LONG TERM SPACE BASED EARTH OBSERVATION AND REMOTE SENSING STRATEGY STUDY

BERCHA GROUP

EXECUTIVE SUMMARY

TO

LONG TERM SPACE BASED
EARTH OBSERVATION
AND REMOTE SENSING
STRATEGY STUDY

TO

INDUSTRY, SCIENCE AND TECHNOLOGY, CANADA
SPACE SYSTEMS DIVISION
OTTAWA, ONTARIO

BY

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

The role of Canada's remote sensing industry within the context of global space-related industrial activities has developed to a highly significant level. However, the best strategy for enhancing the future benefits to Canada's space industry from the global remote sensing markets has not been clearly defined.

Remote sensing and other space related activities have a direct application to earth observation programs. A number of high profile earth observation and remote sensing programs are currently in existence, including Landsat and SPOT, or are in the preparatory stages, such as the Canadian Radarsat program, the European Space Agency's ERS-1 satellite program, and the French SPOT 4 program. Canada's optimal strategy within the context of these programs and global market trends and capabilities needs to be better defined.

Recently, a new alliance called the Western Space Initiative has been formed with the purpose of amalgamating western high technology space and remote sensing industrial resources toward the common goal of developing an environmental monitoring capability and space-based sensor technology of global significance. In order to support the development of a strategy to optimally guide the Western Space Initiative and the Canadian Space Agency (CSA) within the matrix of priorities of the Space Systems Division of the Ministry of Industry, Science, and Technology Canada (ISTC), certain data regarding Canadian industrial capabilities and global market expectations are required.

Accordingly, ISTC recently issued bid documents for a project directed at the assimilation, analysis, and interpretation of such data. The successful contractor, F.G. Bercha and Associates Limited (Bercha) was tasked with such a project within the context of specific objectives and priorities.

In general, the work reported on in the present document consisted of doing a market, capability, and strategy study for earth observation and remote sensing satellite systems covering the period from 1990 to the year 2000 focusing on existing and emerging Canadian industrial capabilities within the context of the global market.

1.2 Objectives of Work

The general objective of this work is the preparation of a market and capability study to serve as a basis for the development of a Canadian industrial strategy for earth observation and satellite system programs for the next decade. Specific objectives of the study include the following:

(a) Definition of global market trends up to the year 2000, including the influence of foreign governments on their industry and the consequences for Canadian industry.

(b) Definition of the size, structure, capability, and performance of the Canadian industrial sector in the space-based industry relative to foreign competitors.

(c) Evaluation of the comparative advantages of using space-based as opposed to airborne remote sensing technologies to gather data to satisfy the market needs.

(d) The impact of developing and emerging technologies and the provision of hardware and related space-based services on a global basis.

(e) The development of optimal strategies for the positioning and development of Canadian industry to improve its competitiveness in domestic and international markets.

For the purposes of this work, the space-based remote sensing industry may be subdivided into three principal sectors as follows:

(a) Companies involved in the supply of satellite systems, subsystems, hardware, software, and services for earth observation and remote sensing of conditions on earth or its surroundings.

(b) Companies involved in the handling of data from earth observation satellites including data reception and processing systems, subsystems, hardware, software, and services.

(c) Companies involved in providing value added services and systems.

The most important objective of the work relates to the definition and analysis of global markets. At least fifty percent of the consultant's effort was to be dedicated to the principal objective. The second most important one is the definition of industrial capabilities within the context of global competitive resources. Thirty-five percent of the consultant's effort was to be dedicated to this objective. The final objective, the assessment of an optimal strategy, is important but considered to merit only the remaining fifteen percent of the total effort.

1.3 Scope of Work

The scope of work designed for the achievement of the above objectives within the context of the resources and time frame available for the present project may be subdivided into three principal tasks as follows:

(a) Task 1: Market Review;

(b) Task 2: Industrial Capabilities Review;

(c) Task 3: Strategic Assessment.

The first two of these three tasks were conducted concurrently due to the timing and methodology utilized. The final task was commenced as the first two tasks neared completion. Details on each task follow.

1.3.1 Market Review Scope of Work

The market review consisted of the identification of current and future international markets to the year 2000 encompassing the three industrial sectors of the space-based remote sensing industry on a global basis. Work consisted of the following principal subtasks:

(a) Identification and quantification on a global basis of current and planned expenditures on remote sensing and earth observation satellite systems.

(b) Definition of the industrial structure and composition of the international supply base in terms of existing technology and services and future trends in the development of remote sensing and earth observation technology and provision of services.

(c) Definition of the structure and composition of international demand for earth observation and remote sensing data.

(d) Identification of the specific types of remote sensing data currently being supplied and particular user markets to which these data are being supplied.

(e) Identification of the types of remote sensing data planned for provision over the next decade, with details including sensitivity of the demand to factors such as timeliness of supply and alternative data sources; identification of future users and sources of funding for these planned programs.

(f) Identification of any unique opportunities or new applications which Canada might optimally address in its industrial strategy.

(g) Review of alternative methods such as airborne methods of collecting remote sensing data to serve the needs of global users.

(h) Definition and projection of trends by foreign governments in their role as motivators and regulators affecting the space-based industry and identification of issues likely to impact on Canada's access to international markets in the space-based industrial sector.

1.3.2 Industrial Capabilities Review

The industrial capabilities review concentrated on the development of a profile of Canadian space-based industrial capabilities within the context of current and future user needs. Specific subtasks constituting this review may be summarized as follows:

(a) Identification of Canadian companies competing in the three principal subsectors and their specific capabilities and potential capabilities.

(b) Definition of the existing technology base in Canada for earth environment monitoring from space in the areas of development of earth observation instruments or sensors, deployment of small satellites and other types of platforms, and data reception, processing, information extraction, assimilation and dissemination systems.

(c) Identification of deficiencies in the Canadian technology base and associated rectification measures required to bring Canadian technology to a level necessary to compete in global markets.

1.3.3 Strategic Assessment

This task consisted of the development of various options directed at optimizing Canadian resources in the space-based industrial sector for the next decade within the context of global markets and capabilities. Specifically, the following subtasks comprised this assessment:

(a) Identification of potential market areas most compatible with Canadian technological and commercial competitive positions.

(b) Development of a prediction of the market share for products and services that may be achieved by Canadian space-based industry together with an assessment of the steps necessary to realize this market share.

(c) Identification of strategic steps to be taken by the federal government to assist Canadian industry in achieving its maximum potential world market share.

(d) Recommendation of other mechanisms for exploiting the identified market opportunities.

(e) Recommendations on areas for further study prior to development within the context of the study objectives.

1.4 Outline of Report

Following this brief introduction, Chapter 2 describes the methodology followed for each task of the study, Chapter 3 presents the results of the study along with a brief summary of the data used to support each conclusion. Finally, Chapter 4 presents the conclusions and recommendations for future studies.

