19/83
(see 34/83 for executive summary)

EVALUATION OF EMR
REMOTE SENSING ACTIVITIES

JULY, 1983

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1. INTRODUCTION

1.1 Background and Terms of Reference

This evaluation report is submitted in fulfillment of DSS Contract 24SR.23354-2-0536, September 30, 1982.

The report was commissioned by the Program Evaluation Branch of the Department of Energy, Mines and Resources, in conformance with Treasury Board directives requiring the evaluation of departmental programs every three to five years. It is based on an earlier Evaluation Assessment* which follows the guidelines established by the Office of the Comptroller General.

The purpose of the study is to carry out an evaluation of the EMR Remote Sensing Activity by focusing on the LANDSAT program and the Technology Transfer process, which are the program responsibility of the Canada Centre for Remote Sensing.

The terms of reference of the study called for an evaluation of:

Landsat Program

1) the extent to which Landsat imagery is used;
2) the nature of that usage;
3) the consequences of terminating the program;
4) the alternatives to providing this imagery information
5) the extent to which the original objectives and benefits for CCRS and the "national remote sensing program", relating to the Landsat program have been achieved; and
6) the relevance of the current objectives.

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* Evaluation Assessment of the Remote Sensing Activity, EMR Program Evaluation Branch Report No. PE 39/1982, June, 1982.

A further requirement was that the evaluation should acknowledge the potential increase in usage which is expected to result from the increased sensor resolution offered by Landsat-D as well as on the increasing costs associated with the Landsat program.

Technology Transfer Process

A. To Industry

1) the extent to which remote sensing technology has been transferred to Canadian Industry, both as part of the R&D process and in the form of completed technologies;

2) past specific achievements of the technology transfer process, i.e. specific technologies transferred;

3) impact of such achievement, e.g. international sales, domestic sales, impact on domestic application areas;

4) technology transfer problems;

5) suggestions for improvement in the technology transfer process.

B. To End Users

1) the extent to which remote sensing technology has been transferred to End Users, as a function of the use of CCRS expertise and facilities;

1.2 Canada Centre for Remote Sensing

The Canada Centre for Remote Sensing (CCRS) is a branch within the Department of Energy, Mines and Resources which is mandated to fulfill the Department's remote sensing activity. The remote sensing activity is one of nine activities of the Mineral and Earth Sciences Program. The objective of the latter is:

"to ensure the availability of mineral policies and strategies, and timely earth science information, technology and expertise related to the landmass of Canada and its mineral and energy resources."

The Remote Sensing Activity contributes to the acquisition of timely earth science information by meeting its current objective:

"to improve remote sensing technology and to facilitate the acquisition and dissemination of remotely sensed data and derived information needed for the management of Canadian resources and for the monitoring of human activity."

The current objectives differ from those approved by Cabinet in CCRS's early years in the following ways (a year of original objective in parentheses):

1. Responsibility for planning operational remote sensing programs, is no longer an explicit objective (1971)

2. Responsibility for "marketing processed data to meet the requirements of government, industries and individuals", is no longer an explicit objective (1971).

3. Responsibility to "foster the development of expertise in Canadian industry in technology related to remote sensing and its application" is no longer an explicit objective (1971).

4. Responsibility for promoting the national remote sensing program through "grants to provincial or regional interpretation centres", has been dropped (1972).

The evolution of CCRS's objectives, since its inception, is traced in Appendix 1.

The history and development of CCRS will be well known to readers of this report. We shall therefore concentrate on the present nature of CCRS, which has changed during the course of this study. CCRS now consists of six organizational units (Figure 1.1 refers):

1. Data Acquisition Division

Has responsibility for gathering satellite and airborne remote sensing data. Is also responsible for R&D applicable to airborne and satellite data collection and to R&D connected with the use of aircraft as platforms for new sensors and related systems.

2. Digital Methods Division

Is responsible for R&D into and operation of systems required for processing and analyzing satellite and airborne remote sensing data.

3. Applications Technology Division

Develops uses for remote sensing data, demonstrates uses and undertakes joint projects in cooperation with users. Also responsible for transferring applications technology and methods to other users and for administering Technology Transfer agreements.

4. Program Planning & Evaluation

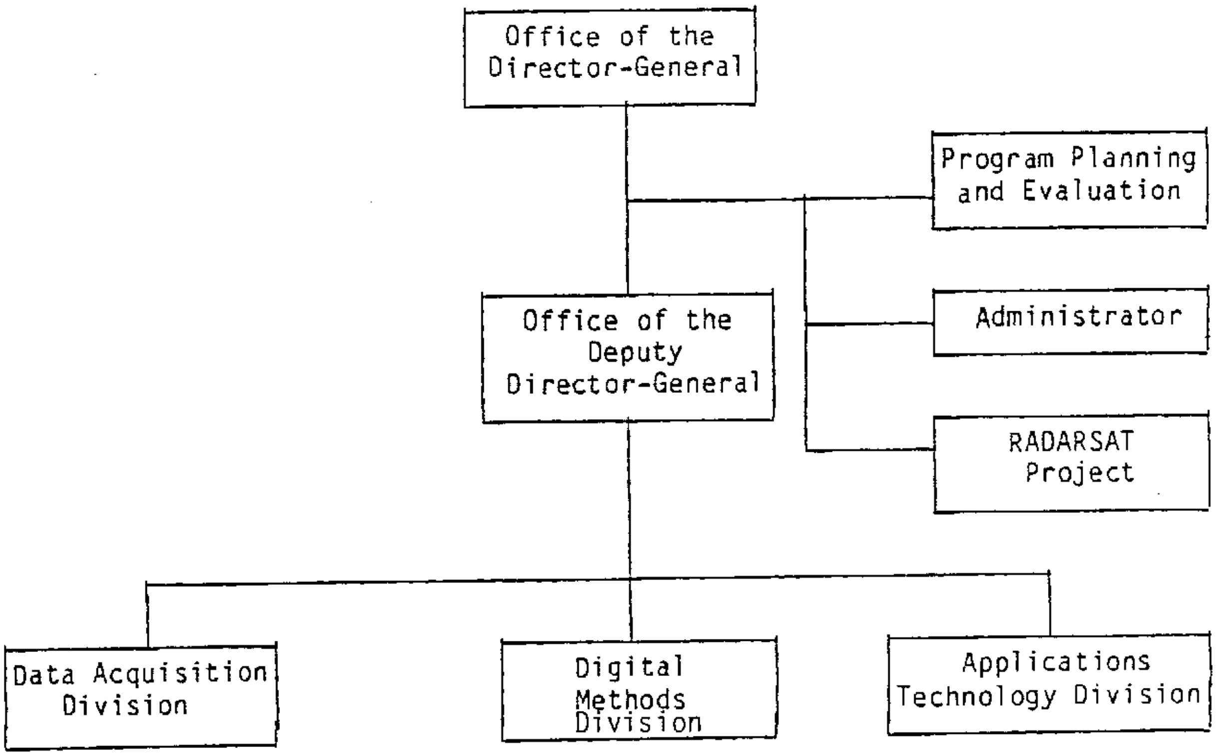
Provides a secretariat for the various planning committees within the Centre as well as a secretariat for the Canadian Advisory Committee on Remote Sensing. Conducts cost benefit studies of remote sensing and provides a project control mechanism for senior management.

5. RADARSAT

Coordinates the interdepartmental Radarsat program, in cooperation with industry, to define requirements for a microwave radar satellite system and helps establish a related Canadian technological capability.

6. Administration

Manages the accounting, financial planning, stores and other administrative services of the Centre.

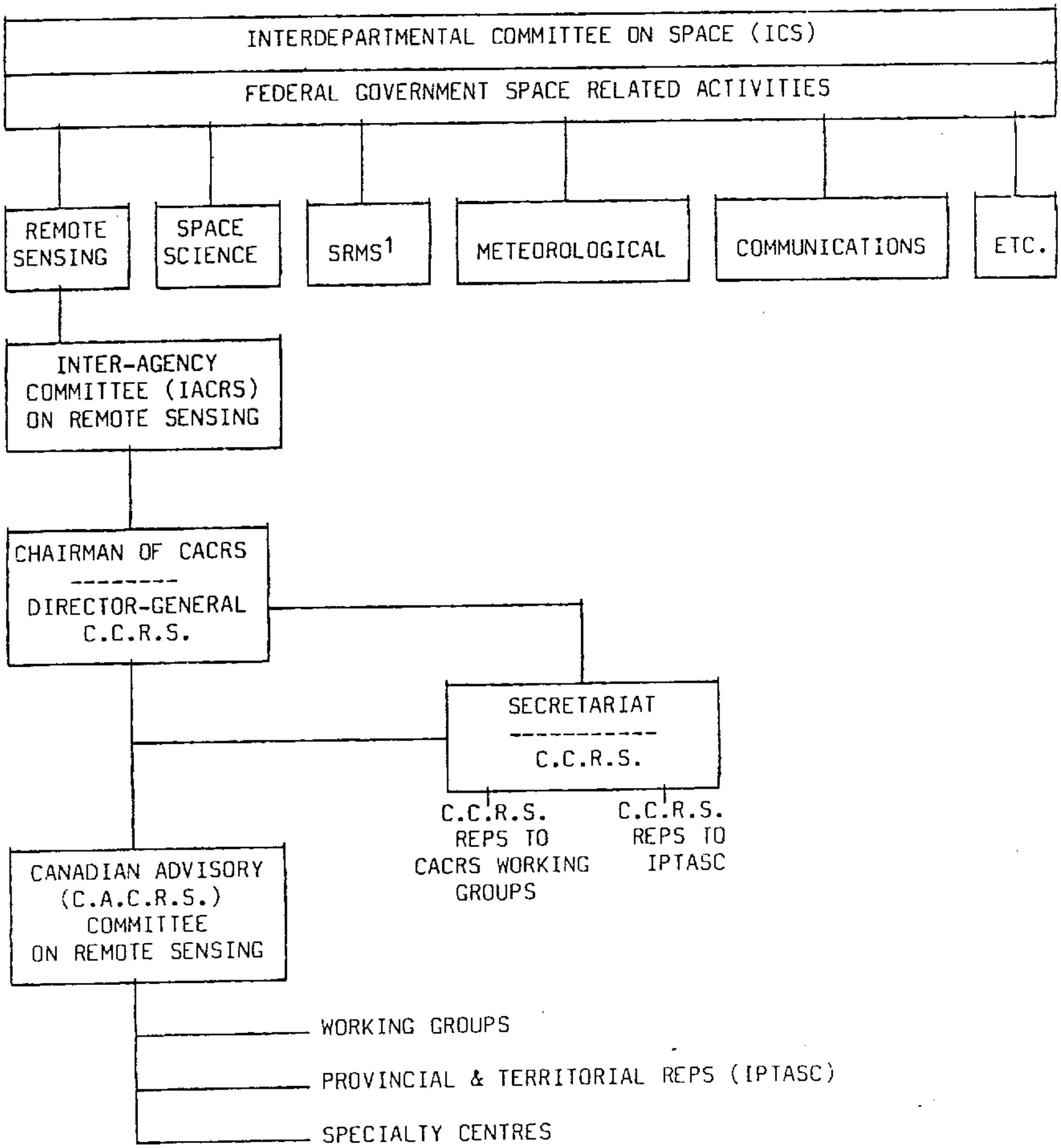


CCRS ORGANIZATION

FIGURE 1.1

FIGURE 1.2

NATIONAL PROGRAM ON REMOTE SENSING



[1]SRMS: Shuttle Remote Manipulator System

1.3 Method of Approach

The OCG guidelines states program evaluation to be:

> "the periodic, independent and objective review and assessment of a program to determine in light of present circumstance, the adequacy of its objectives, its design and its results both intended and unintended. Evaluations will call into question the very existence of the program. Matters such as the rationale for the program, its impact on the public, and its cost effectiveness as compared with alternative means of program delivery are reviewed".

Program evaluation is more concerned with plans, outputs and results than with operations and operational effectiveness which form the principal focus of internal audits. The guidelines describe four general classes of evaluation issues, along with seven more specific basic evaluation questions that could be used in an evaluation. They are presented in Table 1.4. The table shows major issues in a program evaluation to be program rationale and relevance as reflected in the objectives, effectiveness of the program and alternative means of delivery.

As concluded in the Evaluation Assessment, this evaluation singles out two aspects of the Canada Centre for Remote Sensing program for analysis: Landsat, and CCRS's Technology Transfer activities (see Background and Terms of Reference, Section 1.1, above). The way in which these two program components link with the overall objectives and mandate of the organization are discussed in Sections 3.2 and 4.2.

b) By Organization

Table 1.2 Expenditures by Organizational Unit

Unit	PYs	Funds $000's Salaries	Operating	Capital	Grants & Contrib.	Total
Director-General's Office	4	121	112	2	448	683
Finance and Administration	14	425	625	10		1,060
Program Planning and Evaluation	7	212	78	6		296
Data Acquisition Division	27	820	2,288	1,143		4,251
Digital Methods	38	1,154	2,988	1,822		5,964
Applications Technology Division	16	486	913	1,128		2,527
RADARSAT Project	-	-	2,255	1,230		3,485
	106	3,218	9,259	5,341	448	18,266

c) By Function *

Table 1.3 Expenditures by Function

Function	PYs	Funds $000's Salaries	Operating	Capital	Grants & Contrib.	Total	%
Data Gathering	37	1,123	4,451	1,065		6,639	36.3
R&D	34	1,032	3,806	3,992		8,830	48.3
Technology Transfer	11	334	683	260		1,277	7.0
Administration and Overhead	24	729	319	24	448	1,520	8.3
	106	3,218	9,259	5,341	448	18,266	100.0

* These functions were defined by the A-Base Review Team for analytical purposes.

CCRS is the core program delivery agency in the Canadian remote sensing community. However, the Canadian remote sensing community includes many other organizations; provincial remote sensing centres, remote sensing equipment and software suppliers, remote sensing service suppliers, universities, and a network of advisory committees.

The outputs of remote sensing in Canada are the result of a complex interaction among these groups. This report acknowledges that fact. It points out, moreover, that the Canada Centre for Remote Sensing comprises only part--albeit an important part--of the national remote sensing program. Other key elements as shown in Figure 1.2.

CCRS Resources

The departmental A-base review provides the following breakdown of resource appropriations, by sub-activity, organization and function, for FY 1981-82 (taken from A-Base Review)

a) By Sub-Activities

Table 1.1 Expenditures by Sub-Activity

	PYs	Funds $000's				
Sub-Activity		Salaries	Operating	Capital	Grants & Contrib.	Total
Satellite Data	42	1,275	4,440	2,675		8,390
Airborne Program	22	668	2,224	1,298		4,190
Data Applications	8	243	698	1,084		2,025
Applications Services and Technology Transfer	10	303	552	129		984
Management Support	24	729	1,345	155	448	2,677
	106	3,218	9,259	5,341	448	18,266

TABLE 1.4

BASIC PROGRAM EVALUATION ISSUES

Classes of Evaluation Issues	Basic Evaluation Questions
PROGRAM RATIONALE (Does the program make sense?)	To what extent are the objectives and mandate of the program still relevant?
	Are the activities and outputs of the program consistent with its mandate and plausibly linked to the attainment of the objectives and the intended impacts and effects?
IMPACTS AND EFFECTS (What has happened as a result of the program?)	What impacts and effects, both intended and unintended resulted from carrying out the program?
	In what manner and to what extent does the program complement duplicate, overlap or work at cross-purposes with other programs?
OBJECTIVES ACHIEVEMENT (Has the program performed as expected?)	In what manner and to what extent were appropriate program objectives achieved as a result of the program?
ALTERNATIVES (Are there better ways of achieving the results?)	Are there more cost-effective alternative programs which might achieve the objectives and intended impacts and effects?
	Are there more cost-effective ways of delivering the existing program.

Source: A Guide on the Program Evaluation Function in Federal Departments and Agencies; Office of the Comptroller General, August 13, 1980.

Two research techniques were selected in order to acquire the relevant data for the study; a survey questionnaire, and a program of structured interviews. In addition, some data were assembled at the request of the Contractor, by CCRS. Background material for the evaluation was made available by the Program Evaluation Branch of EMR. The evaluation team also had access to a recent evaluation report of the Auditor General and to the Treasury Board A-Base review.

The evaluation was conducted by a team of investigators under the direction of Philip A. Lapp Limited:

Dr. Philip A. Lapp, Philip A. Lapp Ltd.
Mr. Ronald M. Freedman, Philip A. Lapp Ltd.
Mr. David J. Lapp, Polar Research and Engineering
Prof. Ferdinand J. Bonn, Directeur, Laboratoire de Télédetection Départment de Géographie, Université de Sherbrooke
Mr. Joseph R. Ronsyn, Program Evaluation Branch, Department of Energy, Mines and Resources

Professor Donald J. Clough, an original member of the evaluation team, passed away during the course of the study. His place was taken by Dr. J. R. Whitehead, Philip A. Lapp Ltd.

An Advisory Committee was established to support the evaluation consisting of:

Dr. K. Whitham, Assistant Deputy Minister, Research and Technology (Chairman)
Dr. D. Bennett, Director, Program Evaluation Branch
Dr. L. Godby, Director General, CCRS
Mr. J. Ronsyn, Program Evaluation Branch (Secretary)

The Evaluation Team reported to the Director, Program Evaluation, Department of Energy, Mines and Resources.

1.3.1 Survey Questionnaire

The questionnaire employed in the study can be found in Appendix 2. It was designed in conjunction with the Program Evaluation Branch of EMR, Statistics Canada, and with input from CCRS. Part 1 of the questionnaire was aimed at establishing the frequency and nature of respondents' use of the Landsat system, their degree of satisfaction and the alternative data systems available to them.

The study was particularly interested in determining whether respondents were applying Landsat for research purposes, in one-time operational or in operational systems. Respondents were given the opportunity of identifying in which of 15 fields they applied Landsat. (An "other" category was also included, to account for unanticipated uses).

Part 1 of the questionnaire also incorporated a set of questions generated by CCRS and designed by them to assist planning for future activities. These were included as part of the evaluation, rather than put respondents to the trouble of replying to two separate requests for information. Answers to these additional questions have also contributed to the present analysis.

Part 2 of the questionnaire was concerned with the process of technology transfer from CCRS. Separate sections were constructed for the responses of industrial and non-industril respondents.

A primary task of the evaluation was to examine the process of technology transfer from CCRS to industrial firms and to end users, with regard to five specific technologies:

- o Landsat
- o SAR Development
- o Laser R and D
- o Image Analysis R and D
- o Solid State Scanner Development

Section 'A' of the technology transfer part of the questionnaire asked firms about their areas of technological involvement with CCRS, the nature of CCRS's assistance and the value to them of that help.

Section 'B" was directed to non-industrial users of CCRS's facilities and services and asked them to detail the nature of the help they received, their areas of satisfaction (or otherwise) and their suggestions for improving the services and facilities.

A draft questionnaire was distributed to a limited number of respondents (30) in the Toronto area as a pilot test. Difficulties encountered by the group and suggestions for improvement assisted in the drafting of the final questionnaire.

Following consultation with and approval from Statistics Canada and Treasury Board, a total of 2400 questionnaires were mailed to addresses in Canada. The mailing list was derived from two existing contact lists. The first of these was a list of customers of ISIS, International Satellite Information Services, a private company which distributed Landsat data products on behalf of CCRS, until 1980. The second was a (33 percent) random sample of the current

CCRS contact list. The two lists were combined and manually checked for redundancies.

Some time after the questionnaires were mailed, a reminder was sent to respondents whose replies had not been received. Returned questionnaires were edited, coded and keypunched and a computer tape of the results was produced. Open-ended questions were manually tabulated, in a separate exercise.

Questionnaires mailed	2400		
Less Wrong address or other identified reason for non-response	431	1969	100%
Questionnaires Processed		834	42%
Non Response		1135	58%

In our opinion, a significant proportion of the non-response can be accounted for by organizations which consolidated the individual responses of two or more of their employees. The mailing lists, upon which the survey was based, were comprised of individual contacts. Thus, two or more questionnaires may have been sent to individuals in large remote sensing organizations. Many organizations thereby chose to consolidate the responses of two or more employees into one "organizational response". This procedure was indicated by a number of respondents.

Because it was not possible to eliminate all duplication between the two contact lists employed, it is certain that some individuals received duplicate questionnaires. This occurred, for instance, where an individual corresponded with CCRS from two different addresses. In this circumstance, he or she will have been listed twice on the contact lists.

The reasonably even spread of responses over the range of sectors and application areas indicated that the "non-response" did not emanate from a specific component of the target population. Although a statistically rigorous analysis was not attempted, all factors considered, we believe that the response rate achieved (42%) permits a valid interpretation of the results of the questionnaire survey.

1.3.2 Structured Interviews

A second assessment technique involved the conduct of structured interviews with a range of remote sensing users (and non-users) and suppliers of remote sensing goods and services. In total, 84 interviews were held in five Canadian regions. Those interviewed are listed in Appendix 3.

The interview plan was constructed so as to ensure that the study took into account the experience of respondents in the following categories:

1. Heavy Users

A group of individuals and organizations who are heavily involved with CCRS and whose views were considered by all involved--CCRS, EMR and Philip A. Lapp Limited--to be critical to the evaluation.

2. Former Users

A group of respondents who had used CCRS services at one time but who had ceased doing so. This group was interviewed to shed some light on the factors responsible for some groups abandoning their satellite remote sensing activities.

3. Non-Users

A group of large Canadian companies or organizations that were operating in fields that were considered to lend themselves to the use of remote sensing, but were not making use of the technology. This group was chosen to explore the constraints on the spread of remote sensing technology.

4. Miscellaneous Users

A random selection from amongst those who replied to the evaluation questionnaire. These users were chosen to provide an unbiased baseline for the interview results.

Formats for the structured interviews were designed based upon guidelines for evaluation issues published by the Office of the Comptroller General.

2. RESULTS OF NATIONAL SURVEY

The following analysis is based upon responses to the questionnaire survey (Appendix 2). The survey had 3 parts, relating to the Landsat program, to technology transfer and to a group of ancillary questions designed to provide CCRS with planning information. This analysis broadly follows the structure of the questionnaire.

2.1 Respondent Categories (Table 2.1 refers)

Government users (Federal + Provincial) comprised the largest group among the 834 respondents who supplied completed questionnaires. Forty-four percent (44%) of all respondents came from this category. Federal and provincial government respondents (20.2% and 24.2%, respectively) were about evenly represented in the sample.

The proportion of non-manufacturing industrial respondents (22.9%) was about equal to that of the federal and provincial groups. Respondents based in Educational institutions comprised 15.8% of the sample. Forty-six respondents (5.9%) declared themselves to be manufacturers. Municipal Government (8.6%), Crown Corporation (3.9%) and "Other" (6.6%) respondents completed the sample.

TABLE 2.1

RESPONDENT CATEGORY

	Number of Cases	Percentage (Adjusted)
Manufacturing Industry	46	5.9
Non-Manufacturing Industry	178	22.9
Federal Government	157	20.2
Provincial Government	188	24.2
Municipal Government	5	0.6
Crown Corporation	30	3.9
Education	123	15.8
Other	51	6.6
No Reply	56	-
	834	100.0

2.2 Use of Remote Sensing (Table 2.2 refers)

The survey asked respondents to indicate which types of remote sensing they used (they could choose more than one), and the time frame in which they last used it. For purposes of the analysis, respondents were grouped into three categories; current users (used remote sensing in the past year), former users (used remote sensing, but not in the past year) and non users (had never used remote sensing).

About 53% of respondents were current users of Landsat. Fifty-nine percent were current users of airborne remote sensing, and 19% current users of "other" satellite data. Around 29% of respondents declared themselves to be former Landsat users, compared with 14% who were former users of airborne and 9% who were former users of other satellite remote sensing.

TABLE 2.2

Use of Remote Sensing
(Percentage of all 834 respondents)

	Current	Former	Never
Landsat	53.0	29.5	7.4
Other Satellite	19.0	8.9	19.9
Airborne	59.5	14.1	3.0

2.3 Fields of Remote Sensing Application (Table 2.3 refers)

Survey respondents were asked to indicate in which fields they had applied the three types of remote sensing. The most and least popular fields of application (by number of responses) were:

TABLE 2.3

APPLICATION AREAS BY POPULARITY

LANDSAT	OTHER SATELLITE	AIRBORNE
	Most Popular Application Areas	
Geosciences	Ice Monitoring	Cartography
Forestry	Oceanography	Geosciences
Geography	Atmospheric Monitor.	Forestry
Mineral Resources	Water Resources	Engineering
Water Resources	Geosciences	Water Resources
	Least Popular Application Areas	
Atmospheric Monit.	Pollution	Atmospheric
Fishery Resources	Fishery	Fishery
Pollution Detect.	Wildlife	Pollution
Oceanography	Petroleum Resources	Oceanography
Petroleum Res.	Agriculture	Ice Monitoring

Within the grouping of the most popular remote sensing application fields, Geoscience and Water Resource applications made use of all three remote sensing technologies. Forestry applications made use of Landsat and Airborne remote sensing. Mineral Resource and Geography applications were preferred by Landsat users, while Airborne users engaged in Cartography and Engineering projects. Other Satellite users had a preference for air and water types of applications.

In contrast, the least popular Landsat application fields were Air and Water related (Atmospheric Monitoring, Fishery Resources, Pollution Detection and Oceanography), plus Petroleum Resources. The least popular Airborne applications were in similar fields. The least popular Other Satellite application fields tended to complement Landsat. That is, they were terrestrially oriented.

2.4 Types of Landsat Use and Importance of Landsat Data (Tables 2.4, 2.5 refer)

The survey was interested in determining whether respondents were making use of Landsat data in research, for one-time operation or in operational systems (ongoing). The most and least popular fields of application of Landsat in an operational mode were (rank ordered):

TABLE 2.4

OPERATIONAL USES OF LANDSAT

MOST	LEAST
Mineral Resources	Atmospheric Monitor.
Forestry	Oceanography
Cartography	Pollution Detection
Geosciences	Fishery Resources
Wildlife	Petroleum Resources

The most and least popular fields of application of Landsat in a research mode were (rank ordered):

TABLE 2.5

RESEARCH USES OF LANDSAT

MOST	LEAST
Geosciences	Atmospheric Monitor.
Forestry	Fishery
Geography	Petroleum
Mineral Resources	Pollution
Water Resources	Oceanography

Of all applications reported; 47.2% were in a research mode, 31.2% in one-time operation, and 21.1% in operational systems.* Most application areas followed this pattern. Exceptions were in the Engineering and Atmospheric Monitoring fields, where one time operational uses predominated.

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* There were 322 operational systems reported by respondents.

