to think about technological applications that have not yet been developed or with which they are unfamiliar, the incremental development of the grid, and the participants' needs for greater definition of the categories and process. These issues, however, can be addressed with a more planned and thorough distribution of the grid and, for the time being, do not greatly hinder the usefulness of the analysis and its ability to give an idea of which technologies and markets will be important in the future as well as of how effective the technologies are in addressing the future market requirements of the geomatics industry.

This is a good start at analytically determining an issue that traditionally has been difficult to investigate. This exercise can be further developed by addressing the issues that have been brought up in this paper and by incorporating input on the feasibility of the development of the particular technologies and the time frame required to do so. In sum, the entire process as well as its results have been very useful in the analysis of the future key market segments and critical technologies in the Canadian geomatics industry. Furthermore, this sort of analysis should not be confined to the geomatics industry. The experience acquired in applying the Simons technology scanning framework to current work should be continued, and the idea of future work in other sectors should be explored.

APPENDIX D: GLOSSARY

Automated mapping and facilities management (AM/FM) systems: systems that "... automate the mapping process and ... manage facilities represented by items on the map. In the past, when a map was needed, a crew of surveyors, draftspersons and geographers would combine their resources and develop a map on paper. This map was created by hand, updated by hand and reproduced by a professional printer. Today, it can be drawn on a computer screen using a Computer Aided Drafting and Design (CADD) software program. The map program is then connected to a database containing a variety of detailed information related to items on the map. When the map is needed to answer a question, it is displayed on the screen automatically. Updates are made quickly using a digitizing table, a mouse and a keyboard. The entire map, or just portions of it, may be selected to be printed on a plotter. The process is similar to word processing for maps."[14]

Business geographics: the use of GIS technology in general business applications such as retail sales, package goods shipment, real estate and banking. In these applications, GIS is used to help identify optimum locations for new businesses, to improve the efficiencies of operations and to improve decision making. The business geographics market is driving the trend toward integration of GIS with other information technologies to create more consumer-oriented decision tools.

Cadastral surveyor: a person who advises on, reports on, supervises or conducts surveys to establish, locate, define or describe lines, boundaries or corners of parcels of land or land covered with water.

Cadastre: a public register or survey that defines or re-establishes boundaries of public and/or private land for purposes of ownership and/or taxation.

Cartography: the art, science and technology of making maps and charts.

CAT III landing systems: CAT is an abbreviation for Category, and refers to different levels of instrument landing approach guidance, based on distance from and height above the end of a runway (threshold) that is being approached. For example, CAT I is normally described at 1 mile (1.6 km) distance and 200 feet (61 m) above runway threshold, and CAT III normally means zero distance and 50 feet (15.4 m) height above threshold. At these points during the approach, the crew are compelled to decide either to continue the approach to landing or to abort, depending on whether they have visually acquired sight of the runway.

Cellular triangulation: a positioning process that uses measurement of signal transit times from known cellular coverage cells to adjacent cells to approximate the location of a signal (cellular user) within one of those cell sites.

CFIT (controlled flight into terrain) avoidance systems: systems that assist in preventing perfectly functional aircraft and crew from flying into the ground while under full control. This has occurred in the past in mountainous or hilly terrain where visibility is poor and the crew become disoriented while flying on instrument guidance. CFIT avoidance systems are intended to assist the crew to maintain clearance with the ground under these difficult circumstances.

Connectedness: the degree to which the citizens of a nation or community have access to the skills and knowledge information infrastructure in their community, country and world in general.

[14] Geospatial Information & Technology Association (http://www.amfmintl.org/scope.html).

Data visualization: the art, science and technology of presenting data/information in a manner, graphically, audibly, etc., that affords the viewer the greatest appreciation and understanding of the data/information content.

Dead-reckoning system: a rough method of estimating position, based on using a known speed and direction at one moment in time, and projecting the position at any subsequent moment in time, assuming that speed and direction remain constant.