CHAPTER 2

METHODOLOGY

2.1 General Description of Methodology

While the scope of work outlined in Chapter 1 identified a number of different issues to be addressed in the course of this study, the interrelated nature of the various market sectors indicated that a generalized approach to the study would be the most efficient. Therefore, for each of the first two tasks, Market Review and Industrial Capabilities Review, a similar method was used. This approach consisted of data acquisition, correlation, analysis, and interpretation. The third task, strategic assessment, was partially addressed through the data acquisition phase and completed through internal analysis.

Data acquisition was performed on three levels; namely, a literature search, written questionnaires, and personal interviews. Table 2.1 lists the organizations interviewed.

Data correlation and analysis was performed by the researchers with a view towards satisfying the specific requirements outlined in the scope of work. A major part of this work was determining accurate estimations of past and planned activities and expenditures of various organizations and countries. Interpretation of the correlated data sets was performed by the Bercha researchers with the assistance of several expert consultants. The final report represents the result of this interpretation.

TABLE 2.1

LIST OF ORGANIZATIONS INTERVIEWED

ORGANIZATION	LOCATION
Alberta Science and Technology	Edmonton, Alberta
Atmospheric Environment Service, Ice Centre	Ottawa, Ontario
Bakosurtanal	Jakarta, Indonesia
Bercha Group	Calgary, Alberta
Binary Image Corporation	Aldergrove, B.C.
Bristol Aerospace, Inc.	Winnipeg, Manitoba
Canada Centre for Remote Sensing, Applications Division	Ottawa, Ontario
Canadian Astronautics Ltd.	Ottawa, Ontario
Canadian Wheat Board	Winnipeg, Manitoba
Department of Energy and Natural Resources	Manila, Philippines
EOSAT Inc.	Lanham, Maryland
ESA	Paris, France
Intera Technologies Ltd.	Calgary, Alberta
Jet Propulsion Laboratory	Pasadena, California
Lapan	Jakarta, Indonesia
MacDonald Dettwiler and Associates	Richmond, B.C.
Malaysian National Remote Sensing Centre	Kuala Lumpur, Malaysia
Manitoba Remote Sensing Centre	Winnipeg, Manitoba
NASA	Washington, D.C.
National Research Council of Thailand	Bangkok, Thailand
Sabah Foundation	Kuala Lumpur, Malaysia
Saskatchewan Science and Technology	Saskatoon, Saskatchewan
SED Systems Inc.	Saskatoon, Saskatchewan
SPAR Aerospace Ltd.	Ste. Anne de Bellevue, Quebec
SPOT Image	Toulouse, France

CHAPTER 3

RESULTS AND CONCLUSIONS

3.1 Market Review

The following sections summarize the primary conclusions relating to each of the specific subtasks assigned in the scope of work throughout this report, dollar amounts are given in 1990 U.S. dollars.

3.1.1 Identification of Current and Planned Expenditures on Remote Sensing Satellite Systems

Apart from the Soviet Union, the key countries in the global remote sensing market are the United States of America, Japan, and France. Of these, the U.S.A. has the most extensive space program. Japan and France, however, are developing strong programs on their own. Each of these nations have developed their own launch capabilities thus reducing their dependence upon other nations.

In 1990, the U.S. space budget is approximately $30 billion. Space remote sensing programs in the U.S.A. are administered through NASA which is responsible for the U.S. space program, NOAA responsible for the meteorological satellite program, while EOSAT, a private company, is responsible for the acquisition and distribution of Landsat data. Remote sensing satellites for military purposes are administered primarily by the Air Force. At present, funds have been secured for the development of Landsat 6 which is estimated to have a final cost in the order of $300 million at launch time, roughly 1992. The major thrust for the future of the U.S. space remote sensing program is the Earth Observing System (EOS) which will consist of a variety of sensors on multiple platforms serviced from the space station. While international cooperation is a major component of EOS, estimated costs to the U.S. could range to several billion dollars. During the current development phase a sustained yearly budget of $250 million is required to keep these projects on track.

Within western Europe, France has the largest and most extensive space program. The French space program is managed by Centre Nationale d'Etudes Spatiales which also acts as the distributor for the space budget. CNES initiated the formation of SPOT Image, a semi-private corporation with a commercial structure. The SPOT program was initiated with the cooperation of Sweden and Belgium.

In 1989 the French space budget was approximately $1.3 billion. Of this budget, France contributes approximately $400 million to the European Space Agency (ESA) and the remainder is used for international projects. France is unique in being the only member nation in ESA which provides more funds to its own program that it contributes to ESA. At the present time SPOT Image operates two satellites which were each launched at a cost of approximately $300 million. Commitments have been made for at least two more similar systems to be launched at two year periods in 1992 and 1994.

Japan has also been steadily developing a major space program for earth observation. Japan's budget in 1988 was approximately $1.13 billion. A series of satellites have been launched primarily for atmospheric and oceanographic purposes. The recent launch of MOS-1B and the current development of JERS-1, are examples of Japan's commitment to Remote Sensing. Japan intends to support the EOS initiative with the contribution of the Japanese Polar Orbiter (JPOP). Accurate cost breakdowns for these systems are difficult to obtain, however, the total budget for remote sensing on a yearly basis represents roughly 12-15% of the overall Japanese space expenditure.

Other countries with commitments to space remote sensing systems include India which presently has the IRS-1 satellite, similar to the original Landsat systems, operated at a budget of roughly $240 million per year. A second satellite, IRS-2, is planned for launch in 1991 in cooperation with the Soviet Union. The Radarsat program represents Canada's first foray into the space remote sensing market. This system to be launched in 1994 will cost roughly $300 million. The European space agency intends to launch the Earth Resources Satellites (ERS-1) in late 1990 or early 1991 at a cost of approximately $500 million. Commitments for ERS-2 will likely be made within the next year. Brazil, China, and Sweden also have plans for experimental programs.

3.1.2 Structure and Composition of the International Supply Base

The international supply base for remote sensing and earth observation systems and services is primarily concentrated in the major space faring western nations namely; U.S.A., Europe, and Japan. Other nations supply components of varying levels of complexity. Nations which possess a well developed technology base for non-remote sensing satellite systems include: the United Kingdom, West Germany, Canada, Sweden, and Italy. China and the Soviet Union possess both remote sensing and launch capabilities but are not considered part of the international supply base due to internal policies and international restrictions.

The satellite systems sector of the remote sensing industry is heavily dominated by U.S. firms such as Hughes, General Electric, Martin Marietta, Boeing, Rockwell, Lockheed, and TRW. These companies have benefited from the extensive support for earth remote sensing which has been provided by the U.S. Government as well as the ability to commercialize technology originally developed for military purposes. In Europe the major firms are Dornier and M.B.B. in West Germany, Aerospatial and Matra in France, Fokker in the Netherlands, and Marconi and British Aerospace in the U.K. Italy is also well represented by several smaller firms. In Japan, the main companies involved in satellite systems are Toshiba, NEC, Mitsubishi, and Hitachi.

