**SED SYSTEMS INC.**

**CANADIAN SPACE CONTROL CENTRE**

**TABLE OF CONTENTS**

## TABLE OF CONTENTS

# TABLE OF CONTENTS

# 2.0 INTRODUCTION

DRAFT

JUN 2 0 1989

## 2.1 BACKGROUND

SED Systems Inc. of Saskatoon, Saskatchewan, one of Canada's founding companies of Canadian Space technology, identified a need to establish a Canadian Space Control Centre for Scientific Satellites and Space Platforms.

This need was identified after a preliminary analysis by SED Systems Inc. of requirements for the Canadian Space Programs and other foreign market potential. The initial assessment indicated that having a single Canadian Space Control Centre for Scientific Satellites and Space Platforms would:

- minimize the overall cost for a Canadian Space Control Centre by minimizing infrastructure and other related costs
- provide more efficient management of space control systems through a singular Canadian Space Control Centre
- attract international space agencies to cooperate with Canada in supporting space activities
- assist SED Systems Inc. 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 Systems Inc. in further developing this market concept, SED submitted a proposal to the Federal Department of Regional Industrial Expansion seeking funds for a study. The proposal was submitted to the Department of Regional Industrial Expansion (DRIE) under the Canada/Saskatchewan Advanced Technology Agreement -

DRAFT
JUN 2 0 1989

2.1 (Cont'd)

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 and a schedule for completion of the study. The proposal (which is the sole property of SED Systems Inc.) was approved and accepted by both the Federal and Provincial Govern- ments and work commenced in early February 1989.

It is the intent of SED Systems Inc. to distribute the report to all relevant and interested orginizations, institutions, industry, and governments to solicit support for establishment of a Canadian Space Control Centre in Western Canada.

## 2.2 PURPOSE AND OBJECTIVES OF THE STUDY

The purpose of the study is to determine the feasibility of placing a Canadian Space Control Centre 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

2.2 (Cont'd)

- 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 Canadian Space Control Centre in Western Canada
- outline the Space Control Centre's ability in meeting Canada's objectives for the Space Program; namely:
  - further developing Canada's expertise through technology development and advanced engineering of systems to control and test satellites
  - maintaining Canada's position in international cooperation of Space activities
  - ensuring maximum economic and social benefits to Canada.

## 2.3 STUDY PROPONENT

SED Systems Inc. (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 of this work being contracted from the National Research Council. Until the early 1980s, this scientific research was carried out by using sub-orbital 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

2.3 (Cont'd)

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 $7 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 U.K.

## 2.4 CORPORATE OBJECTIVES OF SED SYSTEMS INC.

The following is a listing of Corporate Objectives established by SED to ensure a profitable growing space-related industry in a highly technical and demanding industry.

- To become a centre of expertise for the research and development of the technologies and designs of both hardware and software

2.4 (Cont'd)

systems, which are applied to the testing and control of satellites and space platforms.

- To commercialize the technology and be competitive in satellite test and monitoring and mission control systems on a world-wide basis.

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

- To 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.

- To 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.

- To 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.

- To provide greater marketing and technical support to SPAR Aerospace (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 (Cont'd)

- To 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 Canadian Space Control Centre 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 world-wide basis.

- a foci 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 foci 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 Canadian Space Control Centre. The interviews and meetings were held with the following groups:

2.5 (Cont'd)

- Canadian Industry Representatives
  -
  - SPAR Aerospace
  - Telesat

- Federal Government Agencies and Departments
  - National Research Council
  - Department of Regional Industrial Expansion
  - Transport Canada

- Provincial Agencies and Departments
  - Saskatchewan Department of Industry Science and Technology

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

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

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 first-hand knowledge of existing operating systems which may have similarities to that proposed for the Canadian Space Control Centre. At each location, information was solicited about the organizational structure, responsibilities, facility layout,

2.5 (Cont'd)

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 our 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.
- 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 communica-tion lines. This arrangement is of particular interest to Canadian applications

2.5 (Cont'd)

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 Canadian Space Control Centre 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 Systems Inc. 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 Canadian Space Control Centre.

### 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

2.6 (Cont'd)

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 domestic and international market analysis, defining regulatory issues, and organizational structure, as well as conducting numerous interviews with participants in the Canadian Space Program and other related industries.

**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. It was 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

2.7 (Cont'd)

- 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 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.

DRAFT
JUN 20 1989

## SECTION 3
## TABLE OF CONTENTS

DRAFT
JUN 20 1989

## FIGURES

# 3.0 TECHNICAL AND MARKET ASSESSMENT

## 3.1 THE CANADIAN SPACE PROGRAM

### 3.1.1 Introduction

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

- the Canadian Space Station Program (CSSP)
- Radarsat
- MSat

Space Science, Communications and Remote Sensing R & D, European Space Agency (ESA) contributions and DRIE 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% the Prairies
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 the three major programs, and $847.1 million to be spent by government

3.1.1. (Cont'd)

agencies. The in-house expenditure of $0.7 billion represents the A-base for government agencies in the space program (Space Agency, NRC, MOSST, DOC, EMR, 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 multi-billion 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.

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 kg 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.

In return for its MSS contribution, Canada will have access to Space Station experimental facilities approximately 3% 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 | 139.2 million |
| | 930.6 million |
| Common operations (spent in U.S.) | 135.0 million |
| Government Operation re MSS | 70.0 million |
| **Total Program** | **$1135.6 million** |

### 3.1.3 Radarsat

The original motivation for Radarsat was to provide near real-time data on ice cover twenty-four 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 or 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 also will 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 the requirements of customers with respect to specific viewing angles and beam widths. A private corporation, Radarsat Inc. (RSI), has been formed to market imagery and perform image processing and, if required, image analysis. The company is owned by Spar, MDA, Interra, and Digim.

3.1.3 (Cont'd)

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 km. 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 is the Canadian prime contractor building SAR. Spar will integrate SAR with a spacecraft bus which will be procured in the U.S.

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

| | |
|---|---|
| Federal government | $172.5 million |
| Provincial governments | 59.4 million |
| Canadian industrial work | 232.9 million |
| Operations (federal funding) | 47.0 million |
| Foreign procurement (federal funding) | 157.3 million |
| **Total 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. (TMI). 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.

3.1.4 (Cont'd)

It will be able to offer mobile telephone service through gateway stations which provide access to the public telephone network.

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 (AMSC). Spar 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 (TMI funding) | $194.0 million |
| Federal government purchase of services | 126.5 million |
| Foreign procurement | 110.2 million |
| **Total 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: (10/10/35/35/10%). 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 |
| ESA | 72.5 million |
| DRIE | 25.3 million |
| **Total** | **$582.9 million** |

A detailed breakdown of these expenditures is not available, and they will almost certainly change. These figures were used for planning

3.1.5 (Cont'd)

purposes by the government in September 1988 and should be treated as such.

3.1.6 Canadian Space Plan Influence on the CSCC

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 Canadian Space Control Centre. 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 Canadian Control Centre.

**BRENT McCONNELL - WESTERN SPACE INITIATIVE**

## 3.2 TECHNICAL DEMAND

Before discussing the technical demands which specific space programs would make on the functionality of a Canadian Space Control Centre (CSCC), a brief description of a ground-based satellite control system is presented. 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 to-be 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.

3.2 (Cont'd)

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.

3.2.1 <u>The Ground-Based Satellite Control System</u>

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 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
- A Mission Management Office
- Data Reception Station (s)
- 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 paragraphs.

<u>Telemetry, Tracking and Command System</u>

The Telemetry, Tracking and Command System provides the physical link between the Ground Segment and Space Segment. It consists of an antenna and RF equipment for transmitting and receiving signals from the satellite; baseband equipment for converting the RF signals to a state

3.2.1 (Cont'd)

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 antennae. The antennae transmits and receives the signals from the satellite. It is also used to track the satellite to determine the satellites 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 $MH^{Z}$ 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 $MH_{Z}$. The 70 $MH_{Z}$ 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 $MH_{3}$ 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 re-transmitted by the satellite. The Ranging equipment measures the delay from the transmitted signal to the received signal, and from the delay, calculated 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 dependant on the mission requirements and the physical configuration of the overall network. For the sake of this general discussion, real

3.2.1 (Cont'd)

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.

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 sub-commutation, 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 Mission Control Centre 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 Mission Control Centre, then forwarded to the TT & C computer. The TT & C computer processes the command, then sends them to the command formatter which uses them to be sent to the satellite. The TT & C Computer has the capability to generate and transmit commands in emergency situations.

3.2.1 (Cont'd)

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 antennae and passed to the MCC. The MCC uses this data to calculate satellite range and ultimately, the satellite orbital parameters.

Mission Control Centre

The Mission Control Centre has the primary responsibility for monitor and control of the satellites 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.

