SED SYSTEMS INC.

STUDY FOR
A CANADIAN SPACE
CONTROL CENTRE

AUGUST 1989

SED Systems Inc.
in consultation with:

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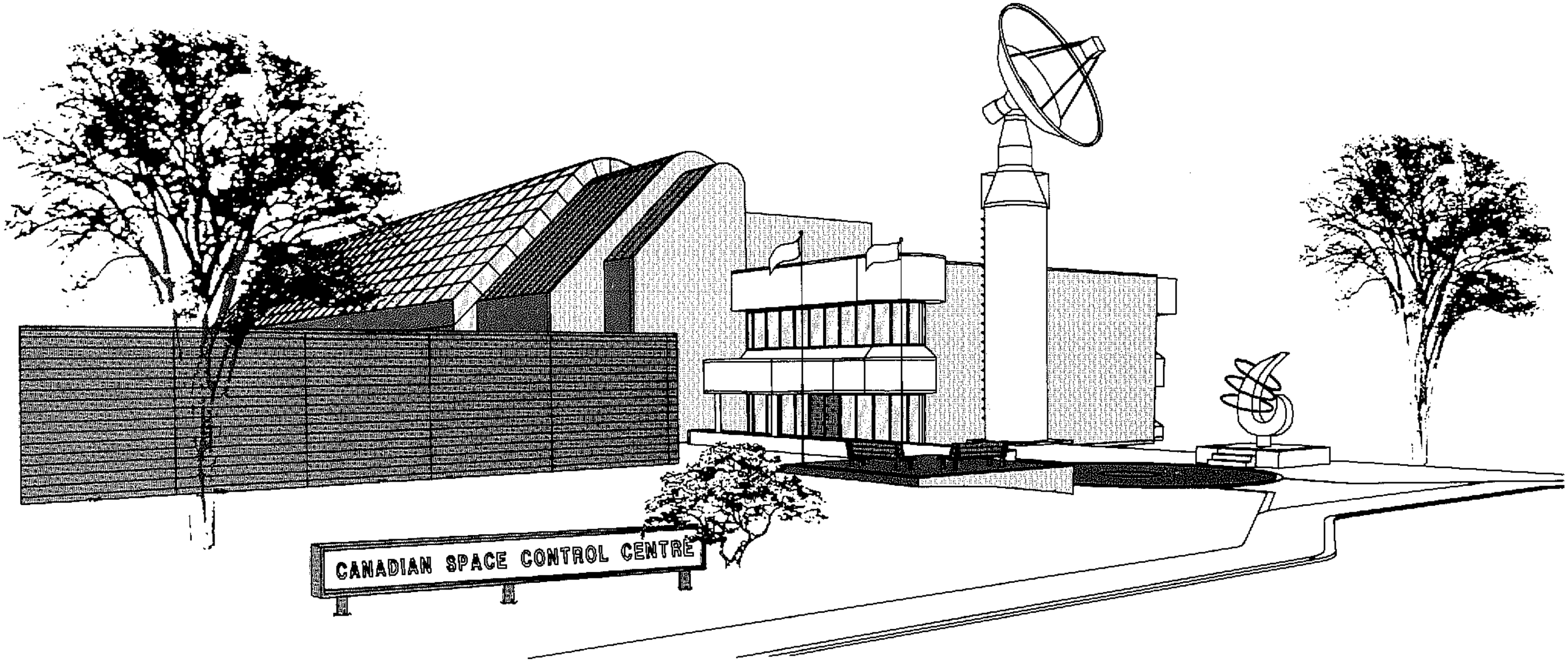


KILBORN

SED SYSTEMS INC.

FEASIBILITY STUDY FOR A

CANADIAN SPACE CONTROL CENTRE

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

SECTION				PAGE NO.

TABLE OF CONTENTS (Cont'd)

SECTION

SED SYSTEMS INC.

FEASIBILITY STUDY FOR A

CANADIAN SPACE CONTROL CENTRE

LIST OF TABLES

SED SYSTEMS INC.

FEASIBILITY STUDY FOR A

CANADIAN SPACE CONTROL CENTRE

LIST OF FIGURES

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

In 1988, SED Systems Inc. (SED) conceived the need for a Canadian centre to control and monitor scientific satellites and space platforms in support of national and international space activities. In order to expand the concept, SED sought support from the Department of Regional Industrial Expansion and the Saskatchewan Department of Science and Technology, which jointly funded this feasibility study under the Canada/Saskatchewan Subsidiary Agreement on Advanced Technology.

The purpose of the study was to investigate the feasibility of establishing a Canadian Space Control Centre in Saskatoon, Saskatchewan and, if appropriate, to recommend further actions required to define and establish the Centre.

1.2 THE CONCEPT

The proposed Canadian Space Control Centre will be a manned facility which will control and monitor scientific satellite and space platforms. The Centre's ultimate objective will be to provide a multiuse satellite ground control facility including data collection and dissemination capabilities. The Centre is envisioned to grow in stages. As a beginning, the Centre will perform the Telemetry Tracking and Command functions for the Radarsat program. The Centre's "start-up core group" will identify further opportunities and requirements, and promote and market the facility's resources and capabilities for both domestic and foreign programs. The Centre's marketing and business development activities will identify new operational, technical and project development requirements. As the Centre grows operationally, the recognition of Canadian space capabilities will increase proportionally, providing further opportunities for Canadian participation in space activities.

1.2 THE CONCEPT (Cont'd)

The Centre will transfer the technical requirements to academic institutions and industry so that advanced technologies, systems and projects may be developed and produced. These systems will be implemented at the Centre for specific programs and/or products for domestic and foreign markets. Thus, the Centre will be a focus of space control technologies and applications.

1.3 SYNOPSIS OF CONCLUSIONS

The study concludes that the placement of a Canadian Space Control Centre in Saskatoon is feasible and highly desirable. The Centre will provide clear benefits in the management and control of Canadian space program operations, and in the technological, social, economic and educational development of the region. In addition, the Centre will assist in achieving national political objectives of regional distribution. The Centre is projected to be a viable and self-sustaining business venture in the short term. The key conclusions of the study can be summarized as follows:

1.3.1 A Space Control Centre is a Viable Business Venture

The Space Control Centre will require financial assistance only during the first two years to cover formulation and start-up costs. Once the Centre initiates a revenue stream from the Radarsat program in 1993, it will become a financially self-sustaining operation as shown in Table 1.1. Capital costs of the program will be financed through long-term debt, and the Centre will easily meet the standard interest coverage and debt-to-equity requirements once it is in an operational mode.

As additional programs are attained, the Centre will become more cost effective, thereby offering a competitively-priced service and providing an excellent return on investment. The Centre will then be in a

TABLE 1.1

CANADIAN SPACE CONTROL CENTRE
10 YEAR FINANCIAL SUMMARY ($000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
REVENUE	-	-	2451	2644	2775	8525	8904	9284	9699	12,508
OPERATING INCOME (AFTER RECOVERIES)	(1051)	(830)	109	120	126	811	846	884	922	1375
OPERATING INCOME AS % OF REVENUE	-	-	4.4%	4.6%	4.6%	9.5%	9.5%	9.5%	9.5%	11.0%
SUSTAINING GRANTS	958	730	-	-	-	-	-	-	-	-
NET INCOME	-	-	53	72	90	290	353	376	443	682
NET INCOME AS % OF REVENUE	-	-	2.2%	2.8%	3.3%	3.4%	4.0%	4.0%	4.6%	5.5%
CAPITAL COSTS	67	-	771	-	-	2260	-	596	-	658
EMPLOYMENT	5	5	22	24	24	73	73	73	79	90

1.3.1 (Cont'd)

favourable position in 1995 to attain programs for the export market to meet its growth potential.

1.3.2 The Space Control Centre is Best Located in Saskatoon

The principal reason for locating the Centre in Saskatoon is that it can be built from an existing facility and infrastructure. Using the SED facility significantly reduces start-up costs that would be incurred if a new facility were required. Also, in the first few years of operation, SED's existing administrative services can be utilized, further reducing initial cost. Colocating the facility at SED will allow existing expertise to be applied to the development and operation of the Centre. SED has been a part of Canadian space programs since 1965, and international projects beginning in the early 1980s. Today, SED is the only Canadian company actively promoting the development of satellite ground control technology and development. In parallel, SED works closely with Canada's space science community developing and producing space science instrumentation. SED provides the technical background, knowledge and capability to make the Centre a success.

Saskatoon provides some advantages because of its physical location. Saskatoon's latitude of 56 degrees provides exceptional tracking coverage over Canada's land masses. Saskatoon receives more sunshine in a year than any other Canadian city. This is technically advantageous for communications and commanding of satellites at higher frequencies.

1.3.3 The Space Control Centre is a Cost-Effective Means to Manage Canada's Space Operations

The Space Control Centre has been designed to be a cost-effective means of managing Canada's Space Control requirements. Because numerous programs can be controlled from a single facility, economies will be

1.3.3 (Cont'd)

achieved by communalizing support functions. In addition, because space allocated to the Centre can grow and shrink as programs require, there is no need to build-in for future expansion. This results in an efficient cost-effective use of facility space.

1.4 THE SPACE CONTROL CENTRE WILL FACILITATE REGIONAL DISTRIBUTION OF THE SPACE PROGRAM

In the May 1985 Space Plan proposed by the federal government, the Prairie region was targeted to receive ten percent of the expenditures on space activities. To date, only the industrial portion of space expenditures has been addressed. Even on this portion of the plan, the Prairie region is falling well short of the targets established. The Prairie region will receive approximately eight percent of the funds against a target of ten percent. This disparity of distribution versus the targets will probably be worse when the non-industrial portion of the work is distributed.

Establishing the Space Control Centre in Saskatoon is probably the most significant way to assist the Prairie region in meeting the ten percent target. It will help achieve the ten percent of the industrial portion, and because it provides a long-term operation, it will help meet the distribution targets of the non-industrial funding. Without the establishment of the Centre, Regional Distribution will be a significant problem in the Prairie region.

1.5 THE SPACE CONTROL CENTRE WILL BRING SIGNIFICANT SOCIOECONOMIC BENEFITS TO WESTERN CANADA

The principal socioeconomic benefit in establishing the Space Control Centre is the creation of employment in the Prairie region. Based on the analysis performed, the Space Control Centre will create over 100 direct jobs for managerial, technical, research and clerical personnel

1.5 THE SPACE CONTROL CENTRE WILL BRING SIGNIFICANT SOCIOECONOMIC BENEFITS TO WESTERN CANADA (Cont'd)

at the Centre. An additional 60 to 85 direct jobs will be created for the development of hardware and software technologies for ground control systems. The creation of approximately 175 direct jobs would result in 450 indirect jobs in the area.

The University of Saskatchewan and other Prairie universities will also benefit from the establishment of the Centre. The Centre will provide employment for graduates, as well as providing application-dependent research into space activities.

The Centre will also provide spin-off opportunities for other high tech and science-related companies.

1.6 RECOMMENDATIONS

Clearly, the establishment of a Space Control Centre in Saskatoon is technically feasible, and within a short time becomes financially viable. It provides significant socioeconomic benefits to Saskatoon and the Prairie region.

However, its establishment requires the support and financial backing of the government. The following actions are recommended:

- Canadian Space Agency support the concept of the Space Control Centre in Saskatoon and provide assistance in soliciting government funding to sustain the Centre's operation until it becomes financially viable.

- Canadian Space Agency and SPAR Aerospace commit to having relevant portions of Canadian space programs allocated to the Centre.

1.6 RECOMMENDATIONS (Cont'd)

- The Centre's core management and marketing staff be established early in 1990 to begin the detailed planning required to make the Centre a success.

Commitments from the Canadian Space Agency, SPAR Aerospace, and government departments are required to make the Space Control Centre in Saskatoon a reality. These commitments are required in the immediate future so that imminent opportunities are not lost.

2.0 INTRODUCTION

2.1 BACKGROUND

SED Systems Inc. (SED) of Saskatoon, Saskatchewan, one of Canada's founding companies of Canadian space technology, identified a need to establish a Canadian Space Control Centre (CSCC) for scientific satellites and space platforms.

This need was identified after a preliminary analysis by SED of requirements for the Canadian Space Programs and other foreign market potential. The initial assessment indicated that having a single CSCC for scientific satellites and space platforms would:

- Minimize the overall cost for a CSCC by minimizing infrastructure and other related costs.
- Provide more efficient management of space control systems through a singular CSCC.
- Attract international space agencies to cooperate with Canada in supporting space activities.
- Assist SED in establishing a centre of expertise for the research and development of the technologies and designs for the testing and control of satellites and space platforms.
- Assist SED in establishing new technologies for sale in the international market.

To assist SED in further developing this market concept, SED submitted a proposal to the federal Department of Regional Industrial Expansion (DRIE) seeking funds for a study. The proposal was submitted to DRIE under the Canada/Saskatchewan Advanced Technology Agreement - Development Analysis Program. The program is jointly administered by DRIE and the Government of Saskatchewan, Department of Science and Technology. The proposal identified the purpose for the study, the scope of work to be undertaken, the consulting team, costs for the study

2.1 BACKGROUND (Cont'd)

and a schedule for completion of the study. The proposal (which is the sole property of SED) was approved and accepted by both the federal and provincial governments and work commenced in early February 1989.

It is the intent of SED to distribute the report to all relevant and interested organizations, institutions, industry, and governments to solicit support for establishment of a CSCC in Western Canada.

2.2 PURPOSE AND OBJECTIVES OF THE STUDY

The purpose of the study is to determine the feasibility of placing a CSCC for scientific satellites and space platforms in Western Canada. To determine the feasibility of the proposal, the study will:

- Outline the current and future programs requiring a Space Control Centre.
- Complete an assessment of domestic and foreign markets for the centre.
- Identify the technical requirements for a Space Control Centre.
- Determine the organizational structure, management philosophy and staffing requirements for operation of the centre.
- Complete a preliminary site evaluation and layout of the Space Control Centre.
- Examine the regulatory issues that may impact the Space Control Centre.
- Determine the capital cost of the facility.
- Determine the operating cost for the Space Control Centre.
- Examine and propose a business plan with ownership/operation alternatives.
- Outline the economic and industrial development benefits resulting from a CSCC in Western Canada.
- Support the objectives of the Canadian Space Program.

2.3 STUDY PROPONENT

SED is one of Canada's founding companies of Canadian space technology. SED's space activities originated with Canada's space science program, upper atmospheric research, in 1965. Since 1965, SED has maintained its profile in space science with all work contracted from the National Research Council. Until the early 1980s, this scientific research was carried out by using suborbital sounding rockets as the vehicles to carry the scientific instruments into space. Worldwide, more and more science is to be carried out with satellite, space platform, shuttle, or space station borne instruments. SED is participating in two programs where the instruments are delivered into an earth orbit.

On February 22, 1989 Japan launched a satellite with eight scientific instruments. Through a seven million dollar contract with the National Research Council of Canada, SED designed and built the first foreign scientific instrument flown by the Japanese.

SED's other major space activity is the design and manufacture of test systems. SED's work in this area began in 1971 with the conversion of the Prince Albert Radar Laboratory into a satellite tracking station for the Earth Resources Remote Sensing Satellite. SED operated this station until the end of 1987, a total of 15 years. Also in the early 1970s, SED provided the real-time software for the control and flight of Hermes, Canada's CTS satellite.

In 1978, SED contracted with Hughes Aircraft Company to provide satellite test equipment. These contracts led ultimately to SED providing the Ground Control System for the Brazilian domestic communication satellite, under contract to SPAR Aerospace. Included in the Brazilian contract, SED designed and developed a communication satellite monitoring and test system. This system's capabilities were further developed and enhanced and have been sold to INMARSAT, Luxembourg's Direct Broadcast Satellite, and British Satellite Broadcasting in the United Kingdom.

2.4 CORPORATE OBJECTIVES OF SED SYSTEMS INC.

The following is a listing of corporate objectives established by SED to ensure a profitable growing corporation in a highly technical and demanding industry.

- Become a centre of expertise for the research and development of the technologies and designs of both hardware and software systems, which are applied to the testing and control of satellites and space platforms.

- Commercialize the technology and be competitive in satellite test and monitoring and mission control systems on a worldwide basis.

- Become Canada's operator for providing tracking and control of both national and international science, remote sensing satellites, and space platforms.

- Cooperate with and support all members of Canada's space community so that through strength of numbers and technical capability, Canada is recognized as a leading space technology country in the world.

- Strengthen the Canadian Space Program through diversification and distribution of the technology across Canada so that all regions can benefit by advancing technology and job opportunities in Saskatchewan and the Prairie region through spin-off technologies, products, and export market opportunities.

- Become clearly recognized as the space leader in the Prairie region, cooperating with and assisting in the development of progressive, innovative and potentially marketable industry in the region.

- Provide greater marketing and technical support to SPAR Aerospace Ltd., (the prime contractor for Canada's Space Program) with ongoing satellite ground segment technology development. SPAR's international marketing efforts will be enhanced with state-of-the-art control, test, and training systems.

2.4 CORPORATE OBJECTIVES OF SED SYSTEMS INC. (Cont'd)

- Cooperate more closely with the universities and academic institutions to translate and convert basic research into commercial space-related applications.

To meet these objectives, SED firmly believes that the placement of the CSCC in Saskatchewan would act as:

- A catalyst for a centre of expertise to encourage the further development in Saskatchewan and Western Canada of the design, development, integration, and marketing of Canadian Satellite Control, Test and Monitoring Systems on a national and worldwide basis.

- A focus of expertise and knowledge to define and develop new technologies to meet the needs of complex satellites and satellite constellations into the 21st century.

- A focus of expertise and knowledge to identify and develop spin-off technologies, projects, systems, and applications that are exportable globally.

In addition, the operation capability of a Space Control Centre could be expanded to include strategically located telemetry, tracking and command (TTC) stations capable of tracking, commanding, and receiving data from polar orbiting satellites. This ring of stations would participate in international science programs, military programs, and the newly initiated international environmental monitoring programs.

2.5 SITE VISITS AND INTERVIEWS

Interviews were conducted with numerous government representatives, agencies, companies, research councils, etc. to better establish the requirements and needs for a CSCC. We would like to thank the organizations identified below for their time and candor, and note that they are in no way responsible for the views and conclusions expressed in this document.

- Canadian Industry Representatives
  - MacDonald Detwiler Associates
  - SPAR Aerospace Ltd.
  - Telesat Canada

- Federal Government Agencies and Departments
  - National Research Council, Space Division
  - Department of Regional Industrial Expansion
  - Department of Communications
  - Canada Centre for Remote Sensing
  - Space Affairs Counsellor, Canadian Embassy, (Paris, France)
  - Radarsat Project, Technical Office

- Provincial Agencies and Departments
  - Saskatchewan Department of Industry Science and Technology
  - Ontario Ministry of Industry, Trade and Technology
  - Saskatchewan Economic Development Corporation

- Foreign Industry Representatives and Government Agencies
  - European Space Agency, European Space Operations Centre, (Darmstadt and Odenwald, Germany)
  - SAT Control (Toulousse, France)
  - SPOT (Toulousse, France)
  - CNES (Toulousse, France)

- Other groups
  - City of Saskatoon
  - Saskatchewan Research Council
  - University of Saskatchewan
  - University of Colorado

2.5 SITE VISITS AND INTERVIEWS (Cont'd)

Site visits were made to two operating control centres in Europe and a smaller university-operated-and-controlled satellite in Boulder, Colorado. The purpose of the site visits was to obtain firsthand knowledge of existing operating systems which may have similarities to that proposed for the CSCC. At each location, information was solicited about the organizational structure, responsibilities, facility layout, operating procedures, hardware and software development, costs, and ownership. The following sites and agencies were visited:

- SAT Control - Toulousse, France
- CNES - Toulousse, France
- ESA (European Space Agency), ESOC (European Space Operations Centre) - Darmstadt, Germany
- ESOC METEOSAT Ground Station - Odenwald, Germany
- SME (Solar Mesosphere Explorer) Satellite Control, University of Colorado - Boulder, Colorado

For the purpose of this report and for the reason of brevity, it is not necessary to discuss the details of each site visit but rather to highlight the significant points raised during discussions:

- The space program was established in Toulousse at the direction of the French National Government to decentralize some high-tech capabilities from Paris to other cities in France. The aircraft industry was already established in Toulousse and the direction of space activities to this City was a natural extension. The significance of this point is that there are striking similarities between this description and the proposal to establish a Space Control Centre in Saskatchewan. These similarities include regional distribution, a city with a high-tech industry base, a strong university, and strong regional support.

2.5 SITE VISITS AND INTERVIEWS (Cont'd)

- The remote Odenwald tracking site is totally automated and controls the METEOSAT satellite using only a skeleton staff of six people for equipment maintenance and facility maintenance. All activities are directed from Darmstadt through communication lines. This arrangement is of particular interest to Canadian applications should the antennae and related control equipment be located in a remote northern site.

- The SME satellite controlled at the University of Colorado is managed with a small, effective team which, in turn, is staffed partly by second year university students. This arrangement is of particular interest in increasing the educational opportunities for university students in Saskatchewan and in establishing a possible long-term commitment and involvement in the existing high-tech space industries of Saskatchewan.

2.6 STUDY ORGANIZATION

Defining the requirements, costs, and benefits of a CSCC was a complex task that required a diverse set of technical, financial, and management skills. No single company could provide the expertise required to complete a comprehensive feasibility study. To ensure all aspects of the study were adequately addressed, SED retained a team of consultants with unique yet complementary skills. The following is a brief description of the roles of each study team member.

SED Systems Inc. - Saskatoon, Saskatchewan

SED is a high technology company with more than 20 years of experience in the satellite communications field. SED acted as the principle investigator of the feasibility study and provided the lead role in defining the technical requirements and preliminary design of the CSCC.

Kilborn (Saskatchewan) Ltd. - Saskatoon, Saskatchewan

Kilborn is a leading Canadian consulting engineering company with extensive experience in the execution of feasibility studies. Kilborn was responsible for the overall management of the study team determining facility requirements, completing capital cost and operating cost estimates, as well as preparing the final report.

Philip A. Lapp Ltd. - Toronto, Ontario

Philip A. Lapp Ltd. is a consulting engineering firm which has been involved in the Canadian Space Industry for the past 20 years. They have had extensive experience in the technological development and market assessment of Canada's Communications and Remote Sensing Satellite programs. Philip A. Lapp was responsible for analyzing domestic and international markets, defining regulatory issues and conceptualizing the structure of the CSCC, as well as conducting numerous interviews with participants in the Canadian Space Program and other related industries.

2.6 STUDY ORGANIZATION (Cont'd)

Deloitte Haskins & Sells - Saskatoon, Saskatchewan

Deloitte Haskins & Sells is a well-known accounting firm in Saskatchewan with offices in Saskatoon, Regina, and Prince Albert. Deloitte Haskins & Sells was responsible for financial analysis and business plan alternatives for the Space Control Centre. They were also responsible for investigating alternative ownership structures and funding mechanisms for the centre.

2.7 REPORT FORMAT

The feasibility study is structured to provide a basic understanding to the reader on the following topics:

- Canadian Space Program
- Demand for a Canadian Space Control Centre
- Technical requirements for the Canadian Space Control Centre
- Organizational structure and staffing for the centre
- Description of the proposed facilities
- Capital and operating cost estimates
- Schedule or development of the programs
- Business plan for the ownership/operation of the centre

For the reader that is more familiar with various aspects of the space industry, references are made throughout the study to the supporting documents which more fully explain the details being discussed.

The final chapter of the study provides a general overview, recommendations, outlines possible future action and makes final conclusions regarding the feasibility of a Canadian Space Control Centre located in Saskatoon, Saskatchewan.

3.0 TECHNICAL DEMAND

3.1 THE CANADIAN SPACE PROGRAM

3.1.1 Introduction

The current Canadian Space Program (CSP) covers the 13-year period from 1988-89 to 2000-01. It includes three major programs:

- The Canadian Space Station Program (CSSP)
- Radarsat - synthetic aperture radar for customized imagery of the earth's surface
- MSat - Mobile Communications Satellite System

Space Science, Communications and Remote Sensing Research and Development, European Space Agency contributions and the Department of Regional Industrial Expansion expenditures make up the balance of the CSP to be spent in industry.

Canada's total commitment over the period will be approximately \$3 billion, \$1.8 billion of which will be spent in industry, \$0.7 billion for in-house federal government activities and \$0.5 billion in foreign procurement.

The government is committed to achieving regional distribution of the industrial expenditures as follows:

10%	Atlantic Canada
35%	Quebec
35%	Ontario
10%	Prairie Provinces
10%	British Columbia

As of September 1988, the industrial expenditures included \$965.4 million to be spent by the prime contractor (Spar Aerospace Ltd.) on

3.1.1 (Cont'd)

the three major programs, and $847.1 million to be spent by government agencies. The in-house expenditure of $0.7 billion represents the A-Base for government agencies in the space program (Canadian Space Agency, National Research Council, Ministry of Space Science and Technology, Department of Communications, Energy Mines and Resources, etc.). The remaining $0.5 billion will be directed to the procurement of Radarsat and MSat buses, as well as other hardware/software which is either unavailable or uneconomical to develop in Canada.

3.1.2 The Canadian Space Station Program

During the Quebec "Shamrock Summit" of March 1985, Canada's Prime Minister accepted the U.S. President's invitation to Canada to participate in developing a multibillion dollar space station. Canada's role would be to develop a Mobile Servicing System (MSS), using the expertise developed in creating the Canadarm. The MSS will include a space-based robotic system and a ground control and simulation facility.

It is anticipated that the space station will be completed in 1997 at an estimated cost of $41 billion, with a projected life expectancy of 30 years. It will provide unique laboratory and manufacturing facilities, storage and repair depots, and the capability to assemble satellites and space platforms too large and fragile to launch directly from earth. The station will also serve as a staging base for manned and unmanned missions to all parts of the solar system. Two other partners in the program - Japan and the European Space Agency - are providing self-contained, pressurized modules to serve as multipurpose laboratories.

When assembled, the space station will consist of a horizontal truss structure, 150 metres long, with photovoltaic solar arrays generating 75 kilowatts of electrical energy. Attached to the centre of the truss will be four pressurized cylindrical modules, each about the size of a bus - two United States modules and the European Space Agency and

3.1.2 (Cont'd)

Japanese modules. The total weight of the station will be 170,000 kilograms, requiring up to 20 shuttle missions during the 1990s to transport all of the pieces into space. The international crew of eight men and women will periodically include Canadian astronauts. The space station will orbit at 500 kilometers, inclined at 28.5 degrees to the plane of the equator.

Canada's MSS will consist of a 17-metre long arm equipped with seven motorized joints and computerized controls. It will be capable of capturing and berthing a 100,000 kilograms shuttle orbiter. A similar, two-armed device called the Special Purpose Dextrous Manipulator will have as many as 19 joints. It will be capable of duplicating many of the servicing tasks performed by space-suited astronauts.

MSS will play a major role in assembling the space station, berthing and deploying vehicles including the shuttle, loading and unloading the shuttle, exchanging logistics modules, servicing payloads anywhere aboard the station, performing station maintenance operations, moving payloads and cargo around the station and supporting extra-vehicular activity around the station.

In return for its MSS contribution, Canada will have access to space station experimental facilities approximately three percent of the time, commensurate with its contribution to the total cost. Canadian astronauts will form part of the crew for these periods, and Canadian users of such facilities will be supported through the User Development Program (UDP). During the life of the space station, it will be necessary to upgrade the MSS. The technology for this purpose is being developed through the Strategic Technologies for Automation and Robotics (STEAR) Program.

3.1.2 (Cont'd)

It is expected that expenditures on the Canadian Space Station Program for the period from 1988-89 to 2000-01 will be as follows:

MSS (via Spar)	$ 666.4 million
MSS Operations	125.0 million
STEAR/UDP Programs	139.2 million
Subtotal Industry Expenditures	$ 930.6 million
Common Operations (spent in the United States)	135.0 million
Government Operation for MSS	70.0 million
Total Canadian Space Station Program	**$1,135.6 million**

3.1.3 Radarsat

The original motivation for Radarsat was to provide near real-time data on ice cover 24 hours a day, year round, to support oil and LNG tankers in the Arctic. Experiments from aircraft showed that a form of radar known as synthetic aperture radar (SAR) operating at C-Band (5.36 GHz) could distinguish between first-year (soft) and multi-year (hard) ice formations, and could therefore be used in ice reconnaissance in all weather conditions. Further studies showed that a C-Band SAR could also be used in vessel movement applications, iceberg detection, ocean sea-state identification, and land renewable resource mapping in agriculture and forestry.

Radarsat will also be valuable for hydrological and geological applications where surface structural mapping of regions covered in dense vegetation is currently difficult and costly.

Radarsat will carry a C-Band SAR with a steerable, adjustable beam structure. This will make it possible to "customize" images to meet

3.1.3 (Cont'd)

the requirements of customers with respect to specific viewing angles and beam widths. A private corporation, Radarsat International (RSI), has been formed to market imagery, perform image processing and, if required, perform image analysis. The company is owned by Spar Aerospace Ltd., Macdonald Detwiler and Associates Ltd., Intera Technologies Ltd., and Digim (NEED CORRECT TITLE).

The Radarsat program has at least three major objectives:

- Present the Canadian Space Industry with a very challenging technological goal

- Maintain the integrity of the Canadian spacecraft prime contractor/subcontractor team

- Acquire data about the earth and oceans of scientific and commercial value to Canada and the rest of the world

Radarsat will be launched by NASA in 1994, and is expected to operate for a period in excess of five years. It will be placed into a sun-synchronous orbit at an altitude of 1000 kilometers. Its steerable beam structure will allow almost total Arctic coverage every day. Most of Canada can be covered in a three-day cycle. Stereo images can be derived from successive passes using beam steering.

Spar Aerospace Ltd. is the Canadian prime contractor building SAR. Spar will integrate SAR with a spacecraft bus which will be procured in the U.S. Canadian Astronautics Ltd. is a major subcontractor on SAR.

Radarsat is supported by both the provinces and the federal government, using a formula based on the amount of value-added, provincial industrial activity generated by Radarsat.

3.1.3 (Cont'd)

It is expected that expenditures on Radarsat will be as follows:

Federal government	$172.5 million
Provincial governments	59.4 million
Subtotal Canadian industrial work	$231.9 million
Operations (federal funding)	47.0 million
Foreign procurement (federal funding)	157.3 million
Total Radarsat Program	**$436.2 million**

3.1.4 MSat

MSat, Canada's domestic mobile satellite system, is planned to be launched in the early 1990s. It will be owned and operated by a Telesat Canada subsidiary, Telsat Mobile Inc. Its purpose is to establish a wide-area communications facility for the provision of two-way voice and data services to domestic land, marine and aeronautical mobile units. MSat is targeted to a market in which there is a need to roam beyond the economic range of terrestrial networks, thus complementing existing facilities such as cellular radio. MSat will allow for the creation of private mobile radio, voice and data networks. It will be able to offer mobile telephone service through gateway stations which provide access to the public telephone network.

Safety-related applications for the service include police, ambulance, search and rescue, fire-fighting and emergency relief operations. Aeronautical and marine applications include operational communications for commercial aircraft, fishing fleets, and coast guard operations, as well as air traffic control. In short, MSat will play a vital role wherever there is a requirement for communications remote from existing facilities. The Canadian government has committed to purchase $126 million of MSat capacity to meet its own needs.

