RADARSAT ILLUMINATED

Your Guide to Products and Services

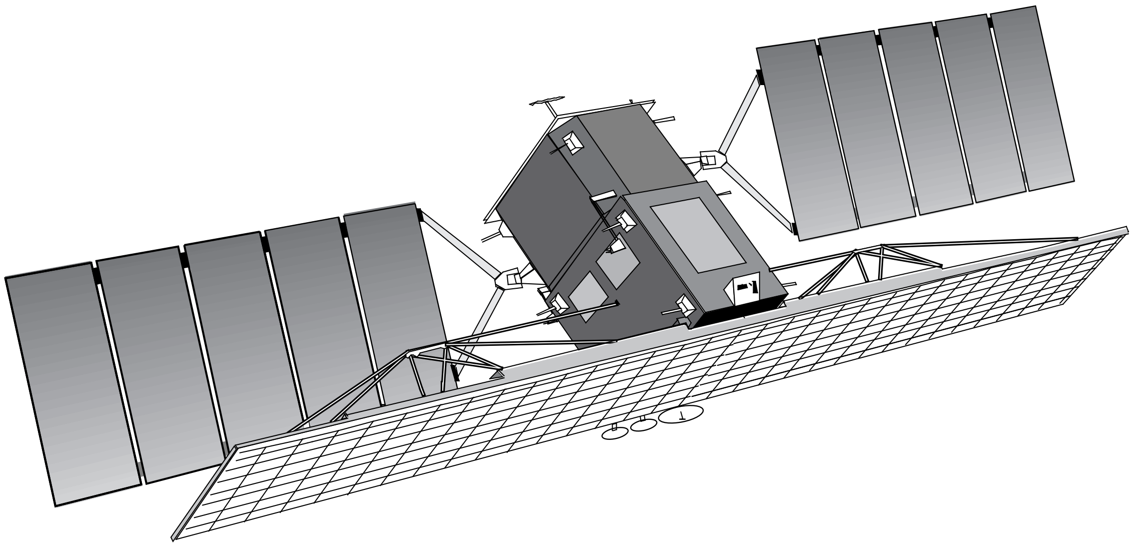
You are ready to open the RADARSAT user guide .pdf file. As you read through this file and turn the pages using the arrow indicators or the scroll bars, you may also wish to view specific pages. This .pdf file has been created to enable quick and easy access to any page, table or figure listed in the Table of Contents, the Quick Reference Guide, and/ or the Index. By positioning your cursor on a specific page number and double clicking you will immediately advance to this information.

You will also find a copy of the RADARSAT Image Request Form at the end of this file. To help you complete this form, position your cursor on any section heading and double click. Next you will find a detailed explanation of the specifications you must include.

We hope you find this digital reference to the RADARSAT user guide helpful.

RADARSAT ILLUMINATED

Your guide to products and services



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RADARSAT
INTERNATIONAL

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INTRODUCTION

RADARSAT is a very flexible source of geographic information. As Canada's first earth observation satellite, RADARSAT will provide valuable information for use in the effective management and monitoring of the world's natural resources. As the exclusive commercial distributor of RADARSAT data, RADARSAT International (RSI) has prepared this document, "RADARSAT Illuminated, Your Guide to Products and Services", to help you order the right RADARSAT product based on your operations / project requirements.

RADARSAT provides 25 possible choices of images; each varies with respect to the area covered and the way in which the earth's surface is viewed. As well, RSI offers a number of data and image products to meet specific analysis requirements. We hope that this user guide will provide you with the information you need to select and order an appropriate RADARSAT product.

Three distinct chapters follow this one. Chapters 2, 3, and 4 have specific objectives and build on the information provided in the preceding chapter(s).

Chapter 2, Choosing your RADARSAT product, is intended for those users who are unfamiliar with radar remote sensing and RADARSAT. It provides:

- complete information on RADARSAT and its capabilities, and
- a means of evaluating your operations / applications requirements and how these relate to your choice of RADARSAT product.

The key factors which will influence your decision in choosing a product are identified in bold italics.

Chapter 3, Ordering your RADARSAT product, focuses on the ordering process and the RADARSAT Image Request Form which you will need to complete to receive your RADARSAT product. It provides:

- details on the information we need to fulfil your order,
- references to Chapter 2 for further clarification, and
- important technical details to help you choose the optimal RADARSAT product.

A pencil icon identifies what information you must indicate on the RADARSAT Image Request Form.

Chapter 4, Using your RADARSAT product, is meant to assist novice users in working with their RADARSAT products. This chapter provides some general guidelines on:

- looking at the data,
- enhancing the appearance of the image product,
- manipulating the data, and
- integrating RADARSAT products with other data sets.

Following Chapter 4 are the Appendices, a Glossary, and an Index.
The Appendices provide supplemental technical information and include:
Appendix A: RADARSAT program specifications, describes the RADARSAT program and the satellite.
Appendix B: Application considerations for RADARSAT, provides general guidelines for selecting RADARSAT products by application area.
Appendix C: RADARSAT product specifications, describes the technical details for each product and information on topics such as calibration and image quality.
Appendix D: Supported map projections, lists the projections available for various RADARSAT products.
Appendix E: General terms of sale of RADARSAT International (RSI), describes the terms and conditions associated with ordering RADARSAT data.
Appendix F: Selected references, provides a number of additional references to help you learn more about RADARSAT, and its applications and products.

Your feedback on this guide is important to us.
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The following chart will help you identify areas within the guide to which you may wish to refer. The key questions (Where?, What?, etc.) relate directly to the RADARSAT Image Request Form.

Quick Reference Guide

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HOW CAN RADARSAT MEET YOUR INFORMATION REQUIREMENTS?

The information requirements and the availability of data to yield that information are important considerations in project or operation planning and implementation. Often, a variety of data sources including radar sensors, aerial surveys, and optical sensors must be used where the format, quality, and level of information vary.

As one source of valuable data, RADARSAT offers a number of major benefits including:

- current and reliable access to data,
- frequent global coverage,
- range of product scales and resolutions, and
- digital georeferenced products which can be integrated with other data sets.

In addition, the unique features of the RADARSAT sensor provide application-specific benefits.

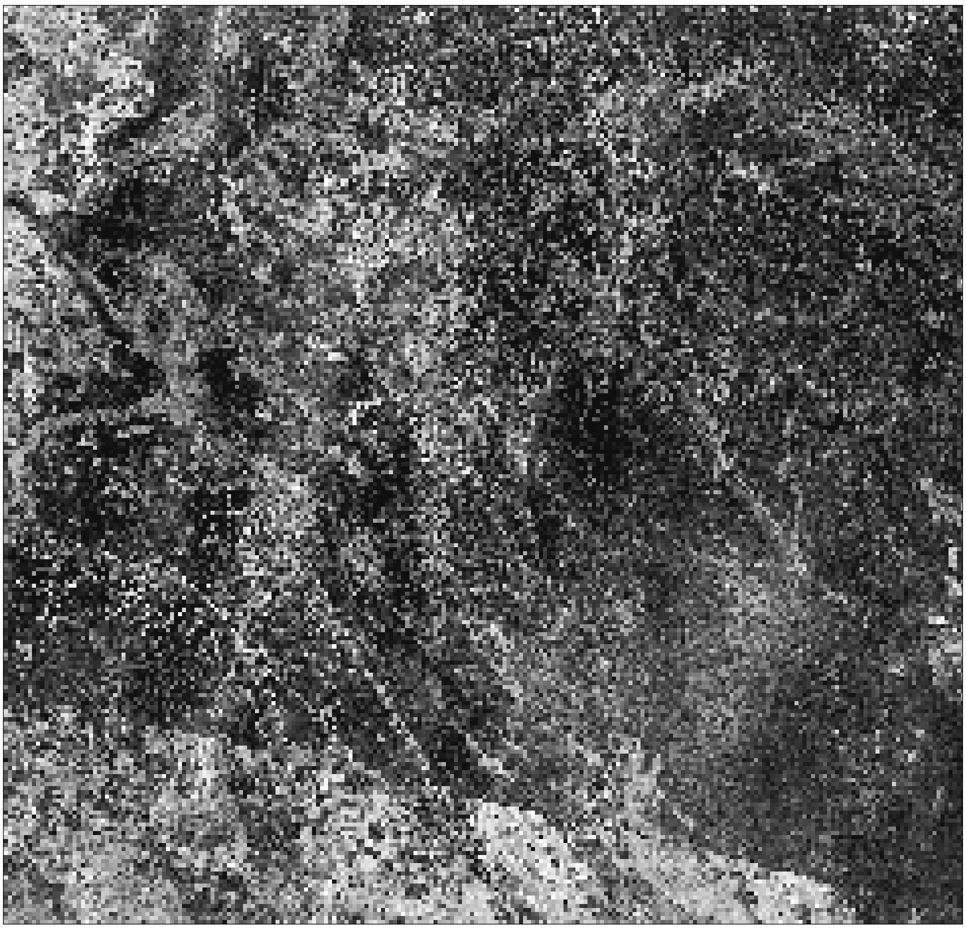
How does RADARSAT differ from optical sensors?

RADARSAT differs from optical sensors in the kind of data it acquires and in how this data is collected. Typical multi-spectral sensors such as SPOT and Landsat collect the energy reflected from the earth's surface at frequencies roughly equivalent to those which are detected by our eyes. These sensors capture the earth's reflected energy within one or more *frequency bands*. Each band or channel represents a unique picture of the earth's surface and can be interpreted singly or in combination with other bands. Image processing techniques make it possible to combine these bands into a colour image of the land surface.

Radar sensors such as RADARSAT make use of energy transmitted at microwave frequencies, which are not detected by the human eye. RADARSAT operates at a single microwave frequency, known as *C-band* (5.3 GHz frequency or 5.6 cm *wavelength*) which generates one channel of data. This "one-channel" image can be combined with multi-date RADARSAT data or data from other sources to create colour images.

As an *active* sensor, RADARSAT's Synthetic Aperture Radar (SAR) transmits a microwave energy pulse to the earth. The SAR measures the amount of energy which returns to the satellite after it interacts with the earth's surface. Unlike optical sensors, microwave energy penetrates darkness, clouds, rain, dust, or haze, enabling RADARSAT to collect data under any atmospheric condition.

