Energy, Mines and Resources Canada
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Canada Centre for Remote Sensing
Centre Canadien de Télédétection

Towards a Canadian Policy on Remote Sensing from Space A Special Report to the Canadian Advisory Committee on Remote Sensing

By
The Working Group on Data Handling and Satellite Technology

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A SPECIAL REPORT TO THE CANADIAN ADVISORY COMMITTEE ON REMOTE SENSING

By

The Working Group on Data Handling and Satellite Technology

RECOMMENDATIONS

1. Canada should develop an overall long-range plan for the utilization of remote sensing satellites.
2. Funded planning for a Canadian Remote Sensing Satellite should be started immediately.
3. Whenever possible and prudent, Canada should continue to participate in the remote sensing programs of other nations, particularly the United States.

FOREWORD

This special report prepared for the Canadian Advisory Committee on Remote Sensing has not been approved by either the Interdepartmental Committee on Remote Sensing or by the Interdepartmental Committee on Space.

Nevertheless, I considered it important to have it published in order to provide a basis for wide discussion amongst both Canadian Space Technologists and the large number of potential Canadian users.

Our hope is that this document will provide the initiative which will lead to a forward looking Canadian remote sensing program from space.

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Dept. of Energy, Mines & Resources.

Ottawa, Ontario
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1.0 INTRODUCTION

The emerging technology of remote sensing from outer space presents an unparalleled opportunity for Canada to monitor and hence manage her vast natural resources. Unless Canada masters this technology and organizes for it within Canada, other nations will take over the job by default. To meet this challenge, Canada must maintain her current position at the forefront of this rapidly developing field.

In order to assist the Canada Centre for Remote Sensing in planning for future data handling and space systems, the Working Group on Data Handling and Satellite Technology was formed in 1972. This group has built upon the work of the original Program Planning Office working groups, which involved data handling techniques and satellite ground station engineering and which were disbanded upon the successful completion of the design of the ERTS receiving station and ground data processing facilities. The sub-working group on Canadian Participation in Remote Sensing Satellite Programs was formed to study the specific field of remote sensing from space and this report is the culmination of the group's efforts over the past 18 months. All members of the sub-working group have considerable experience in space programs, and they represent both government and industry. The members, their present affiliations and a brief description of their space-related experience is listed below:

Mr. J.D. Taylor, Chairman, Canadian Astronautics

Mr. Taylor, until recently, was with Telesat Canada, where he was involved in the ANIK spacecraft program. His major responsibilities included spacecraft control systems, mission analysis and launch vehicle procurement. He was Launch Operations Manager at Cape Kennedy for the ANIK I & II launches.

Dr. W.M. Strome, Canada Centre for Remote Sensing

Dr. Strome is Chief of the Data Processing Division which is responsible for the reception, recording and ground processing of all ERTS data acquired over Canada. He was responsible for the overall system design of the Canadian ERTS data processing facility.

Dr. R.E. Barrington, Communications Research Centre, DOC

Dr. Barrington is manager of the Radio Communications Program of CRC. He was responsible for the conversion of the Prince Albert Radar Station into a ground station for the acquisition of ERTS data. He also managed the development of a prototype radiometer system for remote sensing applications.

Dr. F.J.F. Osborne, RCA Canada Limited

Dr. Osborne is Director of the Communications and Space Technology Laboratories of the R & D Labs. As such he has been involved in several scientific and communications satellite programs. Currently he is directing feasibility studies and R & D programs towards future communications and space application missions.

Mr. John Graham, Spar Aerospace Products Limited

Mr. Graham holds the position of CTS Program Manager and, as such, is responsible for all the company's activities on the Communications Technology Satellite. This has included overall spacecraft system design, and now includes conceptual design, detailed design, build and test of the Structure, Thermal, Attitude Control and Solar Array subsystems.

2.0 TERMS OF REFERENCE

To conduct studies and make recommendations to the Working Group on Data Handling and Satellite Technology in the following areas:

1) A Canadian Earth Resources Satellite Program based on system parameters, available technology, means of implementation and time scale.
2) Canadian involvement in Earth Resources Satellite Programs of other countries.
3) Alternate means of collecting and processing remotely sensed data.
4) Existing and required technological capabilities within Canada.

3.0 BACKGROUND

3.1. U.S. ERTS Program

The Earth Resources Technology Satellite program was designed as a research and development tool with which to demonstrate that remote sensing from space is a feasible and practical approach to the efficient management of the earth's resources. The knowledge gained from the application of data acquired from ERTS-1 and that which will be gained from ERTS-B, will point the way toward development of fully operational and more effective systems.

3.2. CCRS Data Handling and Acquisition

Since the launch of ERTS-1 on July 23, 1972, virtually all data acquired over Canada has been recorded on magnetic tape at either Prince Albert, Saskatchewan or at the Goddard Space Flight Centre Tracking Station (for coverage of Newfoundland). Because of reliability problems experienced with the image recorders at the Canada Centre for Remote Sensing, Ottawa, full processing of this data was not possible until April 1973. However, since that time, all data recorded has been processed and distributed, and the backlog of earlier coverage is gradually being reduced.

Although the quality of the photographic products produced by the Ottawa facility is excellent, it has not been possible with this system to provide turnaround times of less than about four weeks. While this compares very favourably with the NASA system, it is not adequate for the purposes of many Canadian users. In order to circumvent this turnaround problem, the quick-look facility at the Prince Albert Satellite Station (PASS) which was developed primarily as a system checkout tool, has been made available to a commercial organization which reproduces and distributes all data within three days of acquisition.