3.2.1 (Cont'd)

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.

- Failure and Contingency Analysis - Support for the analysis of failures and fro 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.

3.2.1.3 Mission Management Office (MMO)

The MMO provides the overall direction to the post launch operations of the satellite system. The associated activities start about 6 months prior to the launch and continue until to the end of the mission. The MMO is staffed on an 8 hours per day, 5 day per week basis. The MMO establishes overall policies and operational orders for the operations

3.2.1.3 (Cont'd)

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 MMO 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 distributions of data and information products.

3.2.1.4 Data Reception Stations

Data reception stations receive the satellites 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);
- to preserve the real-time value of the data;
- to avoid saturation of on-board recording capability;
- to preserve the privacy of data taken over a politically sensitive region of the earth;
- to share the financial and management burden of pre-processing data into a format acceptable to users; and
- to promote the use of the data for long-term economic, social or political reasons.

### 3.2.2 Radarsat Technical Demand

The requirements for the ground-segment of the Radarsat program 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.

**MISSION CONTROL SYSTEM (MCS) SPECIFICATIONS AND FUNCTIONS**

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 consists of five systems:

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

3.2.2 (Cont'd)

- 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 must be functionally redundant with no single point failures. This requires:

   - 99% availability in each redundant string; and
   - a Mean Time To Repair (MTTR) of 48 hours.

6. A minimum of 8 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.

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.

3.2.2 (Cont'd)

11. The MCC must process and analyze 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 sub-carriers 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.

18. Launch and Early Orbit Phase (LEOP) TT & C stations will utilize existing facilities not co-located with the MCC. However, the MCC must interface with LEOP TT & C.

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

3.2.2 (Cont'd)

20. The five-fold functionality of the Mission Control Centre is given in schematic form in Figure 1.

21. The prime TT & C station has a five-fold functionality which is described in schematic form in Figure 2.

22. Figure 3 is a block diagram of the major systems comprising the Radarsat earth segment, including the MCS.

23. Figure 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.

**RADARSAT IMPLEMENTATION**

Providing the full range of support to Radarsat is a critical first step if CSCC is to become the major Canadian satellite control centre for Canadian and foreign non-communications satellites.

A division of labour in the MCS between, for example, Saskatoon and Ottawa-Gatineau would complicate communications and logistics and place severe demands on human resources in assuring the necessary coordination of tasks. Direct interaction between members of a satellite control team is vital to the efficient management of a satellite, especially in the first few days of Launch and Early Orbit Phase (LEOP). The time team members spend together during LEOP will allow important team strengths and capabilities to develop. The greatest challenge, and hence the greatest tribute to the skill of a satellite control team, is to conduct the LEOP.

3.2.2 (Cont'd)

If CSCC were to operate only the Mission Control Centre (MCC), not including TT & C, it would be difficult to build the foundation needed to develop a full satellite control capability. Radarsat documents clearly state a preference for co-locating TT & C and the Mission Control Centre. If the MCS specifications for the TT & C antenna gain and figure of merit are adequate, the TT & C antenna need be only 3 metres in diameter, thus allowing a much simpler structure than the 9 to 10 metre system traditionally used. Locating the antenna in Saskatoon would be cost-effective for Radarsat, even if it is not adequate for other missions.

**OTHER PROGRAMS FOR CSCC**

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

- the Mobile Servicing System (MSS); and
- Canadian R & D payloads for use on the Space Station known as the User Development Program (UDP).

This assumption has a bearing on how CSCC is designed with respect to size and adaptability. The contents of Figures 1 through 4 are essentially unique to Radarsat, although they are representative of the range of services CSCC could provide to numerous conventional unmanned satellites. SS 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, SS requirements are incremental to Radarsat, and provide an opportunity to build on the Radarsat 'base' installations.

### 3.2.3 Space Station Technical Demand

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 Canadian Space Station Program (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.

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, NM and Goldstone, CA.

- 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 SS ground support.

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

3.2.3 (Cont'd)

- MSS-unique operations: MSS ground support has sole responsibility to plan, monitor, and evaluate operations.

- SS operations in which MSS is a primary resource: MSS ground support is integrated as a primary support source.

- SS operations where MSS is a secondary resource: MSS ground support is an external support source, acting as a technical consultant during SS 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 (CSA) and NASA.

### 3.2.3.1 MSS Technical Demand

As indicated in Figure 5, the MSS Ground Segment has two major components: an Engineering Support Centre or ESC, and a Utilization and Operations Centre, or 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 Utilization and Operations Centre 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

3.2.3.1 (Cont'd)

the MSS Program, directing the utilization and operations planning and scheduling, primarily at the strategic and tactical levels. U & OC will also provide MSS Program policy direction.

The U & OC need not be co-located with the Engineering Support Centre (ESC). Figure 6 illustrates a range of activities appropriate to the U & OC as a whole. Since it is a senior-level function, the CSA

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 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 print-outs.

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).

3.2.3.1 (Cont'd)

It would not be efficient to separate the SOSS and the ILS because of the heavy volume of daily information traffic between them. Figure 7 illustrates a number of activities that would be carried out in the Engineering Support Centre under SOSS and ILS.

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:

- analyze, comment upon and make recommendations with respect to the use of MSS for all SS operations;
- analyze and report on the health of MSS;
- 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 non-standard procedures (NSPs);
- verify integrity of NSPs on MSS simulator;

3.2.3.1 (Cont'd)

- prepare NSPs 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; and
- 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 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;

3.2.3.1 (Cont'd)

- 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 8, 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.

### 3.2.3.2 User Development Program (UDP) Technical Demand

National or international facilities that serve as a focus of operations for Space Station R & D and scientific users under the Canadian Space Station Program's User Development Program are to be designated Regional Operations Centres (ROCs).

By the time Space Station is available for use by the world-wide constituency of scientific users, Canada will have spent $75 million under UDP in 'pre-use' efforts to develop interest and competence to carry out R & D on 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 SS by R & D 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.

3.2.3.2 (Cont'd)

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

- A physically separated work area in CSCC for SS UDP project staff;
- Dedicated communications services to SS 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 R & D experiments on behalf of experimenters;
- Reaction to unexpected events on SS to protect experiments from loss or damage; and
- Data processing to view experimental results in a quick-look mode.

The number of Canadian R & D projects on SS 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 R & D projects is given in Figure 9.

### 3.2.4 Technical Demands of Other Canadian Missions

A number of additional 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. These are:

- Space-Based Radar (SBR), a U.S. Department of Defence (DOD) remote-sensing mission; and

- Radarsat 2.

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

3.2.4 (Cont'd)

benefits of a second mission would be equally attractive. It is worth noting that Radarsat has at least three major objectives:

- to present the Canadian space industry with a very challenging technological goal;
- to maintain the integrity of the Canadian spacecraft prime-contractor/subcontractor team; and
- to acquire data about the earth and oceans of scientific and commercial value to Canada and the rest of the world.

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.

### 3.2.5 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;
- 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); and

3.2.5 (Cont'd)

- 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);
- U.S. Navy Remote Ocean Sensing System (NROSS), 1990-1991; and
- 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 on-going projects which provide potential continuous demand for support, once a business relationship has been established.

3.2.5 (Cont'd)

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

- LEOP 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;
- 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.

### 3.2.6 Other CSCC 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.

3.2.6 (Cont'd)

**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 re-issued 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.

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.

3.2.6 (Cont'd)

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 US, 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 R & D experimenters, CSCC could undertake some low-level data processing as part of its service to SS and other users. This activity, known as zero-level processing, is the capability to analyze 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 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;

3.2.6 (Cont'd)

- appeal to CSCC for clarification of data formats; and
- allow 'private' data to fall into hands for which it is not intended.

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

## 3.3 MARKET ASSESSMENT

**WAITING FOR SED INPUT. MAYBE THIS SHOULD COME LATER. SEE SECTION 3.4.3**

## 3.4 THE CASE FOR A CANADIAN SPACE CONTROL CENTRE (CSCC) IN SASKATOON

This section puts forward the rationale for the establishment of a Canadian Space Control Centre, and for its location in Saskatoon. It deals with the federal government's social objectives for regional economic development and the potential role of SED Systems as a space contractor in the Prairie region. The need for a CSCC and the case for its location at SED in Saskatoon are summarized.

### 3.4.1 SED Systems' Capabilities

**THIS SECTION SHOULD GIVE A BRIEF SUMMARY OF SED'S STRENGTHS AS THEY RELATE TO THEIR CREDIBILITY IN DEVELOPING AND OPERATING CSCC. BEST DONE BY SED.**

### 3.4.2 SED Systems' Corporate Objectives

SED Systems has stated its corporate objectives to be as follows:

1. To 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.

3.4.2 (Cont'd)

2. To commercialize the technology and to be competitive in satellite test and monitoring and mission control systems on a world-wide basis.

