REPORT

ON

BENEFITS OF ROCKET AND SMALL SATELLITE

PROGRAM

Prepared for

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1. Introduction

This report is submitted in fulfilment of Part II of the requirements of SSC Contract No. 31016-0-6019/02-SW entitled "The Identification of Opportunities for Microgravity Research and the Evaluation of the Rocket and Small Satellite Programs". The results will contribute to the long term plan for space science.

2. Study Objectives

The objective of this part of the assignment was to assess the benefits of the rocket and small-satellite programs. Information was sought with respect to:

- (a) benefits to users of the programs;
- (b) benefits to suppliers;
- (c) identification of spin-offs; and
- (d) identification of key success factors, strengths and weaknesses.

3. Background

(Part of what follows is taken from "REPORT OF THE AD HOC COMMITTEE ON THE CANADA CENTRE FOR SPACE SCIENCE, REPORT OF COUNCIL" February 1983.)
In 1965 it was agreed between the governments of the United States of America and Canada that mutual interests would be served by continued availability of the Churchill Rocket Range (hereafter CRR) and that the range should be operated and maintained by Canada. The National Research Council of Canada (NRCC) assumed this responsibility on January 1, 1966 through its Churchill Research Range Branch which was later renamed the Space Research Facilities Branch (SRFB).

Space programs in Canada were totally scientific in nature until 1966 when important applications programs began to be funded. With the launch of the last scientific satellite ISIS II in 1971 funding for space science dropped and stayed at a constant dollar level with little adjustment for rising costs. This led to a deterioration in space science activities, causing concern in the space science community. The NRCC commissioned a study in 1975[1] to determine how the situation might be retrieved. Based on the study recommendations, the NRCC established a Space Science Coordination Office in 1976 to provide leadership in bringing the divers interests of the space science community into a coordinated national program.

A number of new space science proposals were put forward and in 1980 the government approved a new space science program involving cooperation with other countries. In July 1980 the Canada Centre for Space Science (CCSS) was established.
The facilities provided by SRFB (and subsequently CCSS) included rocket and balloon launch capabilities at a number of locations in Canada, engineering support for space experiments and project management for the development and construction of major instruments (i.e. those in the nature of facilities). Most of the work funded was and is carried out under contract to Canadian industry. In 1983 there were eight companies involved with CCSS projects either as contractors or subcontractors.

There is a division of responsibility between the CCSS (now part of the Canadian Space Agency) and the scientists. The CCSS supplies major expense items, the scientists' institutions and/or NSERC cover salaries and travel etc. and non-facility-type instruments, such as the rocket or ground-based instruments used by individual scientists.

For 1982/83 and 1983/84 the Space Science budget was $4.858M and $5.185M for rockets and balloons, and $6.301M and $11.166 for cooperative international projects. These figures do not include the cost of CCSS PY's.

In 1984 CRR was closed as a cost-cutting measure. At the time of the CRR closing two other forces were at work:

(a) Canadian Space scientists were forming new alliances in response to the government policy to promote international cooperative projects;

(b) it was generally accepted that the NASA Shuttle was a reasonable alternative

[1]Forsyth, P.A.,Canadian Research Opportunities in Space. (A report prepared for the Associate Committee on Space research) NRCC, 1975.

technology for accessing space for short term scientific study, and that it would be timely to plan to use this technology for the long term.

The Challenger disaster in the Shuttle program, and the ensuing policy decisions with respect to Shuttle manifests, marked a drastic change in direction in the launch plans of many space scientists.

4. Methodology

The Scientific Authority for the study wrote to a representative cross section of the user and the supplier communities, advising them of the study and requesting their participation in the data gathering phase of the project. An interview guideline was included with the letters. A copy of the guideline is attached in Appendix I.

We contacted eight users from Canadian universities, five suppliers from Canadian industry, and a representative of the Space Science Branch.

The study plan called for one trip to Saskatoon. It proved possible to expand the scope of this trip to include visits to Winnipeg and Toronto, thereby increasing the opportunity for face-to-face interviews.

Face-to-face interviews were carried out with three users, four suppliers and the Space Sciences representative. Two additional face-to-face interviews were conducted, one with a Space Sciences officer familiar with the financial statistics of the rocket and balloon program, the other with a scientist from the Geodetic Survey division, EMR. All other interviews were conducted over the telephone.

All interviews were done between September 19 and November 2, 1990.

A list of the interviewees and the interview dates is given in Appendix II.