3.3. Future U.S. Planning

The second satellite in the series, ERTS-B, is to be launched by NASA in early 1975. (It is hoped that ERTS-1 will continue to operate satisfactorily until that time. To date the technical performance of this satellite has exceeded all expectations.) Since ERTS-B is essentially a copy of ERTS-1, the only additional requirement for reading out the data from the satellite is that of a negotiated agreement between Canada and NASA. Planning for an ERTS-C satellite which is to be launched in 1978 is just beginning. This satellite would carry the Multi-Spectral Scanner (MSS) with the fifth thermal infrared channel. A second MSS for redundancy, or a small pointable imaging device, might also be included. ERTS-C could be funded by either NASA or the Department of the Interior, and could be read out by a proposed receiving station at Sioux Falls. In the event of the failure of ERTS-B, there will be no remote sensing satellite data until 1978.

The only officially approved remote sensing satellite following ERTS-B is a small heat capacity mapping satellite to be launched by a Scout booster in mid-1977. The single sensor on board, a modified version of the Surface Composition Mapping Radiometer, is a two channel scanner, scanning from horizon to horizon with one channel in the thermal IR and one in the near IR. The useful part of the imagery will cover a swath width of about 700 km with .5 km resolution at the nadir and it will provide complete coverage every three days. The orbit, at an altitude of 600 km, will be sun synchronous with equator crossing times of 2 am and 2 pm, approximately the coolest and warmest times of the day. At least once every eight days every area will be covered on consecutive day and night passes and the temperature differences between the two images, combined with reflectance measurements from the near IR channel, will be used to generate heat capacity maps. The data will be transmitted in analogue form at S- band and the satellite will not have the capability for on-board recording.

NASA is developing plans for a series of Earth Observatory Satellites (EOS) based on modular platforms which are adaptable to a variety of missions. The funded phase A/B studies have recently commenced for EOS-A and a launch is planned for 1979. The planned mission parameters are: (a) a circular orbit at an altitude of 914 km; (b) a 17-day repeat cycle; (c) inclination 99.15 degrees (sun-synchronous); (d) equator crossing time at about noon. The payload would probably include a thematic mapper and a high resolution pointable imager. The thematic mapper might have seven spectral bands including the four ERTS-1 bands, two additional near IR bands, at 1.6 microns and 2 microns, and a thermal IR band. The thematic mapper would cover a 185 km wide swath with 30 m resolution. The high resolution pointable imager would probably have the same bands as ERTS-1, and would cover, with 10 m resolution, a 20 km to 40 km square area either inside or outside the thematic mapper swath. The data will probably be transmitted at X-band, but consideration is also being given to Ku band, which is used by the satellite communications relay system.

Although it is not planned for inclusion in the first satellite in this series, a synthetic aperture radar is being considered for a later, possibly hydrographically oriented, EOS. The proposed parameters are: depression angle adjustable from 49 degrees to 60 degrees; swath width 61 km; ground resolution – 20 m x 20 m; frequency X-band (10 gigahertz); input power – 4 kilowatts for up to 10 minutes per orbit.

The projected data rates from EOS satellites – 120 megabits from the thematic mapper – are much higher than those of ERTS, and will require new recording and data handling systems. The Prince Albert antenna would have to be replaced in order to receive X-band transmissions.

For ocean physics and ice reconnaissance applications, NASA is in the process of defining mission requirements for a SEASAT satellite for possible launch in 1978. Candidate sensors are a visible – IR scanner, a microwave radiometer/scatterometer, a radar altimeter, and an imaging radar. Nimbus – G, to be launched in 1977 or 1978, will also be oceanographically oriented.

Although little information is generally available on U.S. military satellites, it must be recognized that the military systems are probably at the forefront of space surveillance technology. An important factor in maintaining Canada's access to information which has been remotely sensed over Canada, is the fact that there is considerable pressure in the U.S. to bring all surveillance-type satellites, including meteorological satellites, under the control of the U.S. military. Should this take place, it is not known what Canada's position will be as far as obtaining access to data.

With regard to launch vehicles, NASA has placed a very high priority on the development of the space shuttle, and it is anticipated that most major satellite launches after 1980, will be required to use this vehicle.

3.4. Other Nation's Interests in Remote Sensing

There is considerable activity in many nations in planning ERTS ground read-out and data processing facilities. Brazil is the first country outside of Canada and the U.S. to obtain such facilities. The receiving station has been collecting data for some time, and the data processing system is currently being installed. Italy and Venezuela are planning to start work in the near future on ERTS receiving and processing facilities.

The European space effort is heavily committed to the manned Space Lab project which is a part of the U.S. space shuttle program. However, ESRO has recently indicated interest in satellite remote sensing using microwave sensors including synthetic aperture radar. It appears that such sensors would be tested by the space lab in the early 1980's before being launched on an operational, long life unmanned spacecraft mission.

3.5. United Nations Activities in Remote Sensing

Under the general direction of the Committee on the Peaceful Uses of Outer Space, the United Nations has initiated a number of studies related to remote sensing of the Earth from space. A back-ground paper was published in 1973 to summarize technical aspects, outline some of the problems related to legal and organizational aspects and provide a comprehensive bibliography. While there was, on the part of some nations, a desire for urgent development of international legal principles for handling remote sensing from space, it is not clear at this time whether such action will be pursued. Certainly there is strong opposition to the development of such principles at a time when both technology and applications are still uncertain in the opinions of many nations. Canada has consistently stressed the need for a broad, balanced and integrated consideration of technical, legal and organizational aspects during this present stage of development. A new task force met in early 1974 to consider aspects of disseminating and utilizing remotely sensed data and has recommended that feasibility studies be initiated in the areas of regional centres for receiving, processing and distributing remote sensing satellite data, regional training centres, and international data archives.