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

4. To strengthen 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.

5. To cooperate with and support 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.

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

7. To become clearly recognized as the space leader in the Prairie region, while assisting in the development of a critical-mass in the industry.

8. To create spinoff technologies, products, and export market opportunities.

9. To expand the operations capability of a Satellite Control Centre to include strategically located TT & C stations capable of

3.4.2 (Cont'd)

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.

10. To cooperate 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 socio-economic benefit, to develop this industry in a region of Canada which requires a stimulus or technology engine.

The degree to which these objectives can be fulfilled depends on the validity of the market, and the realism with which SED envisages its own capabilities and ability to grow into the ambitious role it has attempted to stake out. It is clear that in striving for its goals, SED will need help politically, financially and almost certainly technically. Its management capabilities will be challenged to the limit.

Nevertheless, the politics of regional economic development and the strong support which the Canadian Space Program currently enjoys (as signalled by the fact that the CSP was not impacted by the recent budget cutbacks in other areas), leads to the conclusion that such ambitious objectives are achievable.

### 3.4.3 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,

3.4.3 (Cont'd)

particulary in the tracking and control of scientific and remote sensing satellites and space platforms.

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 (DND) 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 likelihood, timing and nature of this potential demand for the services of CSCC.

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

control, to complete control. CSCC could support such missions with a range of services, such as:

- LEOP 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

3.4.3 (Cont'd)

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 and the Canadian Space Station programs. (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 3 years with a life of, say 6 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.

### 3.4.4 Other Aspects of CSCC'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 on-going commitments in space. Heretofore, government departments (for example DOC and EMR) have had to establish dedicated control stations to support inter-

3.4.4 (Cont'd)

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 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 CSA would interact, instead of facilities scattered among several agencies. Implied in such an arrangement is a deep commitment and affinity between CSA and CSCC. CSCC must be perceived as Canada's chosen instrument for space control.

CSCC can be CSA's window-to-the-world for public information and access, as well as being a technical operation. Accordingly, 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 R & D experiment in SS;
- In-orbit service to a Canadian SS 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. CSCC should have a basic TV studio

3.4.4 (Cont'd)

capability to record and edit this material and to pass it on to Canadian TV networks for their use. This capability may include analog-to-digital and digital-to-analog conversion of television signals.

To service CSA's public constituency, CSCC will require press briefing rooms with professional equipment and comfortable accommodations. These facilities would, of course, also be used by CSCC general management. 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.

### 3.4.5 Regional Distribution

As described in Section 3.1.1, the federal government is committed to the expenditure of 10% 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 directly across Canada under the CSP, 10% 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.

3.4.5 (Cont'd)

In the Prairie region, there are only four major industrial performers - SED Systems, Bristol Aerospace, Boeing 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. The major proportion of CSP work in the Prairie region is therefore almost certainly destined for SED Systems, provided it can exhibit 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 Systems, MDA (BC), CAL and Comdev (Ont.), CAE (Que.) and IMP Aerospace (NS) produced a document, which we understand has been accepted by the federal government, to distribute Spar's contracts according to the regional distribution targets. For the Prairie region, the distribution was as follows:

| Program | Prairies | SED Systems |
|---|---|---|
| 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 | ? |
| | $104.8 million | ? |

## 3.4.6 The Case Summarized

The importance of regional distribution, the limited spectrum of space capabilities among Prairie companies and the capabilities of SED Systems leads to the conclusion that the CSCC should be located at SED Systems in Saskatoon.

These same socio-economic arguments outweigh any logic that the CSCC should be co-located with the CSA. One of the underlying principles and strengths of the Canadian Space Program is that it is regional, and as such is an expression of all the people of Canada, not just a chosen

3.4.6 (Cont'd)

few in the centre of the country. The same principle can be found in the U.S. space program, with space-related facilities and capability distributed throughout the major regions of the U.S., as well as in the European program, where facilities are located in every ESA nation.

FIGURE 1. RADARSAT MISSION CONTROL CENTRE FUNCTIONALITY

**Mission Planning & Command Management System (MPS)**

- process approved observation plans
- determine SAR operational modes
- generate SAR control data tables
- generate command procedure and uplink data files
- input to MOCS

**Flight Dynamics System (FDS)**

- orbit determination and propagation
- attitude determination and validation
- manoeuvre and orbit maintenance planning
- input data to MPS and MOCS

**Management Information System (MIS)**

- all comms and file exchange within entire ground system
- report exchange
- standardize formats for data exchange
- SW/HW for MCC, TT&C, MMO, DAN connectivity
- interface COMS system

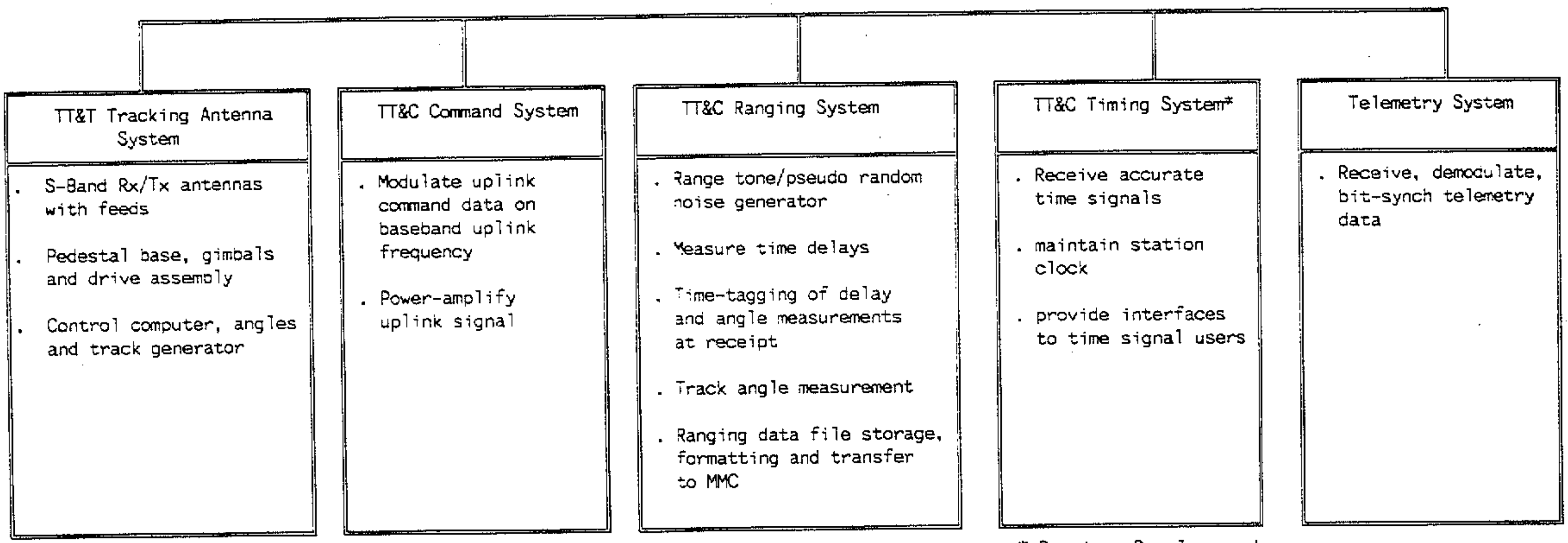
**Voice and Data Distribution System (COMS)**

- data comms LEOP/TT&C/MCC
- voice comms
- data line service for MIS
- facilities to test MIS lines

**Mission Operations Control System (MOCS)**

- command and control the satellite
- process telemetry
  - frame synch. & decommutate data
  - convert to engineering units
  - display
  - limit checks/flags
- health, status, and trend analysis
- satellite data archiving
- archive management

FIGURE 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.