To date, the major commercial usage for satellite technology has been for telecommunications and a number of nations have made commitments to developing these technologies. Nations such as Australia, Canada, Israel, and South Africa all have some form of capability in production of telecommunications satellite components. A number of these technologies may be applied to earth remote sensing such as telemetry, primary sensors, and power supplies. Certain crucial technologies are only available in the U.S.A., Europe, and Japan. These include attitude sensing systems such as horizon and sun sensors, reaction control systems, and platform or bus designs.

Ground reception stations for remote sensing satellites are supplied primarily by four major companies representing Canada, the U.S.A., France, and Japan. The dominant country in this case appears to be Canada, represented by MacDonald Dettwiler and Associates (MDA). STX systems in the U.S.A. is the oldest of the companies and has performed many contracts worldwide. MS2i systems in France is a consortium between SEP and Matra, two of the leading French space corporations. Japan is represented in this field by Hitachi.

Satellite remote sensing data is distributed through two commercial organizations, EOSAT in the U.S.A. and SPOT Image of France, and a number of government owned institutions which operate ground receiving stations and receive data under licence to the above-mentioned companies. Figure 3.1 indicates the current distribution of these ground stations.

The value added industry is divided into suppliers of equipment and software for the enhancement and interpretation of remotely sensed imagery, and the firms which perform the actual image interpretation and enhancement who are usually customers of the first group. Almost all of the developed countries are represented in both of these groups, however, the industry is generally dominated by American firms, such as Intergraph, I²S, and Erdas as equipment and software suppliers

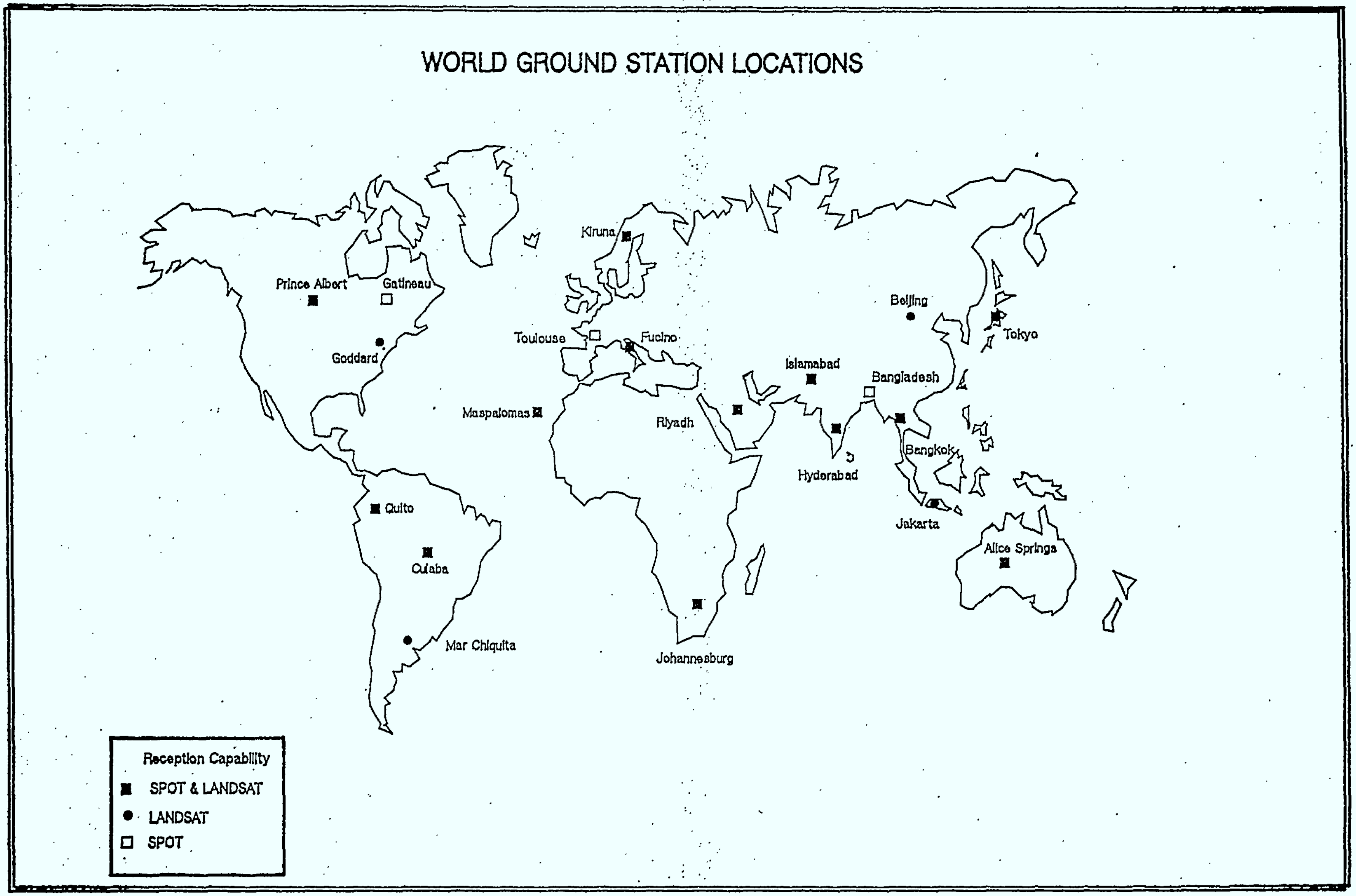
WORLD GROUND STATION LOCATIONS
Kiruna
Prince Albert
Gatineau
Goddard
Toulouse
Fucino
Beijing
Tokyo
Islamabad
Bangladesh
Maspalomas
Riyadh
Bangkok
Hyderabad
Quito
Jakarta
Alice Springs
Cuiaba
Johannesburg
Mar Chiquita
Reception Capability
SPOT & LANDSAT
LANDSAT
SPOT

FIGURE 3.1

and value added companies such as STX, Geospectra, and Earthsat Corporation. Until recently, the United States has been the largest market for value added systems and services and thus the largest concentration of suppliers is located in that country. A relatively large base of supply for both service and software is available from the European countries, Japan, Canada, and Australia. As well, there are a number of value added firms offering services in many of the third-world countries.

In the satellite systems industry one trend which appears to be forming is the cooperation between countries on system development. A primary example is the proposed EOS system which will comprise four polar orbiters contributed by the U.S.A., Europe, and Japan. In terms of ground stations and data suppliers, there has been some movement towards a unification of supply systems through agreements between the various countries regarding access to data, however, this trend is by no means wide-spread. In the data processing, interpretation, and value added sector, the primary trends are towards integration of various data sets from different sensors and the use of Geographic Information System (GIS) software.

3.1.3 International Demand for Earth Observation and Remote Sensing Data

International demand for remotely sensed data appears to be in excess of $40 million for 1989 with reported growths of up to 20% per year. The primary data sources are the SPOT and Landsat satellites. One of the major factors which affect demand is timeliness of supply, a problem which prevents most of the other current remote sensing systems from competing with EOSAT and SPOT as they are not equipped with international processing and distribution facilities. In fact, even with the considerable processing and distribution capability possessed by EOSAT and SPOT delivery of archived products is still often delayed by periods of several months, a problem which has somewhat limited the potential growth of the remote sensing market.