3.1.4 (Cont'd)

The satellite will operate mainly at L-Band (1.5 GHz) and possibly at UHF (800 MHz) to be compatible with terrestrial land, international marine and aeronautical mobile services. A similar system is planned for the U.S. by the American Mobile Satellite Consortium. Spar Aerospace Ltd. is expected to be the payload contractor and integrator for both Canadian and American satellites.

It is anticipated that expenditures on MSat will be as follows:

Canadian industrial work (Telesat funding)	$194.0 million
Federal government purchase of services	126.5 million
Foreign procurement	110.2 million
Total MSat Program	**$430.7 million**

3.1.5 Other Programs

In addition to CSSP, Radarsat and MSat, the federal government funds other space activities in industry which will be subject to the same regional distribution guidelines as the three main programs (namely, 10%/35%/35%/10%/10% - see page 3-1). Over the 13-year period from 1988/89 to 2000/01, these activities will include:

Space Science	$257.5 million
Technology Development related to MSat	41.3 million
Communications R & D	75.8 million
Remote Sensing R & D	110.5 million
European Space Agency	72.5 million
Department of Regional Industry Expansion	25.3 million
Total Other Programs	**$582.9 million**

3.1.5 (Cont'd)

A detailed breakdown of these expenditures is not available, and they will almost certainly change. These figures were used for planning purposes by the government in September 1988 and should be treated as such.

The announcement in the spring of 1989 that the newly-formed Canadian Space Agency will be located at St. Hubert, Quebec, may result in changes to planned expenditures. Moreover, as of May 1989, there is still uncertainty as to the magnitude of the provincial contributions to Radarsat. Nevertheless, expenditures by governments in the order of $1.8 billion will take place in Canadian industry over the 13 year period. It is expected that approximately 10 percent of this amount will be spent in the Prairie provinces.

3.1.6 Canadian Space Plan Influence on the Canadian Space Control Centre

The Canadian Space Plan defines all government expenditures on space activities between now and the year 2000. However, only the Space Station Program and Radarsat program are applicable to the development of the CSCC. Both of these programs have a requirement for ground control facilities which do not currently exist.

The establishment of ground segment facilities for these two programs has been a major driving force behind the concept of establishing a Western CSCC.

3.1.7 Other Domestic Programs

Although space plan programs have the largest influence on the requirement for a CSCC, there are other emerging domestic programs which could make use of the centre. For example, the Western Space Initiative Program will require ground facilities for satellite monitoring and control. This program, which is in the definition phase,

3.1.7 (Cont'd)

will be a Western Canadian initiative to develop an environmental monitoring satellite using the technologies and capabilities of Western Canadian companies. The obvious choice for providing the satellite control capability is the Space Control Centre defined in this study.

3.2 GROUND-BASED SATELLITE CONTROL SYSTEMS

3.2.1 Introduction

Before discussing the technical demands which specific space programs would make on the functionality of a CSCC, we shall present a brief description of a ground-based satellite control system.

This description fulfils a double objective:

- It presents concepts and technology that will be referred to later in the discussion of CSCC as it relates to specific programs; and

- It establishes a generic baseline concept against which the needs of as-yet-vaguely-defined programs for satellite-control support can be judged.

Depending on the particular requirements of a mission, a CSCC could meet the total or a partial requirement for a ground-based satellite control system.

The term 'system' is used in this section to avoid any confusion which could result from the use of the word 'centre' which could be misconstrued as meaning a single physical location.

In the broadest sense, a ground-based satellite control system acts as a gateway between the earth-bound elements of a space project or mission and the space segment. Portions of the system may be distributed geographically but it is still a single system, or more accurately, a subsystem, as long as the elements are integral to the operation in the functional sense. Typically, a ground control system for scientific satellites consists of:

- A Telemetry, Tracking and Command System

- A Mission Control Centre

3.2.1 (Cont'd)

- A Mission Management Office
- Data Reception Station
- A Communications network for interlinking the various facilities and sites.

The physical locations of each of the elements of the ground control system is based on technical constraints, mission requirements, and cost. Each of these elements are further described in the following subsections.

3.2.2 Telemetry, Tracking and Command System

The telemetry, tracking and command (TT&C) system provides the physical link between the ground segment and space segment. It consists of an antenna and radio frequency (RF) equipment for transmitting and receiving signals from the satellite; baseband equipment for converting the RF signals to a state which is usable by a computer; and some computer equipment for performing primary processing. A simplified block diagram of a TT&C is given in Figure 3.

The most visible component of the TT&C system is the antenna. The antenna transmits and receives the signals from the satellite. It is also used to track the satellite to determine the satellite's orbital position.

The RF equipment in a TT&C station is used to provide frequency conversion and RF signal amplification. On the transmit side, signals from the baseband equipment (command and ranging) are frequency converted from 70 MHz to the satellite receive frequency and then amplified by a high power amplifier to levels adequate to be received by the satellite. On the receive side, the low level satellite signal (telemetry and ranging) is amplified, then down-converted to 70 MHz.

3.2.2 (Cont'd)

The 70 MHz signal is fed to the baseband equipment for subsequent processing.

The baseband equipment performs signal processing on telemetry, command and ranging data. For telemetry processing, the signal processing consists of demodulation and decummulation of the data into a serial bit stream which is fed to a computer system for processing. For commanding, the computer generates the commands which are modulated on to a 70 MHz carrier and sent to the RF system for transmission to the satellite. Baseband processing for ranging includes generating of range tones to be transmitted to the satellite, and receiving the tones which are retransmitted by the satellite. The ranging equipment measures the delay from the transmitted signal to the received signal, and from the delay, calculates the range to the satellite. Range data is sent to the computer system for orbit calculations.

The amount of computer processing performed at the TT&C site is dependent on the mission requirements and the physical configuration of the overall network. For the sake of this general discussion, real time processing of the TT&C system will be described as being a function of the TT&C system. Real time processing consists of:

- Satellite Tracking
- Telemetry Processing
- Command Generation
- Range Determination

These functions are performed autonomously at the TT&C site, but they require an extensive interface with the Mission Control Centre (MCC).

3.2.2 (Cont'd)

Satellite tracking consists of steering the TT&C antenna to maintain accurate pointing and contact with the satellite. This is done to maintain communications with the satellite, and to get angular pointing data from the antenna to the satellite. The angular pointing data is used with ranging data to determine orbital position of the satellite. Telemetry processing is performed on the real time telemetry data to determine the instantaneous operational configuration of the payload and satellite bus. Processing includes subcommutation, conversion of primary data to engineering units, displaying the data to the operator, and alarm generation for any satellite parameters which are out of tolerance. Processed telemetry data is sent to the MCC for subsequent analysis and long-term data storage.

Commanding is the process of generating commands to the satellite to control its configuration or perform orbit and attitude correction. Generally, the commands are prepared via the MCC, then forwarded to the TT&C computer. The TT&C computer processes the command, sends them to the command formatter which uses them to send to the satellite. The TT&C computer has the capability to generate and transmit commands in emergency situations.

The ranging function in the TT&C computer system controls the ranging processor and interfaces to the antenna-positioning units. Range measurements are made by transmitting tones to the satellite, and measuring the group delay between the tone transmitted and received. The group delay data is combined with angular pointing data from the ground antenna and passed to the MCC. The MCC uses this data to calculate satellite range and ultimately, the satellite orbital parameters.

3.2.3 Mission Control Centre

The Mission Control Centre (MCC) has the primary responsibility for monitor and control of the satellite's operational condition. Its main functions are:

- Mission Planning
- Flight Dynamics
- Long Term Satellite Performance Analysis
- Satellite System Simulation

All functions within the MCC are automated. The mission planning activity consists of generating and validating a consistent mission time line. Both the spacecraft and ground system schedules are generated automatically by the mission planning system. Since the ground system schedule is dependant on that of the spacecraft, any alterations that are made by editing the spacecraft schedule are reflected in that of the ground system. The output of the mission planning system includes operational procedures and time-based commands for spacecraft operations.

The flight dynamics system is an automated software package to enable timely control of the satellite through all phases of the mission. It provides the following functions:

- Spacecraft Orbital Analysis - Support for the determination, prediction and control of the satellite orbit, including analysis of the ground station coverage. Orbital analysis also includes determination of orbit maintenance maneuvers.

- Spacecraft Attitude Analysis - Ground-based validation of on-board attitude computation via sum sensor, horizon sensor, or magnetometer attitude solutions. Analysis includes determination of attitude control biases for uplink to the spacecraft.

3.2.3 (Cont'd)

- Failure and Contingency Analysis - Support for the analysis of failures and for contingency planning for both satellite attitude, orbit determination and control.

Long-term satellite performance monitoring is typically provided by computer analysis of the stored telemetry data. This function is performed to determine if any of the satellite subsystems are suffering long-term degradations.

Satellite simulations are provided to allow rapid, reliable analysis of now-standard conditions. They are used extensively when an anomaly is detected on the spacecraft. A simulator is also valuable for training operators and validating operating procedures.

3.2.4 Mission Management Office

The Misson Management Office provides the overall direction to the post-launch operations of the satellite system. The associated activities start about six months prior to the launch and continue until to the end of the mission. The Mission Management Office is staffed on an eight-hour-per-day, five-day-per-week basis. The Mission Management Office establishes overall policies and operational orders for the operation of the satellite system. These policies and orders are established on a long-term basis by discussions with senior management of the organizations directly involved and with the national and international users of the data products.

The Mission Management Office provides administrative services to manage and operate the system. These services include provision of finance and accounting control; personnel, clerical and general support; specialized supplies and consumables, offices, operational facilities and warehousing with proper environmental control; and user support including receiving user requests and distribution of data and information products.

3.2.5 Data Reception Stations

Data reception stations receive the satellite's downlink signal which contains the science data rather than the TT&C signals. Scientific data from a satellite is frequently received at more than one geographical site in order to:

- Obtain real-time geographic coverage within the range of the satellite's sensors (as opposed to storing such data until the spacecraft is within range of a ground station)
- Preserve the real-time value of the data
- Avoid saturation of on-board recording capability
- Preserve the privacy of data taken over a politically sensitive region of the earth
- Share the financial and management burden of preprocessing data into a format acceptable to users
- Promote the use of the data for long-term economic, social or political reasons

3.3 TECHNICAL DEMAND OF SPACE PROGRAMS

3.3.1 Radarsat Technical Demand

The requirements for the ground segment of the Radarsat program as described in the following subsections are based on interviews with industry and government officials associated with the program and on the following documents:

- Radarsat MCS Requirements Specification (draft), SPAR
- Radarsat Phase C/D SOW for the Supply of the Radarsat Mission System (draft), SPAR
- System Performance Requirements. Section 4 - Mission Control System Performance Requirements, RPTO, 14/8/86
- Radarsat Phase B Final Report, SPAR, 3/87

3.3.1.1 Radarsat Mission Control System Specifications and Functions

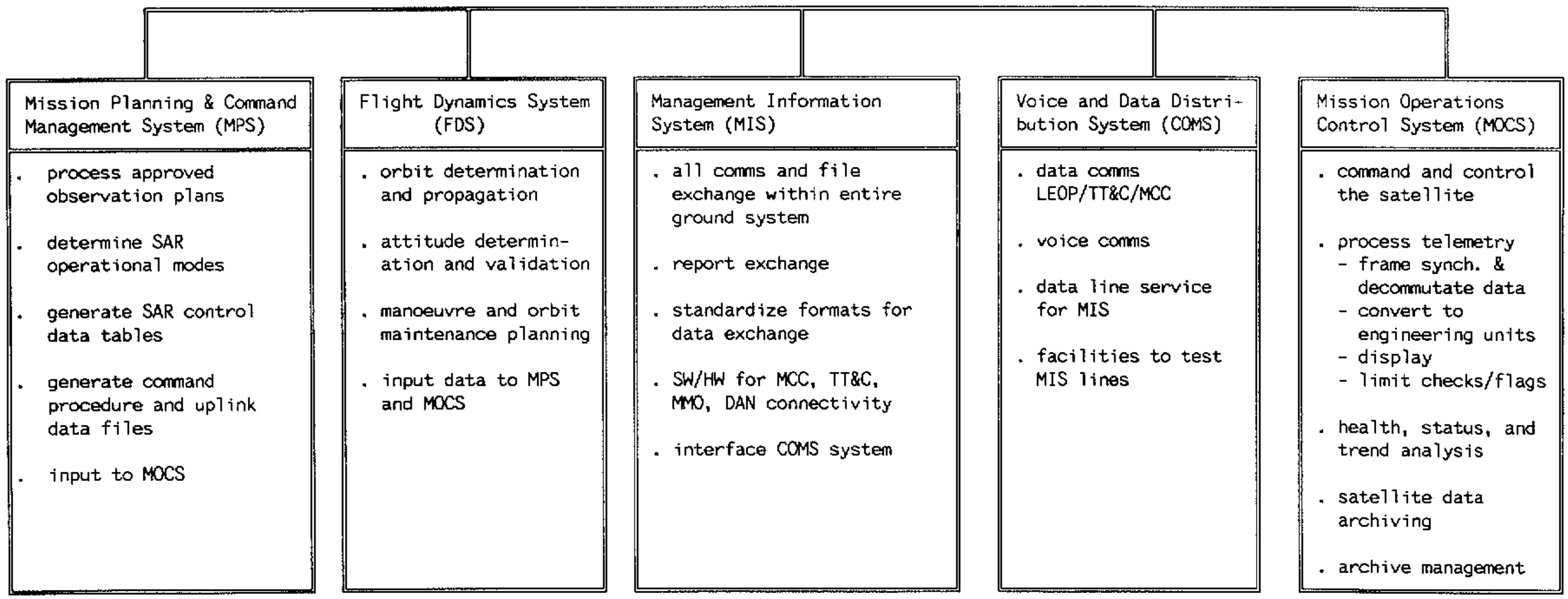
The following is a description of the specifications and functions of the Radarsat mission control system (MCS).

1. The MCS performs all post-launch operations and control. It is composed of the Mission Control Centre (MCC) and TT&C.
2. The MCS for Radarsat consists of five systems as shown in Figure 3.1 and as listed below:

   - Mission Planning and Command Management System (MPS)
   - Management Information System (MIS)
   - Flight Dynamics System (FDS)

FIGURE 3.1

RADARSAT MISSION CONTROL CENTRE FUNCTIONALITY



3.3.1.1 **(Cont'd)**

- Voice and Data Distribution System (COMS)

- Mission Operations Control System (MOCS)

3. The MCS must have fully tested and documented operational procedures for each of the following mission phases:

   - Launch phase

   - Deployment and attitude acquisition phase

   - Dispersion correction phase

   - Commissioning phase

4. The testing of the spacecraft/TT&C/MCC interface must be carried out during the later stages of integration.

5. The prime TT&C station (see Figure 3.2) must be functionally redundant with no single point failures. This requires:

   - 99% availability in each redundant string; and

   - a mean time to repair of 48 hours.

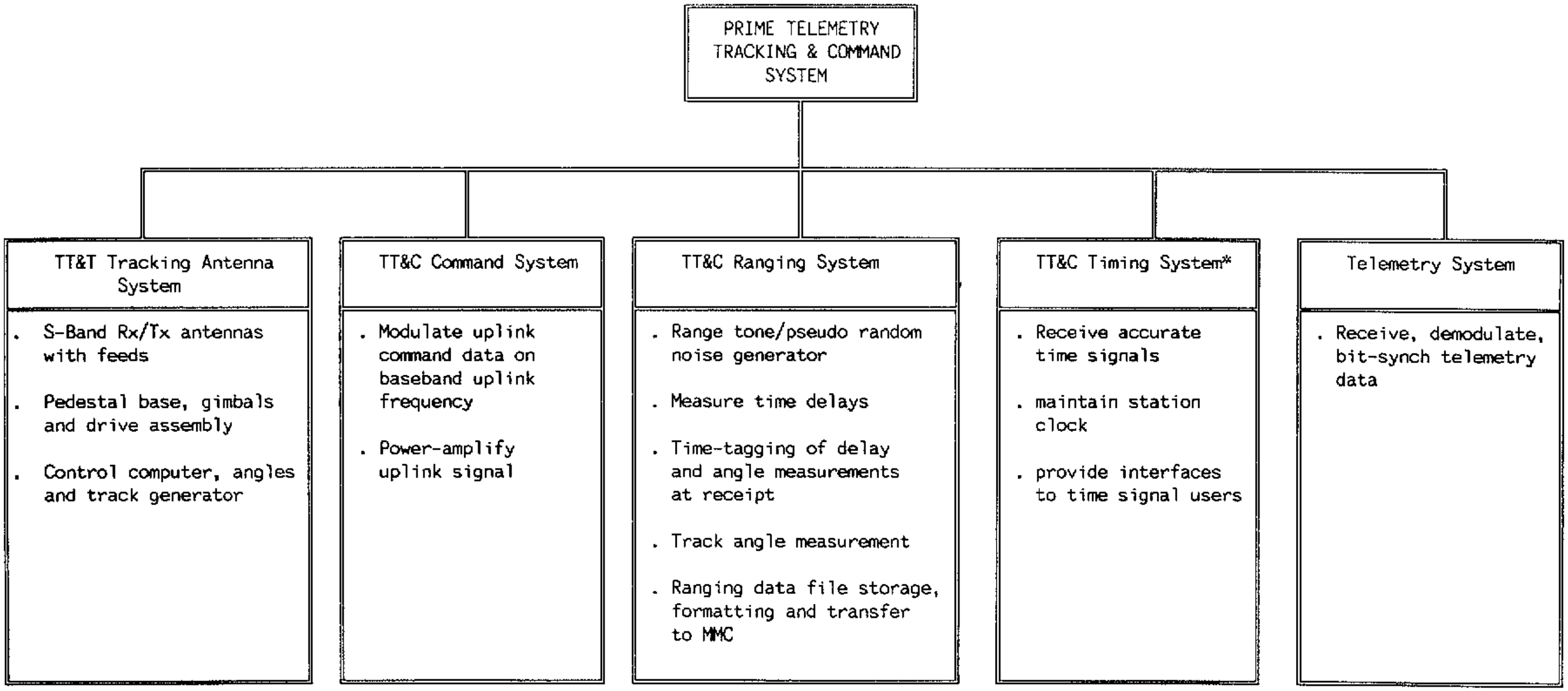
6. A minimum of eight operator positions (10 terminals) and colour CRT displays are required. Hard copy of CRT data must also be available.

7. Commissioning of the spacecraft must occur in the 30 days following final orbit location.

8. Operations control room displays must be capable of providing detailed status reports of the MCS and the TT&C, communications, data acquisition and processing networks, as well as fundamental status reports of the satellite's systems.

FIGURE 3.2

RADARSAT PRIME TT&C FUNCTIONALITY



* Ranging, Doppler, and angle track measurement in TT&C shall be provided to MCC with time-tagging errors no greater than 2 ms. from UTC.

3.3.1.1 (Cont'd)

9. The MCC must be able to process satellite telemetry from the TT&C network in real time. All data will be archived.

10. The MCC will uplink and verify commands or data to the satellite via the appropriate TT&C station in real time.

11. The MCC must process and analyse all housekeeping data off-line. Activities will include display, plotting, researching, and analysis, including trend analysis.

12. The MCC computers must turn tracking data around in near real time. Data must be processed into ephemerides within one hour. Ephemerides will be uplinked to the satellite for inclusion with downlinked payload data. They will be distributed to users.

13. There will be a prime TT&C station and backup TT&C station(s). Backups may not be required to track but will be required to conduct uplink/downlink operations in the event of a failure at the prime station.

14. Operator training must be available throughout the mission to accommodate staff turnover.

15. A basic simulation of the satellite telemetry and command systems will be required. RF elements are not required but post-detection subcarriers are. This simulation will be used to verify the capability of TT&C stations to process telemetred data and to format and send commands and data to the satellite. The simulation will also verify MCS-Communications-TT&C end-to-end operations.

16. In routine operating conditions, the simulation will support the generation of operational procedures and operator training.

17. Communications between the MCC and each TT&C station must support voice circuits and two-way low-rate-data circuits.

3.3.1.1 (Cont'd)

18. Launch and early orbit phase TT&C stations will utilize existing facilities not co-located with the MCC. However, the MCC must interface and communicate with these stations.

19. The prime TT&C station may be co-located with the MCC.

A block diagram of the major systems comprising the Radarsat earth segment, including the MCS is shown in Figure 3.3.

Figure 3.4 illustrates how the control centre might be organized. A distinction is made between on-line real-time control, supported by on-line real-time computer processing, and off-line mission control support, which utilizes off-line computer processing on a more ad hoc basis. This distinction may not be as rigid under operating conditions,when high priority versus low priority demands on shared computer processing facilities will have to be taken into account.

3.3.1.2 Radarsat Implementation

Radarsat is the first Canadian mission which could make use of the capabilities provided by the CSCC. The Radarsat program implementation is anticipating to have the TT&C facility located at the CSCC in Saskatoon, and the MCC at Telesat's facility in Ottawa. From the CSCC perspective, this is not the ideal case, but at least it provides a preliminary foundation from which the CSCC's capabilities can be built. Having the Radarsat TT&C facility located at the CSCC will provide the basis for market development and technology development required to implement full mission capability.

FIGURE 3.3

RADARSAT COMMUNICATIONS NETWORK

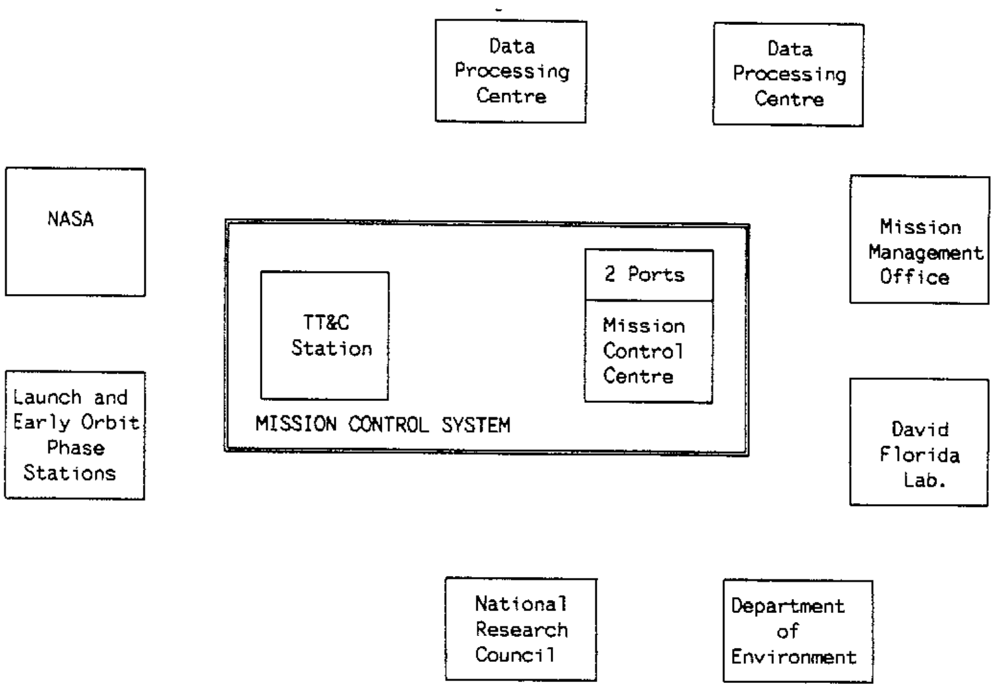
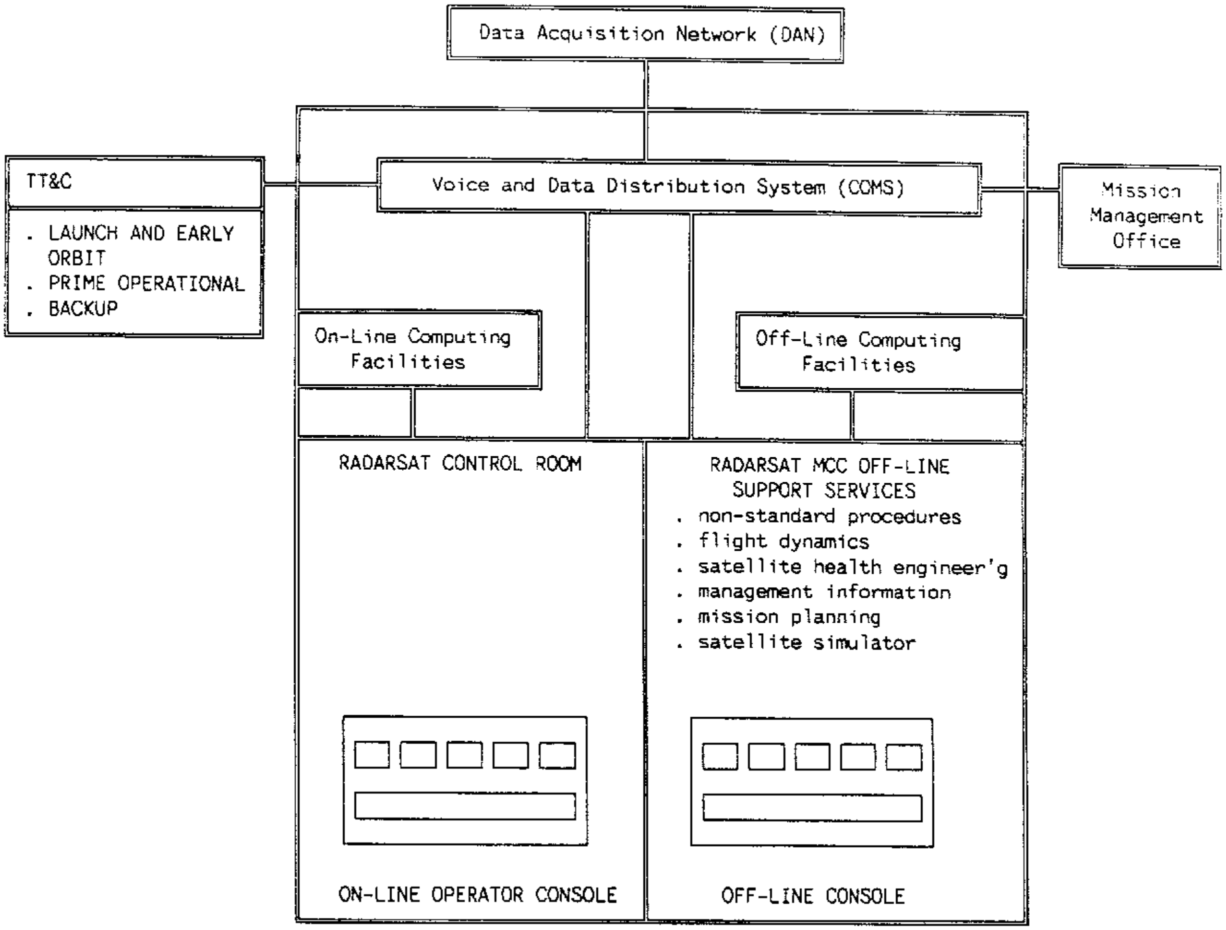


FIGURE 3.4

RADARSAT MISSION CONTROL CENTRE FUNCTIONAL IMPLEMENTATION



3.3.2 Space Station Technical Demand

3.3.2.1 Introduction

It is assumed that the CSCC will be supporting Canadian participation in NASA's Space Station before the Radarsat mission ends. This participation, known as the Canadian Space Station Program (CSSP), will encompass two programs which are of interest to the CSCC:

- The Mobile Servicing System (MSS)

- Canadian Research and Development (R&D) payloads for use on the Space Station known as the User Development Program (UDP)

This assumption has a bearing on how the CSCC is designed with respect to size and adaptability. The contents of Figures 3.5 through 3.8 are essentially unique to Radarsat, although they are representative of the range of services the CSCC could provide to numerous conventional unmanned satellites. Space Station requirements will necessitate additional specialists and computing power to support MSS operations and control. The additional computing power requirements may be very large in order to support the complex MSS simulator used to train astronauts. Nevertheless, Space Station requirements are incremental to Radarsat, and provide an opportunity to build on the Radarsat 'base' installations.

The assumptions detailed below regarding the ground segment requirements for Canadian participation in space station are based on interviews with industry and government officials associated with the CSSP, the MSS program and UDP, as well as documents obtained privately.

It is important to point out that planning and specification of the CSSP technical demands with respect to control centre requirements are still very much in the formative stage. In the case of UDP, requirements will not be firm until the MSS has been in operation for several years. This section describes MSS requirements for CSCC. These will in turn drive the capabilities necessary for UDP.

3.3.2.1 (Cont'd)

While decisions have been taken jointly by Canada and NASA with respect to many aspects of the program, the scenario for ground segment support and the extent to which it will be done in Canada remain to be defined. The following imperatives affect the CSSP ground segment support concept:

- All RF communications in the earth to Space Station direction will originate from NASA facilities, notably, White-Sands, New Mexico and Goldstone, California.
- Canada will maintain a skilled team at Johnson Space Centre to support MSS operations.
- Ground segment support for MSS may be divided with respect to specific responsibilities but, because MSS is integral to the Space Station, all ground support for MSS must be integrated with overall Space Station ground support.

Three modes of MSS operations have been defined. Each mode affects the responsibilities of the Canadian component of MSS ground-segment support:

- MSS-unique operations: MSS ground support has sole responsibility to plan, monitor, and evaluate operations.
- Space Station operations in which MSS is a primary resource: MSS ground support is integrated as a primary support source.
- Space Station operations where MSS is a secondary resource: MSS ground support is an external support source, acting as a technical consultant during operations.

This division of labour with respect to overall MSS ground-segment support is made without any reference to the eventual division of labour between the Canadian Space Agency and NASA.

3.3.2.2 Mobile Service System Technical Demand

As indicated in Figure 3.5, the MSS ground segment has two major components: an Engineering Support Centre (ESC) and a Utilization and Operations Centre (U & OC). The ESC in turn has two distinct subordinate operations: the Space Operations Support Centre (SOSS) and an Integrated Logistics System (ILS).

The CSCC will not have RF facilities to communicate with MSS or the Space Station. However, satellite communications channels may be part of the communications network between CSCC and NASA. These facilities would be of the conventional type, utilizing Canadian or other regional domestic satellites. Additionally, CSCC could monitor TDRSS transmissions to NASA and select and use MSS-related telemetry data.