FIGURE 3. CSCC CONFIGURED FOR RADARSAT (MCS) ROUTINE OPERATIONS

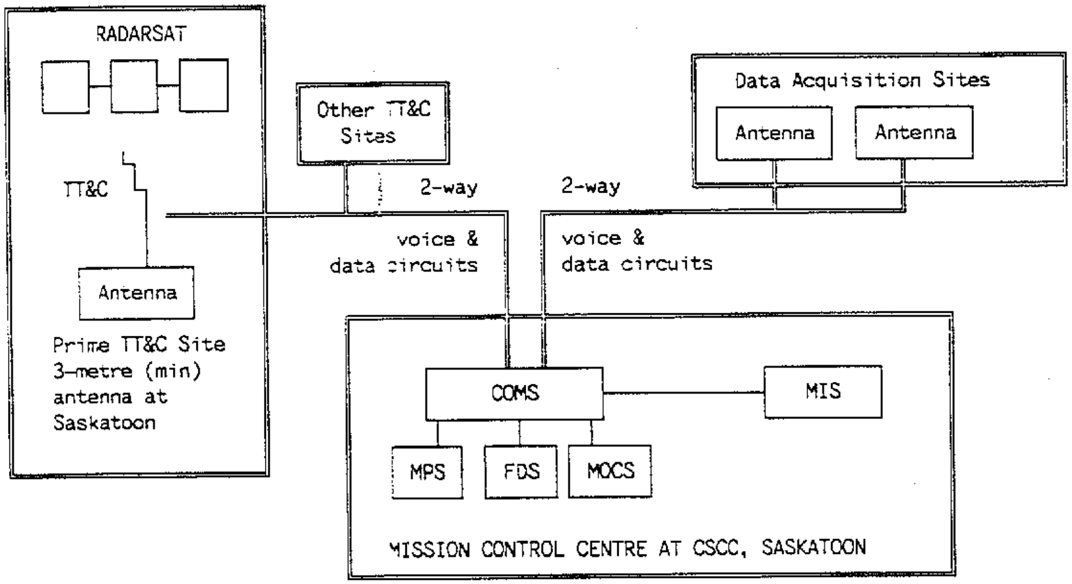


FIGURE 4. RADARSAT MCC FUNCTIONAL IMPLEMENTATION

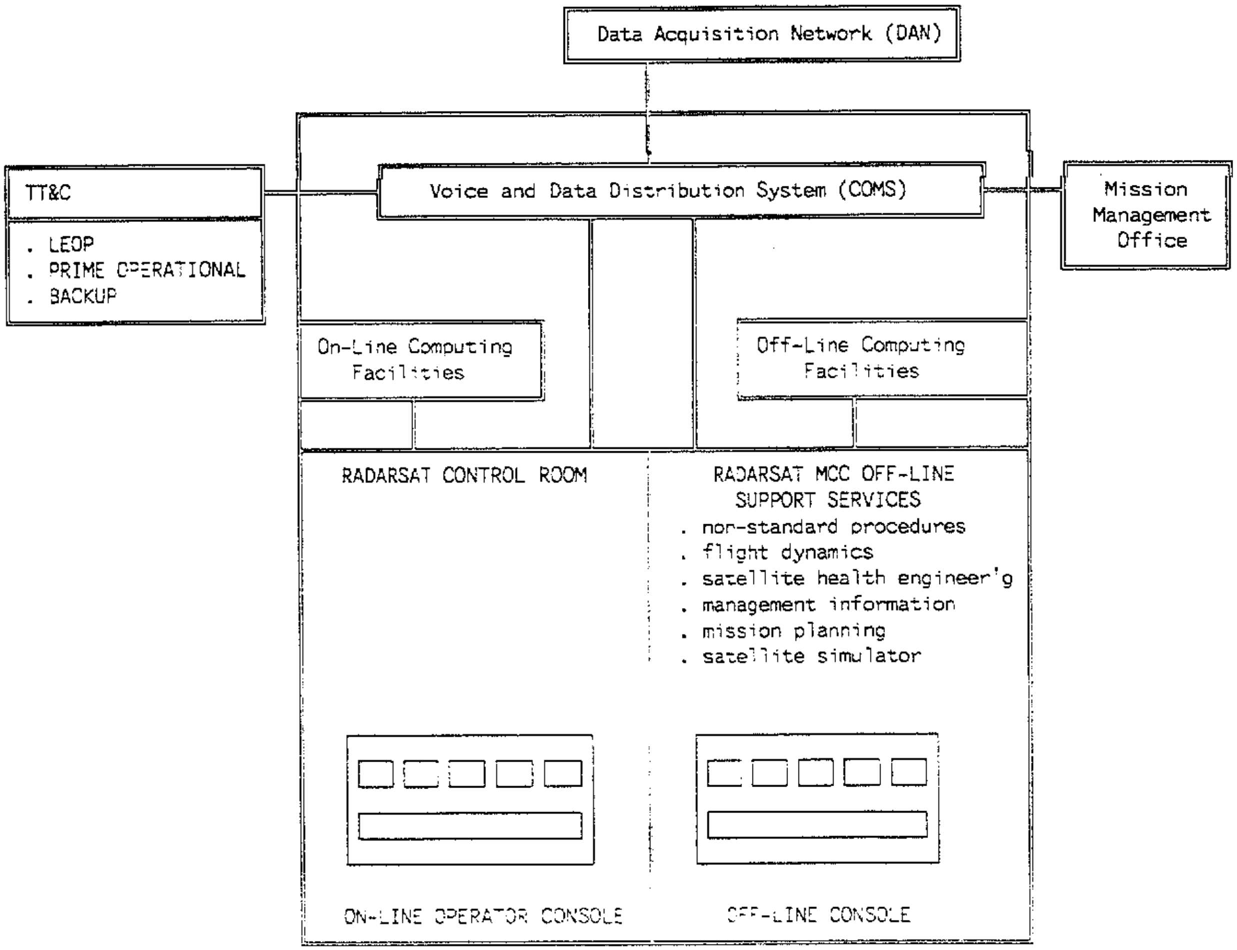


FIGURE 5. CURRENT MSS GROUND SEGMENT ORGANIZATION

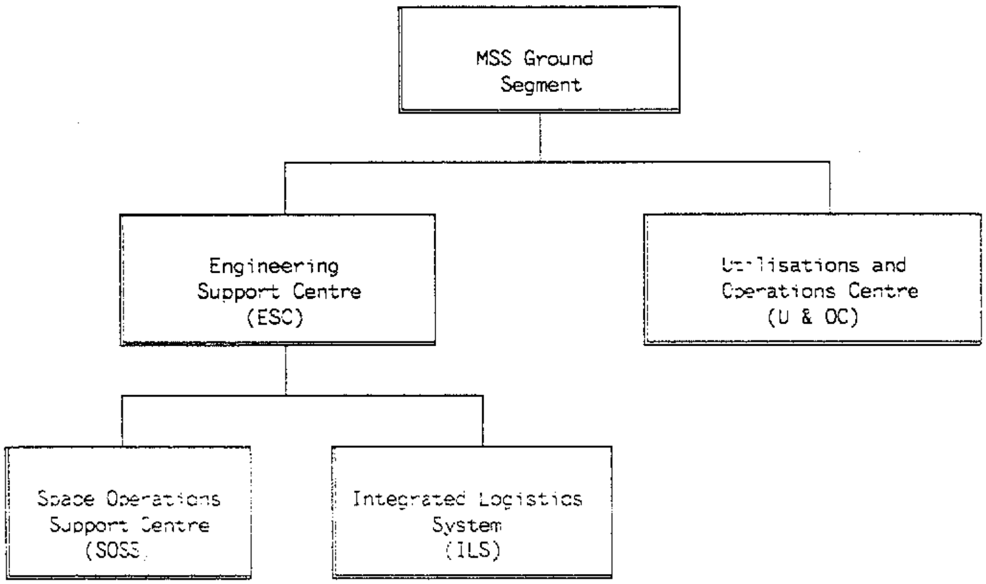


FIGURE 6. MSSP GROUND SUPPORT SEGMENT - UTILIZATION AND OPERATIONS CENTRE (U & OC)

- MANAGEMENT INFORMATION SYSTEM
- PLANNING AND SCHEDULING
- COMMUNICATIONS SYSTEM

FIGURE 7. MSS PROGRAM GROUND SEGMENT SUPPORT - ENGINEERING SUPPORT CENTRE FUNCTIONALITY

MSS PROGRAM ENGINEERING SUPPORT CENTRE (ESC)

| Space Operations & Support Systems (SOSS) | Integrated Logistics Systems (ILS) |
|---|---|
| . Management Information | . Management Information |
| . Monitoring | . Analysis |
| . Command & Control | . Training |
| . Analysis | . Planning & Scheduling |
| . Diagnostics | . Inventory Control/Monitoring |
| . Simulation | . Ground Support Equipment |
| . Training | . Repair |
| . Planning/Scheduling | . Communications |
| . Communications | . Data Management |
| . Data Management | |