Decision support systems: interactive computer-based systems that help decision makers utilize data and models to identify and solve problems and make decisions.[15]

Differential GPS: a GPS receiver fixed at a known location (known as a reference site) that measures the differences between the fixed location and what it derives from GPS satellite measurements. These differences are broadcast so that other mobile receivers can use these "corrections" to improve the accuracy of their own measurements. Typically, GPS system errors are removed to improve mobile position measurements from 100 metres to between 1 and 5 metres.

Edutainment: a process whereby interactive technology is used to both entertain and educate. Edutainment products can either entertain or educate or do both at the same time and are often in the form of a CD-ROM.

Embedded technologies: the inclusion, integration or "embedding" of different technologies into electronic components or consumer products, often so that the user or person benefiting from the technology doesn't need to know about the integrated technology.

Engineering surveying: provides control for the design and development of man-made structures. It is the foundation of all construction and development projects.

Epidemiology: ". . . the branch of medicine that deals with the causes, distribution and control of disease in populations."[16]

Geodetic surveying: a process that measures and represents the shape and size of the Earth and its gravity; an accurate three-dimensional co-ordinate system on which all measurements of the Earth's surface depend.

Geographic information systems (GIS): a computer software system (often including hardware) with which spatial information may be captured, stored, analyzed, displayed and retrieved.

Geomatics: a generic term that covers the disciplines of surveying (geodetic, cadastral, engineering and marine) and includes the global positioning system, mapping (photogrammetry, radargrammetry, cartography, automated mapping/facilities management and charting), remote sensing (data acquisition and application), and the creation and maintenance of spatial or geographic information systems.

Geospatial data: data and information that are referenced to a location on the Earth's surface through precise scientific coordinates such as maps, charts, air photos, satellite images, and land and water surveys.

Global positioning system (GPS): a satellite-based positioning system permitting the determination of the location of any point on the Earth with high accuracy.

GLONASS: a Russian satellite navigation system similar to GPS.

Gyro-compass: a compass that makes use of the properties of a continuously driven gyroscope.

[15] D. J. Power, DSS Glossary, 1997 (http://dss.cba.uni.edu/glossary/dssglossary.html).

[16] ITP Nelson, *Canadian Dictionary of the English Language* (Toronto: Nelson, 1988).

High-resolution sensing: satellite imagery from space-borne satellites that can detect objects and activities as small as 1 or 2 metres.

Hydrography: the art of measuring the topography of the sea and its characteristics and dynamics (tides, etc.).

Hyperspectral imaging: a procedure that measures the reflection of hundreds of wavelengths of light from ground features, from which it is possible to more precisely classify land cover. This is done by comparing the measured response of a feature in the image with a library containing standard responses from a set of known features. Scientists have already developed many techniques for using hyperspectral imagery to determine mineral content, and are now making advances in applying the data to determine vegetation cover.

Image analysis: techniques used to enhance the visible image (e.g. brightening, sharpening) or to derive information by analyzing the digital data that comprise an image (e.g. texture/roughness, classification).

Inertial navigation system (INS): "... a self-contained navigation system consisting of gyroscopes and accelerometers to provide altitude, heading, position, attitude, body/inertial velocity and acceleration information; a primary navigation data source. INS loses accuracy with time due to drift of gyroscopes. INS-DNS is moderately accurate over land, but not good over water."[17]

Intelligent transportation systems (ITS): "... the application of advanced computing and communication technology to transport management and operating systems to achieve increases in efficiency, safety and reductions in negative environmental impacts."[18]

Interoperable: the ability to use applications or information effortlessly within different systems, applications and software platforms, performing in consistent and predictable manners.

Intranet: "... a local area network, which may not be connected to the Internet but which has some similar functions. Some organizations set up World Wide Web servers on their own internal networks so that employees have access to the organization's web documents."[19]

Laser profiling: the science and techniques involved in using airborne or space-borne instruments utilizing lasers to produce a continuous record of terrain elevation along a specified line or flight path.