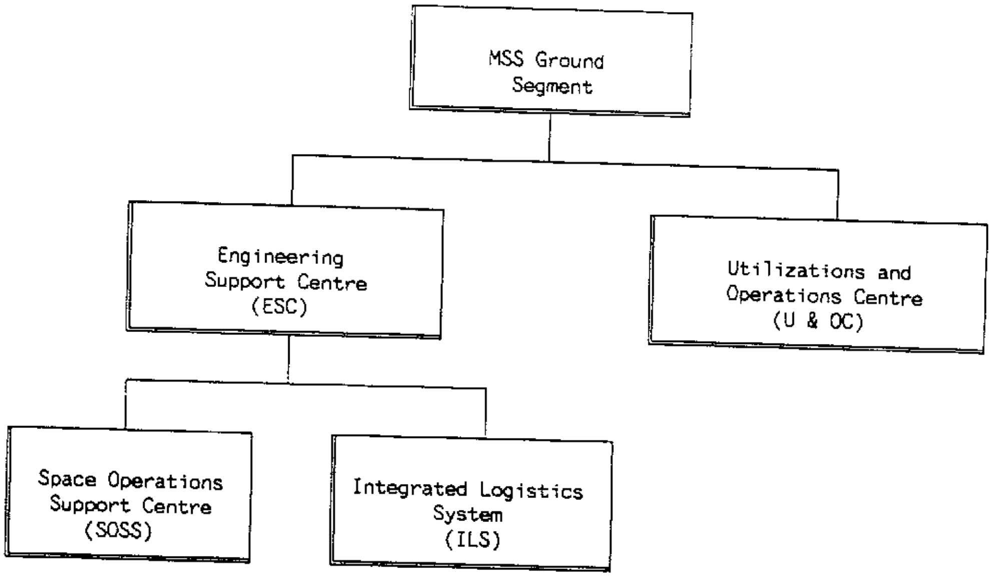
Although the division of labour between NASA and the Canadian Space Agency (CSA) in the U & OC will not be clarified until the role of the U & OC is defined in detail, CSA's role could include high-level policy development over the life of the MSS. Thus, the CSA function would be analogous to that of the Radarsat Mission Management Office, in that it will share in the management of the MSS Program, directing the utilization and operations planning and scheduling, primarily at the strategic and tactical levels. The U & OC will also provide MSS Program policy direction.

The U & OC need not be co-located with the ESC. Since the U & OC is a senior-level function, the activities will likely be conducted from a CSSP mission management office located at, or close to, CSA.

If it were decided to consolidate all CSSP activities at the CSCC, the activities in the CSSP management office would centre around information similar to that used in the SOSS, although the senior management offices would be located in another part of the CSCC complex. The Canadian U & OC function would use much of the data available to SOSS and ILS. It would be necessary to provide access to this data and management information via a small number of display terminals equipped with hard-copy printouts.

FIGURE 3.5

CURRENT MOBILE SERVICE SYSTEM GROUND SEGMENT ORGANIZATION



3.3.2.2 (Cont'd)

Co-locating the Canadian policy/management activities with the ESC would offer savings in communications requirements between ESC and U & OC. These communications requirements could entail several voice channels and low-bit-rate data.

The SOSS would support on-orbit operations of MSS through the operation of a number of subsystems, including the key command and control responsibilities.

The ILS would coordinate and manage functions such as astronaut training, scheduling and the movement of hardware and software to and from the space segment. In general, ILS would act as an administrative clearing-house to ensure an orderly flow of activities in the short term (as opposed to long-term planning done in the U & OC).

It would not be efficient to separate the SOSS and the ILS because of the heavy volume of daily information traffic between them. Figure 3.6 illustrates a number of activities that would be carried out in the ESC under SOSS and ILS subsections.

Some SOSS functions involve on-line control of MSS. SOSS and ILS functions that are not on-line for direct MSS control could be located in CSCC. As the experience and confidence of the Canadian operations team grow, NASA might find it useful and cost-effective to have CSCC prepare and execute commands to MSS during quiet periods, for example when the MSS is not in use.

The technical demands which MSS will put on CSCC are based on the following assumed activities in support of MSS:

- Analyse, comment upon and make recommendations with respect to the use of MSS for all Space Station operations

- Analyse and report on the health of MSS

FIGURE 3.6

MOBILE SERVICE SYSTEM PROGRAM GROUND SEGMENT SUPPORT ENGINEERING SUPPORT CENTRE FUNCTIONALITY

MSS PROGRAM
ENGINEERING SUPPORT CENTRE (ESC)

Space Operations & Support Systems (SOSS)

- Management Information
- Monitoring
- Command & Control
- Analysis
- Diagnostics
- Simulation
- Training
- Planning/Scheduling
- Communications
- Data Management

Integrated Logistics Systems (ILS)

- Management Information
- Analysis
- Training
- Planning & Scheduling
- Inventory Control/Monitoring
- Ground Support Equipment
- Repair
- Communications
- Data Management

3.3.2.2 (Cont'd)

- Receive telemetred MSS operating parameters from NASA
- Conduct performance trend analyses on key elements of MSS
- Input analysis results to mission planning
- Archive key MSS data
- Manage the way in which data is processed
- Develop nonstandard procedures
- Verify integrity of nonstandard procedures on MSS simulator
- Prepare nonstandard procedures for NASA execution
- Generate, verify and send commands (i.e. diagnostics) to MSS during quiet periods
- Utilize a resident MSS/Manipulator Operator Training Simulator to train Canadian and foreign astronauts on the use of MSS
- Update the MSS simulation
- Support NASA in updating command and control procedures

The functions in ILS are not time critical, as are those in the direct command and control functions in SOSS. Thus, the ILS-related functions in CSCC could encompass a wide range of technical administrative tasks.

As its title suggests, the intrinsic value of the ILS lies in its integrative capability. This implies an adaptive approach to solving conflicting demands on human and technical resources. An extensive management information system with user-friendly interfaces will be required. It will take experience and skill to develop a credible ILS that satisfies its users. The software supporting ILS will require

3.3.2.2 (Cont'd)

ongoing attention as the MSS operation becomes more sophisticated, requiring smaller numbers of personnel, but with clearly established priorities based on real experience with MSS.

The following is a list of ILS functions that could be conducted in CSCC. It is not exhaustive.

- Planning, scheduling, and managing astronaut training
- Controlling the movement of MSS hardware and software to and from the MSS (in space)
- Assisting in planning to relocate ground equipment
- Maintaining inventories of hardware and software
- Managing the repair and retesting of MSS flight and ground segment hardware
- Providing general technical administrative support and advice to SOSS and U & OC

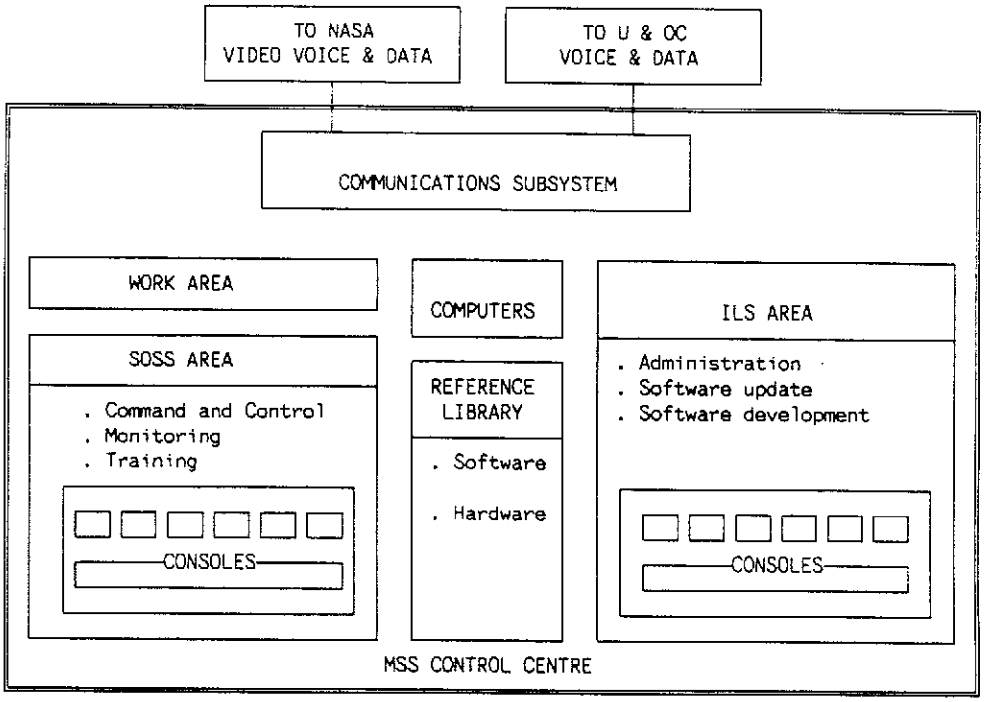
Conducting these SOSS and ILS activities will require special MSS operations rooms with a number of display consoles, hard copy and fax capability, and the complement of hardware normally associated with extensive administrative activities. As can be seen in Figure 3.7, SOSS and ILS share some common data, making co-location advantageous as long as it does not create an environment with too many distractions to personnel engaged in the critical analysis of MSS functioning.

3.3.2.3 <u>User Development Program Technical Demand</u>

National or international facilities that serve as a focus of operations for Space Station research and development and scientific users under the CSSP's UDP are to be designated Regional Operations Centres.

FIGURE 3.7

SPACE OPERATIONS & SUPPORT SYSTEMS/INTEGRATED LOGISTICS SYSTEM OPERATIONS



3.3.2.3 (Cont'd)

By the time the Space Station is available for use by the worldwide constituency of scientific users, Canada will have spent $75 million under UDP in 'pre-use' efforts to develop interest and competence to carry out research and development on the Space Station. UDP will emphasize the utilization of Space Station's microgravity environment for industrial and scientific processes.

The ways in which Canada will support Canadian users emerging from UDP have not yet been developed. It is generally believed that there will be no substantial use of the Space Station by research and development experimenters until the late 1990s. Until a clearer picture of the nature of UDP emerges, it is impossible to respond to these requirements in detail.

However, a conceptual outline of how CSCC might support Canadian Space Station users would include the following:

- A physically separated work area in CSCC for Space Station UDP project staff
- Dedicated communications services to Space Statopm program control
- Real-time or near-real-time data retrieval from NASA
- Orbit predictions
- Data read-out predictions
- Day/night conditions predictions
- Data archiving (at least temporary)
- Control of research and development experiments on behalf of experimenters

3.3.2.3 (Cont'd)

- Reaction to unexpected events on SS to protect experiments from loss or damage

- Data processing to view experimental results in a quick-look mode

The number of Canadian research and development projects on the Space Station under UDP at any given time will not be large. The available space (2 cubic metres), power (1.3 kw), and astronaut time (40 hours per year) will be very limiting factors, not to mention the financial burden of developing flight hardware and the associated shuttle launch costs.

A schematic illustration of the facility to support Canadian UDP research and development projects is provided in Figure 3.8.

3.3.3 Technical Demands of Other Canadian Missions

A number of potential opportunities may be available to CSCC, particularly if Radarsat, MSS and UDP become successful operations for CSCC.

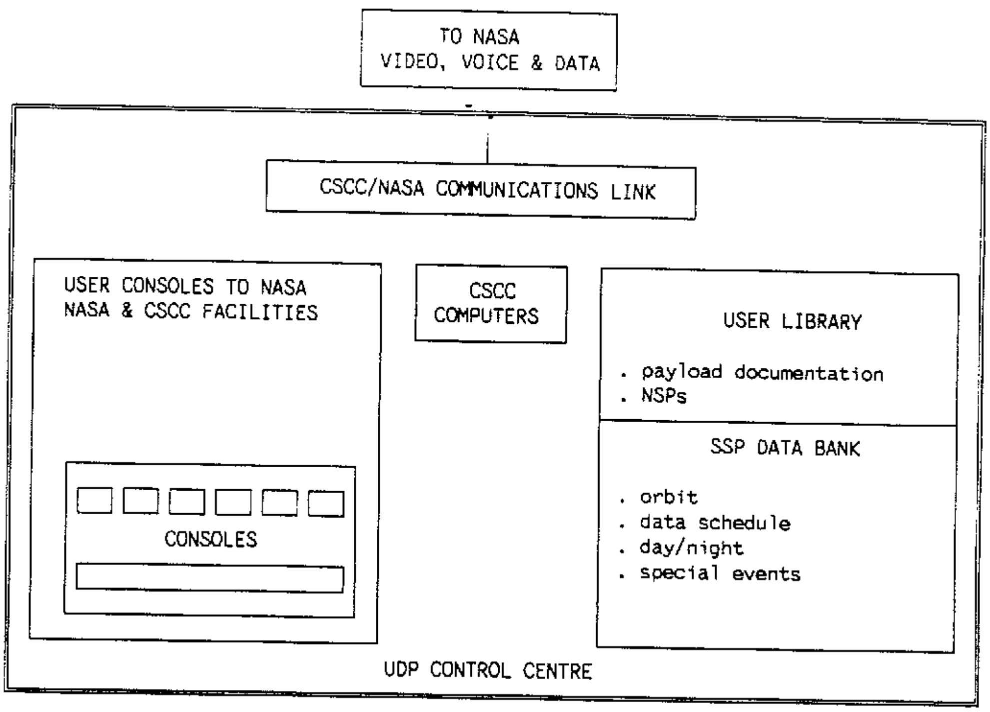
NASA maintains a TT&C station at Gilmore Creek, Alaska, but this station is for TT&C only. There is no built-in capability to provide other essential functions related to control.

For reasons of political sensitivity, some governments may prefer to make arrangements with Canada rather than dealing with the U.S., particularly if CSCC is able to offer a full range of services, ranging from TT&C, to shared control, to complete control.

Two possible future space missions represent opportunities for CSCC support, given the special financial or political interest which Canada will have in them.

FIGURE 3.8

CANADIAN SPACE CONTROL CENTRE SUPPORT FOR USER DEVELOPMENT PROGRAM OPERATIONS



3.3.3 (Cont'd)

These are:

- Space-Based Radar (SBR), a U.S. Department of Defence (DOD) remote-sensing mission
- Radarsat 2
- Western Space Initiative

SBR will be part of the North American strategic air defence system. The Canadian Department of National Defence is participating in the SBR feasibility studies, with major contracts to the Canadian space industry.

Command and control concepts for SBR have not yet been studied extensively. A role for CSCC should not be ruled out at this time, as it is expected that CSCC will have a wide capability.

A decision to proceed with a second Radarsat mission will depend on the technical success and the cost-effectiveness of the data obtained from the first mission. Given that the anticipated benefits of Radarsat are worth the price of the mission, it is logical to assume that the benefits of a second mission would be equally attractive.

A decision to proceed with a second Radarsat mission would provide challenging satellite-control development work for CSCC as well as other Canadian-based expertise in the field.

3.3.4 Technical Demands of Foreign Missions

There are a number of non-Canadian remote-sensing missions which may provide a market for the services of CSCC. These are:

- Follow-on to Japan's first Marine Observation Satellite, MOS-1

3.3.4 (Cont'd)

- India's Remote Sensing Satellites: IRS, IRS-1A to 1C (1992), and IRS-2 (1995)
- NASA/EOSAT Landsat 6/7 (early 1990s)▪Japan's first Earth Resource Satellite, ERS-1 (1991), and follow-on
- SPOT 4 and 5 (mid 1990s)
- Japan's Advanced Earth Observing Satellite, ADEOS (1993)
- NASA's Polar Orbiting Earth Observation System, EOS or Polar Platform (mid 1995)

Meteorological satellites represent another potential market for CSCC. The programs listed below are currently in operational state unless otherwise noted:

- Defence Meteorological Satellite Program (DMSP), U.S. DOD, since 1966
- METEOSAT (ESA), 1987-1990
- TIROS, U.S. National Oceanic and Atmospheric Administration (NOAA)
- Geostationary Operational Environment Satellite (GOES), NOAA
- Geostationary Operational Environment Satellite (GOES), NOAA, 1989-1990
- Geostationary Meterological Satellite (GMS), Japan, since 1977
- Geostationary Operational Meterological Satellite (GOMS), U.S.S.R., 1986
- India National Satellite (INSAT)

3.3.4 (Cont'd)

- U.S. Navy Remote Ocean Sensing System (NROSS), 1990-1991
- Meteor earth resources and meteorological, U.S.S.R., since 1975

Only a small number of these remote-sensing and meteorological missions are likely to have a future requirement for support from CSCC. However, most of the non-Canadian missions listed are ongoing projects which provide potential continuous demand for support, once a business relationship has been established.

CSCC could support such missions with a range of services, such as:

- Launch and early orbit phase support services, including TT&C and real-time orbit calculations and real-time data analysis
- TT&C backup
- Routine TT&C operations
- Use of an existing satellite simulation for a satellite experiencing similar responses to TT&C and to orbit and attitude manoeuvre commands
- Special TT&C operations requiring multiple stations (e.g. emergencies and orbital manoeuvres)
- Part-time control of a mission following a major change in the orbit of a satellite
- Delegated control of all satellite operations

3.3.5 Other Canadian Space Control Centre Requirements

CSCC will require both technical and business management expertise. Financial analysis and control and contract management will be important activities. The interface with CSA will be critical, requiring above-average management skills.

Consultative Committee on Space Data Systems (CCSDS)

In interviews with experienced satellite control personnel at CRC and NRC, reference was made to a Consultative Committee on Space Data Systems. This international committee has eight sitting members including NASA, ESA, NASDA, and the UK. There are also eight 'administrations' with observer status. DOC and NRC are two of the 'observers'. CSA is considering applying for active membership but has yet to come to a decision. This committee was formed several years ago to fill a gap with respect to space-related issues on the Consultative Committee on International Radio (CCIR). CCIR has dealt extensively with satellite communications of the 'bent-pipe' variety and has developed standards for these services. CCIR has not yet addressed satellites as receptors and generators of disparate classes of communications traffic. CCSDS attempts to fill this gap on a voluntary basis without official status in the International Telecommunications Union (ITU) or CCIR but with considerable informal linkage.

CCSDS will hold a plenary session in Ottawa in September, 1989 to put its formal stamp of authority on what is now a 'red' book (following the custom of CCIR). This exercise will result in the 'red' book being reissued as a 'blue' book, again following the custom of CCIR. The current 'red' book, entitled "Advanced Orbiting Systems: Networks and Data Links" is an international standard for TT&C and data downlinks.

Any administration following the principles laid out in the 'red' book would still have to develop standards in order to use it. The original TT&C standards written for Radarsat by D. Boulding (now at NRC) followed those of the 'red' book.

3.3.5 (Cont'd)

No U.S. spacecraft bus supplier or TT&C subcontractor offers a standard system at present. NASA has contracted Fairchild Corporation to study the implications of developing standards. A mission such as Radarsat, committed to the 'red' book authority, is needed to trigger the main body of work. NASA would likely assist if it had a formal Radarsat project office.

CSCC would be wise to cooperate in the development of a working standard with a view to being a 'fully-accredited' S-band TT&C operator and planner.

Consideration is currently being given to moving CCSDS from an International Telecommunications Union (ITU) to an International Standards Association (ISO) umbrella. In either event, it is vital that CSCC be perceived to be a fully functioning TT&C capability built to international standards, and fully conversant with those standards. Such credibility would strengthen CSCC's ability to bid on consulting or TT&C development contracts.

Since our traditional, long-term partner in space has been the United States, the CSCC must design its TT&C to be fully compatible with NASA. CSCC will use NASA's TT&C stations and vice versa. DOC was able to operate and control CTS from NASA's Australian TT&C station because NASA follows a 'bent-pipe' philosophy in TT&C. Everything is done at the main control centre. Bent-pipe TT&C policy permits a rapid change of station.

In keeping with the proposed mandate to be the Regional Operations Centre for Space Station research and development experimenters, CSCC could undertake some low-level data processing as part of its service to the Space Station and other users. This activity, known as zero-level processing, is the capability to analyse the data stream from a satellite and select and direct to separate data channels the data unique to individual experiments, regardless of whether the data

3.3.5 (Cont'd)

originated from different sensors on a satellite or from the same sensor at different times.

The second step in zero-level processing is to merge satellite position, and attitude and time parameters with the data.

This processing capability has proven to be extremely useful to multiple users who would otherwise be forced to:

- Accept and process much more data than they will eventually use
- Appeal to CSCC for clarification of data formats
- Allow 'private' data to fall into hands for which it is not intended

Provision should be made in CSCC planning to accomodate a future zero-level data processing capability.

4.0 THE CASE FOR A CANADIAN SPACE CONTROL CENTRE IN SASKATOON

This section discusses the rationale for the establishment of a CSCC, and for its location in Saskatoon. The section deals with the federal government's social objectives for regional economic development; the potential role of SED as the lead space company in the Prairie region; and the socioeconomic benefits to the region.

4.1 SED SYSTEMS INC.'S CAPABILITIES

4.1.1 Introduction

SED is a leading Canadian advanced technology company specializing in space and communications systems engineering. Since its inception, SED has acquired extensive expertise in space, communications, satellite test and control, defence systems engineering, and custom electronic system manufacturing. With proven professional capabilities, a strong renewing technological base, and an international reputation for excellence, SED is well positioned for growth in Canadian and international markets.

SED has been a successful national and international systems team member on numerous large projects since 1965 and has established associations with numerous commercial and government ventures. As a result of this experience, SED has the project management skills, systems engineering capability, integrated logistics support, and product assurance procedures in place to meet the highest project standards.

SED is a Prairie region advanced space and communications systems technology leader and is already providing guidance and leadership in the provision of industrial benefits to the region through its association with SPAR Aerospace, PARAMAX Electronics, and Raytheon Company. Contacts and associations with advanced technology companies in the region complement SED's capabilities in systems engineering,

4.1.1 (Cont'd)

software development, and custom manufacturing. SED is headquartered in Saskatoon, Saskatchewan and is located in a research and development park near the University of Saskatchewan.

SED currently employs about 325 personnel of whom about 90 are technical professionals. Most personnel are cleared to SECRET level and personnel security is enhanced by regular security briefings and seminars.

4.1.2 The Company's Evolution

SED was founded in 1965 as the Space Engineering Division of the University of Saskatchewan with a mandate to design and build rocket instrumentation for upper atmospheric studies. To date, 64 launches have been completed as a result of this initiative.

After five years of working exclusively in the design and construction of such scientific payloads, SED diversified. Work began on the design and development of space systems technology related to the satellite communications industry. Work on the CTS/Hermes project in 1970 led to the creation of SED's Advanced Systems Engineering Division. That development helped focus the company on systems engineering, which is now its dominant business thrust.

The expertise assembled during this period also led to a contract for the systems' design and conversion of the Prince Albert Radar Laboratory to Canada's LANDSAT Satellite Tracking and Receiving Station (PASS) in 1972. SED operated PASS for over 15 years, acquiring extensive low earth orbit satellite tracking capability and operations experience.

SED became a privately incorporated company in 1972 and has evolved in step with space and communications technology. The company's first commercial satellite earth station was produced in 1973. Since then, hundreds of stations and systems have been designed and installed around the world, many of them employing proprietary SED designs.

4.1.2 (Cont'd)

Since its inception, SED has been involved in hundreds of successful space and communications projects which have ranged in size up to $30 million and have included Satellite Telemetry and Tracking Command Stations, Satellite System Test Sets, Command and Control Centres, Communications Systems, Meteorological Systems, Radar Displays, and various SED proprietary Communications Products and Systems.

4.1.3 Customers

A cornerstone of SED's strategy has been to develop and maintain long-term relationships and strategic associations with major, high quality customers and associates. SED's Canadian and international clients include Transport Canada, the Department of National Defence, SPAR Aerospace, the National Research Council of Canada, Hughes Aircraft, Oerlikon Aerospace, Department of Communications, Raytheon Canada, Raytheon U.S., PARAMAX Electronics, Telesat Canada, and INMARSAT, many of whom SED has done business with for over ten years. SED's quality customer base provides a strong foundation to pursue new contracts with confidence.

4.1.4 Facilities

In February of 1987, SED integrated its operations under one roof in its new 11 000 square metre (125,000 square foot) custom-built facility in Saskatoon. The company, with its significant strength in systems engineering, reorganized along functional lines and placed a clear focus on the systems aspects of its business.

The facility includes 4 000 square metres (43,000 square feet) of manufacturing and integration space, a Class 10000 clean room, and a vacuum chamber. The building is fully secure. Automatic data processing facilities are available for administration, design, engineering, project management, and computer-aided drafting (CAD).

4.1.5 Regional Coordinator Role

SED, as a leading advanced technology company on the Canadian Prairies, is in an excellent position to coordinate the activities of smaller Prairie companies that can provide complementary technology. In such a leadership role, SED provides for increased regional collaboration through distribution of industrial benefits to qualified firms. The result is greatly expanded opportunities and overall capability for both SED and its regional partners.

Throughout its history, SED has developed numerous products and commercial applications of technologies derived from government and commercial contracts. Success in these areas has resulted in a large number of spin-off companies who can trace their roots to SED. The company's own evolution from a minor scientific research division of the University of Saskatchewan to an internationally recognized aerospace systems contractor gives SED hard-earned, first-hand experience to assist other Canadian companies to grow and prosper.

This important role was further strengthened when SED became the Industrial Associate of SPAR Aerospace for the Prairie region. SED was thereby assured of continuing participation in such future Canadian space programs as Space Station, Radarsat, and MSAT, as well as increased responsibility for coordinating Prairie involvement in these regionally distributed programs.

4.1.6 SED Systems Inc.'s Business Sectors

SED has established a strong core of engineering expertise. Consequently, the company employs one of Western Canada's strongest systems engineering teams and has diversified its original space business into four business sectors: space, satellite ground systems, defence, and custom manufacturing. While the relationship among these sectors may not be immediately apparent, their common hardware and software technology base, combined with a common customer base, provides SED with important synergies, and offers opportunities for

4.1.6 (Cont'd)

diversification within the company's capabilities to provide complete systems design, engineering, and installation.

Space Science represents SED's original business sector, with 64 scientific rocket-borne payloads designed and launched to date. GEODE, Canada's first microgravity, rocket-based payload, was launched recently and has successfully demonstrated a proprietary microgravity infrared sensor manufacturing system. SED is also the prime contractor for two space-borne instruments. The first is to be launched on the Shuttle in 1991 and will measure upper atmospheric winds (Wide Angle Michelson Doppler Imaging Interferometer - WAMDII). The second was launched on the Japanese AKEBONO satellite in February 1989 and will measure solar emissions (Suprathermal Ion Mass Spectrometer - SMS). The SMS is the first foreign instrument ever to fly on a Japanese scientific satellite. SED is one of the few Canadian companies with the engineering, scientific, and manufacturing capability to lead projects of this type. The company has gained a solid international reputation as a leader in Space Sciences.

SED has been a leader in Test and Control since the early 1970s, beginning with the design and operation of the ground control station for the Communications Technology Satellite (CTS/Hermes) Program. SED also provided telemetry, tracking, and ground control equipment for the entire ANIK series, SBS, and INTELSAT V. Recently, in association with SPAR Aerospace, SED completed the design, manufacture, and installation of the complete Brazilian Telecommunications Satellite System Ground Segment.

SED's Brazilian experience led directly to another major contract to design and provide, at a minimum, three complete real-time In-Orbit Test Systems and Communications Monitoring Systems to INMARSAT, and two contracts for similar systems for Luxembourg's Direct Broadcast Satellite (SES) and for British Satellite Broadcasting (BSB). A second system for INMARSAT, to be installed in Beijing, China, is also currently underway. These contracts, based on proprietary SED real time

4.1.6 (Cont'd)

monitoring and control software, were won in direct international competition against major European aerospace companies. SED is currently pursuing other markets for this unique system.

SED is one of five lead Canadian companies developing the Mobile Service System which Canada will contribute to the Space Station. SED is responsible for the Ground Segment, including the ground-based test and control systems. The company is also committed to developing applications to be flown on the Space Station, such as GEODE, which was described above.

SED's Defence, Communications and Custom Manufacturing Business Sectors are not discussed in this document.

4.1.7 SED Systems Inc.'s Control Centre Related Track Record

Satellite Ground Systems

Telemetry Tracking and Command

1970-1976	CTS Mission Planning and Support Centre
1972	ANIK A TT&C for Telesat Canada
1972-1987	LANDSAT/GEOS Tracking Station for CCRS
1978-1982	ANIK C&D, SBS, INTELSAT V Ground Segment for Hughes
1978-1980	ANIK C/D TT&C for Hughes Aircraft
1980-1981	Satellite Test Equipment for DOC and Spar
1982-1985	Brazilsat Ground Segment for SPAR
1986-1989	In-orbit Test System for INMARSAT (Fucino, Italy)
1987-1989	In-orbit Test System for Luxembourg
1987-	Space Station
1988-	In-orbit Test System for BSB, U.K.
1988-89	EGSE Definition Study (MSAT) for Spar
1989-	In-orbit Test System for Inmarsat (Bejing, China)

4.1.7 (Cont'd)

Communications Systems

1973-	Hundreds of satellite ground terminals installed
1981-83	Two-way satellite ground system for Telesat
1985-1990	Fifteen-station Skywitch system for NRC
1985-1986	Six-station Skyswitch system for SaskPower
1985	Two-station Skyswitch system for Transport Canada
1986	Skywitch system for Coast Guard
1988	Skywitch system for Newfoundland Telephone

Space Systems

1965	64 Rocket Payloads for NRC and others
1978-1980	Firewheel sub-satellite for NRC
1981-1988	WAMDII for NRC
1985	GEODE for Cominco/NRC
1985-1989	SMS for NRC

4.2 SED SYSTEMS INC.'S CORPORATE OBJECTIVES

SED objectives focus on stable, controlled and profitable growth by further developing its human resources, technological base and facilities to achieve increased sales in commercial, government and international markets. Objectives which relate specifically to the satellite ground systems business include:

- Becoming a centre of expertise for the research and development of the technologies and designs of both hardware and software systems, which are applied to the testing and control of satellites and space platforms.

- Commercializing the technology and competing in satellite test and monitoring and mission control systems on a worldwide basis.

- Becoming Canada's operator for providing tracking and control of both national and international science, remote sensing satellites, and space platforms.

- Strengthening the Canadian Space Program through diversification and distribution of the technology across Canada so that all regions can benefit. The broader the advantages and opportunities, the more acceptable additional programs will be, especially if companies such as SED continue to grow and to export, and to generate advanced technology and job opportunities in Saskatoon and the Prairie region.

- Cooperating with and supporting the members of Canada's space community so that in terms of both the number of players and technical capability, Canada is recognized as a leading space technology country.

- Providing greater marketing and technical support to SPAR Aerospace. With ongoing satellite ground-segment technology development, SPAR's international marketing efforts can be enhanced with state-of-the-art control, test, and training systems.

4.2 SED SYSTEMS INC.'S CORPORATE OBJECTIVES (Cont'd)

- Becoming clearly recognized as the space leader in the Prairie region, while assisting in the development of a progressive, innovative and potentially marketable industry in the region.

- Creating spin-off technologies, products, and export market opportunities.

- Expanding the operations capability of a Satellite Control Centre to include strategically located TT&C stations capable of tracking, commanding, and receiving data from polar-orbiting satellites. This ring of stations would participate in international science programs, military programs, and the newly initiated international environmental monitoring program.

- Cooperating more closely with the universities and academic institutions to translate and convert basic research into commercial, space-related applications.

In summary, SED's vision is to create a profitable and growing space-related industry in technology areas that have no Canadian focus today, and as an additional socioeconomic benefit, to develop this industry in a region of Canada which requires a stimulus or technology engine.

If SED is to achieve its vision and grow into the ambitious role it has set out, the company will require strong support from the provincial and federal levels of government. SED's track record in exporting Satellite In-orbit Test Systems provides clear evidence that satellite ground segment technology is an exportable space product. Achieving SED's objectives will require bringing together satellite operations, technology development, intense marketing and strong government support.

The politics of regional economic development and the strong support which the Canadian Space Program currently enjoys (as signalled by the fact that the program was not impacted by the recent budget cutbacks in other areas), provides the foundation for achieving these objectives.