2.4.1. Importance of Landsat (Table 2.6 refers)

Respondents indicated the fields in which they applied Landsat, and the types of uses to which they put it. The survey was also interested in determining how important Landsat was to their particular application--whether they could have used alternate sources of information, if they would have failed to complete their project, or whether they would have failed to start their project in the first instance.

TABLE 2.6

Classification Code	Importance of Landsat (Number of Responses) 1	2	3	
Agriculture	49	7	25	
Atmospheric	5	--	3	
Cartography	93	12	33	
Engineering	65	12	6	
Fishery	17	3	4	
Forest	126	17	43	
Geography	106	14	32	
Geosciences	119	32	35	
Ice Monitoring	43	20	16	
Mineral Resources	98	17	27	
Oceanography	15	6	7	
Petroleum	25	3	4	
Pollution	21	4	11	
Water Resources	63	22	32	
Wildlife	56	9	26	
Total Responses	901	178	304	1383
	(65%)	(13%)	(22%)	

Code

1. Could have used alternate sources of information
2. Would have failed to complete work on project
3. Would have failed to start project

It is apparent that in most of the applications cited by respondents, alternative sources of information would have enabled them to accomplish their task. However, in 304 (22%) of cases, the absence of Landsat data would have prevented a project getting off the ground.

2.5 Dependency on Landsat (Table 2.7 refers)

In order to establish a measure of users' dependency on Landsat for the completion of their work, a question was included in the survey which asked respondents to indicate whether they were wholly dependent on Landsat or whether they had alternative ways of gathering their required data. (This question differed from the previous one in that it focused on the alternatives, and not on the consequences of program cancellation.)

Only about 9% of respondents indicated they were dependent on Landsat to the extent that they would fail to perform their work if Landsat data were unavailable to them. Most had alternatives, but 40% said the alternative available to them was archived Landsat data. Taking these two figures together, it appears that fully half of respondents found Landsat to be desirable in their work.

Nine percent of respondents would have substituted other satellite imagery for Landsat, given that opportunity. Airborne remote sensing was clearly the most preferred alternative to satellite remote sensing. In this question, it was mentioned by about one-quarter (25.7%) of respondents.

TABLE 2.7

Dependency on Landsat

	Number of Respondents	Frequency(%)	Adjusted* Frequency (%)
Fail to do work	48	7.0	9.2
Use other imagery	48	7.0	9.2
Use aircraft r.s.	177	25.7	34.0
Use field collection	40	5.8	7.7
Use past Landsat	208	30.2	39.9
Other	168	24.4	--
TOTAL	689	100.0	100.0

* Removing "other" category

2.5.1 Characteristics of Dependent Users

A special cross tabulation of the survey results was run, to explore in greater detail the characteristics of respondents to Q6, (which enquired about their dependency on Landsat for the completion of their work). The results of the first crosstabulation, linking Question 6 with respondent category, is presented in Table 2.8.

Seven percent of all responses indicated that survey respondents would "fail to do (their) work" if the Landsat program were to be terminated.

Seven percent of respondents would use other satellite imagery in place of Landsat. One quarter (25.7%) would substitute aircraft remote sensing data for Landsat. Almost one-third would rely on archived Landsat images for their required information.

TABLE 2.8

Dependency on Landsat by Category of User

	Manuf	Non Manuf	Fed Govt	Prov Govt	Mun Govt	Crown Corp	Educ Inst	Total
			(number of responses)					
Fail to Do Work	5	8	9	12	0	1	10	46
Use Other Imagery	1	14	9	6	0	2	11	45
Use Air R.S.	13	20	27	61	1	10	20	162
Use Field Collect.	6	3	7	13	1	3	5	40
Use Past Landsat	1	58	31	40	0	4	38	198
Other	7	46	26	22	1	1	23	131
Total	33	149	109	154	3	21	107	622
			(percentage)*					
Fail to do Work	15	5	8	8	--	5	9	7
Use Other Imagery	3	9	8	4	--	10	10	7
Use Air R.S.	39	13	25	40	33	48	19	26
Use Field Collect.	18	2	6	8	33	14	5	6
Use Past Landsat	3	39	28	26	--	19	36	32
Other	21	31	24	14	33	5	22	21
Total	100	100	100	100	100	100	100	100

* Figures may not total exactly, due to rounding

Within respondent categories (Manufacturing Industry, Non-Manufacturing Industry, etc.), the survey results show Manufacturing Industry respondents to be most reliant on the Landsat program; fifteen percent of them said they would fail to perform their work in its absence.

Manufacturing Industry, Provincial Government and Crown Corporation respondents preferred to substitute aircraft remote sensing data over archived Landsat images. Non-Manufacturing Industry and Educational respondents preferred to substitute past Landsat data, while Federal Government respondents were about evenly split between those two alternatives.

The survey analysis also looked at the characteristics of users' dependency on Landsat, according to the category of the projects they were engaged in (Table 2.9).

Table 2.9

Dependency on Landsat
by Category of Project
(percentages)

	Research		One-Time Operation		Operational System		TOTAL
Fail to do work	58.4	11.3	21.9	6.5	19.7	8.4	100
Use Other imagery	42.3	5.8	36.1	7.5	21.6	6.5	100
Use Air. R.S.	49.0	24.6	34.2	26.2	16.8	18.6	100
Use Field Collect.	44.9	4.9	21.8	3.6	33.3	8.1	100
Use Past Landsat	45.9	29.9	34.0	33.8	20.1	28.9	100
Other	45.6	23.5	28.4	22.4	26.0	29.5	100
TOTAL		100.0		100.0		100.0	

Of the three project categories in Table 2.9, groups engaged in Research projects comprised the largest proportion (58.4%) of those who would "fail to do their work" in the absence of the Landsat program. However, overall, only 11.3% of all Research projects fell into that category. Research projects were also most amenable to all the alternative data gathering methods.

Finally, in order to further identify the characteristics of respondents' Landsat dependency, answers to Question 6 were cross-tabulated with the economic behaviour of users - that is, with the various goods and services which they purchased and sold (Table 2.10).

Table 2.10

Landsat Dependency of Buyers of R.S. Goods and Services

(number of responses)

Code	1	2	3	4	5	6
Air Survey	22	10	100	12	90	64
R.S. Consultant	10	6	21	4	25	23
D.P. Specialist	9	7	18	1	15	11
Custom Data Products	17	11	28	4	32	14
R.S. Equipment	12	8	37	2	18	28
Dig. Anal. Equip/Soft.	10	13	18	4	18	9

Code

1. Fail to do work
2. Use Other Imagery
3. Use Aircraft Remote Sensing
4. Use Field Collection
5. Use Past Landsat
6. Other

(Variations between the totals in Table 2.10 and in Q17 (p.194) are the result of multiple answers to the latter).

Purchasers of aerial survey and custom data product goods and services indicated a higher dependency ("fail to do work") on Landsat than purchasers of other goods and services. These two groups, plus purchasers of digital analysis equipment and software, were prepared to make greatest use of other satellite imagery.

Purchasers of air survey, remote sensing and custom data goods/services indicated that airborne remote sensing was a good alternative for them--more so than buyers of other goods and services.

Buyers of air surveys also tended to be more attracted to the field collection alternative than others.

All groups, excepting those buying remote sensing equipment, indicated that archived Landsat data would be at least as useful an alternative as aircraft remote sensing.

Sellers of remote sensing goods and services indicated the following pattern of responses (Table 2.11).

Table 2.11

Landsat Dependency of Sellers of R.S. Goods and Services (number of responses)

Code	1	2	3	4	5	6
Air Survey	1	4	4	--	2	7
R.S. Consultant	11	7	14	--	21	26
D.P. Specialist	5	3	7	--	9	10
Custom Data Products	2	4	3	--	3	8
R.S. Equipment	1	1	--	--	1	1
Dig. Anal. Equip/Soft	3	1	--	--	4	2
TCTAL	23	20	28	--	40	54

Code

1. Fail to do work
2. Use Other Satellite Imagery
3. Use Aircraft Remote Sensing
4. Use Field Collection
5. Use Past Landsat
6. Other

Amongst sellers of remote sensing goods and services, it would appear that remote sensing consultants would be most affected by a termination of the Landsat program. The answers supplied by data processing specialists also indicated a heavy dependence on Landsat.

2.5.2 Economic Behaviour of Respondents (Table 2.12 refers)

Question 17 of the survey was aimed at establishing the economic behaviour of CCRS's user community. Respondents were asked to indicate which remote sensing goods and services they bought and sold. (Multiple responses were permitted).

Fully 40% of respondents declared themselves to be buyers of aerial survey services. This was ten times the number of aerial survey service sellers. About equal numbers of respondents indicated remote sensing consultancy sales or purchases (103 and 95, respectively). Purchasers of data product specialist services numbered 76, while sellers of those services numbered 45.

There were many more buyers of custom data products (115) than sellers (26). Buyers of remote sensing equipment numbered 130 and sellers, only 8. Ninety (90) respondents indicated they bought digital analysis equipment or software, while 14 respondents declared themselves to be sellers of those products.

Five hundred and ninety-four (594) respondents provided 1145 separate responses to this question. (Multiple answers were allowable). The following table summarizes their responses.

TABLE 2.12

Breakdown of Respondents' Buying and Selling Activities

	Buy	Sell
	(percent of valid responses tabulated)	
Air Survey	40.1	12.4
R.S. Consult.	11.4	39.3
D.P. Specialist	8.4	18.6
Custom Data Products	12.7	10.7
R.S. Equipment	14.4	3.3
Dig. Anal. Eqpt/Soft.	10.0	5.8
Other	3.0	9.9
	100	100

2.6 Landsat Characteristics

In order to determine which particular features of Landsat imagery users found to be satisfactory and unsatisfactory, two open-ended questions were included in the survey.

Table 2.13

Satisfactory Features of Landsat Imagery
(number of responses)

Intensive coverage of large areas/ scales used/large format	205
Discernible water/land/sky images/ visual, impact/resolution	148
Seasonal coverage/ability to monitor changes	67
Multiple bands/variation of bands	40
Ease of acquisition/easy data access	37
Cost/inexpensive	28
Quality of prints/tapes/transparencies	27
Geological interpretation	26
Digital analysis capability	26
Colour quality	19
All satisfactory	15
Speed of receiving CCT information	12
Preliminary monitoring of disturbances/ turbulence	5
Good presentation tool	3
Not suitable for our needs	2
Infrared images	2

TABLE 2.14

Unsatisfactory Aspects of Landsat Imagery
(number of responses)

Resolution/Scale size too small/ no detailed coverage	218
Cloud cover/weather problems	79
Poor quality print/tapes/fiche	41
Slow product delivery	36
Inadequate frequency of coverage	33
Limitation of coverage/no stereo/ inadequate band choice	29
High cost	25
Lack of true colour	9
Inadequate coverage of specific geographic area	8
Insufficient knowledge of Landsat/how to use it	7
Digital analysis problems	4
Classification accuracy	4
Availability of up-to-date imagery	3
Absence/deficiency in catalogue	3

It is apparent from the answers given that the large majority of satisfactory and unsatisfactory features of Landsat imagery related to attributes of the technology system, as opposed to CCRS's performance in program delivery. For instance, many survey respondents cited the advantages to them of the large field of view of Landsat. Others claimed this very feature was a drawback for their work.

Resolution was the most important consideration for users. It was cited in a total of 571 instances as being either a satisfactory or unsatisfactory attribute of Landsat.

As many respondents were satisfied with the cost (28) of data products as unsatisfied (25).

2.7 Technology Transfer to Industry

The technology transfer part of the survey was aimed at industrial respondents (section "A") and others (section "B").

Industrial respondents - those participants who bought or sold remote sensing goods/services for profit - provided information on the nature of their technology transfer activities. (See Table 2.15, below).

Seventy percent of industrial respondents had been involved with CCRS on the Landsat program. About one-fifth had been involved in synthetic aperture radar (airborne and satellite) and airborne image analysis R&D activities, with CCRS. About 5% had been involved in laser R&D or solid state scanner work.

TABLE 2.15

Areas of Involvement with CCRS

	Pct. of Responses	Pct. of Respondents
Landsat	36	70
Satellite SAR	11	21
Airborne SAR	11	21
Laser R&D	3	5
Satellite I.A. R&D	19	38
Airborne I.A. R&D	11	21
SSC	3	5
Other	7	13

Number of Respondents = 80

A key indicator of the impact and the effect of the technology transferred to industry by CCRS, was believed to be the number of domestic and foreign sales which resulted from the interaction between the two groups. The following table indicates the result.

TABLE 2.16

Sales Resulting From CCRS Contact

	Domestic Sales	Foreign Sales
	(number of responses)	
Landsat	15	0
Satellite SAR	2	1
Airborne SAR	5	1
Laser R&D	0	2
Satellite I.A. R&D	12	2
Airborne I.A. R&D	8	1
SSC	3	1
No Sales	3	0

Total number of respondents = 35

Combining the results of the foregoing two tables, we find that 35 of the 80 firms reporting technology transfer contact with CCRS, also reported sales in these areas. The highest number of sales was made as a result of Landsat technology transfer. Twelve companies reported sales in the area of satellite image analysis and 8 companies in the area of airborne image analysis (there was probably some overlap here). In three cases companies stated specifically that their sales did not result from direct CCRS assistance.

Question 21 of the survey was designed to explore in greater detail the nature of the assistance which firms received from CCRS. Of the 80 firms indicating a technology transfer involvement with CCRS in question 19, only 4 chose to specify the nature of that assistance. In view of the very low rate of response to this question, we cannot draw any conclusions from the answers.

Question 22 was constructed in order to measure respondents' perceptions of the value to them--in terms of sales, earnings, growth, new markets, new products, etc.--of CCRS's assistance. This was an open-ended question, the responses to which are categorized below.

TABLE 2.17

Firms' Perceptions of the Value of CCRS's Assistance

	No. of Responses
High positive comments	19
Low positive comments	20
Negative comments	8
Neutral comments	9
Number of Respondents = 56	

It is apparent that the positive comments on the value of CCRS's assistance far outweighed the negative. It is also noteworthy that 56 of 80 industrial technology transfer respondents provided answers to this question.

This would indicate that a large number of firms are closely involved with CCRS in their remote sensing work.

Comments were also solicited from respondents concerning the positive aspects of the technology transfer process, as well as suggestions for improving it. The answers which were provided can be grouped as follows:

Table 2.18

Positive Aspects of Transfer
Process and Suggestions for Improvement

	No. of Cases
Positive Aspects	
Satisfied with help/service	15
Fundamental research	6
Staff exchanges	2
Design	4
Attended CCRS seminars/lectures	2
Use of CCRS facilities	4
Transfer of remote sensing technology	4
Fast service	2
Computing	1
Suggestions	
Slow turnaround	1
Misc. negative	14
Misc. positive	5

As can be seen, positive comments were spread across many aspects of CCRS's work. Suggestions for improvement were relatively few, and fell into no discernible categories.

A typical example of the type of response to this question was received from a Western Canadian remote sensing company:

> "Haggling over trivia has consumed time which could have been more productively spent. Exceptions are a price break on some radar imagery and the passing along of marketing intelligence by CCRS personnel."

Another, from a Quebec-based engineering consultant:

> "We were quite satisfied with the help from CCRS. They were as helpful as our own limited expertise would allow."

A third set of comments comes from a Western Canadian engineering firm, which stated they had:

> "Fifty thousand dollars total sales in past 5 years, bridge funding for research, and CCRS staff assistance on projects."

2.8 Technology Transfer to End Users

Section "B" examined the process of technology transfer from CCRS to end users of remote sensing, that is, to groups which did not engaged in remote sensing activities for profit.

End users were first asked to indicate which CCRS services they used, and their degree of satisfaction with each. The following table summarizes their answers.

TABLE 2.19

Use of CCRS Services and Facilities
(number of responses)

Code	1	2	3	4	5	6	Total
Image Analysis	103	3	11	10	2	15	144
Data Processing	10	6	16	27	3	32	94
Aircraft Provision	11	1	16	10	9	29	76
Advice on New Apps.	-	-	-	2	-	-	2
Applicat. Devpt. Aid	-	-	-	-	3	-	3
CCRS Services	-	-	-	-	-	-	-

Number of respondents = 265

Code

1. Very Satisfied
2. Satisfied
3. Dissatisfied
4. Very Dissatisfied
5. No Opinion
6. Other

One hundred and forty-four (144) respondents indicated that they had made use of CCRS's Image Analysis services or facilities. One hundred and six (74%) of them said they were very satisfied or satisfied with the assistance which they received. Ninety-four (94) respondents indicated they had had CCRS's help with Data Processing of which sixteen (17%) declared themselves to be very satisfied or satisfied with that service. In 43 cases (46%) respondents were dissatisfied or very dissatisfied with the data processing support they received.

Only two respondents indicated they had received CCRS's assistance with new applications, and both of them were very dissatisfied. Three respondents voiced no opinion concerning the applications development assistance they had received from CCRS. Our tendency is to discount the small number of responses to these latter categories.

Respondents who held strong views (very satisfied or dissatisfied) were invited to expand their answers in an open ended question (Q25). Replies were grouped into categories and are described in Table 2.20 on the following page.

TABLE 2.20

Respondents' Reasons for Satisfaction or Dissatisfaction

Satisfaction	No. of Responses
Prompt Service	46
Professional/efficient/accurate/expertise	46
Helpful/cooperative/responsive staff	55
Minimum red tape/easy access	3
Friendly, courteous staff	16
Good quality reproductions	16
Useful	5
Low cost	5
Misc. positive	7
Dissatisfaction	
Slow service/failure to meet schedule	16
Poor quality/wrong image sent	15
Catalogued image not available	8
Poor customer relations in Ottawa	6
Insufficient information on services	3
Hard to book planes/image analysis facilities overloaded	2
High price for imagery	2
Misc. negative	19

Number of Respondents = 167

One hundred and sixty-seven people provided detailed explanations of their satisfaction or dissatisfaction. The satisfied responses tended to focus on the quality of the staff at CCRS. The dissatisfied responses focused on the services received.

The survey had hoped to explore whether, and if so how, end users' technology transfer experience had been applied in research, one-time operational or operational systems (Q26). However, there were insufficient replies to enable any conclusions to be drawn.

Finally, respondents were asked to make suggestions for improving the services and facilities at CCRS. One hundred and sixty-seven respondents made a total of 269 suggestions.

TABLE 2.21

Suggestions for Improving CCRS's Services and Facilities

Keep us better informed of services/ issue catalogues	65
Expand coverage in Canada	29
Improve cost structure for product	28
Improve turnaround time/deliveries	26
Improve resolution/frequency of coverage	21
Develop new technologies (e.g. Radarsat)	19
Be more user oriented	15
Centralize satellite data (e.g. NOAA, Landsat, GOES)	13
Have training/orientation courses	11
Better information on archived data	10
Better information on cloud cover	7
Improved quality	2
Miscellaneous	23

Number of cases = 167

3. LANDSAT ACTIVITIES

3.1 Program

Landsat is one program component of the Canada Centre for Remote Sensing. It is a "vertical" program in a "horizontal" organization. That is, Landsat is but one of the satellite systems for which CCRS gathers, processes and distributes data (others include the NOAA and TIROS satellites). There are no independent units within CCRS which are exclusively responsible for Landsat. Rather, each division of CCRS devotes a part of its activities to Landsat.

Landsat refers to a series of four satellites launched by the United States' National Aeronautical and Space Administration between 1972 and 1982. Canada has had access to data relayed by the satellites, in return for payment of a station charge. The charge is presently $600,000 per station per year.

Until 1983, Canada operated two tracking stations, at Prince Albert, Saskatchewan and Shoe Cove, Newfoundland. The Shoe Cove station was closed in 1982 as the result of a large increase in the station charges imposed by NASA. Since the closure of Shoe Cove, east coast Canadian data have been purchased from the United States. The Prince Albert Satellite Station (PASS) can gather data for most of mainland Canada, but misses large parts of the east coast. In that this study is retrospective in nature, it has taken into account the operations of Shoe Cove.

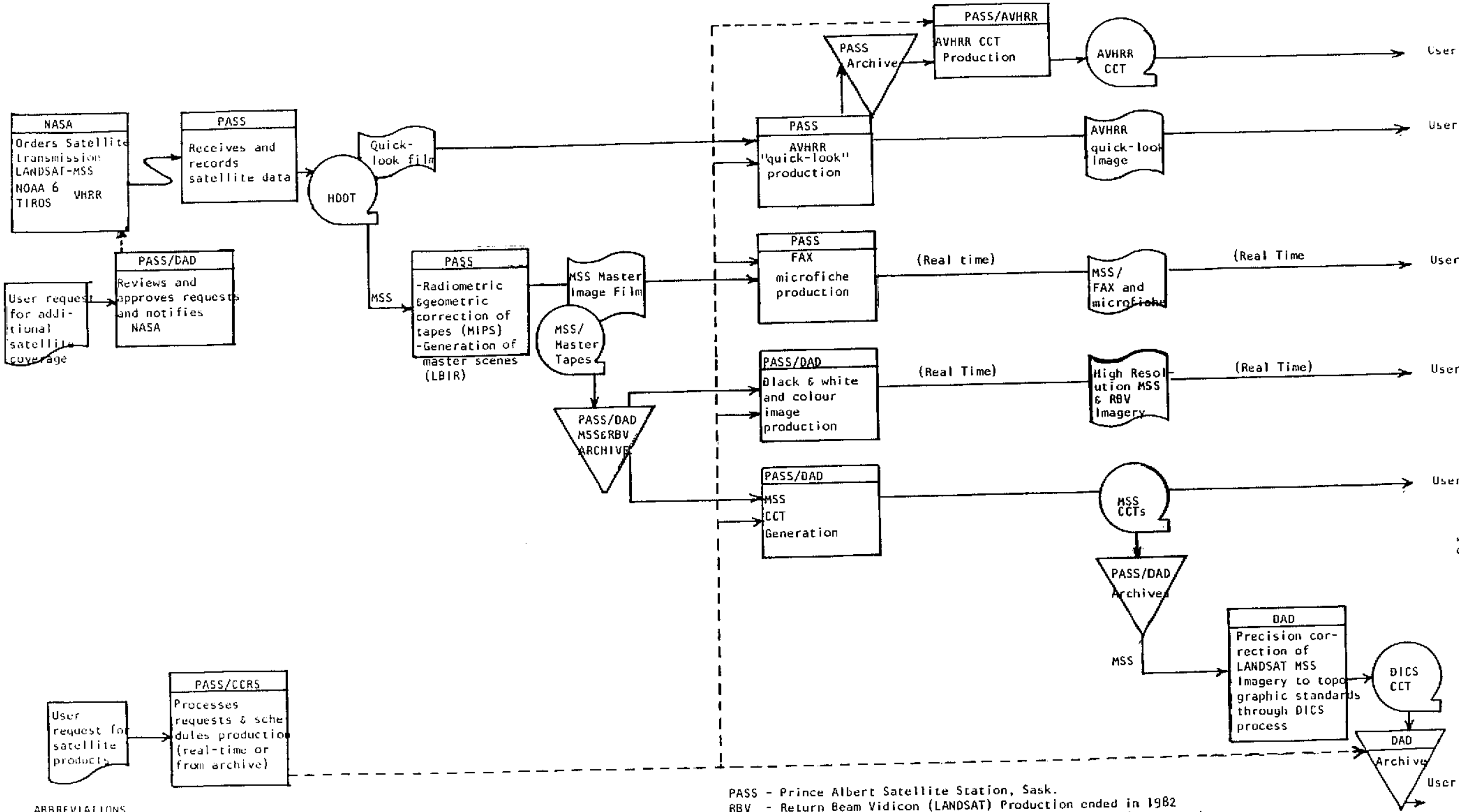
The Landsat satellites have incorporated three main sensor systems, though not all systems were present on each satellite; a Multi-Spectral Scanner (MSS), a Return Beam Vidicon (RBV), and a Thematic Mapper (TM). Landsat-D, the fourth in the series, carried the Thematic Mapper and the Multi-Spectral

Scanner. Landsats 1, 2 and 3 carried the MSS and the RBV. Landsat-D was intended to become the first operational satellite, however technical problems with the TM combined with some uncertainty over the United States' commitment to maintaining a publicly funded program, have cast some doubt on this.

The Canada Centre for Remote Sensing implements the Remote Sensing Activity of EMR. This activity is primarily a research and development program which consists of data collection, data processing, applications development and technology transfer components. CCRS has developed new hardware, and new processing and interpretation techniques in order to make use of the satellite data. It has also worked with industry and end users in order to transfer to them its technology know-how.

Figure 3.1 details the satellite data production process. The Landsat production process begins with the reception of the raw satellite data at the Prince Albert (and formerly Shoe Cove) tracking station. The data is stored on high density digital tape (HDDT), before being processed. A quick-look film can be generated at this stage so the tape can be screened to see if it contains useful scenes.

The HDDT MSS data is then processed through the MIPS system at Prince Albert. This results in a radiometrically and geometrically correct tape. Master scenes can be generated from the tape at this stage using the laser beam image recorder (LBIR).



PASS - Prince Albert Satellite Station, Sask.
RBV - Return Beam Vidicon (LANDSAT) Production ended in 1982
AVHRR- Advanced Very High Resolution Radiometer (NOAA-6, TIROS-N)

ABBREVIATIONS
CCT - Computer Compatible Tape
CIR - Colour Image Recorder
DICS - Digital Image Correction System
EBIR - Electron Beam Image Recorder
DAD - Data Acquisition Division

HDDT - High Density Digital Tape
IPS - Image Processing System
MIPS - Multi-Image Processing System
MSS - Multi-Spectral Scanner (LANDSAT AVHRR)
NAPL - National Air Photo Library (Ottawa)

FIGURE 3.1 SATELLITE DATA RECEPTION PROCESS

The MSS master tapes are used to generate master film images. Tapes and images are archived at PASS. The master MSS tapes and images can be used to generate the final products: AVHRR CCTs, Quick-look Imagery, MSS Fax and Microfiche, MSS RBV Imagery, and MSS CCTs. RBV tapes and images can also be generated from archived data.

In addition, Landsat MSS CCTs can be precision corrected to topographic standards using the DICS system located in Ottawa. The DICS CCTs are archived in Ottawa.

CCRS makes other services and facilities available to Landsat users, in the Data Applications and Applications Services/Technology Transfer fields.

The CCRS Data Applications group develops new applications for remote sensing technology. The group carries out R&D on methods of extracting information from remotely sensed data, often in cooperation with user agencies. Data applications work involves research into information extraction, largely via computer methods. Applications involves R&D into specific applications of remote sensing (e.g. rangeland management, potato inventory).

Applications services and technology transfer involves three activities, in turn: image analysis services, user liaison and technology transfer. Image analysis services make available to users digital and analogue instruments and advice on their use. The user liaison activity includes the marketing of CCRS products and services and the provision of information to users on the range of assistance available to them.