3.6. Canadian Planning for Remote Sensing

To date very little planning has been done towards Canadian post-ERTS involvement in remote sensing from space. The work of this committee will provide the foundation for such planning in the future.

The Canada Centre for Remote Sensing has awarded a contract to Canadian Astronautics and has formed an internal project to study missions for a potential Canadian Remote Sensing Satellite. Based on CCRS cost benefit applications studies, it has tentatively been decided that a Canadian remote sensing satellite should be oriented towards ice reconnaissance, hydrology and data retransmission.

4.0 LIMITATIONS IN SCOPE

In order to concentrate on the task of studying the options which are open to Canada in the pursuit of her continued leadership in the field of space-oriented remote sensing, the working group has had to avoid consideration of certain aspects of such a program. However, it is worthwhile to point out some of the areas which could not be considered by this group.

It has not been possible for the group to examine in detail the availability of suitable sensors, although it is known that there are a number of groups within Canada which have sufficient capabilities to develop these. Also, the group has tacitly assumed that U.S. launch services will be available as required without performing any detailed investigation of this situation.

The working group has not devoted a significant amount of time to the consideration of such factors as the recommended level of Canadian space program funding, or to the effects a Canadian remote sensing satellite program would have on industrial capacity in Canada in relation to other potential space programs. Finally, the working group has not given detailed consideration to the type of program organization which would be required to implement a remote sensing satellite program.

5.0. A RATIONAL APPROACH TO THE DEVELOPMENT OF A REMOTE SENSING PROGRAM

The field of Remote Sensing involves a variety of activities of which spacecraft sensing is only one. This section identifies the relationships between these activities, and in particular identifies those which directly support a spacecraft program and those which implement it. In addition, Canadian capability, involvement and commitment in each of the activities is evaluated.

In planning an applications oriented R & D program, it is customary to establish a specific program goal or objective. Further, for ease of management and implementation, it is common to divide a major program into projects, each one acting as a milestone in the program. The projects may each constitute a lower level of the program so that each one also results in benefits in a manner which is somewhat independent of the main program. Hence the overall program may be approached through its supporting projects in a minimum risk manner since the projects may be justified on the basis of their individual cost/benefits and these benefits may be applicable to several potential programs.

This rational approach to programs appears as a significant possibility in remote sensing where there exist distinctly separable benefits from different projects, and there is a wide variety of types of program and participation. This approach to planning thus appears appropriate in the remote sensing area where there is a policy indicating participation in the area but no concise policy as to program.

It is possible to examine the forms of participation in remote sensing programs by characterizing them according to the type of activity or hardware involved in the program. The following list indicates the alternative forms of participation:

A. Application of fully analyzed data from other parties, national or international (Basically distribution).

B. Data from other parties requiring analysis.

C. Raw data acquired from vehicles directly or from others.

D. Canadian Aircraft Systems.

E. Canadian Specified sensor packages in other programs.

F. Canadian supplied sensor packages to other programs.

G. Joint Canadian/other programs (Sensors plus subsystem elements).

H. Canadian Spacecraft or Canadian lead.

These eight types of program participation are listed in approximate order of increasing magnitude of program. It is apparent that the aircraft program could be largely independent of the space program. However, the converse is not true because of the need for ground truth verifications.

The development projects which are possible to undertake in the field of remote sensing can be classified as follows, again in approximate order of increasing magnitude.

1. Development of Data Analysis Capability Using Standard Established Methods.
   The interpretation for application of data provided in a reduced form.

2. Development of Data Handling Capability.
   Analysis of data as above starting from raw data (telemetry or the like) but according to established techniques.

3. Development of Interpretation Methodology.
   Development of data processing techniques to provide new results. Usually involves ground truth verification studies.

4. Development of Sensor Technology for aircraft.

5. Development of Aircraft Remote Sensing Systems.

6. Development of Space Hardware for Sensing.

7. Development of Spacecraft Supporting Subsystems.

8. Development of (Automated) Spacecraft Systems for Remote Sensing.

9. Development of Manned Space Systems for Remote Sensing.

A possible procedure is to matrix these two classifications in order to pinpoint the nature of program tasks which show the greatest degree of commonality or alternatively are most independent of program policy details. This is indicated by noting in the matrix whether a particular project is required, desirable or not required for each form of participation in remote sensing. The resulting matrix is presented in Table I.

From Table I it is apparent that except in the case of simple distribution of fully analysed data from others, a capability in data analysis and data handling would be required in any program which is envisioned. At the other end of the scale, R & D on spacecraft supporting subsystems specific to remote sensing missions is justified only if it is anticipated that there will be an opportunity to become intimately involved in supplying Canadian hardware to others or to a Canadian spacecraft mission.

In Table II the sub-working group has attempted to assess numerically (on a 0 to 5 scale), the Technology Development Activities in Canada relating to the potential projects, as to present "commitment, involvement and capabilities". In addition, the "forms of participation" are rated as to present involvement. *It is apparent that the present involvement and capabilities are more extensive than is the commitment.* In order to fully utilize the present Canadian capability, an expanded level of program in remote sensing is required.

On the basis of this crude analysis, some preliminary conclusions can be drawn:

1. With respect to commitment, Canada is currently at a point which is indicated by location D-5 on Table I.

2. Most of the elements, while having their own objectives, can be combined with preceding elements to form a cohesive program.