4.3 MARKET ASSESSMENT

SED has demonstrated its expertise and currency in the technologies associated with the testing and control of satellites. It has operated the satellite ground station at Prince Albert (PASS), and has designed and built scientific payloads for satellites and rockets. It now wants to build on this base and enter the mission control centre business, particularly in the tracking and control of scientific and remote sensing satellites and space platforms for both Canadian and foreign requirements.

The domestic market base for, and the viability of, a Saskatoon-based Mission Control Centre over the next decade clearly revolves around the Radarsat and Space Station MSS and UDP programs, as described in Sections 3.2.2 and 3.2.3. Space-based Radar and Radarsat 2, as described in Section 3.2.4, are longer-term possibilities and should be monitored, but will not be a factor for CSCC planning purposes over the next five years, and therefore have been discounted in respect of making a case for a CSCC.

The substantial number of foreign remote sensing and meteorological programs listed in Section 3.2.5 represent an ongoing potential, but likely small, market for the services of a CSCC. However, it is difficult to assess the timing and nature of this potential demand for the services of a CSCC.

For reasons of political sensitivity, some governments may prefer to make arrangements with Canada rather than dealing with the U.S. or other nations with major space programs, particularly if the CSCC is able to offer a full range of services such as TT&C, to shared control, to complete control. As indicated previously, the CSCC could support such missions with a range of services, such as:

- Launch and Early Orbit Phase support services, including TT&C, real-time orbit calculations and real-time data analysis;

- TT&C backup;

4.3 **MARKET ASSESSMENT** (Cont'd)

- Routine TT&C operations;
- Use of an existing satellite simulation for a satellite experiencing similar responses to TT&C and to orbit and attitude manoeuvre commands;
- Special TT&C operations requiring multiple stations (e.g. emergencies and orbital manoeuvres);
- Part-time control of a mission following a major change in the orbit of a satellite; and
- Delegated control of all satellite operations.

At this stage of planning, there is no ready rationale on which to base a market forecast. The domestic market base over the next decade clearly consists of Radarsat, the Canadian Space Station programs, and any other programs which may be initiated within Canada, probably with the involvement or support of the Canadian Space Agency. (It is assumed that all communication satellite control centres located in Canada would continue to be developed and operated by Telesat Canada.)

In addition, the plethora of foreign programs in science, remote sensing and meteorology suggests that, with appropriate sales and marketing efforts, it should be possible to add at least one new mission control centre assignment once every three years with a life of, say six years. In the steady state, such a scenario would lead to two control centre operations for foreign satellites.

For planning purposes, and as outlined in Section 3.2, it is assumed that the CSCC would start by supporting Radarsat, followed by the MSS and UDP programs. With a facility in place and established capability to point to, an additional two mission control centre assignments, most likely for foreign programs, would be added to CSCC by the year 2000.

4.4 OTHER ASPECTS OF THE CANADIAN SPACE CONTROL CENTRE'S ROLE

It has been assumed that, as a matter of principle, the Canadian Space Agency will wish to establish a CSCC to support its ongoing commitments in space. Previously, some federal government departments have had to establish dedicated control stations to support international missions in which they were committed either to operating or to assisting in satellite control. Telesat also has had to establish and operate control stations initially for its ANIK satellites, and now for some foreign communication satellites as well.

With the consolidation of Canada's Space Program under the Canadian Space Agency (CSA), (except for Telesat) there is a compelling reason to create a CSCC. Such a facility will be most valuable when Canada participates in international negotiations on joint programs.

A central CSCC will become a single focus with which the CSA will interact, instead of having facilities scattered among several agencies. Implied in such an arrangement is a deep commitment and affinity between the CSA and the CSCC. The CSCC must be perceived as Canada's chosen instrument for space control.

The CSCC can be the CSA's window to the world for public information and access, as well as being a technical operation. Accordingly, the CSCC should be configured to receive, edit and transmit broadcast quality voice and video traffic on the public-switched network.

Space Station operations involving:

- MSS operations as a prime focus of interest,
- MSS in an in-orbit service role to a Canadian research and development experiment in Space Station,

4.4 OTHER ASPECTS OF THE CANADIAN SPACE CONTROL CENTRE'S ROLE (Cont'd)

- In-orbit service to a Canadian Space Station payload by astronauts, and

- Shuttle Transportation System/Space Station operations in support of a Canadian Space Station payload,

will frequently be available for observation from the ground via television. These transmissions will be passed from NASA to CSCC for technical management reasons. The CSCC should have a basic television studio capability to record and edit this material and to pass it on to Canadian television networks for their use. This capability may include analog-to-digital and digital-to-analog conversion of television signals.

To service the CSA's public constituency, the CSCC will require press briefing rooms with professional equipment and comfortable accommodations. These facilities would, of course, also be used by the CSCC general management. The CSCC will have to have access to a cadre of skilled technical staff capable of discussing space activities in lay terms and able to cope with the pressures of distributing public information in real-time in the event of anomalous events on Space Station. The interface with CSA's overall management responsibility for all Canadian space activities must be clearly established, since there will be little time to sort out responsibilities if an urgent situation develops and the media demands accurate information from a single source.

Such a scenario would position CSCC as a major and vital element in Canadian space operations from the early 1990s onward. It would assist in fulfilling a role that should be part of the CSA mission - public information, mirroring one of NASA's official objectives.

4.5 REGIONAL DISTRIBUTION

As described in Section 3.1.1, the federal government is committed to the expenditure of 10 percent of the value-added activities of the Canadian Space Program (CSP) in the Prairie region. This implies that the Prairie region should receive about $100 million of value-added work, based on the approximately $965 million to be spent by the prime contractor on Space Station, Radarsat and MSat.

In addition, the federal government will spend another $847 million directly across Canada under the CSP, 10 percent of which also should be spent in the Prairies. These funds cover other programs (described in Section 3.1.5), namely the STEAR and UDP programs, as well as MSS and Radarsat operations.

In the Prairie region, there are only five major industrial performers; SED, Bristol Aerospace, Boeing, Intera and the Alberta Research Council (ARC). Neither Bristol, Boeing nor ARC are currently involved as major players in the CSP, although Boeing is a likely supplier of composite structures for MSS, Bristol is involved in the space science program and ARC has a significant contract in artificial intelligence under the STEAR program. Intera is a partner in Radarsat International, which will distribute radar imaging once Radarsat becomes operational. The major proportion of CSP work in the Prairie region is therefore almost certainly destined for SED, which has exhibited the capacity and capability to perform such work.

In September of 1988, Spar, MOSST (now the Canadian Space Agency) and an industrial team consisting of SED, MDA (British Columbia), CAL and Comdev (Ontario), CAE (Quebec) and IMP Aerospace (Nova Scotia) produced a document, which we understand has been accepted by the federal government, to distribute Spar's contracts according to the regional distribution targets.

4.5 **REGIONAL DISTRIBUTION** (Cont'd)

For the Prairie region, the distribution was as follows:

Program	Prairies	SED
Space Station	$61.0 million	$48.0 million
Radarsat	20.0 million	20.0 million
MSat	3.8 million	3.8 million
Other	20.0 million	(not known)
	$104.8 million	$71.8 million (minimum)

4.6 UNIVERSITY PARTICIPATION

4.6.1 University of Colorado Space Program

As indicated previously in the study the project team was fortunate to have visited the Laboratory for Atmospheric and Space Physics (LASP) Solar Mesosphere Explorer (SME) Mission Control Centre located at the University of Colorado in Boulder, Colorado. The following information about the University of Colorado is presented in order to provide a backdrop to determine the feasibility of establishing or expanding similar programs at the University of Saskatchewan and thereby enhance the Space Control Centre's capabilities and benefits in Saskatoon.

The University of Colorado has achieved preeminence as a leading space university in the country. The United States Space Station Program, other space related programs and the potential for commercialization of space has helped to create a healthy environment for a comprehensive thrust into space by the University of Colorado. As stated in the 1986 annual issue of CUEngineering,

> "The University has already capitalized on space research with such novel applications as remote sensing for archaeological studies in Costa Rica and Peru, student operation and control of the Solar Mesosphere Explorer (SME) satellite, student initiative in joining NASA's Get Away Special program, and the offering of a doctoral program in Public Administration at NASA's Johnson Space Centre in Houston. All such efforts broaden the base of support for an expanded Colorado University program in space. The University's strong programs in engineering, business, medicine, law, and the social sciences provide an ideal framework to develop space-directed programs across a variety of technical and nontechnical disciplines. Several high-tech companies that surround the University's four campuses further stimulate the University's interest in pursuing a strong space initiative."

4.6.1 (Cont'd)

The existing space programs at the University of Colorado include a Laboratory for Atmospheric and Space Physics (LASP), a Joint Institute for Laboratory Astrophysics (JILA), a Cooperative Institute for Research in Environmental Sciences, and Space and Flight Systems Laboratory. They were enhanced in 1986 with the addition of three engineering programs and three other science and related programs as listed below.

Engineering Programs

- Colorado Centre for Astrodynamics Research
- Centre for Space Structures and Controls
- Centre for Low-Gravity Fluid Dynamics and Transport Phenomena

Other Science and Related Programs

- Centre for Astrophysics and Space Astronomy
- Centre for Space Law Business and Policy
- Centre for Earth Observation and Remote Sensing

The existing program that has an interesting and direct application in a proposed Canadian Space Control Centre is the LASP SME Mission Control Centre described in the following section.

4.6.2 Laboratory for Atmospheric and Space Physics and the Solar Mesosphere Explorer Mission Control Centre

The Laboratory for Atmospheric and Space Physics (LASP) is an institute of the Graduate School of the University of Colorado conducting basic theoretical and experimental research in planetary, atmospheric, and solar physics. Through LASP, faculty, staff members, and students participate in national space programs. LASP has taken part in major space exploration missions and has operated the Solar Mesosphere (SME) satellite from the Onizuka Space Operations Laboratory on the Boulder campus. The SME program has demonstrated LASP's ability to conceive, design, fabricate, test, and operate space vehicles and instruments and to exploit the data from space experiments. This technological and scientific competence is also in evidence in the development of the instruments, and a sounding rocket program for planetary, solar, and astronomical investigations.

As an outgrowth of the efficient data management and space mission operations of SME, several institutions are examining the possible adaptations of the SME mission operations concepts to other projects. LASP members consult and advise several programs, most notably the Space Station.

The SME satellite launched in 1981 has a payload of six scientific instruments used to study atmospheric ozone including the changes in its distribution and processes creating and destroying ozone. The $17 million (1981 dollars) project was funded by NASA and continued until recently to operate under a NASA grant. The satellite was fully operational during the study team's visit and until April 1989 (which was several years beyond the original life expectancy). However, technical problems related to the power system could not be repaired and the satellite no longer functions.

SME was the only NASA satellite entirely operated by a University and controlled by students. Until recently the control centre operated on a 12 hour basis, but prior to 1987, operated 24 hours a day by professional staff and student employees. At all times one flight

4.6.2 (Cont'd)

controller (professional staff) and at least one command controller (student) were present, ready to communicate with the satellite through NASA Communications Network.

Flight controllers were ultimately responsible for all interaction with the spacecraft. However, the command controllers were fully authorized members of the team. They sent all commands to the spacecraft, checked data quality, coordinated LASP activities with NASA's communications network personnel. As members of the operations team, the students also planned flight activities and established emergency procedures with the flight controllers..

Since the beginning of the mission in 1981, approximately 100 undergraduate students were trained as command controllers. Fifteen primary on-line command controllers working between 15 and 20 hours each week, while five others were employed in science and mission data analysis. Students were paid $7.50 per hour and were given a course credit for their efforts.

In the past, new trainees were selected from freshman and sophomore applicants before the end of the spring semester. The screening committee would look for students interested in space-related activities, perhaps those whose career ambitions oriented toward the technical sciences.

A summer training program was tailored to the trainees' needs. Already-certified command controllers organized the schedule overseen by professional staff members, and staff and scientists lectured on operations and science topics.

Sixty former command controllers have been very competitive in the job market. In some instances the SME experience is a key advantage to job seekers in the engineering-related industries. Former command controllers are presently working at NASA, TRW, Martin Marietta, Boeing, Hughes, and other major aero-related employers within the United States.

4.6.3 University of Saskatchewan

The University of Saskatchewan has participated in the Canadian Space Program for over 25 years. The founding members of SED were faculty members at the University of Saskatchewan. Since that time the University has actively participated in numerous research programs related to the space industry. This research has primarily been conducted through one of the three research groups within the Department of Physics.

- Institute of Space and Atmospheric Studies (ISAS)
- Linear Accelerator Laboratory (LINAC)
- Plasma Physics Laboratory (PPL)

Of particular interest is the Institute of Space and Atmospheric Studies which has been involved in a number of international projects relating to space and the terrestrial atmosphere. The following is a brief description of the activities from the College of Engineering Research Report, 1987-1988; Summary of Research Activities, Engineering Physics.

> "The anticipated return to service of the Space Shuttle has meant that involvements in Shuttle-borne instrument experiments WAMDII and WINDII and the mid-deck locker experiment OGLOW-II, that will be conducted by the second Canadian astronaut Dr. S. McLean, have returned to their former levels. While the Swedish satellite VIKING, that included an ultra-violet imager of Canadian design, has now been switched off the image analysis efforts are continuing unabated. The advantages of remote computer processing and the need for good electronic communication have been clearly demonstrated in this program. Work on the Russian imager satellite, INTERBALL, is also progressing. However, perhaps the major achievement for the ISAS group has been their involvement with the ground truthing studies for the RADARSAT program. This work which is attempting to identify the microwave

4.6.3 (Cont'd)

> signatures of different crops and the effects of aspect sensitivity is of direct interest to Saskatchewan agriculture and clearly demonstrates the importance of space technology to the province."

Preliminary discussions have been held with the University of Saskatchewan, College of Engineering to explore the University's interest in participating in the operation and spin-off developments of the Canadian Space Control Centre. At this time it is difficult to establish in detail the level or form of future participation but it is intended to further develop and pursue a similar program as described for the SME Mission Control Centre, as well as other complementary research activities.

The University welcomed the opportunity and expressed serious interest in participating in such a program. This involvement would assist in further developing the University programs that:

- ensure participation in the space industry and related developments that would reach well into the next century
- act as a nucleus for research and development in other science fields
- foster working relationships with government and industry to translate and convert basic research into commercial space-related applications
- assist in providing an education to students desirous to live and work in Saskatchewan and Western Canada's high-tech industries.

4.7 SOCIOECONOMIC BENEFITS

4.7.1 Introduction

The socioeconomic benefits of locating a Canadian Space Control Centre in Saskatoon will be significant partly due to the limited size of the region that it will impact and the nature of the impacts. The impacts and benefits will occur in several areas:

- direct employment at the CSCC through management, administration, and operation of the control centre;
- construction activity associated with modifications and upgrade to the existing SED building;
- indirect employment through the supply of goods and services to the permanent new positions;
- manufacture of ground-based satellite control system technology hardware
- development of ground-based satellite control system technology software
- research and development in ground-based control system and other related control, test and monitoring systems
- university participation in space research and development activities
- spin-off benefits in other related areas such as:
  - reception, storage and distribution of space data
  - analysis and use of the User Development Program for the Space Station
  - satellite imagery development and enhancement

4.7.1 (Cont'd)

- development of photographic expertise
- development of space-related hardware and software
- development of enhanced storage techniques of scientific data

4.7.2 Direct Employment Benefits

The CSCC will create many direct financial benefits in Saskatchewan. The centre will create direct jobs for managerial, technical, clerical and research personnel and will create indirect jobs through the employees' purchase of goods and services in the region.

Initially the CSCC will have only a small management team of two to three people. As space programs (such as Radarsat, MSS and UDP), are attracted to the control centre, additional operating staff will be required and will increase to approximately seven positions.

The Radarsat Control Centre operations will generate 17 permanent positions which approximates 35,000 hours of employment each year. Although the Radarsat program is only five years in length, it is anticipated the second program will continue the control centre activities past the year 2000.

The MSS and UDP programs will require an operating staff of 31 people. This represents 65,000 manhours of employment each year over a thirty year lifespan of the space station program.

The business plan described in Section 8.0 also assumes that other domestic and foreign programs will be attracted to the centre in the years 1996, 1998, 2000, and 2002. The total number of direct jobs created by the CSCC for Radarsat, MSS, UDP, and foreign and domestic programs is estimated to be over 100 by the year 2002.

4.7.3 Construction and Indirect Jobs

For every new job created it is typical that two to three indirect jobs are created in the region. It is therefore estimated that locating the CSCC in the Saskatoon area would create some additional 200 to 300 indirect jobs in the region based on over 100 permanent new positions.

Jobs will be created from the CSCC indirectly as well. The capital expenditures will lead to employment of trades in the construction industry as well as generate retail trade from the purchase of construction materials. The capital expenditure extends over the life of the CSCC at regular intervals.

The construction work in the form of leasehold improvements, antennae foundations, landscaping, etc., will also provide some direct employment benefit for the Radarsat program as well as the MSS and UDP program. These socioeconomic benefits are relatively small and will be felt over a brief period of three to five months, and are dependent on the schedules for the leasehold improvements. In addition to the direct construction jobs created, equipment and materials in the form of uninterruptible power supply equipment, generators, construction materials, etc., will result in increased economic activity for some local suppliers and manufacturers.

4.7.4 Ground-Based Control System Development Jobs

One of the most significant economic benefits to the Saskatoon area will be for the design of the ground-based satellite control system technology which includes software and system development as well as hardware design and manufacture.

With the preliminary information available at this time, only a range of costs for development of hardware and software can be estimated.

4.7.4 (Cont'd)

The technical demands of the Radarsat, MSS and UDP programs were described in Section 3.0. For the MSS software and hardware development for the Engineering Support Centre (ESC) activities described in the documents, it is estimated that approximately:

- 100 to 150 man-years is required for software development
- 50 to 80 man-years is required for systems development
- $4,000,000 to $7,000,000 is required for manufacturing, materials and subcontracts
- 10 to 20 man-years is required for hardware development
- $3,000,000 to $6,000,000 is required for hardware manufacturing, materials, and subcontracts.

These significant economic benefits would be spread over a three to four year period which would equate to a direct labour staff of 40 to 65 people for each of the four development years. In addition, a significant industrial benefit would accrue to the region and the suppliers and manufacturers providing materials for the construction of the hardware.

The MSS control system described above is far more complex and requires greater coordination and management efforts than a single-user satellite. The Radarsat and UDP programs will require similar development for hardware, software and systems, but to a lesser degree. As an approximation, it is estimated that for a typical Radarsat program a similar development would require 40 man-years. This would likely be executed over a two year period which would create work for 20 people each year.

4.7.4 (Cont'd)

These direct jobs would also create additional indirect jobs. Using a typical multiplier of two to three would again create significant benefit to the region.

The type of work described above is essential for the stable development and growth of the space industry in Western Canada and especially for Saskatchewan-based companies such as SED.

4.7.5 University and Spin-off Job Opportunities

The active research and development programs currently conducted at the University of Saskatchewan (see Section 4.6) will be further enhanced and encouraged with placement of a CSCC in Saskatoon.

The additional number of research grants or programs that the University might attract are not possible to estimate, although an increase in their present program can most certainly be expected. The number of jobs that could be created in spin-off areas cannot be estimated at this time, although the opportunities could be significant.

4.8 THE CASE SUMMARIZED

This section has outlined in detail:

- SED strengths, extensive experience, and strong capabilities in creation and operation of a space control centre in Saskatchewan;
- SED's regional coordination role in the prairie region through involvement with SPAR Aerospace, Canada's designated prime contractor in the space industry;
- SED's corporate objectives and how these objectives would meet the regional distribution goals, technology development goals, and commercialization goals both nationally and internationally of this ground-based satellite control technology;
- the University of Saskatchewan's past involvement and desire to continue to participate with a more active role in the research and development activities of the Canadian Space Program; and,
- the direct and indirect jobs created with the location of the CSCC in Saskatchewan both in the management and operation of the centre as well as the jobs created as a result of ground-based satellite control system technology development.

One of the underlying principles and strengths of the Canadian Space Program is that it is diversified regionally, and as such, is an expression of all the people of Canada. The same principle can be found in the U.S. space program, with space-related facilities and capabilities distributed throughout the major regions of the U.S., as well as in the European program, where facilities are located in every ESA nation.

With the critical mass of resources in place to meet the requirements of a CSCC, SED will become a focus of expertise and knowledge for defining and developing new technologies to meet the needs of future satellite and space programs to the year 2000 and beyond.

4.8 THE CASE SUMMARIZED (Cont'd)

The establishment of the CSCC in Saskatoon will result in synergistic interaction among its components, creating new technologies and products for the Prairie region which can be spun-off to new enterprises.

By locating the CSCC at SED, an important step will have been taken in establishing a centre of expertise in Saskatoon for the design, development, integration and marketing of Canadian satellite control, test and monitoring systems. Building on its considerable track record, SED will become a centre of excellence in its own right for such technologies and will play a lead role in developing a stronger Prairie region space industrial infrastructure.

5.0 OPERATION AND MANAGEMENT OF THE FACILITY

5.1 OPERATION ALTERNATIVES

The Canadian Space Control Centre concept is based on an initial assessment that indicates a single control centre for scientific satellites and space platforms would be beneficial. The operational mechanics of such a single centre could take one of several alternative forms.

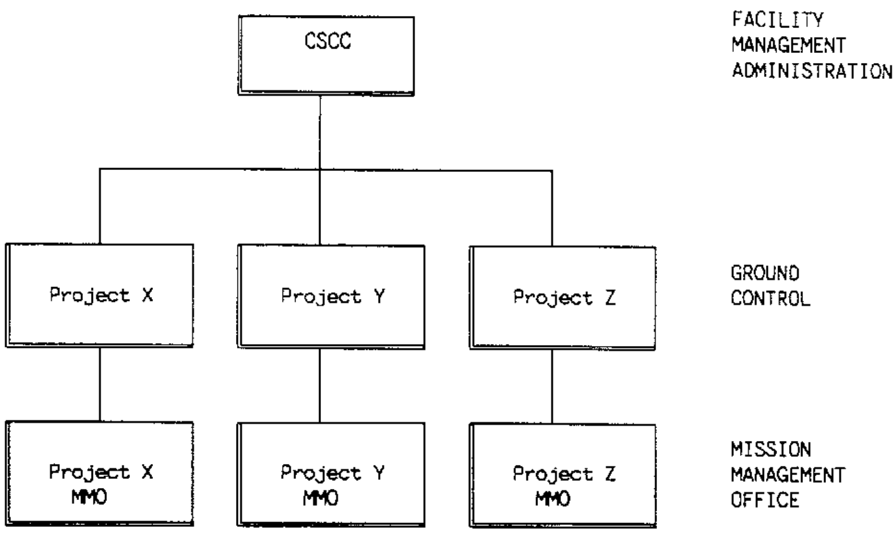
5.1.1 Canadian Space Control Centre as Facility Manager

The CSCC can be seen as providing a facility and support staff for contractors. The centre would provide an infrastructure of administrative and facility management services which would be available to any entity that performs or contracts to provide ground control operations. The contractors would provide program-specific technical personnel and communicate directly with the program management office. The purpose of the CSCC would be to provide a central location where ground control operations would be based, but contractors would not be responsible for the actual operations themselves. Figure 5.1 illustrates the relationships and responsibilities for this alternative. The mandate of the CSCC would be to involve private companies from across Canada in the space industry. The CSCC would be responsible for providing a facility and administration support services. This alternative can be compared to the operation of SAT control in Toulousse, France. SAT Control is supported by the government of France financially, politically, and from a marketing standpoint. The role of SAT Control is to provide a means of involving private enterprise in the space industry by providing operations management of these companies. The actual operations are subcontracted.

The CSCC could be viewed as having communications links with program managers, each of whom may be from a different company. Each specific program manager would communicate directly with the program's mission management office in order to fill the specific program requirements.

FIGURE 5.1

CANADIAN SPACE CONTROL CENTRE AS FACILITY MANAGER



5.1.1 (Cont'd)

The CSCC would act as a central facility manager responsible for maintaining the facility and coordinating and allocating resources as required by specific programs.

The CSCC would provide facilities, management and administrative services to specific projects that choose to locate their ground segment control operations in the CSCC facility.

The CSCC fulfilling a facility managers role would provide advantages and disadvantages as listed below:

Advantages

- low initial cost to provide services
- supports regional distribution initiatives
- provides economy of scale cost reductions whereby multiple programs share a common infrastructure
- provides centralization of ground control operations

Disadvantages

- requires funding of infrastructure costs until a sufficient volume of projects are secured to cover overhead costs
- unlikely to attract clients due to the fact that no domestic entities currently provide ground control operation services
- does not create an environment that promotes the creation of a centre of expertise or development of spin-off technologies

5.1.2 Full Service Centre

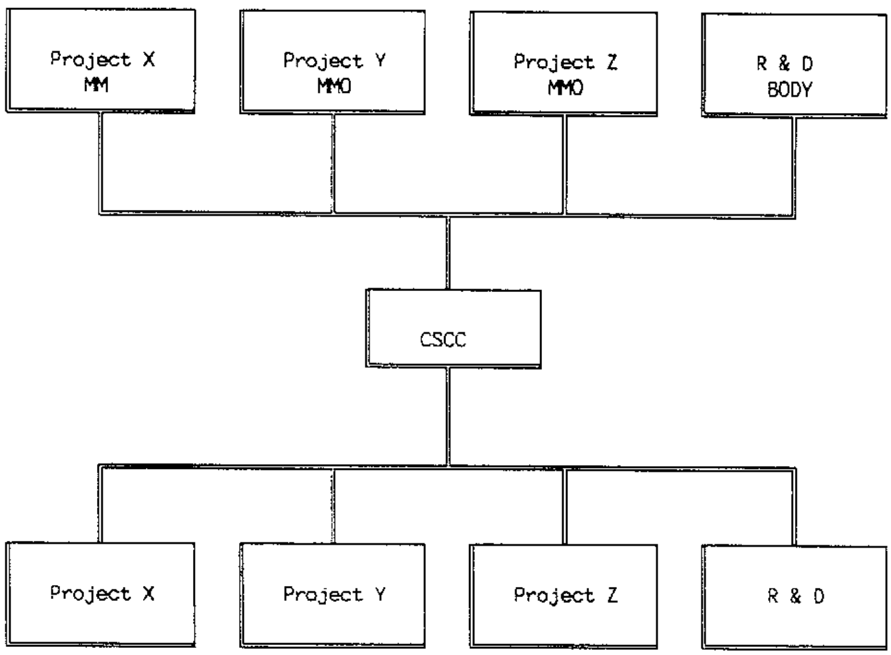
- would not provide a co-ordinated approach to ground control services in terms of developing and utilizing specific technical expertise.

The CSCC could also be seen as the entity that provides a central facility as well as the technical expertise to fully implement and support any type of ground-station activity. The CSCC would provide a full service package to any "customer" that needs ground-station operations for any noncommunications satellite. (The focus would be on noncommunications satellites due to the fact that Telesat has a mandate to control all communications satellites in Canada.) The CSCC would be an autonomous organization with management and technical staff capable of subcontracting all phases of ground-control operations. The administration staff would be in place and be responsible for marketing the centre (both in Canada and internationally) staffing specific projects with appropriate technical personnel, and coordinating research and development efforts to produce and market new products and services. As opposed to dealing with contractors on a fee-for-service basis, the CSCC would be the prime contractor for all ground-control operations projects.

Figure 5.2 illustrates the relationships and responsibilities for a full service centre concept. In this way, a single communication link between the CSCC and project mission management offices is facilitated. The management would be in a position to properly control and allocate resources, since all resources would be "owned" by the CSCC. As well, this structure would allow for integration of research and development results into actual operations on an ongoing basis because the centre would be controlled by the single guiding influence of one management team with total responsibility for all aspects of the centre. This full service facility would enhance the marketing of the centre by portraying an image of complete service for all aspects of ground control satellite operations.

FIGURE 5.2

CANADIAN SPACE CONTROL CENTRE AS A FULL SERVICE CENTRE



5.1.2 (Cont'd)

The CSCC would provide a full service to any project (foreign or domestic) and be in a position to allocate technical staff properly to projects and coordinate all programs in the centre. A direct liaison with Mission Management Offices would simplify communication lines and provide a more focused approach to operating the centre. As well, marketing opportunities will be enhanced because the centre will offers turn-key ground-station service as opposed to simply facilities and administrative services.

The CSCC fulfilling a full service centre role would provide the following advantages and disadvantages:

<u>Advantages</u>

- provides a full service package to potential clients
- low initial costs to provide services
- supports regional distribution in initiatives
- provides economy of scale cost reductions when multiple programs share a common infrastructure
- provides centralized control of ground control operations
- communication lines are simple and direct
- allocation of resources and/or personnel can be made at a level that will allow for more efficient operation of all projects in the facility
- research and development integration into the facility is more defined and obvious

5.1.2 (Cont'd)

- allows for the creation of a centre of expertise with a single entity controlling and monitoring research and development efforts and identifying and marketing spin-off technologies and products.

Disadvantages

- requires funding of infrastructure costs until sufficient projects are secured to cover operation overhead
- may be perceived as competition to Telesat's communication satellite control mandates and result in competitive bidding for ground segment work on a domestic level.

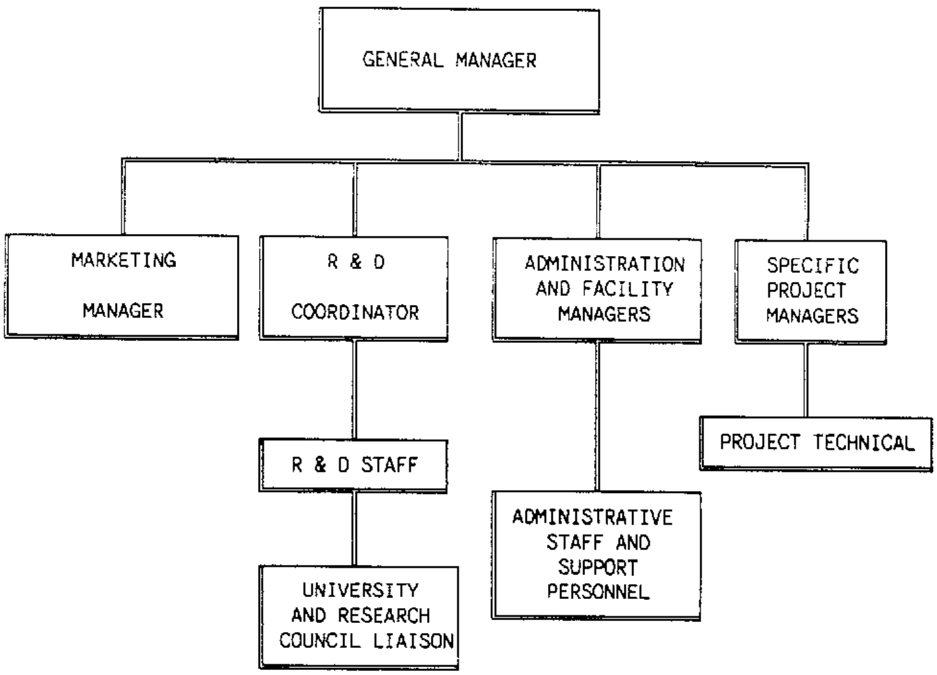
5.1.3 Conclusion

Based on the stated objectives (see Section 2.4) of the CSCC and SED's vision of creating a centre of expertise to encourage development of exportable knowledge and products for satellite control the CSCC must be a full service, centralized organization.