3.1.4 Current Uses of Available Data

As shown in Table 3.1, a number of types of space remote sensing data are, or were, available. The sensors used range from photographic systems to optical and infrared scanners and imaging radar systems. While the list appears to be extensive, for those users requiring large areas of coverage with rapid data access only the operational major systems, such as NOAA, Meteosat, Landsat, SPOT and MOS-1 provide data sets which will satisfy those needs.

TABLE 3.1

SUMMARY OF AVAILABLE SATELLITE DATA

SATELLITE	SENSOR	ORIGINATING COUNTRY	APPLICATION
Mercury/Gemini/Apollo	Hand Held Camera	USA	Earth
Skylab	Hand Held Camera, MSS	USA	Earth
Apollo/Soyuz	Hand Held Camera	USA/USSR	Earth Oceans Atmosphere
Space Shuttle Photography	Hand Held Camera Metric Camera Large Format Camera	USA	Earth Oceans
Soviet Photography	KFA 1000 + MK4 Camera	USSR	Earth
Landsat	RBV MSS TM	USA	Earth
SPOT	PLA MLA	France	Mapping Oceans Earth
MOS-1	MESSR VTIR MSR	Japan	Earth Ocean Atmosphere
IRS	LISS 1 LISS 2	India	Earth
Seasat	SAR	USA	Oceans Earth
Kosmos	RAR	USSR	Oceans
Space Shuttle	SIR-A + B MOMS SMIRR	USA FRG USA	Earth Oceans
HCMM	HCMR	USA	Earth Oceans
NOAA	IR	USA	Atmosphere
NIMBUS	CZCS	USA	Oceans
GOES/SMS	VISSR	USA	Atmosphere
Himawari	VISSR	Japan	Atmosphere
Meteosat	VISSR	Europe	Atmosphere

3.1.5 Future Remote Sensing Satellite Data Acquisition Programs

As shown in Figure 3.2, a number of operational and experimental earth remote sensing satellites are planned for the next decade. These include major operational efforts such as Landsat 6, SPOT 3, 4, and 5, ERS-1, possibly ERS-2, and of course, Canada's Radarsat. While SPOT and Landsat aim to provide continuous supply of a traditional data set based upon multispectral imaging, the other sensors represented on these systems are predominantly imaging radar. Experimental sensors will be flown on missions such as Topex/Poseidon, Geopotential Research Mission, Magnetic Field Explorer, and the Tropical Rain Explorer Mission to name but a few. Most of the experimental systems being developed are cooperative efforts.

3.1.6 Identification of Specific Opportunities for Canadian Industrial Expansion

Opportunities for Canadian industrial expansion exist in several sectors of the global remote sensing market. One opportunity identified relates to the distribution of remotely sensed data on an international basis. As mentioned previously, timely acquisition of recent data is a major requirement for many potential users. The inability of the current distribution system to rapidly respond to data requests, and even sometimes to locate the required data, is one of the major impediments to the market's growth. Canadian expertise in data processing and distribution could be applied to this process by creating an international agency for the location, cataloguing, and distribution of remote sensing data to international users. Such an agency would contribute greatly to the expansion of the remote sensing industry. Major stumbling blocks to the formation of such an agency would be the requirement for cooperation among many national government agencies, however, organizations such as Inmarsat, indicate that such cooperation is possible.

A second opportunity appears in the so-called "Announcement of Opportunity" sensors proposed for many of the larger polar platforms to be launched later this decade. By taking advantage of these space allocations on the large polar orbiters, Canadian companies could potentially orbit commercial remote sensing intruments at a relatively low cost. The trade-off in this case is the fact that the operator of the satellite looses control over the actual orbital position of his sensor and must share the telemetry system with other sensor operators.

A third opportunity appears in the opening of previously untapped markets, specifically the Soviet Union. Due to the similarity in geographic position, Soviet needs for imagery from Radarsat are undoubtedly similar to Canadian requirements. The Soviet Union has already made attempts to fulfil their needs using lower resolution radar satellites such as Okean, however, it seems likely, that

FUTURE EARTH OBSERVATION PROGRAMS AND THEIR EXPECTED PERIOD OF ACTIVITY

COUNTRY/ GROUP	FIELD	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
ESA	Atmosphere	MOP 2 x			MOP 3 x					MSG * ?	
	Land	ERS 1 x				Aristoteles * ?			* EPOP 1		
	Ocean	* ? MFE				ERS 2 * ?					EPOP 2 * (MID 2000)
FRANCE	Land	SPOT 2 o		SPOT 3 x			SPOT 4 *				SPOT 5 *
	Ocean		Poseidon (TOPEX) x	(France/USA)							
INDIA		IRS 1B x		IRS 1C x ?							
JAPAN	Atmosphere					GMS 5 x ?		* ? TREM (USA/Japan)			
	Land			JERS 1 x		?					
	Ocean	MOS 1b x				* ADEOS				JPOP 1 *	
U.S.A.	Atmosphere	GOES I x; NOAA I	x; GOES J x; UARS x	x GOES K; x NOAA J	NOAA K x		x NOAA L	GOES L x ?; NOAA M *; * ? TREM	GOES M x ?		
	Land		Landsat 6 x		SIR C x	GRM * ?; SIR C x; * ? Landsat 7	x SIR C	* NPOP 1; (USA/Japan)		* NPOP 2	
	Ocean		TOPEX (Poseidon) x	(France/USA)							
OTHERS	Atmosphere				(China/Brazil) BRESEX x						
	Land				x LGS (Italy)	x Radarsat (Canada)					
	Ocean	x SAR (USSR)		?							

NOTE: o operational x under development * planned ? period of activity unknown

FIGURE 3.2

political considerations aside, the Soviet Union is an excellent potential market for Radarsat data and possibly ground stations.

3.1.7 Review of Alternative Methods

In this study, alternative methods to space based remote sensing are considered in terms of application area. The application areas discussed include agriculture, atmosphere, engineering, surveying and mapping, forestry, geology, hydrology, oceanography, land use, glaciology, ice surveillance, and general surveillance. Table 3.2 summarizes the sensors used for both space and airborne remote sensing for each of these applications and discusses some of the general advantages of each.

At the present time the primary alternative to space based remote sensing continues to be aerial photography. In spite of the high costs and logistical difficulties inherent in the photographic approach, the familiarity of the product, and its high resolution coupled with an extensive historical data base in some regions ensure that this technique will continue to be used for quite some time. Oceanographic and atmospheric studies are among those which are best suited for satellite remote sensing due to the large areas which need to be covered. For most other application areas, airborne remote sensing, either using photography or more advanced systems, is quite competitive due to the ability of the end-user of the data to control the precise manner of data acquisition such as spectral and spatial resolution, look direction, time of day, etc. Such advantages are unlikely to be realized by space-borne systems for quite some time.