Technology transfer became a separate CCRS sub activity in FY1983-84. Though technology transfer is an implicit objective of all of CCRS's work, prior to that it absorbed about 1% of the budget, now it is in the range of 7% (see Table 1.3).

3.2 Objectives

Landsat is the longest-running of the satellite remote sensing programs. The launch of Landsat-D in 1982 was intended to mark the beginning of a fully operational system. (Subsequent technical problems have cast some doubt on this.)

The objectives of the Landsat program are derived from combining the objective prescribed for the remote sensing activity generally (Activity Objective) with the specific sub-objectives of the Satellite Data, Data Applications, and Applications Services and Technology Transfer branches of CCRS.

Activity Objective

"To improve remote sensing technology and to facilitate the acquisition and dissemination of remotely sensed data and derived information needed for the management of Canadian natural resources and for the monitoring of human activity."

Satellite Data Sub-Objective

"To ensure the timely availability of remotely sensed data from satellites for resource management and environmental monitoring."

Under this sub-objective, there are two primary sub-sub activities related to Landsat:

Satellite Operations and Products

Remote sensing imagery is the primary output of CCRS. The Prince Albert Satellite Station is equipped with antennas, tape recorders and image processing systems to convert satellite data into film products, computer tapes and facsimile transmissions. Total sales in 1981-82 amounted to $470,895.

Satellite Data Acquisition and Processing R&D

To guarantee timely access to Canadian resource and environmental data at 30-meter resolution, and to develop and demonstrate Canadian ground station technology. R&D activities were undertaken on The Multi-Observation Satellite Image Correction System (MOSAICS) Program to determine user requirements for a precision processing facility that would provide users with access to geocoded data from LANDSAT-D by 1986 and the proposed French satellite SPOT by 1987.

A third sub-sub activity "Satellite R and D" relates to satellite radar data and Radarsat, and not to the Landsat program.

Data Applications Sub-Objective

"To develop and implement procedures to extract relevant information from remotely sensed data as well as to establish and demonstrate practical applications of that information in the management of Canadian resources and in monitoring of the environment."

Applications Services and Technology Transfer Sub-Objective

"To provide analysis facilities as well as information and advisory services to assist users and to increase the use of remote sensing data through technology transfer to resource management agencies."

The technology transfer process, as it relates to the Landsat program will be covered in Section 4.

3.3 Outputs

The outputs from the Landsat program include a range of photographic and digital products (see Figure 3.1):

1. "QUICK LOOK' IMAGERY

A photographic product based upon the Landsat MSS and RBV (Return Beam Vidicon), that also includes NOAA and TIROS VHRR sensor data. The 'quick look' allows a user to preview uncorrected imagery he may later decide to order.

2. MSS and RBV FAX and MICROFICHE

High resolution imagery is processed at PASS in near real time and sent by FAX (facsimile transmission) or mailed as microfiche to subscription users.

3. HIGH RESOLUTION MSS AND RBV IMAGERY

Landsat multi-spectral scanner data is radiometrically and geometrically corrected at Prince Albert (PASS) by the Multi-Image Processing System (MIPS). Master scenes are then generated using the Laser Beam Image Recorder (LBIR) and the resulting tapes and negatives are archived. The archived master scenes are developed into photographic products (e.g. prints, transparencies) at the request of users.

4. MSS and RBV CCTs

Computer compatible tapes (CCTs) are generated from archived master tapes that have been radiometrically and geometrically corrected through the MIPS and IPS system. VHRR tapes are converted to CCT format at PASS. RBV CCTs are generated at DAD. MSS CCTs can be generated at PASS or DAD, depending on the location of the original tape.

5. DICS CCTs

DICS (Digital Image Correction System) is a system for precision converting Landsat MSS digital imagery to be compatible with NTS maps.

In 1982, CCRS's quantity of product outputs were as follows:

TABLE 3.1

CCRS PRODUCT OUTPUTS

	1982*
B&W Images	3,941
Colour Images	2,601
FICHE Subscriptions	4
Facsimile (months)	14
CCTs	962
(of which) DICS	394

* This represents the total of all CCRS's outputs. Landsat products comprise over 90% of the total.

Other CCRS outputs (in 1981-82) involving Landsat were in the areas of image analysis, and scientific and technical information:

Image Analysis Facility Outputs

2000 hours of CCRS Image Analysis System work
200 hours of time-sharing Research Image Analyses
400 hours of Photo-interpretation Density Slicer time

Scientific and Technical Information Outputs

180 library cataloguings
924 information searches
2 newsletters
editorial assistance on 72 CCRS publications
9,101 bibliographic searches and 4,654 newly indexed documents
ad hoc assistance to 200 users
3 remote sensing displays
3 trade exhibits
workshops

3.4 Impacts and Effects

The impacts and effects of Landsat activities in Canada were measured through the use of the questionnaire (Appendix 2), the interviews (listed at Appendix 3) and information obtained directly from CCRS. This section explores the extent of Landsat usage, the nature of that usage and the degree to which users are satisfied with Landsat services.

a) Extent of Landsat Useage

Table 3.2 and Figures 3.2 and 3.3 trace the sales of satellite imagery products from 1972. The eleven years described here can be divided into roughly three periods. First, the period 1972-75, during which Landsat imagery first became available at very low cost. Sales of Black and White and Colour imagery leapt between 1972 and 1975. CCTs first became available in 1973 and their use grew rapidly. The proportion of Canadian images sold by the United States (though not necessarily to Canadians--this information was unavailable) was about 5% of CCRS's sales. American CCT sales of Canadian scenes was about 9% of Canadian CCTS sales at the end of the period.

In the period 1976 to 1979 sales of all image products declined. CCT and EBIR sales, when combined, actually increased. American sales of Canadian data also fell, though not so sharply. Over the period, the U.S. sales of photographic products averaged around 9% of the Canadian. During these years, the marketing and production of Canadian data products was undertaken by a private company, ISIS, under contract to CCRS.

TABLE 3.2

CCRS SATELLITE IMAGERY SALES (1972-82)

Product	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Black & White	8,229	75,916	70,000	52,000	27,000	13,881	12,363	6,287	7,611	8,935	3,941
Colour	4	8,421	13,000	10,400	6,421	7,876	1,681	1,943	1,638	2,778	2,681
TOTAL	8,233	84,337	83,000	62,500	33,421	20,957	14,844	8,150	9,249	11,785	6,542
FICHE Subscriptions	-	-	34	22	21	17	19	20	12	7	4
Facsimile (1) (Months)	-	-	7.5	6	6	4.5	4	16	10	39.5	14
CCTs	-	140	430	559	408	430	325	387	709	779	962
DICS CCTs	-	-	-	-	-	-	-	-	283	359	394
SALES VOLUME ($000)	11.7	142.0	150.0	140.0	175.0	224.5	289.1	240.8	345.0	414.1	375.3

EROS DATA CENTRE

IMAGES/CCTs SOLD OF CANADA

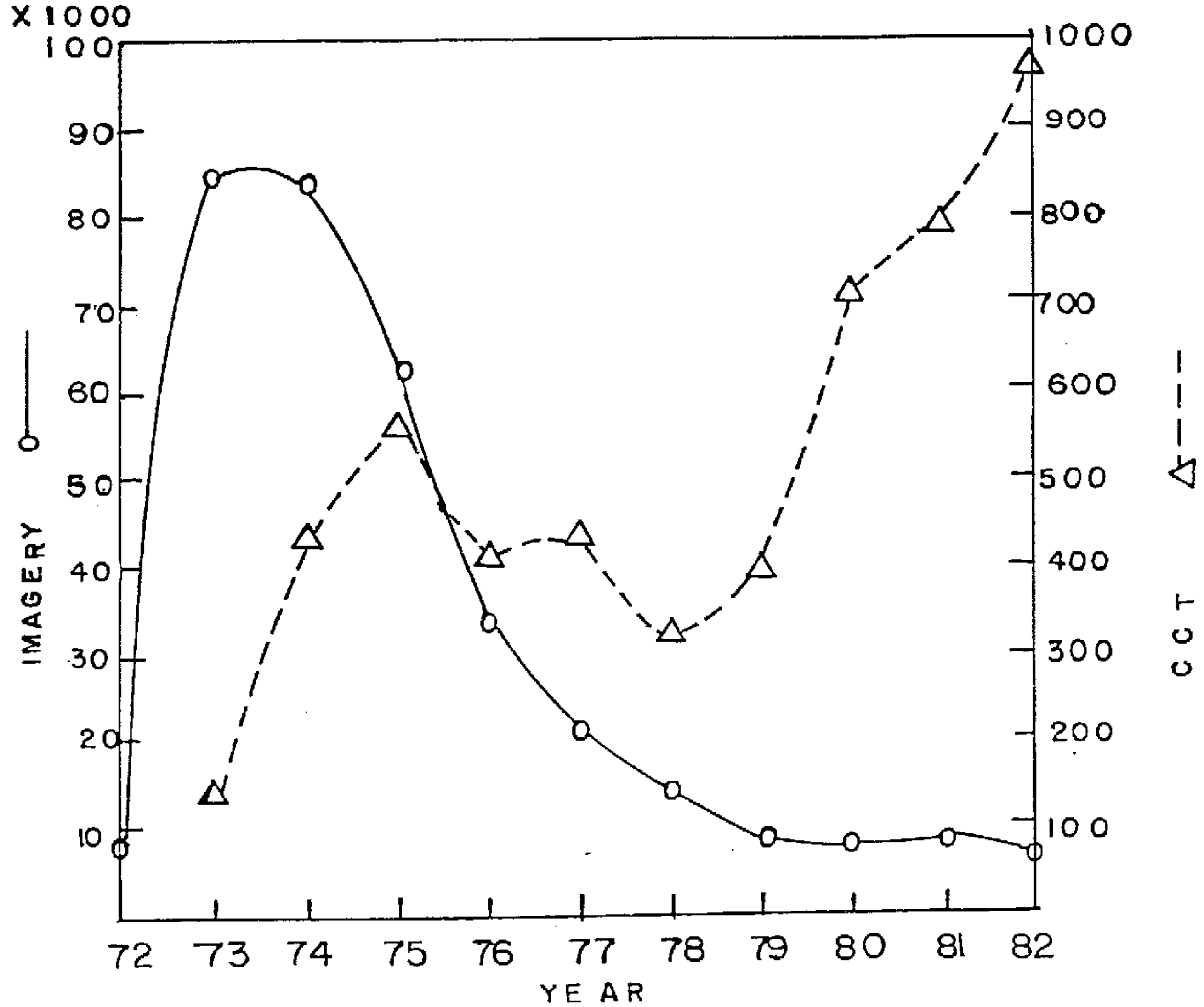
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Photographic Scenes by Product Count	N/A	N/A	N/A	3,640	2,562	1,307	837	2,400	1,262	783	5,630
CCTs by Scene Count	N/A	N/A	N/A	49	12	51	26	63	55	44	108

NOTES

1. Facsimile transmission is purchased by the month with varying quantities of imagery delivered. The main customer for this service is AES Ice Branch.

FIGURE 3.2

CCRS IMAGERY AND CCT SALES, 1972-82



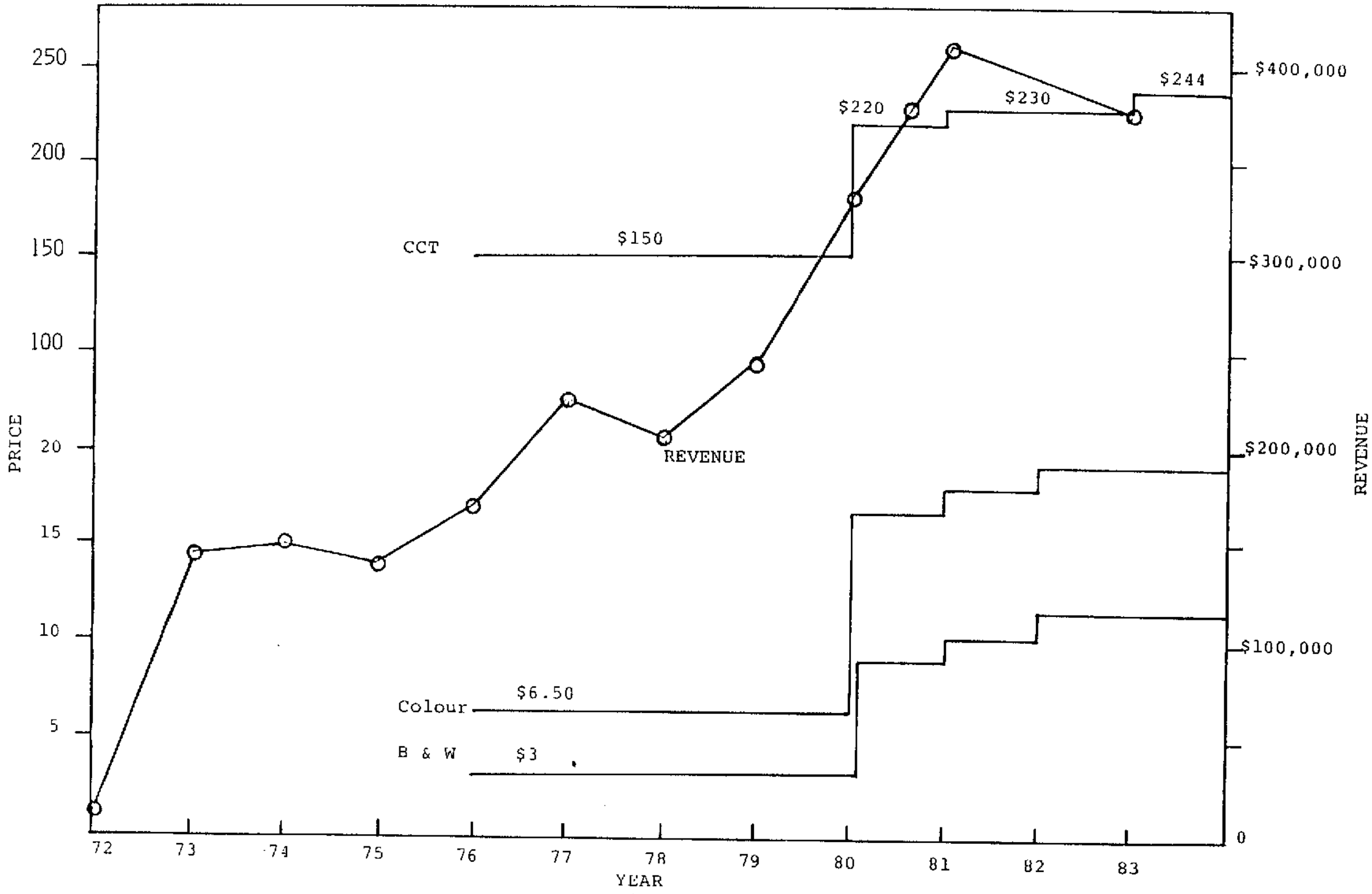


FIGURE 3.3 PRICE AND REVENUE COMPARISON

The third period, from 1980 to the present, shows a continuing decline in the sales of photographic images. There is a corresponding large increase in the sales of computer data products, much of that attributable to sales to the expanding number of owners of digital image analysis facilities and the growing popularity of DICS imagery. (Table 3.1 shows a 40% growth in DICS sales since they were introduced in 1980.) U.S. sales of Canadian data continued to decline, but showed an unexplained jump in 1982. In the years 1980-82 inclusive, U.S. sales of photographic products averaged almost 28% of the Canadian; CCT sales averaged around 8% of the Canadian. During this period, Canadian product marketing was transferred to the Prince Albert station operators, SED Systems.

The early peak reached in 1973 occurred at a time when Landsat imagery was being introduced to the user community and prices were low. Certain users needed only one set of images to suit their needs. This group included some in the educational sector, users that required only one set of cloud-free images and had no need to detect change, and those that found inadequacies due to resolution or coverage shortcomings. It is suggested that the large initial surge in Landsat imagery sales can be accounted for by such one-time users, and that the fall-off since 1974 has been created not only by the escalation of prices, but also by the fulfilment of cloud-free scenes for those applications that do not need time-series images (e.g. certain branches of geology), and disappointment with resolution and frequency of coverage.

Nearly 1/3 of the survey respondents declared themselves to be "former" users of Landsat (Table 2.2). This is a higher proportion than former users of other remote sensing techniques. The large number of respondents who indicated problems with technical aspects of Landsat in Table 2.13 (resolution, scale, cloud cover, band choice) provides some clues to the large number of former Landsat users.

The extent to which Landsat is used in Canada covers a wide range of disciplines, as evidenced by the survey. While all of the application areas listed in the questionnaire (Q.2) claimed use of Landsat, two-thirds of the applications were in geosciences, forest resources, geography, mineral resources, cartography and water resources.

In summary, the largest use of Landsat imagery occurred in the mid-1970s when it was novel and the cost was low. The continual decline in the use of imagery since then has been accompanied in recent years by growth in CCT sales, indicating the incidence of fewer but more sophisticated users in the marketplace that have invested in the digital image processing and analysis equipment required to make use of such tapes. This latter conclusion is corroborated by the expanding sales of the three principal image analysis hardware suppliers in Canada (Dipix, MDA and OVAAC-8).

b) Nature of Landsat Usage

The nature of Landsat usage is important insofar as it indicates the extent to which users are committed to the program, and the degree of economic benefit derived from a Canadian involvement. As indicated in Appendix 2, (Q.3) nearly half the applications were in research, about one third in a one-time operational context and one fifth in a fully operational mode.

Over two-thirds of the operational users were in forest resources, mineral resources, cartography, geosciences, wildlife and wildlands management, and water resources. Engineering projects can be added to this list for one-time operational applications, reflecting the nature of such engineering work. Research applications are widely heterogeneous, although also heavily oriented toward geological users and forestry.

The least popular applications among respondents were meteorology, fisheries and petroleum resources. Meteorology supports its own satellite program and thus is understandably not a significant area for Landsat use. The low numbers in fisheries and the petroleum industry in both research and operations is more surprising, although the high incidence of cloud over the offshore regions of Canada may explain some reluctance of these user communities to use Landsat. Also, it is likely that much of the petroleum industry usage of Landsat is based in Houston, Texas.

The criteria for selecting Landsat users to be interviewed resulted in an uneven coverage of the application areas. However, most of the significant user groups were contacted. In general, the view was expressed that Landsat was oversold in the earlier years, and users became disappointed with the coverage (due to cloud cover and frequency) and resolution achieved. The advent of digital image analysis techniques in recent years has resulted in a slow but accelerating acceptance of Landsat as an operational tool by the more serious and sophisticated resource managers.

In forestry, Landsat data is being employed in a major integrated operational system for the B.C. forest inventory. It is also being used for operational forest fire mapping in Manitoba. It will be used for clear-cut mapping of maritime forests in a demonstration project which could lead to its operational use there by the forest industry.

Activities related to mineral resources and geosciences use Landsat data for a variety of purposes associated with major structural features. Of those interviewed (only three users in this sector), there has been a recent decline in the use of Landsat imagery in favour of other geophysical methods including more sophisticated use of aircraft imagery. A successful application of Landsat data by Inco is in vegetation monitoring around its sites at Sudbury and Thompson to establish the before and after effect of large stack installations. As in many other applications, Landsat overviews permit the more efficient use of aircraft and the elimination of areas less likely to yield results from more detail exploration.

In cartography, Landsat is used to detect broad cultural changes and thus more intelligently plan revision aerial photography. (For the Surveys and Mapping Branch, Landsat use has resulted in aerial photography savings ranging from 30% to 50% for 1:50,000 and 1:250,000 scale NTS maps, which amounts to $150,000 - $200,000 per year). Landsat imagery can be used for 1:250,000 scale direct revision for non-cultural features. At 1:50,000 scale, such imagery can be used only in preliminary revision mapping for linear features and water, due to resolution limitations. In fact, the national survey revealed that 1:50,000 and 1:250,000 map scales were favoured by the remote sensing community, for use in conjunction with their work (see Q.10 of the survey). Some islands in the arctic have been positioned more accurately using Landsat, which also can readily distinguish land from ice floes.

The ability to distinguish water has led to the use of Landsat imagery for wetland inventory purposes. Hydrologists and environmental agencies typically use Landsat imagery for water quality monitoring, flood forecasting and major drainage patterns. Efforts are being made to measure snow-pack depletion and water equivalent of snow-pack using Landsat data. Evidently water quality parameters would be more readily separated with higher spectral resolution than exists with current Landsat imagery. Water resources was the fifth most popular application field for Landsat (Table 2.3).

Engineering applications of Landsat data cover such broad areas as regional hydrology (for the "big picture"), river ice movement in support of dam and bridge construction, acquifer contamination, gravel deposit definition, lake management, etc. One major consulting firm contacted claimed it uses Landsat in approximately 10% of its projects, mainly in the areas of soils, bedrock and hydrology.

AES Ice Branch is one of the largest purchasers of Landsat imagery. It improves the ability to analyse the NOAA satellite wide-swath imagery received daily, and the narrow-swath data received from AES aircraft ice reconnaissance flights. It also assists in directing the aircraft to the most critical areas. In general, Landsat enhances Ice Branch's mission and helps to maintain continuity. Landsat also is used by glaciologists for measuring progression, surges and mass balance of glaciers. The growing popularity of Landsat for ice surveillance is indicated by the increase in the sales of facsimile transmission/months, from a low of 4 in 1978 to 14 in 1982 (Table 3.2).

The low end of the applications scale includes agriculture, oceans and fisheries (Table 2.3). The use of Landsat by the agricultural community has been disappointing. A major problem is the acquisition of cloud-free imagery at the right time and place for sampling and inventory purposes - the window in time is very narrow for most crops. However, a demonstration project in the maritimes will attempt to apply Landsat to soil erosion and crop monitoring in an effort to be more responsive to agricultural needs. A major agricultural potential for Landsat lies in its use in estimating foreign farm production which is needed for export marketing purposes. The U.S. Foreign Agricultural Service has made good use of Landsat data to predict poor Russian grain crops in the past few years, and revealed the efficacy of Chinese irrigation systems when a poor wheat crop was expected.* Such uses of Landsat by Canada would not be practical without the ability to command and control the satellite and receive the data promptly.

The oceans community has not been a significant user of Landsat mainly because of the problems of weather. Cloud cover and fog dominate coastal regions and obscure optical images. Also the temporal coverage is too infrequent for most oceans applications. The daily, extensive coverage provided by the NOAA satellites, while still affected by weather, is more attractive to the oceans sector. For similar reasons, fisheries have not used Landsat to any major extent, although Landsat has been used in B.C. for coastline mapping for fisheries purposes. Fisheries-related agencies think ships, not aircraft or satellites.

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* "Cost and Uses of Remote Sensing Satellites", U.S. GAO/RCED-83-11 March 4, 1983

The above paragraphs summarize the nature of Landsat usage as revealed by the survey and field visits of this evaluation. It should be emphasized that the usage described is far from complete because of the uneven nature of the application areas contacted. However, it can be seen that Landsat applications cover a wide range of disciplines, and that there are only a very few truly operational systems in place that rely on Landsat. However, with the advent of commercially-available digital image analysis systems, the applications scene is changing rapidly.

c) Degree of Satisfaction with Landsat Services

Questions 4 and 5 of the survey probed those features of using Landsat imagery found to be satisfactory and not satisfactory. The results are summarized in Appendix 2. Areas of satisfaction mentioned by key respondees were:

- extensive coverage of large areas
- scales used
- large format
- discernable water/land boundaries
- visual impact

Other positive attributes cited were ease of acquisition, multi-spectral character of the data and the ability to monitor change.

On the negative side, the principal features found not satisfactory were:

- resolution and discernable images
- scale too small
- slow product delivery
- poor quality prints/tapes/fiche
- limitation of coverage due to clouds

Other concerns expressed included the long time between samples and the need for more frequent coverage, band choice and cost. Many of those interviewed from the Atlantic region expressed consternation over the closing of the Shoe Cover Satellite Station in Newfoundland.

The concerns about Landsat expressed by those interviewed can be grouped under the following headings:

- continuity of service
- price
- quality of service
- characteristics of imagery
- archiving
- cataloguing
- emphasis on technology

Users having or planning operational systems that rely on Landsat expressed deep concern about the continuity of Landsat data should the Reagan Administration implement its intention to privatize Landsat (and the Metsats). The only real insurance against this possibility for Canada is to receive a variety of satellite data including the French SPOT, the European ERS-1 and ultimately Canada's Radarsat. Such diversity provides a hedge against the loss or inaccessibility of any particular satellite such as Landsat.

Price was given as a reason for the termination of several early applications of Landsat. Conversely, there were some users who emphasized that the cost to them of Landsat products is only a small fraction of the total cost of using Landsat. To them, price is not an issue - at least until it becomes a significant proportion of their total program costs. In general, the Landsat user community is resigned to price escalation - but one of the persons interviewed pleaded that CCRS "be very gentle and do it gradually", Significantly, only 25 respondents indicated that the high cost of imagery was a deterrent to their use of Landsat (Table 2.13).

There were some who expressed dissatisfaction with the quality of service from Prince Albert, particularly in the early years. Most users contacted remarked that service has improved immensely from PA, but complained of unpredictable delays in receiving DICS products from Ottawa (a product of increasing popularity that was never intended for rapid production throughput). There were anecdotal cases of dissatisfaction related to special user needs brought to the attention of the evaluation team, but by and large users were very pleased with the present service from PA, had delivery problems with products from CCRS, Ottawa, but generally were satisfied with the quality of Landsat products. A universal complaint from the oceans community was that, with the exception of Radarsat, CCRS appears to show little interest in oceans-related applications. Finally, a view was expressed by some that CCRS should not set itself up to provide operational service, but rather should leave that to the private sector - a point to which we shall return in a later section.

Quality of service was not an overriding problem for survey respondents. Positive comments about CCRS's service outweighed the negative in the survey (Table 2.20). Also, few people mentioned service-related reasons for their dissatisfaction with Landsat (Table 2.13).

A characteristic of the imagery most referred to in the interviews was resolution. Many users stated they would use satellite data more if higher resolutions were available. The advent of the thematic mapper in Landsat 4 and high-resolution data from SPOT will certainly expand the community of satellite users. Stereo capability was another desired feature cited by many users, particularly those in the earth sciences and mineral resources areas. Another concern, though not exclusively related to Landsat, is the quality and cost of transmitting satellite data using the common carriers. This problem was raised repeatedly by those users that rely on the <u>timely</u> arrival of such data to meet their needs.

Some of the major users of CCTs complained about the poor condition of certain tapes which have been over-used. (There were 41 such complaints voiced in the survey--Table 2.13). Also some tapes evidently have been reformatted and now cannot be used readily. According to some users, a better method of archiving Landsat data is needed. It was suggested that how archiving is done and criteria as to what data should be archived should be left to the CACRS Executive Committee. While not directly related to Landsat, there were a number of complaints about lack of archiving of NOAA data and the difficulty in obtaining specific Seasat imagery, mainly from the oceans community.