In order to meet the stated objectives, a coordinated approach to ground control operations and related research and development activities is required. Such an approach is only feasible through a single body coordinating all facets of satellite control. The CSCC must therefore be operated as described in section 5.1.2 in order to be feasible and credible in this industry. The proposed organizational structure is presented in Figure 5.3.

FIGURE 5.3

PROPOSED CANADIAN SPACE CONTROL CENTRE ORGANIZATIONAL STRUCTURE



5.2 OWNERSHIP ALTERNATIVES

There are basically three general alternatives to the ownership of the Canadian Space Control Centre.

- 100 percent government ownership
- government/private joint venture ownership
- 100 percent private ownership

5.2.1 Government Ownership

The idea of a government-owned-and-operated facility is a logical starting point in reviewing alternatives since the majority of projects available for Canadian Space Control Centre (CSCC) consideration are direct government initiatives. The government has made specific commitments for both spending totals (project specific) and regional distribution of funds. In analyzing any ownership alternatives, an obvious adjunct to the government initiatives would be a facility to satisfy the needs of both current and future projects and meet the regional distribution goals. By having government ownership of the facility, projects could be planned and controlled more effectively, while at the same time allowing centralization of special skills related to mission management and control. The process of selecting sites for each mission and segmenting the skills base is obviously inefficient and tends to create problems that are not easily overcome. A government-owned-and-operated facility in Western Canada would:

- provide a focus point for government-backed projects in the space sector
- centralize skills and expertise in Western Canada
- be more cost-effective as it would reduce the profit factor built into competitive bidding situations

5.2.1 (Cont'd)

- satisfy regional distribution initiatives
- be a logical base for the Canada Space Program
- eliminate any tax issues that would apply to a privately-held entity

Government-owned organizations exist primarily to render services and the CSCC would certainly be a service-oriented business. The decision-making criteria of most government organizations is to provide the best possible service, given restrictions on funds available for operations. The funding of the Canadian Space Program is relatively well-defined and only certain amounts are available for project-specific expenditures on a domestic level. Within these funding limitations, it is expected that a certain level of service and enhancement of Canada's position in the space industry will be attained. Since the majority of programs that would require the services of the CSCC would be government sponsored and funded, a government-owned-and-operated facility is a logical alternative to meet its spending and service goals.

The problems associated with government ownership are difficult to quantify as they primarily stem from a performance measurement and motivational source. Because the importance of the centre's functionality is not governed by normal marketplace demands, but rather primarily by government initiative, the primary success measure of the centre is dependent on its ability to satisfy those that provide resources. There may be a tendency to lose focus of the stated objectives of the centre, which are not typical objectives of a government organization. Specifically, since it requires less effort to secure domestic programs, the objective of commercializing technology and becoming competitive in satellite control and monitoring and mission control systems on a worldwide basis may not be given the proper priority. The objectives of the centre are all focused on providing competitive, marketable products and services on a worldwide scale and these goals are not typical of government organizations.

5.2.1 (Cont'd)

As well, government ownership leads to political involvement and this may hinder the marketing of the centre internationally, although most countries are not unwilling to deal with the Canadian government at this time.

5.2.2 Government/Private Joint Venture Ownership

A combination of government and private ownership is attractive from the point of view that this approach has already been used in other situations (such as TeleSAT and more recently, in the privatization of several crown corporations). The joint ownership approach allows a combination of government backing with the added incentive of profitability because of the private enterprise affiliation. The government provides stability and credibility to the entity while the private element ensures that a profitable and efficient organization will result from the partnership.

In view of the economic reality of the CSCC, especially in its initial stages, at least some portion of government ownership is attractive to users and investors as it shows government support for the project and infers that government funds will be used to support the operations. In the space industry, government involvement is given, due to the nature of most space operations and the government sponsorship of the actual projects. Such a combination of government/private ownership would also allow the government to have some say in the allocation of projects to the CSCC as opposed to requiring the centre to competitively earn ground control segment projects. A joint government/private joint venture ownership position in a Western Canadian facility would:

- provide a focus point for government backed projects in the space sector

- centralize skills and expertise in Western Canada

5.2.2 (Cont'd)

- satisfy regional distribution initiatives
- require a profit motive and possibly increase competitiveness on a global scale
- be accountable to private investors and therefore likely more efficient from a cost control standpoint
- be more acceptable to government bodies given the current political privatization emphasis
- provide an entity analogous to TeleSAT for noncommunication satellites (given that TeleSAT's stated mandate currently covers only communication satellites)

A joint government/private enterprise ownership of the facility would have certain income tax effects but these effects are unlikely to affect the feasibility of the centre.

This structure may also be preferable from an international marketing perspective. Foreign investros may be more likely to deal with the centre if they know it has the stability and support of government as witnessed through their ownership position. As well, for investors that are somewhat intimidated by dealing with political bodies, the private enterprise involvement may be appealing.

The specific ownership details could be complex to negotiate and implement, and have not been dealt with in this study. This form of ownership is, however, very feasible given that government support, both in principle and financially, is required for the long term success of the CSCC.

5.2.3 100 Percent Private Ownership

Complete ownership of the CSCC by private enterprise is also an alternative. This alternative is especially attractive given the current trend toward government privatization and the political support being shown for private enterprise. As well, a 100 percent privately-owned company has more flexibility in terms of organizational structure and may be better able to respond quickly to competitive bid situations. The "freedom" of such an organization may also allow the centre to accept projects that governments may not wish to become involved with. The pure profit motivation of private enterprise would also make the centre as efficient and competitive as possible, increasing the likelihood of securing projects.

The primary impediment to pure private ownership is the capitalization, funding and uncertain financial future of the centre. Since government contracts are typically awarded with a fixed level of profit attached to each program, the ability to improve profits is primarily dependent on the ability of the centre to secure higher margin foreign contracts.

As well, given that the market is driven primarily by government programs plus initiatives, the ultimate balance of economic power would rest with government departments not the investors or owners of the centre. It is unlikely that many third parties would be interested in such an investment.

SED, however, has a vested interest in the space industry and is committed to increasing its presence in Western Canada. As well, SED is in an excellent position to promote such a centre in a manner consistent with its objectives considering their

- reputation in the space industry in Canada and internationally
- location near the University of Saskatchewan in Saskatoon
- past involvement in satellite missions

5.2.3 (Cont'd)

- software and equipment development capabilities and expertise
- technical strengths in the satellite control sector.

SED's commitment to the concept of the centre and their proven capabilities logically lead to their involvement in the centre's ownership. In order to maintain a segregation from their current business activities and give a proper Canadian identity to the centre, it is apparent that SED would not own the centre. A distinct, separately identified corporate entity is required to make the centre truly Canadian, as opposed to a local centre.

It is likely that a new corporation, capitalized and wholly owned by SED, with a specific Canadian identity separate from SED, would provide a base for the CSCC to develop from. Based on funding requirements, other equity partners may enter the picture, but the primary ownership and direction of the CSCC must come from SED.

5.3 MANAGEMENT PHILOSOPHY

A review of existing space centre operations in the United States and Europe indicated that there is a high degree of government involvement in each of the operations. A central agency has been assigned the responsibility of coordinating the space program and has established specific entities to control the ground segment operations. Each of these entities has the total support of the associated government in delivering its mandate. The Canadian Space Control Centre would like to establish itself as a more entrepreneurial enterprise as opposed to being a government-sponsored organization. This requires that the management philosophy recognize this entrepreneurial spirit and be prepared to run the Canadian Space Control Centre as a profitable entity. This requires the following management orientation:

- aggressive marketing department to investigate both domestic and foreign opportunities for satellite ground control
- aggressive marketing department capable of operating effectively on the global scale and interfacing with domestic and foreign government departments, industry, and research bodies
- willingness to take risks in the process of establishing new technologies for sale in the domestic and international market and willingness to sponsor research projects aimed at developing such new technology
- the ability to recognize and capitalize on identified market opportunities
- willingness to take a proactive approach to the space industry as opposed to reacting based on specific projects announced by the government
- profit-based financial accountability to owners and directors
- budgets, earnings targets, and cost control measures consistent with the profit objectives of the entity

5.3 MANAGEMENT PHILOSOPHY (Cont'd)

- efficiency and cost minimization goals and objectives

This management philosophy represents a new approach to the space industry and requires an innovative management team to properly implement strategies to attain the stated goals of the Canadian Space Control Centre.

The management team must be capable of operating in a competitive environment as it is likely that TeleSAT would be bidding for the same projects as the Canadian Space Control Centre.

5.4 MANAGEMENT REQUIREMENTS

The Canadian Space Control Centre will require, at a minimum, the following management personnel:

- GENERAL MANAGER - responsible for overseeing the entire operations and a direct communication link to specific project mission control offices.

- MARKETING MANAGER - responsible for all aspects of marketing on a domestic and international level.

- OPERATIONS MANAGER - required at a future date when the number of projects undertaken by the Canadian Space Control Centre reaches a point where it is not cost-effective to subcontract the services of SED. At this point the facilities manager will be responsible for maintenance, security, and other facility-related issues.

- FINANCIAL CONTROLLER - required at some future point. In the interim period, SED can provide this function on a fee-for-service basis.

- PROJECT-SPECIFIC STAFF - includes managers, technicians, analysts, and support staff for the projects undertaken by the Canadian Space Control Centre. Each project will have specific staff responsible for these functions.

- SECRETARY/RECEPTIONIST - responsible for the day-to-day office requirements of the Canadian Space Control Centre core functions.

5.5 ORGANIZATION AND STAFFING

The CSCC will operate as a stand-alone facility with only a core of administrative staff responsible for maintaining operations and generating business. Most facility costs and administrative support work will be provided by SED on a fee-for-service basis. The details of operating cost and ongoing service fees has been outlined in detail in Section 8.3, Basis of Economic Evaluation.

Each project will have a complement of administrative and technical staff responsible for the specific project. These costs are not relevant to the staffing of the CSCC as they have been allocated as specific project costs and included as the projects are secured. These staff members as well as some other facility costs, are incremental in nature and will be incurred as projects are initiated.

The core services of the CSCC are required regardless of the level of activity in the centre. The cost to provide these services are relatively fixed and increase only when volumes justify adding additional personnel.

Table 5.1 summarizes the staffing requirements for the Canadian Space Control Centre including the management team and program staffing requirements for the Radarsat, MSS and UDP control centres.

Ideally, the CSCC management team will have had previous experience in Canada's space industry, preferably ground-based satellite control systems. The General Manager, Marketing Manager, and Financial Controller will be university graduates with several years experience in industry.

The program's specific personnel for the Radarsat or MSS and UDP control centres will have varying experience and qualifications. Typically the operator or controller will be graduates of a technical school or college. It will be desirable to have thirty percent of the operators with some previous work experience. Other operators will be entry level positions with on-the-job training programs.

TABLE 5.1
STAFFING

Canadian Space Control Centre

Position	Management*	Radarsat**	MSS and UDP
General Manager	1		
Marketing Manager	1		
Controller	1		
Operations Manager	1	1	1
Support Staff	1	2	2
Controllers		10	21
Analysts		4	7
Services (Security & Janitorial)	2		
	7	17	31

* During the initial years of CSCC, SED will provide some of the management functions on a fee-for-service basis. As additional programs are brought to the centre, permanent staff positions will be created.

** The Radarsat staffing levels are typical of the personnel required for similar control centre for other domestic or international satellites.

5.5 ORGANIZATION AND STAFFING (Cont'd)

The analysts or dignosticians will have a university degree with 30 percent having had previous direct experience in satellite analysis. Other analysts can also be trained on the job (30 to 50 percent), while the remainder will have had some previous direct experience in the space industry.

6.0 SITE LOCATION AND FACILITY DESCRIPTION

6.1 GENERAL

The technical demands and requirements for the CSCC have been detailed in Section 3.0 of this study. In addition, the organizational structure and staffing requirements were also identified previously. This section of the study translates this program information into the physical requirements for the CSCC facility.

The drawings presented in this section are based on:

- Radarsat Document MCS Requirements Specification (draft), SPAR
- Canadian Space Station Program, Mobile Servicing System Ground Segment, System Concept Document
- detailed discussions with SED
- existing drawings of SED's building in Saskatoon, Saskatchewan
- discussions with Saskatchewan Economic Development Corporation (SEDCO) and the University of Saskatchewan for site planning criteria.

6.2 FACILITY DEVELOPMENT

A phased development approach is presented in this study for the CSCC. At this time only the Canadian Space Program segments are addressed for the facility. The facility has the capability to be expanded to serve other domestic, commercial or foreign satellite requirements in the future.

The Canadian Radarsat program is better defined and will likely be operational some four years before the Canadian Space Station Control Centre for Mobile Servicing System (MSS) and User Developed Programs (UDP) components is required. Regardless, the proposed Radarsat Control Centre is typical of the requirments and facilities that would be necessary for other domestic or international satellites.

RADARSAT CONTROL CENTRE

To serve the needs of the Radarsat program or other similar programs, a 500-square-metre facility is required. This spatial requirement can be easily accommodated on the first or second floor of the existing SED building. Initial installation of the facility on the main floor would be less costly since a separate entrance consisting of a stairwell to the second floor would not be required. Additional office space for the CSCC management team is also available on the first floor and can easily be expanded as greater demands are exerted on the centre.

CANADIAN SPACE STATION - MSS AND UDP CONTROL CENTRE

Depending on the exact schedule for implementation of the Space Station MSS and UDP components the 930-square-metre facility could be installed on the first or second floor of the existing SED building. For the purpose of this study, it is assumed that the MSS and UDP facility will be located on the second floor. This will require architectural, mechanical and electrical modifications to the existing office area on the second floor.

6.3 SITE LOCATION

Initially several sites in and around Saskatoon were considered acceptable; however, the most desirable site was Innovation Place in Saskatchewan Economic and Development Corporation Research and Development Park, north of the campus of the University of Saskatchewan, (see drawing number 1).

In 1986, SED's operations were consolidated and moved to a new 11 400-square-metre (122,000-square-foot) facility in Innovation Place. The building contains 5 000 square meters of office space on two floors, 1 700 square meters of atrium space, and 4 700 square meters of manufacturing space. A prominent feature of the building and site is the indoor atrium and beautiful outdoor landscaping inherent in the park, consisting of trees, shrubbery, contoured embankments and fountains.

Once spatial requirements were determined for each proposed phase of the CSCC, SED corporately committed the use of the SED facility to the centre. Sufficient flexibility was incorporated into the original building design to transform contemporary office space into a high technology facility.

The alternatives of using the existing SED building offered numerous cost and other advantages over an entirely separate new facility. The advantages of modifying the existing SED building on Innovation Place are:

- less costly than a new facility
- centrally located in Saskatoon
- easy and quick access to all parts of the city and the airport
- adjacent to the University of Saskatchewan

6.3 SITE LOCATION (Cont'd)

- efficient access to technical support and for maintenance of equipment

- architecturally attractive setting within close proximity of high-tech companies, research agencies, and laboratories.

Preliminary discussions have been held with federal government departments to determine the regulatory requirements for radio frequency spectrum slots for communications between the satellites and the ground stations. From these discussions and knowledge of satellite radio-frequency communication systems, it appears that adequate channels are available to establish the necessary communication link from a Saskatoon based ground station. Once a decision is made to proceed with the Space Control Centre, a more detailed discussion and formatl application will be completed.

6.4 SITE DESCRIPTION

The Innovation Place Research and Development Park is located just north of the University of Saskatchewan, east of the South Saskatchewan River. The park is a showpiece in Saskatoon and features several unique building designs and beautifully landscaped surroundings. Tenants in the park include:

- Saskatchewan Research Council and Environmental Testing Laboratories
- National Hydrology Research Centre
- SRC Resources Research Facility, SRC Pilot Plant
- Local Energy Systems (A Business Unit of AECL)
- as well as fifty other tenants.

Easy access is provided by road to the park from the main artery, Preston Avenue or from the University of Saskatchewan, Perimeter Road. The CSCC will be located in the northeast corner of the existing SED office building area. The control centre will become visually apparent by the 15-metre-high antennae tower located at the east end of the SED building.

A separate entrance will be created for security reasons and to distinguish the facility from the existing SED facility. The architecturally-designed entrance and landscaped plaza will welcome the visitor and encourage participation in the centre. Signage located in the plaza will initiate the visitor to the facility explaining the purpose of the antennae and introducing other aspects of the Canadian Space Program.

The new entrance will require removal of existing landscaped knolls, grass and trees. A drop-off area will be provided for visitors although employee parking will be provided at the west end of the SED building.

6.4 SITE DESCRIPTION (Cont'd)

All outdoor site modifications or improvements will incorporate the high design standards inherent in the existing park landscaping. All designs will incorporate wheelchair accessible features.

Preliminary discussions have been held with representatives of Saskatchewan Economic and Development Corporation and the University of Saskatchewan regarding building criteria and planning for the centre. Both SEDCO and the University strongly support the centre; however, final design features including landscaping, parking, antennae structure, and architectural details, etc. will require formal approval by both groups once a decision is made to proceed with the facility.

6.5 CANADIAN SPACE CONTROL CENTRE - RADARSAT CONTROL CENTRE

6.5.1 General

In the early phases of the CSCC with only the Radarsat program, or some other similar program, offices will be provided for the Space Control Centre Manager as well as a Business Development Manager. As additional program demands are made on the CSCC, office space will be increased within the existing SED building on the main floor. The Radarsat Control Centre or other similar programs, will consist of the following function areas:

- reception area
- waiting area and public viewing gallery
- control room
- computer room
- analysis room including two offices
- data centre
- equipment room
- communications room
- satellite control centre administration
  - manager's office
  - maintenance office
  - inventory office
  - office services
  - conference room
  - spare office

6.5.2 Radarsat Control Centre Description

The facility interior centres around two important rooms, the computer room and the control room. The 69-square-meter control room is the largest room and most of the operation functions will be executed here. Surrounding the control room will be "service function" rooms; the computer, analysis and maintenance rooms. The computer room will also have direct access to the data centre where tape storage is provided.

To ensure good public relations the Radarsat facility will be easily assessible to the public. A public viewing gallery has been incorporated in the design to permit the control room and computer room to be viewed through glass partitions by the public. Signage within the gallery area as well as bright informative visual displays will help convey some of the features and purpose of the facility.

The antennae will be located at the east end of the SED building near the main entrance. A 15-metre-high structure will be required to ensure an unobstructed view of the horizon by the antennae. The antennae will be approximately ten meters in diameter with full rotational capability in all directions.

The administrative areas will enjoy all assets of a contemporary office and some offices will have a view of the existing atrium.

Security systems will be a necessary part of the facility. Access will be restricted to the control room, analysis area, and computer room through combination door lock or electronic cards. Alarmed emergency exits will be provided between the Radarsat facility and the existing SED building to meet all building codes and fire regulations.

6.5.3 Mechanical System

The existing mechanical system was designed to serve a typical office environment. Therefore the mechanical system will require upgrading to meet the new demands of the Radarsat Control Centre. As is customary

6.5.3 (Cont'd)

with most computer and control room facilities, the mechanical heating, ventilating, and air conditioning modification will be integrated with a raised floor throughout the control and computer room area. The system will also be designed to provide a dust-free environment in these key areas.

Since access to the existing SED washrooms is not possible, separate washrooms will be provided for the Control Centre while at the same time maintaining the security of both buildings.

Fire protection is an important mechanical requirement for the facility. The existing sprinkler system will be altered to ensure proper coverage and sprinklers will be removed from the control room, data centre, and computer room. Those areas excluded by sprinkler coverage will be served by a Halon gas system. All modifications will be in full compliance with the National Building Code, City Building Code and fire regulations.

6.5.4 Electrical System

It is essential that the Radarsat Control Centre be in operation at all times. Therefore it is necessary to have a 100 percent reliable electrical power system. Critical electrical loads for the Radarsat project have been identified as all main data processing units, operator consoles, information displays, selected communication equipment, emergency lighting and antennae drive systems. These loads require 100 percent electric power reliability and will be supplied by a combination of uninterruptible power supply and a diesel-powered emergency generator.

The uninterruptible power supply will be equipped with batteries capable of powering the critical loads for a period of fifteen minutes which would be long enough to allow the generator set to be started and warmed up. The critical loads will be handled by a 30 kva system. This

6.5.4 (Cont'd)

includes 10 kva built-in expansion capability for the system to accommodate future unknown program requirements.

The diesel generator set, uninterruptible power supply and batteries will be housed in a small building located at the southeast corner of the existing building. The building will be sized to accommodate the Radarsat system as well as the larger Space Station MSS and UDP component system which may be installed several years after the Radarsat installation. Sealed batteries will be used to minimize hazards caused by the release of hydrogen gas. A one-day storage for diesel fuel is also included and will be located on the building perimeter.

All other power supply requirements will be provided through the main electrical supply panel for the SED building provided by the City of Saskatoon. Typical electrical lighting and electrical distribution systems will be provided throughout all areas of the facility.

6.6 CANADIAN SPACE CONTROL CENTRE - MSS AND UDP CONTROL CENTRE

6.6.1 General

As stated in Section 5.5, the CSCC administrative functions will be accommodated within the existing SED office area west of the Radarsat Control Centre on the main floor. The office space will be designed to meet the needs of the centre as it expands. The Control Centre for the MSS and UDP components will consist of the following function areas:

- main entrance and reception
- waiting area and public viewing
- computer room for both components
- data centre
- analysis room for MSS including four analysis offices and one SOSS procedures office
- analysis room for UDP including two analyst offices
- communications room
- storage and maintenance room
- MSS and UDP Control Centre administration
  - managing director of CSCC
  - SOSS managers office
  - GOSS managers office
  - logistics and analyst office
  - inventory office
  - office services area
  - training centre
  - conference room

6.6.1 (Cont'd)

- copy room and office supplies
- spare office
- lunchroom/lounge
- public washrooms

6.6.2 MSS and UDP Control Centre Description

The facility will be located on the second floor and will be centred around the MSS and UDP control rooms. A large glassed-in public viewing area will be provided and permits clear, unobstructed views of the computer room and both control rooms.

Surrounding both control rooms will be the relevant support or services function rooms such as analysis and maintenance areas. The control rooms will be spacious and will be designed to permit the addition of further control functions as the need arises. As well, additional office area has been provided within the centre to permit expansion of various functional areas as the demands of the programs change. Signage and visual aids will help direct and inform the visitor touring the facility.

For security purposes the lobby and public viewing area will be essentially separated from the other areas through controlled access using combination locks or electronic card access. To meet fire regulations, emergency exits will be provided at other locations in the facility which open on to the SED atrium which will allow ultimate access from the building.

The MSS and UDP antenneas will consist of a 10-metre diameter antennae supported on a fifteen-metre-high structural foundation.

The raised structure will allow an unimpeded view of the horizon in all directions. Other features are similar to the Radarsat Facility Description outlined previously in the report.

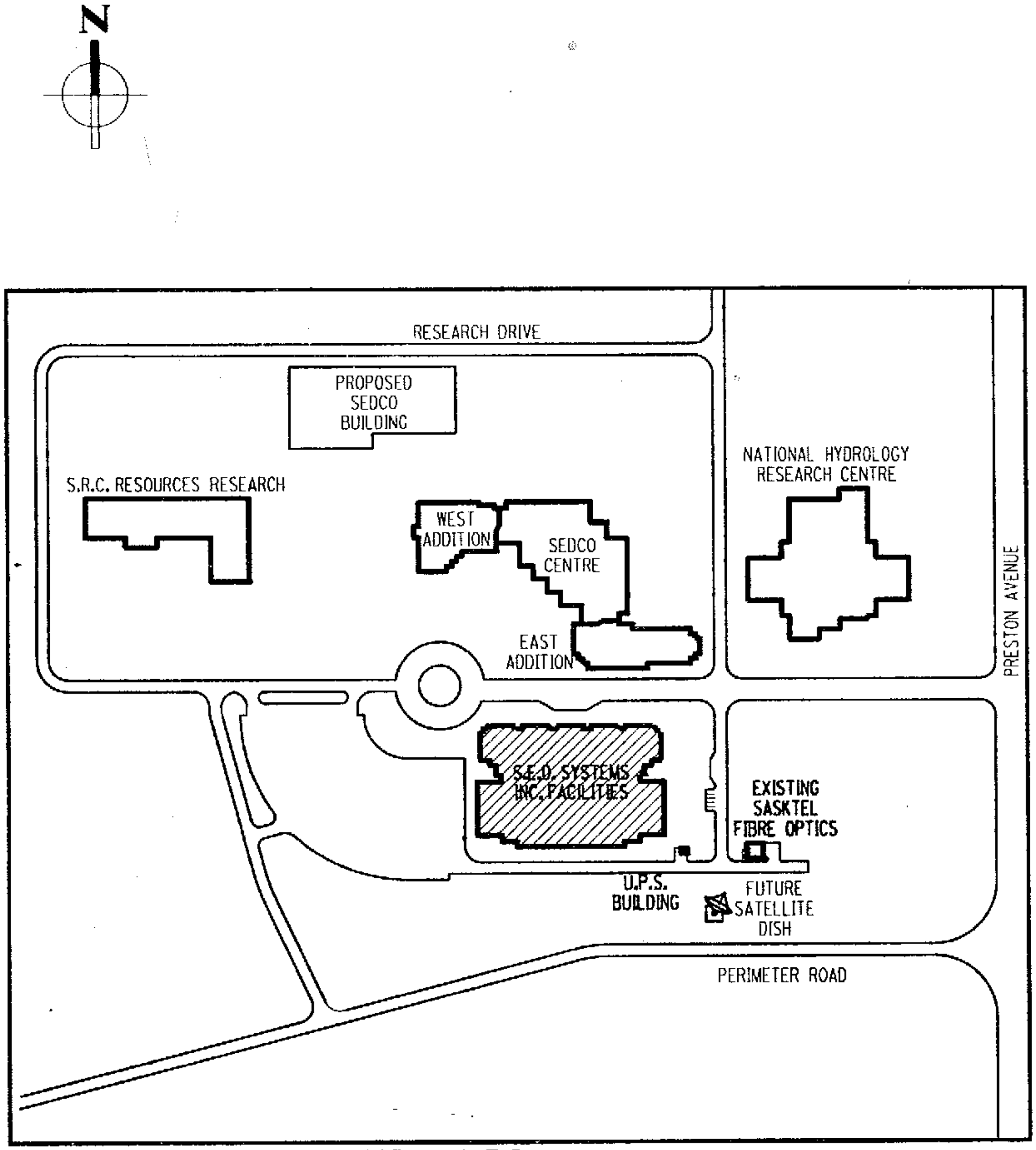
6.6.3 Mechanical System

The mechanical system upgrade for MSS and UDP components is much larger and will require more modifications than the Radarsat mechanical system to meet the new demands. The heating, ventilating, and air conditioning systems will be upgraded to meet the demands of the larger computer room and control rooms. The sprinkler system will be modified and a Halon gas system will be used in the key areas of the control centre. With the MSS and UDP control centre occupying half of the second floor of the existing SED building, the existing washrooms will be assessible only to the control centre personnel. For security reasons, access to this common area will be denied to SED staff.

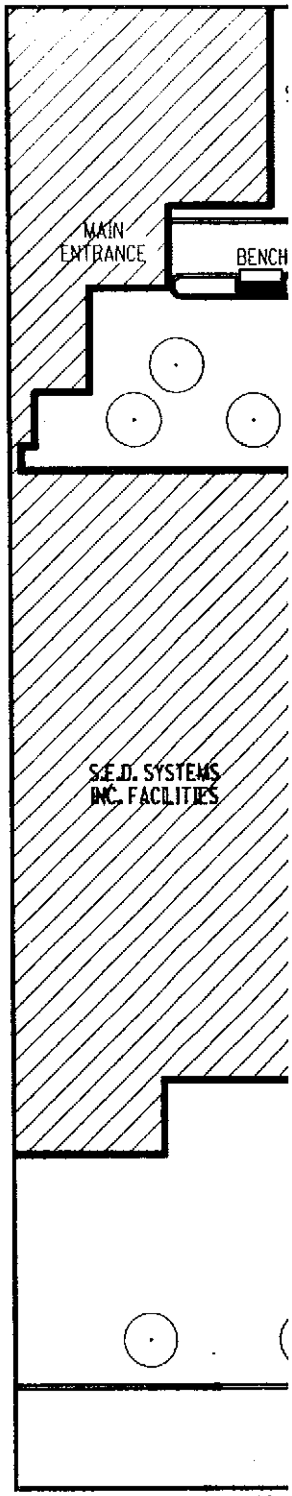
6.6.4 Electrical System

As described with the Radarsat system, an uninterruptible power supply will be installed to provide a 100 percent reliable power system to serve all critical loads. A 100 kVA system will be provided in addition to the 30 kVA system provided for Radarsat. The batteries and generator will be located in a separate electrical building initially built for the Radarsat system. The primary reason for the increased load is the electrical drive demand for the ten-metre-diameter fully rotational antennae located near the facility. Other demands relate to the larger loads for the control rooms, computer room, and support facilities.

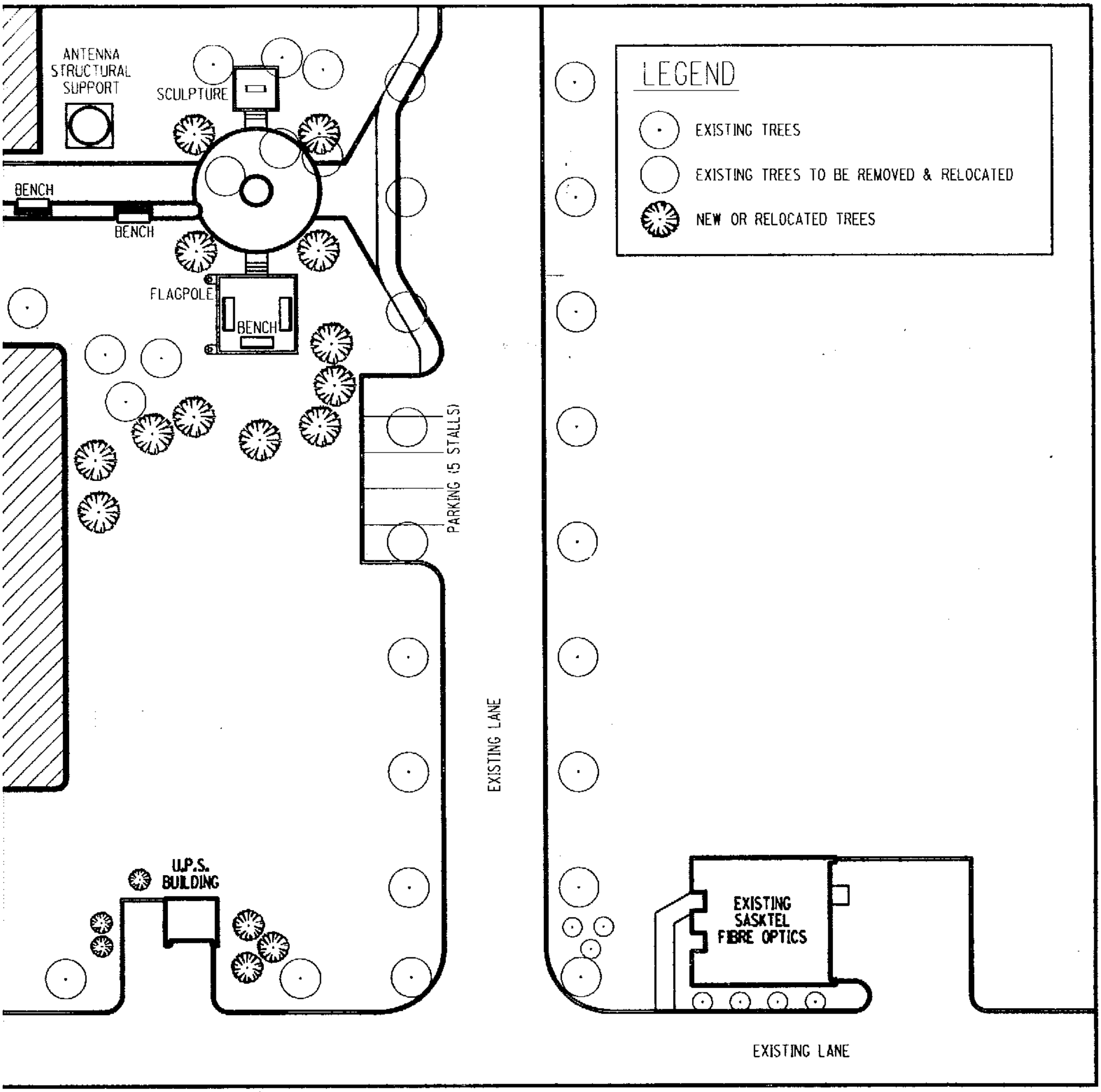
Other electrical services relate to improved and modified lighting levels and electrical distribution throughout the facility.