RADARSAT transmits its C-band microwave energy in a horizontal orientation (known as *polarization*). The energy which returns to RADARSAT's sensor is



This SAR image shows surface texture, water/land boundaries, and soil moisture.
 ERS-1 data received and processed by the Canada Centre for Remote Sensing.

captured using the same polarization. This is known as a HH polarization system. Variations in the returned signal (*backscatter*) are a result of variations in the surface roughness and topography as well as physical properties such as moisture content. A detailed description of RADARSAT's SAR is provided in Appendix A.

RADARSAT was designed to respond to a diverse range of application requirements. Table 2.1 highlights RADARSAT's responsiveness to the earth's surface features.

TABLE 2.1: RADARSAT responses to surface features

SURFACE FEATURES/ PARAMETERS	RADARSAT RESPONSE
Surface Roughness	The amount of energy returned to the satellite is strongly influenced by surface roughness. RADARSAT can distinguish textural differences created by forest clearcuts, agricultural tillage, and crop practices to name a few.
Topography	Radar backscatter is greater for slopes facing the radar sensor than for slopes facing away from the sensor. This creates a "shaded relief" image from which geological and geomorphological information can be derived.
Land/Water Boundaries	Smooth water surfaces tend to reflect microwave energy away from the satellite sensor. Land surfaces tend to be rougher and reflect more energy back to the satellite. As a result, RADARSAT provides sharp contrast between land/water boundaries.
Man-Made Features	Man-made features such as buildings and ships strongly reflect microwave energy back to the SAR sensor. These appear as bright point targets on RADARSAT images.
Moisture	The amount of moisture in the soil or on vegetation affects the amount of SAR backscatter. This is represented as tonal variations in the image.

CHOOSING YOUR RADARSAT PRODUCT

Before choosing a data source, the requirements and constraints of your project / application need to be evaluated. The following variables are important in your assessment:

- geographic area and type of terrain,
- scale or level of detail required,
- ability of data to provide the required information,
- quality and reliability of the data sources,
- how quickly the data is needed, and
- required data format.

The rest of this chapter is intended to assist you in evaluating these variables, and examines how RADARSAT can respond to your requirements. It has been designed to correspond with the sequence of information required in the ordering process (which is reviewed in Chapter 3).

WHERE?

RADARSAT can acquire SAR data of nearly any location in the world. Data collected by the satellite is either directly transmitted to a local ground receiving station or stored on one of RADARSAT's tape recorders. The stored data is then transmitted to a RADARSAT ground receiving station in Prince Albert, Saskatchewan or Gatineau, Québec, Canada. Once the data is received at the ground station, it can then be processed to produce a wide range of RADARSAT data and image products.

The collection of geographic data by spaceborne or airborne optical sensors over some environments is often difficult. The following table highlights RADARSAT solutions for acquiring data over a variety of "challenging" environments.

TABLE 2.2: Worldwide data acquisition

TYPE OF ENVIRONMENT	CHALLENGE	RADARSAT SOLUTION
Remote	Accessibility for data collection.	Global coverage and availability.
Tropical / coastal	Cloud cover, fog, and rain hamper data collection using optical sensors.	Microwave energy penetrates cloud, fog, rain, and haze.
Coastal / lakes	Differentiating land from water, mapping shorelines or flood limits.	HH polarization of microwave energy is preferred for land/water discrimination.
Equatorial	High sun angle hinders the interpretation of terrain features.	RADARSAT'S SAR sensor provides a range of shallow and steep viewing angles.
Polar	Long periods of darkness preclude the use of optical sensors.	The RADARSAT SAR has its own source of illumination and can operate in darkness.
Disasters	Volcanic eruptions, dust storms, or weather-related flooding create atmospheric conditions which hamper data collection by optical sensors.	C-Band microwave energy can penetrate atmospheric dust as well as cloud and rain.

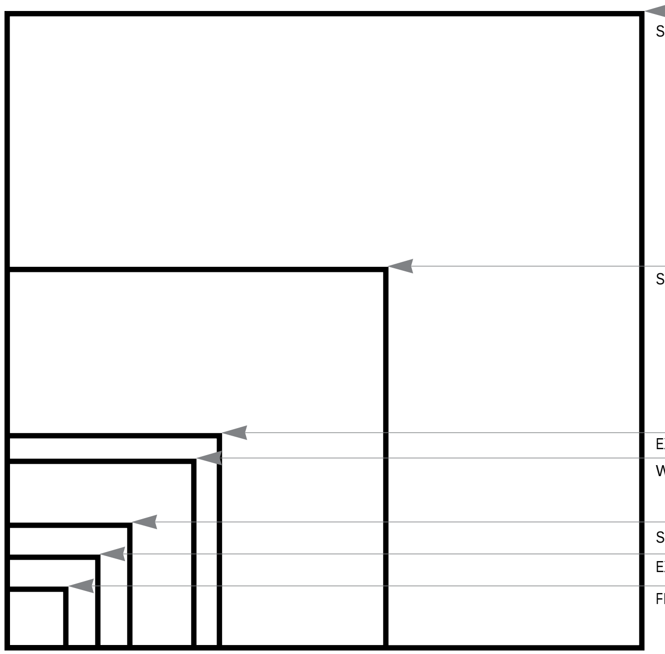
WHAT SCALE?

The success of deriving useful information from a data source will depend on the level of detail provided by the data source as compared to the information being sought. RADARSAT data has the advantage of providing a range of product scales to facilitate a match with your project requirements. There are seven image sizes, termed *beam modes*, which RADARSAT can acquire.

In choosing the most appropriate beam mode, you will need to consider:

- *the size of your area,*
- *what you are trying to see, and*
- *your desired final output scale.*

FIGURE 2.1: RADARSAT beam modes



BEAM MODE	NOMINAL AREA COVERED (KM)	NOMINAL RESOLUTION (M)
SCANSAR WIDE	500 X 500	100
SCANSAR NARROW	300 X 300	50
EXTENDED LOW	170 X 170	35
WIDE	150 X 150	30
STANDARD	100 X 100	30
EXTENDED HIGH	75 X 75	25
FINE	50 X 50	10

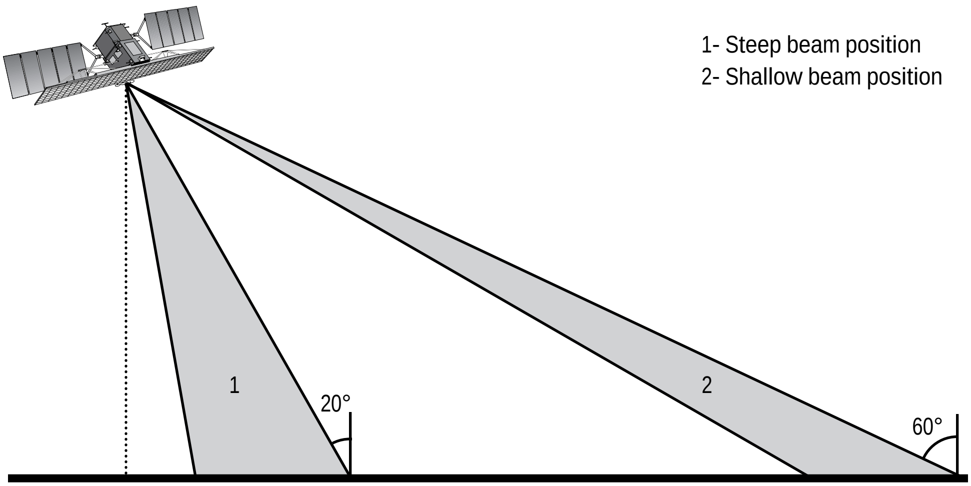
Each beam mode is defined by the area it covers and the level of detail (*resolution*) available (see Figure 2.1). RADARSAT offers a selection of beam modes ranging from Fine (which covers a 50 x 50 km area) to ScanSAR Wide (which covers a 500 x 500 km area).

The ScanSAR beam mode is a feature unique to RADARSAT. It will provide repeat coverage of large areas and will yield critical information for strategic planning operations such as routing ships through polar regions or monitoring coastlines. In addition, ScanSAR will provide information for program scales between 1:5,000,000 to 1:250,000. The Standard and Wide beam modes will be useful in small scale (1:1,000,000 to 1:100,000) monitoring and mapping programs, and Fine beam mode will provide an additional level of detail for projects requiring larger scales (1:250,000 to 1:50,000).

WHAT ANGLE?

Each RADARSAT image is defined by the oblique angle, termed *incidence angle,* at which it was acquired (see Figure 2.2). For some applications, the incidence angle is very important, and for others, it has very little impact. RADARSAT offers a range of incidence angles from less than 20° (steep angle) to almost 60° (shallow angle).