Several of those interviewed raised the question of the need for an up-to-date catalogue of Landsat products, some being unaware of the fiche program. A view was expressed that CCRS should make greater efforts to provide information on new applications and techniques for using Landsat data as well as catalogues on the data itself. Evidently CCRS is not well advertised outside the CACRS orbit. In fact, the largest group of suggestions for improving CCRS's services/facilities was received in the "better information" category (Table 2.21).

A universal observation by CCRS critics is the heavy emphasis on the development of new technology as opposed to applications development and data utilization. Survey respondents appeared to be less critical than interview respondents; at least they were less specific in their criticisms. However the small numbers indicating they had received advice on new applications (Table 2.19) would indicate to us that all is not well in this area. This concern essentially focusses on the priorities within CCRS and was voiced by representatives from the mining and geological communities, hydrology, agriculture and oceans application areas. Some suggested that CCRS was trying to "do too much with too little", while others were concerned that too much emphasis was placed on working with other countries at the expense of Canadian users and needs at home. These latter criticisms represent views held by specific individuals and were supported by only a small minority of those contacted. The question of emphasis between new technology and methodology development on the one side, and applications development on the other, did emerge from the evaluation as an important issue which will be dealt with in more depth later in Section 3.8.

In connection with the physical problems associated with the production of Landsat products, a number of those interviewed questioned whether or not it was wise to mix production and research together in the same organization. To some extent this has been addressed recently by combining both aircraft and satellite data acquisition activities of CCRS within the Data Acquisition Division. This question leads to the issue of whether or not the private sector should take on the production of Landsat and other satellite data products as a private venture - a suggestion made by some of those interviewed. This issue will be covered in Section 3.7.

3.5 Objectives Achievement

The objectives of CCRS related to the Landsat program are laid out in Section 3.2. More simply stated, the objectives of the program are:

- to provide Landsat products in timely fashion to users in the government, industry and academic sectors.
- to develop and demonstrate Canadian ground station and image processing technology.
- to develop and demonstrate practical applications of Landsat data in the managing of Canadian resource and in environmental monitoring.
- to provide analysis, information and advisory services to assist users and to increase use of Landsat data.

The evidence received through the questionnaire and interviews has led us to conclude that with the exception of DICS products from CCRS in Ottawa, the first and major objective has been achieved. The demand for DICS products which evidently has been increasing will be met in a more timely fashion when the objectives of the MOSAICS program have been achieved. Since the closure of the Shoe Cove Satellite Station in October, 1982, portions of eastern Canada and the offshore have not been covered by Landsat. Arrangements with NASA Goddard to provide such coverage have not been in place long enough to assess whether continuity or the availability of such data can be counted on in a timely fashion for Canadian users over the long term.

Canadian ground station and image processing technology has been developed and demonstrated through the facilities at Prince Albert and the now-dismantled satellite station at Shoe Cove, Newfoundland. These installations have been the forerunners of export sales by Canadian industry and have provided a showcase for Canadian remote sensing technology. Similarly, Canadian image processing technology applicable to Landsat developed in concert with CCRS also has achieved world-class recognition and export sales. (These areas will be dealt with in more detail under the Technology Transfer aspects of the evaluation).

Fully 70% of industrial respondents indicated an involvement with CCRS on the Landsat program, and significant numbers on other technologies (Table 2.15). Fifteen of them indicated Landsat sales and 14 image analysis sales as a result of that contact (Table 2.16).

While CCRS has certainly developed and demonstrated practical applications of Landsat data to a wide range of Canadian users, there are still communities of users that have not embraced Landsat technology to the extent hoped for in original plans. They include agriculture, pollution detection and monitoring, meteorology, oceans and fisheries. The same can be said for the provision of analyses, information, and advisory services where budgetary restrictions and some confusion over jurisdictional responsibility have led to uneven service to potential users.

Originally, it was expected that once data and facilities were made available, and once successful demonstrations were conducted of Landsat usage in resource management or environmental monitoring, the new technology would be adopted by the relevant user communities. By and large, it has not been this simple and while some users have been brought on stream (such as forestry geology and mineral resources), others for a variety of reasons have been reluctant to view Landsat usage with much more than skepticism, and in some quarters (oceans sector) downright cynicism.

Jurisdictionally, some agencies of the federal government, in failing to adopt Landsat in their operations, express the view that CCRS should assume the operational role, while others jealously guard their prerogatives but eschew Landsat as being irrelevant or too expensive. Likewise, some provinces either are not ready to adopt Landsat into their governmental operations, are not convinced of its merit, consider it too expensive or have taken the position that Landsat is a federal program into which they are not prepared to be pushed.

The entire question of applications development has emerged in the evaluation as a major policy issue that needs to be defined more carefully in the objectives. Relevance of the current objectives will be addressed in Section 3.8.

3.6 Duplication and Overlap

The principal activity in which there is significant duplication and overlap in the Landsat program is in the acquisition, processing and dissemination of Landsat imagery and tapes. The US EROS (Earth Resources Observation System) Data Centre at Sioux Falls, South Dakota distributes Landsat data products acquired by the US Landsat network. The network consists of three receiving stations at Goddard, Maryland; Goldstone, California and at Fairbanks, Alaska, and tape recorders in several foreign stations including Australia, Japan and India. The EROS Data Centre receives tapes from these disparate locations from which it generates imagery and CCTs for distribution to users. Landsat stations at Goddard and Alaska can cover most of Canada (including most but not all of the East coast regions not now covered by Prince Albert after the closing of the Shoe Cove Satellite Station). Thus it is possible for the U.S. Landsat network to overlap most of Canada and thereby duplicate part of what is being done at the Prince Albert Satellite Station.

The EROS Data Centre offers an alternative approach to the current Landsat receiving station in Canada, and so it was included among the field visits conducted by the evaluation team. The Centre is operated by the U.S. Geological Survey, Department of the Interior. Since October, 1982, when NOAA took over the Landsat program from NASA, EROS has been under contract to continue its role in processing, distributing and archiving Landsat data. The Centre also performs the same functions for earth resources imagery from other spacecraft (excluding Meteorological satellites) and from USGS aircraft.

EROS sells data covering countries other than the US including Canada. The team was told there are 223 Canadian-based accounts at EROS, but they do not necessarily order data. Canadian users account for 5% of world Landsat sales. Table 3.2 shows the growth in sales of Canadian imagery over the past eight years which, for example, totalled 5630 photographic scenes and 108 CCTs in 1982. The country or agency of origin of these orders would not be revealed by EROS. There are approximately 350 persons working at the Centre, 40-50 of whom are government employees. It is a chronically underutilized facility which currently is operating at about 25-30% of capacity for digital and film/paper products. There would appear to be no difficulty in taking on Canadian requirements in terms of facilities. However, the major problem in obtaining fast delivery to Canadian clients is Canada Customs which is claimed to be the cause of most delays that have been encountered.

The price of Landsat products from EROS is listed in Table 3.3 Pricing policy is based on full cost recovery (excluding the satellite) beginning with Landsat 4. As shown in the table, by 1985 a full-scene CCT for the thematic mapper will cost US$4400! Current Canadian prices, increases in which have been curtailed by the 6 and 5 program, amount to approximately 30% of current EROS prices for MSS CCTs. Other products are not directly comparable, but with the exception of 70 mm. BW imagery, Canadian prices appear to fall within the 30%-50% range of US prices.

TABLE 3.3 NOAA PRICE LIST FOR LANDSAT PRODUCTS AND SERVICES

	M S S and R B V		THEMATIC MAPPER		
Image Products	Now	Eff.1 Feb. 1985	Now	Eff.1 Oct. 1983	Eff.1 Feb. 198!
70mm film Pos(BW)	$ 26	30	-------Not Offered--------		
70mm film Neg(BW)	32	35	-------Not Offered--------		
10in film (BWpos)	30	35	$ 38	50	75
10in film (BWneg)	35	40	42	60	80
10in paper(BW)	30	35	33	50	75
20in paper(BW)	58	65	70	95	140
40in paper(BW)	95	105	115	150	200
10in film(colorPos)	74	80	105	140	190
10in paper(color)	45	50	75	115	170
20in paper(color)	90	110	135	200	235
40in paper(color)	175	195	235	275	290
Digital Products					
MSS CCT, full scene, 9 track, 1600 or 6250 BPI, 1 Tape	650	730			
RBV CCT single sub-scene, 9 tr. 1600 or 6250 BPI, 1 Tape	650	730			
RBV CCT full scene 9 track, 1600 or 6250 BPI 4 Tapes	1300	1460			
TM CCT, full scene 9 track, 6250 BPI, 4 Tapes (*,**)			2800***	3400	4400
TM CCT quarter scene 9 track, 6250 BPI, 1 Tape*			750**	925**	1350
Services					
Color Composite	195	220	290	305	325
Retrospective Orders to GSFC Archive				****	****

Special Acquisition (For these rates and services and additional information contact NOAA, NESDIS, Washington DC 20233)

* 1600 BPI tapes will be available; number of tapes to be determined
** Expected to be available in mid- or late-1983
*** TM SCROUNGE data is available on 9 track, 6250 BPI, 3 tapes or 1600 BPI, 7 tapes
****To be provided later

Other potential areas of duplication or overlap in the Landsat program could be in the digital image analysis area. Here the private sector is beginning to show a degree of independence in the R and D aimed at new products following earlier market successes. No such duplication has been specifically identified by the team. Provided R and D time horizons are sufficiently separated in terms of meeting technological objectives, there is little likelihood for significant duplication.

3.7 Alternate Methods

In conducting an evaluation using OCG guidelines, it is required to address the question of alternatives - are there better ways of achieving the desired results? For Landsat, the basic question is whether or not Canadian users could be as well served by purchasing Landsat products from the EROS Data Centre in the US instead of from Prince Albert or CCRS Ottawa. If so, the savings from closing the Landsat components of the Prince Albert station would be substantial.

The principal factors that govern such a decision would appear to be as follows:

- coverage
- equivalence of product
- timeliness
- continuity
- security of supply
- cost

The relative importance of each factor would differ from one user to the next, and so the above list is not in any order of precedence.

Coverage of Canada is not complete either from US stations or from Prince Albert (or Churchill). US Landsat stations do not cover parts of the extreme north-eastern arctic (Baffin Island, Davis Strait and parts of the NW passage) which would be lost if there were no Canadian station. The main user of Landsat data for this part of Canada is likely to be AES Ice Branch which uses the data as backup to other sources such as NOAA and AES aircraft. While more recently, Ice Branch has reduced its demand for images because of problems with Landsats 3 and 4, it relies on such imagery to improve efficiency by permitting more effective use of the aircraft. It also has improved AES's ability to analyze NOAA imagery by providing higher resolution data. Thus AES Ice Branch would be adversely impacted should Landsat receiving facilities at Prince Albert (or Churchill) be removed, resulting in a reduction in the quality of the ice charts used by arctic marine navigators.

While CCRS and EROS produce Landsat tapes and imagery, there is not complete equivalence across all the products and services provided by the two agencies. Canadian DICS products, facsimile and colour enhancements are not presently listed as EROS products or services. DICS and its 1986 successor MOSAICS are unique Canadian products. The demand for such NTS-compatible products is increasing in Canada, and provision would have to be made to continue production using EROS CCTs should Canadian Landsat receiving facilities be closed down.

Timeliness is an important factor for those users that are concerned with time-varying phenomena. Turnaround time between receipt of order and product out-the-door at EROS is claimed to be as follows:

Digital Products: 2-3 days if HDDT in-house; longer if necessary to obtain from Goddard

Black and White Products: 7 - 10 days

Colour Products: 10 - 14 days

While such times are reasonable, Canadian users have to face delays due to Canada Customs - a problem that can be partially overcome, but not without additional cost (through the use of a customs broker).

For operational users who rely on Landsat products for on-going management or monitoring, continuity is a major concern. Recent plans by the Reagan Administration to privatize Landsat has left some doubt about program continuity and the ability of some current users to pay fully commercial (unsubsidized) rates for Landsat data. Moreover, recent reliability problems have not built confidence among those operational users that are or would be totally dependent on Landsat.

Diversity in data sources is the only defence against the discontinuity of any one source. Fortunately other satellites will soon accompany the Landsat series beginning with the French SPOT satellite in 1984, and followed by the European Space Agency's ERS-1 and Canada's Radarsat. While the sensors on these satellites will differ in various ways, such a plurality of sources should help to mitigate the concerns of some operational users.

Security of supply of Landsat data, while closely related to continuity, was an issue raised by some users. Continuity refers to whether or not Landsat will continue as a program, whereas security relates to the accessibility of Landsat data from a source outside Canadian control. At any time, and for any arbitrary reason, it has been argued that the US could cut off Canadian access to Landsat data purchased from EROS through the stroke of a presidential or congressional pen. The fact is that Canada is subject to such arbitrariness at any time, whether there is a Canadian receiving station or not. The nation owning the satellite has full command and control over the operation of the satellite's transmitters. Thus data gathered by the satellite is made available to any particular earth receiving station only at the pleasure of the nation that owns the satellite. The only defence against arbitrary action is for Canada to own and thus control the satellite.

Finally, cost of data to Canadian users is an issue that might bear on any decision to close down a Canadian Landsat receiving facility and thereby rely solely on purchasing data from the EROS Data Centre. As shown in Table 3.4, NOAA prices are now higher than Canadian prices by a considerable margin, and will increase substantially after February, 1985. It is unrealistic to draw a fine comparison with Canadian prices while the present 6 and 5 guidelines apply. However, it is useful to compare current US Landsat prices with prices for the same products in other countries. Table 3.4 compares prices (in US dollars) as they stood in October, 1982. The table shows that, with the exception of Brazil and ESA, world prices (including Canada) were substantially lower than US prices suggesting greater government subsidization in these countries.

It is particularly important to examine the prices of CCTs which are experiencing increased popularity as more image analysis equipment finds its way into the hands of users.

INTERNATIONAL LANDSAT DATA PRICES
(In U.S. Dollars)
October, 1982

Product	Argentina	Australia	Brazil	Canada	ESA	India	Japan	So. Africa	Thailand	USA
1:1,000,000 Scale, B/W Film	29.00	13.00	65.00	11.00	38.00	12.00	18.00	12.00	10.00	30.00 (Pos.)
1:1,000,000 Scale, B/W Paper	18.00	12.00	41.00	9.00	32.00	12.00	17.00	12.00	2.50	30.00
1:1,000,000 Scale, Color Film	37.00	33.00	83.00	18.00	96.00	20.00	51.00	18.00	40.00	74.00
1:1,000,000 Scale, Color Paper	29.00	20.00	65.00	17.00	85.00	15.00	46.00	18.00	10.00	45.00
1:500,000 Scale, B/W Paper	34.00	23.50	85.00	21.00	51.00	20.00	N.A.	14.00	7.50	58.00
1:500,000 Scale, Color Paper	58.00	42.00	130.00	40.00	128.00	65.00	N.A.	36.00	22.50	90.00
1:250,000 Scale, B/W Paper	38.00	42.00	172.00	37.00	77.00	35.00	N.A.	24.00	15.00	95.00
1:250,000 Scale, Color Paper	66.00	94.00	N.A.	75.00	192.00	150.00	N.A.	90.00	75.00	175.00
Computer Compatible Tapes-MSS	300.00	310.00	560.00	190.00	426.00	225.00	292.00	120.00	N.A.	650.00
Computer Compatible Tapes-RBV	N.A.	N.A.	560.00	N.A.	426.00 Subscene	225.00	150.00 Subscene	N.A.	N.A.	650.00 Subscene

NOTES:
Australia: Based on full scene, priority 3. ($1 Australian=$.9392 U.S.)
Brazil: CCT's based on bulk prices.
Canada: Add handling charges to prices - $5 per order. ($1 Canadian=$0.82 U.S.)
ESA (Earthnet): Price conversion is 1AU=1.0659 U.S. dollars; color prices based on prints from Earthnet catalogue.
India: Add packing, forwarding, and shipping charges to prices - 10% of order.
Japan: Price conversion is 232.7 yen = 1.00 U.S. dollar. Prices include shipping charges - charge varies with product.
South Africa: R1=$1.2 U.S.
Thailand: Reversal products.
USA: Prices effective October 1, 1982.

TABLE 3.4

REFERENCE: EROS Data Center

The cost of CCTs in Canada is among the lowest in the table (only S. Africa is lower). Should Prince Albert continue to receive Landsat data, Canadian prices undoubtedly will rise to reflect increased station charges from the US and increased direct costs of producing the products. It is difficult to predict either how much the US will increase its station charges to Canada in future, or the degree to which the Canadian government is prepared to insulate Canadian users from significant price increases if US charges are accelerated. The price of CCTs are now substantially lower in Canada (by a factor of 3.4), which undoubtedly is contributing to their more widespread use and providing a stimulus to the fledgling Canadian image analysis equipment manufacturers.

Present NOAA charges for Landsat attempt only to recover current operating expenses and not the cost of building the satellite and ground stations. The US investment in Landsat amounts to $573 million by the end of fiscal year 1983, and $46 million in future years under current commitments. Any future attempt to recover this investment, a distinct possibility, would send Landsat prices skyrocketing.

In addressing the question of alternate methods, there is no question that if Canadian users were to depend solely on receiving Landsat products from EROS, they would be more directly susceptible to changing US pricing policies. This situation could place the Canadian resource manager in considerable jeopardy if he or she were relying on Landsat data in an operational sense.

A second alternative that needs to be considered in the evaluation relates to the question of mixing research and production in the same organization. As pointed out at the end of Section 3.4, there were some who expressed a view that the production processes of the Landsat program should be privatized, or at least moved away from the research-oriented elements of CCRS. Experience with the ISIS Ltd. approach originally established for marketing Landsat data would suggest that privatization should be approached with extreme caution.

Under circumstances where the private sector takes on all the assets and liabilities of a "business", sales volume and profit levels each must meet some threshold for the business to be viable. In such an enterprise, there would need to be a significant investment in fixed assets, and substantial overhead costs to maintain an adequate level of readiness for meeting anticipated demands for products and services. The evaluation did not develop the details needed to arrive at the threshold levels.

During the latter stages of the ISIS Ltd. tenure at Prince Albert, annual sales ranged in the $200 to $300 thousand region. Sales in 1982 amounted to $375 thousand, and it is doubtful that this level is adequate to achieve a commercially-acceptable return on investment. Thus, until sales increase substantially above present levels, the alternative of privatizing Landsat production is unlikely to be much more successful than the original ISIS venture. Moreover, if it becomes necessary for government to subsidize even further the Landsat program in the interests of Canadian operational users for the reasons outlined above, the privatized solution becomes even more questionable as to its viability and logic.

Another alternative that has arisen during the evaluation is to shift the production function of CCRS to another government agency more accustomed to the management of production functions. The Surveys and Mapping Branch immediately springs to mind, because that Branch is primarily devoted to the production and distribution of cartographic and photographic products that are similar to some of the products produced by CCRS. This option was not explored in any depth during the evaluation, but may prove to be worth studying at some time in the future because of the potential for combining like kinds of products into a well-established distributions network resulting in wider diffusion of Landsat products at potentially-lower unit cost.

3.8 Conclusions

The foregoing paragraphs on the Landsat program addressed the basic OCG program evaluation issues as laid out in Table 1.4. They also dealt with certain of the terms of reference of the evaluation as described in Section 1.1. The following conclusions are structured along the lines of the terms of reference.

a) Extent of Usage

Major use of Landsat among those responding to the survey is in geosciences, forest resources, geography, mineral resources, cartography and water resources. Only minimal use is made of such data in meteorology, oceanography and fisheries, and in pollution detection and monitoring. The advent of digital image analysis equipment is resulting in increased sales of CCTs, coupled with a long-term decline in imagery sales since the mid 1970s. It can be summarized that the earlier, more widespread use of Landsat is becoming focussed into a smaller more sophisticated user community.

b) Nature of Usage

Landsat is being used in a wide variety of applications in resource management and environmental monitoring. Its major limitations include resolution, cloud cover and frequency of coverage. These problems have restricted its usage in the agriculture and oceans-related areas. We have concluded that in cases where the above fundamental limitations do not apply, Landsat usage will expand with the increased use of digital image analysis methods.

While Landsat use continues to be dominated by research, demonstration and one-time operational applications, its spread into fully operational use may be restricted due to concern about continuity of service and security of data supply.

c) Consequences of Program Termination

The Landsat program consists of several components that are somewhat mutually-exclusive, the major portions being data collection, processing and distribution, image analysis methodology and services, and applications development activities. Termination of any one component does not necessarily mean that the others should be terminated.

Termination of Landsat data reception at Prince Albert will result in a series of consequences detailed in Section 3.7. We conclude that it would impact on the quality and cost of the AES Ice charts in critical parts of the north west passage, introduce further delays in the reception of data by current Canadian users and likely reduce the rate at which Landsat would be put to operational use in Canada.

The consequences of terminating Landsat image analysis and services are difficult to forecast because such activity would continue in anticipation of receiving data from SPOT and other future earth-viewing satellites. It would imply a major re-orientation of current activities with little likelihood of reduced costs or other savings. Conversely, it would deny Canadian Landsat users the more efficient means of extracting information from Landsat data that would result from improved methodology. We conclude that nothing is to be gained by terminating image analysis and services activities.

Applications development of Landsat data has not been a major activity of CCRS, but its termination would seriously restrict the further diffusion of the technology throughout the potential Canadian community of users. Examination of Table 1.2 shows that the Applications Technology Division receives only 15% of the CCRS dollar budget compared with 33% for the Digital Methods Division. We have concluded that there may be an imbalance in allocating resources which is addressed below under current objectives.

d) Alternatives

As discussed in detail in Section 3.7, the alternative to providing Landsat imagery from Prince Albert is to rely on receiving it from the EROS Data Centre in Sioux Falls, South Dakota. The issues surrounding this alternative include coverage, equivalence of product, timeliness, continuity, security of supply and cost. On the grounds of coverage (loss of part of the NW passage), timeliness (Canada Customs and priorities at EROS) and cost, we have concluded that Landsat data should continue to be collected, processed and disseminated in Canada. Continuity and security cannot be be made any more certain because Canada does not control the satellite.

A variation on the above alternative is to terminate the reception of Landsat data in Canada (and related NOAA user charges), and arrange to receive HDDTs from Goddard and Fairbanks. CCTs and other products could continue to be produced in Canada as before. This option still results in reduced coverage (NW passage) and leaves open the question of cost of the HDDTs to Canada. It is reasonable to expect that US charges for this type of service would differ little from the user fees already being charged for Landsat reception Thus there would be little to gain in terms of total cost to Canada.

Privatizing Landsat data collection, processing and distribution does not appear to be a starter at present levels of sales. We conclude that viable levels of revenue need to be established at which Landsat could become attractive as a business in the private sector.

e) Objectives Achievement

Section 3.5 addresses the achievement of objectives of the Landsat program as a basic OCG evaluation issue. It was concluded that in the provision of timely data to users, the objectives by and large have been achieved. Also, satellite data processing and ground station demonstration objectives have been achieved. Where there has been a shortfall is in those objectives related to applications development and technology transfer.

It is most difficult to measure the degree to which objectives related to the development and demonstration of applications and the transfer of Landsat technology have been met. The questionnaire and interviews provided as much feedback as could be hoped for in such an evaluation. The ultimate test is the extent to which users have progressed through the research and demonstration stages to where they have adopted Landsat in their day-to-day operations. The difficulty with the latter is that the degree of adoption is not entirely within the influence of CCRS. Continuity and security of data supply remains entirely within the hands of the US and outside direct Canadian control.

The results of the questionnaire and interviews have led us to conclude that Landsat data applications objectives have not been met with respect to certain of the user groups including agriculture, pollution detection and monitoring, meteorology, oceans and fisheries. We would find it difficult to disagree with the Auditor General's evaluation team recommendation that CCRS establish goals and targets for its technology transfer to the various user groups. Our conclusion is not based on the accomplishment of any such set of goals, but rather on the input received by written and verbal contact concerning the user's perception. The evaluation of Landsat technology transfer is covered in section 4.

As a corollary we should emphasize that, in our opinion, the intention behind the objective has been met with many other user groups including geology, forest resources, mineral resources, ice mapping, cartography and geography.

The methodology component of the data applications objective would appear to have been met in that the user community that has made contact with CCRS has expressed their satisfaction with the techniques available for image analysis and enhancement. Indeed, considerable resources have been devoted to this area of technology development over the years. The Centre and the supporting industry have gained substantial distinction and international recognition for their pioneering work in digital image analysis and related methodology.

f) Relevance of Current Objectives

The current objectives would appear to lay equal stress on the development of methodology to extract relevant information from remotely sensed data, and on the establishment and demonstration of practical applications for that data. In addition, the current objectives also call for the use of technology transfer to increase the use of remote sensing. Yet, as stated earlier, only 14% of the CCRS funds and 15% of CCRS person years are devoted to the Applications Technology Division where most of the applications development work takes place.

We have concluded that the objectives are too general, do not spell out specific targets or goals, and do not appear to be entirely congruent with current priorities, based on budget allocations. We would point out that some of the user groups identified as applications targets in the early days of CCRS may not be appropriate in the light of experience and more recent events. For example, meteorologists have their own series of satellites optimized for that application. Cloud cover and frequency of coverage defeat many applications in agriculture, oceans and fisheries. Resolution limits the use of Landsat in cartography, geography and other applications where fine detail is needed. Thus any new objectives drawn up for Landsat should recognize these limitations and be more specific as to application targets and levels of expected achievement.

g) Landsat 4

The terms of reference required that the evaluation team acknowledge the potential increase in usage that is expected to result from increased sensor resolution offered by Landsat 4. Launched July 16, 1982, Landsat 4's MSS has been operating ever since (with minor shutdown periods). Its thematic mapper (TM), which provides 30-metre resolution, was activated on July 20, 1982 and stopped transmitting on February 15, 1983 due to an electronic failure. During the 210 days of operation, very impressive imagery had been obtained. In future, transmissions will be possible only via the Tracking and Data Relay Satellite (TDRS-A) which transmits to a receiving station in White Sands, N.M., thence via communication satellite to Goddard and then, as required, on to EROS Data Centre, Sioux Falls, N.D. by mail or courier for processing into CCTs or imagery for transmission to customers.

From the samples of thematic mapper (TM) imagery distributed to users, there is no question that wider use will be made of Landsat in future. Virtually all users that have worked with TM data acclaim it to open up new avenues of application heretofor impossible. However, the Landsat 4 TM is not a panacea for all applications, and there are subtle features of the imagery not readily explained or even understood. (For example, the writer was shown TM imagery of the Medicine Hat area where none of the cultural features were discernable due to the particular reflectance of the prairie soil at that time of year.)

