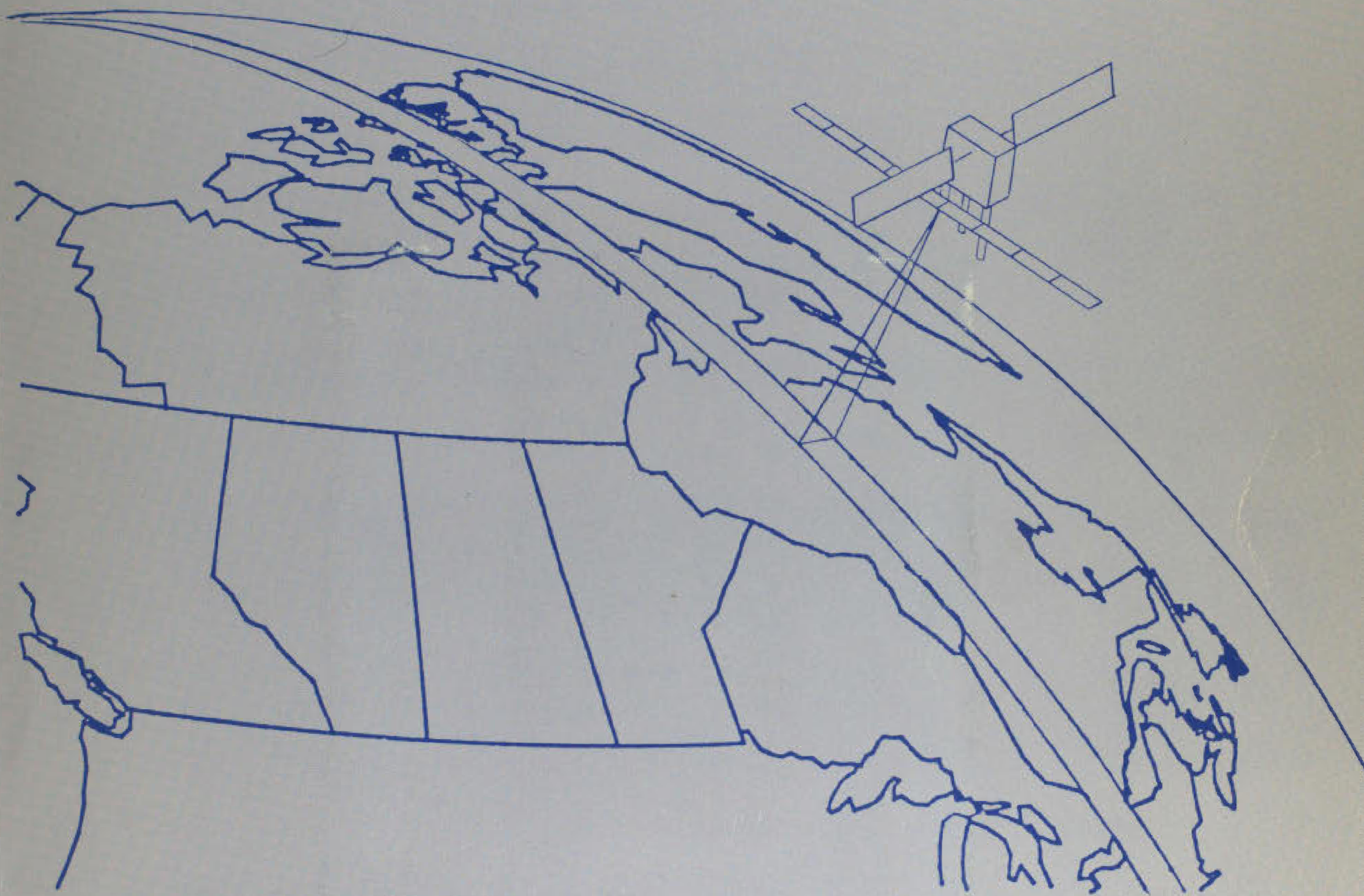
SURSAT

A CONCEPTUAL DESIGN STUDY

EXECUTIVE SUMMARY



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CANADIAN ASTRONAUTICS LIMITED

Suite 201, 1024 Morrison Drive, Ottawa, Ontario K2H 8K7

(613) 820-8280

A CONCEPTUAL DESIGN STUDY FOR FUTURE OPERATIONAL REMOTE SENSING SATELLITE SYSTEMS

EXECUTIVE SUMMARY

Prepared For: Dr. Keith Raney, Scientific Authority
Canada Centre for Remote Sensing
Energy, Mines and Resources

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Project Manager: Mr. J.D. Taylor
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TABLE OF CONTENTS

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1.0 INTRODUCTION

This Executive Summary describes a preliminary conceptual design for a SURSAT remote sensing satellite mission arising from work done by Canadian Astronautics Limited under DSS Contract 1 SQ78-00116 for the SURSAT Project Office, Canada Centre for Remote Sensing, Department of Energy Mines and Resources.

The objectives of the study were to investigate major system design trade-offs for a satellite mission which would satisfy future Canadian requirements for the application of remote sensing satellite technology and then to develop an initial conceptual system design for planning and evaluation purposes. This document describes the resulting system design while the Main Report presents detailed engineering analysis and design data.

The major thrust of the contemplated satellite mission is in the direction of establishing a prototype-operational system of frequent surveillance over a limited geographic area using the inherent all-weather, day/night capability of synthetic aperture radar. Due to the characteristics of near polar orbits for remote sensing satellites and the growing resource exploitation activity in Canada's Arctic region, this area is the logical choice in which to establish an initial quasi-operational system capability which will provide recurring sensor coverage every 2-3 days to support operational transportation, navigation and environmental monitoring needs.

However, the projected satellite mission is also intended to provide continued support to the broad community of users that have developed in the last eight years as a result of the availability of data from programs such as the U.S. LANDSAT. In addition, the SURSAT mission is required to provide world wide coverage so that possibilities for international cooperation and participation are available.

The design of the SURSAT satellite system was further constrained to utilize existing facilities and technology so that program costs and risks would be minimized to the extent possible while still meeting system performance requirements.

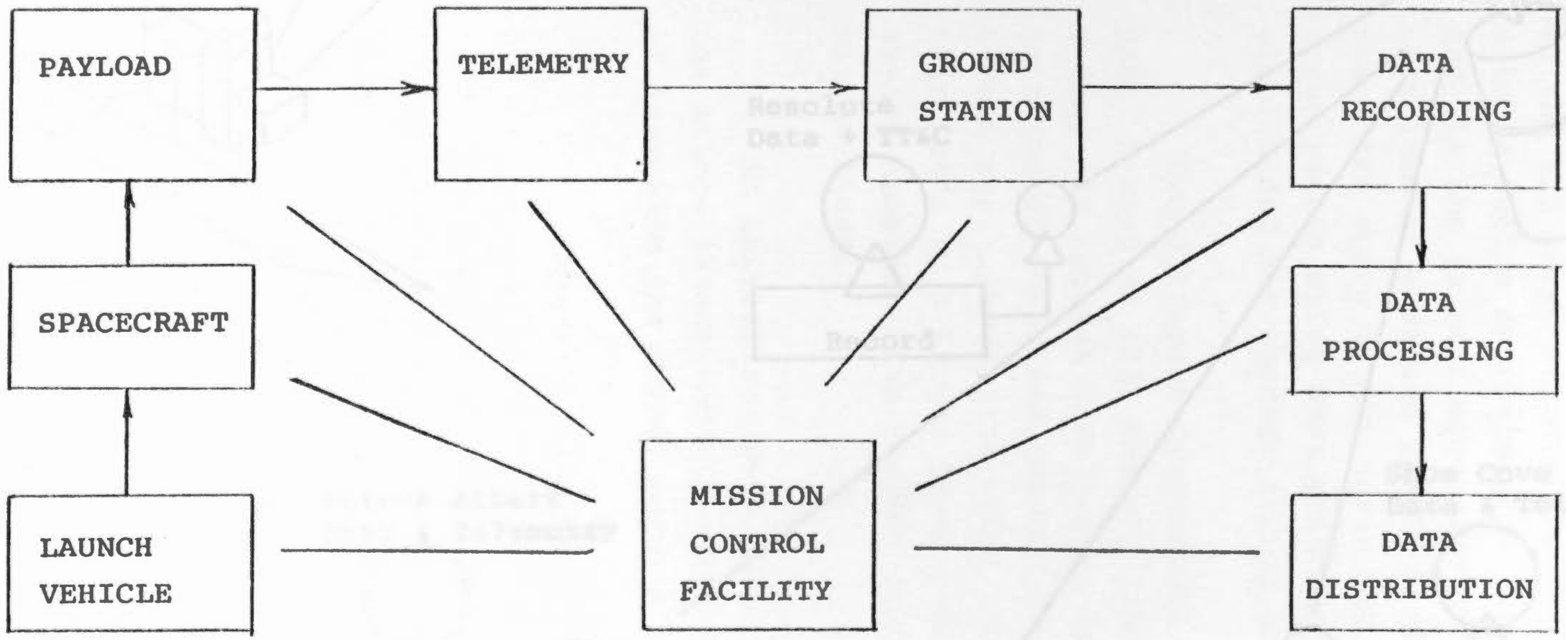
2.0 SYSTEM DESIGN

The SURSAT Remote Sensing Satellite System consists of nine basic elements as illustrated in Figure 2-1. The launch vehicle, spacecraft, payload and telemetry comprise the space segment which generates the raw data. The ground stations, data recording equipment, data processing facilities and data distribution systems are the elements which form the link between the space sensors and the end users of the data. The Mission Control Facility interfaces with most of these elements to control the total system and ensure a smooth, reliable operation. The particular configuration of elements selected for the SURSAT mission is illustrated in Figure 2-2.