3.1.8 Trends and Impact of Foreign Government Policies

As motivators and regulators of the remote sensing industry, governments use their research and development agencies as well as taxation and procurement policies to promote their internal business interests. Accordingly, some foreign countries present a good business potential for Canadian industries, whereas others tend to protect their national interests and thus do not represent a favourable market. In the satellite systems sector, which is characterized by intensive capital requirements and high risk, government policies are most influential. Either through selective procurement procedures or financial support for national organizations. France and Japan are the most aggressive nations in this regard. The U.S. tends to use restrictions on technology transfer to ensure that American firms are favoured for certain satellite contracts. Canadian firms, in competing with organizations from the above-mentioned nations, must rely on a considerable amount of government support in order to win foreign contracts. In the data reception and value added sectors of the industry, competition is relatively even and unaffected by government policy.

TABLE 3.2

SUMMARY OF SPACEBORNE AND ALTERNATIVE COLLECTION TECHNIQUES FOR VARIOUS APPLICATIONS

APPLICATION	SPACE	AIRBORNE
AGRICULTURE	Sensors: MSS,TM,SPOT,AVHRR Ability to identify cropped versus uncropped fields, estimation of crop yields, plus in some cases crop health. Low resolution is a disadvantage.	Sensors: Camera, MEIS, Radar Permits identification of crops and conditions, diseased areas, and soil moisture. Expense of these sensors is a disadvantage.
ATMOSPHERE	Sensors: Radiometer, AVHRR, Scatt, Lidar, MS Provides synoptic views of the earth, measurements of wind speed, surface temperatures. A disadvantage is that local temperatures and conditions cannot be measured.	Sensors: Balloons, Aircraft Measurements such as wind speed, temperature and humidity at various altitudes are available. Cannot provide synoptic coverage.
ENGINEERING, SURVEY AND MAPPING	Sensors: MSS,TM,SPOT Ability to study regional conditions which might affect large structures. Stereo SPOT imagery can provide elevation data. Some nations use SPOT for small scale mapping. Stereo SPOT is not of sufficient accuracy for topographic mapping and satellite imagery does not permit detail identification of construction materials.	Sensors: Camera, MEIS, Radar Airborne data provide best information for topographic mapping, and local site conditions for construction. Best for studying local environmental conditions. Radar is useful for studies of ice dynamics as they relate to ocean structures that will encounter ice conditions. Expense of data is a major disadvantage.
FORESTRY	Sensors: MSS,TM,SPOT,AVHRR Useful for monitoring clear cut areas, diseased forests over large regions. Disadvantage is that tree species, local environmental impact cannot be assessed and often imagery can be cloud covered.	Sensors: Camera, MEIS, Radar Useful for tree species identification, diseased forests, and various densities of forest cover.

TABLE 3.2 - Continued

SUMMARY OF SPACEBORNE AND ALTERNATIVE COLLECTION TECHNIQUES FOR VARIOUS APPLICATIONS

APPLICATION	SPACE	AIRBORNE
GEOLOGY AND GEOMORPHOLOGY	Sensors: MSS,TM,SPOT,Seasat,SIR The imagery is useful for delineation of structure and geobotanical studies. Radar (Seasat - SIR) have been used for this purpose and provide a side view highlighting topography. Satellite multispectral data presents a planar view and does not highlight topography. Multispectral imagery is susceptible to cloud cover.	Sensors: Camera, MEIS, Radar, TIR,Magnetometers,Gravity Imagery has been used extensively in geomorphological and geological interpretations as well as geobotany and mapping. Radar has been more useful for structural mapping. Geophysical instruments provide data which can be used to support and assist interpretations from airborne imagery. Multispectral imagery has been used in Geobotany. These types of data are expensive to acquire.
HYDROLOGY	Sensors: MSS,TM,SPOT,Seasat,SIR Imagery has been used for study of regional hydrologic processes but not local processes. Problems occur on multispectral data where clouds and snow are similar in reflectance.	Sensors: Cameras, MEIS, Radar, TIR Useful for determination of sedimentation, algae, shallow aquifers and soil moisture. Imagery is expensive to acquire but confusion between snow and clouds does not exist.
OCEANOGRAPHY	Sensors: MSS,TM,SPOT,SIR,Seasat,AVHRR Useful for study of ocean processes, currents, wave patterns, plankton and surface temperature are all measured from satellites. Clouds present problems by obscuring ocean.	Sensors: Camera,TIR,MEIS,Spectrometers,Radar,FLI Sensors are useful for studying oceanic processes, identifying ships and oil spills. This imagery is only capable of covering small areas. Few geographic reference locations available in open ocean.
LAND USE	Sensors: MSS,TM,SPOT,SIR,Seasat Imagery can be used to identify land use practices more frequently over regional areas and updating road networks. Clouds are the greatest problem for multispectral data sets.	Sensors: Camera, MEIS, Radar Imagery is most valuable for updating urban land use changes. The expense is high for this imagery.

TABLE 3.2 - Continued

SUMMARY OF SPACEBORNE AND ALTERNATIVE COLLECTION TECHNIQUES FOR VARIOUS APPLICATIONS

APPLICATION	SPACE	AIRBORNE
GLACIOLOGY	Sensors: MSS,TM,SPOT,SIR,Seasat,AVHRR Used to monitor glacial environments such as polar ice caps and glacial movement. Orbital paths are not advantageous for monitoring polar caps in the case of some satellites and there is difficulty in separating snow from cloud in multispectral images.	Sensors: Camera, MEIS, Radar Imagery is used to study ice. Radar penetrates the snow to produce surficial glacier features. Ice penetrating radar provides information on ice thickness. Cost is the most prohibitive aspect of this imagery.
ICE SURVEILLANCE	Sensors: TM,MSS,AVHRR,SPOT,Seasat,SIR Imagery is used to monitor ice conditions. Radar is best for this surveillance because of the all weather and light conditions sensing capabilities. However, there are no active satellite radar sensors at present. Multispectral sensors can be used when light conditions improve.	Sensors: Camera,Radar,MEIS Radar is the most usable form of ice surveillance data. Low northern light conditions in winter months permit the acquisition of multispectral data. Radar also provides information about the ice type not available from multispectral sensors.
GENERAL SURVEILLANCE	Sensors: None Events such as forest fires, erosion, and flooding require continuous coverage in near real time which is not available from satellites.	Sensors: Camera,MEIS,Radar These images provide data on events which are not covered using satellites. Although costly, this information is required for planning strategies prior to the occurrence of severe damage.

3.2 Market Review

Remote sensing and earth observation technology have received considerable attention in Canada. This attention is due partly to the applicability of existing capability in space systems and data processing, and partly due to the continual need in Canada for up to date mapping and resource information. The result has been the growth of a number of private and government organizations with some level of expertise in all three sectors of the space remote sensing industry.

The following sections describe some of these organizations according to the sector in which they operate. A discussion of the nations technology base with specific application to the design of earth observation sensors, small satellites, and data reception systems follows. Finally, some of the deficiencies in Canada's technology base are pointed out with an attempt to identify areas for development and improvement in international markets.