CCRS has a major hardware and software development program underway to create a Landsat D Image Analysis System, which will be ready in approximately 5 years. Meanwhile the image analysis industry is aiming for a shorter time horizon. Both developments should be complementary and appropriate to their respective timeframes, but the future of Landsat 4 is still in question. TDRS (A) did not achieve its required geostationary orbit due to a failure of the Inertial Upper Stage launched by the Shuttle. An attempt is currently underway to achieve the appropriate orbit for TDRS(A) using on-board fuel. The success or failure of this attempt will be known by the early summer of 1983.

The problems of Landsat 4 coupled with the attempts to privatize the entire Landsat program create a large degree of uncertainty about the future. If the program continues, Landsat usage should be expanded because of the higher resolution; if it does not continue, Canada will have to rely on SPOT data which is expected to have even higher resolution than Landsat 4 and be available in 1984.

4. TECHNOLOGY TRANSFER

4.1 Program

For most of the period of CCRS's operation there has been no formally constituted technology transfer program. Beginning in the 1983-84 fiscal year Treasury Board approval was received for a federal-provincial technology transfer program. The program is budgeted at $500,000 and 4 person-years. Under this new program CCRS has signed agreements with the Province of Manitoba and with the Atlantic Provinces collectively through the Council of Maritime Premiers and the Maritime Resource Management Service (MRMS).

Notwithstanding the absence of a formal technology transfer program within CCRS, substantial parts of CCRS's resources and activities have been devoted to technology transfer to industry and to end users of remote sensing.

Taking the 1981-82 fiscal year as an example, we see that CCRS devoted approximately 7% of its resources to technology transfer activities (Table 1.3). Technology transfer can refer to many of an organization's activities. In CCRS's case these may include:

1. Awarding of contracts to develop CCRS technology
2. Contracts to develop company technology
3. CCRS help with fundamental research, prototypes, design, specifications, computing, marketing, testing, problem solving, etc.
4. Attendance at CCRS training courses, seminars, symposia or meetings.
5. Staff exchanges
6. CCRS publications

7. Access to licenses or patents owned by CCRS
8. Advice on new applications for remote sensing
9. Use of CCRS facilities
10. Use of CCRS services (e.g. testing, calibration)
11. Purchase by CCRS of non-standard products (resulting in a new market for those products)
12. Sales of standard imagery or data products

It should be recognized that many of the potential routes for technology transfer are informal and therefore not easily quantifiable. Moreover, many technology transfer activities are attributed to "overheads" (e.g. publications) and are not recorded as technology transfer expenditures, per se.

In some respects, it could be argued that a very large part of CCRS's raison d'être is technology transfer. That is certainly implied in the remote sensing activity objective:

> "to improve remote sensing technology and to facilitate the dissemination of remotely sensed data and derived information needed for the management of Canadian natural resources and for the monitoring of human activity".

There is an equal emphasis here on technology development and the diffusion of the products of that technology (data and information).

The Canadian Advisory Committee on Remote Sensing (CACRS), with its associated working groups, is sponsored by CCRS. CACRS has a dual role, to advise CCRS on user requirements and to assist in diffusing CCRS's technology to the Canadian user community. As such, CACRS may be viewed as another aspect of CCRS's technology transfer program.

The formal technology transfer program which is in place in 1983-84 allows for such activities as the loan of equipment (in the case of Manitoba) and the financing of the salaries of technical experts at the local remote sensing centres (Manitoba and the Atlantic Provinces--Fredericton and Lawrencetown). In addition, CCRS will make available internal staff and equipment resources in support of the demonstration programs which are the focus of the technology transfer agreements.

The terms of reference of this evaluation call for examinations of technology transfer to Canadian industry and to end users of remote sensing. With regard to technology transfer to industry, the evaluation examines the following points:

1. the extent of technology transfer, as part of the R&D process (generally) and in the form of completed technologies (specifically).
2. achievements of the technology transfer process.
3. impact of the achievements.
4. problems of technology transfer.
5. suggestions for improvement.

With respect to end users, the evaluation examines the extent of transfer as a function of the use of CCRS expertise and facilities.

Five specific technologies are under investigation:

1. Landsat

The Landsat program evaluation in Section 3 dealt with the acquisition, processing and dissemination of Landsat data, the current usage of the data and the potential increase in usage resulting from the special attributes of Landsat 4. The technology transfer component of the evaluation of Landsat deals with the extent to which Landsat technology has been transferred to Canadian industry and end users. The Prince Albert Satellite Station is presently being operated under contract by SED Systems Ltd. of Saskatoon. Before it was shut down, the Shoe Cove Satellite Station was operated under contract by NORDCO Ltd. of St. John's, Nfld.

Landsat data has been adopted by a cadre of end users including provincial governments, federal departments, industry and others. The extent to which the technology has been transferred to these users is also to be evaluated.

2. <u>SAR Development</u>

Synthetic aperture (SAR) development at CCRS includes satellite and aircraft SAR. Current satellite SAR programs relate to the post Phase A work being conducted on Radarsat, the principal contractors being Spar Aerospace Ltd. for the space segment, and MacDonald Dettwiler Ltd. for the ground station. This constitutes a technology transfer activity. Past programs in satellite SAR containing a technology transfer component include the Sursat program and the European Space Agency's Preparatory Remote Sensing Satellite Program, leading to the ERS-1 satellite.

Aircraft SAR includes the SAR 580 program involving the installation of a modified X- and L-band SAR developed by the Environmental Research Institute of Michigan (ERIM) in the CCRS Convair 580, which supported the Sursat Program. Currently, aircraft SAR work is focussing on a C-band SAR for installation in the Convair 580, being developed by MDA (data processor) and Canadian Astronautics Ltd. (front end), to support work on Radarsat.

3. Laser R and D

Laser R and D at CCRS has focussed in the past on two applications:

- oil spill monitoring using a laser fluorosensor
- aerial hydrography using laser bathymetry.

Oil spill monitoring involved the development of a pulsed laser fluorosensor which measures the fluorescent response of a laser-illuminated target. The original Canadian pulsed laser fluorosensor was developed by the University of Toronto Institute for Aerospace Studies, the second generation system by Barringer Research Ltd.

Aerial hydrography makes use of a laser bathymeter to provide spot depths in support of a photogrammetric system for hydrographic surveying. A more recent development for hydrographic surveying consists of a scanning laser bathymetre. to provide continuous bathymetric data. Both laser projects were conducted by Optech Inc.

4. Image Analysis R and D

Image analysis R and D resulted in the CCRS Image Analysis System (CIAS) for applications requiring analysis of multi-temporal image sets and the Modular Interactive Classification Analyser (MICA) which, along with the scanning micro-densitometer, are used for digital image analysis of user tapes at CCRS. Currently, efforts are being directed toward the Landsat D Image Analysis System (LDIAS) to be operational in the latter half of the decade for the analysis of Landsat 4 and SPOT data. Three Canadian companies - Dipix, MDA and OVAAC-8 - have benefited from CCRS involvement in image analysis R and D and in user community stimulation.

5. Solid State Scanner Development

An airborne scanner, using a linear CCD array, and known as MEIS (Multi-Band Electro-Optical Imaging Sensor), operating in push-broom fashion has been developed by MacDonald Dettwiler and Associates (MDA) for CCRS. Originally the subject of an unsolicited proposal by MDA, an operational scanner has been developed under contract to CCRS and is now being tested.

MEIS can be used to simulate imagery in the appropriate wavelength bands of the Landsat 4 TM and the SPOT scanners. As an airborne MSS, it can be used in the same application areas as conventional scanners, but with superior imagery, and is readily amenable to digital format. Therefore, it is expected that its range and depth of usage will expand.

4.2 Objectives

As with the Landsat program, CCRS's technology transfer objectives must be taken from the activity, sub-, and sub-sub activity objectives of the organization. (This is because there has been, until recently, no separately budgeted technology transfer unit/activity within CCRS).

From the remote sensing activity objective, we have abstracted the following technology transfer objective:

> "...to facilitate the acquisition and dissemination of remotely sensed data and derived information..."

From the data applications sub-objective

> "to establish and demonstrate practical applications..."

From the airborne program sub-objective

> "to establish and demonstrate improved airborne remote sensing technologies..."

From the applications services and technology transfer sub-objective

> "to provide analysis facilities as well as information and advisory services to assist users," and

> "...to increase the use of remote sensing data through technology transfer to resource management agencies", and

> "to integrate remote sensing technologies into provincial and territorial environmental and resource management information systems".

From the satellite R&D sub-sub objective

> "to establish Canadian technological competence in radar remote sensing by 1984".

From the laser sensor R&D sub-sub objective

> "To develop techniques using laser sensors for charting shallow coastal areas and monitoring marine pollution to ensure that full industrial capability is available by 1986".

From the microwave (radar) sensor R&D sub-sub objective

> "To undertake R&D in the design and testing of new systems for receiving and processing radar/microwave reflections".

From the visible and infrared sensor R&D sub-sub objective

> "R&D to develop improved sensors for recording data with the use of visible and infrared wavelengths".

4.3 Outputs

Technology transfer outputs are essentially the extent to which technology has been transferred to the recipient industrial enterprises or end user agencies. As such, the outputs are intangible insofar as there is no ready way of quantifying a level or degree of technology transfer. Moreover, attributing contribution to a successful technology transfer among a plurality of contributing components often can be invidious and extremely subjective. All the facts are seldom available or accurately recallable in reconstructing the history of an industrial success.

In the evaluation of CCRS technology transfer activities, it must be recognized that CCRS is never the sole transfer agent, that success will always depend on the calibre of the engineer and businessman in the transferee's facility, and that these individuals will be the largest contributors to any success achieved. Thus technology transfer outputs should be thought of as only one component in the ingredients contributing to the success of a technology implanted in an operation external to CCRS, be it a private company or another government department or agency. It could be misleading or even dangerous to credit CCRS with all the successes associated with CCRS technology transfer outputs.

4.4 Impacts and Effects

The following paragraphs address the first three terms of reference of the technology transfer evaluation: viz. the extent of transfer to industry or end users, specific achievements and technologies transferred, and the impact of such achievements.

4.4.1 Landsat

The extent of transfer of Landsat technology to end users has been covered in Section 3.4 (a and b). The ultimate objective is reached when an end user adopts Landsat data in an operational role, and it was revealed through the questionnaire and interviews that while many user groups are employing the technology in their operations, there are other target users that have not adopted Landsat. It was concluded that for some users, Landsat may not be appropriate, and that objectives should be recast to reflect these types of realities.

The questionnaire showed (through Q.8) that the Landsat multi-spectral scanner was by far the most popular of all earth-viewing satellite sensors among respondents, and that the use of photographic products by this group still outweighs computer tapes by a large margin. Computer compatible tapes comprised only 14% of the usage of satellite data products in Question 9. The digital technology being developed by CCRS thus has not penetrated the full user community to a significant extent yet. This observation is further confirmed by the response to Question 15 where only 11% of the methods used for image analysis involve digital analysis computer systems.

The impact of the use of Landsat technology on end users was also dealt with in Section 3.4 Virtually all of the cases cited were the result of some level of technology transfer effort on the part of CCRS. However, a major factor in the transfer of Landsat technology to end users has been the activities at the provincial level. In its early days, CCRS devoted considerable effort to encouraging provincial governments to establish their own remote sensing centres, or at least to join in forming regional centres. By the mid-1970s this effort was curtailed. The earlier work had met with varying success, as measured by the survival of provincial centres.

Today there are strong, multi-disciplinary remote sensing activities at the provincial level in Alberta, Manitoba, and Quebec. In British Columbia most of the on-going activity is in forestry, and in Manitoba the efforts are being focussed through a technology transfer memorandum of understanding between CCRS and the Manitoba Centre for Remote Sensing (MCRS). A similar agreement has been arranged with the Council of Maritime Premiers covering the provinces of New Brunswick, Nova Scotia and Prince Edward Island, to be implemented by the Maritime Resource Management Service, Amherst, Nova Scotia.

Provincial activities in remote sensing are planned and promoted by the Interprovincial/Territorial Advisory Subcommittee to CACRS--called IPTASC. Reporting to CACRS, IPTASC makes a major contribution to the planning and promotion of technology transfer and applications development with end users outside of the federal government. Provincial and regional centres were originally conceived as providing the basic coupling mechanism between the technology developed by and for CCRS, and the end users.

The Ontario Centre for Remote Sensing (OCRS) has been very active in applying Landsat technology to resource management and environmental monitoring problems in the province. The Director stated categorically that "OCRS could not exist without the Landsat program", and indeed is concerned about Landsat's continuity. OCRS has developed its own image analysis procedures using products from PASS, and claims now to be self-sufficient insofar as technology transfer activities are concerned.

While Ontario appears to be the most active in terms of applications R and D, Alberta's Remote Sensing Centre has focussed more on training and use of facilities, and does not perform research or interpretational services. There is no physical centre in Quebec; however, there is a very active society and a provincial coordinator within the Quebec government. Quebec interviews revealed a very active remote sensing community, and some of the most useful inputs for the evaluation of transfer to end users came from Quebec.

As the provincial and regional initiatives gain in strength, there should be less need for CCRS to devote resources to the transfer of technology (including Landsat technology) to end users. However, at present the governments of Saskatchewan and Newfoundland do not appear to have been impacted to any significant extent by remote sensing activities, and CCRS is still some distance off from achieving the penetration intended at the provincial level except for Ontario, Quebec and possibly Alberta.

The constitution of the CACRS working groups gives some indication of the way remote sensing technology has had an impact across Canada. Table 4.1 lists the working groups and the provinces/territories of origin. The 16 working groups divide into two major categories: 12 users, 3 technologies plus one in education. Membership in the user working groups is dominated by Ontario, Alberta and B.C. which jointly make up two-thirds of the user groups; adding Quebec brings the total up to three-quarters. It is worth noting that, aside from the territories, lowest representation in CACRS is from PEI and Manitoba. Saskatchewan, Newfoundland and New Brunswick each share 4% of the representation.

Whereas the questionnaire indicated that Landsat was the most popular of the technologies to be evaluated among recipients (Q.19), Question 20 showed that Landsat also generated the most domestic sales, but no foreign sales. In actual fact, it is known that at least two firms have made extensive foreign sales--MDA and Dipix. MDA's sales have involved Landsat earth receiving stations, Dipix's have been

TABLE 4.1

CACRS WORKING GROUP REPRESENTATION

(Source: CCRS letter to CACRS Working Group Chairmen, June 14, 1983; Appendix A)

Working Group	No. in Group	Province/Territory of Origin												
User Groups		YT	NWT	BC	Alta	Sask	Man	Ont	Que	NB	NS	PEI	Nfld	USA
Agriculture	20	-	-	1	3	3	3	7	1	1	-	1	-	-
Cartography & Photogrammetry	8	-	-	-	1	-	-	5	1	1	-	-	-	-
Engineering Applications	8	-	-	1	-	1	1	4	-	-	-	-	1	-
Forestry	15	1	-	3	2	-	-	5	2	1	1	-	-	-
Geography	6	-	-	-	2	-	-	3	1	-	-	-	-	-
Geoscience	11	-	1	-	1	1	-	6	1	-	1	-	-	-
Non-Renewable Resources	17	-	-	1	2	-	-	8	3	1	2	-	-	-
Ice	16	-	-	1	4	-	-	7	-	-	-	-	3	1
Oceanography	13	-	-	2	1	-	-	7	-	-	2	-	-	1
Oceans/Radarsat	21	-	-	5	3	-	-	7	-	1	4	-	1	-
Renewable Resources	14	-	-	-	-	1	-	9	2	-	1	-	1	-
Water Resources	16	-	1	2	1	1	1	7	2	1	-	-	-	-
Total	165	1	2	16	20	7	5	75	13	6	11	1	6	2
%		0.5	1	10	12	4	3	45	8	4	7	0.5	4	1
Technology														
Data Handling	13	-	-	1	1	-	-	8	2	-	-	-	1	-
Image Analysis	12	-	-	2	1	-	-	8	1	-	-	-	-	-
CCT	11	-	-	1	2	-	-	6	1	1	-	-	-	-
	36	-	-	4	4	-	-	22	4	1	-	-	1	-
General														
Education	2	-	-	-	-	-	-	2	-	-	-	-	-	-
Grand Totals	203	1	2	20	24	7	5	99	17	7	11	1	7	2
%		0.5	1	10	12	3	2	49	8	3	5	0.5	3	1

of image analysis equipment which will be covered in Section 4.4.4.

Perhaps the largest success story of all Canadian remote sensing companies is MacDonald Dettwiler and Associates Ltd. of Richmond, B.C. MDA, now a $20 million per year company, owes its presence in the remote sensing field, its largest and most profitable activity, to CCRS. MDA's first two remote sensing contracts were with the Communications Research Centre (CRC) in the conversion of the Prince Albert Satellite Station to receive the then-named ERTS-1 (now Landsat). MDA built the demultiplexer and quick-look systems and had contracts with CCRS to design and build parts of the image analysis system at Sheffield Rd., based on the PDP-10 computer.

The major breakthrough for MDA, however, was in designing and building the PERGS system (Portable Earth Resources Ground Station) through an unsolicited proposal with CCRS as sponsor. This system became the core station at Shoe Cove and paved the way to significant export sales. Today there are six "turnkey" Landsat ground station systems built by MDA in other countries. They are Australia, Thailand, South Africa, Indonesia, Sweden and the USA (U. of Alaska). The company also has acted as a sub-contractor for Landsat stations in eight other countries. No other single company anywhere has fully installed more than one station. Current cost of a turnkey station is in the order of $8-10 million. CCRS supports such sales in third-world countries by providing training--a task that could not be performed by industry in a commercially-viable fashion.

The basic philosophy adopted by MDA, and indeed by other companies in advanced technology areas, is to seek government funding to complete the R and D on the prototype, and then to exploit the technology so created on the export (and occasionally domestic) market. For Landsat, it was the support for the PERGS station. More recently, the geometric correction system, known as MOSAICS (Multi-Observational SAtellite Image Correction System)--to provide users with geocoded data for Landsat 4 and SPOT--is being developed by MDA and funded by government. It will form the basis for future export sales of Landsat-related products.

The Prince Albert Satellite Station (PASS) is being operated entirely by SED Systems Ltd. of Saskatoon. SED Systems was involved contractually in the original PASS upgrading and subsequently operated the station. After the demise of ISIS Ltd. in 1980, SED Systems took over operation of the entire station including data processing, archiving, image production and order processing. While SED has not elsewhere exploited the particular skills and experience gained in operating PASS, it has found it valuable to continue with the contract because of the exposure to the marketplace, and the application of the technology acquired to its other business activities.

Similarly, NORDCO Ltd. of St. John's, Nfld., a company owned in part by the Newfoundland government, operated the Shoe Cove Satellite Station before its closure in 1982.
Again, NORDCO has not made specific use of its experience at Shoe Cove. However, the company does operate a weather forecasting service for the offshore industries. It makes use of NOAA, TIROS and GOES imagery, but not Landsat because of its limited use in cloud-cover and fog conditions (the other satellite imagery is used for determining ice edges when clear, and for discriminating between cloud cover and fog). As in the SED Systems case, the experience gained from operating Shoe Cove probably has been of value in other aspects of NORDCO's business. Since Landsat has not been adopted to any significant extent by the oceans community, there is no reason

to expect that the related technology should be exploited by the oceans-related industries.

4.4.2 SAR Development

The impact and effects of synthetic aperture radar (SAR) technology transfer result from SAR research and development work sponsored by CCRS for satellite and aircraft platforms. The value of satellite SAR was demonstrated by the U.S. Seasat program--a satellite that carried, among 4 other oceans-related sensors, a synthetic aperture radar operated at L-band. Penetrating darkness, fog and cloud cover, Seasat showed the value of SAR for ice reconnaissance in the arctic. The need for such a sensor to support year-round shipping of hydrocarbons from the arctic led to the Radarsat project, which is now through its preliminary design phase and awaiting approval in 1984 to proceed with detailed design and development.

A Canadian project known as Sursat revealed that satellite SAR had potential applications beyond ice reconnaissance, including oceanography, renewable and non-renewable resource exploitation. Thus satellite SAR in general, and Radarsat in particular, should have a future impact on a wide range of users, if the promise of SAR holds true.

Up to the present, the impact of satellite SAR development has focussed on two major Canadian companies--Spar Aerospace and MacDonald, Dettwiler and Associates. Essentially a

SAR consists of a "front end" including the antenna and RF circuitry, followed by a signal processor which contains computer and data handling sub-systems, and a very large, complex software system. Spar is gaining experience in the design of the front end through its Radarsat contract and is developing the systems engineering capability needed to integrate SAR into the satellite. It is far too soon to expect any impact or effect from this early work on satellite SAR at Spar.

On the other hand, MDA's SAR experience pre-dates Spar's by several years. In recognizing the intrinsic value of radar for the Canadian environment (i.e. its weather and darkness penetrating capability), CCRS encouraged MDA to submit an unsolicited proposal to develop a SAR processor for Seasat. The MDA processor operated entirely electronically, in contrast with the then U.S. approach using an optical technique. The development was entirely successful and according to MDA would have led to significant commercial sales had Seasat and its planned successors survived. Based on this design, MDA built the SAR processor that was installed at Shoe Cove, Nfld. A malfunction of the satellite permitted only 100 days of imagery during the year 1978, and the next satellite SAR to be launched is the European Space Agency's (ESA) ERS-1 in the mid-1980s.

Logically, ESA was the next target, and MDA built a $1.5 million prototype SAR processor for ESA's Preparatory Remote Sensing Satellite Program (PERSSP) similar to the Seasat processor. MDA has conducted design studies for the ground segment of ERS-1. Also, the company is expanding its space processor to accommodate aircraft operation for the German space agency DFVLR. MDA subcontracted from Canadian Astronautics Ltd. (CAL) the preliminary design studies for Radarsat ground stations, and is presently doing preparatory work for the Radarsat SAR processor.

Thus while satellite SAR development is in its early phases in Canada, the Canadian capability has achieved world recognition and is well poised to capitalize on future programs. Technology transfer through the awarding of contracts to Canadian industry, and by providing mature advice and guidance in the development of the technology in Canada has won CCRS a strong vote of confidence from the companies contacted.

Airborne SAR development has followed a somewhat different track.* In June, 1977, the Canadian government approved the Canadian Surveillance Satellite Program (Sursat) which involved participation in the NASA Seasat-A proof of concept satellite experiment. Part of this participation included the acquisition of complementary surface data and supplementary data from areas not covered by the satellite. Among the data sources employed was the modified X- and L-band SAR leased and subsequentially purchased from the Environmental Research Institute of Michigan (ERIM) and installed in the CCRS Convair 580 aircraft.

The SAR 580 showed the many advantages (and disadvantages) of airborne SAR, in addition to its support of Seasat. In particular, along with other private sector initiatives, it showed the advantages for airborne ice tactical reconnaissance -

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*It is important to distinguish SAR - synthetic aperture radar - from SLAR side-looking airborne radar. SLAR is an older technology already exploited by the private sector in Canada (e.g. F.G. Bercha and Assoc.) SLAR has inherently lower resolution than SAR, but the relative merits of SLAR and SAR are arguable in many applications.

particularly in the Beaufort Sea where pack ice threatens drilling operations during the entire drilling season. SAR is not as effective in detecting iceberg hazards off the east coast because of the radar reflective qualities of icebergs, and the frequently-encountered heavy seas.

Private sector interests have seized upon the commercial opportunities provided by the extensive Beaufort Sea drilling conducted by Dome Petroleum's subsidiary Canmar Marine Ltd. A surveillance X-band SAR is being developed by MDA (the processor), and ERIM (the front end), for Intera Environmental Consultants Ltd. which has offered Dome a 3-year service contract for tactical ice reconnaissance, starting in the fall of 1983. This program is strictly a private sector initiative, and no government money is directly involved.

In support of the Radarsat and ERS-1 programs which will employ a C-band SAR, CCRS has contracted with CAL for the front end, and MDA for the processor. This airborne SAR system is scheduled for delivery during the first quarter of 1984.

Thus, airborne SAR technology is being exploited commercially in Canada as a result of CCRS initiatives. The impact is being felt in the private sector as companies can see profits both from providing the equipment and from selling services using such equipment. There has been little if any export activity, but Intera sees the export market eclipsing the domestic very shortly.

4.4.3 Laser R and D

Laser R and D at CCRS has developed along two main lines of application - laser fluorosensing for oilspill and pollution monitoring, and laser bathymetry in support of aerial hydrographic surveying. The history of Canadian laser fluorosensing goes back to a contract between CCRS and the University of Toronto Institute for Aerospace Studies (UTIAS) in 1970-71 (sponsored by the Sensor Working Group of CACRS). The purpose was to exploit the fluorescence properties of oil and other pollutants when illuminated by light of an appropriate wavelength. A detector boresighted with the laser and sensitive to light of the correct wavelength senses the characteristics of the fluorescence which then provides data on the presence of oil or pollutant (such as dye spills, pulp mill effluent and chlorophyll) wherever the laser is pointing. The UTIAS sensor was brought to CCRS in 1974-75 and adapted for installation as one of a number of sensors available on CCRS aircraft.

The fluorosensor was intended for use by such agencies as the Atlantic Geoscience Centre for detecting offshore oil seeps, the Environmental Protection Service for such programs as AMOP (Arctic Marine Oilspill Program) and DOT for the control of vessel source pollution. The hopes for such applications appears never to have reached fruition for a number of reasons. The principal problem seems to have been one of cost - not for the fluorosensor alone, but for the entire system of other complementary sensors and data processing equipment needed to perform the specific missions assigned to these agencies. The fluorosensor remained quiescent for a number of years.

In 1975-76, Barringer Research Ltd. took on the task of developing the fluorosensor for commercial exploitation. Funded through an unsolicited proposal by CCRS and DSS, the program ran into some of the usual development pitfalls, but resulted in an instrument that could be used operationally.*

* The Barringer fluorosensor employs a nitrogen laser manufactured in Germany by Lambda Physik. Thus the technology has focussed on using the laser as part of a system, and not on the laser itself.

None of the originally-intended impacts of the fuourosensor has been achieved; however, Barringer in its role as an exploration company has recently borrowed the instrument for use in oil exploration. Supporting exploration in California and in Europe, the fluorosensor may have found its niche in a market area never expected in the beginning.

In aerial hydrography, a laser is used like radar to measure water depth. The laser beam is pointed at the surface, and the time delay for light reflected from the surface and from the bottom is used to infer depth. Lasers with a reflected beam detector and time delay measurement capacity are called "Lidars", and their use in measuring water depths is termed "laser bathymetry". Their use is limited to waters and depths that will produce an adequate bottom return to be detectable at the lidar. The best light wavelength for most water conditions is in the visual green band.