FIGURE 8. SOSS/ILS OPERATIONS

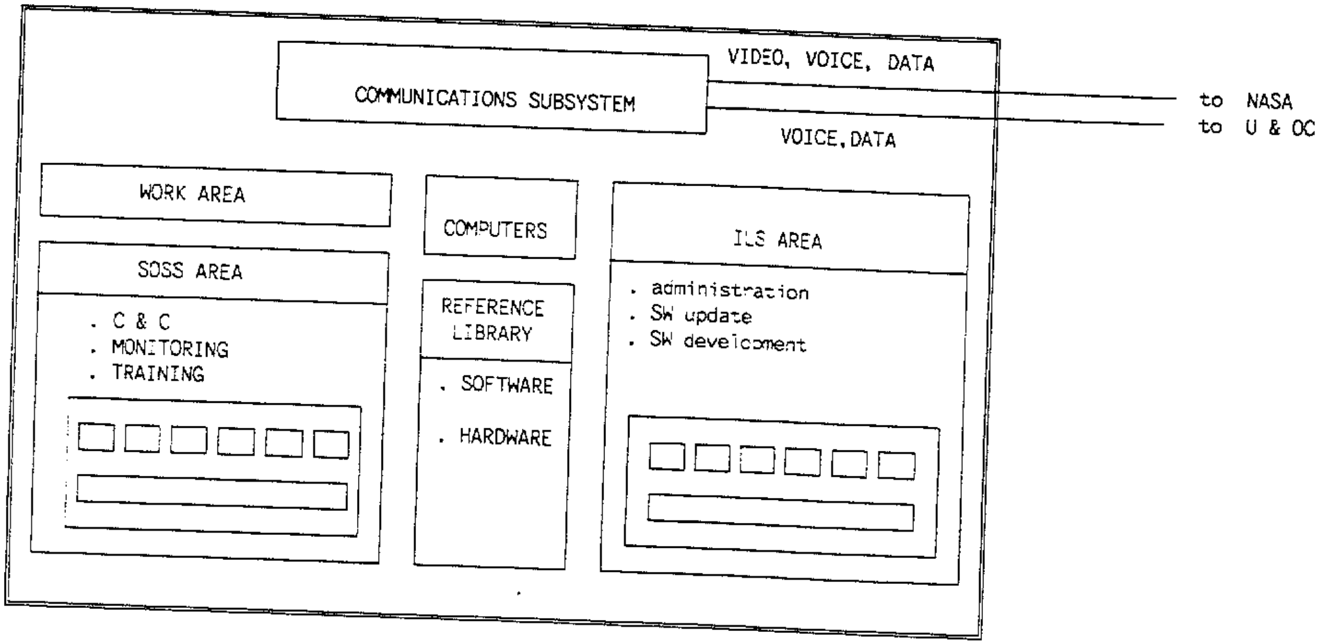


FIGURE 9. CSCC SUPPORT TO UDP

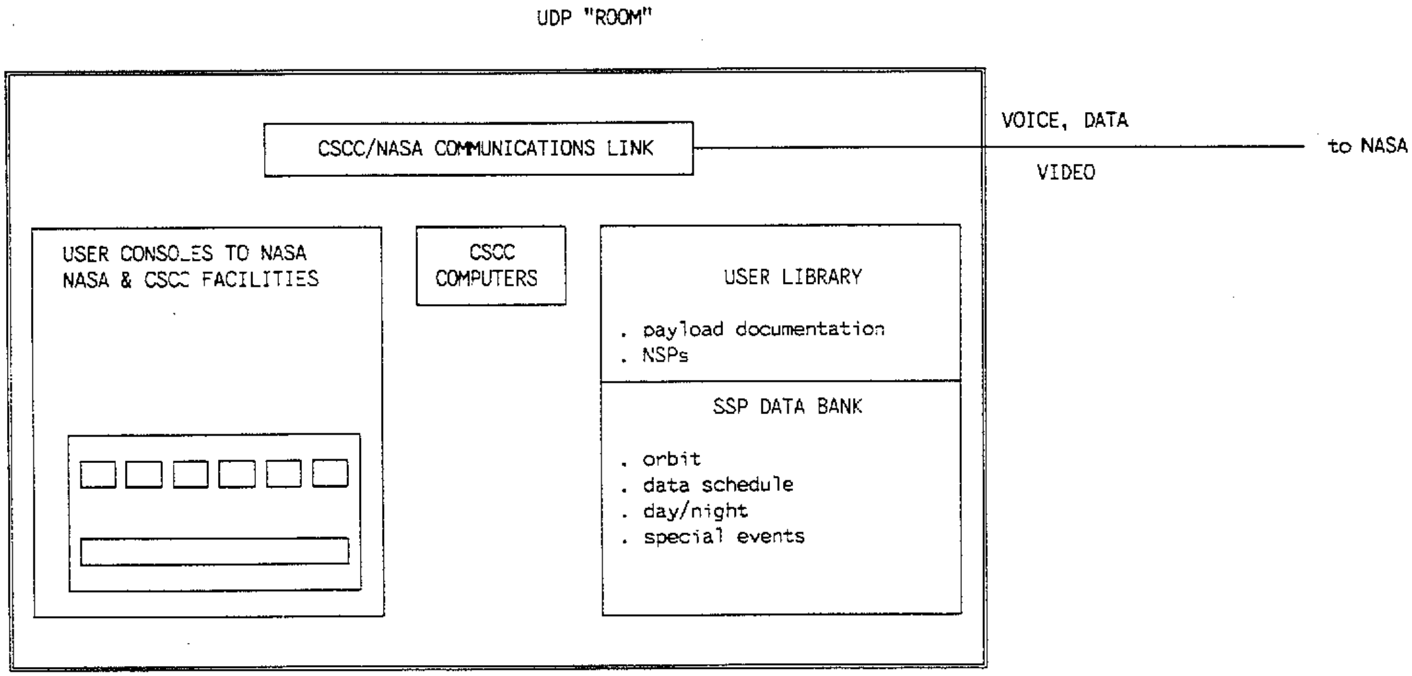


TABLE AA: STAFFING REQUIREMENTS FOR KEY TECHNICAL POSITIONS IN SATELLITE CONTROL

| FUNCTION/LOCATION | SPOT (CNES) | CRC | ESOC |
| --- | --- | --- | --- |
| TT&C STATION | . no comment | .all "remote" experience is with NASA bent-pipe TT&C stations<br>.CRC stations alwaya co-located<br>.staff included with other tasks | . 2(min) per shift for routine maintenance if station is remote and completely automatic |
| N-LINE Operators or ..ntrollers | . 1 per shift at Control Centre<br>. 1 per shift at Mission Centre | . 2 per shift (1 senior + 1 junior assistant to load tapes, change paper charts, carry out top-level maintenance) | . 1 satellite controller per shift<br>. 2 TT&C operators per shift |
| OFF-LINE specialists | . flight dynamics, 2 per shift all shifts,<br>. 4 S/C specialists, 5 sh/wk each | .OIC sceduling and data analysis, 5 sh/wk<br>.scheduler, command writer,user interface at the working level, 5 sh/wk<br>.S/C dynamics, 5 sh/wk<br>.computer maintenance, SW updates,etc., 5 sh/wk<br>.RF and other analog maintenance, 5 sh/wk | . S/C operations manager, 5 sh/wk<br>. S/C operations engineer, 5 sh/wk<br>. S/C analyst, 5 sh/wk<br>. SW maintenance, 5 sh/wk<br>HDWE maintenance, 5 sh/wk |
| ..tals for 24-hr satellite control | 5420 shifts<br>5420/225=24 staff<br>BUT CNES may operate SPOT control with 1 shift per day except for the staff necessary to send the commands. If the commands can be uploaded once per day no staff are needed in the night shift. (SPOT is in a 10:00am/10:00pm sun-synchronous orbit) | 3490 shifts<br>3490/225=15 1/2 staff | 6775 shifts<br>6775/225=30 staff |

# 4.0 OPERATION AND MANAGEMENT OF THE FACILITY

## 4.1 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.

### 4.1.1 FACILITY MANAGER

The Canadian Space Control Centre could be seen as a provider of a facility and support staff for specific control mission contractors. The centre, would provide an infrastructure of administrative and facility management services to outside contractors. The outside contractors would provide the program specific technical personnel and communicate directly with the program management office. This alternative can be compared to a landlord - tenant relationship.

Figure 4.1 describes this alternative in graphic form.