3.2.1 Canadian Companies and Capabilities

The following discussion of Canadian industrial capabilities is restricted to commercially available (i.e. non-military) systems. Because of the secrecy required of those companies supplying military systems, determining their true technical capability is not possible using the methods of this study.

3.2.1.1 Satellite Systems and Subsystems Capability

Canada's space industry is primarily concerned with communications systems and has an excellent reputation for quality and innovation. Due to the lack of national programs, the technologies unique to remote sensing satellites have received much less attention. With the advent of Radarsat, planned for launch in 1994, this singular focus will hopefully change. In the meantime, a number of Canadian firms have developed expertise in these technologies by contributing sub-systems and components to other countries earth observation systems.

The list of major sub-systems for a typical communications satellite shares a number of common features with that for a remote sensing satellite. These sub-systems include;

- the bus, or basic structure,
- attitude and orbital control systems,
- telemetry, tracking and control (TTC) systems,
- power systems.

Sub-systems which are unique to a remote sensing satellite include;

- the earth sensor,
- data storage facilities,
- data transmission systems.

Depending upon the requirements of the design, each of the above sub-systems may range in complexity from a single component to an extensive integration of many devices which require a number of dedicated computer controllers in order to coordinate their functions. As satellites have grown larger over the past three decades, the trend has been to more complex systems.

A number of Canadian firms have a demonstrated capability for the provision of components or services for space systems. Of the over 140 companies identified, six are considered "major" in terms of capacity and experience in remote sensing systems development.

The leading company is SPAR Aerospace, located in Quebec, which is the prime contractor for Radarsat. SPAR has considerable capability in systems integration, radar systems development, TTC, structural systems, optics, and solar arrays.

Canadian Astronautics Ltd. (CAL), located in Ontario, is a research oriented company which specializes in radar and optical sensors as well as TTC. CAL has supplied an ultraviolet imager to the Swedish satellite Viking, and is supplying the antenna for Radarsat.

Com Dev, also located in Ontario, is a major supplier of microwave components for communications and remote sensing satellites. SED Systems, of Saskatchewan, supply optical sensors, microwave components, and TTC systems. Bristol Aerospace, of Manitoba, is primarily involved in rocket engines but is developing the capability for systems integration and structural component manufacture.

The sixth company, MacDonald, Dettwiler, and Associates (MDA), of British Columbia, is a supplier of military and commercial airborne radar sensors and is a recognized leader in the supply of specialized processing systems.

3.2.1.2 Data Reception and Handling Capability

In spite of the small number of Canadian companies participating in this sector, the international market which is served by them is considerable. Remote sensing ground stations are essentially a combination of specialized radio equipment for receiving the satellite signal, combined with computer and data storage equipment for archiving and processing the data.

Many of the components necessary for the construction of a ground station may be acquired from a variety of sources, while the integration and software are the key technology. Four Canadian companies are capable of producing components or complete systems.

MacDonald Dettwiler and Associates (MDA), mentioned in the previous section, are the leading company in Canada, and indeed one of the leaders in the world for remote sensing ground station technology. MDA's primary strength appears to lie in the ability to integrate components obtained from other sources.

SED Systems, of Saskachewan, is also experienced in the design, construction and operation of ground stations. Although they have not built a complete system for remote sensing, they were the original operator of the Prince Albert receiving station for the Canada Centre for Remote Sensing, and have considerable capability for producing radio frequency equipment such as antennas and receivers.

Canadian Astronautics Ltd. (CAL) has capabilities similar to SED and is pursuing the communications market at this time. Array Computing Systems supplies ground stations for meteorological systems such as the GOES satellites.

3.2.1.3 Value Added Systems and Services

A large number of Canadian firms are involved in this sector, both for the provision of services and the sales of hardware and software. In addition, a number of companies which may be considered "end users" possess considerable capability for value added work.

Companies which provide remote sensing interpretation services on an international basis include The Bercha Group, Dendron Resource Surveys, Electromagnetic Sensing and Interpretation Ltd., Horler Information, Intera Technologies, and Nordco. Over one hundred organizations, including some government agencies and universities, have been identified which possess some capability for providing value added services.

Eight companies in Canada are developing and marketing software and hardware for the processing and interpretation of remotely sensed data. These are MDA, PCI Inc., Dipix Technologies, Applied Terravision Systems, Eidetic Image Co., Pamap Graphics, Imago Ltd., and Nucor Inc.

3.2.2 The Existing Technology Base

Canadian technology for earth observation sensors is primarily focused on synthetic aperture radar systems (SAR). The primary companies in this field are MDA, CAL, and Spar. Other sensor technologies which Canadian companies have some ability to produce are optical and ultraviolet imaging systems, microwave scatterometers, infrared scanners, and multispectral scanners. The record for Canadian instruments in space has generally been very good, however the rate of technological progress in these field is extremely high and a heavy commitment to research is needed to maintain this success.

The technology required to design and build a small satellite may be within the existing capability of Canadian industry. Canada is missing several key technologies such as reaction control and attitude sensing systems. These devices, however, can be commercially obtained from foreign sources. It would appear that the primary requirement for a successful small satellite development program is a launch capability in order to control operational costs.

The Canadian technology base for data reception systems is primarily grounded in software and design. In order to improve the existing technology base, advanced computer and data storage technologies will need to be pursued.

3.2.3 Deficiencies in the Canadian Technology Base

The space systems sector of the remote sensing industry presently lacks the technology to build a multipurpose satellite bus, launch it, and maintain its attitude and position in orbit. These technologies are all available on the commercial market. For the production of ground receiving stations, the only major deficiency appears to be the ability to manufacture high quality telemetry antennas. In the value added sector, few deficiencies can be identified however some improvement could be made in the transfer of technology from government research centres to private industry.

3.2.4 Areas for Development and Improvement in International Markets

The continued development of SAR system technology is very important for the Canadian space industry. Due to the inherent advantages of these active sensors, they will remain the major focus of remote sensing research for quite some time. This will lead to a growing industry for the development and operation of space based SAR systems. In order to tap this new market, Canadian firms must maintain their technological edge in antennas, receivers, and processors.

More important from a general industry viewpoint is the development of applications technology for solving real-world problems using space remote sensing data. This is a function of the government sponsored research centres and the various value added firms. Support for innovative research and more general distribution of research data and findings will promote the quest for these solutions.

3.3 Strategy Assessment

The purpose of the strategy assessment task is to develop optional strategies for the application of Canadian capabilities to the international remote sensing market. This was done through the identification of growing market areas which match existing Canadian capabilities, identification of Canadian capabilities which can be effectively enhanced, prediction of potential future market share attainable by the various sectors of Canadian industry, and a recommendation for Canadian government policies which would serve to further the interests of the Canadian industry. Finally, a recommendation is made for continuing monitoring of market conditions in order to ensure that the proposed strategies outlined below are having their desired effect.