2.1 Spacecraft

The U.S. Space Shuttle, launched from the Western Test Range at Vandenberg Air Force Base injects the spacecraft into a low altitude orbit with sun synchronous inclination of about 98 degrees. After deployment from the Shuttle, the spacecraft is maneuvered under ground control to a higher orbit with an altitude of about 678 km above the equator. This sun synchronous orbit has an orientation such that south going orbit passes occur at 10:30 AM local time at 50° N latitude.

The spacecraft consists of a bus vehicle which provides basic subsystems for structure, power, attitude control, reaction control, thermal control and housekeeping telemetry and command services and a mission payload which includes primary sensors, secondary communication transponders and a data telemetry subsystem. The primary sensors are a Synthetic Aperture Radar (SAR) and a Thematic Mapper (TM) optical instrument. The three secondary communication transponders are for Search and Rescue, Data Collection and Cooperative Target Identification and Location.



FUNCTIONAL SYSTEM ELEMENTS

FIGURE 2-1

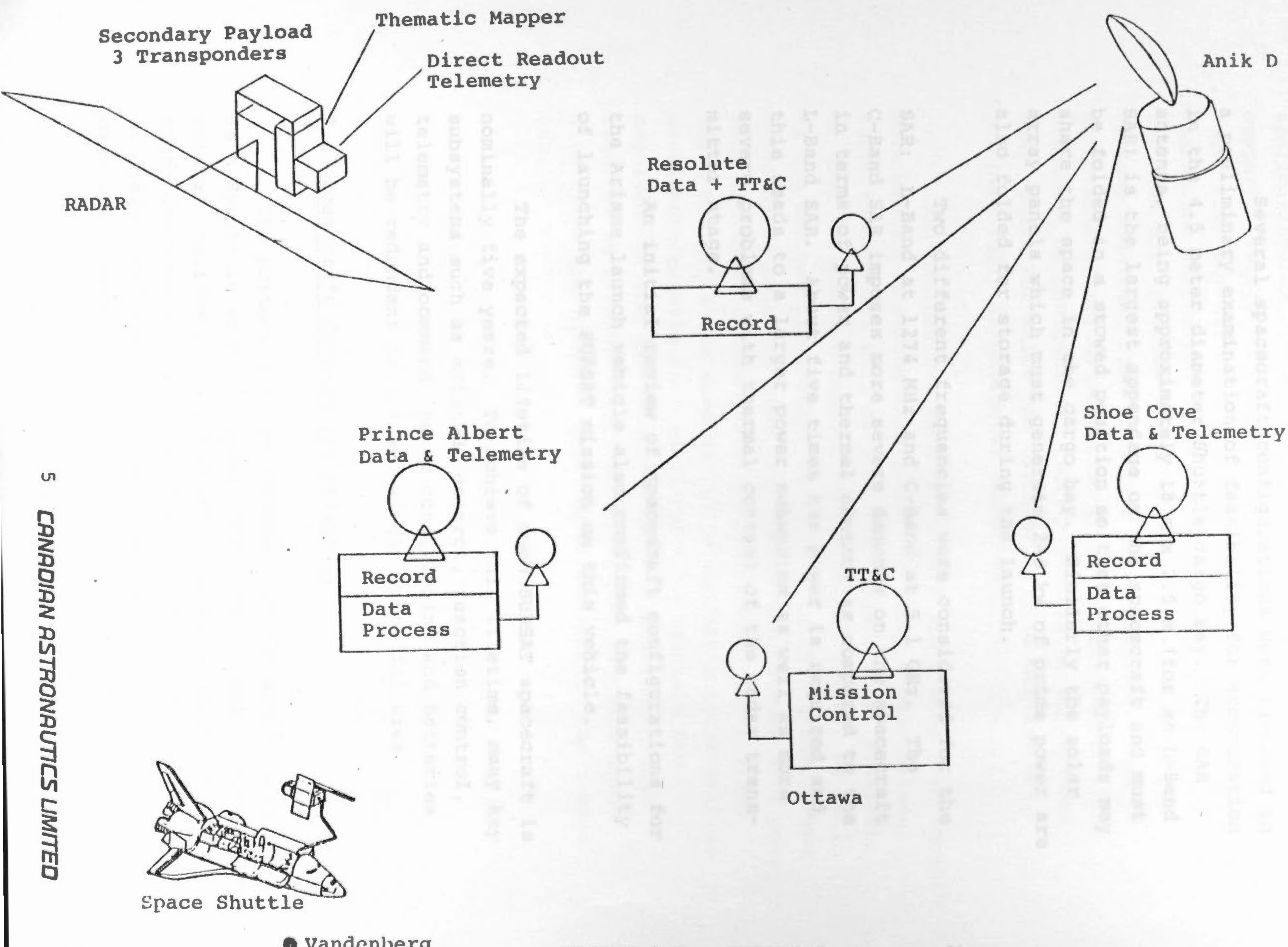


FIGURE 2-2 SURSAT System Configuration

Several spacecraft configurations were reviewed in a preliminary examination of feasibility for accomodation in the 4.5 meter diameter Shuttle cargo bay. The SAR antenna, being approximately 18 m x 2.5 m (for an L-Band SAR) is the largest appendage on the spacecraft and must be folded in a stowed position so that other payloads may share the space in the cargo bay. Similarly the solar array panels which must generate 2-3 kw of prime power are also folded for storage during the launch.

Two different frequencies were considered for the SAR: L-Band at 1274 MHz and C-Band at 5.1 GHz. The C-Band SAR imposes more severe demands on the spacecraft in terms of power and thermal control as compared to the L-Band SAR. About five times the power is required and this leads to a larger power subsystem as well as more severe problems with thermal control of the radar transmitter stage.

An initial review of spacecraft configurations for the Ariane launch vehicle also confirmed the feasibility of launching the SURSAT mission on this vehicle.

The expected lifetime of each SURSAT spacecraft is nominally five years. To achieve this lifetime, many key subsystems such as attitude control, reaction control, telemetry and command, power conditioning and batteries will be redundant to prevent single point failures.

2.2 Spacecraft Payload and Telemetry

The primary payload selected for the SURSAT mission is a Synthetic Aperture Radar (SAR) and a Thematic Mapper (TM) optical instrument. The SAR provides all weather, day and night coverage and responds in large measure to the types of operational users requiring near real time surveillance data and coverage every 2-3 days. Typical of these applications are ice reconnaissance for ship navigation support, iceberg monitoring for shipping and oil drilling rigs, ship surveillance, seismic exploration support, search and rescue and disaster assessment. However the SAR will also provide useful data for many other applications requiring data on a less urgent basis. These applications include cartography, geophysical exploration, placement of navigational aids, hydrological surveys and many others for which the applicability of SAR has not yet been fully investigated and proven.

SAR designs for both the L-Band and C-Band frequencies were developed during this study. A final choice between these frequencies will have to take into account research on user information content in the output imagery as well as the engineering factors considered in this study. From a technical point of view, the C-Band SAR antenna will pose many difficult challenges since its length, for a given swath width, is the same as the L-Band SAR but the smaller wavelength results in a requirement to maintain the magnitude of the flatness tolerance to one-fourth that required at L-Band. The C-Band SAR also requires about five times the transmit power as compared with the L-Band SAR.

Table 2-1 lists the basic SAR parameters selected for the SAR designs. Due to the anticipated difficulty in development of a long C-Band SAR antenna, a shorter length of 14 meters as compared with 18 meters for the L-Band SAR was selected with a concurrent reduction in swath width from 200 km to 150 km. This results in a requirement for three operating C-Band spacecraft in orbit as opposed to two for the L-Band SAR and has major financial implications in the long term. Hence it is crucial to carefully evaluate just how far the technology can be pushed in the direction of longer antenna lengths befor a final design is adopted.