5. Benefits

In our interviews the benefits of the rocket program were expressed clearly and with a high degree of confidence because the program was formally established and had an 18-year baseline. The benefits of a small-satellite program were more difficult to establish because a Canadian small-satellite program did not exist per se. Small-satellite experience is based essentially on a series of individual project opportunities in Canada and elsewhere, not on a stand-alone funded program. Alouette I was the first such opportunity.

The Flexible Orbiting Carrier Utilizing Shuttle or FOCUS class of satellite was used as a baseline for discussion of small satellites because, although FOCUS has yet to be implemented, it has been under active discussion in Canada since the mid 1980's and is familiar to the majority of Canadian space scientists.

The FOCUS class is also conveniently relatable to the Alouette/ISIS satellites.

5.1 Benefits to Users

In this section we present the user benefits from the rocket program. They are followed by the user benefits from small-satellite projects.

5.1.1 Rockets

With one notable exception all users commented positively on the benefits of the rocket program. In the case of the exception there were three catastrophic failures, i.e. no data, in three launches. Failures were attributed to unreliable ground support (tracking) equipment in one instance, failure of a clamshell to open in another, and, in a third, premature termination of payload power when an on-board sequencer failed to execute properly. These failures occurred at CRR in the early 1970's and the scientist in question concedes that some of the unreliability may have been corrected in the intervening years but he has had no further direct experience. On the positive side, it was noted later in the interview that the Black Brant is a good rocket.

The major benefits obtained are:

(i) Graduate Student Training

The typical timetable of a rocket experiment from "gleam to launch" is 3-4 years. This is an excellent match to the average time for a PhD thesis research project to be completed. The rocket program therefore provided a dependable context in which to plan and execute PhD programs in space science. The graduates from these programs are the Principal Investigators of the future because they have had hands-on experience with this specialized discipline.

The increasing sophistication of instruments in recent years has prevented students in some physics programs from participating in the development of the hardware; they use the data. In other faculties such as engineering, however, the increased complexity of the hardware and the software is itself one of the goals of the research because of the emphasis on new technology as well as space science; students are very much directly involved with the conception, development and qualification for flight of the technology.

Interviewees were unanimous in their praise of rocket programs for the opportunity they provide potential young scientists to learn the techniques of space science in a relatively low-risk context. Pride of authorship was cited in the case of students who return to the university to see how the technology they developed was functioning.

Five university research directors who have been active in rocket programs over an extended time provided quantitative results. Each reported on his personal experience as follows:

Director #1: 7 grad students, over several years, were involved with data analysis. Mature PDF's and skilled technical staff were used for the technology;

Director #2: For $70K graduate students developed and qualified for flight a digital-analog system that would have cost $300K to purchase from a US aerospace supplier. Graduate students continue to work on developing the technology as part of their training;

Director #3: One student was involved with instrument technology in the late 70's. Four students are currently working on satellite and ground-based data;

Director #4: Over the life of the rocket program only a few students were involved with the hardware technology. PDF's and technicians provided most of the manpower; and

Director #5: By 1975 12 PhD students had used small satellite or rocket data; 5-6 had also had a hand in instrument development; 5-6 Masters candidates also obtained experience with the data or the technology. After 1975, rocket launches were too far apart to be a reliable basis for a thesis program. Other less risky scenarios were chosen.

(ii) Scientific Results

The rocket program yielded consistently high quality and sometimes spectacular scientific results over a long period of time. This benefit manifested itself in the Canadian space science program being recognized internationally both for the consistent high quality of the science and the excellence of the instrument technology that supported it. This recognition gave Canada an international identity as a country respected for its accomplishments. It conferred respect on the individual members of the Canadian space science team and earned numerous invitations to scientists to place instruments aboard foreign rockets and satellites.

The scientific results were the 'currency' used to exchange scientific data with foreign scientists. (It is axiomatic that information is only offered freely in exchange for other information of comparable quality.)

A particularly noteworthy scientific result and benefit was the application of propogation effects to the Search and Rescue satellite program. Without the propogation data obtained from rockets and small satellites it is doubtful that Sarsat would have been successful.

(iii) Scope

Projects carried out under the rocket program required minimal management effort. Accordingly, they were well suited to the capability of a research leader in a university to meet the time demands for effective management. Subsequent experience with 'big science' projects has revealed the high degree of government control and the extensive, formal management system required in big budget projects. The informal interaction that characterized projects in the rocket program is missing in large expensive projects.

(iv) Cost

Rocket experiments were successfully planned and carried out because the cost of instrument development was within the normal capability of a university research leader's budget.