LEVEL OF DEVELOPMENT PROJECT MAGNITUDE

PROJECTS DEVELOPMENT OF:								
9. Manned Space Systems	NR	NR	NR	NR	NR	NR	NR	NR
8. Automatic Space Systems	NR	NR	NR	NR	NR	NR	NR	X
7. Supporting Subsystems	NR	NR	NR	NR	NR	D	D	X
6. Space Sensors	NR	NR	NR	NR	D	X	X	X
5. Aircraft Systems	NR	NR	NR	X	D	D	D	D
4. Aircraft Sensors	NR	NR	NR	X	D	D	D	D
3. Interpretation Methodology	NR	NR	D	X	X	X	X	X
2. Data Handling	NR	X	X	X	X	X	X	X
1. Data Analysis	NR	X	X	X	X	X	X	X
PROGRAMS INVOLVING:	A	B	C	D	E	F	G	H

LEVEL OF PROGRAM MAGNITUDE AND SOPHISTICATION

A. Application of Data
B. Analysis of Data
C. Acquisition of Raw Data
D. Use of Aircraft Systems
E. Canadian Specified Sensors
F. Canadian Supplied Sensors
G. Joint Programs
H. Canadian Spacecraft

NR - not required
D - desirable
X - required

Interpretation

- For a particular type of program, the vertical column indicates the development projects required for program implementation.
- For a particular development project, the horizontal column indicates the types of programs to which it has application.

RELATIONSHIP BETWEEN DEVELOPMENT PROJECTS AND TYPES OF PROGRAM

TABLE I

Technology Development Activities		Commitment	Involvement	Capability
1	Development of Data Analysis by Standard Established Methods	5	4	5
2	Development of Data Handling	5	5	5
3	Development of Interpretation Methodology	5	3	3
4	Development of Sensor Technology for Aircraft	3	3	5
5	Development of Aircraft Remote Sensing Systems	3	4	5
6	Development of Space Hardware for Sensing	0	1	3
7	Development of Spacecraft Supporting Subsystems	0	0	4
8	Development of Automatic Spacecraft Systems for Remote Sensing	0	0	3
9	Development of Manned Spacecraft Systems for Remote Sensing	0	0	1

Forms of Participation in Remote Sensing Programs		Involvement
A	Fully analyzed data from other parties, national or international	5
B	Data from other parties requiring analysis	5
C	Raw data acquired from vehicles directly or from others	5
D	Canadian Aircraft Systems	5
E	Canadian supplied packages to other programs	1
F	Canadian input to specified packages in other programs	0
G	Joint Canadian/other programs (Sensors plus subsystems)	0
H	Canadian S/C programs or Canadian Lead	0

Evaluation of Canadian Commitment, Involvement and Capability in Development Projects and Programs

TABLE II

3. There are indications that the present involvement and capabilities are broader in scope than are the policy and commitment in this field and consequently a policy to increase participation could be quickly and effectively implemented. It appears that policy may be the limiting factor in Canadian participation in remote sensing.

6.0. CANADIAN GOVERNMENT, INDUSTRY AND UNIVERSITY CAPABILITY

In examining the question of whether Canada should have a remote sensing satellite program, the Canadian industry capability for implementing the program should be considered. Canada has built and has had four satellites launched. A fifth one, the CTS, is now under construction. In addition, components and subsystems for other satellites have been exported.

Table III gives some brief data on the five satellite projects which have been undertaken to date. In addition to this information, the following is presented to reveal the extent of the experience that existing government and industrial organizations have had in the space field to date. This capability has been built up over the last fourteen years as a result of the five spacecraft programs mentioned above, and through extensive participation in the space programs in other countries, particularly that of the United States. In addition to the organizations listed below, there are many companies across Canada which supply ground stations, components and related products. These companies form a wide support base for space programs in Canada.

A. Department of Energy, Mines and Resources, Canada Centre for Remote Sensing

CCRS has developed considerable expertise through the program to acquire and process data from the ERTS-1 satellite. The experimental radar station at Prince Albert was converted to a tracking station for ERTS and much operational experience has been gained. Recently modifications to the station have enabled the station to receive thermal IR imagery from the NOAA weather satellites.

CCRS has developed and implemented a highly efficient data handling and processing center in Ottawa to allow analysis and distribution of ERTS data within Canada. This computer facility produces high quality ERTS imagery and also contains special support systems which allow researchers to develop interpretation methodology. CCRS has implemented a vigorous applications program which aims to discover and prove out methods of applying remote sensing data to practical problems in a cost effective manner.

CCRS has also supported the development of new sensors and conducted operational field trials including the use of them in aircraft. The aircraft program includes operational data gathering from a number of aircraft using a variety of sensor equipment. An airborne data acquisition system is being developed to allow remotely sensed data to be processed at the data processing center in Ottawa.

B. Department of Communications Communication Research Centre (CRC)

CRC initiated the ISIS program consisting of four satellites, which were launched between 1962 and 1971. The general objective was to conduct comprehensive studies of the ionosphere. The satellites were designed and constructed in Canada and were launched on NASA vehicles. CRC ran the Alouette I program (the first of the series) as the prime contractor and had some of the subsystems made by Canadian industry. CRC made other subsystems, integrated the spacecraft, tested it and provided a team for the launch operations. For the remaining three satellites, CRC progressively relinquished the role of prime contractor to Canadian industry as the latter's capability grew but CRC remained the Design Authority.

CRC, in co-operation with NASA, has now embarked on the Communications Technology Satellite program, an experimental project which will carry Canadian technology into the second generation of communication satellites. For this project, CRC is providing Project Management, R & D support, and a spacecraft assembly and test facility. Detailed design and fabrication of subsystems have been contracted to Canadian industry. NASA will provide the launch vehicle, access to some advanced electronic components and spacecraft environmental test facilities.