		L-Band	C-Band
Swath Width	km	200	150
Far Side Incidence Angle	deg	45	43
Near Side Incidence Angle	deg	33	33.9
Antenna Length	m	18	14
Antenna Width	m	2.74	.99
Bandwidth	MHz	9.19	8.95
Pulse Width	μs	35.4	27.9
Wavelength	m	0.2351	0.05656
Cross Track Resolution (Near Side)	m	30	30
Along Track Resolution (3 looks)	m	24	18
System Noise Temperature	deg. K	460	649
Noise Equivalent Scattering Coefficient	db	-32	-31.2
Receiver Losses	db	3.3	3.4
Processing Losses	db	2.0	2.0
Average Power	watts	166	1003
Peak Power	kw	5	22
PRF Nominal	Hz	944	1315

SAR Radar Parameters

Table 2-1

The radar geometry was deliberately chosen to produce incidence angles (with respect to vertical) in the range of 30-45 degrees. This is a result of recent research by CCRS which has shown that discrimination of icebergs and ships against sea clutter is difficult in the 20-30 degree incidence angle range which is typical of SEASAT A and which is preferred from an engineering point of view because it minimizes the required antenna length for a given swath width.

The radar design requires the use of a shaped antenna beam in the elevation (or cross track) direction to suppress range ambiguities. In addition, the actual PRF is stepped several times per orbit to maintain synchronization of the return echos with the transmitted pulses. A time guard band of about 15%, around the desired echo is maintained to account for orbit eccentricity, earth oblateness and terrain height variations.

The Thematic Mapper provides an advanced optical/IR sensing capability which supplements the SAR data and extends the usefulness of the mission to a very broad spectrum of users which have developed primarily as a result of the U.S. LANDSAT program. The SURSAT system also has the capability for supplying optical data to users on a quick reaction basis. However, this capability is limited by cloud cover and lighting conditions.

Two other optical scanners the LANDSAT MSS and the SPOT HRV were considered in this study. The Thematic Mapper, however, provides extremely advanced performance and will likely become a relatively standard instrument for many users as a result of the LANDSAT D program which will shortly be going into flight operations. The Thematic Mapper is the most demanding of the three instruments with respect to spacecraft resources and cost. Table 2-2 provides comparative data for the three instruments that were considered.

The payload for the SURSAT mission also includes three RF transponders carried as secondary payloads. They are used for Search and Rescue, Data Collection and Co-operative Target Identification and Location. The selected orbit altitude of 678 km is less than the 1100-1200 km which is optimum for system coverage by these secondary payloads but performance is still adequate.

The spacecraft transmits sensor data directly to the ground stations using an X-Band link. This permits high bandwidth data to be accomodated (approximately 180 Mbps for simultaneous SAR and TM) and the link is

BAND #	MSS - LANDSAT D			THEMATIC MAPPER - LANDSAT D			HRV - SPOT		
	BAND (MICROMETERS)	RESOLUTION (METERS)	SENSIT-IVITY NEΔP	BAND (MICROMETERS)	RESOLUTION (METERS)	SENSIT-IVITY NEΔP	BAND (MICROMETERS)	RESOLUTION (METERS)	SENSIT-IVITY NEΔP
1				0.45-0.52	30	0.8%			
2	0.5-0.6	82	0.57%	0.52-0.60	30	0.5%	0.50-0.59	20	0.5%
3	0.6-0.7	82	0.57	0.63-0.69	30	0.5%	0.61-0.71	20	0.5%
4	0.7-0.8	82	0.65%						
5				0.76-0.96	30	0.5%	0.80-0.91	20	0.5%
6	0.8-1.1	82	0.70%						
7				1.55-1.75	30	1.0%			
8				(2.08-2.35)*	(30)	(2.4%)			
9	10.5-12.5	246	1.4K(NEΔT)	10.4-12.5	120	0.5K(NEΔT)			
							0.5-0.9*	10	

*Panchromatic Mode

SPECTRAL BANDS, RESOLUTION AND RADIOMETRIC SENSITIVITY

TABLE 2-2

compatible with the LANDSAT D system. Spacecraft housekeeping telemetry and command uses the standard unified S-Band (USB) frequency. The secondary payload transponders have uplinks in the VHF and UHF bands. The Data Collection and Cooperative Target Identification and Location Systems transmit signals to the ground via the X-Band downlink while the Search and Rescue transponder uses an L-Band downlink to make it compatible with the SARSAT system.

2.3 Ground Stations and Recording

The SURSAT system makes use of the two existing remote sensing satellite ground stations at Prince Albert and Shoe Cove. In addition, to provide full Canadian coverage with the relatively low satellite altitude of 678 km, a third station is required at Resolute in the Arctic Islands. The coverage pattern for this ground station configuration is shown in Figure 2-3.

These three stations are equipped with 10 m diameter, fully tracking receiving antennas. Since Prince Albert and Shoe Cove stations will be configured to operate with the LANDSAT D X-Band data telemetry system, relatively minor modifications are required to handle the SURSAT X-Band downlink. Figure 2-4 is a block diagram of the ground station configuration.

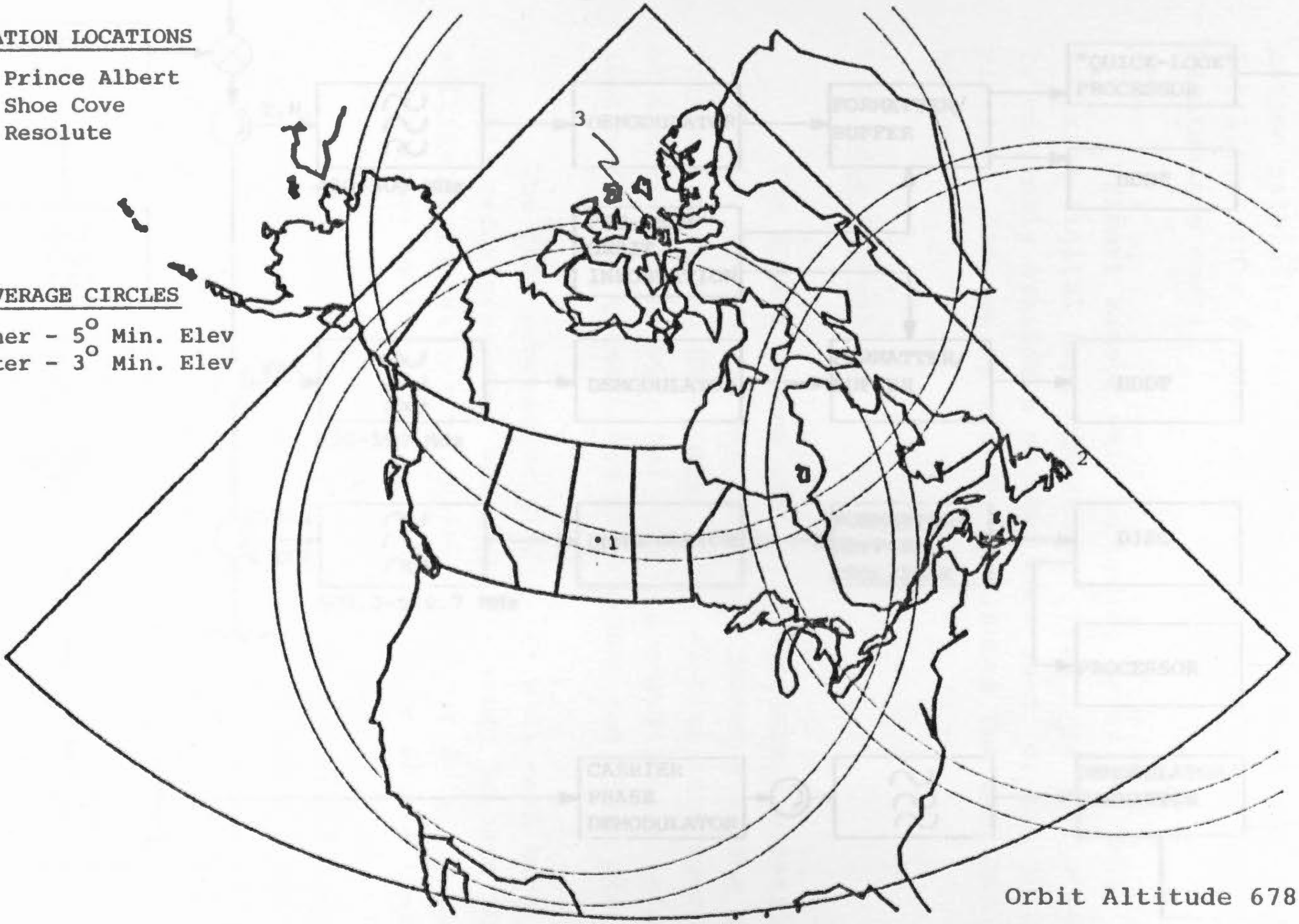
The Resolute Station is a completely new installation. Due to the severe environment it will probably be enclosed in a radome. The station is designed to be operated in a semi-manned configuration. Remote control communication links will permit full operation of the station for short periods when it is unmanned. In this manner operating costs are minimized.