SITE PLAN - INNOVATION PLACE N.T.S.



PARTIAL SITE PLAN



PLAN - ENTRANCE N.T.S.

CANADIAN SPACE CONTROL CENTRE
RENOVATION OF EXISTING
S.E.D. SYSTEMS INC. FACILITY
DRAWING NUMBER 1 JULY, 1989

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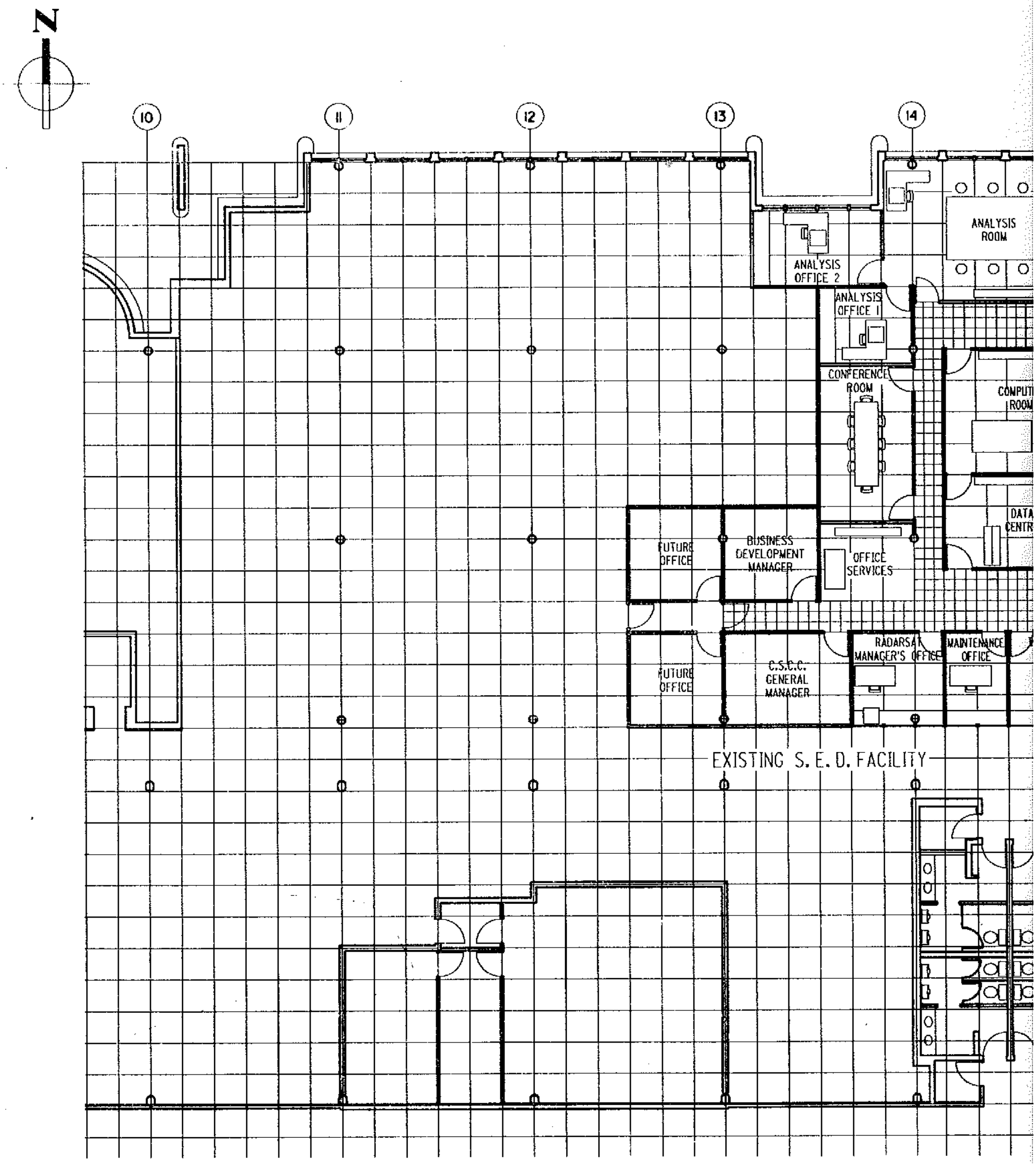
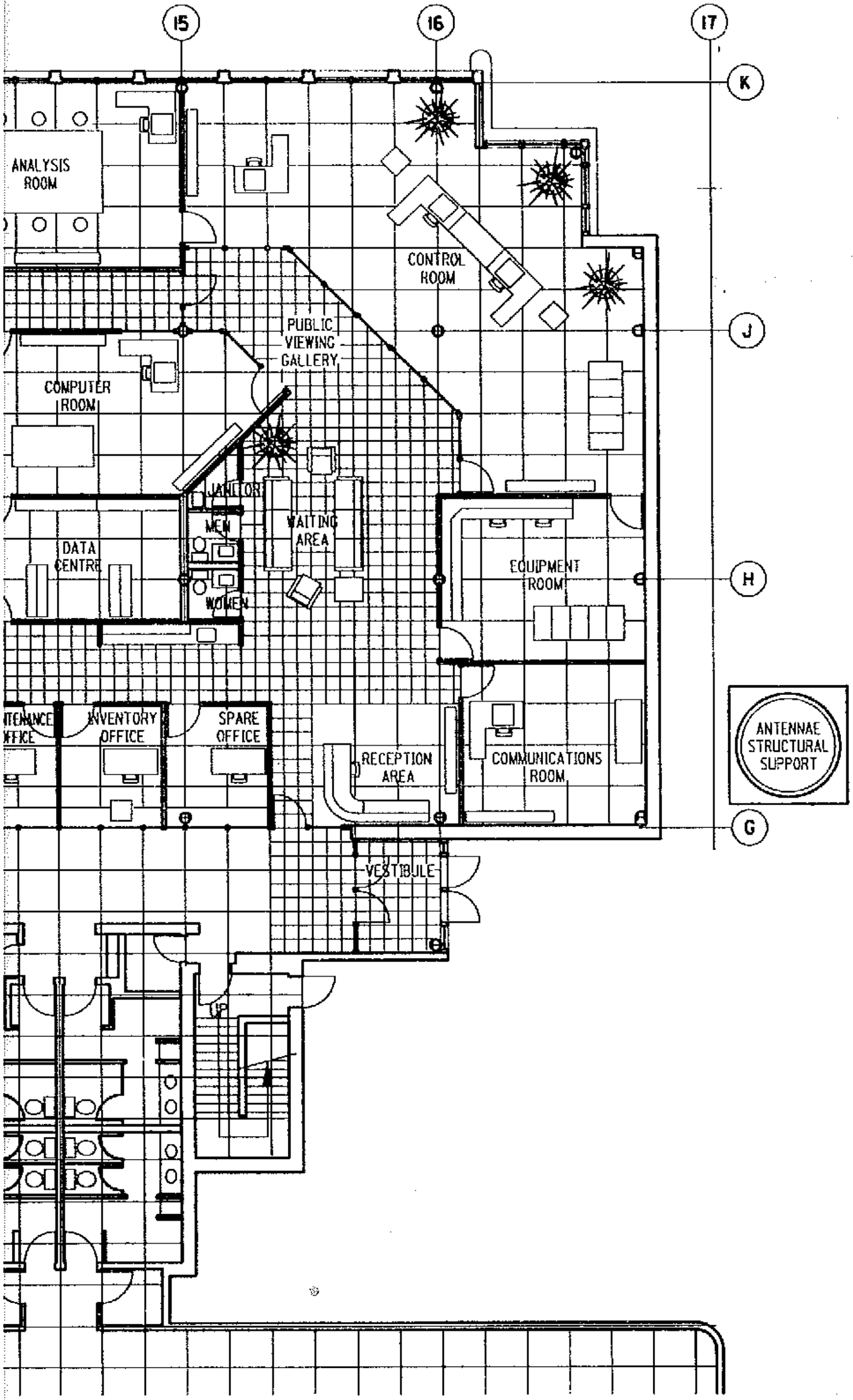
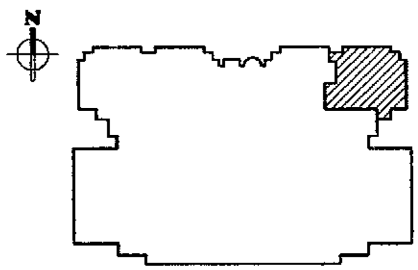

N
10
11
12
13
14
ANALYSIS ROOM
ANALYSIS OFFICE 2
ANALYSIS OFFICE 1
CONFERENCE ROOM
FUTURE OFFICE
BUSINESS DEVELOPMENT MANAGER
OFFICE SERVICES
FUTURE OFFICE
C.S.C.C. GENERAL MANAGER
RADARSAT MANAGER'S OFFICE
MAINTENANCE OFFICE
EXISTING S.E.D. FACILITY





KEY PLAN

CANADIAN SPACE CONTROL CENTRE
RADARSAT CONTROL CENTRE
PLAN - MAIN FLOOR
RENOVATION OF EXISTING
S.E.D. SYSTEMS INC. FACILITY
DRAWING NUMBER 2 SCALE - 1:200 JULY, 1989

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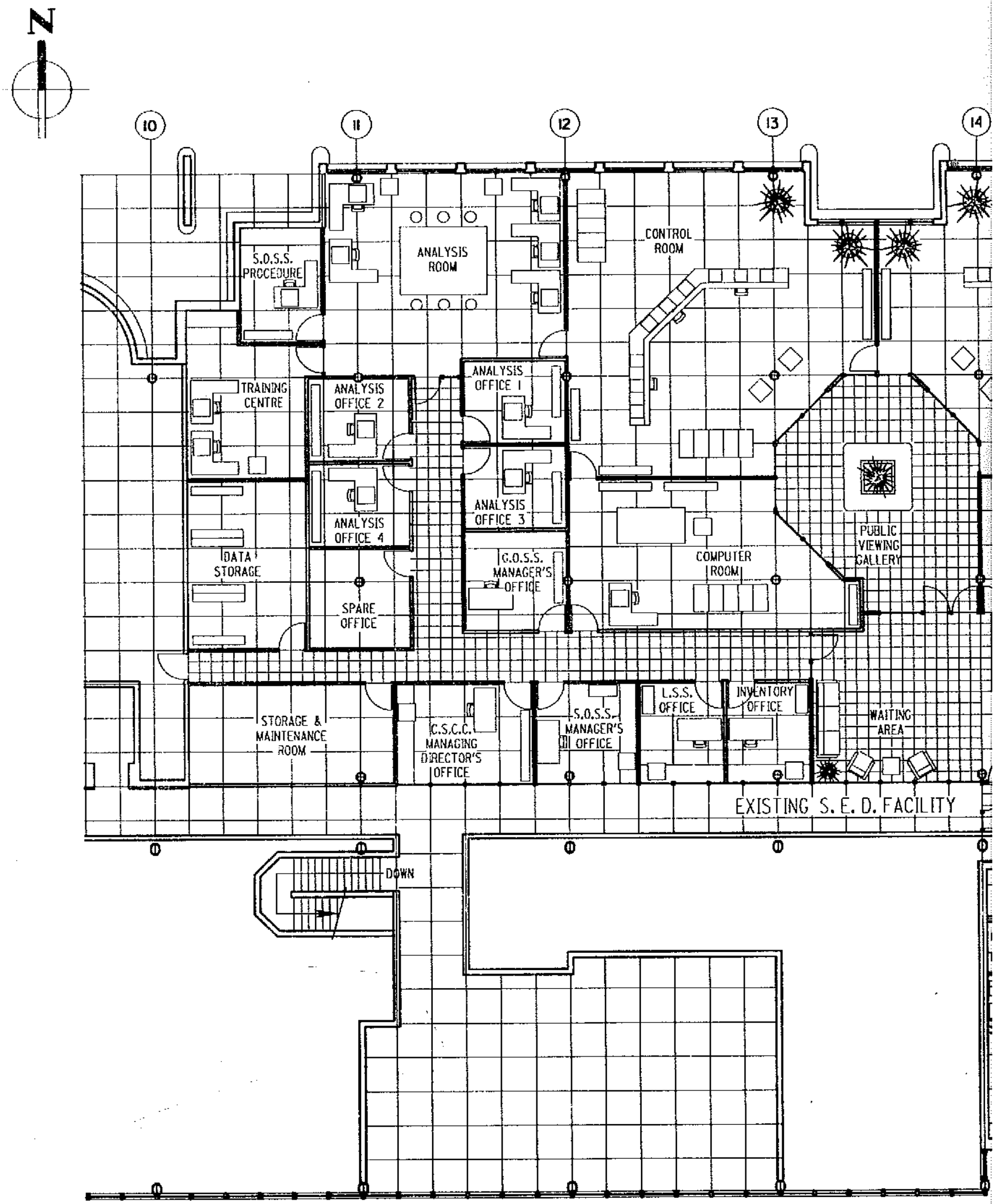
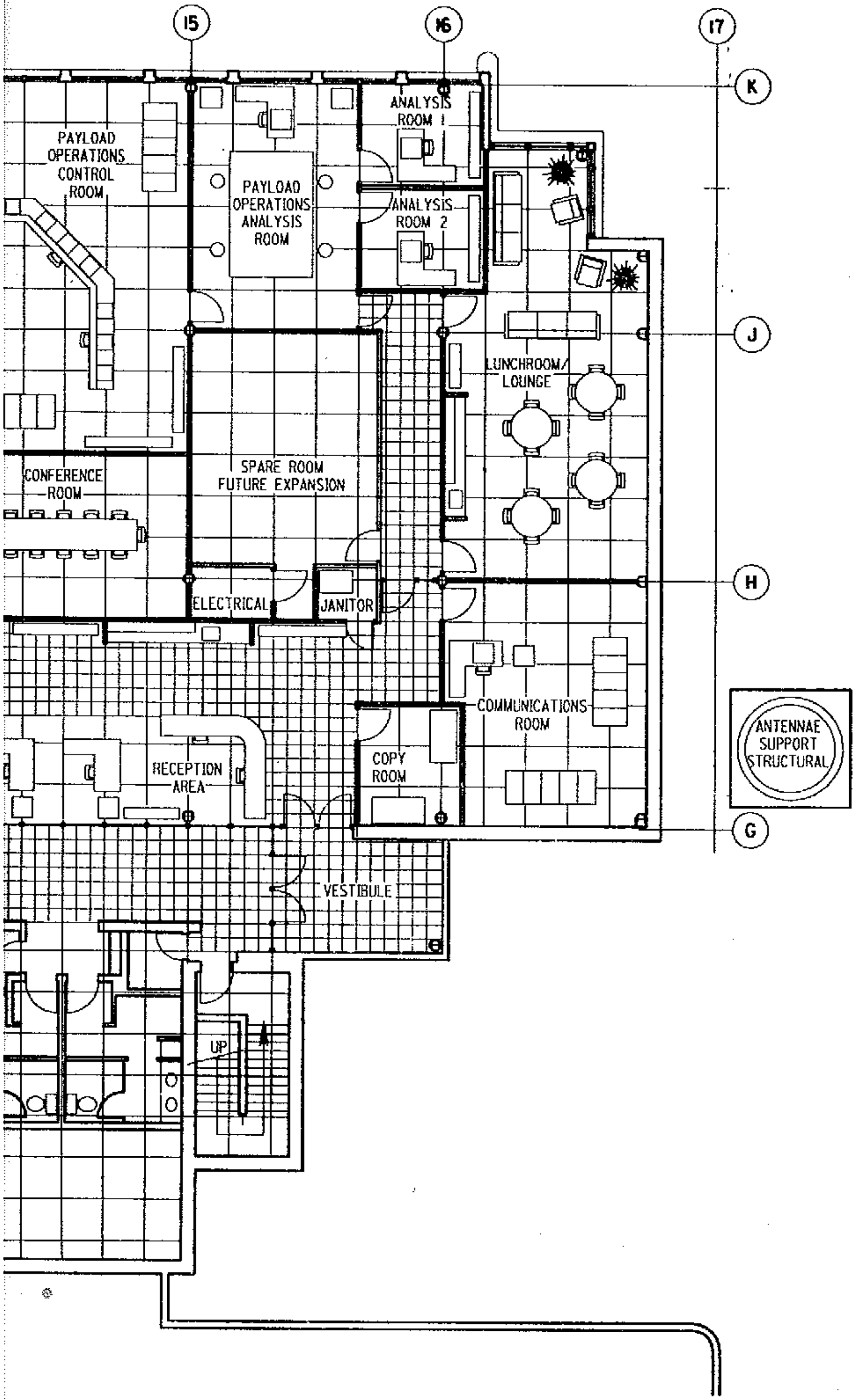
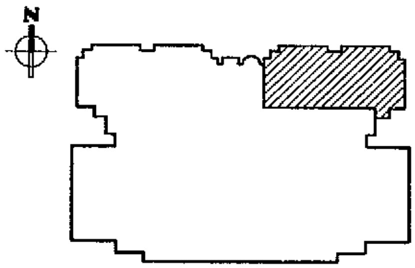

N
10
11
12
13
14
S.O.S.S. PROCEDURE
ANALYSIS ROOM
CONTROL ROOM
TRAINING CENTRE
ANALYSIS OFFICE 2
ANALYSIS OFFICE 1
ANALYSIS OFFICE 3
ANALYSIS OFFICE 4
DATA STORAGE
SPARE OFFICE
C.O.S.S. MANAGER'S OFFICE
COMPUTER ROOM
PUBLIC VIEWING GALLERY
STORAGE & MAINTENANCE ROOM
C.S.C.C. MANAGING DIRECTOR'S OFFICE
S.O.S.S. MANAGER'S OFFICE
L.S.S. OFFICE
INVENTORY OFFICE
WAITING AREA
EXISTING S. E. D. FACILITY
DOWN





KEY PLAN

CANADIAN SPACE CONTROL CENTRE
MSS & UDP CONTROL CENTRE
PLAN - SECOND FLOOR
RENOVATION OF EXISTING
S.E.D. SYSTEMS INC. FACILITY
DRAWING NUMBER 3 SCALE - 1:200 JULY, 1989

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7.0 CAPITAL COST ESTIMATES

7.1 SUMMARY

As discussed in previous sections of the report, the concept for a Radarsat Control Centre better defined than other space programs at this time. Therefore, it has been identified separately in presentation of the capital and operating cost estimates. The Radarsat facility is typical of the requirements of other space control centres for domestic or international satellites.

The development of a CSCC with the Mobile Servicing System (MSS) and the User Development Program (UDP) has also been estimated separately. Both options can be easily developed within the confines of the existing SED building located in the Saskatchewan Economic Development Corporation Research and Development Park located near the University of Saskatchewan campus.

The capital cost estimate for the Radarsat facility is $636,000 and for the MSS and UDP control centre facility $1,223,000. The basis and details of the estimates are presented in Sections 6.2 and Section 6.3 respectively. The capital cost estimates presented in this study consist of the following items:

- architectural modifications
- mechanical upgrades
- electrical upgrades
- antennae foundations
- civil and plaza landscaping
- electrical uninterrupted power supply
- electrical building

7.1 SUMMARY (Cont'd)

- furniture and office equipment
- miscellaneous items
- construction indirects
- engineering and architectural services
- contingency

7.2 BASIS OF CAPITAL COST ESTIMATES

The capital cost estimates are based on the following information:

- Radarsat MCS Requirements Specification (draft), SPAR
- Canadian Space Station Program Mobile Servicing System, Ground Segment, System Configuration Document, March 1989 -Prepared by SED Systems Inc.
- Site Plans as shown on drawing number 1
- Floor Plans as shown on drawing numbers 2 and 3
- Facility description (see Section 6.0)
- Program requirements identified by SED
- Kilborn in-house costs and factors
- Supplier estimates for major electrical and mechanical components

For the purpose of the capital cost estimate, it has been assumed that:

- all costs are in second quarter 1989 Canadian dollars
- the work will be executed utilizing fixed price construction contracts for various work packages (electrical, mechanical, architectural, landscaping)

No allowances have been made in the capital estimate for:

- modification to the main power supply to the existing SED facility from the City of Saskatoon system

7.2 BASIS OF CAPITAL COST ESTIMATES (Cont'd)

- escalation beyond the second quarter 1989
- working capital and interest
- site surveys, legal surveys, or geotechnical studies
- land costs
- licensing fees, royalties, permits, government approvals and inspections
- course of construction insurance
- spare equipment and parts (these costs are included within the Radarsat Program Costs)
- owner's engineering and management.

7.3 DETAILS OF CAPITAL COST ESTIMATE

7.3.1 Introduction

The information presented in Table 7.1 and Table 7.2 summarizes the cost for two project development phases:

- Canadian Space Control Centre, Radarsat Control Centre
- Canadian Space Control Centre, MSS and UDP Ground Segment Operations

The Radarsat Centre separately is estimated to cost approximately $636,000. The average cost per square metre is $1,154.00 or $107.00 per square foot. The modifications required for the CSCC with MSS and UDP components will cost approximately $1,223,000. The average cost per square metre for the MSS and UDP is $1207.00 or $112.25 per square foot.

The Radarsat capital cost estimate includes the building entrance, landscaping and plaza development costs as well as the electrical building for the uninterrupted power supply (UPS) system. The MSS and UDP capital cost estimates excludes costs for the plaza development and electrical UPS building.

Each capital cost estimate is divided according to direct costs (direct construction activity) and indirect costs (contractor costs, engineering and architectural services, and contingency).

TABLE 7.1

CAPITAL COST ESTIMATE

CANADIAN SPACE CONTROL CENTRE

RADARSAT CONTROL CENTRE

Direct Costs	
Architectural Modification	$ 56,000
Civil and Plaza Landscaping	51,000
Antennae Foundation	25,000
Mechanical Upgrades	83,000
Electrical Upgrades	22,000
Electrical Supply and UPS System	155,000
Electrical Building	20,000
Furniture and Office Equipment	45,000
Miscellaneous	25,000
Subtotal Direct Costs	$482,000
Indirect Costs	
Construction Indirects	$ 24,000
Engineering and Architectural Services	72,000
Contingency 10 %	58,000
Subtotal Indirect Cost	$154,000
TOTAL CAPITAL COST ESTIMATE	**$636,000**

TABLE 7.2

CAPITAL COST ESTIMATE

CANADIAN SPACE CONTROL CENTRE

MSS AND UDP CONTROL CENTRE

Direct Costs	
Architectural Modifications	$ 142,000
Civil and Plaza Landscaping	0
Antennae Foundation	65,000
Mechanical Upgrades	132,000
Electrical Upgrades	48,000
Electrical Supply and UPS System	370,000
Electrical Building	0
Furniture and Office Equipment	114,000
Miscellaneous	50,000
Subtotal Direct Cost	$ 921,000
Indirect Costs	
Construction Indirects	$ 46,000
Engineering and Architectural Services	145,000
Contingency 10%	111,000
Subtotal Indirect Costs	$ 302,000
TOTAL CAPITAL COST ESTIMATE	**$1,223,000**

7.3.2 Radarsat Control Centre - Details of Capital Cost

All capital costs have been based on the modifications or new construction required as shown on drawing number 2. Where possible, quantity take-offs have been made and costs applied to each unit. Architectural modifications will require alteration to existing facilities to accommodate fire protection, raised floors, dust-reduced environments, and electrical UPS systems. Other architectural improvements relate to entrances, door sizing, viewing areas, conference rooms, etc.

Civil and landscaping costs are only shown against the Radarsat Control Centre option since these improvements are required for the initial development. The civil and plaza landscaping costs are for construction of a separate identifiable entrance, roadways, drop-off, sculpture court, planters, benches, signage, canopies, with an open space concept involving the visitor with the centre.

The electrical and mechanical upgrades relate to air conditioning improvements, fire protection system upgrades and sewer, water, building services, and electrical distrubution throughout the facility. The UPS electrical system has been sized only for Radarsat requirements at this time, although some expansion capacity (10 kVA) is available within the system provided to accomodate program changes. The electrical building will house the generator and battery system and will be finished similar to the existing SaskTel building nearby.

The electrical UPS system includes the following items to accommodate a 30 kVA load, generator set, UPS system, batteries and rack, power conditioner/fitter, transformer, feeder breaker panels, lights, cable, and fittings. Preliminary quotations were received from vendors for the major electrical components. Electrical upgrades include lighting modifications and electrical supply throughout the facility, but exclude wiring and connection of program equipment, computers, and radio frequency components.

7.3.2 (Cont'd)

Furniture and office equipment includes tables, chairs, desks, lounge furniture, photocopier, planters, console housing construction, audio/visual equipment, word processing equipment, facsimile, telephone systems, etc. Miscellaneous items include security system, fire alarms, and signage.

Indirect costs are estimated as a percentage of the direct capital cost. A five percent fee is included for contractors' costs. Engineering and architectural services, including design drawings, specification preparation and construction management is estimated at 15 percent of the total direct cost. A 10 percent contingency allowance (on the total direct cost, plus construction indirects and engineering) is also included to account for possible unforeseen cost factors.

7.3.3 MSS and UDP Control Centre - Details of Capital Cost

The architectural modifications for the MSS and UDP Control Centre includes partitioning, doors, windows, raised floors, lounge and kitchen facilities, and public gallery/lobby/reception area development. Civil work and plaza landscaping costs are not included against the MSS and UDP estimate since the establishment of Radarsat at the existing SED building required expenditures for this item in that initial development. Mechanical upgrades relate to heating, ventilating, air conditioning, and fire protection modifications.

Lighting changes and electrical service throughout the main floor are reflected in the electrical upgrade capital costs. The electrical upgrade cost does not include connection and installtion of the Control Centre's program equipment, computers, or radio frequency components.

A larger electrical UPS system is required for MSS and UDP components. Major system component costs were verified with suppliers by telephone. A saving of approximately 20 percent may be realized if the Radarsat, MSS and UDP Control Centres were to be combined as one larger system.

7.3.3 (Cont'd)

The individual items comprising the cost estimate for furniture and office equipment and miscellaneous items are as described in Section 7.3.2 of the Radarsat Control Centre - Details of Capital Cost Estimate.

As discussed in the previous section 7.3.2, an allowance for indirect costs for construction indirects, engineering and contingencies is also included in the capital cost estimate.

8.0 FINANCIAL ANALYSIS

8.1 BUSINESS PLAN

The Business Plan for the CSCC is based on the premise that the Centre will operate as an independent body that provides complete ground control for a variety of satellite missions. The business plan has been structured such that a core set of costs related to the management and operation of the facility are required regardless of whether any projects are undertaken. It is likely that in the initial stages of operation there will be no projects but the basic infrastructure will still be required. When specific projects are undertaken by the Control Centre, revenues will be generated to cover the costs of providing the core services. As more projects are procured the Centre will become more profitable and costs related to providing the infrastructure for the Centre will be recovered from a larger number of projects. Once a certain volume of work has been secured, the Centre will become self-sustaining and profitable. It is anticipated that this will occur within six years of the commencement of operations based on the assumptions that have been made regarding program implementation time frames and profit levels.

The business plan has been designed such that capital and operating costs are minimized in the initial stages. This minimization of costs will be accomplished through a modular approach to construction for capital costs, and subcontracting the majority of support services from the existing building tenant, SED. Volumes will reach a point where subcontracting is not as cost-effective as providing support services internally. At this time it is anticipated that the CSCC will hire its own staff and run as a completely autonomous business unit.

The specific project costs included in the business plan assume that each project will fund all direct costs of the project as well as providing a reasonable profit margin to cover overhead costs and a recovery of capital cost expenditures. The business plan has attempted to identify specific direct project costs as well as incremental

8.1 **BUSINESS PLAN** (Cont'd)

indirect costs related to the project. Each project is supported by a schedule of capital and operating costs to the extent that they can be defined. For domestic work, we have attempted to use a reasonable profit factor based on standard government contract procedures. For foreign projects, we have included a higher profit margin to reflect the premium that such services should command in the marketplace.

Specific assumptions and critical factors used to determine the financial viability of the Canadian Space Control Centre are described in detail in the notes to the projected financial statements. (See Appendix A).

The time frame covered by the business plan is 15 years to properly reflect the effect of specific projects that we have assumed are critical to the financial viability of the centre. Specifically, this time frame will encompass the Radarsat project as well as the MSS/UDP project. These two programs are considered critical to the success of the Canadian Space Control Centre and we have concentrated our financial analysis on these projects due to the fact that they are relatively defined in the requirements and a reasonable assessment of potential costs is available. Other projects are not as well defined and we have made specific assumptions relating to the timing of these projects based on the market assessment and technical demand as defined in Section 3 of this report. Due to the time frame that the model encompasses, it is likely that there will be significant variations in the program costs associated with future projects described in the business plan and such variations could be material in amount.

Standard financial accounting policies and generally-accepted accounting principles have been used in preparing the projected financial statements. We have also used SED as a model for the specific operating costs of the centre due to the fact that the facility will use existing SED facilities and services (in the initial stages of operation). We have reviewed in detail the operating costs of SED and determined realistic operating costs for the core services as well as indirect costs for specific projects.

8.1 BUSINESS PLAN (Cont'd)

On a project-specific basis, we have assumed that all costs relating to technical equipment and software will be funded separately. The operations of the CSCC do not include project-specific equipment and software costs. They include only the operations component of the ground segment phase. This includes staff, facility and project management costs.

We have assumed that the CSCC will operate as an autonomous entrepreneurial business unit as described in Section 5.0 of this report. In the initial stages of operation, it is apparent that the Canadian Space Control Centre will require some assistance to sustain operations prior to projects being initiated. The specific source of these funds has yet to be determined, but it is likely that some sort of government sustaining grant will be required. Based on the results of operations, this sustaining grant may be repaid in later years through profits generated by on-going projects.

Details of the financial analysis are included in the projected financial statements in Appendix A.