Object-oriented database: "... a database in which data are stored as objects in an object-oriented programming environment, and which is managed by an object-oriented database management system."[20]

Object-oriented programming: "... an approach to programming in which each data item with the operations used on it is designated as an object; the routines used to operate on the data item are called methods; and objects are grouped in a hierarchy of classes, with each class inheriting characteristics from the class above it. Some uses of object-oriented programming are simulation; work with vectors and other mathematical objects; and work with graphic objects. Examples of object-oriented programming languages are SIMULA, Smalltalk, C++, Object Pascal, Objective C, Oblog."[21]

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17 http://g.oswego.edu/dl/acs/glossary/section3_1.html

18 Industry Canada (http://silicon.sim.qc.ca/its_const/ntst.html).

19 *Computer Currents Magazine* (http://www.currents.net/resources/dictionary/dictionary.phtml).

20 Ibid.

21 Ibid.

Object-relational database systems: database systems that ". . . have some of the capabilities of object-oriented database systems and additional unique capabilities, such as the ability to contain sets of record-structured values in a single column or row."[22]

Ortho-imaging: the technique of creating an image derived from a conventional perspective image by differential rectification so that it is devoid of displacements caused by camera or sensor tilt and terrain elevation.

Photogrammetry: the art and science of obtaining measurements from aerial photographs.

Polychrome mapping: the technique of digital, full-colour mapping.

Radargrammetry: the technology of extracting geometric object information from radar images.

Relational database systems: ". . . a database in the form of tables that have rows and columns to show the relationships between items, and in which information can be cross-referenced between two or more tables to generate a third table. A query language is used to search for data. If data are changed in one table, they will be changed in all related tables. A database that has only one table is called a flat file database."[23]

Remote sensing: the science of capturing, identifying, classifying and evaluating objects, areas or phenomena using data recorded by sensing devices in aircraft or in satellites.

Satellite wide-area systems: systems that use differential corrections from a network of several reference sites. These corrections include differential measurements and information on the "health" of the visible satellites. The corrections are collected at a central location, and a wide area correction is formed, which is then broadcast throughout the coverage area. The coverage area is normally over the area where the reference sites are located, and the signal is normally distributed by satellite uplink and is re-broadcast.

Seamless: information or data without breaks or gaps in coverage, regardless of how the information is stored, managed and manipulated.

Server centric computing: a computing system in which "the database server (typically a mainframe or Unix machine) does all the work and the clients are merely dumb terminals."[24]

Spatial data: ". . . data in the form of two- or three-dimensional images." [25]

Spatial data infrastructure: a national network-based solution to provide easy, consistent and effective access to geographical information maintained by public agencies throughout Canada that provides and promotes the use of geographical information in support of political, economic, social and personal development by all Canadians.

Standard Query Language (SQL): ". . . a language used to create, maintain and query relational databases. It is an ISO and ANSI standard. SQL uses regular English words for many of its commands, which makes it easy to use. It is often embedded within other programming languages."[26]

Supervisory control and data acquisition (SCADA): ". . . the process by which real-time information is gathered from remote locations for processing and analysis; and the process by which equipment is controlled. SCADA is

[22] Price Waterhouse, *Technology Forecast: 1998* (Menlo Park, CA: Price Waterhouse, 1998) p. 474.

[23] *Computer Currents Magazine* (http://www.currents.net/resources/dictionary/dictionary.phtml).

[24] http://www.data.com/Tutorials/WAN_Design.html

[25] *Computer Currents Magazine* (http://www.currents.net/resources/dictionary/dictionary.phtml).

[26] Ibid.

used in the electric, telecommunications, transportation, pipeline, water/wastewater, oil and gas, and infrastructure/government fields. AM/FM/GIS and SCADA relate by allowing for "live" maps and real-time databases that are used to manage large systems and networks. Through the integration, SCADA becomes spatially related, and AM/FM/GIS systems become real-time."[27]

Video-imaging: the use of video technology to create an analogue image and scanning to produce a digital image.

[27] Geospatial Information & Technology Association (**http://www.amfmintl.org/scope.html**).

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