(v) **National Team-Building**

The all-Canadian, Canadian-controlled aspect of the rocket program promoted strong mutual support among Canadian space scientists. This support and the enthusiasm that went with it was noted by several interviewees. It was noted further that this kind of enthusiasm and support is difficult to establish in a country as vast as Canada.
One scientist believes the community of space scientists owes its existence to the rocket program.

The continuity of the program also supported the growth of strong and effective university/industry teams.

(vi) **Uniqueness**

Rockets reach altitudes in the range 40-250Km that are otherwise inaccessible by balloons or satellites. These regions are the up-down coupling regions between the atmosphere and the ionosphere where some man-made pollution effects are found.
Rockets can 'hover' for measurements integrated in time. Satellites don't.

(vii) CRR

The rocket program while it was based at CRR provided Canadian scientists with the world's best-located high latitude range due to location, geographical extent and weather. CRR is 'head and shoulders' above the other three ranges in the Western world.

(viii) Industry Support

The payload integration teams built up at SED and Bristol Aerospace over the life of the program provided 'superb' engineering for users. CRR also provided training and jobs for skilled ground-support personnel.

(ix) Complementarity

Research carried out under the rocket program complemented the data obtained from the extensive network of measurements from the ground and from satellites.

(x) Instrument Development and Qualification

Rocket payloads are excellent test beds for proof-of-concept of new instruments. Many of the instruments now in satellites began as rocket experiments, and received their space qualification in the process.

NASA and ESA are becoming increasingly insistent on prior qualification of instruments proposed for inclusion in their payloads.

(xi) Data Analysis

By the time CRR was closed extensive computer facilities had been built up for data analysis. These facilities are now a valuable resource getting wide use.

5.1.2 Small-Satellites

Benefits to users of small-satellites mirrored many of the benefits of the rocket program, but the baseline of small-satellite experience is much smaller than the rocket baseline. The key benefits highlighted in our interviews were :

- The project schedule is acceptable for graduate training;
- The Alouette/ISIS satellites produced a wealth of new scientific knowledge and brought recognition to Canada as the third country to have its own satellite;
- Projects like FREJA are small enough to permit informal interaction among experimenters;
- Canadian industry has provided quality engineering support; and
- Small-satellite projects are manageable in the university context. University students are building small-satellite payloads in the USA and UK.

The early respect Canadian national space science achievements earned through the rocket program and the Alouette/ISIS projects has waned, although the outstanding success of the Viking UV Imager has regained some of the momentum. An all-Canadian small-satellite program in the future could re-establish Canada as a leader in auroral and ionospheric physics. These two points were made to us repeatedly in interviews, with emphasis on a made-in-Canada policy and a commitment to a program spanning several years.

5.2 Benefits to Suppliers

5.2.1 Rockets

Three of the suppliers - SED, Bristol Aerospace and ADGA, spoke from a base of extensive experience in the rocket program. Neither COMDEV nor Canadian Astronautics was able to offer comment on the rocket program.

Since its beginning in 1965 SED has completed 65 launches under the rocket program. Bristol Aerospace has been involved over the same period and has completed 120 payloads. ADGA supplied skilled range support staff to the balloon and rocket programs from 1978 until CRR was closed.

Major benefits were identified as:

(i) Start-Up of a High-Technology Base

SED owes its existence to the rocket program. It began as the Space Engineering Division of the University of Saskatchewan expressly mandated to build rocket payloads. The rocket program provided steady growth and challenging hi-tech work to the division and, after incorporation in 1972, the company.

Bristol Aerospace stated that the rocket program was a critical element in the companies's development. Without it the company would never have had a base from which to diversify into satellite technology and missiles.

The continuity of the rocket program and the long time period over which it was in place contributed to the systematic evolution of rocket launchers and payload technology.

(ii) Skilled Manpower Base

Space science payloads attracted young engineers.
Integration of payloads is exceptionally effective as a mechanism for training young engineers. These specially trained personnel are then in high demand in other company divisions because of their breadth of experience in detailed engineering design and manufacture and in systems engineering.

When CRR was closed ADGA had a strength of 33 skilled range support staff. Seven were permanently based at Churchill, the other 26 were based at Gimli, Man. and were moved to CRR for launches. In 1984 ADGA claimed that this team was one of only three in the world trained and capable of supporting balloon and rocket preparation, handling, launch and data acquisition.

(iii) Regional Development

The rocket program provided challenging work to graduates of Western universities.

In Saskatoon twelve local companies provide technical support to SED. It is believed that the twelve were established as a result of SED's presence and growth.