8.2 CAPITAL COST FUNDING MECHANISMS

The feasibility of the Canadian Space Control Centre is dependent on minimizing capital cost requirements. The business plan has included a reasonable measure of profits that, over the life of the specific project, will be sufficient to recover any project-specific capital expenditures. In the interim, however, a funding source is required to finance the required leasehold improvements for each project. As well, a source of financing for initial capital costs and operational needs is required until operations become self-sustaining.

Several alternative sources of financing have been identified that may be appropriate for the Canadian Space Control Centre needs.

- Bank financing (term loans)
- Equity financing (share offering)
- SEDCO grants or loan guarantees
- Western Diversification program grants or loans
- Government grants (from municipal, provincial, or federal governments)

8.2.1 Bank Financing (Term Loans)

Bank financing is a traditional source of financing that usually requires a significant amount of security or guaranteed repayment ability on the part of the borrower. In analyzing the operations of the CSCC, the operations and projected results are speculative due to the nature of the industry it will operate within. Therefore, repayment ability is not guaranteed and banking institutions would be unlikely to evaluate the CSCC as a good risk.

8.2.1 (Cont'd)

Security and the value of security available to the banks is also a prime factor in obtaining financing. Banks typically value real property and tangible assets as good forms of security. The majority of financing required for the CSCC is to fund leasehold improvements to an existing building. Banks traditionally have avoided leasehold improvements as security on term loans as these improvements are relatively intangible and the title to these improvements typically is held by the building owner, not the lessee. In terms of other forms of security, the CSCC will be in a new and relatively complex (and possibly risky) business, and they will have no real assets to pledge as security. As well, there will be no history for banking institutions to review and make informed decisions about.

Based on the nature of the CSCC and the requirements commercial lending institutions demand, it is unlikely that banks would be willing to extend funds to the CSCC for capital expenditures.

8.2.2 Equity Financing (Share Offering)

Equity financing is an attractive form of funding capital expenditure requirements in that it does not have the carrying charges associated with debt instruments. In order to entice investors, however, the investment must have many of the same qualities that debt financiers require. In particular, investors look for the following in making any investment decision:

- security of asset base
- guaranteed return or capital appreciation
- liquidity of the investment
- intrinsic value of investment

8.2.2 (Cont'd)

- relative potential compared to competing investments
- level of risk

Unfortunately, the CSCC is speculative and it is unlikely that private investors will be willing to invest in such a risky venture, in terms of evaluating the investment from a potential return basis. Therefore, it is unlikely that equity financing attempts would yield positive results for capital cost financing.

8.2.3 Saskatchewan Economic Development Corporation

SEDCO has a number of programs available to stimulate investment in the business sector. Their current focus appears to be small business enterprises. Virtually any type of business qualifies for SEDCO programs and the CSCC meets all relevant criteria. The financial assistance available can take one of three forms:

- Term Loans
- Loan Guarantees
- Equity Capital

Term Loans

Term loans are available for capital investment and have a maximum term of 20 years. In terms of CSCC requirements, loans with a five year term would be sufficient to fund the capital improvement for any specific program. Since the CSCC is a new venture, unlikely to qualify for traditional term loans, and will generate a significant amount of direct economic activity in Saskatchewan (due to its location in Saskatoon), it is an attractive prospect for SEDCO. The business plan and projected

8.2.3 (Cont'd)

financial statements show an ability to repay and therefore, funds may be available from SEDCO in the form of repayable term loans.

Loan Guarantees

This program allows companies to obtain financing from traditional lending institutions based on a guarantee from SEDCO. The normal guarantee term is one year, but it may be extended when renegotiated.

This alternative will likely be available to help the CSCC obtain financing for capital expenditures but the terms are not as attractive as direct financing by SEDCO due to the renegotiation requirements. Although this is an option for the CSCC, it is not likely to be sufficient for their purposes in the long term.

Equity Capital

SEDCO is prepared to make a direct equity investment in companies to encourage industrial development in Saskatchewan. The normal provisions require that SEDCO take a minority share investment. Buy-back provisions are also included.

SEDCO will likely be agreeable to taking an equity position in the CSCC and the centre will likely qualify based on stated approval criteria. Since the CSCC will provide a number of benefits to the province in terms of direct job creation and its contribution to the university programming, as well as developing and exploiting new technology, SEDCO will likely be willing to provide some equity and take a partial ownership position.

8.2.4 Western Diversification Program

The Western Diversification Program is a federal government initiative designed to broaden and strengthen the economic base of the West. The

8.2.4 (Cont'd)

eligibility requirements are structured based on a series of tests that each application must pass. The basic requirements are that the project:

- create a new product or service for Western Canada
- create a new technology in the West
- create a product or service that provides a new export market
- provide improved industry productivity in the West
- satisfy the goal of import replacement

The CSCC objectives and programs will meet these conditions easily and the CSCC will definitely qualify for assistance from the program based on the evaluation criteria.

Funds from the program usually provide assistance in the form of contributions which normally require repayment. The projected financial statements show an ability to repay based on cash flow projections.

8.2.5 <u>Government Grants</u>

Grants or capital injections in the form of forgivable or repayable loans may be available from all levels of government to establish the CSCC and fund any capital expenditures. Because the CSCC will promote the image of Canada in the space industry internationally, create an investment base and enhance the image of Saskatoon as a high-tech centre, and create local economic activity in Saskatoon, governments may be willing to contribute funds to promote these activities. There are no formal programs in place to accommodate projects such as the CSCC by any level of government other than those previously discussed, and

8.2.5 (Cont'd)

discussions and negotiations will be required to determine whether any funds may be available.

Based on the economics of the centre, it is apparent that any source of funds in the initial stages of operation will be welcome. Therefore, it is recommended that the management of the CSCC investigate grants or other sources of financial backing from all levels of government.

8.3 BASIS OF ECONOMIC EVALUATION

The economic evaluation of the Canadian Space Control Centre is based on the following factors:

- Project-specific capital costs (stated in second quarter 1989 Canadian dollars, adjusted for inflation) as described in Section 6.0

- Project-specific operating costs (stated in second quarter 1989 Canadian dollars, adjusted for inflation) as described in Section 8.3.2.

- Management wages and salaries for the Canadian Space Control Centre (in second quarter 1989 Canadian dollars, adjusted for inflation) as described in section 8.3.3.

- Program implementation time frames as described in section 8.3.4

- Control Centre operating costs (determined with reference to SED's actual operating costs for their current facility) as described in Section 8.3.5.

- Rental rates and indirect costs subcontracted from SED, as described in Section 8.3.6.

- Analysis of operating costs of similar facilities gained through the site visits to the University of Colorado, SAT Control in Toulousse, France, ESA (European Space Agency), ESOC (European Space Operation Centre) in Darmstadt, Germany, ESOC Meteosat in Odenwald, Germany, and from discussions with Canadian Space Industry Representatives on specifically-identified space projects.

The economic evaluation assumes that the Canadian Space Control Centre will be an independent Canadian-controlled corporation subject to Canadian tax laws and Canadian accounting principles. Inflationary factors have been determined based on historical trends in Canada.

8.3 BASIS OF ECONOMIC EVALUATION (Cont'd)

Interest rates and other operating parameters have been assumed at the current rate as there is no justification to assume that these parameters will change materially in the foreseeable future.

Overhead costs of the centre have been allocated to specific projects based on actual overhead costs incurred. When several projects are operating simultaneously, the overhead costs will be allocated based on the actual square footage that each project occupies. As more projects are procured by the centre, overhead charged to each specific project will actually drop due to this allocation method. Profit margins will be based on total direct and indirect project costs. Profit margins consistent with current government standards have been used for domestic programs. Higher profit margins have been used for foreign programs to reflect the anticipated premium this work should command.

8.3.1 Basis of Operating Cost Estimate

Operating costs have been determined based on a project-by-project basis. Certain projects (Radarsat and Space Station) have reasonably defined parameters and specifications. In these cases, operating costs were determined based on these specifications with a degree of certainty. Other projects are anticipated in the future but these projects have not yet been defined. For these programs, it was determined that the Radarsat represented a typical model of the type of program the centre could anticipate supporting. Therefore, Radarsat program costs have been used as the basis of determining costs for future programs.

In determining operating costs for each project, the following information was considered relevant:

- Radarsat program specifications

8.3.1 (Cont'd)

- MSS/UDP program specifications
- Information gathered from site visits and interviews with SAT Control, European Space Agency, and the University of Colorado SME program
- Kilborn in-house costs and factors
- SED facility costs
- Standard labour rates based on anticipated qualifications required for program staff members
- Facility and office costs from similar facilities in Saskatoon

In all cases, the costs have been stated in 1989 Canadian dollars. The financial projections adjust the basic operating costs for inflationary factors as outlined in the notes to the projected financial statements.

As well, the following assumptions relating to each program have been made:

- The facility and programs will be functional 365 days per year.
- Operators will be required 24 hours per day, 365 days per year.
- Operators will work 12 hour shifts.
- Managers, secretaries, analysts, and diagnosticians will work 8 hours per day, 40 hours per week with observance of statutory holidays and vacations.
- All costs presented are for a one year cycle.
- The operating estimate analysis has not included allowances for taxes, financing or carrying charges and owner's costs not described in the study.

8.3.2 Description of Project-Specific Operating Costs

Each project that the centre becomes involved with will have certain operational specifications that must be filled. It is likely that each project will be unique in its requirements. In order to prepare an estimate of operating costs, certain assumptions were made because future programs have not yet been identified or confirmed. Due to the nature of the market environment in this industry, and technological changes that may affect this market in the future, the estimates used may not be valid in future years. Based on these issues, it was determined that the Radarsat program is typical and would be used as a model for future, as yet undefined, programs.

Only direct operating costs of each program were identified. Overhead allocations and other charges (such as depreciation and amortization) were identified and quantified in the projected financial statements. For the purposes of this section of the report, only direct program costs have been quantified and presented.

For each program described, the following conditions apply:

- Operating costs presented are stated in 1989 Canadian dollars and cover a one year period.

- Rent is based on a rate of $12.50 per square foot for floor space in the existing SED facilities.

- Occupancy costs are $7.00 per square foot and cover a variety of facility costs including:

  - security
  - janitorial services
  - basic utilities
  - water and sewer costs
  - insurance on the facility
  - maintenance and repairs
  - snow and garbage removal

8.3.2 (Cont'd)

- property taxes
- grounds maintenance
- heating costs

- A burden rate of 25 percent was used on all wages and salaries to cover miscellaneous benefits including:

  - vacation pay
  - sick leave
  - statutory holidays
  - employer portion of statutory deductions
  - other employee benefits

- Project-specific hardware and software costs (including related maintenance and support) were excluded as they will be covered under a separate program contract.

- Special communication changes for sophisticated satellite connections of data communications connections with mission management offices have been excluded as there is no way to determine the required complexity or cost of these systems at this time.

8.3.2.1 Radarsat

Labour

A total of 17 permanent personnel are required to operate the Radarsat component of the Control Centre. The staff is comprised of one manager, two secretary/clerk/receptionists, ten operators, and four analysts. Operators will work shifts and will be in attendance 24 hours per day, 365 days per year. All other staff will work a regular 40 hour week. Depending upon the intricacy of various phases of the missions, some of the analysts may also be on call on a 24-hour basis.

8.3.2.1 (Cont'd)

The labour rates in Table 8.1 are indicative of wage scales in the industry. A 25 percent payroll burden has been used to account for vacation pay, sick leave, statutory holidays, and other employee benefits.

Office Expenses

Office expenses include costs for office supplies such as stationery, office equipment maintenance, furniture replacements, etc. Office communication for this category includes telephone systems, facsimile, telex. The more sophisticated communication connections with other Radarsat offices are not-included in this budget.

An allowance of $20,000 has been allotted for business-related travel expenses by management and analysts.

Rent and Occupancy Costs

Costs for rent and occupancy were established from discussions held with SED. The costs are based on current expenditures for the existing SED building and from determining a fair market value based on costs for other similar Saskatoon offices. The space requirement for Radarsat has been estimated at 5,300 square feet. Details of the yearly operating costs for the Radarsat Program are provided in Table 8.1.

8.3.2.2 Mobile Servicing System and User Development Program

Labour

The technical requirements for MSS and UDP were outlined in Section 3.0 of this study. More staff are required for the MSS and UDP components than for Radarsat as a result of the complexities and demands of the program. Salary rates and payroll burdens are the same as those for the Radarsat program.

TABLE 8.1
YEARLY OPERATING COST ESTIMATES
RADARSAT CONTROL CENTRE

Labour	
Manager (1)	$ 70,000
Office Support personnel (2)	40,000
Operators (10)	400,000
Analysts (4)	220,000
Employee Benefits (25% of wages)	182,500
	$ 912,500
Office Expenses	
Office Supplies and Replacements	$ 25,000
Office Communications	12,000
Travel and Living Expenses	20,000
	$ 57,000
Rent and Occupancy Costs	
Rent	$ 66,250
Occupancy	37,100
	$ 103,350
TOTAL	$1,072,850

8.3.2.2 (Cont'd)

The staff is comprised of one manager, seven analysts and diagnosticians, two secretary/clerk/receptionists, and twenty-one operators. Operators will be on shift 24 hours per day, 365 days per year. All other staff will work a regular 40 hour week. Some analysts will likely be on call 24 hours per day.

Office Expenses

Similar types of office expense operating costs are also provided for the MSS and UDP Control Centre as are provided for the Radarsat program identified in 8.3.2.2.

Rent and Occupancy Costs

Costs for rent and occupancy costs were established from discussions with SED and are based on a cost per square foot. The space requirements for the MSS and UDP Control Centre has been estimated at 12,500 square feet. Details of the operating costs for the MSS and UDP programs are provided in Table 8.2.

8.3.2.3 Other Projects

The operating costs for other projects are based on Radarsat program operating costs. Since the Radarsat program has been evaluated as typical, all other projects have been estimated using the same parameters. It is anticipated that there will be one more additional domestic program prior to the year 2000 and three foreign programs before 2005. The costs for all other programs are identical to the costs used for Radarsat, described in Table 8.1.

TABLE 8.2

YEARLY OPERATING COST ESTIMATES

MOBILE SERVICING SYSTEM AND USER DEVELOPMENT PROGRAM CONTROL CENTRE

Labour		
Manager (1)	$ 70,000	
Office Support Personnel (2)	40,000	
Operators (21)	840,000	
Analysts and Diagnosticians (7)	385,000	
Employee Benefits (25% of wages)	333,750	
		$1,668,750
Office Expenses		
Office Supplies and Replacements	$ 75,000	
Office Communications	24,000	
Travel and Living Expenses	60,000	
		$ 159,000
Rent and Occupancy Costs		
Rent	$ 156,250	
Occupancy Costs	87,500	
		$ 243,750
TOTAL		**$2,071,500**

8.3.3 Canadian Space Control Centre Management Labour Costs

Management wages and salaries for the CSCC core service functions are based on standard wage scales for similarly qualified personnel. The staff included in the management wages are:

- General Manager (at commencement)
- Marketing Manager (at commencement)
- Financial Controller (in 1996)
- Secretary/Receptionist (at commencement)
- Marketing Assistant/Clerk (1994)

All project-related staff, including project management staff, have been included in the project operating costs.

All salaries are stated in second quarter 1989 Canadian dollars and are base salaries only. Table 8.3 describes the details of the management wages and salaries for the core services of the CSCC.

Benefits have been calculated at a rate of 25 percent of salary costs and include vacation pay, sick pay, statutory holidays, statutory employee benefits and other employee benefits.

8.3.4 Program Implementation Time Frames

The CSCC business plan assumes that a certain number of programs will be procured to use the facility. In the initial stages of operation, there will be a period of time when no programs are in place due to the fact that there is a limited market for the centre's services and each program requires a long period of planning to fully develop the specifications and funding parameters.

TABLE 8.3
MANAGEMENT WAGES AND SALARIES

POSITION	BASE SALARY	DATE OF HIRE
General Manager	$ 90,000	1991
Marketing Manager	65,000	1991
Financial Controller	75,000	1991
Secretary/Receptionist	25,000	1991
Research and Development Manager	75,000	1991
Marketing Assistant/Clerk	25,000	1994
Clerical Staff	20,000	1994

8.3.4 (Cont'd)

Currently there are two relatively well-defined programs in Canada: Radarsat, and MSS and UDP.

These programs were used as models because they have already been defined and implementation timetables have been established. Of these two programs, Radarsat can be viewed as typical of the type of program the CSCC will be tarketing. Based on market assessment, it is likely that one additional program, similar in scope to Radarsat, will be initiated prior to the year 2000.

Foreign programs are also a target for the CSCC. There are no defined programs currently that would make use of the centre, but based on the market assessment, it is likely that there would be three foreign programs that would make use of the centre prior to the year 2005. These programs would be similar in scope to Radarsat but have a duration of six years instead of five.

Table 8.4 describes the program implementation timetable that has been used in preparing the business plan and projected financial statements.

8.3.5 Control Centre Operating Costs (Core Costs)

The CSCC will require certain operating costs to meet its objectives and operate as intended. These costs are required regardless of the volume of activity and have therefore been determined to be core costs. The core costs have been segmented into four major categories:

- Marketing
- Office and Administration
- Operations
- Research and Development

TABLE 8.4
CANADIAN SPACE CONTROL CENTRE
PROGRAM TIMETABLE

PROJECT	IMPLEMENTATION DATE	DURATION (YEARS)
Radarsat	1993	5
MSS/UDP	1996	30
Domestic Project I	1998	5
Foreign Project I	1996	6
Foreign Project II	2000	6
Foreign Project III	2002	6

8.3.5 (Cont'd)

Each category has several components and cost estimates have been completed for each component. All costs have been stated in second quarter 1989 Canadian dollars and adjusted for inflation in the projected financial statements.

8.3.5.1 Marketing

The marketing costs reflect a complete marketing department for the CSCC. This department will be responsible for promoting the centre domestically and internationally and securing contracts for the centre. The basic annual cost estimates for the marketing function are outlined in Table 8.5.

8.3.5.2 Office and Administration

The office and administrative function will provide management services to all projects undertaken by the CSCC and controls the overall operations of the centre. The basic annual cost estimates for the general administration of the CSCC are outlined in Table 8.6.

TABLE 8.5
CANADIAN SPACE CONTROL CENTRE
ESTIMATED ANNUAL MARKETING COSTS

Computer System Costs	$ 10,000
Marketing Consultants	25,000
Media Advertising and Promotion	25,000
Miscellaneous	5,000
Promotional Materials	20,000
Proposals	25,000
Publications and Dues	3,500
Seminars	10,000
Stationery	5,000
Telephone	4,000
Trade and Technical Shows	15,000
Travel and Living Expenses	50,000
Wages and Benefits (including 25% burden)[1]	81,250
Total Estimated Annual Marketing Costs	**$278,750**

[1] An additional marketing assistant will be hired in 1994 at a salary of $31,250 (including a 25% payroll burden)

TABLE 8.6
CANADIAN SPACE CONTROL CENTRE
ESTIMATED OFFICE AND ADMINISTRATION COSTS

Audit	$ 10,000
Bank charges	2,500
Business taxes	2,000
Consulting fees	10,000
Data Processing costs [1]	30,000
Equipment rentals	5,000
Hardware maintenance	15,000
Human resource costs	5,000
Legal	15,000
Miscellaneous	5,000
Office supplies	15,000
Postage	5,000
Recruitment costs	3,500
Subscriptions, publications and dues	5,000
Telephone	12,500
Training	5,000
Wages and benefits (including 25% burden)[2]	112,500
TOTAL ESTIMATED OFFICE AND ADMINISTRATION COSTS	**$258,000**

[1] Discussions with SED indicated that the CSCC could use their data processing resources and personnel for a fee. The fee was negotiated as a minimum of $30,000 annually or 3% of gross revenues if this amount exceeded $30,000. Based on these parameters, it was determined that a dedicated data processing function for the CSCC would be more cost effective than subcontracting in the year 1996.

[2] Wages include a general manager's salary only in the initial period of operations. In 1994 an additional clerkf will be added at a cost of $25,000 (including a 25% burden charge for benefits) and in 1996 a financial controller will be added at a cost of $93,750 (including a 25% burden charge for benefits).

8.3.5.3 Operations

The operations costs relate to general facility costs not included in any other cost categories. It also includes costs that are not covered by the occupancy costs included in the rental fee. Rent for the basic CSCC office space, not project-specific space requirements is included. The office space requirements have been estimated at 500 square feet. The secretary/receptionist's salary has been included in wages and benefits. The basic annual cost estimates for operations are outlined in Table 8.7.

8.3.5.4 Research and Development

Research and development is a critical component of the CSCC operations. In order to meet its stated objectives, the centre must concentrate on the development of new products and technologies for the satellite control industry. For the purposes of the business plan, we have assumed that all research and development efforts will be funded by external sources. Therefore, we have not detailed research and development cost components but have included an estimated research and development manager's salary in the plan. We have also included a grant as income to cover this salary. It is assumed that the base salary will be $93,750 (including a 25 percent burden charge to cover benefits).

8.3.6 Costs Subcontracted From SED

In order to minimize initial costs related to the CSCC, SED will provide certain services on a fee-for-service basis. As well, the rental rate includes an occupancy charge per square foot that covers a number of facility-related costs.

TABLE 8.7

CANADIAN SPACE CONTROL CENTRE

ESTIMATED OPERATIONS COSTS

Computer System Maintenance and Support	$10,000
Equipment Rental	5,000
Miscellaneous	5,000
Rent	9,750
Training Materials	5,000
Wages and Benefits (including 25% burden)	31,250
TOTAL ESTIMATED OPERATIONS COST	$66,000

8.3.6.1 Occupancy Costs

An occupancy cost per square foot at $7.00 has been determined through an analysis of SED's actual costs for operating their current facility. This cost covers:

- maintenance (building, grounds and general)
- base electrical costs
- security requirements
- snow and garbage removal
- sewer and water costs
- heating and ventilating system costs
- property taxes
- building insurance

These costs are based directly on the actual square footage rented by the CSCC.

8.3.6.2 Other Costs

Certain other services will also be subcontracted, regardless of the amount of space used by the CSCC. These costs are relatively fixed and SED will provide the services and resources until it becomes cost-effective for the CSCC to provide these services themselves. In the initial phase of operation, accounting records, data processing facilities and financial management services are required. The volume of work, however, does not warrant full time resources. The cost of providing these internally by CSCC employees is prohibitive.

8.3.6.2 (Cont'd)

Therefore, SED has agreed to:

- set up initial accounting records and financial systems for an initial fee of $15,000.

- provide data processing resources and personnel for a fee of $30,000 or 3 percent of the CSCC gross revenues (whichever is greater) and include financial management advice for this fee.

These services will be used until the CSCC procures several space programs that allows them to provide these services internally in a more cost-effective manner.

8.4 SENSITIVITY AND CRITICAL FACTORS

The financial results of the CSCC are dependent on several factors which are critical. Changes in these critical factors would materially affect the results of operations.

8.4.1 Availability of Sustaining Grant

In the initial period of operations before any programs are initiated, it is critical that the CSCC receive funding for operations. To build a base on which future projects can be place, it is critical that the centre become functional and make its mandate and objectives known, both within Canada and internationally. The primary focus of this period will be to build a marketable identity for the CSCC and give the concept credibility. Without some sort of funding mechanism, the centre cannot become functional and will likely never succeed in fulfilling its objectives.

For purposes of the business plan, we have assumed this funding will be in the form of a nonrepayable grant, The projected financial statements show, however, that some form of repayable funding is also feasible given the future cash flows indicated by the assumptions made. It is likely that $1.5 million to $2.0 million will be required over a two year period to sustain operations and plan for operation of the centre as intended.

8.4.2 Program Implementation Timetable

The most critical factor affecting the CSCC is the assumption that satellite programs are or will be implemented that use the CSCC as their control centre. If projects requiring the CSCC do not materialize, the centre can never be self-sustaining. The business plan demonstrates that even with a single program similar in scope to Radarsat, operations generate a positive cash flow and costs are not outside the proposed Radarsat program funding parameters. In terms of economic feasibility,

8.4.2 (Cont'd)

the CSCC would be successful given the assumptions made regarding operation. If however, the anticipated programs do not materialize or if the timing of these projects is significantly different from the assumptions, the financial results indicated will not be attained.

We have assumed that like current government programs in this sector, overhead costs will be reviewed annually and absorbed only to the extent that each specific program uses the facility, An under funding of overhead costs will occur when there is excess, unutilized space in the centre. The costs associated with maintaining this space must be funded from operating profits generated by other programs. If a significant period of time elapses when this situation persists this would seriously affect the financial stability of the CSCC. Therefore, the financial results of the centre hinge on an appropriate volume and funding of satellite control programs being secured.

8.4.3 Overhead Recovery and Profit Margins

The business plan assumes that overhead will be recovered based on the programs using the CSCC. They will be recovered based on the ratio of each project's square footage used to total floor space of the CSCC. It is assumed that all overhead charges will be recovered, regardless of the number of projects, if all available space is utilized. If there is excess, unutilized space, costs associated with that space will not be recovered. Since the overhead costs of the facility are substantial, a critical factor in the success of the CSCC is full utilization of all space available to ensure full overhead recovery through programs.

Profit margins for domestic programs are 10 percent before taxes. Profits have been calculated on all direct costs for each program, plus an overhead allocation as described above. Profit margins on foreign projects will be 20 percent calculated in a similar manner. If these profit margins are not realized, there will be a major effect on the

8.4.3 (Cont'd)

operating profits of the CSCC. To maintain cash flows given the assumptions that have been made, a profit margin of at least 8 percent is required for all projects on average. Therefore, it is apparent that any changes in the profit margins as in the calculations base for profit margins, will affect the financial well-being of the CSCC in the long term.

8.4.4 Capital Cost Funding

Capital costs are required for both the start-up period and for each project undertaken by the CSCC. The initial capital costs are not significant (approximately $60,000) but a funding mechanism is required to initiate the CSCC operations. As well, each program requires capital expenditures for leasehold improvements and furniture and equipment. The costs are more substantial (estimates are between $500,000 and $1.75 million based on the specific program requirements.) In order to maintain ongoing operations, an external source of financing is required to fund these capital expenditures, especially in the initial stages of operations.

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

The study has firmly demonstrated that the placement of a ground-based satellite control centre in Saskatoon is not only feasible but has significant social, economic, educational and industrial benefits to the region.

The following conclusions were reached:

Regional Distribution and SED Involvement

- Placement of the CSCC in Saskatchewan would contribute significantly to the regional distribution goals of the Canadian Space Program. It would strengthen the Canadian Space Program through diversification and distribution of technology across Canada so that all regions can benefit by advancing technology and job opportunities in Saskatchewan and the Prairie Region through spin-off technologies, products, and export market opportunities.

- The CSCC in Saskatchewan would consolidate and centralize the Canadian Space Program's control centre activities for future national programs as well as international negotiations on joint programs.

- The space control centre would assist SED in establishing a centre of expertise for the research and development of the technologies and design of both hardware and software systems, which are applied to the testing and control of satellites and space platforms.

- Placement of the CSCC in Saskatoon will complement and enhance the corporate objectives of SED, the regional coordinator for SPAR Aerospace Ltd. (the prime contractor for Canada's Space Program).

9.1 CONCLUSIONS (Cont'd)

- SED has the demonstrated technical strength, experience and capabilities in ensuring the successful operation of the space control centre.

Canadian and Foreign Space Program

- The success and viability of the CSCC over the next decade clearly revolves around the Radarsat and Space Station MSS and UDP programs being directed to the control centre.

- The market assessment of foreign programs in science, remote revising and meteorology suggests that it would be possible to add at least one new mission control centre assignment once every three years. This further demonstrates the growing demand internationally for a space control centre in Saskatchewan.

Employment

The CSCC in Saskatchewan would create the following employment benefits:

- The operation of the space control centre will create over 100 direct jobs for managerial, technical, clerical and research personnel once the centre is fully operational.

- The development of ground-based technology for software, hardware and systems development would create 60 to 85 direct jobs.

- These 160 to 185 direct jobs would likely create over 450 indirect jobs in the area.

- Facility constructions as well as other spin-off opportunities would be created with placement of the centre in Saskatoon.

9.1 CONCLUSIONS (Cont'd)

University Involvement

The involvement of the University of Saskatchewan would assist in further developing the University space-related programs by:

- ensuring participation in the space industry and related developments that would reach well into the next century;
- acting as a nucleus for research and development in other science fields;
- fostering working relationships with government and industry to translate and convert basic research into commercial space-related applications;
- assisting in providing an education to students desirous to live and work in Saskatchewan and Western Canada's high-tech industries.

CSCC MANAGEMENT

- In order to meet the stated objectives of the CSCC and SED, a coordinated approach to ground control operations and related research and development activities is required. Such an approach is only achievable through a single body coordinating all facets of satellite control. As well as day-to-day operations of the satellite control centre programs the CSCC would provide focus for marketing and research and development activities as well as administration and facility management.

9.1 CONCLUSIONS (Cont'd)

Business Plan

- The CSCC should be operated through a new corporation capitalized and wholly owned by SED.

- During the critical years of operation the CSCC will require some form of sustaining grant prior to satellite programs being operated from the centre.

- The most significant business factors affecting the success of the CSCC are:

  - the ability to receive a sustaining grant prior to CSCC receiving domestic programs,

  - the timetable for implementation of domestic and foreign programs,

  - full utilization of all space within the facility to permit recovery of overhead charges.

Facility Location

- The CSCC would be best served within the existing SED facility located north of the University of Saskatchewan in Saskatoon's prestigious SEDCO research and development park.

Estimated Costs

- In the first phase the CSCC Radarsat Control Centre would be located on 500 square meters on the main floors of the SED building. The capital cost estimate for the facility renovations is $636,000.

9.1 CONCLUSIONS (Cont'd)

- For the second phase the MSS and UDP control centre would be located on the second floor of the existing SED facility and would occupy approximately 930 square meters. The cost for the MSS and UDP facility modifications is $1,223,000.

- The Radarsat Control Centre yearly operating cost is $1,072,850 and includes labour costs, office expenses, rent and occupancy costs.

- The MSS and UDP Control Centre yearly operating costs is $2,071,500 and includes labour costs, office expenses, rent, and occupancy costs.

- The yearly operating cost for CSCC management excluding costs for specific satellite control operations will be approximately $700,000. This cost includes business development or marketing costs, office and administration facility operation and maintenance, research and development.

9.2 RECOMMENDATIONS AND FUTURE ACTION

From the investigations completed and the analysis presented in the study, it is recommended that:

- The Canadian Space Agency and SPAR Aerospace support the establishment of the CSCC in Saskatoon as the Canadian centre for control of scientific and space platforms for the Canadian Space Program.

- The Canadian government through the Canadian Space Agency and other agencies assist in development of CSCC by providing sustaining grants until such time that sufficient space programs are operated from the centre.

- The Western Provincial Governments support the concept for a CSCC in Saskatchewan and provide the necessary government support to ensure its success.

- The proponent of CSCC formally solicit funds from various agencies (ie: Saskatchewan Economic Development Corporation and Western Economic Development Fund) for support in construction or operation of the centre.

- The Canadian government assist in promoting the CSCC concept with international governments.

- The University of Saskatchewan support the CSCC and identify complimentary and beneficial programs that would assist in development and the continued operation of the CSCC.

- The proponent formally present the findings of the study to the western space industry, especially Bristol Aerospace, Boeing, and Intera;

- The proponent of the CSCC initiate contacts with foreign governments and international space agencies to determine more accurately the timing and needs of satellite control from a CSCC.