It is considered that this is a very complex satellite and an appreciable capability has been gathered within both CRC and Canadian industry to build both the main communications subsystem and all the supporting subsystems necessary for it. For most subsystems, new engineering development and design work had to be carried out.

C. Department of Environment

The Atmospheric Environment Service of the Department of Environment has developed the capability to receive data and imagery from weather satellites. For the last 10 years this type of data has been used operationally as a part of weather prediction and analysis work. The department continues to follow new developments in weather satellite technology.

The department has also experimented with remote data collection platforms as a part of the ERTS-1 program. Following initial success in this field, additional platforms will be deployed. These new platforms will also be convertible to the data collection system on the SMS satellite which was recently launched.

D. Telesat Canada

By an Act of Parliament in 1969 Telesat was established as an operational, domestic communications satellite program, thus creating a capability for technical management of space systems development and for operating complex spacecraft missions. The Anik I and II missions, after the launch vehicle's injection into transfer orbit, were controlled entirely from Telesat's Ottawa headquarters. Station keeping manoeuvers with these satellites are routinely performed.

Satellite	Weight lb	Launch Vehicle	Launch Date	Stabilization	Power	Mission Objectives
Alouette I	320	Thor Agena	Sept 29/62	Spin	24 W	Ionospheric Research
Alouette II	322	Thor Agena	Nov 29/65	Spin	30 W	"
ISIS I	580	Delta	Jan 28/69	Spin	60 W	"
ISIS II	582	Delta	Mar 31/71	Spin	60 W	"
CTS	800	Delta	late 1975	3 Axis	1.3 kW	Communications research, high power outputs

CANADIAN SPACECRAFT DATA

TABLE III

In addition, Telesat has acquired the capability to manage the development and installation of complex ground tracking and communication stations.

E. **Bristol Aerospace Limited**

Bristol manufactures the family of solid propellant, high altitude, research rockets which are called Black Brants. These rockets have been developed over a period of ten years and seven different models have now been flight proven and are available for scientific use. In addition, Bristol produces telemetry equipment and ancillary systems for rockets. Payload integration, checkout and environmental testing is also carried out by the company.

Over 230 Black Brants have been launched and have been used by many scientific agencies in both North America and Europe.

F. **Northern Electric Company Limited**

The company has manufactured the electronics "payload" for three ANIK type satellites, two of which have been launched. This payload consists of the microwave transmitters and receivers, telemetry and command system, the power control electronics, and the battery system.

Corresponding electronics has also been manufactured for three follow-on ANIK satellites which are for use in U.S. domestic systems.

Northern Electric has also manufactured the microwave transmitting-receiving equipment on the fourth flight model of INTELSAT IV.

G. **R.C.A. Limited**

RCA Limited has been involved with the space electronics of over sixty programs during the past fourteen years. This involvement has been primarily in the fields of earth stations and satellites. However, in addition to this, the research laboratories of RCA have carried out a significant number of space research programs for the Canadian and American governments. These programs included studies, experiments and investigations.

In 1961, RCA was selected to develop and supply the communications transponder system for the RELAY satellite, the first NASA satellite to provide transatlantic television service. The experience developed on advanced semiconductor device research was successfully used to furnish telemetry transmitters for Alouette I and for two NASA scientific satellites – Explorer XX and Pegasus.

In 1963 RCA was contracted to the Defence Research Board (now CRC) and was responsible for the participation in the Alouette II program by Canadian industry. Subsequently, as prime contractor, the company became responsible for the full design, manufacturing and testing of the ISIS I and II satellites.

In the Communications Technology Satellite program, RCA has participated with CRC in systems planning and program definition. RCA is responsible for most of the electronics design in the spacecraft including SHF antennas and transponder, telemetry and command antennas, transmitters and receivers and power conditioning as well as having a subcontract from SPAR Aerospace for the Attitude Control electronics.

RCA is presently designing and manufacturing the communication payload (transponder and antennas) for the RCA Satcom satellite for U.S. domestic service.

H. **SED Systems Limited**

(Previously. the Space Engineering Division of the University of Saskatchewan).

The Space Engineering Division was incorporated on July 18, 1972, into SED Systems Limited, a company which is wholly owned by the University of Saskatchewan. The company is engaged in space activities through contracts with the Canadian government, universities and companies in Canada and other countries.

SED is involved in attitude acquisition simulation studies and instrumentation for the Communications Technology Satellite.

In addition, SED is very heavily involved in the development and building of rocket payloads and the instrumentation associated with them.

I. **Spar Aerospace Products Ltd.**

During the past 15 years, Spar has been a major participant in all of the Canadian satellite programs and has exported satellite subsystems and equipment to the United States and many countries in Europe. More than 500 space mechanisms have been launched aboard satellites from these countries.

Throughout the 1960's, Spar was a principle contractor for the Alouette and ISIS series of satellites. Tasks included mission analyses, configuration studies and definition, stabilization analyses, structural design and fabrication, thermal design and test, and extendible antenna development and fabrication.

For the ANIK Domestic Communications program, Spar participated in design and feasibility studies, provided engineering support in the overall design, and fabricated the spacecraft structures. There have been subsequent orders for many structure sets similar to ANIK.

Since May, 1970, Spar has been the major contractor for the CTS program, with responsibilities including program definition, mission analysis, satellite configuration studies, design and development, and hardware fabrication.

Presently, Spar has completed the design and construction of qualification models of the main mechanical subsystems including the structural subsystem, thermal control subsystem, attitude control subsystem, and the mechanisms and structure associated with the Solar Array subsystem which provides the spacecraft power.