5.2.2 Small-Satellites

All suppliers except ADGA have supplied instruments or subsystems for satellites and all have strong views about the benefits of small satellites. The benefits were identified more by stating what experience has shown to be wrong with large satellite programs than by analyzing past experience with small satellites. One comment was offered, based on experience with the FREJA project:

> FREJA is being carried out with minimal management documentation. As a consequence engineers find the project stimulating because their time is spent on hardware development instead of management paperwork.

The suppliers see the large space science satellite programs becoming too expensive and too bureaucratic, even in unmanned missions. The big projects drain resources, reduce the number of companies and tie up money for too long. The Canadian space science budget of $17M is too small, and the funds too thinly spread to cope.

They see the benefits of a small-satellite program as the opposite of the problems with big programs. Many of the benefits are similar to those of a rocket program:

- relatively low cost;
- 2-3 years to launch;
- graduate student participation; and
- good space science.

As in the case of the users, the suppliers endorse a made-in Canada program both to repatriate Canadian space science and to build a technology base for exporting small applications-oriented satellites.

6. Spin-offs

Five companies were identified in the interviews as direct spin-offs of the rocket and balloon program. Four are active in Western Canada, one is in Quebec. All are suppliers of hi-tech instruments ranging in application from space science to agriculture.
The skills developed under the rocket program contracts provided the manpower base from which to build other hi-tech divisions in the companies:

> SED now has four divisions. The annual budget has grown from $250K in 1965 to current sales of $25M. Staff is now at 270 people. Bristol Aerospace maintains a strength of 25 professionals plus technical support staff in the space systems group. The company now covers a wide range of satellite technologies.

Significant exports have resulted from the rocket program. Bristol Aerospace claims most of the free-world market for sub-orbital flight, with 30 to 40 launches per year. NASA alone plans 28 Black Brant launches in 1990. In addition the company is integrating rocket payloads for NASA and European clients.

Instruments conceived and developed for the rocket program have been the source of most space science instrument technology for satellites.
The presence of the ADGA staff brought annual payroll and other expenses in the amount of $1.9M to the Gimli and Churchill economy. Rocket events at CRR provided significant income to the local economy during the tourist off-season.

While it has been mentioned above as a benefit, the emergence of Canada as a nation respected for its space science and the payoff that investment brought in international goodwill might well be regarded as a spin off, because it was more of a bonus than a prime objective of the rocket program or the Alouette/ISIS satellites.

7. Key Success Factors

Interviewees cited the key success factors of the rocket program as:

- the key to the success of the Alouette program was timing;
- the rocket program was an "enlightened program";
- in the early days the rocket program was industry driven. Bristol Aerospace contacted potential payload users to make them aware of the opportunities for experimentation;
- the success rate was high;
- a limited number of companies were involved;
- repetition of the launches built reliability;
- repeated experience refined the engineering skills and kept the same people on the job;
- enthusiasm and mutual support among scientists and engineers was high;
- good science was carried out;
- Canadian control meant that participants were their "own bosses";
- Black Brant is a very reliable rocket;
- CRR is a good physical range for recovery; and
- External Affairs promoted the program internationally.

8. Strengths

- science was left to the scientists;
- short projects allowed students to participate directly;
- students obtained a good perspective on the profession;
- an all-Canadian program; and
- more development work in industry than in the case of 'big' science payloads.

9. Weaknesses/Problems

Some interviewees could not recall any serious weaknesses. Others commented as follows:

- lost payloads;
- delays on the pad waiting for (unrealistic) optimum conditions have cost much time and money;
- too much a shoestring operation, with inadequate interface testing, no high-reliability techniques;
- not enough PR to the public about the quality of the science and the spin-offs;
- government labs were reducing space science programs, universities were contracting for the work but the scientific community was too small to maintain depth; there were too few proposals near the end of the program, so there was little incentive to be daring; nearly all proposals were accepted; and
- by the time CRR was closed in 1984 the operation at Churchill had become too expensive. Permanent staff cannot be justified. Closing the range except during campaigns, as is done in Andoya and Kiruna makes more sense.

10. Future Interest

We received a strong expression of future interest in a small-satellite program and strong recommendations that such a program be established in Canada.

The work being carried out under the Earth Environment Space Initiative (EESI) project could involve Canadian space scientists in the development of unique instruments. Small remote-sensing satellites on short missions are needed to complement large satellites such as Radarsat.