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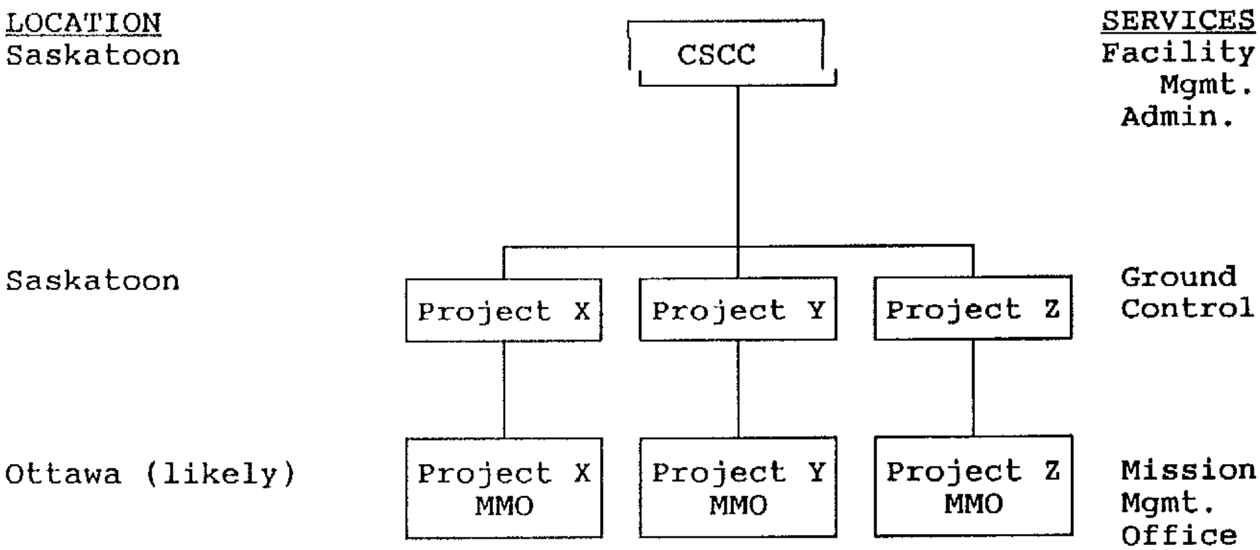
FIGURE 4.1



4.1.1 (Cont'd)

The CSCC would act as a provider of services to specific projects that choose to locate their ground segment control operations in the CSCC facility.

ADVANTAGES

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

DISADVANTAGES

- Will require funding of infra-structure costs until a sufficient volume of projects are secured to cover overhead costs
- unlikely to attract clients due to the fact the no domestic entities provide ground control operation services currently
- Does not create an environment that promotes the creation of a centre expertise or development of spin-off technologies
- Would not provide a co-ordinated approach to ground control services in terms of developing and utilizing specific technical expertise.

## 4.1.2 FULL SERVICE CENTRE

This model would see CSCC as the organization or entity that provides both a central facility as well as the technical expertise to fully implement and support any type of ground-station activity. CSCC would provide a full service package to any "customer" that needs ground-station operations for any non-communications satellite. The focus would be on non-communications satellites due to the fact that TeleSAT has a mandate to control all communications satellites in Canada.

Figure 4.2 describes this alternative in graphic form.

FIGURE 4.2

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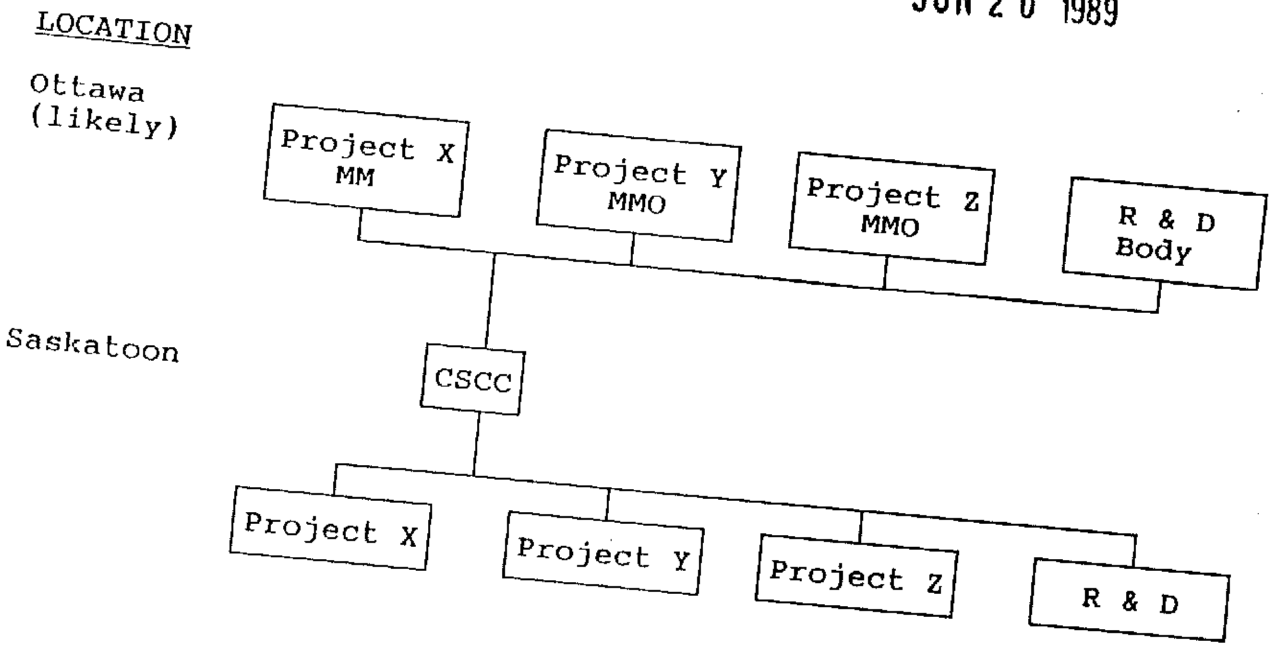


4.1.2 (Cont'd)

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 co-ordinate 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 are enhanced because the centre offers a turn-key ground-station service as opposed to simply facilities and administrative services.

ADVANTAGES

- 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 for centralized control of ground control operations.
- communication lines are simple and direct.
- allocation of resources/personnel can be made at a level that will allow for more efficient operations of all projects in the facility
- R & D integration into the facility is more defined and obvious
- Allows for the creation of a centre of expertise with a single entity controlling and monitoring R & D efforts and identifying and marketing spin-off technologies and products.

4.1.2 (Cont'd)



DISADVANTAGES

- Will require funding of infrastructure costs untilsufficient projects are secured to cover operations 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

**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 co-ordinated approach to ground control operations and related research and development activities is required. Such an approach is only feasible through a single body co-ordinating all facets of satellite control. The CSCC must therefore be operated as described in section 4.1.2 in order to be feasible and credible in this industry.

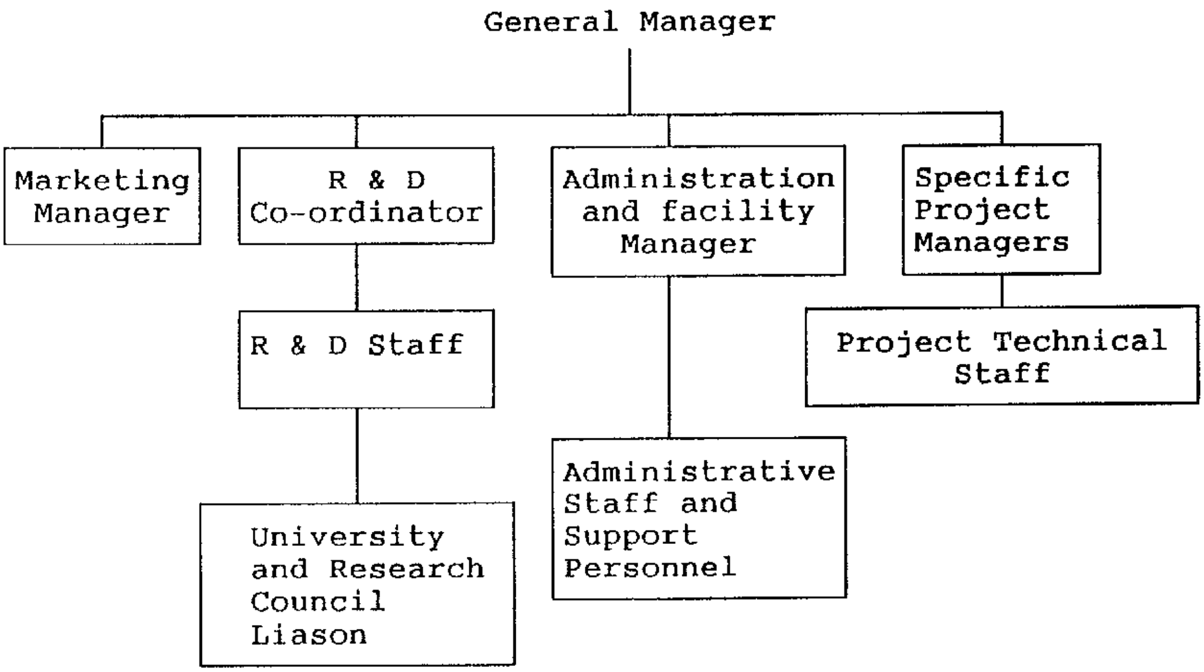
The detailed operating structure is defined in figure 4.3.

JUN 20 1989

FIGURE 4.3

PROPOSAL FULL OPERATIONAL

CSCC ORGANIZATIONAL STRUCTURE



## 4.2 OWNERSHIP ALTERNATIVES

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

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

### 4.2.1 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 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

- 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

A government facility has several disadvantages as well. There would be a tendency for the CSCC to become a branch of the CSA and forsake some of the objectives of the Canadian Space Control Centre. As well, a government owned facility would tend to become overly bureaucratic and possibly inefficient. Since the objective is to develop a ground segment technology that is competitive on a global basis, this represents a serious disadvantage to government ownership.