9.2 RECOMMENDATIONS AND FUTURE ACTION (Cont'd)

- The provincially sponsored research councils namely Manitoba Research Council, Saskatchewan Research Council, and Alberta Research Council support the concept for the CSCC in Saskatchewan and assist in identifying complementary programs for operations and development of the centre.

It is further recommended that the study be updated once further information is received from government representatives regarding the funding mechanism, preferred ownership arrangements, operation alternatives, and foreign government interest. The report could then be appended to reflect the most recent government plans for the Canadian Space Program, ground-based satellite control systems.

APPENDIX A

FINANCIAL STANDARDS

Deloitte Haskins+Sells

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Saskatoon, Saskatchewan S7K 7E5
(306) 244-8900
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To the Directors of
SED Systems Inc.:

We have compiled the accompanying projected balance sheet as at the end of each year from 1991 to 2005 and the projected statements of income and retained earnings and of changes in financial position for each year from 1991 through 2005, on the basis of the appended assumptions and from other information supplied to us by other consultants involved in the feasibility study for a Canadian Space Control Centre. We have not examined, reviewed, or otherwise attempted to verify the reasonableness of the assumptions or the completeness of this projection.

We do not express any opinion concerning the accompanying financial projection.

The accompanying projection and this communication were prepared to assess the feasibility of locating a Canadian Space Control Centre in Saskatoon, and should not be relied on for any other purpose.

Deloitte Haskins & Sells.

Saskatoon, Saskatchewan
July 19, 1989

CANADIAN SPACE CONTROL CENTRE

PROJECTED STATEMENT OF INCOME AND RETAINED EARNINGS

FOR EACH YEAR FROM 1991 THROUGH 2005

(000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
REVENUE															
Project revenues - RadarSat			2,451	2,644	2,775	2,006	2,181								
- Space Station (MSS/UDP)						4,212	4,394	4,593	4,795	4,866	4,749	4,977	5,228	5,404	5,762
- Domestic Project I								2,253	2,354	2,400	2,512	2,627			
- Foreign Project I						2,227	2,329	2,438	2,550	2,602	2,611				
- Foreign Project II										2,640	2,761	2,805	3,023	3,162	3,173
- Foreign Project III												2,900	3,043	3,181	3,329
			2,451	2,644	2,775	8,525	8,904	9,284	9,699	12,508	12,633	13,397	11,294	11,827	12,264
EXPENSES															
Marketing - Schedule 1	310	334	347	407	429	448	471	496	520	547	573	601	631	662	698
Office and administration - Schedule 2	289	299	349	400	424	572	599	632	660	698	730	765	808	843	890
Operations - Schedule 3	87	88	89	91	97	97	99	105	109	115	120	124	132	137	145
Research and development - Schedule 4	103	109	114	120	126	132	139	145	153	160	168	177	186	195	205
Project related expenses															
RadarSat - Schedule 5			2,228	2,404	2,523	1,896	1,983								
Space Station (MSS/UDP) - Schedule 6						3,829	3,995	4,175	4,360	4,424	4,317	4,525	4,752	4,986	5,238
Domestic Project I - Schedule 7								2,048	2,140	2,182	2,204	2,308			
Foreign Project I - Schedule 8						1,056	1,941	2,032	2,125	2,168	2,176				
Foreign Project II - Schedule 9										2,200	2,301	2,404	2,519	2,635	2,644
Foreign Project III - Schedule 10												2,423	2,536	2,651	2,774
	789	830	3,127	3,422	3,599	8,830	9,227	9,633	10,067	12,494	12,669	13,407	11,564	12,108	12,594
OPERATING INCOME (LOSS)	(789)	(830)	(676)	(778)	(824)	(305)	(323)	(349)	(368)	14	(36)	(10)	(270)	(281)	(330)
OTHER INCOME (EXPENSE)															
Sustaining grant	958	730													
Research and development grants	103	109	114	120	126	132	139	145	153	160	168	177	186	195	205
Overhead recovery			785	898	950	1,116	1,169	1,233	1,290	1,361	1,424	1,490	1,277	1,335	1,409
Startup costs - Schedule 11	(262)														
Interest expense	(10)	(9)	(123)	(104)	(82)	(395)	(319)	(320)	(240)	(248)	(127)	(199)	(141)	(100)	(53)
	789	830	776	914	994	853	989	1,058	1,203	1,273	1,465	1,468	1,322	1,430	1,561
INCOME BEFORE INCOME TAXES			100	136	170	548	666	709	835	1,287	1,429	1,458	1,052	1,148	1,231
INCOME TAXES			47	64	80	258	313	330	392	605	672	685	495	540	578
NET INCOME			53	72	90	290	353	376	443	682	757	773	558	609	652
RETAINED EARNINGS, BEGINNING OF PERIOD				53	125	215	506	859	1,234	1,677	2,359	3,116	3,889	4,447	5,056
RETAINED EARNINGS, END OF PERIOD			53	125	215	506	859	1,234	1,677	2,359	3,116	3,889	4,447	5,056	5,708

CANADIAN SPACE CONTROL CENTRE

PROJECTED BALANCE SHEET

FOR EACH YEAR END FROM 1991 THROUGH 2005

(000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
ASSETS															
CURRENT ASSETS															
Cash	28	28	164	266	361	924	1,339	1,759	2,193	2,958	3,794	4,581	4,950	5,557	6,231
	28	28	164	266	361	924	1,339	1,759	2,193	2,958	3,794	4,581	4,950	5,557	6,231
FURNITURE AND EQUIPMENT - Schedule 12	45	36	76	61	48	234	187	215	176	213	174	221	189	163	143
LEASEHOLD IMPROVEMENTS - Schedule 12	9	7	575	431	286	1,756	1,211	1,223	716	667	448	734	493	252	126
	54	43	651	492	334	1,990	1,398	1,438	892	880	622	955	682	415	269
	82	71	815	758	695	2,914	2,737	3,197	3,085	3,838	4,416	5,536	5,632	5,972	6,500
LIABILITIES															
CURRENT LIABILITIES															
Income taxes payable			47	64	80	258	313	333	392	605	672	685	495	540	578
			47	64	80	258	313	333	392	605	672	685	495	540	578
LONG-TERM DEBT - Schedule 13	57	46	690	544	375	2,126	1,540	1,604	991	849	603	937	665	352	189
	57	46	737	608	455	2,384	1,853	1,937	1,383	1,454	1,275	1,622	1,160	892	767
SHAREHOLDERS' EQUITY															
SHARE CAPITAL	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
RETAINED EARNINGS			53	125	215	506	859	1,234	1,677	2,359	3,116	3,889	4,447	5,056	5,708
	25	25	78	150	240	531	884	1,259	1,702	2,384	3,141	3,914	4,472	5,081	5,733
	82	71	815	758	695	2,914	2,737	3,197	3,085	3,838	4,416	5,536	5,632	5,972	6,500

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CANADIAN SPACE CONTROL CENTRE

PROJECTED STATEMENT OF CHANGES IN FINANCIAL POSITION

FOR EACH YEAR FROM 1991 THROUGH 2005

(000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
OPERATING ACTIVITIES															
Working capital from operations															
Net income			53	72	90	290	353	376	443	682	757	773	550	609	652
Depreciation and amortization	13	11	163	159	158	604	592	556	546	670	258	391	273	267	146
	13	11	216	231	248	894	945	932	989	1,352	1,015	1,164	831	876	798
Changes in working capital components															
Income taxes payable			47	17	16	178	55	20	59	212	67	14	(191)	45	39
			47	17	16	178	55	20	59	212	67	14	(191)	45	39
Cash generated from operations	13	11	263	248	264	1,072	1,000	952	1,048	1,565	1,082	1,177	640	921	837
INVESTING ACTIVITIES															
Additions to long-term assets	(67)		(771)			(2,260)		(596)		(658)		(724)			
Cash used for investing activities	(67)		(771)			(2,260)		(596)		(658)		(724)			
Cash (deficiency) before financing	(54)	11	(508)	248	264	(1,188)	1,000	356	1,048	907	1,082	453	640	921	837
FINANCING ACTIVITIES															
Increase (decrease) in long-term debt	57	(11)	644	(146)	(169)	1,751	(586)	64	(613)	(142)	(246)	334	(272)	(313)	(163)
Proceeds from issue of shares	25														
Increase in cash	28		136	102	95	563	414	420	435	765	836	787	368	608	674
Cash, beginning of period		28	28	164	266	361	924	1,339	1,759	2,193	2,958	3,794	4,581	4,950	5,557
Cash, end of period	28	28	164	266	361	924	1,339	1,759	2,193	2,958	3,794	4,581	4,950	5,557	6,231

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CANADIAN SPACE CONTROL CENTRE

ASSUMPTIONS AND NOTES TO THE FINANCIAL PROJECTIONS

This financial projection expressed in Canadian dollars is an estimate of financial position, results of operations, and changes in financial position, based on assumptions concerning future events and circumstances that are not necessarily the most likely. The assumptions set forth below are those believed to be significant to the projection or are key factors upon which the financial results depend. Some assumptions inevitably will not materialize, and unanticipated events and circumstances may occur subsequent to July 19, 1989 the date of this projection. Therefore, the actual results achieved during the projected period will probably vary from the projection, and the variations may be material.

Project Revenues

Project revenues are derived directly from associated project costs, including overhead allocations. Project costs are marked up by a certain percentage based on industry profit parameters and government program guidelines. Domestic projects have a 10% assumed profit margin and foreign projects have a 20% assumed margin. The time frame for each project is based on the best estimates of project occurrence resulting from a market assessment of the industry.

Marketing Costs

Marketing costs are based on management's best estimates of costs to support and promote the centre's operations.

Office and Administration Costs

Office and administration costs are based on management's best estimates of costs and personnel requirements for the centre.

Operations Costs

Operations costs are based on management's best estimates of ongoing costs and actual costs for the facility in which the centre will be located.

Research and Development Costs

Research and development costs include salaries for research and development personnel only. It is anticipated that all research and development costs will be offset by corresponding grants to finance these activities.

CANADIAN SPACE CONTROL CENTRE

ASSUMPTIONS AND NOTES TO THE FINANCIAL PROJECTIONS

Project Related Expenses

Project related expenses are based on estimated capital costs and manpower requirements for each specific project. Leasehold Improvements are amortized over a period of 5 years. Furniture and fixtures are depreciated using the declining-balance method at a rate of 20%. Overhead has been allocated based on the number of square feet that each project will require as a percentage of the total square footage that the centre utilizes. All non-project related costs are assumed to be overhead costs.

Income Taxes

Income taxes have been provided for at a rate of 47% of net income.

Interest Rate

The interest rate for financing is assumed to be 15%.

Employee Benefits

Employee benefits have been provided for at a rate of 25% of direct salary rates for all employees.

Inflation

An annual inflation rate of 5% has been assumed for the projection period. All figures have been stated in second quarter 1989 Canadian dollars adjusted for inflation.

Long-Term Debt

Long-term debt has been assumed to be available to finance the capital costs for each project. All project financing has been asusmed to be repayable over a five year term.

Sustaining Grant

Sustaining grants required to fund the start-up of the centre have been assumed to be non-interest bearing and non-repayable.

CANADIAN SPACE CONTROL CENTRE

SCHEDULE OF MARKETING COSTS

FOR EACH YEAR FROM 1991 THROUGH 2005

(000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Computer system costs	11	12	12	13	13	14	15	16	16	17	18	19	20	21	22
Marketing consultants	28	29	30	32	34	35	37	39	41	43	45	47	49	52	55
Media advertising and promotion	28	29	30	32	34	35	37	39	41	43	45	47	49	52	55
Miscellaneous	6	6	6	6	7	7	7	8	8	9	9	9	10	10	11
Promotional materials	22	23	24	26	27	28	30	31	33	34	36	38	40	42	44
Proposals	28	29	30	32	34	35	37	39	41	43	45	47	49	52	55
Publications and dues	4	4	4	4	5	5	5	5	6	6	6	7	7	7	8
Seminars	11	12	12	13	13	14	15	16	16	17	18	19	20	21	22
Stationery	6	6	6	6	7	7	7	8	8	9	9	9	10	10	11
Telephone	4	5	5	5	5	6	6	6	7	7	7	8	8	8	9
Trade and technical shows	17	17	18	19	20	21	22	23	24	26	27	28	30	31	33
Travel and living expenses	55	58	61	64	67	70	74	78	81	86	90	94	99	104	109
Wages and benefits	90	104	109	155	163	171	179	188	198	207	218	229	240	252	264
	310	334	347	407	429	448	471	496	520	547	573	601	631	662	698

SCHEDULE 2

CANADIAN SPACE CONTROL CENTRE

SCHEDULE OF OFFICE AND ADMINISTRATION COSTS

FOR EACH YEAR FROM 1991 THROUGH 2005

(000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Audit	11	12	12	13	13	14	15	16	16	17	18	19	20	21	22
Bank charges	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5
Business taxes	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4
Consulting fees	11	12	12	13	13	14	15	16	16	17	18	19	20	21	22
Data processing costs	33	35	74	79	83	84	89	93	98	103	108	113	119	125	131
Equipment rental	6	6	6	6	7	7	7	8	8	9	9	9	10	10	11
Hardware maintenance	17	17	18	19	20	21	22	23	24	26	27	28	30	31	33
Human resource costs	6	6	6	6	7	7	7	8	8	9	9	9	10	10	11
Legal	17	17	18	19	20	21	22	23	24	26	27	28	30	31	33
Miscellaneous	6	6	6	6	7	7	7	8	8	9	9	9	10	10	11
Office supplies	17	17	18	19	20	21	22	23	24	26	27	28	30	31	33
Postage	6	6	6	6	7	7	7	8	8	9	9	9	10	10	11
Recruitment costs	4	4	4	4	5	5	5	5	6	6	6	7	7	7	8
Subscriptions, publications and dues	6	6	6	6	7	7	7	8	8	9	9	9	10	10	11
Telephone	14	14	15	16	17	18	18	19	20	21	22	24	25	26	27
Training	6	6	6	6	7	7	7	8	8	9	9	9	10	10	11
Wages and benefits	124	130	137	176	185	325	342	359	377	395	415	436	458	481	506
	289	299	349	400	424	572	599	632	660	698	730	765	808	843	890

SCHEDULE 3

CANADIAN SPACE CONTROL CENTRE

SCHEDULE OF OPERATIONS COSTS

FOR EACH YEAR FROM 1991 THROUGH 2005

(000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Computer system maintenance and support costs	11	12	12	13	13	14	15	16	16	17	18	19	20	21	22
Depreciation and amortization	13	11	9	8	8	4	3	2	2	1	1	1	1	1	1
Equipment rental	6	6	6	6	7	7	7	8	8	9	9	9	10	10	11
Miscellaneous	6	6	6	6	7	7	7	8	8	9	9	9	10	10	11
Rent	11	11	12	12	13	14	14	15	16	17	18	18	19	20	21
Training materials	6	6	6	6	7	7	7	8	8	9	9	9	10	10	11
Wages and benefits	34	36	38	40	42	44	46	48	51	53	56	59	62	65	68
	87	88	89	91	97	97	99	105	109	115	120	124	132	137	145

SCHEDULE 4

CANADIAN SPACE CONTROL CENTRE

SCHEDULE OF RESEARCH AND DEVELOPMENT COSTS

FOR EACH YEAR FROM 1991 THROUGH 2005

(000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Wages and benefits	103	109	114	120	126	132	139	145	153	160	168	177	186	195	205
	103	109	114	120	126	132	139	145	153	160	168	177	186	195	205

CANADIAN SPACE CONTROL CENTRE

SCHEDULE OF RADARSAT PROJECT COSTS

FOR EACH YEAR FROM 1991 THROUGH 2005

(000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Capital Costs															
Building - Antennae foundation			30												
Building - Architectural modifications			68												
Building - Civil/Landscaping Plaza			62												
Building - Contingency			65												
Building - Electrical			24												
Building - Electrical upgrades			27												
Building - Electrical UPS			188												
Building - Mechanical upgrades			101												
Building - Miscellaneous and indirect costs			147												
Building Total			712												
Furniture and equipment - Contingency			5												
Furniture and equipment - Office equipment			24												
Furniture and equipment - Office furniture			30												
Furniture and equipment Total			59												
Total Project Capital Costs			771												
Operating Costs															
Labour															
Manager (1)			85	89	94	98	103								
Office support (2)			49	51	54	56	59								
Operators (10)			486	511	536	563	591								
Analysts (4)			267	281	295	310	325								
Burden (at 25% of labour costs)			222	233	245	257	270								
Wages and benefits			1,109	1,165	1,224	1,284	1,348								
Travel and living costs			24	26	27	28	30								
Office supplies and replacements			30	32	34	35	37								
Leasehold improvements amortization			142	142	142	142	142								
Furniture and fixtures depreciation			12	9	8	6	5								
Overhead allocation			785	898	950	256	268								
Rent and occupancy costs (5300 sq. feet)			126	132	138	145	153								
Total Project operating costs			2,228	2,404	2,523	1,896	1,983								

CANADIAN SPACE CONTROL CENTRE

SCHEDULE OF SPACE STATION (MSS/UDP) PROJECT COSTS

FOR EACH YEAR FROM 1991 THROUGH 2005

(000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Capital Costs															
Building - Antennae foundation						91									
Building - Architectural modifications						200									
Building - Contingency						140									
Building - Electrical upgrades						60									
Building - Electrical UPS						521									
Building - Mechanical upgrades						186									
Building - Miscellaneous and indirect costs						339									
Building Total						1,545									
Furniture and equipment - Contingency						16									
Furniture and equipment - Office equipment						160									
Furniture and equipment Total						176									
Total Project Capital Costs						1,721									
Operating Costs															
Labour															
Manager (1)						98	103	109	114	120	126	132	139	146	153
Office support (2)						56	59	62	65	68	72	75	79	83	87
Operators (21)						1,182	1,241	1,303	1,368	1,437	1,509	1,584	1,663	1,746	1,834
Analysts and Diagnosticians (7)						542	569	597	627	658	691	726	762	800	840
Burden (at 25% of labour cost)						470	493	518	544	571	600	629	661	694	729
Wages and benefits						2,348	2,465	2,589	2,718	2,854	2,998	3,146	3,304	3,469	3,643
Travel and living costs						84	89	93	98	103	108	113	119	125	131
Office supplies and replacements						106	111	116	122	128	135	141	148	156	164
Leasehold improvements amortization						309	309	309	309	309					
Furniture and fixtures depreciation						35	28	23	18	14	12	9	7	6	5
Overhead allocation						604	633	667	698	599	626	656	691	723	763
Rent and occupancy costs (12,500 sq. feet)						343	360	378	397	417	438	460	483	507	532
Total Project operating costs						3,829	3,995	4,175	4,360	4,424	4,317	4,525	4,752	4,986	5,238

SCHEDULE 7

CANADIAN SPACE CONTROL CENTRE

SCHEDULE OF DOMESTIC PROJECT I COSTS

FOR EACH YEAR FROM 1991 THROUGH 2005

(000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Capital Costs															
Building - Antenna foundation								39							
Building - Architectural modifications								87							
Building - Contingency								83							
Building - Electrical								31							
Building - Electrical UPS								240							
Building - Miscellaneous								39							
Building Total								519							
Furniture and equipment - Contingency								7							
Furniture and equipment - Office equipment								31							
Furniture and equipment - Office furniture								39							
Furniture and equipment Total								77							
Total Project Capital Costs								596							
Operating Costs															
Labour															
Manager (1)								109	114	120	126	132			
Office support (2)								62	65	68	72	75			
Operators (10)								621	652	684	718	754			
Analysts (4)								341	358	376	395	415			
Burden (at 25% of labour costs)								283	297	312	328	344			
Wages and benefits								1,416	1,486	1,560	1,639	1,720			
Travel and living costs								31	33	34	36	38			
Office supplies and replacements								39	41	43	45	47			
Leasehold improvements amortization								104	104	104	104	104			
Furniture and fixtures depreciation								15	12	10	8	6			
Overhead allocation								283	296	254	266	278			
Rent and occupancy costs (5300 sq. feet)								160	168	177	186	195			
Total Project operating costs								2,048	2,140	2,182	2,284	2,388			

SCHEDULE 8

CANADIAN SPACE CONTROL CENTRE

SCHEDULE OF FOREIGN PROJECT I COSTS

FOR EACH YEAR FROM 1991 THROUGH 2005

(000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Capital Costs															
Building - Antennae foundation						35									
Building - Architectural modifications						79									
Building - Contingency						75									
Building - Electrical						28									
Building - Electrical UPS						218									
Building - Miscellaneous						35									
Building Total						470									
Furniture and equipment - Contingency						6									
Furniture and equipment - Office equipment						28									
Furniture and equipment - Office furniture						35									
Furniture and equipment Total						69									
Total Project Capital Costs						539									
Operating Costs															
Labour															
Manager (1)						98	103	109	114	120	126				
Office support (2)						56	59	62	65	68	72				
Operators (10)						563	591	621	652	684	718				
Analysts (4)						310	325	341	358	376	395				
Burden (at 25% of labour costs)						257	270	283	297	312	328				
Wages and benefits						1,284	1,348	1,416	1,486	1,560	1,639				
Travel and living costs						28	30	31	33	34	36				
Office supplies and replacements						35	37	39	41	43	45				
Leasehold improvements amortization						94	94	94	94	94					
Furniture and fixtures depreciation						14	11	9	7	6	4				
Overhead allocation						256	268	283	296	254	266				
Rent and occupancy costs (5300 sq. feet)						145	153	160	168	177	186				
Total Project operating costs						1,856	1,941	2,032	2,125	2,168	2,176				

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CANADIAN SPACE CONTROL CENTRE

SCHEDULE OF FOREIGN PROJECT II COSTS

FOR EACH YEAR FROM 1991 THROUGH 2005

(000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Capital Costs															
Building - Antennae foundation															
Building - Architectural modifications										43					
Building - Contingency										96					
Building - Electrical										92					
Building - Electrical UPS										34					
Building - Mechanical upgrades										265					
Building - Miscellaneous										43					
Building Total										573					
Furniture and equipment - Contingency										8					
Furniture and equipment - Office equipment										34					
Furniture and equipment - Office furniture										43					
Furniture and equipment Total										85					
Total Project Capital Costs										650					
Operating Costs															
Labour															
Manager (1)										120	126	132	139	146	153
Office support (2)										68	72	75	79	83	87
Operators (10)										684	718	754	792	832	873
Analysts (4)										376	395	415	436	457	480
Burden (at 25% of labour costs)										312	328	344	362	380	398
Wages and benefits										1,560	1,639	1,720	1,808	1,898	1,991
Travel and living costs										34	36	38	40	42	44
Office supplies and replacements										43	45	47	49	52	55
Leasehold improvements amortization										115	115	115	115	115	
Furniture and fixtures depreciation										17	14	11	9	7	5
Overhead allocation										254	266	278	293	306	323
Rent and occupancy costs (5300 sq. feet)										177	186	195	205	215	226
Total Project operating costs										2,200	2,301	2,404	2,519	2,635	2,644

CANADIAN SPACE CONTROL CENTRE

SCHEDULE OF FOREIGN PROJECT III COSTS

FOR EACH YEAR FROM 1991 THROUGH 2005

(000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Capital Costs															
Building - Antennae foundation												47			
Building - Architectural modifications												106			
Building - Contingency												101			
Building - Electrical												38			
Building - Electrical UPS												292			
Building - Miscellaneous												47			
Building Total												631			
Furniture and equipment - Contingency												8			
Furniture and equipment - Office equipment												38			
Furniture and equipment - Office furniture												47			
Furniture and equipment Total												93			
Total Project Capital Costs												724			
Operating Costs															
Labour															
Manager (1)												132	139	146	153
Office support (2)												75	79	83	87
Operators (10)												754	792	832	873
Analysts (4)												415	436	457	480
Burden (at 25% of labour costs)												344	362	380	398
Wages and benefits												1,720	1,808	1,898	1,991
Travel and living costs												38	40	42	44
Office supplies and replacements												47	49	52	55
Leasehold improvements amortization												126	126	126	126
Furniture and fixtures depreciation												19	15	12	9
Overhead allocation												278	293	306	323
Rent and occupancy costs (5300 sq. feet)												195	205	215	226
Total Project operating costs												2,423	2,536	2,651	2,774

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CANADIAN SPACE CONTROL CENTRE

SCHEDULE OF STARTUP COSTS

(000's)

Capital costs	
Leasehold improvements (office space)	11
Furniture and fixtures	28
Signage and logo design	28
	67
Operating costs	
Consulting fees	28
Recruiting expenses	178
Training	11
Legal fees	28
Accounting system design and setup	17
	262
Total startup costs	329

SCHEDULE 12

CANADIAN SPACE CONTROL CENTRE

SCHEDULE OF FIXED ASSETS

FOR EACH YEAR FROM 1991 THROUGH 2005

(000's)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
FURNITURE AND FIXTURES															
Beginning cost		56	56	115	115	115	360	360	437	437	522	522	615	615	615
Cost of additions	56		59			245		77		85		93			
Ending cost	56	56	115	115	115	360	360	437	437	522	522	615	615	615	615
Beginning accumulated depreciation		11	20	39	54	67	126	173	222	261	309	348	394	426	452
Depreciation expense	11	9	19	15	13	59	47	49	39	48	39	46	32	26	20
Ending accumulated depreciation	11	20	39	54	67	126	173	222	261	309	348	394	426	452	472
Ending Net Book Value	45	36	76	61	48	234	187	215	176	213	174	221	189	163	143
LEASEHOLD IMPROVEMENTS															
Beginning cost		11	11	723	723	723	2,738	2,738	3,257	3,257	3,830	3,830	4,461	4,461	4,461
Cost of additions	11		712			2,015		519		573		631			
Ending cost	11	11	723	723	723	2,738	2,738	3,257	3,257	3,830	3,830	4,461	4,461	4,461	4,461
Beginning accumulated amortization		2	4	148	292	437	982	1,527	2,034	2,541	3,163	3,382	3,727	3,968	4,209
Amortization expense	2	2	144	144	145	545	545	507	507	622	219	345	241	241	126
Ending accumulated amortization	2	4	148	292	437	982	1,527	2,034	2,541	3,163	3,382	3,727	3,968	4,209	4,335
Ending Net Book Value	9	7	575	431	286	1,756	1,211	1,223	716	667	448	734	493	252	126

SCHEDULE 13

CANADIAN SPACE CONTROL CENTRE

SCHEDULE OF LONG-TERM DEBT

FOR EACH YEAR FROM 1991 THROUGH 2005

(000's)

		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
STARTUP CAPITAL COSTS	- Principal	67	57	46	33	18										
	- Payments	(20)	(20)	(20)	(20)	(21)										
	- Interest	10	9	7	5	3										
		57	46	33	18											
RADARSAT	- Principal			771	657	526	375	201								
	- Payments			(230)	(230)	(230)	(230)	(231)								
	- Interest			116	99	79	56	30								
				657	526	375	201									
SPACE STATION (MSS/UDP)	- Principal						1,721	1,466	1,173	836	447					
	- Payments						(513)	(513)	(513)	(514)	(514)					
	- Interest						258	220	176	125	67					
							1,466	1,173	836	447						
DOMESTIC PROJECT I	- Principal								596	507	405	288	154			
	- Payments								(178)	(178)	(178)	(177)	(177)			
	- Interest								89	76	61	43	23			
									507	405	288	154				
FOREIGN PROJECT I	- Principal						539	459	367	261	139					
	- Payments						(161)	(161)	(161)	(161)	(160)					
	- Interest						81	69	55	39	21					
							459	367	261	139						
FOREIGN PROJECT II	- Principal										658	561	449	320	171	
	- Payments										(196)	(196)	(196)	(197)	(197)	
	- Interest										99	84	67	48	26	
											561	449	320	171		
FOREIGN PROJECT III	- Principal												724	617	494	352
	- Payments												(216)	(216)	(216)	(216)
	- Interest												109	93	74	53
													617	494	352	189
TOTAL	- Principal	67	57	817	690	544	2,635	2,126	2,136	1,604	1,649	849	1,327	937	665	352
	- Payments	(20)	(20)	(250)	(250)	(251)	(904)	(905)	(852)	(853)	(1,048)	(373)	(589)	(413)	(413)	(216)
	- Interest	10	9	123	104	82	395	319	320	240	248	127	199	141	100	53
		57	46	690	544	375	2,126	1,540	1,604	991	849	603	937	665	352	189

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APPENDIX B

LIST OF ACRONYMS

APPENDIX B
LIST OF ACRONYMS

ADEOS	Japan's Advanced Earth Observing Satellite
BSB	British Satellite Broadcasting
CAD	Computer-Aided Drafting
CCIR	Consultative Committee on International Radio
CCSDS	Consultative Committee on Space Data Systems
COMS	Voice and Data Distribution System
CSA	Canadian Space Agency
CSCC	Canadian Space Control Centre
CSP	Canadian Space Program
CSSP	Canadian Space Station Program
CTS	Communications Technology Satellite
DMSP	Defence Meteorological Satellite Program
DOC	Department of Communication
DOD	US Department of Defence
DRIE	Department of Regional Industrial Expansion
EOS	Earth Observation System
ERS-1	Japans's 1st Earth Resource Satellite
ESA	European Space Agency
ESC	Engineering Support Centre
FDS	Flight Dynamics System
GEOS	Geostationary Operational Environment Satellite
GMS	Geostationary Meterological Satellite
GOMS	Geostationary Operational Meterological Satellite
ILS	Integrated Logistics System
INSAT	India National Satellite
IRS	India's Remote Sensing Satellite
ISAS	Institute of Space and Atmospheric Studies
ISO	International Standards Association
ITU	International Telecommunications Union

APPENDIX B

LIST OF ACRONYMS (Cont'd)

JILA	Joint Institute for Laboratory Astrophysics
LASP	Laboratory for Atmospheric and Space Physics
LEOP	Launch and Early Orbit Phase
LINAC	Linear Accelerator Laboratory
MCC	Mission Control Centre
MCS	Mission Control System
MDA	MacDonald Dettwiler and Associates
MIS	Management Information System
MOCS	Mission Operations Control System
MOS-1	Japan's 1st Marine Observation Satellite
MOSST	Ministry of Science Space and Technology
MPS	Mission Planning and Command Management System
MSAT	Mobile Communications Satellite System
MSS	Mobile Servicing Station
NOAA	US National Oceanic and Atmospheric Administration
NRC	National Research Council
NROSS	US Navy Remote Ocean-Sensing System
PASS	Prince Albert Satellite Station
PPL	Plasma Physics Laboratory
R & D	Research and Development
RF	Radio Frequency
RSI	Radarsat International
SAR	Synthetic Aperture Radar
SBR	Space-Based Radar
SED	Sed Systems Inc.
SEDCO	Saskatchewan Economic Development Corporation
SES	Luxembourg's Direct Broadcast Satellite
SME	Solar Mesosphere Explorer
SMS	Suprathermal Ion Mass Spectrometer

APPENDIX B

LIST OF ACRONYMS (Cont'd)

SOSS	Space Operations Support Centre
SS	Space Station
STEAR	Strategic Technologies for Automation and Robotics
TTC	Telemetry, Tracking and Command
UDP	User Development Program
U & OC	Utilization and Operations Centre
WAMDII	Wide Angle Michelson Doppler Imaging Interferometer