Interest in a rocket program was expressed also, but of the two options the small satellite was the clear choice. Rockets are seen as an excellent test-bed for proof of concept and qualification but satellites are preferred for space science because of their cost-effectiveness. The availability of other ranges calls into question the need to re-activate CRR, at least as a first priority.

10.1 Conditions

- future programs must be made-in Canada, be Canadian controlled and have Canadian objectives;
- programs must have assured continuity;
- scientists are too committed and the present cadre of scientists is too small to begin a new program before about 1993-4;
- the Canadian space science researcher base should be restored to the level of the early 1980's; it is now only 50% of the earlier level;
- clear up jurisdictional problems with AES regarding research in the lower atmosphere: CSA should cover all altitudes;
- study off-shore markets for small applications-oriented satellites; and
- small-satellite missions must be innovative and not copy existing techniques.

11. Conclusions

Our interviews have established that the rocket program brought important and distinct benefits to Canada for almost 20 years. Both users and suppliers obtained direct benefits, and Canada gained as a country in the numerous spin-offs that came as a bonus.

The study has revealed the particular benefits of an indigenous program:- national identity and team building. Since 'going international' the reputation of individual scientists has continued to be maintained but the Canadian space science community has lost it's sense of identity and is subject to external priorities over which it has little or no control.

We sensed a strong appeal to CSA to weigh the cost of future proposals for international big-science projects and to re-introduce an innovative made-in-Canada component into the Canadian space science program.

Table 1 contains a summary of the benefits.

12. Additional Comments

During the interviews we received many comments about the current state of affairs in Canadian space science and suggestions for the future. Many of these comments have been used in our report to place the views of the benefits of the rocket and small-satellite programs in context. Others deal with present problems and policies that are beyond the scope of our task. Still others concern benefits that are not yet proven. A summary of these comments is given here, in no particular order.

- Every country with a space program has a space science program.
- Government policy to participate internationally hurt the domestic program.
- Large international programs are 'peaky' with big valleys. Manpower loading is difficult to optimize.
- A big problem with small-satellite programs is keeping them small. Budget control may be the most effective method.
- The management demands of a satellite program are often under-estimated. This responsibility must be emphasized and taken into account at the planning stage.

Table 1. Summary of Benefits

Category	Benefits	Key Success Factors
USERS	. good science;	. regular predictable rocket launchings;
	. data complements satellite and ground-based measurements;	. simple management;
	. graduate student training;	. affordable;
	. Canadian team, with mutual support;	. high quality industry support;
	. international recognition with data exchange;	. rocket altitudes are unique;
	. new instruments for rockets and satellites;	. Canadian control.
	. foreign invitations.	
SUPPLIER	. hi tech start-up;	. regular events;
	. base for diversification;	. predictable time-tables;
	. steady, challenging work;	. team kept together;
	. attracted young workers;	. repetition built up reliability and high success rate;
	. training in systems engineering.	. limited number of companies;
		. industry/university teams.
SPIN-OFFS	. international 'Canadian' identity in space science;	as above
	. foreign sales of rockets;	
	. regional development in the west;	
	. corporate diversification;	
	. new hi-tech companies.	

- Norway and Sweden have developed and maintained at-home programs, Canada has not.
- If Canada must participate in international programs there should be a companion Canadian program in small science.
- Closing CRR produced a domino effect that saw the decline of rocket payloads even though a rocket program as such was not cancelled.
- Canada cannot afford to let Canadian policy be guided by international forces.
- There are no career positions in Canadian universities to establish a small-satellite program; 3-year appointments are going begging. Permanent appointments are required to rebuild the Canadian space science community, especially the solar-terrestrial component.
- The centres of excellence have bought four years of short-term improvement. Long-term outlooks are not optimistic without a change in government policy.
- Canadian scientists have developed amazing instruments that command world-wide respect. Much of that development has ceased with the demise of rocket payloads. The only active party is HIA.
- NSERC funding is not well suited to instrument development. It is short term whereas instrument development can take up to 10 years. The average award of $30K will only pay a part-time technician or a PDF.
- NASA proposals are harder to win, they are going to US scientists.
- Canadian space science must not be tied to NASA without a made-in-Canada component.
- Canada should consider an innovative project for the Moon-Mars program that is Canadian planned and executed, including the launch costs. There are big challenges for SPAR for example in robotics of an unmanned earth-observation station on the moon.
- A Canadian small-satellite program could be put in place quickly and at a reasonable cost using launchers such as Pegasus which can place 250Kg in a 400Km polar orbit for less than $20M.
- After development of a bus, small satellites could be built for $5M or less.