Since the current trend of government bodies is towards privatization, it is unlikely that a government would be willing to establish and own this type of centre. As such, it is unlikely that government owned Canadian Space Control Centre would be feasible at this time.

### 4.2.2 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 Canadian Space Control Centre, 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
- satisfy regional distribution initiatives
- require a profit motive and possibly increase competitiveness on a global scale

4.2.2 (Cont'd)

- 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 non-communication 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 projects may be more likely to deal with the centre if they know it has the stability an support of government as widened through their ownership position. As well, for projects 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.

### 4.2.3 100% PRIVATE OWNERSHIP

Complete ownership of the CSCC by private enterprise is also an alternative. This alternative is especially attractive given the current trend towards government privatization and the political support being shown for private enterprise. As well, a 100% privately owned company has more flexibility in terms of organizational structure and

4.2.3 (Cont'd)

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.

JUN 20 1989

## 4.3 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 estiblished 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

4.3 (Cont'd)

- budgets, earnings targets, and cost control measures consistent with the profit objectives of the entity

- 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.

## 4.4 MANAGEMENT REQUIREMENTS

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

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

- MARKETING MANAGER - responsibility for all aspects of marketing the Canadian Space Control Centre on a domestic and international level

- OPERATIONS MANAGER - Will be 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 Systems Inc. At this point the facilities manager will be responsible for maintenance, security, and other facility related issues.

- FINANCIAL CONTROLLER - at some future point a financial controller will be required for the Canadian Space Control Centre. In the interim period, SED Systems Inc. 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.

The specific capabilities and qualifications of each of these identified staff members is described in detail in section 4.5 of this report.

## 4.5 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 Systems Inc. on a fee for service basis. The details of operating cost and ongoing service fees has been outlined in detail in Section 8.5 Basis of Economic Evaluation.

Each project will have a complement of administrative and technical staff responsible for the specific project. These costs are not relevent 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 re

## 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 non-technical 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 Services

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

Other 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 Lasp and the SME 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 are

4.6.2 (Cont'd)

to 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 adaption 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 twelve hour basis, but prior to 1987, operated 24 hours a day by professional and student employees. At all times one Flight 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, and were the voice of LASP that coordinated 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 have been trained as Command Controllers. There were 15 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.

JUN 20 1989

### 4.6.3 University of Saskatchewan

The University of Saskatchewan has participated in the Canadian Space Program for over twenty five (25) years. The founding members of SED Systems Inc. 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 signatures of different crop and the effects of aspect sensitivity is of direct interest to Saskatchewan agriculture and clearly demonstrates the importance of space technology to the province."

4.6.3 (Cont'd)

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.

# 5.0 SITE LOCATION AND FACILITY DESCRIPTION

## 5.1 GENERAL

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

The drawings presented in this section are based on:

- Radarsat document (NEED CORRECT TITLE)
- Canadian Space Station (NEED CORRECT TITLE)
- 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.

## 5.2 FACILITY DEVELOPMENT

For this study a phased development approach is being presented for the Canadian Space Control Centre. At this time only the Canadian Space Program segments are being addressed for the facility, with capability to expand 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 (4) years before the Canadian Space Station Control Centre for MSS and UDP components is required. Regardless, the

5.2 (Cont'd)

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 Canadian Space Control Centre 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 would be located on the second floor. This would require architectural, mechanical and electrical modifications to the existing office area on the second floor.

## 5.3 SITE LOCATION

Initially several sites in and around Saskatoon were considered acceptable, however the most desirable site was at Innovation Place in Saskatchewan Economic and Development Corporation Research and Development Park, north of the campus of the University of Saskatchewan. (See Drawing 100-10-001 Rev. A).

5.3 (Cont'd)

In 1986, SED Systems Inc.'s operations Were consolidated and moved to a new 11,400 square metre (122,000 square foot) facility in Innovation Place. The building contains 5000 square meters of office space on two floors, 1700 square meters of atrium space, and 4700 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 Canadian Space Control Centre, 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
- efficient access to technical support and for maintenance of equipment
- architecturally attractive setting within close proximity of high-tech companies, research agencies, and laboratories.

5.3 (Cont'd)

Preliminary discussions have been held with federal government departments to determine the regulatory requirements for radio frequency spectrum slots for communications between the satellites ant 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.

## 5.4 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 owht 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 Canadian Space Control Centre 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.

5.4 (Cont'd)

A separate entrance way will be created for security reasons and to distinguish the facility from the existing SED building. The architecturally designed entrance way and landscaped plaza welcomes the visitor and encourages 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 way 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. 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.

## 5.5 <u>CANADIAN SPACE CONTROL CENTRE - RADARSAT CONTROL CENTRE</u>

### 5.5.5 <u>General</u>

In the early phases of the Canadian Space Control Centre with only the Radarsat Control Centre, 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 Canadian Space Control Centre, office space will be increased within the existing SED building on the main floor. The Radarsat Control

5.5.5 (Cont'd)

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
  - managers office
  - maintenance office
  - inventory office
  - office services
  - conference room
  - spare office

## 5.5.2 Radarsat Control Centre Description

The facility interior centres around two important rooms, the Computer Room and the Control Room. The Control Room is the largest room at 69 square meters and it is here where most of the operation functions are executed. Surrounding the Control Room are "service function" rooms; the Computer, Analysis and Maintenance Rooms. The Computer Room also

5.5.2 (Cont'd)

has direct access to the data centre where tape storage is provided.

To ensure good public relations the Radarsat facility will be easily assessable to the public. A Public Viewing Gallery is 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 steel structure will be required to ensure an unobstructed view of the horizon by the antennae. The antennae will be approximately three (3) 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.

### 5.5.3 Mechanical System

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

5.5.3 (Cont'd)

Separate washrooms are also provided for the Control Centre since access to the existing SED washrooms is not possible 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.

5.5.4 Electrical System

It is essential that the Radarsat Control Centre be in operation at all times and hence it is necessary to have a 100% 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% 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 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

5.5.4 (Cont'd)

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.

## 5.6 CANADIAN SPACE CONTROL CENTRE - MSS AND UDP CONTROL CENTRE

### 5.6.1 General

As stated in Section 5.5, the Canadian Space Control Centre 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

5.6.1 (Cont'd)

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

## 5.6.2 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 is provided and permits clear, unobstructed views of the Computer Room and both Control Rooms.

Surrounding both Control Rooms are the relevant support or services function rooms such as analysis and maintenance areas. The Control Rooms are spacious and are designed to permit the addition of further control functions as the needs arise. 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 on his tour of the facility.

For security purposes the lobby and public viewing area is essentially separated from the other areas through controlled access using combination locks or electronic card access. To meet fire regulations,

5.6.2 (Cont'd)

emergency exits are provided at other locations in the facility which open on to the SED atrium and hence ultimate access from the building.

The MSS and UDP antennea's will consist of a ten (10) metre deameter antennae supported on a fifteen (15) metre high structural foundation.
**SED TO PROVIDE**

Other features are similar to the Radarsat Facility Description outlined previously in the report.

### 5.6.3 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 assessable only to the control centre personnel. For security reasons, access to this common area will be denied to SED staff.

### 5.6.4 Electrical System

As described with the Radarsat system, an uninterruptible power supply will be installed to provide a 100% 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 (10) metre diameter fully rotational antennae located near the facility. Other demands relate

5.6.4 (Cont'd)

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.

# 6.0 CAPITAL COST ESTIMATE

## 6.1 SUMMARY

As discussed in previous sections of the report, the concept for a Radarsat Control Centre is more advanced and developed and hence 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 inter-national satellites.

The development of a Canadian Space Control Centre with MSS and UDP operations has also been estimated separately. Both options can be easily developed within the confines of the existing SED Systems Inc. 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 $__________and for the MSS and UDP control centre facility $_________ . The basis and details of the estimates are presented in the subsequent sections 6.2 and 6.3 inclusive. 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

6.1 (Cont'd)

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

## 6.2 BASIS OF CAPITAL COST ESTIMATES

The capital cost estimate is based on the following information:

- Radarsat program specifications (NEED CORRECT TITLE)
- 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 100-10-001,Rev. A
- Floor Plans as shown on drawing numbers 100-10-002 Rev. A and 100-10-003 Rev. A
- Facility Description (see Section 5.0)
- Program requirements identified by SED Systems Inc.
- Kilborn in-house costs and factors
- Supplier estimates for major electrical and mechanical components

6.2 (Cont'd)

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
- 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.