Spar has been engaged in pure and applied research in the remote sensing field since 1953 and has carried out the detailed engineering and manufacture of a wide range of devices and systems. Applications have ranged from the control of industrial processes to advanced infrared aerospace systems (including missile fusing and guidance) and from complete infrared target acquisition systems to a wide spectrum of specialized ground and airborne electro-optical and electromagnetic measurement equipment.

J. **Canadian Astronautics**

Canadian Astronautics is a small but rapidly growing company with expertise in the fields of system design, mission analysis, software development and mission operations. It was recently formed by personnel who have had experience with the Telesat Canada Anik program. Business to date has included several contracts with the Canadian government and a contract with a U. S. Domestic Communications Satellite Company.

K. **Bell-Northern Research**

As the research centre of the Bell Canada-Northern Electric group of companies, Bell-Northern Research is engaged primarily in the creation and development of communications systems.

Space and satellite activities are focussed on the planning, evaluation and design of communications systems which are used in satellite and space projects.

L. **Universities**

The University of Toronto Institute for Aerospace Studies has conducted experiments and developed instruments for a large number of studies of the atmosphere and space environment. A laser beam recorder was also developed for use by CCRS in producing ERTS images.

At York University, development of a wide variety of sensors for detecting atmospheric constituents, molecular structure and ionospheric properties has been carried out. A number of these sensors have considerable potential for inclusion in the payload of future remote sensing satellites.

7.0 BASIC PROGRAM ALTERNATIVES

7.1. Introduction

While Canadian participation in remote sensing satellite programs takes many forms, these may be divided into two broad classes each with its own advantages and difficulties. On the one hand Canada may undertake the lead role in the design and construction of a remote sensing satellite largely using her own resources of skilled manpower and money, or, she may enter into an agreement with another country or countries under which the lead role is assumed by that country or a consortium of countries. This chapter discusses the alternatives available within these two approaches to remote sensing satellite programs.

7.2. Co-operative Programs

If Canada does not assume the initiative in developing her own remote sensing satellites, a number of bilateral or multinational arrangements involving joint project management are possible. One incentive for entering into a co-operative program is the possibility of reducing project costs for each participating nation. However, apparent savings might be partially offset by inherent organizational inefficiencies in a bi-national or multinational program. For example, it is usually necessary to allow each nation to participate in the implementation and management of the program and the resulting management structure can detract from the effectiveness of the program. In addition, it may be necessary to make compromises on the mission parameters and this could substantially reduce the benefits to Canada. The initiation of such programs usually takes longer than that of an internal program and this can increase total costs. In the past, multi-national programs in the aerospace field which involved joint management responsibilities have tended to produce long, costly and ineffective programs. Another factor to be considered is that it is difficult to mesh a combination of international and domestic programs which would fully utilize Canadian technological resources as there is less control over the demands of the international program.

The following are brief discussions of the most likely alternatives for international remote sensing programs:

A - **Joint Program with the United States**

Traditionally, the U.S. has been the partner of Canada in space programs. This has been advantageous to Canada because of the former's launch vehicle capability, its "know-how" with respect to controlling a spacecraft through its ascent into orbit, and its overall space technology expertise.

It may be difficult to work out a mission of mutual advantage with the United States because the latter has definite plans with respect to earth observation. These include the present ERTS series, the SKYLAB and the EOS followed by the various programs associated with the shuttle program. In light of this extensive program, it may well be difficult for Canada to develop a program which has sufficient interest for the United States to warrant their participation. On the other hand, the heavy funding commitment to the Space Shuttle may make a joint program (with Canada) in the field of remote sensing economically attractive to the United States.

B - **Joint Program with the USSR**

Because of the many common features of the Russian and Canadian land masses, there may well be missions which are of interest to Canada and the USSR. Both countries want to develop their northern regions, and both have a strong interest in the Arctic. A spacecraft and sensor complement which is specifically designed for gathering information about the Arctic areas of each country could be mutually advantageous.

Unfortunately, at this time it is probably premature to consider a joint program with the Russians. Canada would need to have more extensive contacts with the USSR at all levels in order to have confidence that a joint program could be carried out in a cost and time effective manner. It is quite possible that future programs could be usefully carried out with the USSR after such contact has been made. This would certainly not be soon enough to provide a follow-on to the present Canadian involvement in the ERTS program.

C - **Joint Program with other Countries such as Brazil, Japan, Germany, France, etc.**

With any of these technologically advanced countries, the various facets to be considered in a shared program are the following:

i) Management
ii) Sensor complement
iii) Subsystem complement
iv) Data
v) Industrial participation.

It is traditional in co-operative space programs for any cost sharing to be managed in such a way that each country's industry shares in the work in proportion to its investment. It is probable that in any program with one or more technologically advanced countries, such an arrangement would be essential. Hence, in addition to the problem of finding a mission of sufficient mutual interest, there is the problem of cost sharing arrangements. These problems grow with the number of participating countries. Many joint programs have provided examples of the difficulties in arranging and initiating a program in a timely and cost effective manner.

A cost sharing arrangement with an underdeveloped country would probably not involve that country's industrial participation. However, an underdeveloped country is not as likely to commit its financial resources to something as esoteric as satellite remote sensing, or to the development of ground processing facilities. In addition there is the possibility that such countries may be supplied data free from the earth resources programs of either the USA or USSR.