FIGURE 2.2: Beam position / incidence angle definition



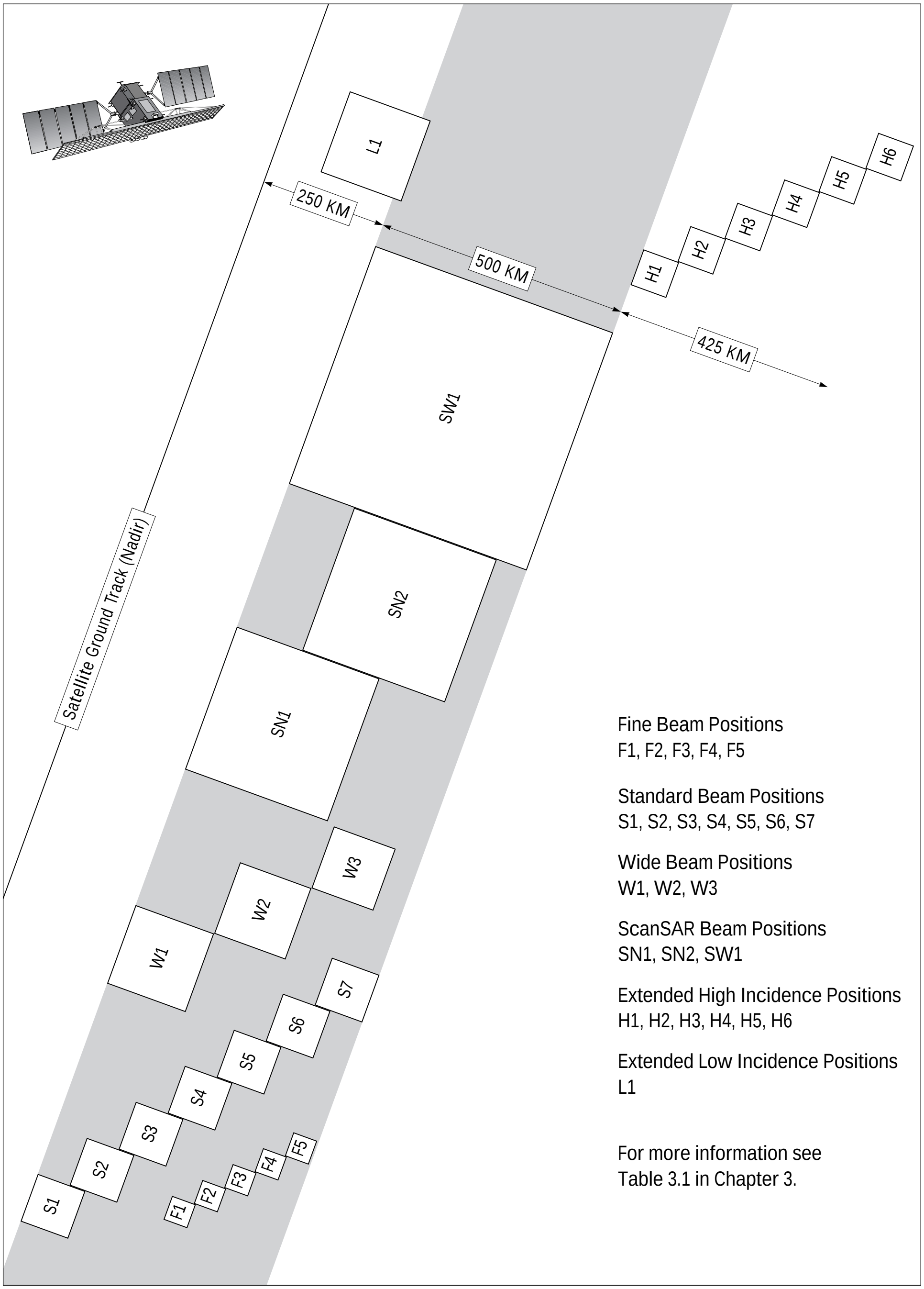
Not drawn to scale. Satellite height is 798 km and ground distance is 1,000 km.

NOTE: RADARSAT defines its beam positions by pre-defined incidence angle ranges.

An incidence angle is the angle between the radar beam and a flat earth surface.

Within each RADARSAT beam mode, a number of incidence angle positions are available (see Figure 2.3). These are called *beam positions.* For example, Standard beam mode, which covers a 100 x 100 km area, has seven beam positions. By specifying a beam position, one of seven 100 x 100 km images within a 500 km accessible swath will be collected.

FIGURE 2.3: Beam positions for RADARSAT beam modes



Factors affecting your choice of beam position will include:

- *the sensitivity of your application to the incidence angle,*
- *the type of terrain being imaged,*
- *your requirements for stereo imagery, and*
- *how often you need coverage of the area.*

Application sensitivity

Some applications are sensitive to the way terrain is viewed. For example, point targets such as ships are best viewed using shallow incidence angles. Ocean features, however, are best viewed using steep incidence angles. More information on selecting incidence angle positions for specific applications is found in Appendix B.

Type of terrain

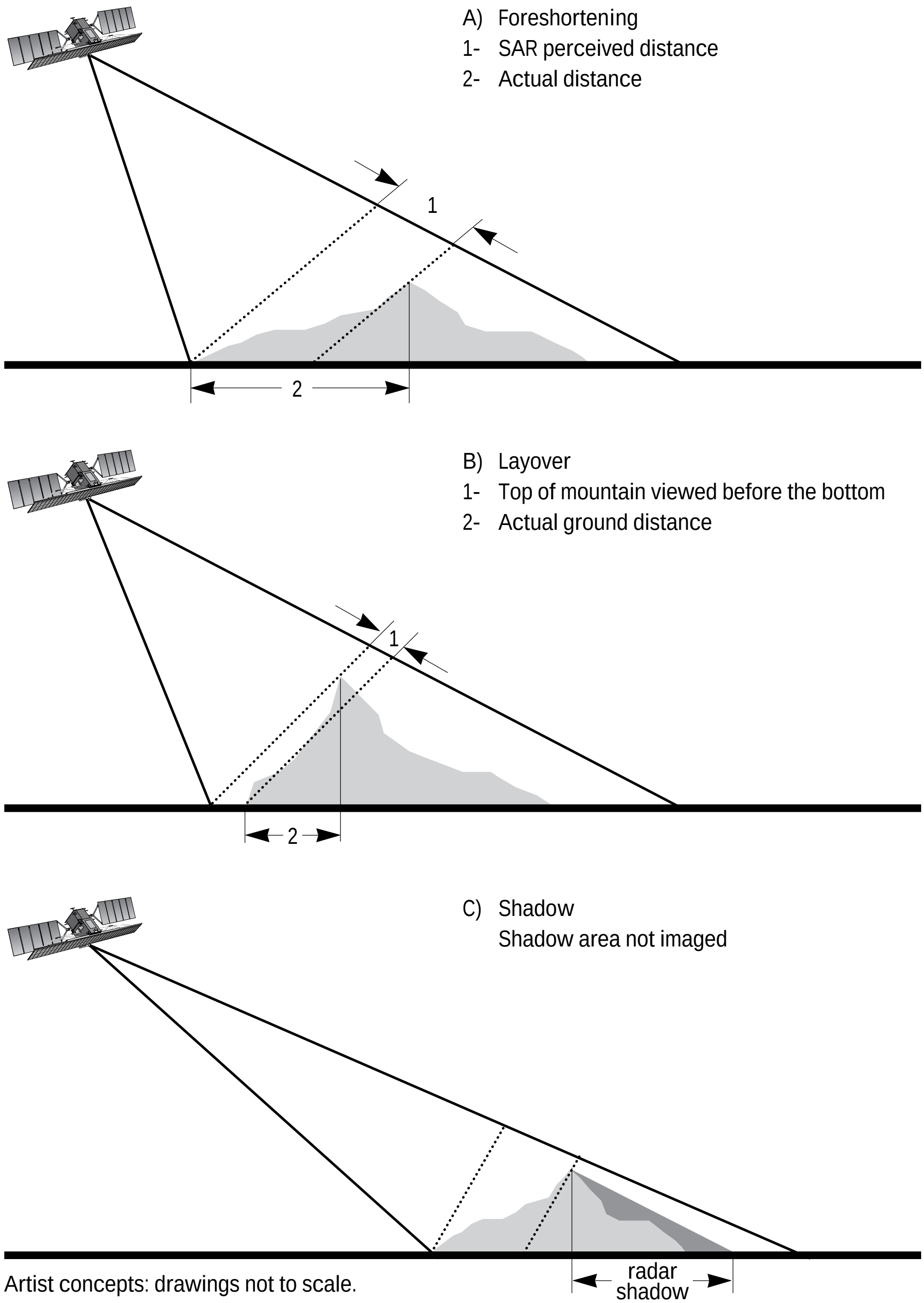
When a SAR sensor acquires data, it is actually measuring the time it takes for the microwave energy to leave the satellite, interact with the earth's surface, and return to the satellite sensor. This measurement of time is then converted to a ground distance. Depending on the topography of the area, some relief displacement may occur on the resulting image.

When SAR is used to view, or image, areas of high relief (e.g., mountains), the time it takes for the energy to image the top of a mountain is less than the time required to image its base. This is known as foreshortening (see Figure 2.4a). In extreme cases, this produces a distortion known as layover (see Figure 2.4b). The extent of the distortion depends on the incidence angle used to image the high relief terrain. If the incidence angle is greater than the slope of the terrain being imaged, layover can be minimized.

Selecting an appropriate beam position will depend on the terrain. For flat terrain, the incidence angle position will likely not matter. Conversely, for high relief terrain, you can expect:

- a steep incidence angle position to produce severe layover, and
- a shallow incidence angle position to minimize layover. However, shadows (non-imaged areas) can occur on the lee side of mountains (see Figure 2.4c). (More information on collecting data in shadow areas is found on page 2-13.)

FIGURE 2.4: Effects of terrain relief on viewing geometry



Artist concepts: drawings not to scale.

Stereo imagery requirements

RADARSAT's range of beam positions offers you an opportunity to acquire pairs of images for stereo analysis. To obtain stereo pairs, the same area is viewed from two different beam positions (see Figure 2.5). It is also possible to collect stereo pairs by viewing the same area from an ascending and a descending orbit pass (see "What direction?").

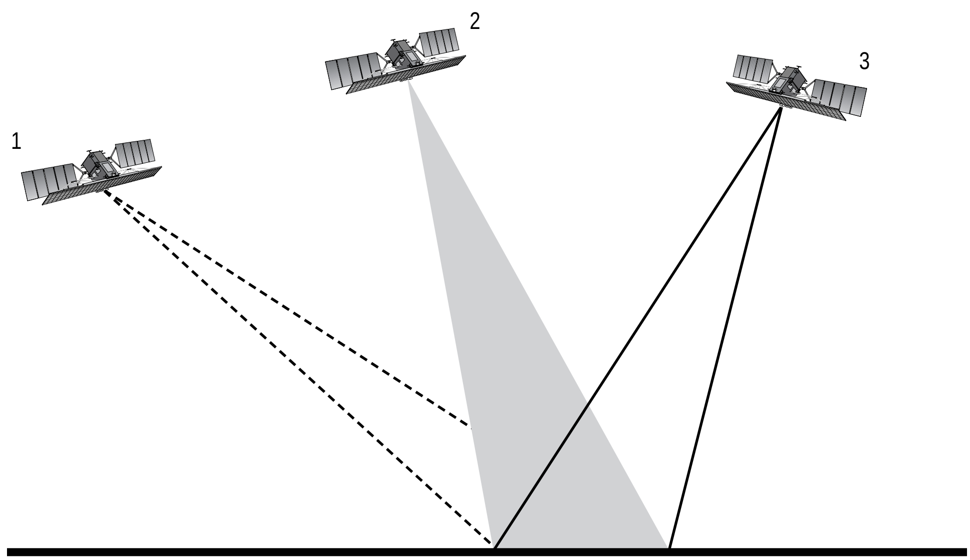
Repeat coverage requirements

The RADARSAT orbit has a 24 day cycle, meaning it returns to the same location every 24 days. Fortunately, RADARSAT's radar beam can be steered to provide a more frequent revisit cycle (see Figure 2.5 and Table 2.3). This is particularly useful when your application is time-sensitive and acquiring an image on a specific date is important. We can help you choose a beam position by assessing:

- the dates or timeframe during which your image must be acquired,
- the satellite's orbit during that timeframe, and
- the latitude of your area of interest.