STATION LOCATIONS

1) Prince Albert
2) Shoe Cove
3) Resolute

COVERAGE CIRCLES

Inner - 5° Min. Elev
Outer - 3° Min. Elev

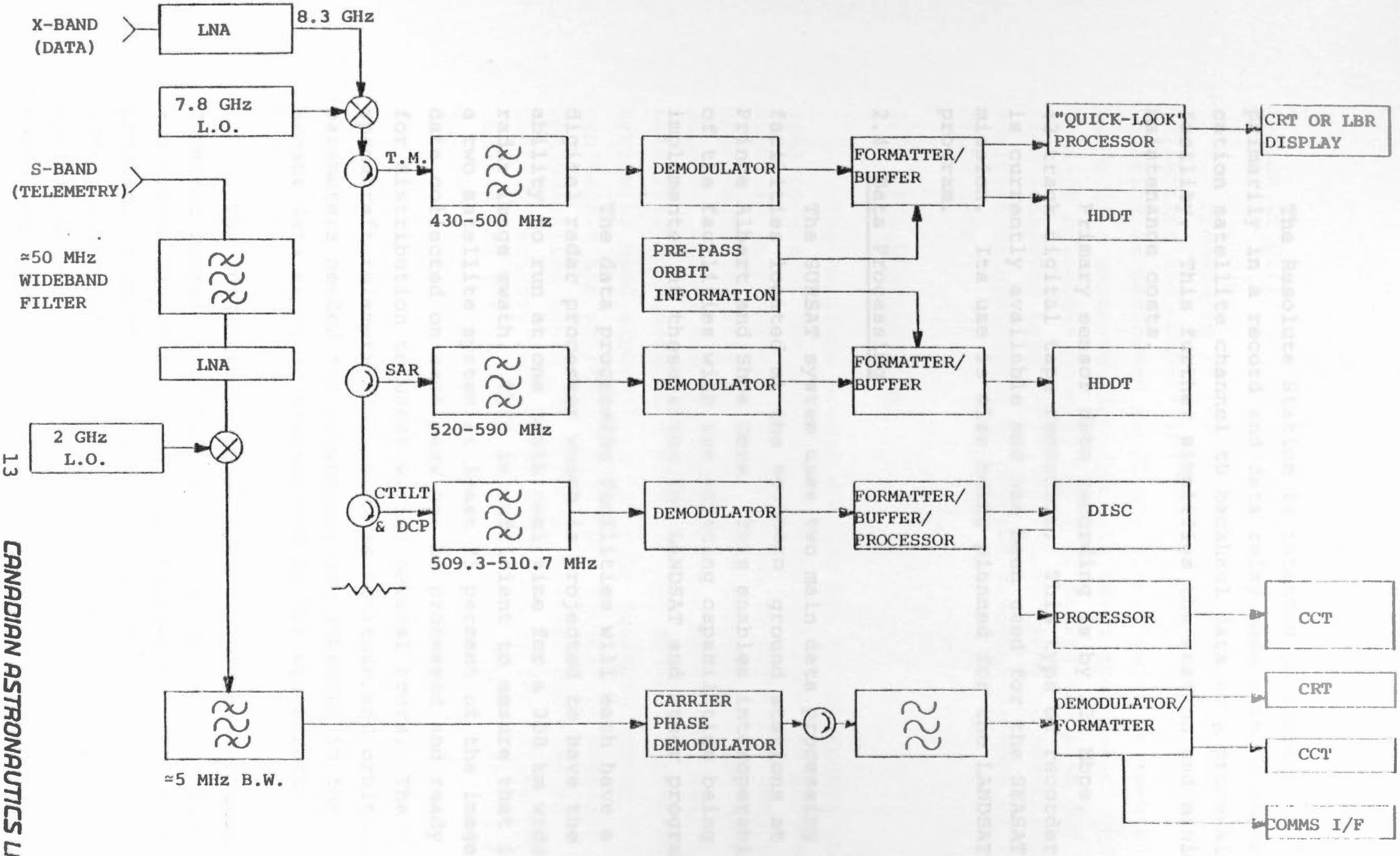


Orbit Altitude 678 km

SURSAT GROUND STATION COVERAGE

(EXISTING STATIONS PLUS RESOLUTE)

FIGURE 2-3



TELEMETRY & DATA RECEPTION BLOCK DIAGRAM

FIGURE 2-4

The Resolute Station is intended to operate primarily in a record and data relay mode using a communication satellite channel to backhaul data to a processing facility. This further simplifies the station and minimizes maintenance costs.

Primary sensor data recording is by 120 Mbps, 42 track digital tape recorders. This type of recorder is currently available and has been used for the SEASAT A mission. Its use is also being planned for the LANDSAT D program.

2.4 Data Processing

The SURSAT system uses two main data processing facilities located at the southern ground stations at Prince Albert and Shoe Cove. This enables interoperability of the facilities with the existing capabilities being implemented at these sites for LANDSAT and other programs.

The data processing facilities will each have a digital radar processor which is projected to have the ability to run at one tenth real time for a 200 km wide radar image swath. This is sufficient to ensure that in a two satellite system at least 25 percent of the image data collected on each pass can be processed and ready for distribution to users within several hours. The spacecraft telemetry data such as attitude and orbit parameters needed for processing are imbedded in the sensor data as it is transmitted by the spacecraft.

The SURSAT system will make use of the existing Thematic Mapper processing facilities to be installed at the Prince Albert and Shoe Cove stations for the LANDSAT D program. A quick look image production system is also incorporated in these stations for rapid distribution of optical data. The quick look capability is also quite useful for station checkout and test purposes and for this reason it will also be installed at the Resolute Station.

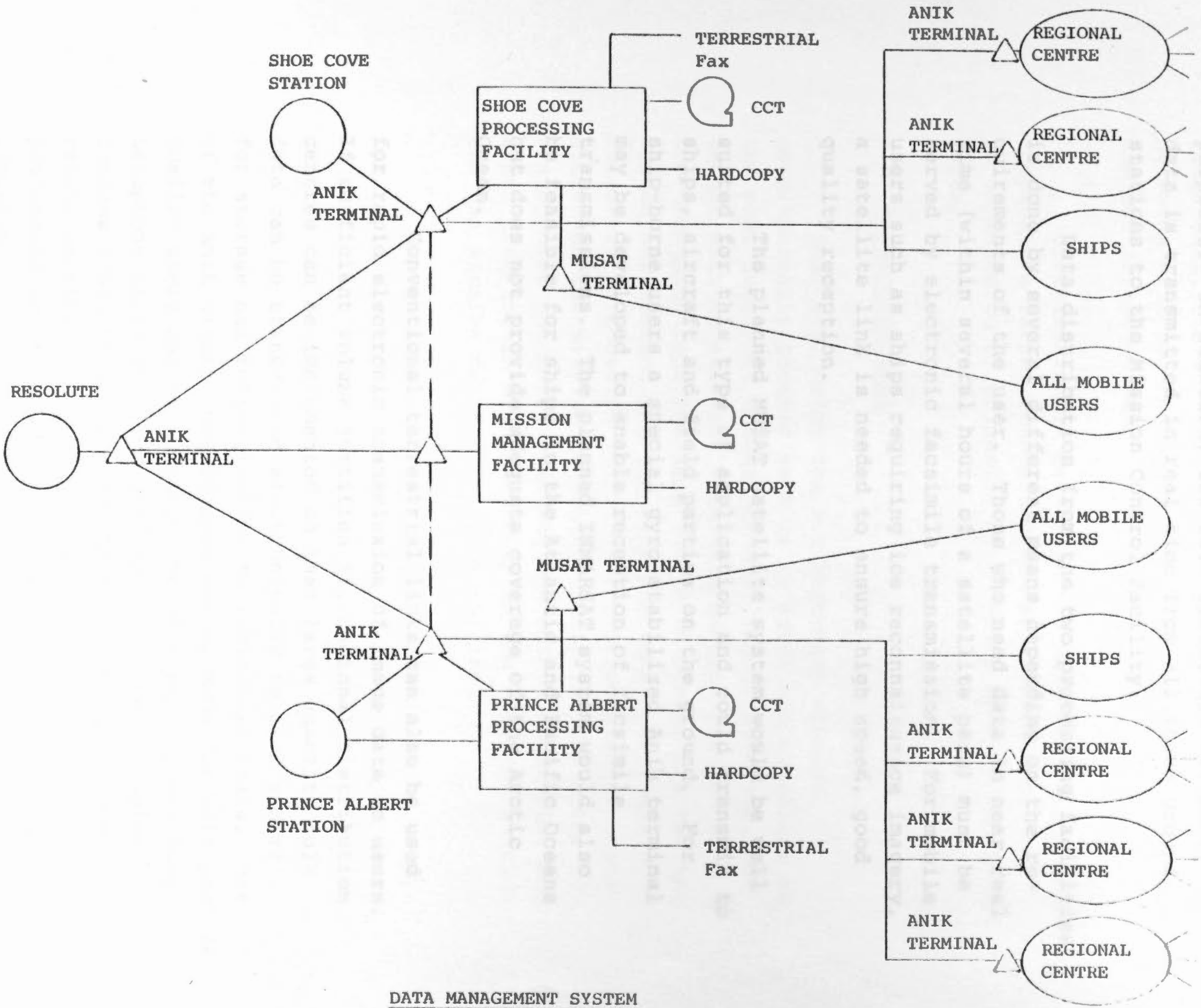
Processing of the secondary payload data for Data Collection and Cooperative Target Identification and Location is performed at Prince Albert and Shoe Cove by means of a separate mini-computer based processor. This data is collected on computer disc during the pass and then separated into individual files based on identification. Position determination by doppler location is done on the CTILT data.