3.3.1 Areas of Potential Market Growth

The space based earth observation and remote sensing industry is currently in a position of early development and thus has a large capacity for potential growth. Actual growth over the next decade, however, is difficult to predict due to the high cost and associated difficulties of budget mobilization for the realization of technological advances in this field. Based upon current funding, planned by the various space agencies, a number of specific subsectors of the industry can be expected to grow over the next ten years.

Announcements of future earth observation satellites by the various executing agencies indicate that the market for complete satellite systems for earth observation may be expected to increase over the next decade. Unfortunately for Canada, the complete satellite system market is strongly protected by the nations which supply the funding, therefore, any major benefits to Canadian industry will be dependent upon Canadian government funding and initiatives such as contributions to NASA or ESA. It is likely that the best hope for Canadian satellite producers would be a government commitment with follow-on to Radarsat and, possibly, a long-term small satellite based earth observation system.

Manufacturers of satellite components and subsystems may see significant expansion in their sector. This potential applies particularly to makers of sensors, specifically those of radar antennae and associated components as well as custom-optical components, power systems, telemetry and control systems, and solar arrays.

The ground receiving station market will likely see small to medium growth over the next decade. The potential construction of between two and six new ground stations in order to provide complete Landsat and SPOT coverage of the earth's land mass is likely. Canadian industry is well positioned to benefit from this general market growth. Additional potential for the upgrading of existing ground station also exists. The demand for radar processing capability in order to use data generated by Radarsat ERS-1 and JERS-1 fits very well with existing Canadian cpability.

Growth in the value added sector is dependent upon the successful demonstration and marketing of specific applications of remote sensing data to existing needs in the mapping and resource sectors. It seems likely that this will occur leading to moderate to extensive growth in the value added sector.

3.4 Prediction of Market Share

Canadian industry currently posseses a small but relatively stable portion of the international markets for each of the sectors of the remote sensing industry. Factors which affect market share in these sectors include the following:

(a) Level of technology relative to competitors;

(b) Pricing;

(c) Type and level of government support;

(d) Quality of marketing effort; and

(e) International perception of Canadian capability.

As mentioned previously in the satellite and ground station market segments, government support is extremely important. In the value added sector, government support is somewhat less important although foreign aid policies such as the projects administered by CIDA do tend to affect international marketing. Table 3.3 summarizes the predicted Canadian market share which may be attained from the total international market in terms of products and services for the three industry sectors. The technology enhancements required to achieve these market shares focus primarily on the technology of synthetic aperture imaging radar systems. For the space sector, specific technology which must be pursued include steerable beam antennae, multi-polarization, and multi-frequency systems, high speed array processors and the reduction of transmitter power requirements. Ground station manufacturers must concentrate on improvement of software systems, the use of parallel and

TABLE 3.3

SUMMARY OF PREDICTED CANADIAN MARKET SHARE

MARKET	ANTICIPATED 10 YEAR TOTAL	POTENTIAL CANADIAN SHARE	
	$ US	%	$ US
PRODUCTS:			
Satellite Systems	20×10^9	7	14×10^9
Ground Stations	82×10^6	55	45×10^6
Value Added	100×10^6	20	20×10^6
SERVICES:			
Satellite Systems	2×10^9	4.5	90×10^6
Ground Stations	40×10^6	25	10×10^6
Value Added	600×10^6	10	60×10^6
TOTAL	22.822×10^9	7.1	1.625×10^9

array processors, high capacity storage system development, and improved data management techniques. The value added sector must pursue the integration of GIS and image processing software, the extraction of digital elevation models from satellite imagery, the integration of multi-sensor data sets, the use of shape and texture in the analysis of high resolution data sets, and the efficient analysis of imaging spectrometer data.

3.5 Recommended Government Strategies to Enhance Canadian Competitiveness

With the pending launch of Radarsat, Canada is moving into a leading role among space remote sensing nations. The opportunity exists at this time for Canada to solidify its position as a world player in the earth observation field. This opportunity, however, demands close cooperation between both the provincial and federal governments as well as private industry.

The corner stone upon which a significant Canadian industrial base can be built is a strong, clear, consistent and long-term commitment by the federal government which embraces remote sensing as a field which Canada has chosen as one of great importance to Canada's international business strategy. This commitment will provide a strong framework within which private industry may expand. Such an expansion will require visible policies that can be referred to constantly both domestically and itnernationally in order to generate the greatest possible confidence in Canada's commitment to the remote sensing industrial sector. Table 3.4 highlights the policy and funding commitments recommended for the provincial and federal governments in order to meet these goals.

3.6 Basis for Further Studies

Based upon the proposals advanced in the previous sections, several topics should be investigated. These include a study of the requirements and benefits accruing of the Radarsat 2 program, a strategic study for implementation of commercial marketing support for the value added remote sensing industry, an investigation of the structure of federal and provincial environmental monitoring requirements and programs, and an investigation of the opportunities to promote Canadian educational programs overseas.

TABLE 3.4

HIGHLIGHTS OF STRATEGIC ASSESSMENT

POLICY

1. **Environmental Monitoring:**
   Increase requirements for environmental monitoring by resource users and regulatory agencies. Upgrade provincial and federal environmental monitoring programs.

2. **Use of Remotely Sensed Data:**
   Enact legislation requiring the use of remotely sensed data for above environmental monitoring regulations.

3. **Industry Input:**
   Government should actively seek private industry input on establishment of research and international market development priorities.

FUNDING

1. **Radarsat 2:**

   Commitment should be made prior to launch of Radarsat 1.

2. **Promotion of Canadian Industry:**
   The export of Canadian expertise should be promoted through the provision of technically literture trade officers in key market areas. A catalogue of Canadian companies and their capabilities should be published to aid in this endeavour.

3. **Research and Development:**
   R&D efforts should address:
   - Advanced SAR sensors and Applications of SAR Data;
   - Imaging spectrometer;
   - Wide field of view V/IR scanner;
   - Microwave scatterometer;
   - Atmospheric lidar sensors.

4. **Education and Technology Transfer:**
   Canadian Technical expertise should be marketed internationally through the supply of professors and instructors to key international instutions to teach remote sensing theory and practise. Support for the training of international students at Canadian institutions should be supplied.

5. **International Cooperation:**
   Canada should actively pursue cooperative efforts with other countries in remote sensing programs. Specific programs which should be considered include:
   - EoS;
   - ERS-2;
   - SPOT 5;
   - NOAA.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

4.1.1 Study Overview

This report presents the results obtained from the review of the global market for remote sensing and earth observation technologies and services as they relate to existing and potential Canadian industrial capabilities. For the purposes of this study, the remote sensing industry has been subdivided into three sectors. These sectors may be generally characterized as suppliers of satellite systems and components, suppliers of ground receiving stations, and suppliers of value added systems and services.

The methodology for the assimilation of the information required to perform this review was based upon an extensive literature review supplemented by interviews with knowledgable representatives of government organizations and private corporations. A final source of data was a series of questionnaires which were distributed to a large number of organizations throughout the world.