FIGURE 2.5: RADARSAT beam position flexibility

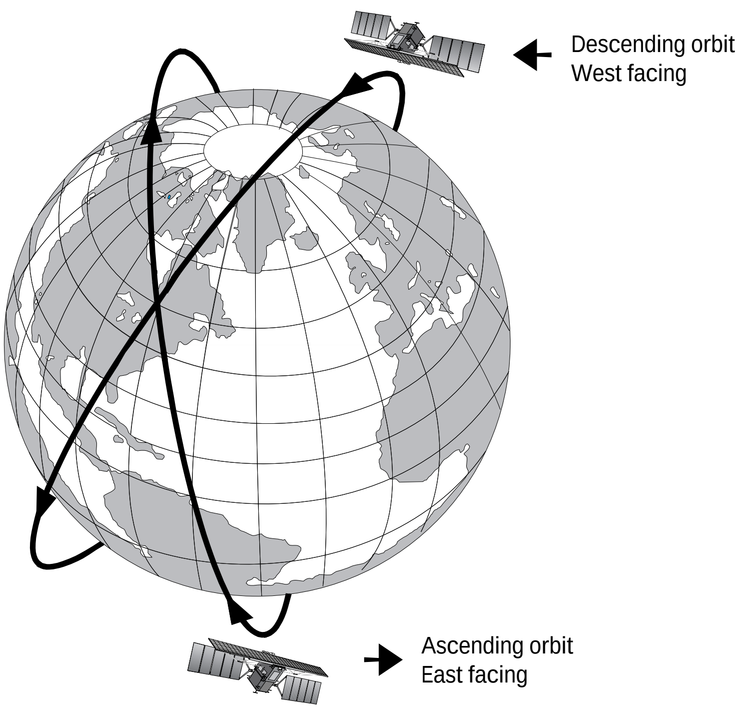
1- shallow beam position, ascending orbit
2- steep beam position, ascending orbit
3- descending orbit



WHAT DIRECTION?

RADARSAT offers two *look directions* (east facing or west facing) from which to view the earth. As RADARSAT descends from the north pole (a descending orbit pass), it views the earth in a westerly direction. As it ascends from the south pole (an ascending orbit pass), it views the earth in an easterly direction (see Figure 2.6).

FIGURE 2.6: RADARSAT orbit characteristics



Choosing an east or west facing direction is important when:

- *you are working with areas of high terrain relief,*
- *you are interested in highlighting features with a particular orientation,*
- *you prefer either early morning or early evening acquisition times, and*
- *the output from the project will be a mosaic of several RADARSAT images.*

For many applications, however, specifying the direction is unnecessary. In fact, not indicating a particular look direction will provide you with twice as many imaging opportunities.

High terrain relief

In mountainous terrain, the use of a shallow incidence angle can result in radar shadowing (or non-imaged areas) on the lee side of mountains. (Figure 2.4c shows how this happens.) By obtaining imagery from the east and west facing passes of the satellite, both sides of the mountain can be imaged to provide a more complete data set.

Feature orientation

There are applications in which the alignment and orientation of features are of particular interest. These include the mapping of geological lineaments and structures, analysis of agricultural tillage and crop planting practices, drainage patterns, and mapping of cultural features such as roads and railways. The direction from which features are viewed can affect how easily these features are identified on the resulting images.

The detection of linear features is enhanced when they are aligned near-perpendicular to the look direction of the satellite. Conversely, linear features can be suppressed if aligned parallel to the look direction. RADARSAT's look direction will vary with latitude. Between latitudes of 60°N and 60°S, the look direction is fairly constant at approximately 98° (8° off east) for the east facing pass and at 278° (8° off west) for the west facing pass.

Time of day

RADARSAT will pass over a given geographic location at two different times during the day. On the west facing (descending) orbit, the satellite crosses the equator at approximately 6:00 a.m. local time, and on the east facing (ascending) orbit, the satellite crosses the equator at 6:00 p.m. local time. The actual time the satellite passes over a given location will vary slightly with latitude.

For assistance in calculating the actual time that RADARSAT passes over your area of interest, please contact your Client Services representative.

Producing a RADARSAT mosaic

In mapping large areas, you will likely require more than one RADARSAT image. Often, images are mosaicked together to produce one full coverage output. All the individual RADARSAT images should view the terrain in the same way (e.g., all were obtained using an east facing orbit). This will ensure that the geometric and radiometric properties of each image will be similar, producing an appealing and easily interpreted final product.

WHEN?

RADARSAT I is designed to have a five-year lifespan. However, with the subsequent launches of RADARSAT II and III, imagery will be available well into the next century. Therefore, long term planning of RADARSAT image acquisitions is possible and encouraged, particularly for monitoring applications.

Deciding when to acquire your RADARSAT images will be influenced by:

- *RADARSAT's orbit characteristics,*
- *how quickly you need the data,*
- *your application and operational requirements, and*
- *whether you need to collect other supporting data.*

Orbit characteristics

To some extent, RADARSAT's orbit characteristics will determine the specific date when an acquisition can be made and the number of days between subsequent acquisitions. The revisit schedule for a specific location will depend on:

- the latitude of the location,
- your desired beam mode, and
- the flexibility in changing the beam position.

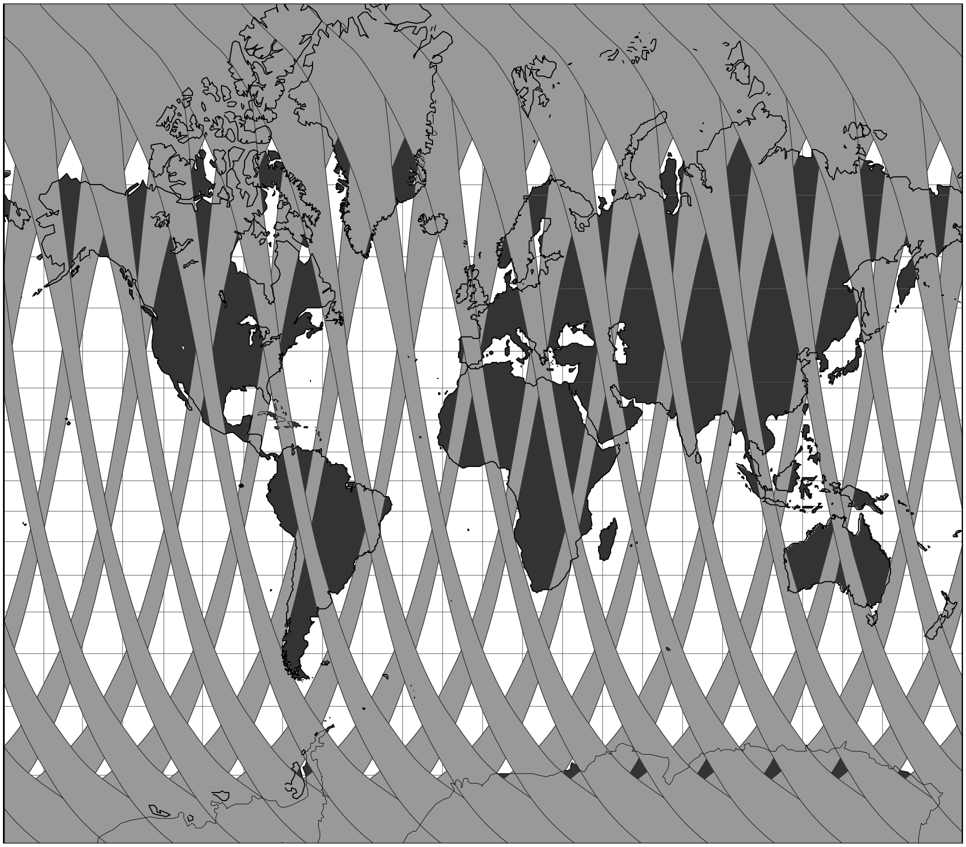
It takes RADARSAT 24 days to return to its original orbit path. This means that for most geographic regions, it will take 24 days to obtain exactly the same image (same beam mode, position, and geographic coverage). However, one of the main advantages of RADARSAT is the ability to acquire images on a more frequent basis. Because the ScanSAR beam mode covers such a large area, a location can be viewed as frequently as once a day in high latitudes and in less than five days at the equator. (See Table 2.3 and Figure 2.7.) For other beam modes, the beam position can be changed so a location can be revisited more frequently.

TABLE 2.3: RADARSAT revisit schedule (days)

LATITUDE	FINE BEAM MODE		STANDARD BEAM MODE		WIDE BEAM MODE		SCANSAR BEAM MODE	
	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.
0°	4	10	2	5	2	5	2	5
10°	4	9	2	5	2	5	2	5
20°	4	8	2	4	2	4	2	4
30°	3	8	2	4	2	4	2	4
40°	3	6	2	3	2	3	2	3
50°	3	5	2	3	2	3	2	3
60°	2	3	1	2	1	2	1	2
70°	2		1		1		1	

NOTES:
Fine beam mode does not extend over the full 500 km swath. As a result, revisits are less frequent. See Figure 2.3.
The minimum and maximum revisit capability is influenced by where the east and west facing orbits cross (see Figure 2.7). Locations where the orbits cross will enjoy a more frequent revisit schedule.

FIGURE 2.7: World coverage (one day ScanSAR)



COURTESY RADARSAT PROGRAM OFFICE / CANADIAN SPACE AGENCY

Turnaround time

Advance planning for projects and operations is sometimes overlooked and you may find you require a RADARSAT image on very little notice. Although it is preferable to plan acquisitions well in advance, we offer a range of programming, processing, and delivery services which will help expedite your order.

Previously-collected RADARSAT data will be stored in a RADARSAT archive. This archive can be searched for available data in your geographic region.

If you decide to order from the archive, consider that:

- the delivery of images may be faster since the imagery exists,
- trade-offs may occur regarding your optimum beam mode, position, and look direction versus what is available, and
- the specific date of the acquisition will depend on what is available in the archive.

For future date acquisitions, the satellite will be programmed to collect data using the beam mode, position, and look direction that you have requested. If the turnaround time is critical, we offer Urgent programming as well as Rush processing services. Please see the "How fast?" section for more information on these services.