2.5 Data Distribution

The Resolute ground station has to retransmit its data to one of the southern ground stations for processing since it is considered uneconomical to install a complex processing facility so remote from maintenance and backup support. Since the transmission must be in near real time, satellite communications link via the Telesat Canada Anik D system is used since it is the only feasible system that can handle the extremely high data rates. In addition, communication links are required between the Mission Control Facility and the ground stations for telemetry, command and system control functions. Figure 2-5 illustrates the SURSAT Data Management System.

A full period transponder channel is leased on the Anik D satellite system and is configured for multiple functions. Four, 10 m diameter fixed antenna Anik terminals are used to tie the three ground stations and the Mission Control Facility together.

The Anik transponder channel has a maximum data rate of approximately 50 Mbps and can transfer at about 25-30% of the real time rate. Besides backhauling data from Resolute to one of the two southern stations, it is also available to transfer raw data or processed data



DATA MANAGEMENT SYSTEM

FIGURE 2-5

between the ground stations for backup or distribution purposes. In addition, low rate spacecraft telemetry data is transmitted in real time from all three ground stations to the Mission Control Facility.

Data distribution from the two processing facilities is done by several different means depending on the requirements of the user. Those who need data in near real time (within several hours of a satellite pass) must be served by electronic facsimile transmission. For mobile users such as ships requiring ice reconnaissance imagery, a satellite link is needed to ensure high speed, good quality reception.

The planned MUSAT satellite system would be well suited for this type of application and could transmit to ships, aircraft and field parties on the ground. For ship-borne users a special gyro-stabilized Anik terminal may be developed to enable reception of facsimile transmissions. The planned INMARSAT system would also be feasible for ships in the Atlantic and Pacific Oceans but does not provide adequate coverage of the Arctic Ocean.

Conventional terrestrial links can also be used for rapid electronic transmission of image data to users. If sufficient volume justifies it, regional distribution centres can be implemented so that large quantity bulk data can be transmitted electronically to each centre for storage and redistribution to individual users. Use of the Anik transponder channel may be made for this purpose. Smaller users can then obtain the data rapidly via local telephone lines or by courier service. These regional centres could be implemented by the existing provincial remote sensing centres and could provide applications processing services as well as the basic distribution function.

For other users not requiring urgent delivery of image data, the existing courier or air mail distribution networks will be adequate for delivery of both hard copy and CCT formatted data.

Distribution of data from the Data Collection and Cooperative Target Identification and Location systems is expected to be primarily by a system of computer to Telex.

2.6 Mission Control

Resolute, being the northern-most station, is geographically located such as to track the satellite on the most number of orbits per day. Hence Resolute, together with an existing satellite control station at the Communications Research Centre in Ottawa are the two spacecraft command and tracking stations. Spacecraft telemetry is received at all four stations and is transmitted to the Mission Control Facility via the Anik. transponder channel. However, spacecraft commanding and orbit tracking is performed only by the Resolute station and the Mission Control Facility station.

The Mission Control Facility consists of two major elements. A Satellite Control Centre monitors spacecraft operation and actively commands the space segment. A Mission Management Facility oversees the operation of the entire data acquisition, processing and distribution system.

The Mission Control Facility is located in Ottawa where existing satellite control facilities at the Communications Research Centre may be used and where there is a large pool of space program engineering talent to support the mission. The Mission Management Facility is best colocated with the Satellite Control Centre to permit common support services and staffing redundancy.

3.0 SYSTEM PERFORMANCE

The SURSAT mission provides two primary sensor outputs. The SAR output is a high resolution (better than 30 m) image with a swath width of approximately 200 km in the case of an L-Band SAR and 150 km for the C-Band SAR. The imaged SAR swath lies to the right of the sub-satellite track at a distance of about 390 km. The Thematic Mapper provides multi-spectral images in 6 bands covering the optical to thermal IR spectrum. The 185 km swath width is centered on the sub-satellite track and produces a resolution of 30 m in the optical and near IR bands.

The SURSAT orbit is selected to provide optimum coverage frequency in the northern coverage zone defined as the area above 60 deg. N latitude. By selecting the appropriate orbit altitude, a coverage cycle can be obtained which provides full coverage in the total system zone (arbitrarily defined as the area north of 30 deg. latitude) while also resulting in an approximation to a more frequent cycle in the northern coverage zone above 60 deg. latitude.

3.1 Radar Coverage

At an altitude of 678 km above the equator, each SURSAT satellite using a 200 km swath L-Band radar provides a 14 day main coverage cycle with either the north or the south going satellite passes. With two properly phased satellites, a 3 day northern coverage subcycle is approximated again using either the north going or south going satellite passes. Since the radar can operate day or night, both north and south going passes can be used for coverage and therefore the "mean coverage interval" is approximately 1.5 days at 60 deg. latitude and 3 days at 30 deg. latitude.

The C-Band SAR requires a slightly different orbit with an altitude of 676.7 km and three satellites are required to give roughly equivalent performance to the L-Band approach. Table 3-1 indicates the mean coverage intervals of various SURSAT configurations.

Coverage to the equator is provided by the two satellite L-Band configuration. However, the particular orbit altitude selected for the C-Band system only provides full coverage to 20 deg. latitude. Full world coverage can be obtained by selecting a slightly longer main cycle coverage pattern for the C-Band system.

RADAR	# SATS	MEAN COVERAGE INTERVAL (days) AT 30° N	AT 60° N	LOWER LIMIT OF 100% COVERAGE
L-BAND	1	5.9	3.4	equator
	2	2.9	1.7	equator
C-BAND	1	7.8	4.5	20° N
	2	3.9	2.3	"
	3	2.6	1.5	"