## 6.3 DETAILS OF CAPITAL COST ESTIMATE

### 6.3.1 Introduction

The information presented in the following tables (See Tables 6.1 and 6.2) summarizes the cost for two project development phases namely:

- Canadian Space Control Centre, Radarsat Control Centre
- Canadian Space Control Centre Mobile Servicing System and User Developed Payload Ground Segment Operations

The Radarsat Centre separately is estimated to cost approximately $636,000. The average cost per square metre is $1154.00 or $107.00 per square foot. The modifications required for the Canadian Space Control Centre with MSS and UDP components will cost approximately $1,260,000. The average cost per square metre for MSS and UDP is $1198.00 or $111.50 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 of the capital cost estimates are divided according to direct costs (direct construction activity) and indirect costs (contractor costs, engineering and architectural services, and contingency).

### 6.3.2 Radarsat Control Centre - Details of Capital Cost

All capital costs have been based on the modifications or new construction required as shown on drawing 100-10-002 Rev. A. 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

# TABLE 6.1

## 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 |
| Sub Total Direct Costs | $482,000 |
| **Indirect Costs** | |
| Construction Indirects | $ 24,000 |
| Engineering and Architectural Services | 72,000 |
| Contingency 10 % | 58,000 |
| Sub Total Indirect Cost | $154,000 |
| **TOTAL CAPITAL COST ESTIMATE** | **$636,000** |

# TABLE 6.2

## 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 |
| Sub Total Direct Cost | $921,000 |
| **Indirect Costs** | |
| Construction Indirects | $ 46,000 |
| Engineering and Architectural Services | 145,000 |
| Contingency 10% | $ 111,000 |
| Sub Total Indirect Costs | 302,000 |
| **TOTAL CAPITAL COST ESTIMATE** | **$1,223,000** |

6.3.2 (Cont'd)

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, 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 uninterrupted power suppy (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 Sask Tel 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 excludes wiring and connection of program equipment, computers, and radio frequency components.

Furniture and office equipment include 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 (5) percent fee is included for contractors costs.

6.3.2 (Cont'd)

Engineering and architectural services, including design drawings, specification preparation and construction management is estimated at fifteen (15) percent of the total direct cost. A ten (10) percent contingency allowance (on the total direct cost, plus construction indirects and engineering) is also included to account for possible unforseen cost factors.

6.3.3 <u>Canadian Space Control Centre - MSS and UDP Components</u>

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, ventilation, 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 install- tion of the Control Centre's program equipment, computers, or radio frequency components.

To accommodate a ten (10) metre diameter fully rotational antennae a more rigid structure is required than for the smaller Radarsat antennae. 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 twenty percent may be realized if Radarsat, MSS and UDP Control Centres were to be combined as one larger system.

The individual items comprising the cost estimate for furniture and office equipment and miscellaneous items are as described in subsection 6.3.2 of the Radarsat Control Centre - Details of Capital Cost Estimate.

6.3.3 (Cont'd)

As discussed in the previous section (See 6.3.2) an allowance for indirect costs for construction indirects, engineering and contingencies are also included in the capital cost estimate.

## 7.2 BUSINESS PLAN

The Business Plan for the Canadian Space Control Centre 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 actual projects are undertaken. It is likely that in the initial stages of operation, there will be no projects but the basic infra-structure 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 come on stream the centre will become more profitable as the costs related to providing the infrastructure for the centre will be spread over a larger number of projects. Once a certain volume of ground control work has been secured by the centre, the centre itself will become self-sustaining and profitable. It is anticipated that this would occur within six years of the commencement of operations.

The business plan has been designed such that capital and operating costs are minimized in the initial stages before operations become self-sustaining. This minimization of costs will be accomplished through a modular approach to construction for capital costs, and subcontracting the majority of services from the existing building tenant, SED Systems Inc. Operating costs will reach a point where subcontracting is not as cost effective as providing services internally once a certain volume of activity has been reached. At this time it is anticipated that the Canadian Space Control Centre would provide 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

7.2 (Cont'd)

incremental indirect costs related to the project. Eachspecific project is supported by a schedule of all capital costs 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 market place.

Specific assumptions and critical factors used to determine the financial viability of the Space Centre are described in detail in the notes to the projected financial statements.

The time frame of the business plan is fifteen 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 CSCC 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. We have used standard financial accounting policies and generally accepted accounting principles in preparing the projected financial statements. We have also used SED Systems Inc. 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) to a large extent. We have reviewed in detail the operating costs of SED Systems Inc. and determined

7.2 (Cont'd)

realistic operating costs for the core services as well as the specific projects.

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

We have assumed that the Canadian Space Control Centre will operate as a autonomous entrepreneurial business unit as described in Section 4 of this report. In the initial stages of operation, it is apparent that the CSCC will require some assistance in sustaining 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 would 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 I.

## 7.4 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.

- Project specific operating costs (stated in second quarter 1989 Canadian dollars, adjusted for inflation) as described in Section 7.4.2.

- Management wages and salaries for the Canadian Space Control Centre (in second quarter 1989 Canadian dollars, adjusted for inflation) as described in section 7.4.3.

- Program implementation time frames as described in section 7.4.4.

- Specific operating costs (as determined with reference to SED Systems Inc. actual operating costs for their current facility.) as described in Section 7.4.5.

- Rental rates and indirect costs subcontracted from SED Systems Inc. (as determined through discussions with SED Systems Inc.) as described in Section 7.4.6.

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

7.4 (Cont'd)

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. 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 core services of the Canadian Space Control Centre have been allocated to specific projects based on a factor applied to the direct labour component for each specific project. Rates have been determined such that overhead applied to each specific project is indicative of the actual overhead costs for that project. Profit margins have been based on specific project costs with a reasonable mark-up to provide a recovery of overhead and capital costs.

### 7.4.1 BASIS OF OPERATING COST ESTIMATE

The operating cost estimate is based on the following information:

- Radarsat program specification (NEED CORRECT TITLE)
- Canadian Space Station Program Mobile Servicing System, Ground Segment, System Configuration Document, March 1989 - Prepared by SED Systems Inc. for the National Research Council (?)
- Interviews with SAT Control, European Space Agency, University of Boulder SME Program
- Kilborn in-house costs and factors
- CRC data (NEED MORE DETAIL)

7.4.2.1 Introduction

- Utility costs from similar office facilities in Saskatoon.

Tables 7.1 and 7.2 present the yearly operating cost for the Radarsat Control Centre and for the Canadian Space Control Centre.

MSS and UDP components; for both programs the most significant yearly operating cost is labour which represents 70 to 80% of the total operating budget. Other factors such as security, janitorial office expenses, rent, and utilities comprise the remaining 20 to 30% of the budget. The total yearly operating cost for Radarsat is $1,187,500 and for MSS and UDP components is $2,310,350.

For the purpose of project operating cost estimates, it has been assumed that:

- All costs are in second quarter 1989 Canadian dollars.

- The facility is functional for 365 days per year

- Two operators are required 24 hours per day, 365 days per year for each program

- Operators are on 12 hour shifts

- Managers, secretarial, analysts, diagnosticians 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 yearly operating estimate excludes:

- Escalation beyond second quarter 1989

- Taxes

7.4.2.1 (Cont'd)

- Financing or carrying charges
- Owners costs not described in the study

7.4.2.2 **Radarsat Control Centre, Details of Yearly Operating Cost Estimate**

Labour

A total of 17 permanent personnel are required to operate the Radarsat Control Centre. The staff is comprised of one manager, two secretarial/clerical/receptionists, ten operators, and four analysts. Operators will be on shift 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 called on a 24 hour basis.

The labour rates in the table 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.

Services

The business conducted by SED requires certain security measures and precautions. The cost for one part-time security person is included within the yearly Radarsat operating budget. The facility would have security available over a sixteen hour period on a part-time basis. The provision of security services is equivalent to one paid staff position for one eight hour shift per day.

Janitorial services will be provided through contracts currently in place with SED Systems Inc.

7.4.2.2 (Cont'd)

Office Expenses

The category includes 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 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 or analysts.

Rent and Utilities

Operating costs for rent and utilities were established from discussions held with SED Systems Inc. The costs are based on current expenditures for the existing SED building and from determining a fair market value based on a cost per square metre for other similar Saskatoon offices.

MSS and UDP Control Centre - Details of Operating Cost Estimate

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 previously described. Salary rates and payroll burdens are the same as those for Radarsat program.

Services

Security demands are similar to the Radarsat program since area surveillance can be provided by one-half times security staff over a sixteen hour period. Janitorial services will be provided throughout contracts currently in place with SED Systems Inc.

7.4.2.2 (Cont'd)

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 7.4.2.2.

Rent and Utilities

Operating costs for rent and utilities were established from discussions with SED Systems Inc., and are based on a cost per square metre.