Application / operations requirements

For many applications, the dates on which the imagery is acquired are very important. For example, in crop monitoring activities, images must be acquired at specific times during the crop growth cycle. For time-sensitive applications, particularly in a monitoring program, it is advisable to plan your RADARSAT acquisitions well in advance.

Environmental conditions may also influence when imagery should be collected. For example, some studies suggest that forest clear cut operations in Boreal forests are best imaged in the winter months.

Collection of other data

It may be important to acquire your RADARSAT image at the same time as other data is being collected. The ability to satisfy your specific date requirements will be influenced both by RADARSAT's orbit and your flexibility on the choice of beam mode, position, and look direction.

You may also need to collect supporting data to help you interpret your RADARSAT image. For example, in acquiring RADARSAT images of the ocean, the sea-state will affect what can be seen in the SAR image. Therefore, it may be helpful to collect weather data on the same day that RADARSAT is acquiring an image of the ocean.

RADARSAT International and your RADARSAT Distributor offer a number of services to assist you in obtaining the RADARSAT products which best meet your needs. These include:

- RADARSAT acquisition planning through satellite programming and / or archive catalogue searches,
- processing RADARSAT data to a range of products,
- offering a selection of product storage media,
- shipping and delivery options, and
- turnkey solutions to project requirements.

The levels of service available are described in the following sections.

Acquisition planning

Before the satellite is programmed, we will help you decide which RADARSAT beam mode, position and look direction you require. Depending on how quickly your image has to be acquired and how flexible you are on the acquisition date, we offer three levels of programming service. All programming services are subject to the availability of satellite resources.

Basic: At this level, you should try to initiate an order at least one month before the image has to be acquired. We require that the order be finalized fourteen days in advance of acquisition. We will make every effort to program your acquisition during the period requested, depending on satellite resources.

Priority: This service level gives you top commercial priority. You should still initiate your order as soon as possible, and finalize it seven days in advance. As a priority service client, the agreed-upon acquisition date will be honoured.

Urgent: This service is tailored for time-sensitive applications (such as natural disasters) which cannot be planned in advance. At this level of service, RADARSAT images are acquired on a “first available opportunity basis”, and, therefore, do not require the usual lead time for ordering. The request must be finalized at least two working days prior to acquistion.

Catalogue searches: This service level offers access to available RADARSAT imagery in the archive.

Processing

Once RADARSAT has acquired the data, it will be processed to one of six products (discussed in the “Which product?” section). Depending on how quickly you require delivery of your RADARSAT product, we offer three levels of processing service.

Regular: This standard level of service is recommended when there is no urgency in receiving your imagery. However, we will endeavour to process your data as quickly as possible. The turnaround time may vary and will depend on where the processing is performed, but should not typically exceed fourteen days.

Rush: This service level is recommended for time-sensitive applications (e.g., crop monitoring applications). Processing turnaround time is less than 48 hours after the data arrives at the processing centre. Although Rush service is available for both programming and archive data acquisitions, not all RADARSAT products are available at this level of service. (See “Which product?” section.)

Near-Real Time: This level of service is recommended when products are required for immediate decision-making. Once the data arrives at a processing centre capable of providing this service, it will be processed within hours. Currently, RSI’s processor at Gatineau, Québec, Canada provides this service.

Shipping and delivery

Our standard method of shipping your RADARSAT product is by courier. If you require a faster turnaround time, we can deliver some RADARSAT products electronically. To make arrangements for electronic delivery, please contact your Client Services representative.

Near-Real Time application requirements

Some organizations require Near-Real Time service for monitoring dynamic situations including:

- tracking ice movement,
- detecting ships, and
- detecting oil slicks.

In these applications, RADARSAT data will need to be acquired, processed, and delivered in as close to near-real time as possible.

The Atmospheric Environment Service in Canada has implemented the infrastructure capable of obtaining RADARSAT data in near-real time to support their Ice Service operations. The two ground receiving stations in Canada receive the RADARSAT data in real time. This data is directly linked to our processor which can process data in as little as four hours. Also, a telecommunications system is in place to ensure immediate delivery of the product via electronic transfer.

This example highlights the elements required to utilize RADARSAT data for near-real time applications. Please contact your Client Services representative to discuss this option.

WHICH PRODUCT?

Your RADARSAT product is a combination of the satellite parameters (beam mode and position) and the level of processing your data requires. Processing typically involves the following:

- correcting errors generated by the SAR system, ground reception, or resulting from the motion of the satellite,
- calculating the latitude and longitude for each line of data,
- calibrating the data,
- converting the stored data units from "time intervals" (slant range) to a ground distance (ground range) format,
- framing the image to a square scene, and
- improving the positional accuracy of the image using map projections, ground control points, and, if available, digital elevation data.

Six RADARSAT processing levels are available. In choosing the appropriate processing level, you need to consider:

- *your analysis requirements,*
- *your hardware and software capabilities, and*
- *how quickly you need the data.*

Analysis and software / hardware requirements

Choosing an appropriate RADARSAT product will strongly depend on how you need to use it. Table 2.4 provides a list of typical analysis requirements and recommended processing levels.

TABLE 2.4: Analysis requirements and recommended products

ANALYSIS NEEDS	RECOMMENDED PRODUCT PROCESSING LEVELS
Integration with other data sources (e.g., satellite data, vector data, historical data)	Precision Map Image Map Image Path Image (if user performs map corrections)
RADARSAT is primary (or sole) data source. Visual interpretation techniques used.	Path Image Map Image
Quantitative Target Analysis	Path Image Plus
Interferometry	Single Look Complex
SAR Processing	Signal Data

Processing speed

As described in the previous section “How fast?”, there are two options available to quickly process RADARSAT data into products. Path Image, Path Image Plus, Signal Data, and Single Look Complex are available at Rush and Near-Real Time processing service levels.

This section describes the products available through the Canadian SAR processor and RADARSAT International. Some reception facilities may not offer these products directly. However, all data can be processed through RADARSAT International if required. Product names have been defined by RSI. Table C.1 in Appendix C provides a summary of comparable processing levels for other satellite systems.

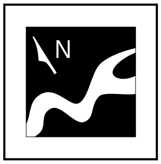
Table 2.5 summarizes the characteristics of RADARSAT products and describes the suggested software / hardware capabilities needed to utilize RADARSAT digital data.

TABLE 2.5: Product characteristics

PRODUCT NAME	GENERAL CHARACTERISTICS	SOFTWARE/HARDWARE REQUIREMENTS
Signal Data	Data remains in slant range.	SAR processor
Single Look Complex	Data remains in slant range. Image is calibrated. Minimal processing provided.	Sophisticated image processing software (radar modules)
Path Image	Data converted to ground range. Image remains oriented in direction of orbit path. Image is calibrated.	Image processing software or print media
Path Image Plus	Data converted to ground range. Image remains oriented in direction of orbit path. Image is calibrated.	Image processing software or print media
Map Image	Image re-oriented to a map projection. Positional accuracy improved.	GIS software and/or image processing software
Precision Map Image	Image re-oriented to a map projection. Ground control points used to improve positional accuracy.	GIS software and/or image processing software

Regular products

Path Image

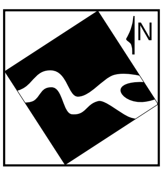


Path Image products are recommended for individuals and organizations experienced in image processing or who do not require positional accuracy. The image product is aligned parallel to the satellite's orbit path. Latitude and longitude positional information has been added to represent the first, mid, and last pixel positions of each line of data. The products are also calibrated. Data from all beam modes can be processed to this product.

Path Image Plus

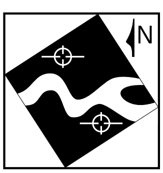
The difference between Path Image and Path Image Plus lies in the spatial sampling procedure used in calibrating the products. Path Image Plus uses a smaller pixel spacing to retain full RADARSAT beam mode resolution which will enhance your ability to measure point targets. However, it will create a digital file which is considerably larger than a Path Image product. Data from all beam modes with the exception of ScanSAR can be processed to this product.

Map Image



Map Image products are oriented with "NORTH UP" and are corrected to a user-requested map projection. We offer these products in a wide variety of map projections (see Appendix D for more information on map projections). The positional accuracy of Map Image products depends on the terrain relief and the beam mode. This topic is reviewed in detail in Appendix C. Data from all beam modes with the exception of ScanSAR can be processed to this product.

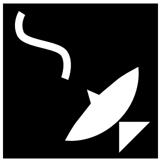
Precision Map Image



Precision Map Image products have even greater positional accuracy than Map Image products. Ground Control Points (GCPs) as well as a map projection are used to spatially align the image.

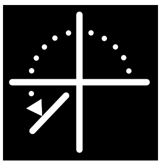
To order a Precision Map Image product, ground control points from a map or provided through Global Positional Satellite (GPS) technology are required. To further enhance the positional accuracy of the image, Digital Elevation Models (DEMs) can be used to correct terrain distortions. A DEM at sufficient detail will be needed to provide ortho-correction services. Call your Client Services representative for more information about this service.

Signal Data



Signal Data is an unprocessed matrix of time delays. The data has been repackaged to fit into standard CEOS format. Otherwise, the data is unprocessed. Users will require SAR processing capabilities to use this RADARSAT product. All beam modes can provide Signal Data.

Single Look Complex



Although Single Look Complex data is stored in slant range, it has been corrected for satellite reception errors, includes latitude / longitude positional information, and is calibrated. Single Look Complex data retains the optimum resolution available for each beam mode and the phase and amplitude information of the original SAR data. Applications such as interferometry will benefit from this RADARSAT product. Data from all beam modes, with the exception of ScanSAR, can be processed to this product.

PRODUCT DELIVERY AND PROCESSING SERVICE

A major strength of the RADARSAT program and RADARSAT International is the commitment to fast delivery of RADARSAT products. As described in the section “How fast?”, we offer a Rush and Near-Real Time level of processing. This is available for Path Image, Path Image Plus, Signal Data, and Single Look Complex digital products.

You should be aware that the positional accuracy may vary slightly for Path Image products provided on Rush service. For Rush service, the RADARSAT data is corrected using the predicted satellite position, whereas for Regular service the more precise satellite positional information is used. (See Table C.3.)

After the data has been processed, your product is ready to be delivered. One option for quick delivery is using an electronic delivery network. Since RADARSAT image files are usually large, data compression routines can be used to reduce the size of the files and make them more compatible for electronic transfer. For information on compression techniques and setting up an electronic transfer of your RADARSAT product, please contact Client Services.

WHICH MEDIA?