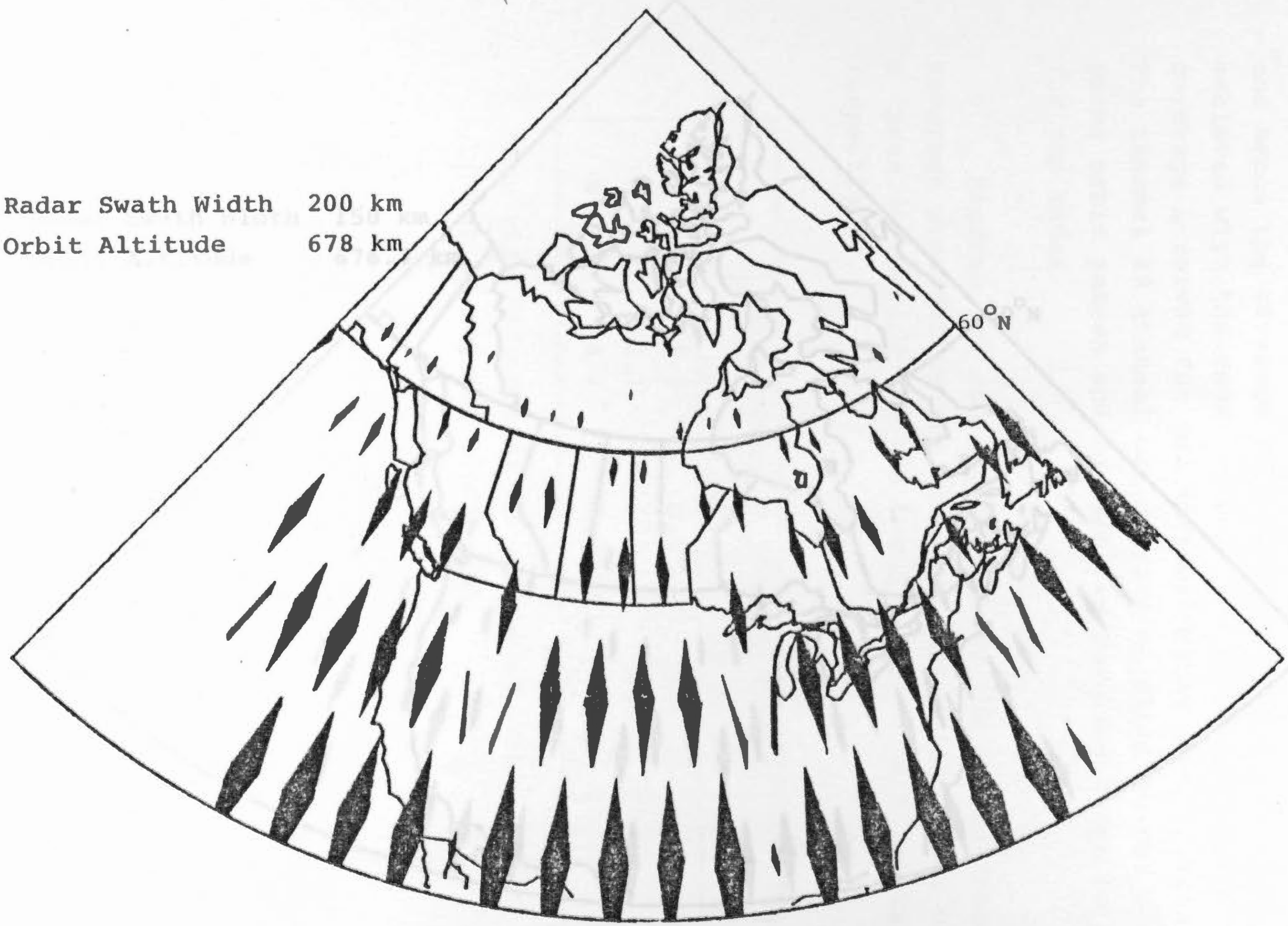
SAR MEAN COVERAGE INTERVALS

TABLE 3-1

Figures 3-1 and 3-2 illustrate the SURSAT system coverage in a 3 day period using both north and south going passes. Since the north and south going passes cross at a small angle, not all points in the northern coverage area receive coverage at constant intervals of time. For the L-Band system, complete coverage in the northern zone is provided twice every 3.4 days and there are some very small areas which occasionally don't receive coverage for up to three days. These patches of long coverage intervals move around depending on the subcycle and so are not expected to be a significant operational problem.

Radar Swath Width 200 km

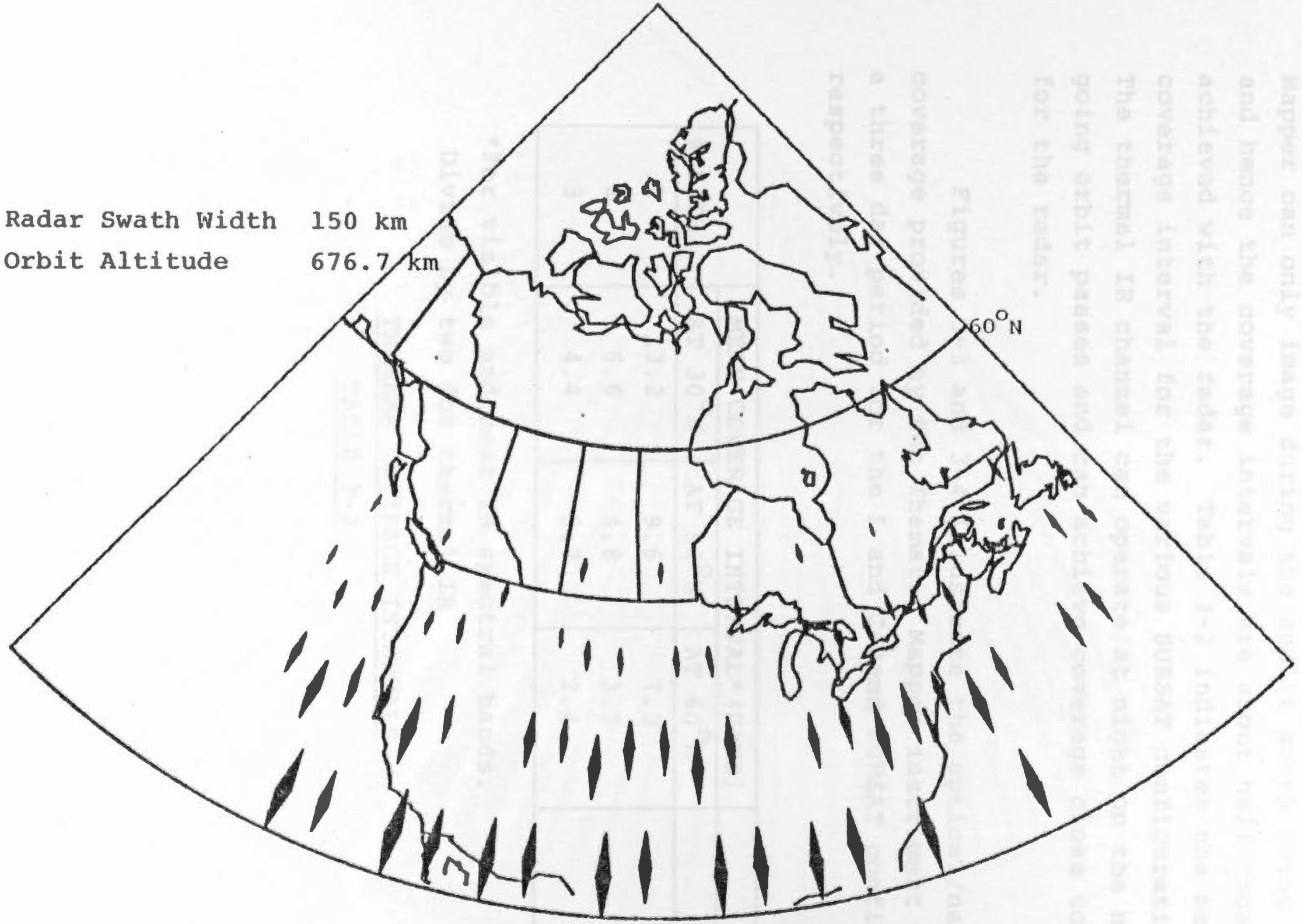
Orbit Altitude 678 km



THREE DAY COVERAGE PATTERN

L-BAND SAR, 2 SATELLITES

FIGURE 3-1



THREE DAY COVERAGE PATTERN

C-BAND SAR, 3 SATELLITES

FIGURE 3-2

3.2 Thematic Mapper Coverage

The optical and near IR channels of the Thematic Mapper can only image during the sunlit south going orbit passes and hence the coverage intervals are about half those achieved with the radar. Table 3-2 indicates the mean coverage interval for the various SURSAT configurations. The thermal IR channel can operate at night on the north going orbit passes and can achieve coverage close to that for the radar.