- Benefits of a Canadian small satellite program would be immediate:

- payback in industry;
- payback in the environment;
- payback in the universities;
- payback to the provinces in the form of environmental solutions.

- A large market is opening up for small-satellites in low orbits, 70% of which are polar. A typical project is 250-300 lbs in a 400Km polar orbit.

- A Canadian small-satellite bus would sell off-shore. Because of it's heritage it would be space-qualified.

- EESI is geared to a 1st launch in '94. The currently funded study is a program definition and ends in 1991 with the delivery of an implementation plan. The build-up of capability in the program will be incremental. Applications to environmental monitoring needs are being examined. Benefits and Canadian capability are being studied. A Canadian environmental mission will be proposed.

  The EESI team is staying close to the users. University scientists will advise on how to monitor the critical parameters of the environment.
  A key objective is to develop the technology.

- A Canadian launch for orbital flight from CRR is a practical proposition. With the Canadian expertise in satellite development and integration, the technology for a launcher based on the Black Brant, and the CRR, Canada could be in a position to offer turnkey small satellite projects to off-shore clients requiring polar orbits.
  A launch rate of one per month would be reasonable with Canada 'buying' one per year. Canada should look into this market and analyze the economics of such a scenario immediately as part of a 10-year plan.

13. Acknowledgements

We wish to acknowledge the support received from a number of people in the Space Sciences Division of the Canadian Space Agency. Immediate response to requests for information together with constructive feedback has allowed our assignment to progress efficiently.

Appendix I

ROCKET AND SMALL-SATELLITE PROGRAM BENEFIT STUDY

Interview Guide

ROCKET AND SMALL-SATELLITE PROGRAM BENEFIT STUDY

INTERVIEW GUIDELINE

History of participation in the program:
dates; $; role(s) as provider or scientific user; good/bad result.

Benefits:

1.Economic:
time span; $ level per year(for example); unique, skilled, manpower base for space and other; technology base; capital plant; export market; Return On Investment(R.O.I.); seed base for industrial diversification;
future prospects in 1984, before and after termination;
source of offshore funding for provider or scientist;
spin-off companies; seed for other research funding.

2.Political/social/cultural:
made-in-Canada; international profile; attracting new workers;
confidence, in Canada, in scientific research; solving Canadian problems; international leverage for sharing projects.

3.Scientific:
short-term; long-term; military; international leverage for sharing results; future researcher base.

Key Success Factors:
Strengths:
Weaknesses/Problems:

Future Interest:
short/long term;
conditions.
Additional Comments:

Appendix II
LIST OF INTERVIEWEES

LIST OF INTERVIEWEES

Name	Affiliation	Interview Date	Type of interview
Dr.D. Kendall	CSA	19/9/90	Face-to-face
Mr.J.Dorey	COMDEV	25/9/90	Telephone
Dr. G. Rostoker	University of Alberta, Calgary	25/9/90	Telephone
Dr.L.Cogger	University of Calgary	27/9/90	Telephone
Mr.A.Raab	Canadian Astronautics	27/9/90	Face-to-face
Mr.Barry Payne	Bristol Aerospace	2/10/90	Face-to-face
Mr.D.Epp	SED Systems	2/10/90	Face-to-face
Dr.D.McEwen	University of Saskatchewan	2/10/90	Face-to-face
Dr.R.Nicholls	York University	3/10/90	Face-to-face
Dr.R.Tennyson	UTIAS	15/10/90	Telephone
Dr.J.Murphree	University of Calgary	17/10/90	Telephone
Dr.P.Forsyth	University of Western Ontario	2/11/90	Face-to-face
Mr. J.Hill	ADGA	1/11/90	Face-to-face
Dr. Demitris Delikaraoglou	Geodetic Survey of Canada	30/10/90	Face-to-face

Appendix III
GLOSSARY OF ABBREVIATIONS

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AES	Atmospheric Environment Service
CCSS	Canada Centre for Space Science
CRR	Churchill Rocket Range
CSA	Canadian Space Agency
EESI	Earth Environment Space Initiative
EMR	Energy Mines and Resources
FOCUS	Flexible Orbiting Carrier Utilizing Shuttle
FREJA	A Scandinavian satellite
ISIS	International Satellite for Ionospheric Studies
NASA	National Aeronautics and Space Administration
NRCC	National Research Council of Canada
NSERC	National Science and Engineering Council
PDF	Post-Doctorate Fellow
PR	Public Relations
SFRB	Space Research Facilities Branch