RADARSAT products are available on a number of media. These include:

Digital:

- CD-ROM
- Data cartridge (8mm)
- Computer Compatible Tape (CCT) (9 track)

Hardcopy:

- film
- print

Your RADARSAT product is provided on a digital medium. A hardcopy medium is provided upon request. Detailed information on digital file sizes and film product scales is found in Table 3.4 in Chapter 3. In addition, user-defined scales can be specified for print reproductions.

Digital RADARSAT products are stored in CEOS format. Many image processing software packages will have the capability to read RADARSAT's digital format. A list of RADARSAT-compatible software packages is available from your Client Services representative. For a detailed description of the format, please contact us.

ORDERING YOUR RADARSAT PRODUCT

In the previous chapter, we highlighted the many options available to you in selecting a RADARSAT product which will meet your operation / project requirements. This chapter will focus on the ordering process and the information we need to deliver your RADARSAT products.

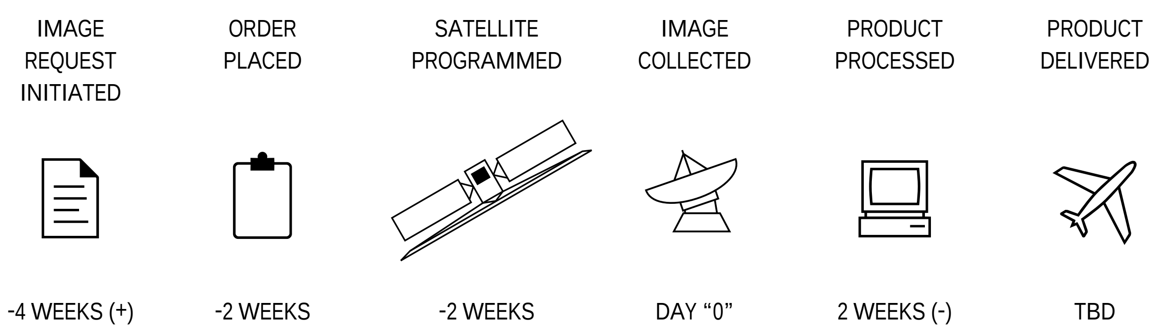
Who do I contact to order my RADARSAT product?

RADARSAT International (RSI) has the exclusive responsibility to distribute RADARSAT data to the international user community (with the exception of Canadian and U.S. government requirements). In order to best serve you, we have established a worldwide distribution network to support our international marketing, ordering, and client services activities. This network includes ground reception stations which receive and potentially process the RADARSAT data.

In the back sleeve of this guide, a preliminary list of RADARSAT distributors and participating ground stations is provided. Please call Client Services so we can advise you on the appointment of new distributors in your area or, if you prefer, you can order your RADARSAT product directly from RSI.

The ordering process – Basic service example

There are a number of steps involved to deliver a RADARSAT product to you. The diagram below represents the various steps and an itemized timeline representing Basic service. The sections that follow the diagram describe each of these steps and when your involvement is important.



The first step of the ordering process is planning your RADARSAT acquisition. The amount of time you should allocate for this step depends on your familiarity with RADARSAT and the complexity of your order. This planning involves:

- yourself,
- your distributor's Client Services representative, and
- access to the Order Desk system (in most cases, this access will be provided through the distributor or RSI).

To facilitate this process, we suggest reviewing two documents:

- this User Guide, and
- the RADARSAT Image Request Form.

At this time, you will need to provide your Client Services representative with the information outlined on the RADARSAT Image Request Form. Your Client Services representative will help you by:

- answering any questions,
- providing additional reference documentation,
- providing access to radar application experts, and
- providing educational and training services and materials.

After the Request Form is completed, we will prepare an acquisition plan and a cost quotation based on the information you have provided. This plan and quotation will be faxed or sent electronically to you and it will indicate:

- the number of images required to cover your area,
- the date(s) on which RADARSAT can acquire your image(s), and
- the estimated price.

You should review this plan thoroughly. In addition, you can modify the information provided on the Request Form until an optimal acquisition plan and cost quotation are reached.

Once you are satisfied with the plan, we will need signed approval and a purchase order with pre-payment or prior approved credit. After the acquisition plan is signed, you are bound to purchase the data acquired on your behalf. The acquisition order is then input to the Mission Control System.

RADARSAT data acquisition

Once the order has been placed, the Mission Control System (managed by the Canadian Space Agency) will confirm the availability of the satellite to collect the data. In the event of a conflict (i.e., two organizations ordering two different RADARSAT beam modes and positions for the same area on the same day), the following guidelines, in order of priority, will be applied to determine what the satellite will do:

- satellite health and safety, orbit, and altitude maintenance,
- urgent service level orders and international emergencies,
- priority service level commercial orders including time-critical acquisitions, and
- basic service level commercial orders.

If a conflict does occur, your Client Services representative will contact you.

After the satellite is programmed with your request, data will be collected and either directly downlinked to an available participating ground station or, if a station is unavailable, the data will be stored on one of RADARSAT's on-board tape recorders. The recorded data will be downlinked to a Canadian ground station at a later date. (See Appendix A for more information.)

RADARSAT data processing

Once the data is received at a ground station, it is archived as signal data. An Acquisition Report will then be sent to you to confirm the status of your order.

Data will be processed to supply the product indicated on the final order. Processing may be performed at one of the participating ground stations or processing centres, or carried out by RADARSAT International at either our processing facility in Gatineau, Québec or Richmond, British Columbia, Canada. Once the processing is completed and payment is received, the data will be delivered to you.

Obtaining data from the archive

Data can also be ordered directly from the archive by completing the RADARSAT Image Request Form. Your Client Services representative will search the archive for all past acquisitions to determine if a match can be made. A list of available data and a cost quotation will be provided to you. From this, you can choose what imagery you wish to purchase or, if nothing is available, you can place a programming request with us.

Again, we will need signed approval and a purchase order with pre-payment or prior approved credit for your archive data order. Once signed and approved, you are contractually obligated to purchase the data. After you have provided your Client Services representative with this documentation, the data is then shipped from the archive to the appropriate processing facility and processed to provide the product you requested. Rush and Near-Real Time processing services are available should you require your products quickly.

THE RADARSAT IMAGE REQUEST FORM

The sections that follow examine the options available to you in completing the RADARSAT Image Request Form. A copy of this form can be found in the back sleeve of this manual. You can obtain additional copies from your Client Services representative.

APPLICATION/OPERATION INFORMATION

A description of your application will assist us in recommending the best RADARSAT product for your program or operation.

Some examples of specific application descriptions include:

Agriculture
- crop identification / delineation
- soil moisture

Cartography
- base mapping
- topographic mapping
- interferometry
- stereo / radargrammetry

Hydrology
- soil moisture
- watershed studies / flood plain mapping
- mapping

Forestry
- broad class mapping
- harvest mapping

Land Use
- urban mapping
- target detection
- transportation network

Disaster
- flood monitoring
- land slide identification
- oil slick identification

Geology
- oil and gas exploration
- mineral exploration
- terrain mapping
- natural hazard monitoring

Ice
- regional mapping
- engineering studies
- ship routing

Coastal / Open Oceans
- ocean features
- wave spectra
- coastal interaction
- aquaculture identification
- ship monitoring

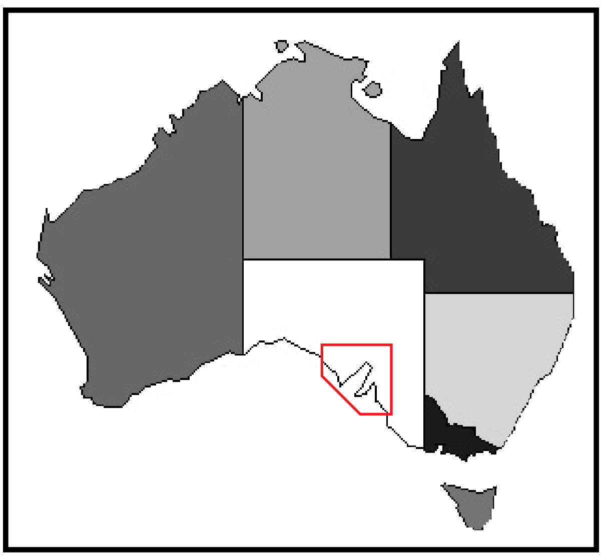
Other information such as the scale of your project, terrain conditions (indicated in metres by the elevation range within the area), and other considerations (e.g., the need for imagery during a particular season) will help us to assist you in defining the correct product and acquisition time.

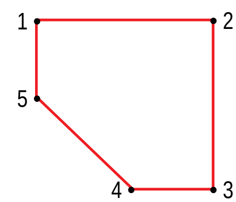
On the RADARSAT Image Request Form, describe your application requirements in terms of what information you need from RADARSAT, the type of terrain elevation, and any other project considerations.

We will need to know the geographic location of your area of interest. The geographic region is defined by both the political boundaries (country, region) in which it falls, and by the set of latitude / longitude coordinates which bound the area. We will use these latitude / longitude coordinates in our RADARSAT planning software to define your area of interest.

You may wish to provide us with a map of the region, particularly if the area has an unusual shape (e.g., an island). This will allow Client Services to target your area more specifically.

FIGURE 3.1: Specifying latitude / longitude coordinates





1. S 32° 0’ E 134° 40’
2. S 32° 0’ E 140° 0’
3. S 37° 30’ E 140° 0’
4. S 37° 30’ E 139° 0’
5. S 34° 30’ E 134° 0’

NOTE:
Conventions for specifying latitudes/longitudes: A compass direction (N,S,E,W) is required to accurately locate an area. Latitudes are 0° to 90° North or South of the equator. Longitudes are 0° to 180° East or West of the Prime Meridian which is located through Greenwich, England.