Aerial hydrography provides a technique for shallow water hydrographic surveying that promises to be faster and cheaper than conventional surveying using a sounder mounted in a launch. Originally aerial hydrography consisted of coupling photogrammetry with inertial navigation to establish the precise location of each stereo model. A technique developed by Dr. S. Masry of the University of New Brunswick provided the corrections necessary to infer water depth from stereo photographs of the bottom using an analytical plotter. The technique obviously is valid only down to those depths that are visible on the aerial photograph.

The integration of lidar and photo hydrography was expected to yield a more accurate system than photo hydrography alone. In the integrated system, the lidar provides spot depths along the track of the aircraft which can be used to improve the accuracy of depths measured photogrammetrically.

The lidar bathymeter used in the integrated system was developed by Optech Ltd. Known as the Mk. 2 lidar bathymeter, it was tested separately on the west coast, and then integrated with the photo hydrography system for tests at Gananoque where, in those turbid waters, it achieved readings to depths of 4.4 metres. Further tests of the bathymeter were conducted in the Magdalen Islands and of the integrated system at the Bruce peninsula in Ontario. While the integrated system showed test results in the St. Lawrence that could meet the requirements of the Canadian Hydrographic Service (CHS) and the international community, the results in Lake Huron were less consistent. The technique has not yet been adopted operationally by the CHS.

The current direction of development is to employ a scanning lidar that operates much along the lines of the Landsat MSS. A scanning laser bathymeter provides total coverage and thus eliminates the need for photogrammetry. Optech has initiated the development of a scanning lidar through an unsolicited proposal to DSS funded for the current year at $0.6 million from DSS and $0.35 million from the CHS. Known as the Larsen 500, the system consists of a pulsed lidar and a conically-scanning prism which causes the beam to strike the water at an optimum angle that simplifies the air/water correction algorithms. This design was supported by CCRS and Moniteq Ltd., through an unsolicited proposal. The CHS commitment to the Larsen 500 is for $0.45 million and one person-year each year for the subsequent 4 years. The scanner is scheduled for test in November, 1984.

While there has been no direct sale of the Mk. 2 bathymeter as a hydrographic instrument, there were two projects with the Swedish military which might result in the sale of a scanner. Of equal interest, however, is the use of the Mk. 2 bathymeter as a laser terrain profiler. Dendron Resource Surveys Ltd. is using a Mk. 2 as a profiler. Another spinoff from the Mk. 2 is the development by Optech of a high altitude ice profiler for the AES Ice Branch. CHS funded the feasibility study and CCRS picked up the cost of the development program totalling approximately $0.5 million. The same expertise is presently being exploited for a high-altitude (30,000 ft.) terrain profiler for use in aerial photogrammetry.

Thus while the originally-intended use of the lidar bathymeter has not reached fruition, the same technology has been exploited for other important uses. Also, the original bathymeter design was the necessary stepping stone to the scanning bathymeter which seems to portray all the earmarks of success, judging by the commitment of CHS resources to the project.

It should also be mentioned that the inertial navigation technology for position-fixing in the photo hydrography system involved the use of Kalman filter methods. This technology has been applied by Huntec (1970) Ltd. (formerly Huntec-Lapp Systems Ltd.) in motion compensation systems for airborne radars and underwater deep-tow sonars, and for advanced towfish track recovery systems.

4.4.4 Image Analysis R and D

Image analysis R and D at CCRS has been conducted mainly in-house. Thus the technology transfer impact and effects have been felt indirectly by those who have used the resulting services provided by the outputs of the R and D. The image analysis supply industry has benefited mainly from direct supporting contracts and from the general stimulation of the user community as a result of CCRS activities in image analysis. Turning first to those that have used the image analysis facilities at CCRS, both the questionnaire and the interviews addressed the question of satisfaction.

In Question 24, there were 144 respondents that used CCRS image analysis services. By far the majority, 72%, were "very satisfied". However, 15% were either "dissatisfied" or "very dissatisfied". The interviews caught a few of these unhappy users.

The general complaint was that users of the CCRS Image Analysis System (CIAS), in spite of the presence of an operator supplied by CCRS, did not have access to all the information on the potential of the programs available in the system. It was claimed there is no User Manual for CIAS, so that the system cannot be fully exploited by an external user. One user stated "the CIAS is hand-made and has no brothers or sisters". Despite these complaints, others were very satisfied with the service they received and the results obtained using CIAS. Another dissident view was that most of the methodologies related to the study of vegetation, while the earth sciences were generally under-represented, both in terms of the positions allocated at CCRS and the methodologies developed.

A further concern from the province of Quebec was expressed as follows:

> "Au niveau du transfert de technologie, les exemples de réussite sont encoure rares, et l'usager externe a l'impression que les chercheurs du centre constituent une tour d'ivoire, pour laquelle la collaboration avec les usagers n'est qu'une fonction secondaire. Ceci se remarque par exemple au niveau des horaires d'utilisation de CIAS, qui n'est accessible aux usagers externes qu'en dehors des heures normales. Cet état de fait n'est pas

> attribuable aux chercheurs eux mêmes, mais plutôt à une ambiguité dans la définition du rôle de recherche au Centre, ainsi qu'à des critères de promotion pour les chercheurs qui semblent basés uniquement sur leur production interne".

Basically, the issue is that CCRS has not adequately separated the research function from the production and service operations in the opinion of some respondents. They claim that each serves the other (for internal CCRS projects) which leads to a lack of consistency in the quality and timeliness of the product and/or service to external users.

These users expressed similar concerns with respect to the current methodology thrust - LDIAS (Landsat D Image Analysis System). They noted a tendency for CCRS to develop "monstres technologiques", and expressed the hope that the same will not be true for LDIAS.

Whether or not CCRS has been responsible for any technological monsters, there have been an expanding amount of image analysis equipment sales thanks to the use of CCRS equipment and products. There are three major image analysis equipment manufacturers, each of which acknowledge strong CCRS support, and stated they would not be in the business were it not for CCRS. They do not feel their success has been due to any direct transfer of technology from CCRS as such. CCRS uses the industry to build parts of its systems, but no one company seems to have had major benefits from such contracting.

The problem for CCRS is compounded by the fact that there are three companies in the business - Dipix, MDA and OVAAC-8, and CCRS is not prepared to favour any one at the expense of the others. Dipix appear to have been the most successful of the three in terms of sale of image analysis systems. To date, 45 Dipix systems have been sold, 14 of them in Canada, 31 abroad*. They claim a capture of 20-30% of the world market. Present annual revenues are in the $5 million bracket.

MDA have not sold stand-alone image analysis systems so far, but include this capability in their earth stations. The core software for the MDA image analysis system for Landsat was bought from TRW Inc. to whom they pay a royalty for every system sold. OVAAC-8 Ltd., also in the image analysis field, is the smallest of the three and has faced a difficult struggle over the past 10 years. CCRS was instrumental in the design of their basic product, and has purchased software from them. The company has found its feet over the past 2 years and has developed an enhanced version of the DICS capable of handling satellite data other than Landsat. Over the past 12 months, OVAAC-8 has sold 5 image analysis systems, 4 in Canada - mainly, it would appear, to the oceans community.

The supplier industry argues vehemently that the most effective technology transfer has occurred when there was a direct transfer of personnel. Indeed CCRS personnel have moved to industry, but not necessarily in a planned fashion. When a competent scientist or engineer is captured by industry, there has been an unplanned positive impact on the technology transfer objective of CCRS.

By and large, the supplier industries were very satisfied with their relationships to CCRS, and it is worth quoting verbatim the words of the Chairman of MDA:

> "CCRS is the best agency MDA works with in the federal government with respect to its overall ability to work effectively with industry".

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* Dipix has sold systems to Indonesia, Argentina, Peru, USA, Sweden, Norway, Holland, Italy, Germany, Thailand, China, Australia and the U.K.

4.4.5 Solid State Scanner Development

The Multi-Band Electro-Optical Imaging Sensor (MEIS) was originally developed by MDA through an unsolicted proposal in the 1974-76 time frame. The sensor employs CCD line arrays that scan the terrain in pushbroom fashion. The original Mk. 1 system employed 2 512-element CCD arrays, the current operational system now under test uses 5 1728-element arrays thus providing imagery in 5 wavelength bands.

The major advantages of MEIS over the more conventional flying-spot scanner such as is used in the Landsat MSS and current airborne MSSs (such as Daedelus) is a longer dwell time for each pixel on each element of the array, and potentially higher resolution. Also there are no moving parts and thus higher reliability. Another major advantage is its geometric stability and thus, its ready adaptibility to digital output and geometrical corrections needed for map overlay. Also spectral bands and instantaneous field of view are readily altered.

A particular feature of MEIS is its amenability to strip stereo recording which has great potential for topographical mapping.

MEIS is still in a pre-operational phase. Potential users have marvelled at the clarity and high resolution provided by the Mk. 2 instrument. MDA plan to demonstrate it to the Australians shortly and export sales are likely to follow.

Aside from the above comments, it is too early to expect any significant impacts or effects from the MEIS development. Its uses in simulating satellite imagery (such as the Landsat 4 TM) and in replacing current airborne MSS show promise of major impacts in due course. Moreover, in the master plan to converge satellite and airborne imagery into a common geometrical digital data base compatible with national, provincial and municipal digital information systems, MEIS is the obvious initial candidate for the airborne sensor, but later for the satellite as well.

4.5 Objectives Achievement

The objectives of CCRS related to technology transfer are set out in Section 4.2. These objectives can be re-worded and summarized along the lines of the five technologies examined in this evaluation, viz.

1. Landsat - to broaden the base and increase the use of Landsat technology by end users, and to develop viable levels of Landsat technology among the appropriate Canadian hardware, software and service industries.

2. SAR Development - to design and test new systems for receiving and processing radar/microwave reflections and transfer such technology to users and Canadian industry by 1984.

3. Laser R and D - to develop hydrographic and marine pollution monitoring capacity using lasers, and ensure full industrial capability is available by 1986.

4. Image Analysis R and D - to develop and demonstrate new methods for image analysis, and transfer the technology to user agencies.

5. Solid State Scanner Development - to develop improved sensors for recording data using visible and infrared wavelength, and to ensure that such technology resides in Canadian industry.

4.5.1 Landsat

The extent of Landsat technology transfer by CCRS directly to end users has been covered in Section 3. Section 4.4.1 examines the extent to which other agents, namely provincial governments, have been enlisted to pick up the crusade and become the couplers of Landsat and other remote sensing technologies to users in the provinces. To this end, CCRS has been partially successful. Ontario, Alberta and Quebec have adopted the technology in varying degrees and have become transfer agents. The objectives also have been achieved in B.C. with respect to forestry, but not in other disciplines. There is a technology transfer initiative referred to earlier via memoranda of understanding with Manitoba and with the Council of Maritime Premiers covering Nova Scotia, New Brunswick and Prince Edward Island. Saskatchewan and Newfoundland along with the territories remain without any significant initiatives toward Centres of remote sensing.

It was pointed out by CCRS to the evaluation team that technology transfer seems always to receive a "rough ride" in the CCRS budget. Evidently the argument is that if remote sensing is so beneficial, why don't the provinces (and other federal departments) and industrial end users fund their own technology transfer activities. There does not seem to be an easy or single answer to the question. Generally, the benefits of Landsat technology need to be demonstrated. This is the thrust of the current initiatives in Manitoba and the maritimes. However, other factors are also critical, such as the presence of an organizational unit within the province with a commitment to the technology, and the ability to provide appropriate levels of service. If initial efforts by CCRS fail, it is easy to understand a reluctance on the part of federal decision makers to continue supporting such efforts in the face of other priorities.

The hard facts are, nevertheless, that if the community of Canadian users fail to adopt Landsat and related technology, then there is no point in supporting the technology in the first place. It is the old story of technology push vs demand pull. In any enterprise, whether it is generating user goods and services, or only responding to the needs of others, a certain level of "sales" effort is needed to sustain operations. CCRS is no different, and while it is unquestionably a "technology push" operation, some level of continual sales effort is essential if only to secure investments already made in the new technology. The establishment of provincial or regional centres is tantamount to the creation of "local distributorships" and should be a key element in any "sales" strategy. This subject will be revisited in Section 4.8.

The transfer of Landsat technology to the Canadian supplier industries, while not spelled out specifically in the objectives, has met with considerable success. MDA is the best example, but companies responsible for operating Prince Albert (SED Systems) and Shoe Cove (NORDCO) have benefited in other ways through their participation in Landsat specifically, and remote sensing in general.

4.5.2 SAR Development

The fulfillment of objectives in SAR development technology transfer is still a year away, and yet considerable progress has been achieved. SAR technology is being developed in three Canadian companies: Spar Aerospace, MDA and Canadian Astronautics Ltd. Satellite SAR development presently focusses on Radarsat and a Canadian ground station contribution to ERS-1, and these programs are progressing as planned. The Radarsat program office, now a separate division of CCRS, oversees the development of SAR technology at Spar and MDA. The industrial development effort is continuing at a limited level while the program office is preparing its submission for the next phase. Present plans call for a launch by 1990, and a resumption of major design activity in 1984.

More intensive efforts are being devoted to airborne SAR in two programs--one in the private sector involving MDA, and one supported by CCRS involving MDA and CAL. They will result in operational systems in late 1983 and early 1984 respectively. All indications are that the SAR development objectives are being achieved.

4.5.3 Laser R and D

The use of lasers for hydrographic surveying has progressed through a rocky history over the past decade, having run up against several shoals. Its use in an integrated photo hydrography system has given way to the scanning laser (Larsen 500) which now has the full support and long term (5 year) commitment of the Canadian Hydrographic Service. There seems little doubt that the Laser R and D objective of ensuring full industrial capability by 1986 will be met.

Even the Mk.2 bathymeter associated with photo bathymetry has taken on new life as a terrain profiler which, when appropriately adapted for high altitude operation, will be used to profile ice pressure ridges and in photogrammetry.

The laser fluorosensor originally destined for use in oilspill and pollution monitoring has gone through a similar metamorphosis. While the initial objectives of becoming an operational tool by pollution regulatory agencies have not been met, the instrument is being used in connection with geophysical exploration.

Thus in both applications, the original objectives for Laser R and D have changed as experience has been acquired. In both cases, the changes have been brought about principally because of the involvement and investment (both in dollars and in opportunity costs) by the private sector. However, it must be recognized that without the continuing support of CCRS during periods of doubt and hesitation, the Laser effort would likely have died and the investment lost forever.

4.5.4 Image Analysis R and D

Inhouse image analysis work at CCRS has resulted in the CIAS system which is operational and available to outside users. Current efforts are directed to LDIAS. Both of these image analysis systems developments fulfil the objective to develop and demonstrate new methodology. If there is any shortfall in meeting objectives, it lies on the side of transferring the technology to user agencies. Since it is impossible to quantify such an objective, the alternative is to turn to the qualitative responses to the questionnaire and the input received during interviews

Section 4.4.4 described the responses that indicated a number of areas of concern expressed by users who were dissatisfied with the services received (which, it should be stressed, consisted of only 15% of the 144 respondents who answered that portion of the questionnaire). Their concerns focus on the mixing of a service operation with an R and D activity which may have been responsible for some of the problems cited. In any event, and in all fairness, it cannot be said that image analysis technology transfer to user agencies has been fully achieved, and there certainly appears to be room for improvement.

In part, some of the technology transfer to end users is being assumed by other groups. For example, OCRS and other provincial groups have been very active in proselytizing end users, as have been the major firms in the image analysis business--DIPIX, MDA and OVAAC-8. There is not much evidence yet of major efforts with end users by the consulting companies, with some important exceptions. The same can be said of the surveys and mapping industries. This issue will be picked up again in Section 5.

4.5.5 Solid State Scanner Development

The achievement of the objective related to solid state scanners appears to have been accomplished in that an improved visual and infrared scanner has been developed by Canadian industry (MDA). Moreover, the future looks most promising. The objective needs to be recast to reflect more specific goals and market penetration so that the scanner can be integrated into a well-defined master plan for CCRS.

4.6 Duplication and Overlap

The duplication and overlap evaluation issues associated with technology transfer are few in number. For Landsat, they centre around who should be interfacing with end users--CCRS, the provincial or regional centres, or the industry. The potential for overlap is always there when more than one agency carries the same responsibility. The situation is clear enough when CCRS possesses a unique piece of equipment; it is less clear when industry believes CCRS is competing with it in providing specialized services. There was little evidence yet of the latter among those companies visited by the evaluation team--a situation that could change as more service companies acquire image analysis equipment and offer such a service to clients.

There was some confusion among certain of the users visited as to whether they should be contacting CCRS or the local provincial centre on matters related to the application of Landsat and remote sensing technology. Provided the IPTASC sub-committee of CACRS continues to fulfil its functions, one of which is "to encourage the efficient cooperation between federal and provincial/territorial efforts to better serve regional remote sensing practitioners and potential users", little more can be done to prevent federal/ provincial overlap in the transfer of Landsat technology to end users.

It is to be hoped that federal efforts could be lessened as the provinces and industry pick up the task of dealing directly with end users. However, it would be a serious error for CCRS to lose contact with a representative cross-section of users to ensure that the technology being created by or through CCRS remains relevant.

The evaluation team could not identify any duplication or overlap in respect of SAR laser and solid state scanner developments within Canada. Outside Canada, there are competing developments in most if not all remote sensing technologies being supported by CCRS. For example, Canada could rely on SAR developments in the U.S. and in Europe. However, SAR technology is critical to many of Canada's economic and sovereign ambitions. Other studies have concluded that SAR technology must be stimulated in Canada, and indeed Canadian industry already has shown its ability to compete internationally in SAR processor technology.

Laser and solid state scanner programs have evolved as industry initiatives sponsored by CCRS and DSS through the unsolicited proposal mechanisms. International markets appear to be opening up for these two development areas.

With three companies in the image analysis R and D field, there is indeed potential for duplication and overlap with CCRS work on methodology development. However, as a fledgling industry, its sights must be set to the near term for immediate survival. CCRS thus can afford to aim its efforts over a longer time horizon, and the LDIAS system is a five-year program--well beyond the planning horizon of the industry at present. The problem will arise in future when the industry gains in strength and is able to undertake longer range planning investments and related R and D. The overlap potential then becomes very large, and CCRS may wish or even be forced to change its policies with respect to image analysis R and D (i.e. the young chimpanzee can grow up to become a ferocious gorilla).

4.7 Alternative Methods

An EMR evaluation using OCG guidelines is required to examine whether or not there are more cost-effective alternative programs which might achieve the objectives and intended impacts and effects. The objective of technology transfer is to implant in the related industries, centres and end user groups remote sensing technology through programs undertaken by CCRS. The intended impact and effects are the establishment of viable businesses in the industry that then is capable of serving end users, and the implantation of the necessary technology in regional and provincial centres to enable them to serve end users effectively.

The mechanisms for meeting these broad objectives are summarized in Section 4.1 which lists 12 classes of activities underway at CCRS. The alternatives that present themselves for the technology transfer process is not to seek alternative programs, but rather to probe whether there are more cost-effective ways of delivering the existing program. This amounts to an examination of the relative emphasis placed on the 12 classes of activities which comprise the technology transfer program of CCRS. However, for an evaluation team to weigh credibly the relative merits of 12 program delivery means, it would be necessary to undertake a detailed analysis of the management and decision-making processes of CCRS well beyond the terms of reference of such an evaluation.

Instead, we will focus on one aspect only, which was brought to the attention of the team in several interviews. It was stated on a number of occasions that the best technology transfer occurs when there is a transfer of personnel. The government does have a program wherein senior staff can be transferred to industry (and provincial governments) for periods up to three years. It would appear that the technology transfer process might be enhanced in a cost-effective fashion (industry covers transferee's salary) through greater participation in staff exchanges with industry.

The other obvious alternative would be to rely on the U.S. and other countries to provide the technology needed to use or exploit remote sensing. Such an option does not fulfil the basic technology transfer objectives and thus was not pursued by the evaluation team.

4.8 Conclusions

As in Section 3.8, the foregoing paragraphs addressed the basic OCG evaluation issues. The following conclusions are structured under the headings of the terms of reference as laid out in Section 1.1 for the technology transfer process.

a) Extent of Technology Transfer

From the evidence provided by the national survey and interviews, it can be concluded that the technology transfer to industry has achieved levels which permit the companies involved to compete in the domestic and, in some cases, the international market place. This conclusion applies to SAR processor, aircraft SAR, laser, digital image analysis and solid state scanner technologies. The companies that have achieved this level of competence* are:

SAR processor:	MacDonald Dettwiler and Assoc. Ltd. (MDA)
Aircraft SAR:	MDA and Canadian Astronautics Ltd.
Laser technology:	Optech Inc. - laser bathymetry and derivatives Barringer Research Ltd. - laser fluorosensor and derivatives (excluding laser itself)
Digital Image Analysis:	Dipix Ltd. MDA Ltd. OVAAC-8 Ltd.
Solid State Scanner:	MDA Ltd.

Companies such as SED Systems and NORDCO have acquired ground station and data processing technology, but have not exploited this technology directly in support of Landsat applications.

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* Another firm, Imapro Ltd., has developed a colour image recorder for use in image production which is enjoying international sales. Emerging from the LBIR development group, Imapro claims it owes its existence to CCRS.

Satellite SAR R and D work at Spar has not yet reached a critical level where it can be exploited outside the market for Radarsat.

The extent to which remote sensing technology has been transferred to end users cannot be measured readily with the type of survey and interview structure employed, which necessarily had to cover a wide range of subject areas. In large measure, the extent of transfer to users was covered in Section 3 dealing with Landsat insofar as discipline groups and fields of application are concerned. In Section 4.4.1, the process of transfer to end users was covered. In particular, it was concluded that provincial and regional centres provide appropriate coupling mechanisms to users, and can be thought of as "regional distributors".

After contacting various provincial authorities, it was evident that there is a wide spread of views as to the merits of remote sensing held by provincial authorities across Canada. Provincial response was strongest in Ontario, Quebec and Alberta, weakest in Saskatchewan and Newfoundland. Time has been too short to evaluate the extent of transfer in Manitoba and the maritimes where memoranda of understanding have been signed only recently, and programs are now just underway. It can be concluded that if such programs meet any significant level of success, similar exercises ought to be conducted in Saskatchewan and Newfoundland.

b) Achievements and Impacts of Technology Transfer

Achievements and impacts of Landsat technology transfer to end users have been covered in Section 3. The requirement for Canadian Landsat stations has resulted in the establishment of skills and expertise at MDA in Landsat (and related earth-viewing satellite) ground stations, data processing and image analysis. This industrial team has been successful in marketing eight fully-equipped "turnkey" stations, six in other countries, and has been a subcontractor in eight other countries. It can be concluded that Canada possesses a world-class industry in earth resource satellite ground stations.

The impact of supporting SAR processor development at MDA has resulted in significant contracts with ESA in connection with the preparatory program and ERS-1 - a satellite that will be of use to Canada. Again, it can be concluded that through CCRS support, MDA has become a world-class supplier of SAR processors. Aircraft SAR in support of tactical ice reconnaissance is another systems supply area that has been developed in Canada. Domestic sales to Dome Petroleum and to CCRS suggest that the market has gained sufficient confidence to place such supply contracts in Canada.

Achievements and impacts of laser R and D have not turned out quite as originally intended - nevertheless they should be significant. The laser fluorosensor was a technological success but never found its market, mainly because of the high cost of the complete system needed to support the fluorosensor. It could prove valuable, however, as a geophysical tool - a purpose for which it is being employed by Barringer Research Ltd., its developer, at the present time.

The original laser bathymeter was intended for use with a photogrammetric technique of aerial hydrography. Subsequent development and testing showed that the scanning laser method had more promise. The Canadian Hydrographic Service has committed over $2 million over the next 5 years to the project. It is concluded that the Canadian company involved, Optech Inc., has achieved through CCRS support a significant technological capability in laser hydrography that could result in export sales of equipment and/or charting services. Derivatives of the original bathymeter are finding new and unexpected applications as a high altitude profiler for ice reconnaissance and photogrammetry.

Image analysis R and D at CCRS has been conducted as an in-house program, with the use of outside contractors to provide portions of the CCRS systems. The present system, CIAS, is providing a service to users with which the majority of those contacted expressed full satisfaction. However, there were some important dissenting views which expressed doubts about the wisdom of combining R and D activities with a service function under the same roof. The evaluation team could not disagree with these views, but recognized the importance of keeping such in-house R and D activities close to the needs of users, lest they may otherwise become too academic and irrelevant. We concluded that any obvious shortcomings of CCRS image analysis services should be corrected if at all practicable, but that any dissatisfied users in future should be more able to seek out alternatives at the appropriate provincial centre or service supplier in the private sector.

While not related directly to a CCRS program or strategic plan, a growing image analysis industry has taken hold in Canada. Three companies - Dipix, MDA and OVAAC-8 - are in the business in varying degrees, with Dipix leading by a considerable margin, claiming 20-30% of the world market. We have concluded that image analysis is moving into a demand pull era, and that commercial forces will increasingly dominate developments in this field.

It is too early to measure the achievements and impacts of solid state scanner development except to conclude that early indications look very promising for this class of sensor. Its intrinsic properties lends itself to digital formats, and the necessary geometric corrections are carried out readily. The solid state scanner should enjoy a bright future provided it can keep ahead of its competition.

c) Technology Transfer Problems

Dealing first with problems associated with technology transfer to the supply industry, the evaluation team could not identify any major impediment to the process, save for a lack of funds in some instances. The unsolicited proposal fund, administered by DSS, has been used most effectively in bringing remote sensing ideas and initiatives in the private sector to fruition. It appears to have worked very successfully for CCRS.

The interviews uncovered a few supply or service companies that were unhappy with CCRS. In any competitive environment, such dissidence is to be expected. The evaluation team took some care to seek out valid situations of inequity with such firms, without success. The closest we could come is that there may be some greater difficulty for a small firm at a large distance from Ottawa to deal as readily with CCRS as a firm of comparable size near Ottawa.

Perhaps the largest problem inhibiting technology transfer to the supply industry is the distribution of talent between CCRS and the industry. Within CCRS are scientists and engineers with excellent ideas and track records that should be most effective in an industrial setting. The difficulties associated with transplanting some of this talent to industry for temporary but meaningful periods of time we would cite as a significant technology transfer problem.

The most difficult problems of technology transfer, however, are those associated with end users. In part, the problems have been compounded by the reluctance of federal decision makers to permit the expenditure of resources in this area. However, CCRS is not entirely without blame. Reasons for some level of dissatisfaction with image analysis services already have been cited. We should also draw attention to the responses to Question 24 in respect of level of satisfaction with CCRS services or facilities. Question 6 showed that a major alternative to Landsat would be to use remote sensing aircraft. There was indeed a large measure of dissatisfaction with the provision of aircraft (57% of respondents), an aspect of CCRS activities that was not covered in the evaluation. (The high level of dissatisfaction with data processing, we ascertained, was associated more with earlier problems at Prince Albert, and slow delivery of DICS imagery which has been addressed in Section 3).