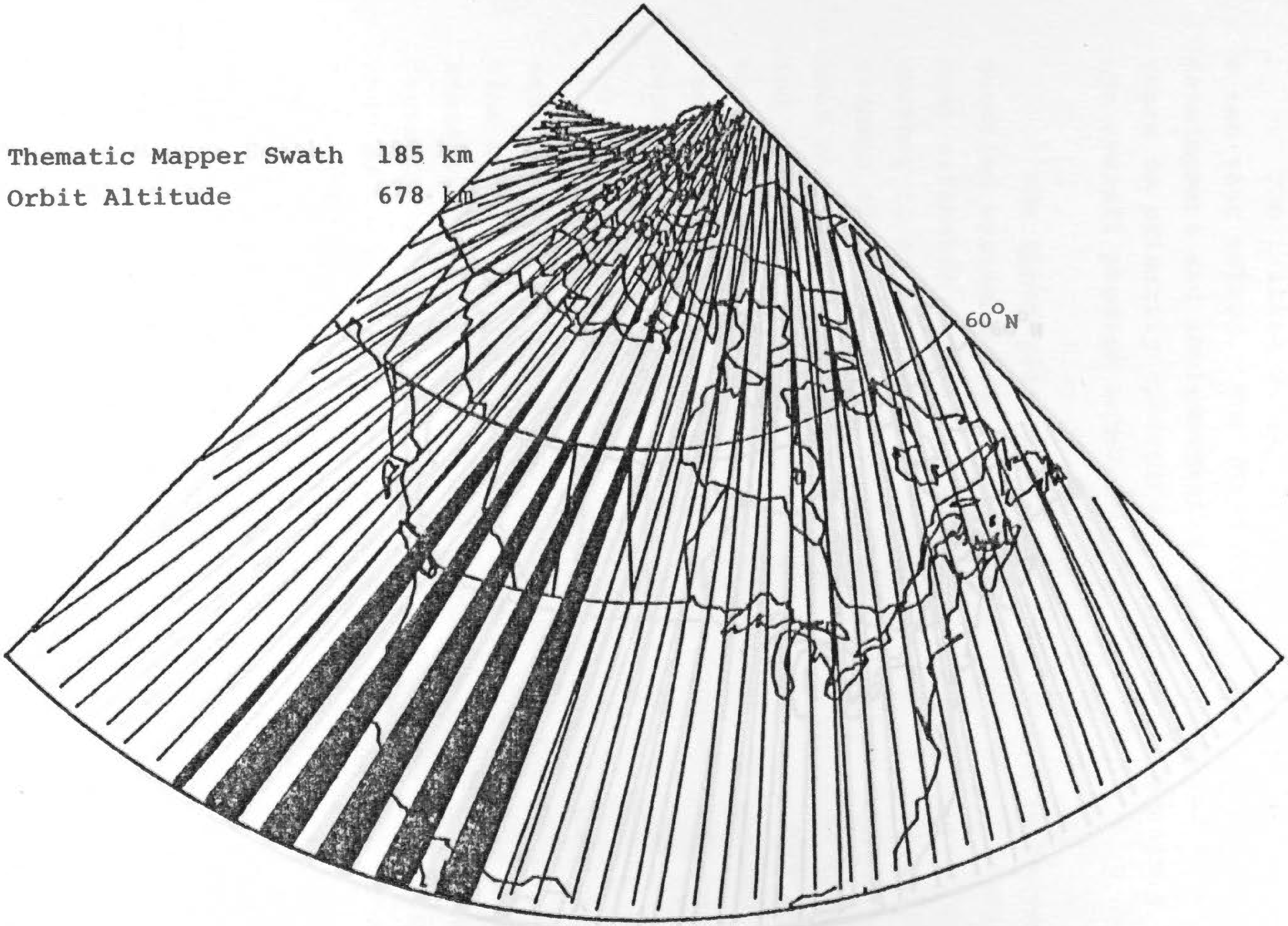
Figures 3-3 and 3-4 illustrate the optical/near IR coverage provided by the Thematic Mapper instrument during a three day period for the L and C-Band SURSAT configurations respectively.