There are drawbacks to all of the international arrangements that have been discussed. In addition to these factors, it is important for Canada to ensure its independence and autonomy with respect to its own resources. Remote sensing of such resources is one part of the elaborate fabric that Canada should build for itself to protect its future. Because the exact nature of an operational remote sensing program is not immediately apparent, Canada must retain its flexibility so that changes can be made in the desired direction when events make this necessary. This will probably be far easier in an independent program than one in which Canada is "locked-in" to an agreement with other countries. Hence it is felt that a co-operative program involving joint management of a Remote Sensing Satellite Program is not a desirable option for Canada.

7.3. Canadian Remote Sensing Program

Programs that will be considered in this section are those in which Canada plays the lead role. Such programs may involve arrangements with other countries to provide launch services and even satellite platforms, or a sharing of the acquired data. However, it is assumed that these arrangements would not seriously limit Canada's freedom of action in planning the program to serve her own interests. There are a number of broad options that are available for such a program. In considering them, only programs which provide a suitable follow-on from the present ERTS program, and which represent an appreciable development of Canadian expertise in the remote sensing field seem worthy of consideration.

A - **Sub-system Development**

Probably the least expensive and lowest risk program that would extend the present Canadian remote sensing capability would be the development of some space hardware that would form an integral part of a remote sensing satellite. The development of a specific type of sensor would be an attractive possibility but other options such as attitude control sub-systems, high reliability batteries, etc., may be considered. The type of hardware to be developed should be chosen to suit specific Canadian requirements or capabilities. The prime requirement of such a program should be the development of Canadian expertise in some aspect of remote sensing satellite sub-systems to serve as a base for Canadian participation in an international remote sensing program. Such an option gives great flexibility in the choice of hardware that is to be developed and hence could capitalize on outstanding achievements of past space activities. In addition, it would mean little or no change in the existing agencies, industries and programs which are involved with space activities.

Such a limited, one-time commitment to the remote sensing field, is really only a project and should not be construed as a program. It implies a rather slow development of the remote sensing field in Canada, whereas the country is in a unique position to capitalize on the benefits that seem certain to emerge from remote sensing programs. While this approach provides considerable flexibility in adjusting to future developments it also implies a heavy reliance on programs outside the country. In fact few concrete benefits could emerge from such activity without extensive co-operation with another country. Finally, virtually the whole basis of this approach could be undermined if some other country was to surpass Canada in her chosen area of hardware development. If this occurred, the entire Canadian investment might be worthless since such work on its own would not provide resource management data, which would be of value to the country.

B - **Prototype Operational Program**

In this case it is assumed that an experimental prototype remote sensing satellite would be developed as well as organizational structures and interfaces with the users. Such a program represents the minimal commitment of resources which would provide experience and develop capabilities in all aspects of remote sensing from satellites. It amounts to an independent Canadian program that would be largely self-sufficient and also would in large measure protect the national sovereignty in this area, no matter how programs developed in other nations. It would also provide a firm basis for Canadian participation in any future international programs that appeared attractive.

The impact of such a program on the participating user agencies would be minimal, at least until a functioning satellite was in orbit. However, once this is achieved it would be relatively easy to rapidly expand the program to an operational one, if the satellite performance proved to be satisfactory. Thus this approach would minimize risks without unduly delaying the benefits that could flow from an operational program.

A program of this type requires identification of user requirements at an early stage. Initial cost benefit studies at the Canada Centre for Remote Sensing indicate ice reconnaissance and hydrology to be desirable mission requirements. Additional work will be necessary to evaluate all potential user applications.

C - **Operational Program with a Few Specific Objectives**

At the outset, such a program implies a commitment for the acquisition, on a routine and long term basis, of certain types of remotely sensed data which would have high relevance to specific Canadian requirements. This option would achieve virtually all of the benefits of option B with the added feature that early commitments to the program, by at least some user groups, would undoubtedly develop. A very cost effective program could result on this basis and meaningful cost benefit figures might be developed even before the program was initiated. Moreover the total range of management capabilities that are relevant to the remote sensing field would be developed and enhanced and Canada would maintain its position in the satellite remote sensing field.

Undoubtedly this option is considerably more costly and involves greater risks than does the previous one. Its success relies heavily on the ability, at an early stage, to identify remote sensing applications that are not only feasible but also cost effective. This represents a considerable challenge to the current Canadian and international expertise in this field. It would also seem likely that some restructuring of existing agencies, or the creation of new ones, would be necessary for the proper management and support of this program.

D - **Operational Program to Satisfy all Feasible Data Requirements**

A program of this magnitude would permit the most rapid and the broadest application of satellite remote sensing technology to national problems and would give Canada a dominant position in this field. It would minimize any implicit or real threats to Canadian Sovereignty and Canadian natural resources in the remote sensing programs of other nations. Such advantages are in addition to those which have been outlined for the previous options.

High costs and high risks are the two most unattractive features of this approach. Moreover in trying to do everything that appears feasible, the limited available expertise might be dissipated without achieving significant success. Some degree of failure seems almost certain in such an ambitious undertaking and this would tend to make the program less cost effective than the other options.

A prototype operational program is probably the best course for Canada to follow at the present time. The field of remote sensing is developing too quickly to allow for commitment, with any degree of confidence, to an operational type of program, while the development of only sub-systems will not maintain Canada's capability to an adequate degree in this rapidly growing field.

8.0 CONCLUSIONS

Although the full impact of remote sensing technology is not clearly evident, experience to date with ERTS-1 would suggest that throughout the next decade this technology will have a profound effect on the management of the world's resources. Those nations that are able to exploit it will enjoy economic and social advantages that will not accrue to those who have not. Canada, which is dependent on the wise use of her natural resources for her continued well being, cannot afford to ignore this promising technology. Hence, Canada must be among those nations which are skilled in the field of remote sensing from space.