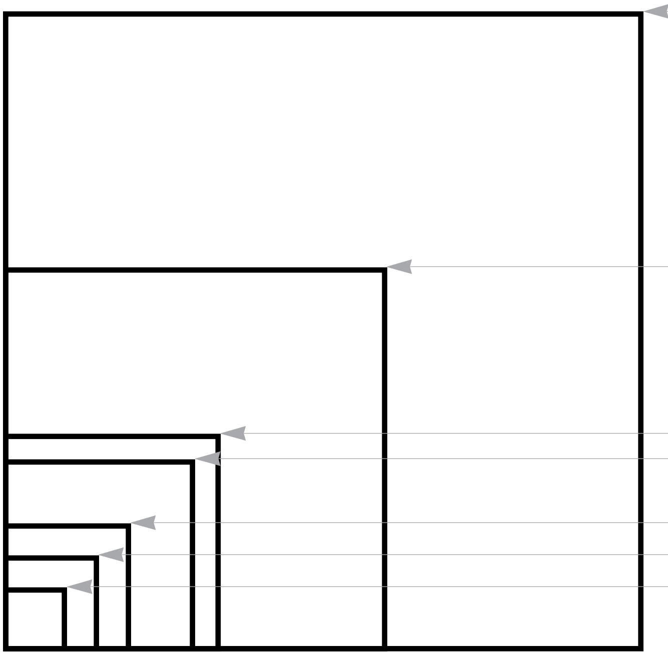
On the RADARSAT Image Request Form, specify the country or region of interest. Also, specify the latitude/longitude coordinates in degrees and minutes bounding your area. Please indicate the compass direction of your coordinates by checking the appropriate box.

In choosing the most appropriate beam mode, you will need to consider:

- *the size of your area,*
- *what you are trying to see, and*
- *the final output scale you desire.*

[Refer to Chapter 2.]

FIGURE 3.2: RADARSAT beam modes



BEAM MODE	NOMINAL AREA COVERED (KM)
SCANSAR WIDE	500 X 500
SCANSAR NARROW	300 X 300
EXTENDED LOW	170 X 170
WIDE	150 X 150
STANDARD	100 X 100
EXTENDED HIGH	75 X 75
FINE	50 X 50

Your selection of beam modes will be made in conjunction with your selection of incidence angles or beam positions. Specific information is provided in Table 3.1. The coverage and resolution vary slightly for each beam position within a beam mode. As well, the resolution varies slightly between processing levels. Appendix C provides detailed information on RADARSAT beam mode and product specifications.

Factors affecting your choice of beam position will include:

- *the sensitivity of your application to the incidence angle,*
- *the type of terrain being imaged,*
- *requirements for stereo imagery, and*
- *how often you need coverage of the area.*

[Refer to Chapter 2.]

Table 3.1 summarizes the incidence angle ranges and the beam position identifiers available for each beam mode. We will need to know the optimum beam position that you require for your project. To help you choose an appropriate beam position, please provide us with as much information as possible about your specific application and the terrain conditions. (See Chapter 2 and Appendix B.)

Because more than one beam position will satisfy most application requirements, we recommend that you specify a number of beam positions. This will give us more flexibility in meeting specific dates for acquiring your data and in optimizing the number of images required to cover your area.

On the RADARSAT Image Request Form, check the box(es) which correspond to your chosen beam position(s).

TABLE 3.1: Beam position characteristics

OPERATIONAL BEAM MODE	BEAM POSITION	INCIDENCE ANGLE POSITIONS (DEGREES)	NOMINAL RESOLUTION (M)	NOMINAL AREA (KM)	NUMBER OF PROCESSING LOOKS
Fine (5 positions)	F1	37 - 40	10	50 x 50	1 x 1
	F2	39 - 42			
	F3	41 - 44			
	F4	43 - 46			
	F5	45 - 48			
Standard (7 positions)	S1	20 - 27	30	100 x 100	1 x 4
	S2	24 - 31			
	S3	30 - 37			
	S4	34 - 40			
	S5	36 - 42			
	S6	41 - 46			
	S7	45 - 49			
Wide (3 positions)	W1	20 - 31	30	165 x 165	1 x 4
	W2	31 - 39		150 x 150	
	W3	39 - 45		130 x 130	
ScanSAR Narrow (2 positions)	SN1	20 - 40	50	300 x 300	2 x 2
	SN2	31 - 46			
ScanSAR Wide	SW1	20 - 49	100	500 x 500	2 x 4
Extended High (6 positions)	H1	49 - 52	25	75 x 75	1 x 4
	H2	50 - 53			
	H3	52 - 55			
	H4	54 - 57			
	H5	56 - 58			
	H6	57 - 59			
Extended Low	L1	10 - 23	35	170 x 170	1 x 4

NOTES:
The numbers shown in the table are approximations.
The actual resolutions will vary slightly and are defined in Appendix C.
Definition of Processing Looks is found in the Glossary.

LOOK DIRECTION (WHAT DIRECTION?)

RADARSAT provides two look directions which correspond to the satellite's ascending and descending orbit passes; the ascending orbit pass is "east" facing and the descending orbit pass is "west" facing.

Choosing between an east or west facing direction is important when:

- *you are working in areas of high terrain relief,*
- *you are interested in highlighting features with a particular orientation,*
- *you prefer either early morning or early evening acquisition times, and*
- *the output from the project will be a mosaic of many RADARSAT images.*

[Refer to Chapter 2.]

Specifying "not important" on the Request Form will provide you with twice as many opportunities to acquire imagery over your area.

✎ On the RADARSAT Image Request Form, indicate which imaging direction you prefer.

LEVELS OF SERVICE (HOW FAST?)

There are three opportunities in the RADARSAT product acquisition schedule to specify a level of service which meets your requirements. These are:

- *Acquisition planning (When?)*
- *Data processing (Which product?)*
- *Shipping and delivery*

[Refer to Chapter 2.]

These options are identified in the "When?" and "How?" sections of the RADARSAT Image Request Form. A summary of the options available to you follows.

Acquisition planning

1) CATALOGUE SEARCHES: Computer searches of previously-acquired RADARSAT data stored in the archive.

2) PROGRAMMING REQUESTS: The satellite is programmed to collect data. Programming will depend on the availability of satellite resources.

Urgent	• for emergency situations and natural disasters • images acquired on a first available opportunity basis
Priority	• order is finalized seven days in advance • top commercial priority to meet your requested acquisition dates
Basic	• order is finalized fourteen days in advance • request may be pre-empted by Urgent and Priority orders

Processing

Near-Real Time	• digital data processed within hours of data reception at Gatineau, Québec or RADARSAT processing centre with this capability
Rush	• digital data processed within 48 hours of data reception at Gatineau, Québec or RADARSAT processing centre with this capability
Regular	• digital data processed on a first available opportunity basis • digital data processed within fourteen days of data reception at a RADARSAT processing centre

NOTE:
Map Image and Precision Map Image products are not available for Rush and Near-Real Time processing service.

Delivery

Courier	• standard mode of delivery
Electronic	• contact your Client Services representative to arrange this type of delivery

On the RADARSAT Image Request Form, please indicate your preferred level of service for Acquisition planning, Processing, and Delivery. If nothing is indicated, Basic and Regular levels of service will be assumed.

ACQUISITION DATES (WHEN?)

Deciding when to acquire your RADARSAT images will be influenced by:

- *RADARSAT's orbit characteristics,*
- *how quickly you need the data,*
- *your application and operational requirements, and*
- *whether you need to collect supporting data.*

[Refer to Chapter 2.]

If data must be acquired on a specific date because of field work or other application requirements, please indicate it. Otherwise, please provide us with a range of dates during which data can be collected. This will ensure that the optimum beam mode, beam position, and look direction are available. Although we will endeavour to meet your requirements, trade-offs between the optimum beam mode and beam position may occur.

It is possible that the satellite may be unavailable for your requested date due to other scheduled requests. Advance ordering and selecting the appropriate level of programming service will help minimize the possibility of conflicts.

You are encouraged to plan multitemporal image acquisitions as soon as possible. Time intervals corresponding to your requirements for multi-date images can be specified on the RADARSAT Image Request Form. Outlining your requirements in advance will help ensure that the satellite is reserved for you.

On the RADARSAT Image Request Form, please indicate your required image acquisition date(s), multitemporal requirements, and any deadlines which we must meet.

RADARSAT data is processed to one of six products for each RADARSAT beam mode and position. Your choice will depend on:

- *your analysis requirements,*
- *your hardware and software capabilities, and*
- *how quickly you need the data.*

[Refer to Chapter 2.]

A RADARSAT product is the combination of satellite parameters (beam mode and positon) and the processing level. Table 3.2 summarizes the characteristics of each product. Descriptions of each processing level are found in Chapter 2. The availability of processing levels for the various beam modes is summarized in Table 3.3. Please note that Map Image and Precision Map Image products are not available for Rush and Near-Real Time processing service.

TABLE 3.2: RADARSAT product characteristics

PRODUCT NAME	PRESENTATION PLANE	IMAGE ORIENTATION	USER DEFINED INPUT
Signal Data	N/A	N/A	None
Single Look Complex	Slant range	To satellite orbit	None
Path Image	Ground range	To satellite orbit	None
Path Image Plus	Ground range	To satellite orbit	None
Map Image	Ground range	To map	Map projection
Precision Map Image	Ground range	To map	Map projection, ground control points

For Map Image products, the projection and parameters for the projection (see Appendix D) need to be specified. For Precision Map Image products, additional information on ground control points is required. If available, ground control points can be taken from existing maps. You may wish to provide us with maps if your Client Services representative does not have one of your area.

You can also provide GPS information for ground control. Please specify this alternative if applicable.

Product specifications for each beam mode position and processing level are found in Appendix C.

TABLE 3.3: RADARSAT beam mode and processing level availability

BEAM MODE	PATH IMAGE	PATH IMAGE PLUS	MAP IMAGE	PRECISION MAP IMAGE	SIGNAL DATA	SINGLE LOOK COMPLEX
Fine	✔	✔	✔	✔	✔	✔
Standard	✔	✔	✔	✔	✔	✔
Wide	✔	✔	✔	✔	✔	✔
ScanSAR Narrow	✔	N/A	N/A	N/A	✔	N/A
ScanSAR Wide	✔	N/A	N/A	N/A	✔	N/A
Extended High	✔	✔	✔	✔	✔	✔
Extended Low	✔	✔	✔	✔	✔	✔

On the RADARSAT Image Request Form, please indicate the required level of processing. If Map Image or Precision Map Image products are requested, you will need to provide additional information such as projections and parameters, and the availability of ground control points.

PRODUCT STORAGE (WHICH MEDIA?)

Your RADARSAT product will be delivered on a digital medium unless you specify otherwise. Digital products are available on Computer Compatible Tape (CCT), data cartridges, or CD-ROM. Please indicate the digital medium you prefer. Hardcopy products are generated on request. Table 3.4 shows the digital file sizes and the scales for RADARSAT film products. Prints can be generated from film at user-defined scales.