# SATS	MEAN COVERAGE INTERVAL* (DAYS)			
	AT 30°N	AT 50°N	AT 60°N	
1	13.2	9.6	7.3	
2	6.6	4.8	3.7	
3	4.4	3.2	2.4	

*For visible and near IR spectral bands.
Divide by two for thermal IR

TM MEAN COVERAGE INTERVALS

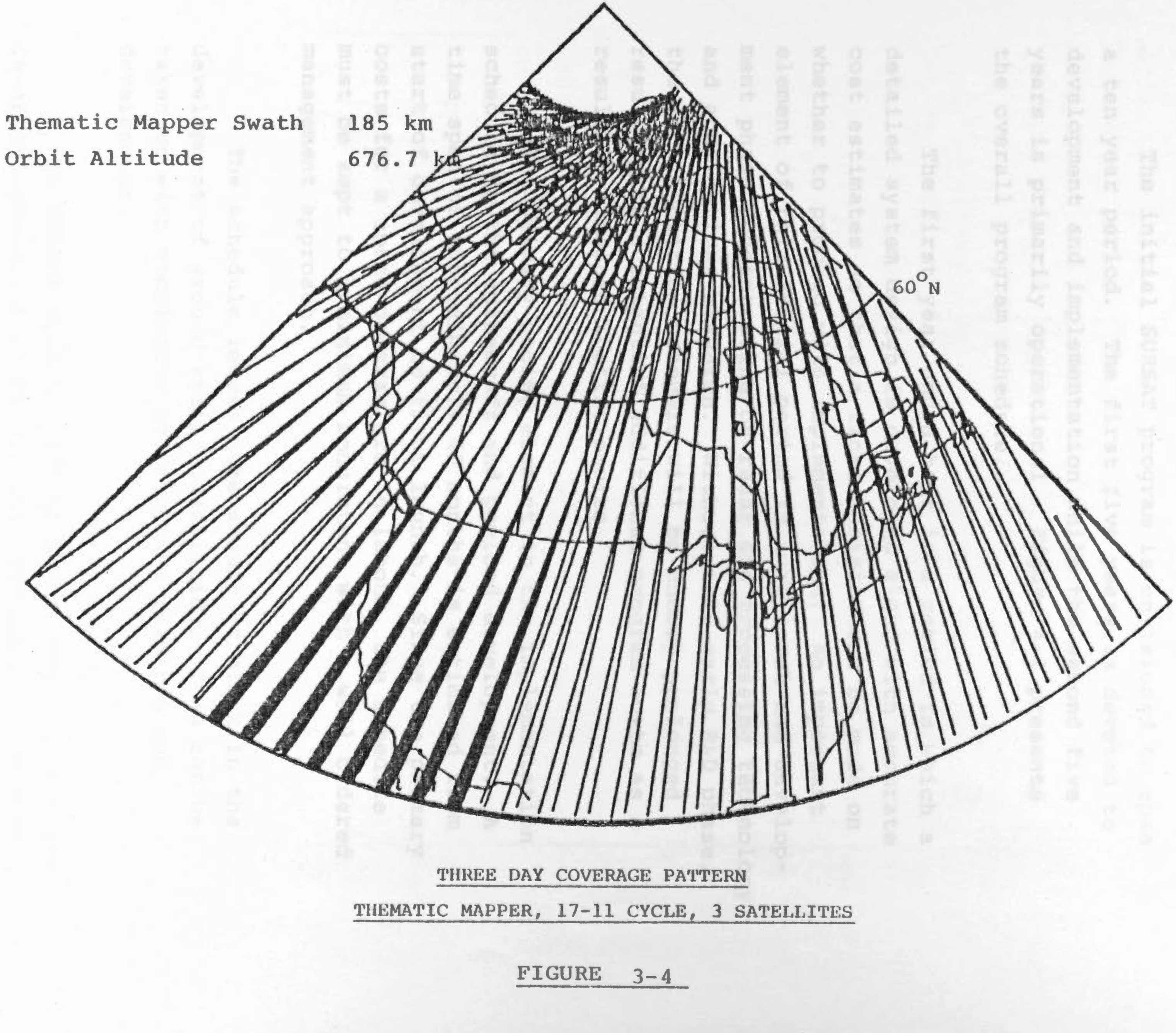
TABLE 3-2



THREE DAY COVERAGE PATTERN

THEMATIC MAPPER, 14-9 CYCLE, 2 SATELLITES

FIGURE 3-3



THREE DAY COVERAGE PATTERN

THEMATIC MAPPER, 17-11 CYCLE, 3 SATELLITES

FIGURE 3-4

4.0 PROGRAM PLAN AND COST ESTIMATES

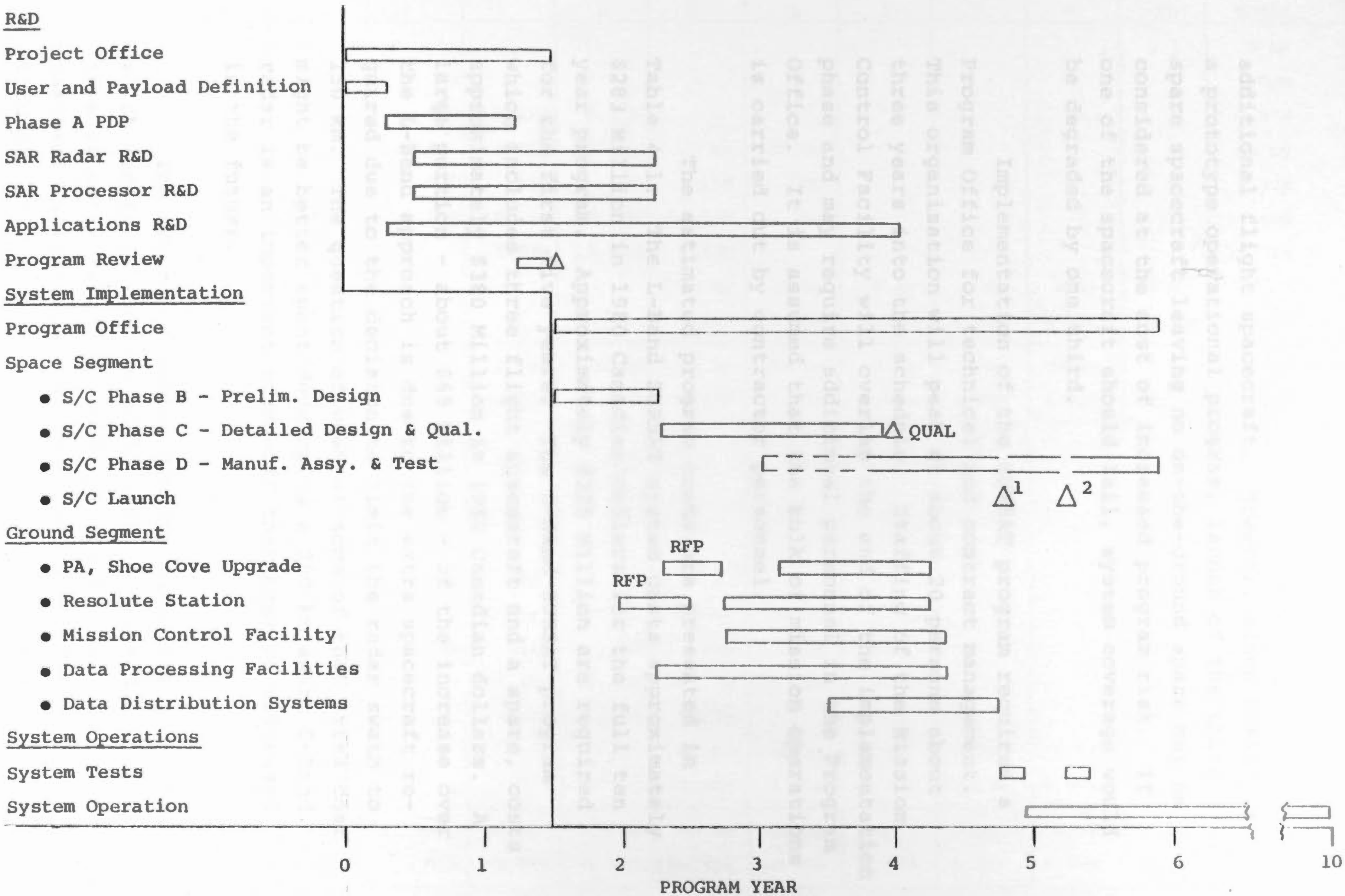
The initial SURSAT program is envisioned to span a ten year period. The first five years is devoted to development and implementation while the second five years is primarily operational. Figure 4-1 presents the overall program schedule.

The first year and a half is a period in which a detailed system design is developed along with accurate cost estimates so that a final decision can be made on whether to proceed with implementation. An important element of this initial period is a research and development phase concentrating on radar and processing technology and applications research. Without this early R&D phase, the implementation schedule will be unduly prolonged resulting in substantial additional program costs as a result of schedule inefficiencies.

The primary pacing element in the implementation schedule is the spacecraft and payload development. A time span of approximately 40 months is estimated from start of development to first launch. Since the primary costs for a space program are in labour, the schedule must be kept to a minimum consistent with a well ordered management approach.

The schedule leaves some amount of slack in the development of ground station facilities. This can be taken up with completion of processor research and development.

The SURSAT system using an L-Band SAR requires two in-orbit spacecraft which are launched about six months apart. A third on-the-ground spare spacecraft is built by refurbishing the qualification model spacecraft. The C-Band radar approach requires three in-orbit spacecraft and therefore would normally require production of an



OVERALL PROGRAM SCHEDULE

FIGURE 4-1

additional flight spacecraft. However, since SURSAT is a prototype operational program, launch of the third spare spacecraft leaving no on-the-ground spare may be considered at the cost of increased program risk. If one of the spacecraft should fail, system coverage would be degraded by one third.

Implementation of the SURSAT program requires a Program Office for technical and contract management. This organization will peak at about 20 persons about three years into the schedule. Staffing of the Mission Control Facility will overlap the end of the implementation phase and may require additional personnel in the Program Office. It is assumed that the bulk of mission operations is carried out by contractor personnel.

The estimated program costs are presented in Table 4-1. The L-Band SURSAT system costs approximately $283 Million in 1980 Canadian dollars for the full ten year program. Approximately $225 Million are required for the first five years. The C-Band SURSAT program which includes three flight spacecraft and a spare, costs approximately $380 Million in 1980 Canadian dollars. A large portion - about $65 Million - of the increase over the L-Band approach is due to the extra spacecraft required due to the decision to limit the radar swath to 150 km. The question of whether some of that extra cost might be better spent developing a 200 km swath C-Band radar is an important trade-off that must be addressed in the future.

The nature of remote sensing satellite programs which generally provide world wide coverage due to the type of orbit required logically lends itself to international cooperation. While Canada has a vigorous space industry with broad based capabilities, there are some significant components of the SURSAT program which would come from other nations and which would ideally be supplied

	PROGRAM YEAR										
L-Band System Approach	1	2	3	4	5	6	7	8	9	10	TOTAL
Project Office	4 my	2 my									6 my
	.02M	.01M									.03M
R&D Phase	1.89M	4.45M	1.25M	0.3 M							7.89M
Program Office		10 my	20 my	20 my	20 my	10 my					80 my
		.07M	.11M	.13M	.15M	.08M					.54M
Space Segment		5.13M	48.10M	68.72M	64.23M	33.28M					219.46M
Ground Segment			3.67M	15.91M	5.73M						25.31M
Systems Operations					20 my	20 my	8 my	8 my	8 my	8 my	72 my
					4.46M	5.25M	4.95M	4.95M	4.95M	4.95M	29.51M
TOTALS	4 my	12 my	20 my	20 my	40 my	20 my	8 my	8 my	8 my	8 my	158 my
	1.91M	9.66M	53.13M	85.06M	74.57M	38.61M	4.95M	4.95M	4.95M	4.95M	282.74M
C-Band System Approach											
Project Office	4 my	2 my									6 my
	.02M	.01M									.03M
R&D Phase	2.04M	6.80M	1.65M	0.30M							10.79M
Program Office		10 my	20 my	20 my	20 my	10 my					80 my
		.07M	.11M	.13M	.15M	.08M					.54M
Space Segment		5.23M	54.48M	79.48M	98.37M	75.38M					312.94M
Ground Segment			3.67M	15.91M	5.73M						25.31M
Systems Operations					20 my	20 my	8 my	8 my	8 my	8 my	72 my
					4.52M	5.45M	4.99M	4.99M	4.99M	4.99M	29.93M
TOTALS	4 my	12 my	20 my	20 my	40 my	30 my	8 my	8 my	8 my	8 my	158 my
	2.06M	12.11M	59.91M	95.82M	108.77M	80.91M	4.99M	4.99M	4.99M	4.99M	379.54M

1980 C Dollars

SURSAT PROGRAM COST SUMMARY

TABLE 4-1

through an international cooperative effort.

The launch is an area in which Canada does not have any technology capabilities. In addition, the optical scanner is a technology in which Canada has not previously developed space hardware and which is a good area for international cooperation. A third area which may be a possibility for external program cooperation is the spacecraft bus which contains the standard housekeeping systems such as structure, attitude control, power, thermal control and propulsion. Although Canada clearly has the capabilities to develop the entire spacecraft it may be more desirable from the point of view of cost and program risk for a Canadian prime contractor to obtain an already developed spacecraft bus as the starting point for the SURSAT spacecraft. There would still remain considerable effort to be done in terms of system design, program management, payload development, system integration, test, telemetry and other mission peculiar items.

Table 4-2 indicates the potential program costs with international participation in just the three areas described above. Undoubtedly there are other areas where foreign participation may be possible. It is best to arrange such participation in areas where a very clean interface can be defined so that program management costs can be kept under control.

The most likely countries that may want to participate in the Canadian SURSAT program are the United States and several in Europe such as Germany, France and the U.K. European participation may be arranged through the European Space Agency.

L-Band SURSAT System		
Total Program Cost		$283 M
2 Shuttle Launches	$16 M	
Program Cost		$267 M
3 Thematic Mappers	$85 M	
Program Cost		$182 M
3 MMS Bus	$35 M	
Potential Program Cost		$147 M

C-Band SURSAT System		
Total Program Cost		$380 M
3 Shuttle Launches	$24 M	
Program Cost		$356 M
4 Thematic Mappers	$110 M	
Program Cost		$246 M
4 MMS Bus	$44 M	
Potential Program Cost		$202 M

1980 C Dollars

SURSAT Program Cost Summary

Table 4-2