Action is now required to develop the expertise needed to achieve the benefits from satellite remote sensing and to protect Canadian interests. Only through a substantial program such as a prototype operational program as recommended in Chapter 7 will Canada develop sufficient capabilities to be able to understand and use this rapidly moving technology. This course of action will bring about a national ability to develop, construct and operate remote sensing spacecraft. This will allow future flexibility, in that as trends in satellite remote sensing develop, this ability can be used to quickly implement appropriate programs as they are required.

Canadian involvement and capability, both by industry and government, appears to exceed the present commitment to this field. Hence, policy decisions to expand activity in remote sensing can be quickly implemented. Past industrial experience has given Canada the elements of a vital technology which is necessary to develop and construct spacecraft. The justifications for Canadian involvement in satellite remote sensing exceed those for most other nations. Canada has a large area-to-population ratio, an abundance of natural resources, a high technology industry and a strong economy. These are all the ingredients necessary for a successful program in satellite remote sensing.

Because of the importance of this technology to Canada's future, it would be unwise to entrust Canadian competence to an international co-operative program in which the Canadian role is not dominant. Lack of flexibility and control over the direction of a jointly managed international program argues in favour of an independent Canadian program. However, a national program will give Canada a strong basis for co-operating in future international efforts where an exchange of data rather than joint development is required.

The immediate need is to further develop the potential options available to Canada by carrying out appropriately funded system studies. This will lay the foundation for specific plans for a remote sensing program and will enable Canada to decide on the correct course to follow in this field of technology.

APPENDIX A
COMBINED MISSIONS

A Canadian remote sensing satellite mission would probably use some type of near-polar orbit in order to obtain proper coverage across the country. It is possible that the satellite could have auxiliary sub-systems, designed to serve other functions. Two possibilities that have been considered are a remote data collection sub-system, and a search and rescue sub-system.

The function of collecting data from a number of remote, unattended measurement platforms has been provided by several other satellites – the NIMBUS, ERTS and SMS satellites all have this capability. Canadian scientists and agencies have used the ERTS system quite successfully. With increasing concern about the environment, and the development of the North, there is a need for an expanded capability for taking measurements at remote sites over long periods of time. The satellite equipment needed to provide this capability is a receiver and antenna, working at VHF or UHF frequencies, and a transmitter to relay the data to the ground. The transmitter function could probably be provided by the sensor data transmitter. The power and weight required for this sub-system would be quite small as compared to the overall payload weight.

The search and rescue function is also very simple to implement. Aircraft are now required to carry an Emergency Location Transmitter (ELT) which, in the event of an accident, emits a distress signal at 121.5 MHz. A receiver and antenna is required on the spacecraft to detect the distress signals and to retransmit them to a ground station; the doppler shift of the signal is measured at the station and the position of the ELT can be calculated. DND is currently conducting studies on a search and rescue satellite since there are considerable economic and human benefits to be gained from improving the search and rescue function.

In summary, a remote sensing satellite in a near-polar orbit may be suitable for serving several auxiliary functions. The two areas mentioned in this section would require very little payload and power, and would be relatively easy to implement on a remote sensing satellite mission.

APPENDIX B

LAUNCH VEHICLES

In considering a Canadian remote satellite program, the question of launch services must be examined. In the past, Canadian satellite launches have all been done by the United States. The Alouette and ISIS programs were co-operative programs with the U.S., hence the launch services were supplied as part of the American contribution to the program. However, the Telesat Canada communications satellite program was implemented by contracting directly between Telesat and NASA, after intergovernmental approval, for launch services which were performed on a strictly cost reimbursable basis. The CTS program is a co-operative program and will receive launch services as a part of the U.S. contribution.

The United States has a policy of launching foreign satellites on a cost reimbursable basis and NASA is empowered to do so under the Satellite Act of 1962. All requests for such launch services are normally accepted unless the satellite mission contravenes international treaties or poses a threat to U.S. security.

The United States NASA has available a variety of launch vehicles and several launch sites. For a Canadian remote sensing satellite mission, a near-polar orbit would probably be required and the Western Test Range at Vandenberg Air Force Base in California would be the launch site. From that location, three launch vehicle configurations are currently available from NASA. They are listed below together with their payload ranges for low polar orbits.

Scout D	100-200 lbs.
Delta 2910	2000-3000 lbs.
Titan III C	10000-15000 lbs.

The Scout payload would probably be suitable only for small experimental satellites which carry low power sensors. The structure, attitude control and power generating subsystems would require most of the weight leaving less than half of the payload for the sensors and the communications subsystem. The Delta provides adequate payload for a wide range of sensor payloads. It also has an inertial guidance system on the final stage which gives very low orbit injection errors. The Titan has such a large payload that only an extremely complex and sophisticated spacecraft employing many different types of sensors could be considered. By 1982, the Space Shuttle should be operational and will provide approximately 30,000 lbs of payload into polar orbit. Multiple payload launches will likely be flown with the Space Shuttle.

Other nations have launch vehicle programs and may be able to offer launch services to Canada in the future. However, with the exception of the USSR, all of these launch vehicle programs are not sufficiently developed to permit serious consideration at the present time. The USSR has the technical capability to provide launch services to Canada but security and political considerations pose a serious barrier to such arrangements. Further scientific co-operation and exchange will hopefully improve the prospects for making Russian launch services available in the future.

In summary, it is believed that the United States continues to be the best source of reliable launch services. Furthermore, in the light of past experience, if there is reason to believe that a remote sensing satellite mission may be attractive to the U.S., a co-operative program may be undertaken where the launch services are provided as part of the U.S. contribution to the program in exchange for free access to data from the spacecraft.