The market review focused upon a number of key issues including:

- tabulation of current and planned expenditures on space remote sensing systems;
- quantification of the international supply and demand for systems, services, and data;
- identification of current uses of available data and the sources of such data;
- investigation of planned remote sensing systems;
- a review of alternative methods of data acquisition; and,
- the impact of foreign government policies.

4.1.2 Market Review Conclusions

In general, the major suppliers of space based systems, data, and value added services have been identified as the U.S.A., Japan, and the major European nations, dominated by France, Germany, the United Kingdom and Italy. While Canada maintains a presence in all sectors of the market, her primary strengths are in ground receiving stations and value added services. The international demand for remotely sensed data appears to be growing in a number of sectors of the earth sciences. However, a number of critical applications are highly dependant upon timely delivery of the data and have specific requirements for both spectral and spatial resolution. It is these applications which offer the potential for significant market growth over the coming decade, providing the needs of the user community can be met with existing technology.

A number of space based remote sensing systems are planned for the next decade, offering a wide array of data characteristics. It should be noted that some of these proposed systems will not be completed due to lack of funding or technical difficulties. At the present time, it is clear that France, Japan, ESA, the U.S.A. and Canada have confirmed intentions to each launch at least one satellite over the coming decade for the purpose of earth observation. Less certain intentions have also been expressed by Brazil, India and China. The plans of the Soviet Union are not clear at this time but this country is known to have considerable capability in earth observation technology.

The primary alternative to space based data collection remains aerial photography. In some cases this is only due to the general familiarity of the user community with this form of information. In other cases, this situation persists because of the superior resolution and operational flexibility of airborne data collection. This indicates a potential need for ultra-high resolution visible and infrared optical sensors which are expected to be available before the end of the decade. The imagery obtained could have direct application to engineering and land use mapping, thus opening up large new markets for the space remote sensing industry.

Government policies which impact directly or indirectly on Canadian industry are generally positive as world trade barriers are lowered and the value of remotely sensed data is recognized for planning and monitoring purposes. France and Japan stand out as potential negative areas, however, as these countries strive to promote their national interests through protection of local markets and heavy subsidization of national industry. The remainder of Europe and the U.S.A. are mixed in terms of opportunities and disincentives for business. In general, these areas represent potentially lucrative markets, however the level of competition for these markets is high. The third world countries, especially those in South America and Asia, represent the largest potential market for products and services. These are also the least developed markets in terms of user sophistication and identification of requirements.

Generally, the international market volume for satellite systems is expected to total roughly $22 billion over the coming decade. Due to the long term nature of these contracts, yearly market volumes are difficult to assess and somewhat misleading. The market for ground receiving stations is expected to total $122 million over the same period. Value added systems and services are currently estimated to represent a $25 million per year market. Growth in this industry is likely to exceed 15% per year, leading to a total volume of over $700 million for the decade.

4.1.3 Capability Assessment Conclusions

Canadian industrial capabilities were assessed by:

- identifying Canadian companies competing in the three sectors of the industry and their specific capabilities.
- defining the existing technology base in Canada for earth environment monitoring with specific emphasis on capabilities for:
  - design, development, and building of earth observation instruments or sensors;
  - small satellites and other types of platforms; and,
  - data reception, processing and information extraction, dissemination, and assimilation systems.
- identifying the deficiencies in the Canadian technology base and the development and improvement needed to compete in international markets.

Using the results of the capability survey, and information extracted from industry directories and interview notes, the capabilities of Canadian companies and institutions were tabulated according to the three market sectors. Several companies had significant capabilities in more than one sector but for the majority of firms, the classification was unique. The potential for the Canadian space industry to compete in international markets appears to be increasing. This is due in large part to the expertise being acquired through the development of the Canadian Radarsat program. Other contributing factors are technological achievements which have resulted from Canada's involvement with NASA and ESA through cooperative agreements.

The Canadian technology base is still weak in several key areas. Specifically these are:

- Attitude control systems;
- Orbit control systems;
- Lack of launch capability;
- Satellite bus design;

- Optical sensor technology.

These deficiencies prevent Canada from developing and operating satellite systems without the involvement of other countries. Due to cost considerations and the increasing availability of these technologies from foreign sources, the development of these technologies are unlikely to become priorities in the near future. The exception to this statement is optical sensor technology. Current research and development efforts indicate that these technologies are within Canada's means to develop on a commercial scale. Whether this technology is as promising as other sensors is a subject for further study.

4.1.4 Strategy Conclusions

The final requirement of this project was for the development of strategic recommendations, based on the above findings, aimed at improving the competitive status of Canadian industry. Specific items addressed were:

- identification of growing market areas that are most aligned with Canadian capabilities and competitive position;
- prediction of the market share in products and services that may be obtained together with an assessment of the technological enhancements that would have to be supported to realise this market share;
- development of strategic proposals for the federal government to assist Canadian industry in penetrating the international market;
- suggesting mechanisms for exploiting the identified market opportunities; and,
- indicating a basis for further study in this sector.

The strategic proposals developed were the result of discussion among the researchers based upon ideas and recommendations generated through the questionnaire and interview processes. The major proposals focused on expanding the international market share held by Canadian industry, however major consideration was given to the need to promote the overall expansion of the remote sensing market. The overall theme of the developed strategy is that the federal government should demonstrate a firm, long-term commitment to the expansion of the Canadian remote sensing industry through the support of international marketing efforts, an active space program, and the cultivation of the national market. The highlights of the strategic proposals are as follows:

- increase requirements for use of remotely sensed data through expanded environmental monitoring programs and regulations;
- commitment for a follow-on program to Radarsat;

- support funding for research and development into advanced sensor technology and small satellites;
- direct support for international marketing of value added firms; and,
- partial funding for a technology transfer program to foreign institutions and organizations.

While support for research and development of remote sensing satellites is primarily a government responsibility, the contribution of the value added sector, which acts as the main sales force for the data products, must be recognized and supported if commercialization of the Radarsat program is to take place. By promoting the profitability of current remote sensing programs, the government can reduce the requirements for funding for future programs as space remote sensing becomes a self supporting industry.

4.2 Recommendations

Based on the strategic recommendations given above, further studies are warranted in a number of areas. Foremost among these is the need for a determination of the possible future economic benefits to Canada which would follow from a commitment for the construction and launch of Radarsat 2. Such benefits would stem from sales to foreign markets of ground station upgrades, data acquisition licenses, radar processing software and value added services. The potential magnitude of these sales will have a direct relationship to the eventual payback to Canada for supporting this program. Naturally, such a study would be a prerequisite to any government commitment to such a program.

Other recommendations include studies into;

- Implementation of Commercial Marketing Support for the Value Added Industry;
- Investigation of the Structure of Federal and Provincial Environmental Monitoring Requirements and Programs; and,
- Investigation of the Opportunities to Promote Canadian Educational Programs Overseas.

A final recommendation would include a follow-on study to this project which would update the database of market information and Canadian companies and assess the progress of Canadian industry in the world market.