While the above problems at CCRS may have had some adverse impact on technology transfer to end users, the largest problems centre around Landsat itself, and the ability to enlist other delivery agents or distributors of the technology.

The problems of Landsat have been dealt with in Section 3, the most serious being continuity and security of supply. The problem of enlisting distributors is a serious one, and yet is essential to the long-term success of remote sensing. Demand pull cannot be manufactured out of ether, and a continual sales level is needed at the grass roots level - in the provinces and among the disciplines.

The reluctance of some federal departments to adopting the technology is based in part on jurisdictional grounds, and in part on the relevancy and true value of remote sensing to their missions. We believe that truly the missions of some departments originally targeted by CCRS may be inappropriate in the light of experience with operational remote sensing systems. However, in future improved systems may be able to meet requirements when some of the current problems are overcome (e.g. higher resolution, more frequent coverage, etc.)

Jurisdictional problems can be most difficult within the bureaucracy. There is a tendency in some departments, particularly where remote sensing offers only marginal improvements or benefits, to expect CCRS to bear costs that more appropriately should be borne by the user agency in many cases.

d) Suggestions for Improvement

As stated above, problems associated with technology transfer to the supply industry are not nearly as critical as those connected with end users. We gained the impressions from discussions with suppliers that some would welcome the opportunity of acquiring for a temporary period, certain key people at CCRS with expertise that would be valuable in exploiting the technology. We believe the pros and cons of this practice should be weighed by CCRS, and a policy developed with respect to its supply industry.

The approved objectives for CCRS do not spell out specific goals for technology transfer to the supply industry. We believe that such objectives should be established which stretches CCRS in directions where it already has shown some considerable success.

In dealing with the problem of technology transfer to end users, we already have alluded to the very low percentage of total expenditures devoted to this area (7% shown in Table 1.3). In Section 3, we suggested that either objectives should be altered to reflect this evident priority by CCRS budget makers, or priorities should change in the budget to reflect current objectives as they stand. If budget priorities are re-examined, we would suggest that in addition to the current efforts with Manitoba and the maritime provinces, Saskatchewan and Newfoundland receive some attention as further potential candidates for memoranda of understanding. The establishment of distributorships we believe should take priority over directly dealing with end users.

However, we would not wish to suggest in any way that CCRS should forego direct contact with end users at any time. As already suggested, it is important that CCRS scientists and engineers make continual contact with end users. In fact, criticisms were received by the evaluation team that CCRS should be more in contact with operational people, not theorists. Another suggestion was made that CCRS should include implementation and learning as part of its approach to technology transfer. This suggestion followed a general criticism expressed by a few that after CCRS puts a new user-related technology into place, it leaves too soon before it has taken root. CCRS should insist on implementation as an integral part of the transfer process.

The image analysis system supply industry can and should be the largest promoters of remote sensing technology among users. As this industry expands, the technology transfer task of CCRS should diminish. The multiplier effect of supporting this industry should not be overlooked in developing future strategies and industrial policies to meet CCRS objectives.

5. GENERAL ISSUES

This part of the evaluation focuses on a number of ancillary issues which have arisen in the course of the study. Some of these have been mentioned elsewhere in the report, in connection with one or more of the main evaluation issues. However, we judge them to be sufficiently important to warrant separate discussion.

5.1 U.S. Data

We have found evidence that the EROS Data Centre is making significant sales of Landsat information of Canada. During the years 1980-1982, EROS photographic sales of Canadian scenes averaged 34% of Canadian sales. In the same period, EROS CCT sales averaged 9% of the Canadian.

We have no way of knowing what proportion of the EROS sales were made to resident Canadian firms or individuals. Our impression is that the bulk of the EROS sales of Canadian scenes is to non-Canadians. Canadian Landsat users have told us that for the most part they are pleased with the service which they receive from CCRS. The large price advantage which Canadian users enjoy further suggests that the EROS sales are being made to non-Canadian customers, and groups that are not aware they can be served by CCRS.

If Canada is being asked to pay a large fee for the privilege of reading out Landsat data recorded over Canada, then it seems to us that that fee ought to provide for some proprietary rights over the sale of the information. We find it hard to envisage that EROS would countenance a parallel situation, in which Canada made American imagery available on the world market, in competition with the U.S.

In so saying, we fully recognize the paramount importance which Canada should attached to the maintenance of good formal and informal working relations with EROS. We also recognize that the sources of civilian satellite data are expected to grow rapidly in this decade (viz. SPOT, ERS-1 and Radarsat). These new satellite systems will reduce Canada's sole dependence on the United States. We believe that CCRS is in a strong position to negotiate a satellite data production agreement with EROS. This agreement should provide Canada, in return for payment of station changes, exclusive world production and distribution rights for Landsat data collected over Canada.

5.2 Research versus Operations

Throughout this study in interviews and in questionnaires, respondents raised issues which were related to the problem of combining research and operational activities in a single organization. This issue has three main components:

1. The balance of effort which CCRS devotes to long term technology development, and to short term applications development and technology transfer.
2. The availability of CCRS facilities (e.g. SAR 580) for operational applications.
3. The way in which CCRS is organized to manage research and operations.

Many respondents remarked to us that applications development work at CCRS was suffering for lack of attention. They pointed out that the operational applications of Landsat were relatively few and that some key application areas (e.g. agriculture) were badly under-developed. At the same time most recognized the need for CCRS to maintain its technological capabilities and to contribute to international efforts to improve remote sensing tools. One respondent summarized this problem by exclaiming that "our problem in Canada is that we have too much remote sensing data, but not enough information!".

Another aspect of this situation is the difficulty which some users had in implementing operational remote sensing programs using CCRS facilities that had a primary research focus. Several users mentioned problems in booking CCRS aircraft (and associated sensors) and in being able to rely on their services being available in a timely fashion.

The evaluation team is conscious of the problem of combining research and operations in a single organization. We recognize too, that there can be significant benefits from closely linking research activities with the needs of end users. The problem, we feel, has both a time and a balance component.

In our opinion, some of the problems which operational users experience will be solved as remote sensing technology becomes commonplace and available through commercial sources. The Intera/Intertech SAR commercialization seems to us to be an ideal example of government-sponsored R&D resulting in a commercial system.

Prior to its latest re-organization CCRS was not well equipped to meet users' needs on a day-to-day basis. We are most encouraged by the present organizational structure at CCRS, which we feel will greatly ease the frustrations which CCRS itself must have felt before in managing research and operational activities side-by-side.

Still, it is clear to us that there has been some neglect of applications research at CCRS, in the face of an omni-present need to develop improved remote sensing technology. This balance of effort can be redressed in two or three ways. First, the Government could add new monies to CCRS's budget for applications development and technology transfer. (The technology transfer program which was put in place in 1983-84 is an example). Secondly, CCRS could divert resources from technology development to applications development and slow down the pace of the former. A third option would combine the two approaches.

Before suggesting a direction for CCRS to take, it would be informative to trace some of the arguments and historical developments which have resulted in the present situation. As it was originally conceived, CCRS was to be the national centre for the development of remote sensing data acquisition and processing equipment and techniques. Applications work was to be undertaken by individual federal government departments that had missions in the application areas (e.g. environment, transport, agriculture, etc.). Those groups were to work with CCRS in developing specific uses for satellite and airborne information, using monies they had applied for (and received) in their departmental appropriations.

In any event, those departments--with some exceptions--had no desire to devote their hard-won resources to an untried technology, especially when there was already in existence a federal government organization dedicated to its promotion. As a result, CCRS found itself without the personnel and resources necessary to become expert in all application areas.

The original idea of federal funding for regional interpretation centres was dropped early on in the game when a few (wealthy) provinces established their own remote sensing centres. As a result, the quality and quantity of remote sensing in the provincial governments varies widely from place to place in Canada. In most provinces, there is no remote sensing organization which is technically equipped to work with end users in developing new applications.

Based on our survey results, the belief expressed in some federal government circles that the chief value of remote sensing technology is in the management of natural resources--and therefore a provincial responsibility--does not appear to be correct. Federal and provincial users of remote sensing are about equal in numbers.

Most provinces do not have the capability to develop applications. The substantial federal investment in a national remote sensing infrastructure will be far less effective than it could otherwise be, if additional effort is not put into broadening the geographic base for that infrastructure.

In our opinion, the national remote sensing program will be best served by a stronger initiative at CCRS to extend operational applications for its technology. Not until those applications are proven and the next generation of (operational) satellites--encompassing better resolution and all-weather capability--is in place will satellite remote sensing achieve its original promise.

5.3 University Remote Sensing

Many in the Canadian remote sensing community expressed their disappointment at what they perceived as the failure of the universities to adequately support remote sensing. They pointed out that at most universities, remote sensing tends to be the isolated preserve of a single department. In university "A" remote sensing may be housed with the geologists, in university "B" with the foresters and in university "C" with the biologists. In those places, other disciplines--physics, computer science, engineering, etc.--will have no remote sensing involvement. Few Canadian universities have vibrant programs of remote sensing research or teaching.

In our opinion this situation has had a detrimental effect on the national remote sensing program. In the first place, Canadian science and engineering students are lacking opportunities to learn about remote sensing and the way in which it could be applied in their disciplines. In the second, Canadian remote sensing R&D is losing out at all levels--data acquisition and processing, image analysis, applications development, and technology transfer--in the potential contribution of university scientists and engineers.

There are two factors responsible for this situation. The first is the cross-disciplinary nature of remote sensing. Remote sensing technology applies to many application fields. As such it does not fit well into the university discipline structure. (The same problem applies in government.) The second problem has been in the funding of university remote sensing. Universities do not have access to research or equipment grants which are not tied to work in a specific discipline. Individual scientists may apply for funds through NSERC for, say, work on a particular problem in biology. However, in general, universities have no NSERC route to acquire the necessary capital facilities for remote sensing research activities which may apply across the board. (Though, again, individual scientists may apply for major equipment grants through NSERC).

CCRS does not participate in the EMR Research Agreements Program (RAP), so there are no remote sensing funds available through the Department. Such requests as are received by the RAP are funelled to CCRS for consideration for contract funding.

Universities have been the victims of fiscal circumstance. At just the time when remote sensing was growing by leaps and bounds nationally, university budgets and new programs were being severely curtailed by provincial fiscal restraint policies. University remote sensing programs never developed the needed momentum.

In our opinion the situation of remote sensing in Canadian universities is of sufficient concern to warrant special attention from CCRS and EMR. EMR should review its Research Agreements Program to find ways in which universities and university scientists can be encouraged to contribute more fully to the national remote sensing program.

We believe that EMR should, in addition, specifically examine the potential benefits of a limited program of support--perhaps through an expanded Research Agreements Program, perhaps through better liaison with NSERC--for remote sensing capital facilities at Canadian universities, such facilities to be made available to all disciplines at the university. We believe that the presence of such facilities at the universities could spur new remote sensing activity in all fields.

5.4 Canadian Advisory Committee on Remote Sensing (CACRS)

CACRS was established by CCRS to provide advice on the requirements of the national remote sensing program and to act as a vehicle for the transfer of know-how from the federal body to remote sensing users. In the course of the study we heard two main lines of discussion concerning CACRS.

First, from some CACRS members, we heard that the recommendations produced by their annual meeting fell upon deaf ears in the federal government. Most were ready to acknowledge, however, that the situation had recently improved and that the dialogue with EMR was more positive.

Another discussion, raised by CACRS members and non-members alike, concerned the membership of the organization and its vitality. Many people pointed out that the CACRS membership has remained static in large part. Many CACRS members were no longer using remote sensing in their daily activities. It was felt that these people used the CACRS meetings as an opportunity for brushing up on developments in the field, rather than contributing to those developments.

Almost everyone acknowledged that the success of individual CACRS working groups was dependent upon the voluntary contributions of the members, and more frequently, the chairmen. Some people pointed out that the membership of many working groups had also remained static and that new people had not the opportunity to make their contribution. Others mentioned that some of the standing working groups had not met for a long time.

We should point out that only a tiny minority of people seriously suggested that the CACRS system should be dismantled. Most believed it was an important model for the development of remote sensing not just in Canada, but internationally.

It is difficult to quantify the comments and criticisms which were expressed to us. However, in our opinion their thrust is a valid one. We have noted a recent trend towards a greater task-orientation for CACRS working groups. This is a trend which we support. In order to further increase its effectiveness, we believe that CACRS should establish appropriate terms of office for its Working Group representatives. By establishing terms of office for existing members, CACRS can expand the opportunities for new people to participate in its work.

5.5 Consolidation of Activities

This study has looked into the past to assess the Canada Centre for Remote Sensing. However, we would be first to acknowledge that important changes in CCRS's operating environment will shortly affect the operations of the agency, in a significant way.

We refer specifically to the new satellite data systems with which CCRS and the Canadian remote sensing community will have to contend during the 1980s. The decade of the 1970s, CCRS's first, was devoted to establishing an infrastructure of hardware and techniques in relation to satellite remote sensing, based on Landsats 1, 2, and 3. These first generation remote sensing satellites were similar in their hardware and image analysis requirements.

Moreover, the remote sensing user community learned its skills and operational techniques by employing the Landsat system. In other words, a great deal of capital--human and material--has been invested in Landsat.

Under a normal pattern of development, we would expect the decade of the 1980s to be one of consolidation for CCRS and for the Canadian remote sensing community. We would expect that hardware, analysis, interpretation and production techniques would become standardized; that users' comfort and familiarity with the technology and techniques would lead to a further development and in some cases, maturation, of the remote sensing applications; and that the number of operational applications would steadily grow.

However, there are developments afoot which we believe will confound the process of consolidation. We refer chiefly to rapid and perhaps fundamental changes in satellite technology which may well strain CCRS resources in the 1980s. Between 1983 and 1993 we expect that three and perhaps five new satellite data systems will become available: Landsat-4, SPOT, ERS-1, Radarsat and MOS (from Japan). In addition, new private sector initiatives in the U.S. and Europe may expand and confuse the market even further.

The extent to which these systems will draw on CCRS's human and financial resources is not yet clear. In the case of Landsat-4, the one system for which we were able to form an impression, the draw appears to be substantial. A further question in our minds is the extent to which these new systems will interfere with consolidation at the level of users and producers of remote sensing goods and services. It may be that the resources which they have invested in remote sensing over the past decade will to some extent be made redundant.

We should emphasize that in the long term these new technologies will contribute much to remote sensing. Taken together, they show promise in overcoming the technical drawbacks of the present system, including improved frequency of coverage, all-weather capability, resolution and spectral bands. Moreover, they will advance the trend towards fully integrated digital land resource information systems. Our concern is that they may prove to be too difficult to swallow in one decade.

We have no specific recommendations to offer in this connection. We wish merely to point to what we view as a potential difficulty in the development of remote sensing in Canada (and for that matter, elsewhere) and to suggest to CCRS that it make some provision for this possibility in its long term planning.

APPENDIX 1

A SYNOPSIS OF THE EVOLUTION OF THE CCRS OBJECTIVES

1. Original CCRS Objectives

These objectives and sub-objectives were confirmed by Treasury Board Memorandum 782700, January 15, 1971.

1.0 to "produce in a timely and effective manner remotely sensed data and derived information needed for the management of Canada's resources and environment and to perform and support research and development on the collection, processing and interpretation of such data".

1.1 to plan, on a continuing basis experimental and operational remote sensing programs pertinent to the management of Canada's resources and environment;

1.2 to acquire relevant data from sensors located on spacecraft, aircraft, balloons and other platforms;

1.3 to process remotely sensed data and assemble them in formats appropriate for interpretation;

1.4 to market processed data to meet the requirements of governments, industries and individuals;

1.5 to interpret data and foster interpretation by governments, industries, universities and individuals;

1.6 to improve the scope and effectiveness of the data and derived information through research and development on sensing systems, data processing and interpretation;

1.7 to promote and co-ordinate international and national cooperation and information interchange in designated areas of remote sensing;

1.8 to foster the development of expertise in Canadian industry in technology related to remote sensing and its application.

(Note regarding the Airborne Program)

The T.B.M. directed that the airborne program would be oriented towards research and development. Measurements of an operational type would be restricted to those for which the program had a specialized unique instrumentation and/or expertise. Proven technology would normally be transferred to Canadian federal and provincial agencies as well as industry at the earliest possible date. It was felt that the airborne program would add flexibility above and beyond the satellite program. Airborne data was also considered necessary to verify satellite data and to provide a backup for the satellite data.

2. Updating of CCRS Objectives, 1972

Treasury Board approved a July 6 CCRS request for program approval for objectives, activities, a cost recovery plan and an operating budget for 1973-76. The objectives and sub-objectives which were approved at that time included:

2.1 to collect, process, disseminate and develop applications for data applicable to resource management and environmental control of Canadian land and ocean masses (through):

2.2 a satellite program to receive all available earth resources data relevant to Canada and to process and market these data;

2.3 an airborne program to survey selected areas of Canada in response to user demands and develop new data acquisition systems for this task;

2.4 an applications program to develop and demonstrate methods for using remote sensing data;

2.5 fostering national cooperation in remote sensing technology through grants to provincial or regional interpretation centres and fostering international cooperation in the space adventures of this science.

Specific activities which were related to these objectives included:

- a four year experimental program with the U.S.A. to use ERTS

- a program to provide qualified users airborne remote sensed data. A program to develop and test new remote sensing devices.

- to develop and demonstrate new applications for remote sensing data.

- to develop and implement new automated methods of analyzing data from airborne and satellite programs.

- to provide training and liaison services to users to enable them to make better use of the data.

- to provide users and potential users with the technical information and service on remote sensing.

Note: Treasury Board approved the July 6 submission and indicated that the program should concentrate on the collection and dissemination of remotely sensed data to public and private sector users and that users should play a greater role in the development of remote sensing applications suitable to their particular missions.

3. Updating of CCRS Objectives, 1974

Treasury Board agreed to civilian involvement in the airborne program. Industry's role would be to perform the operational part of the program and to actively discover customers, expand applications and attempt all innovations possible within its fund-raising and risk-taking capabilities.

4. Updating of CCRS Objectives, 1975

Following a direction from Cabinet to examine the feasibility of a Canadian satellite surveillance system, CCRS submitted a Memorandum to Cabinet in 1976 (December 6). Cabinet agreed that:

- Canada move towards the utilization of a surveillance satellite system in accordance with anticipated forecasting needs in 1980-2000.
- Canada participate in the SEASAT A experiment the U.S.A.
- EMR undertake experiments for a Canadian satellite surveillance system by 1985.

5. Updating of CCRS Objectives, 1978

In March 1978 Canada and the United States signed an agreement for cooperation in the development of a space remote sensing system for global crop information, including participation by CCRS.

6. Updating of CCRS Objectives, 1979

On July 6, the strategic objectives and sub-objectives of the Remote Sensing Service Activity were approved as follows:

6.1 To facilitate the acquisition and dissemination of remotely sensed data and derived information needed for the management of Canadian natural resources and for the monitoring of human activity.

6.2 To develop, document and demonstrate the practical applications of remotely sensed data and existing technology. Specifically, by 1984 provide systems for (a) up-dating information on forest, water and agricultural resources and (b) monitoring environmental changes associated with the construction of dams, pipelines and highways; by 1985 provide airborne and satellite monitoring systems in support of exploration, drilling, shipping, locating oil spills, and the remote determination of shallow water depth; and by 1988 provide a pilot operational system (using all weather sensors) for the monitoring of ice, sea state, and human activity on the ocean and in the sparsely settled areas of Canada.

6.3 To ensure that remote sensing data is acquired, processed and made available to users in a timely, effective manner. Specifically, during the period from the present to 1995, to provide (a) satellite data for all of Canada at low resolution on a daily basis, and at high resolution on a 15 day cycle, and

(b) airborne remote sensing data for applications development and to satisfy the requirements of user agencies.

6.4 To develop instrumentation systems and data analysis techniques needed to improve resource management information systems. Specifically, by 1982 to develop an airborne imaging radar for ice, ship and oil slick surveillance; by 1984 to develop advanced airborne sensors for vegetation monitoring and water quality measurement; and by 1984 to develop a new system for integrating remotely sensed data with other resource data bases.

6.5 To provide image analysis, technical information, laboratory and computer services in support of other sub-activities, and in certain areas to outside users.

6.6 In January 1979, Cabinet authorized EMR to participate in an ESA preparatory program to define the need and technical specifications of a SAR satellite.

Note: The attached figures illustrate the sub-sub-activity breakdown as it was at the end of the period.

7. Updating of CCRS Objectives, 1980

7.1 Cabinet authorized CCRS to initiate a satellite radar study program, including the option of a predominantly Canadian satellite system, implemented alone or in cooperation with the U.S.A.

8. Updating of CCRS Objectives, 1981

In March 1981, Cabinet authorized EMR to initiate a RADARSAT Phase A and technology R&D program, an upgrade of Ground stations and image analysis facilities to handle Landsat-D data, a technology transfer program to encourage the use of remote sensing data in provincial/ territorial resource management agencies, and an extension of Canadian participation in ESA's Preparatory Program.

In November 1981, Cabinet authorized EMR to install a precision processing facility called Multi-Observation Satellite Image Correction System (MOSAICS) to provide users with geocoded data for the next generation of remote sensing satellites, and to undertake R&D programs to develop digital resource data through a Remote Sensing Geographic Information System (RSGIS). (RSGIS was subsequently deferred to 1984-85. No decision has been made on the future of this program.)

9. Current Activity Objectives of the Remote Sensing Program

"To improve remote sensing technology and to facilitate the acquisition and dissemination of remotely sensed data and derived information needed for the management of Canadian natural resources and for the monitoring of human activity."

Current sub-activity objectives of the Remote Sensing program:

9.1 Satellite Data

"To ensure the timely availability of remotely sensed data from satellites for resource management and environmental monitoring."

9.2 Airborne Program

"To establish and demonstrate improved airborne remote sensing technologies for resource management and environmental monitoring".

9.3 Data Applications

"To develop and implement procedures to extract relevant information from remotely sensed data as well as to establish and demonstrate practical applications of that information in the management of Canadian resources and in monitoring of the environment."

9.4 Applications Services and Technology Transfer

"To provide analysis facilities as well as information and advisory services to assist users and to increase use of remote sensing data through technology transfer to resource management agencies."

(This synopsis has been taken from "Report of the A-Base Review of the Canada Centre for Remote Sensing. April 1983".)

NAME:

BUSINESS ADDRESS:

POSITION:

PHONE:

QUESTIONNAIRE STATUS	
Q's Mailed	2400
Q's Returned (undelivered)	270
Non-Particip. (refused)	161
Non-Response	1135
Valid Q's	834

AREA OF PRINCIPAL ACTIVITY (CIRCLE ONE)

MANUFACTURING INDUSTRY	46
NON-MANUFACTURING INDUSTRY	178
FEDERAL GOVERNMENT	157
PROVINCIAL GOVERNMENT	188
MUNICIPAL GOVERNMENT	5
CROWN CORPORATION	30
EDUCATIONAL INSTITUTION	123
OTHER (specify) ____	51
Missing	56
	834

NOTE: If your organization operates as a Crown Corporation rather than as a federal government department please circle "Crown Corporation".

PART I — THE USE OF LANDSAT AND OTHER TYPES OF REMOTE SENSING DATA

(ALL RESPONDENTS PLEASE ANSWER THESE QUESTIONS)

Q.1 When was your most recent use of remotely-sensed data?
(Circle one only in each column)
(See glossary for definition of these terms.)

	LANDSAT	OTHER SATELLITE REMOTE SENSING	AIRBORNE REMOTE SENSING
Past month	197	99	327
Past 1-6 months	145	33	120
Past 6-12 months	100	28	49
Past 1-5 years	219	56	85
More than 5 yrs.	27	18	33
Have never used	62	166	25
Total	750	400	639

Q.2 Under each column below (where applicable) please circle those application areas, up to a maximum of three, where you have used (or are using) remote sensing

APPLICATION AREA	LANDSAT	OTHER SATELLITE REMOTE SENSING	AIRBORNE REMOTE SENSING
Agriculture & Crop Monitoring	70	12	70
Atmospheric Monitoring	14	44	14
Cartography & Photogrammetry	113	115	177
Engineering Projects	75	14	116
Fishery Resources	17	7	23
Forest Resources	162	17	150
Geography (e.g. Land use)	142	20	127
Geosciences	189	38	156
Ice Monitoring	73	50	47
Mineral Resources	136	24	99
Oceanography	32	46	37
Petroleum Resources	36	10	27
Pollution Detection & Monitoring	29	4	35
Water Resources & Hydrology, Hydrography	118	42	108
Wildlife & Wildlands	81	9	81
Other (specify) ____	42	22	40

IF YOU HAVE NOT USED LANDSAT IMAGERY (AS YOU INDICATED IN QUESTION 2) PLEASE GO TO QUESTION 7

FOR USERS OF LANDSAT IMAGERY ONLY

Q 3a) In question 2, you indicated up to three application areas where you have used LANDSAT. Please indicate, by circling the appropriate code, whether your use of LANDSAT imagery was for **Research purposes**, **One-time Operational** use and/or use in an ongoing **Operational System**. (SEE GLOSSARY FOR DEFINITIONS OF THESE TERMS.)

Q 3b) Now please indicate what would be the consequences for that use if LANDSAT imagery had not been available, by putting the appropriate code in the space beside those numbers you circled in question 3a).

Consequences	**Consequences Code**
Could have used alternate sources of information.	1
Would have failed to complete work on project.	2
Would have failed to start project.	3
Other (specify) ________________	9

APPLICATION AREA	RESEARCH (including pilot projects) Q3a	Q3b	ONE-TIME OPERATIONAL Q3a	Q3b	OPERATIONAL SYSTEM Q3a	Q3b
Agriculture & Crop Monitoring	50	____	20	____	15	____
Atmospheric Monitoring	5	____	7	____	2	____
Cartography & Photogrammetry	58	____	43	____	43	____
Engineering Projects	25	____	46	____	17	____
Fishery Resources	9	____	7	____	9	____
Forest Resources	80	____	63	____	48	____
Geography (e.g. Land Use)	76	____	59	____	24	____
Geosciences	113	____	62	____	34	____
Ice Monitoring	53	____	20	____	18	____
Mineral Resources	76	____	53	____	49	____
Oceanography	24	____	6	____	2	____
Petroleum Resources	14	____	13	____	12	____
Pollution Detection & Monitoring	23	____	11	____	4	____
Water Resources & Hydrology, Hydrography	71	____	38	____	20	____
Wildlife & Wildlands	49	____	27	____	25	____
Other (specify) ________		____		____		____
	726		475		322	

Q.4 Please indicate which features of using LANDSAT imagery you found to be satisfactory.

____

____

____

Q.5 Please indicate which features of using LANDSAT imagery you found were not satisfactory.

____

____

____

____

Q.6 If the LANDSAT program were to be terminated, what alternatives, if any, would be available to you to obtain the information necessary for your work.
(Circle one only)

Will fail to perform work.	48
Would use imagery from other satellites such as the NOAA weather satellite.	48
Would use aircraft remote sensing.	177
Would undertake a field data collection project.	40
Would use past LANDSAT images.	208
Other, (specify) ________________	168

ALL RESPONDENTS PLEASE ANSWER THE REMAINDER OF THIS SECTION.

Q.7 If you have used AIRBORNE remote sensing in the past, please indicate which types of imagery you have used. (Circle as applicable)

Black and white photography	625
Colour and colour infrared photos	460
Stereo photos — colour or black and white	559
Multi-spectral scanner imagery	158
Thermal infrared imagery	193
Television & low light level TV	57
Passive microwave radiometer imagery	18
Radar imagery	140
Other (specify) ________________	52
None	37

Q.8 If you have used SATELLITE remote sensing, please indicate which satellites. (See glossary) (Circle as applicable)

LANDSAT Multi-spectral scanner	621
LANDSAT Return Beam Vidicon Camera	104
GOES	52
NIMBUS	47
NOAA and TIROS weather satellites	138
SEASAT	85
Other (specify)	24
None	47

Q.9 Which types of SATELLITE remote sensing data products do you use? (Circle as applicable)

Photographic prints	583
Photographic transparencies	248
Enlargements	339
Strip film or print	51
Facsimile	31
Fiche	64
Computer Compatible Tapes	221

Q.10 If you use maps in conjunction with remote sensing data, which map scales do you typically use? (Circle as applicable for each column)

	LANDSAT	OTHER SATELLITES	AIRBORNE REMOTE SENSING
1:1,000	4	-	52
1:2,000	-	-	66
1:5,000	9	0	116
1:10,000	22	1	213
1:25,000	58	6	200
1:50,000	232	14	359
1:100,000	74	9	45
1:250,000	403	37	133
1:1,000,000	182	31	24
1:3,000,000	9	21	3
1:10,000,000	8	15	3
Other (specify)			
Not applicable			

Q.11 Which data collection platforms have you used in your past work? (See glossary for definition) (Circle as applicable)

Atmospheric — Radiosonde	25
Ice data platforms	32
Land data platforms	75
Ocean data buoys	50
Weather data platforms	69
Snow data platforms	22
Stream gauge platforms	49
Water level platforms	49
Other (specify)	17
Have not used data collection platforms	641

Q.12 Which are the approximate ground resolutions you work with in your use of remote sensing? See glossary for the definition of ground resolutions.
(Circle as applicable)

	AIRBORNE REMOTE SENSING
Less than 1 metre	166
2 - 5 metres	288
6 - 10 metres	179
11 - 20 metres	108
21 - 25 metres	88
26 - 50 metres	86
51 - 100 metres	89
101 - 500 metres	49
501 - 1 kilometre	35
2 - 10 kilometres	22
Over 10 kilometres	12

	SATELLITE REMOTE SENSING
Less than 25 metres	87
26 - 50 metres	121
51 - 100 metres	243
101 - 500 metres	136
501 - 1 kilometre	103
2 - 10 kilometres	72
11 - 100 kilometres	44
Over 100 kilometres	21

Q 13 Do you require **SATELLITE** stereo images? (Circle one only)

Yes	179
No	591

Q.14 If you use ground elevation data, what is the most frequent contour interval you require?
(Circle one only)

Less than 10 centimetres	10
10 cm - 1 metre	104
2 - 10 metres	233
11 - 25 metres	77
26 - 50 metres	64
51 - 100 metres	21
Other (specify) ______	9
Do not require such data	9

Q.15 Which data analysis methods do you use for remote sensing (both satellite and airborne)? (Circle as applicable)

Manual photo-interpretation	494
Optical-mechanical devices (e.g. zoom transfer scope, stereo scopes)	255
Electronic analogue devices (e.g. density slicer)	43
Digital analysis computer systems	123
Other (specify) ______	244

Q.16 In what format is the information output from your analysis of remotely sensed data? (Circle as applicable)

Statistical data	305
Thematic maps	482
Forecasts	60
Warnings (drought, flood, earthquake etc.)	46
Other (specify) ______	144

Q.17 Which remote sensing goods and services do you buy and sell?
(Circle those numbers as applicable)

	BUY	SELL
Air Survey Service	362	30
Remote Sensing Consultant	103	95
Specialist in Data Processing	76	45
Custom Data Products	115	26
Remote Sensing Equipment	130	8
Digital Analysis Equipment/Software	90	14
Other (specify) ______	27	24

Q.18 How many person months did your organization devote to remote sensing in the past fiscal year?

16,918 person months

PART II — TECHNOLOGY TRANSFER

This part is in two sections:

SECTION "A" to be answered by respondents who buy or sell remote sensing equipment or services for profit.
(E.g. a company manufacturing satellite components or one selling image analysis services.)

SECTION "B" to be answered by respondents who buy or use remote sensing equipment or services from CCRS but do not sell them for profit.
(E.g. companies using remote sensing for geological exploration, forest inventory, etc.) (These respondents go to question 24).

SECTION "A"

Q.19 In what project areas have you been involved with CCRS? (Circle as applicable)
SEE GLOSSARY FOR DEFINITION OF PROGRAMS.

LANDSAT	56
Satellite synthetic aperture radar (SAR)	17
Airborne SAR	17
Laser Research and Development (R & D)	4
Satellite Image Analysis R & D	30
Airborne Image Analysis R & D	17
Solid State Scanner	4
Other (specify) ________	10

Q.20 Has your work with CCRS enabled you to make sales in any of these project areas? (Circle as applicable)

	Domestic Sales	Foreign Sales
LANDSAT	15	–
Satellite SAR	2	1
Airborne SAR	5	1
Laser R & D	0	2
Satellite Image Analysis R & D	12	2
Airborne Image Analysis R & D	8	1
Solid State Scanner	3	1
No Sales from direct CCRS Assistance	3	–
Other (specify) ________	16	9

Q.21 What was the nature of your contact with CCRS regarding these projects? (Circle as many as are applicable). (4 valid cases)

NATURE OF CONTACT	LANDSAT	SATELLITE SAR	AIRBORNE SAR	LASER R & D	SATELLITE IMAGE ANALYSIS	AIRBORNE IMAGE ANALYSIS	SOLID STATE SCANNER	OTHER/GENERAL
1. Contracts to develop your own technology or expertise.	2							
2. Contracts to develop CCRS technology or expertise.	1							
3. CCRS help with:								
a) Fundamental Research	1							
b) Prototypes	1							
c) Design	1							
d) Specifications	1							
e) Computing	2							
f) Marketing								
g) Problem Solving								
4. Attendance at CCRS training courses, seminars, symposia etc.	1			1				
5. Staff Exchanges								
6. CCRS publications	4							
7. Access to licenses owned by CCRS.	1							
8. Advice on New Applications for your remote sensing products.	2							
9. Advice on General Remote Sensing Technological Trends, Market Trends.	1							
10. Use of CCRS facilities.	4							
11. CCRS Services (e.g. testing, calibration).				1				
12. Purchase of Non Standard Products by CCRS which resulted in a market for the product.								
13. Purchase of Standard Imagery and/or Data from CCRS.	1			1				
14. Other (specify) ________								

Q.22 Could you describe specifically the value of CCRS's assistance to you in terms of sales, earnings, growth, new markets, new products, etc.?

____

____

____

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____

Q.23 In this study we define technology transfer to industry as "the capability of a government laboratory to improve Canada's scientific and technical base and to promote a nationally and internationally competitive industry".

Using this definition and thinking back to your own experiences with technology transferred to you from CCRS, could you indicate the positive aspects of the transfer process as well as make any suggestions on how it could have been improved.

____

____

____

____

____

SECTION "B" — USE OF CCRS FACILITIES AND SERVICES

Q.24 a) CCRS provides various services in the form of facilities, advice, data, etc. Please circle those areas of assistance which you have used.

b) Now, for each service which you circled in question 24a, please indicate in the space beside it, your satisfaction or dissatisfaction with the assistance provided, by placing the appropriate code as stated below.

Satisfaction Level	**Code**
Very Satisfied	1
Satisfied	2
Dissatisfied	3
Very Dissatisfied	4
No Opinion	5

SERVICE OR FACILITY	Q24 a) USE	Q24 b) SATISFACTION	1	2	3	4	5
Image Analysis Services			103	3	11	10	2
Data Processing			10	6	16	27	3
Provision of Aircraft			11	1	16	10	9
Advice on New Applications			-	-	-	2	-
Applications Development Assistance	3	____	-	-	-	-	3
CCRS Services (e.g. testing, calibration)	2	____	-	-	-	-	-
Publications		____					
Library services (e.g. computer search)		____					
General Advice		____					
Provision of data		____					
Provision of software		____					
Other (specify)							
______________		____					

Q.25 If you were **very satisfied** or **very dissatisfied** with the services used, please indicate why.

____

____

____

Q.26 Regarding your use of the above services, please circle for your area(s) of application whether your use of services was for **Research Purposes, One-time Operational** use and/or for use in an **Operational System.** (SEE GLOSSARY FOR DEFINITION OF THE ABOVE TERMS) (Circle up to a maximum of 3 application areas)

APPLICATION AREA	RESEARCH (Including pilot project)	ONE-TIME OPERATIONAL	OPERATIONAL SYSTEM
Agriculture & Crop Monitoring			
Atmospheric Monitoring			
Cartography & Photogrammetry	NO RESPONSES		
Engineering Projects			
Fishery Resources			
Forest Resources			
Geography (e.g. Land use)			
Geosciences			
Ice Monitoring			
Mineral Resources			
Oceanography			
Petroleum Resources			
Pollution Detection & Monitoring			
Water Resources & Hydrology			
Wildlife & Wildlands			
Other (specify) ______			

Q.27 If you indicated any **operational system(s)** in Q.26, please provide a title or short description.

	APPLICATION AREA	TITLE OR SHORT DESCRIPTION
1.	______	______
2.	______	______
3.	______	______

Q.28 What suggestions can you make for improving the service and facilities at CCRS?

______

______

______

______

Thank you for your cooperation!

QUALITATIVE RESPONSES TO QUESTIONNAIRE

QUESTION 4 - Please indicate which features of using LANDSAT imagery you found to be satisfactory.

Comment	No. of Responses	%
Intensive coverage of large area/ scales used/large format	150	21
Discernable water/land/sky/images/ visual impact/resolution	148	21
Ease of acquisition/easy data access	37	5
Speed of receiving information/CCT	12	2
Infrared images	2	-
Overview of forest development/regional pictures	55	8
Geological interpretation	26	4
Colour quality	19	3
Cost/inexpensive	28	4
Quality of prints/tapes/transparencies	27	4
Preliminary monitoring of disturbances/ turbulance	5	1
Digital analysis	19	3
Multiple bands/variations on bands/multi spectral	36	5
Seasonal coverage	5	1
Frequent up to date changes can be monitored	31	4
Good set of images over times/multidate	22	3
Repetitive coverage	9	1
Good base map	17	2
Good presentation tool/useful for presentation	3	1
Automated/computer classification capabilities	7	1
All satisfactory	15	2
Not suitable for our needs	2	-
MSS Data	4	1
Misc. mentions	23	3
Not stated	241	34

QUESTION 5 - Please indicate which features of using LANDSAT imagery you found were not satisfactory.

Comment	No. of Responses	%
Covered too large an area/scale size/ scale too small/no detailed coverage	48	7
Resolution/discernable images/water-land-sky etc.	170	24
Slow product delivery	36	5
Frequency	14	2
Cloud cover restriction/weather problems	79	11
Colour poor/lack of true colour	9	1
Cost/expensive	25	4
Poor quality print/tapes/fiche	41	6
Limitation of coverage/lack stereographic coverage	29	4
Band choice	15	2
18 day sampling time/cycle/more frequent coverage	19	3
Not enough coverage of arctic/specific area	8	1
Lack of knowledge of Landsat/how to use it	7	1
Availability of up to date imagery	3	-
Digital analysis problems	4	1
Classification accuracy	4	1
Catalogue doesn't adequately indicate cloud cover	4	1
Absence of catalogue of services available	3	1
Misc.	40	6
Not Stated	320	45

QUESTION 22 - Could you describe specifically the value of CCRS's assistance to you in terms of sales, earnings, growth, new markets, new products, etc.?

Comment	No. of Responses	%
High positive comments	19	3
Low positive comments	20	3
Negative comments	8	1
Neutral comments	9	1
Not stated	657	92

QUESTION 23 - In this study we define technology transfer to industry as "the capability of a government laboratory to improve Canada's scientific and technical base and to promote a nationally and internationally competitive industry".

Using this definition and thinking back to your own experiences with technology transferred to you from CCRS, could you indicate the positive aspects of the transfer process as well as make any suggestions on how it could have been improved.

Comment	No. of Responses	%
Satisfied with help/service	15	2
Fundamental research	6	1
Staff exchanges	2	1
Design	4	1
Attended CCRS seminar/lecture	2	-
Use of CCRS facilities	4	1
Transfer of remote sensing technology	4	1
Fast service	2	-
Computing	1	-
Slow turnaround	1	-
Misc. negative	14	2
Misc. positive	5	1
Not Stated	661	92

QUESTION 25 - If you were very satisfied or very dissatisfied with the services used, please indicate why.

Comment	No. of Responses	%
Prompt service/good turnaround time	46	6
Professional/efficient/accurate/expertise	46	6
Helpful/cooperative/staff responsive	55	8
Minimum red tape/little hassle/easy accessible	3	-
Friendly/courteous staff	16	2
Good quality reproductions	16	2
Useful	5	1
Low cost	5	1
Not sure what is available	2	-
Misc. positive	7	1
Provide more information on what's available	3	-
Poor customer relations in Ottawa	6	1
Area agreed to not totally covered	8	1
Inefficient/wrong image sent	7	1
Slow service/failure to meet schedule	16	2
Poor quality	8	1
Hard to book planes/image analysis overloaded	2	-
Hard to get reasonable price for imagery	2	-
Misc. Negative	19	3
Not stated	546	77

QUESTION 28 - What suggestions can you make for improving the service and facilities at CCRS?

Keep us informed of services/issue catalogues	65	9
Improve/greater resolution/frequency	21	3
Improve turnaround time/deliveries	26	4
Better information on archival information/image holding	10	1

QUESTION 28 (Cont'd)

Comment	No. of Responses	%
Improve cost structure for product	28	4
Develop new technologies (e.g. radar satellite techniques)	19	3
Centralize availability of satellite information e.g NOAA/Landsat/Goes	13	2
Be more user oriented	15	2
Expand coverage in Canada/cooperation maintained (increase support)	29	4
Have a training/orientation course	11	2
Cloud cover interference	7	1
Improved quality	2	1
Misc.	23	3
Not Stated	499	70

APPENDIX 3

LIST OF INTERVIEWEES

1. Mr. Frank Hegyi
   Inventory Division
   British Columbia Forest Service
   Victoria

2. Mr. W. Emery, Dr. P. Leblond
   Institute of Oceanography
   University of British Columbia
   Vancouver

3. Dr. John S. MacDonald, Mr. R. Orth, Mr. D. Freedman
   MacDonald, Dettwiler and Associates Ltd.
   Richmond, British Columbia

4. Dr. P. Murtha, Chairman
   U.B.C. Remote Sensing Council
   Vancouver

5. Mr. Michael Dunn
   B.C. Lands Directorate
   Environment Canada
   Vancouver

6. Mr. L. Kraus
   Reid Collins & Associates Ltd.
   Vancouver

7. Mr. R. A. Brocklebank, President
   McElhanney Surveying and Engineering Ltd.
   Vancouver

8. Dr. J. Marko
   Arctic Sciences Ltd.
   Victoria

9. Dr. James F. Gower
   Institute for Ocean Sciences
   Department of Fisheries and Oceans
   Sydney, B.C.

10. Mr. Bill Kuhnke
    River Forecast Centre
    Department of The Environment
    Edmonton

11. Mr. Cal Bricker
    Alberta Remote Sensing Center
    Edmonton

12. Dr. J. B. Mercer
    Remote Sensing Group
    Dome Petroleum Limited

13. Mr. Brian Bullock, Ms. M. Diane Thompson
    Intera Environmental Consultants Ltd.
    Calgary

14. Dr. Frank G. Bercha
    F. G. Bercha and Associates Limited
    Calgary

15. Mr. Don Epp
    SED Systems Inc.
    Prince Albert

16. Mr. Roy Irwin
    Canada Centre for Remote Sensing
    Prince Albert

17. Dr. D. H. Kjosness
    SED Systems Inc.
    Saskatoon

18. Dr. J. Whiting
    Saskatchewan Research Council
    Saskatoon

19. Dr. Donald G. Somers
    Saskatchewan Mining Development Corporation
    Saskatoon

20. Dr. Jack Mollard
    J. D. Mollard and Associates Limited
    Regina

21. Mr. Allan D. McLeod
    Saskatchewan Wheat Pool
    Regina

22. Mr. Merv M. Ross
    Research Division
    Saskatchewan Crop Insurance Corporation
    Regina

23. Dr. J. F. Benci
    Weather and Crop Surveillance Branch
    Canadian Wheat Board
    Winnipeg

24. Mr. W. G. Best
    Manitoba Remote Sensing Centre
    Winnipeg

25. Mr. G. W. Curle
    Ducks Unlimited
    Winnipeg

26. Mr. W. A. Nash
    Noranda Exploration Company
    Winnipeg

27. EROS Data Centre
    Sioux Falls, North Dakota
    U.S.A.

28. Mr. Don Carlin
    Forest Management Branch
    Department of Natural Resources
    Fredericton

29. Dr. Michael Dillon
    Farm Land Identification Program
    New Brunswick Department of Agriculture
    Fredericton

30. Dr. E. Derenyi
    Department of Survey Engineering
    University of New Brunswick

31. Mr. Jim Stanley
    Maritime Resource Management Service
    Amherst, Nova Scotia

32. Dr. Clive Mason
    Bedford Institute of Oceanography
    Halifax

33. Mr. A. Ruffman, President
    Geomarine Associated Ltd.
    Halifax

34. Mr. Richard D. Worsfold, President
Remotec Applications Inc.
St. John's

35. Dr. Angus Bruneau
BRM Incorporated
St. John's

36. Dr. Roger A. Stacey
NORDCO Limited
St. John's

37. Dr. Denes Bajzak
Faculty of Engineering
Memorial University
St. John's

38. Mr. Ian Hale
Bird & Hale Consulting Engineers
Toronto

39. Dr. P. Howarth
Department of Geography
McMaster University
Hamilton

40. Mr. J. A. Alum
INCO Metals Limited
Mississauga, Ontario

41. Mr. Mike Kirby
Innotech Aviation Ltd.
Ottawa

42. Dr. S. Peteherych
Satellite Data Laboratory
Atmospheric Environment Service
Toronto

43. Mr. V. Zsilinsky
Ontario Centre for Remote Sensing
Toronto

44. Mr. C. F. Crowe
Canada Patents & Development Ltd.
Ottawa

45. Dr. R. Protz
Land Resource Sciences
University of Guelph

46. Mr. J. Pullen
    Marshall, Macklin, Monaghan Ltd.
    Toronto

47. Mr. Louis Cardinal
    Public Archives of Canada
    Ottawa

48. Mr. James Bridgman
    IMAPRO Ltd.
    Ottawa

49. Mr. R. B. Proud
    Crops Section
    Agriculture Canada
    Ottawa

50. Mr. E. Benware
    Kenting Earth Sciences
    Ottawa

51. Mr. H. A. Lee
    Lee Geo-Indicators Ltd.
    Ottawa

52. Mr. S. Ommanney
    National Hydrology Research Institute
    Department of the Environment, Ottawa

53. Dr. J. R. Norton
    Norpak Corporation
    Ottawa

54. Prof. Ferdinand J. Bonn
    Département de Géographie
    Université de Sherbrooke

55. M. Hervé Audet
    Ministere de L'Energie et des Ressources
    Quebéc

56. Prof. Guy Rochon
    DIGIM Inc.
    Montréal

57. M. Jean Beaubien
    Centre de Recherches Forestière des Laurentides
    Environment Canada

58. Prof. James Gray
Département de Géographie
Université de Montreal

59. Prof. Marc Tanguay
Département de Genie Minéral
Ecole Polytéchnique
Montreal

60. M. Pierre Laframboise
Sociéte de Developpement de la Baie James
Montreal

61. Mr. J. Wightman
Nova Scotia Land Survey Institute
Lawrencetown, N.S.

62. Mr. E. Miller
OVAAC 8
Toronto

63. Mr. D. Carter
Canadian Astronautics Ltd.
Montreal

64. Dr. R. N. Delabio
Geological Survey of Canada
Ottawa

65. Mr. R. Piirvee
Petawawa National Forestry Institute
Chalk River

66. Dr. A. R. Mack
Soil Research Institute
Agriculture Canada

67. Mr. B. S. Mathur
Ministry of Transportation and Communications
Toronto

68. Dr. H. Zwick
Moniteq Ltd.
Toronto

69. Dr. A. Gregory
Gregory Geoscience Limited
Ottawa

70. Mr. Don McLarty
Canadian Association of Aerial Surveyors
Ottawa

71. Dr. M. Evans
Interdepartmental Committee on Space
Ministry of State for Science and Technology

72. Mr. E. A. Godby
Canada Centre for Remote Sensing
Ottawa

73. Dr. W. M. Strome
Canada Centre for Remote Sensing
Ottawa

74. Mr. Leon Bronstein
Canada Centre for Remote Sensing
Ottawa

75. Dr. E. Shaw
Canada Centre for Remote Sensing
Ottawa

76. Mr. J.-C. Henein
Canada Centre for Remote Sensing
Ottawa

77. Mr. J. D. Heyland
Canada Centre for Remote Sensing
Ottawa

78. Dr. J. H. Davies
Barringer Research Ltd.
Toronto

79. Mr. J. E. Bruton
Canada Centre for Inland Waters
Burlington

80. Dr. V. R. Slaney
Geological Survey of Canada
Ottawa

81. Mr. T. Mullane
AES Ice Branch
Ottawa

82. Dr. Paul Pearl, President
DIPIX Systems Ltd.
Ottawa

83. Dr. J. M. Zarzycki
Surveys and Mapping Branch
EMR

84. Mr. N. Beesley
Kilbourn Engineering
Toronto

APPENDIX 4

SUMMARY OF OPEN-ENDED QUESTIONNAIRE RESPONSES

Q.4 Please indicate which features of using LANDSAT imagery you found to be satisfactory.

Intensive coverage of large area/scales used/ large format	150
Discernable water/land/sky images/visual impact/ resolution	148
Ease of acquisition/easy data access	37
Speed of receiving information/CCT	12
Infrared images	2
Overview of forest development/regional pictures	55
Geological interpretation	26
Colour quality	19
Cost/inexpensive	28
Quality of prints/tapes/transparancies	27
Preliminary monitoring of distrubances/turbulance	5
Digital analysis	19
Multiple bands/variations on bands/multi spectral	36
Seasonal coverage	5
Frequent up to date changes can be monitored	31
Good set of images over times/multidate	22
Repetitive coverage	9
Good base map	17
Good presentation tool/useful for presentation	3
Automated/computer classification capabilities	7
All satisfactory	15
Not suitable for our needs	2
MSS data	4
Misc. mentions	23
Not stated	241

Q.22 Could you describe specifically the value of CCRS's assistance to you in terms of sales, earnings, growth, new markets, new products, etc.?

High positive comments	19
Low positive comments	20
Negative comments	8
Neutral comments	9
Not stated	657

Q. 23 In this study we define technology transfer to industry as "the capability of a government laboratory to improve Canada's scientific and technical base and to promote a nationally and internationally competitive industry".

Using this definition and thinking back to your own experiences with technology transferred to you from CCRS, could you indicate the positive aspects of the transfer process as well as make any suggestions on how it could have been improved.

Satisfied with help service	15
Fundamental research	6
Staff exchanges	2
Design	4
Attended CCRS seminar/lecture	2
Use of CCRS facilities	4
Transfer of remote sensing technology	4
Fast service	2
Computing	1
Slow turnaround	1
Misc. negative	14
Misc. positive	5
N.S.	661

Q.25 If you were very satisfied or very dissatisfied with the services used, please indicate why.

Satisfied	
Prompt service/good turnaround time	46
Professional/efficient/accurate/expertise	46
Helpful/cooperative/staff responsive	55
Minimum red tape/little hassle/easy accessible	3
Friendly/courteous staff	16
Good quality reproductions	16
Useful	5
Low cost	5
Not sure what is available	2
Misc. positive	7
Dissatisfied	
Provide more information on what's available	3
Poor customer relations in Ottawa	6
Area agreed to not totally covered	8
Inefficient/wrong image sent	7
Slow service/failure to meet schedule	16
Poor quality	8
Hard to book planes/image analysis overloaded	2
Hard to get reasonable price for imagery	2
Misc. negative	19
Not stated	546

Q.28 What suggestions can you make for improving the service and facilities at CCRS?

Keep us informed of services/issue catalogues	65
Improve/greater resolution/frequency	21
Improve turnaround time/deliveries	26
Better information on archival information/ image holding	10
Improve cost structure for product	28
Develop new technologies (e.g. radar satellite techniques)	19
Centralize availability of satellite information e.g. NOAA/Landsat/Goes	13
Be more user oriented	15
Expand coverage in Canada/cooperation maintained (increase support)	29
Have a training/orientation course	11
Cloud cover interference	7
Improved quality	2
Misc.	23
Not stated	497

Q.5 Please indicate which features of using LANDSAT imagery you found were not satisfactory.

Covered too large an area/scale size/scale to small/ no detailed coverage	48
Resolution/discernable images/water-land-sky, etc.	170
Slow product delivery	36
Frequency	14
Cloud cover restrictive/weather problems	79
Colour poor/lack of true colour	9
Cost/expensive	25
Poor quality print/tapes/fiche	41
Limitation of coverage/lack stereographic coverage	29
Band choice	15
18 day sampling time/cycle/more frequent coverage	19
Not enough coverage of arctic/specific area	8
Lack of knowledge of Landsat/how to use it	7
Availability of up to date imagery	3
Digital analysis problems	4
Classification accuracy	4
Catalogue doesn't adequately indicate cloud cover quality	4
Absence of catalogue of services available	3
Misc.	40
Not stated	320