TABLE 3.4: RADARSAT digital file sizes and film scales

BEAM MODE	PROCESSING LEVEL	DIGITAL IMAGE SIZE (PIXELS x LINES)	DIGITAL FILM SIZE (MB)	FILM IMAGE SIZE (CM)[a]	FILM SCALE (1:)
Fine	Path Image Plus	16,000 x 16,000	512	N/A	N/A
	Path Image	8,000 x 8,000	128	20 x 20	1:250,000
	Map Image	8,000 x 8,000	64	20 x 20	1:312,500
Standard	Path Image Plus	12,500 x 12,500	313	N/A	N/A
	Path Image	8,000 x 8,000	128	20 x 20	1:500,000
	Map Image	8,000 x 8,000	64	20 x 20	1:625,000
Wide	Path Image Plus	15,000 x 15,000	450	N/A	N/A
	Path Image	12,000 x 12,000	288	15 x 15[b]	1:250,000
	Map Image	12,000 x 12,000	144	20 x 20[c]	1:625,000
ScanSAR Narrow	Path Image	12,000 x 12,000	144	15 x 15[b]	1:500,000
ScanSAR Wide	Path Image	10,000 x 10,000	100	20 x 20	1:625,000
Extended High	Path Image Plus	9,375 x 9,375	176	N/A	N/A
	Path Image	6,000 x 6,000	72		
	Map Image	6,000 x 6,000	36		
Extended Low	Path Image Plus	17,000 x 17,000	578	N/A	N/A
	Path Image	13,600 x 13,600	370		
	Map Image	13,600 x 13,600	185		

NOTES:
Precision Map Image products have the same specifications as Map Image products.
a Film size is 24 x 24 cm.
b The digital product is divided into quarters and imaged onto four 24 x 22 cm film transparencies.
c The 8,000 x 8,000 line image is noted to be NORTH UP which requires approximately 40% additional image area.

Limited processing of the imagery is carried out before a film transparency is created. A histogram stretch is performed to ensure that maximum contrast is achieved in the imagery.

On the RADARSAT Image Request Form, please specify the desired storage medium for your digital product. If a print is requested, you may also indicate the desired output scale.

SHIPPING AND DELIVERY

Shipping is the final stage of the process in obtaining your RADARSAT product. If your product has been processed at our Richmond, British Columbia or Gatineau, Québec facility, the standard method of shipping will be by courier. We can arrange the shipping or you can make your own shipping arrangements. Please provide us with your shipping address as well as the address of your accounting department for invoicing purposes.

Delivery of RADARSAT products from either our Richmond or Gatineau processing centre to destinations in most major cities will usually take:

- 1 day (North America),
- 2 days (Europe), or
- 3 days (Latin America, Asia, Africa, Middle East).

✎ On the RADARSAT Image Request Form, please indicate your preferred method of shipping and provide your shipping and invoicing address.

Once your RADARSAT product is delivered to you, the next step is to decide how best to utilize the data. Your RADARSAT product and the information derived from it can be integrated with:

- RADARSAT products acquired on previous dates (you may have already purchased a multitemporal data set),
- other satellite data (e.g., Landsat or SPOT), and
- other data sets.

In this chapter, we provide some general guidelines on how to get started in using your RADARSAT product(s). The following topics will be highlighted:

- A first look at the data,
- Enhancing the appearance of the RADARSAT image product,
- Image manipulation,
- Integrating RADARSAT products with other data sets, and
- Output.

A FIRST LOOK AT THE DATA

Hardcopy products

Hardcopy products are often the most convenient product media to use. They are portable and can be easily used in remote locations. Also, prints and film products can be utilized as field maps and interpreted directly to extract application information. Hardcopy RADARSAT products contain the actual image plus auxiliary information. The auxiliary information is outlined in Table 4.1.

Digital products

Digital RADARSAT products can provide you with greater flexibility in how the data is manipulated and utilized. All digital RADARSAT products conform to CEOS (Committee of Earth Observation Satellites) format standards.

You can read the CEOS format using any leading commercial image analysis software package. A list of RADARSAT-compatible software packages is available from Client Services. However, if you are unable to read your digital RADARSAT data, we can provide you with a CEOS reader which will decode the auxiliary text files and copy the data to your hard drive. A detailed description of the CEOS format is available from your Client Services representative.

TABLE 4.1: Hardcopy film annotation

TEXT ANNOTATION CATEGORY	PARAMETER	EXAMPLE INFORMATION
Mission and Sensor Parameters	Satellite / Sensor ID	RADARSAT 1 / SAR
	Radar Frequency / Polarization	5.3 GHz / HH Polarization
	Beam Mode	Standard 3
	Nominal Incidence Angle (deg)	34.00
	Ground Track Heading	+344.914 A
	Orbit Absolute / Relative	1577 / 12
Acquisition Parameters	Scene Centre Time	GMT 01APR96 13:23:45
	Archive ID	123456789
Processing Parameters	Processing Data	GMT 03APR96 11:22:45
	Processing Facility	CDPF
	Number of Looks	Azim 4 / Range 1
	Pixel Spacing	Azimuth / Range: 12.5 m
	Algorithm	Range Doppler
Image Presentation	Film Production Date	PST 04APR96 22:10:14 GMT
	Image Size (lines / pixels)	8000 / 8000
	Image Centre Coordinates	N 33-15-15 E 187-34-10
	Map Projection / Geoid	UTM / NAD 1923
Product Information	Production Order Number	123456
	Product Type	Path Image
	Copyright	Copyright CSA 1996

ENHANCING THE APPEARANCE OF THE RADARSAT IMAGE PRODUCT

RADARSAT image products can be described in terms of “lines of data”. Each line of data is sub-divided into a number of pixels or “cells”. A product may have 8000 lines of data, each consisting of 8000 pixels. Each pixel is associated with an area on the earth’s surface and has a corresponding numerical value. This value represents an estimate of the strength of the radar signal returned from that area on the earth’s surface. The numbers range in value from 0 to 255 (for 8-bit Map Image products), and when combined, provide a two-dimensional matrix of cells with varying degrees of brightness that we refer to as an image.

A radar pixel is rarely interpreted individually, but rather in combination with surrounding pixel values creating shapes and patterns which provide the basis for interpreting features on the earth. In order to ensure that these pixel values relate to variations in earth surface conditions, the RADARSAT image is calibrated to compensate for errors related to satellite movement, the SAR antenna, and ground reception. Four calibration sites in Canada are used to routinely check the quality of the data being collected. Calibration provides a means of ensuring the consistency of data quality both within the image (relative calibration) and from one image to another (absolute calibration).

Calibration information is indicated in the ancillary file included with your digital data. The calibration parameters are used to calculate the *backscatter coefficient*. This is important if you are interested in quantitatively measuring, for example, soil moisture, snow water equivalent, or other quantities which can be directly related to the backscatter. For these measurements you need to have greater confidence in the values represented in the image. However, the precise values may be less important if you are looking at patterns to distinguish one agricultural field from another. More information on calibration is available in Appendix C.

As mentioned previously, the pixel values represent the strength of the returned radar signal from the earth's surface. For each surface feature, there is a statistical distribution of the probable strength of that returned signal. Each pixel representing that surface will be assigned a value randomly selected from the statistical distribution. Therefore, a seemingly homogeneous surface area will have an irregular distribution of light and dark pixels, producing a granular effect. This effect is termed "*speckle*" and is an inherent property of radar images.

Speckle can be controlled at the initial image processing stage by data sampling. This sampling is defined as the *number of looks* associated with a particular image product. Unfortunately, there is a trade-off between image resolution and processing looks. As a result, RADARSAT Fine beam mode products (which provide 10 m resolution) are single look images in both *range* (x axis) and *azimuth* (y axis) while RADARSAT Standard beam mode products (30 m resolution) are four look images in azimuth and one look in range. Although RADARSAT Fine beam mode products have better resolution, their appearance may be more granular than Standard beam mode products.

You can also modify speckle by utilizing filtering techniques included in the radar modules of commercially available image analysis software packages. Typically, these filters employ various techniques of pixel averaging to smooth out the speckle. Although smoothing can produce a less granular texture, it creates larger pixels and may give the appearance of softened edges in the image. The extent to which these effects are apparent will vary with the filtering technique and how it is implemented.

Table 4.2 describes a number of common filters which are used to reduce speckle. The more complex filters can average relatively homogeneous areas yet retain finer scale variability. However, these filters are generally more computationally intensive than the more simple filters.

TABLE 4.2: Common image filters

FILTER	WHAT IT DOES	WHEN TO USE RADAR
Median	Uses the mid pixel value for a user defined window	Areas of relatively homogeneous terrain
Mean	Averages pixel values for a user defined window	Areas of relatively homogeneous terrain
Adaptive Filters (e.g., Lee, Frost)	Selectively smooths speckled areas while preserving point target detail	Areas where specific details need to be retained

IMAGE MANIPULATION

For many applications, it is necessary to geometrically adjust the satellite imagery to ensure that the image conforms to a particular geographic coordinate system. This is especially important because of the unique characteristics associated with the radar sensor's viewing geometry and the type of information represented in the radar image. Moderate to high terrain relief can affect the positional accuracy of ground features in the radar image. Appendix C provides more information on the expected positional accuracy of RADARSAT products.

In ordering your RADARSAT data, you will have specified what type of product you needed according to the level of geometric accuracy you require. Applying a projection to the data (e.g., Map Image) is fairly common. To increase positional accuracy, ground control points (GCPs) should be used (e.g., Precision Map Image).

The unique image characteristics of radar including speckle and elevation related effects (such as layover and shadow) may make it difficult to find suitable control points for registration to a reference map. Likewise, the quality of available maps for registration may pose problems. Using GPS technology may be a realistic alternative to obtaining ground control points. If so, you may want to take a print of your RADARSAT image to the field when collecting GPS ground control points. This will allow you to pinpoint the location of your GPS measurements on the image.

Positional inaccuracies will also be created by elevation differences within the image. If a suitable Digital Elevation Model (DEM) is available, it can be used to correct distortions such as foreshortening and layover. Although the use of DEMs will correct the positioning of hills and mountains, new radiometric information for the foreshortened or shadowed areas cannot be generated.

INTEGRATING RADARSAT PRODUCTS WITH OTHER DATA SETS

Depending on your application, a single RADARSAT image may be the only data you need. For some applications, however, it may be useful to have several RADARSAT images which cover a large area or have been acquired at different times or from different look directions. Furthermore, you may want to integrate (or fuse) RADARSAT data with other image products, map data, or database information associated with features on the image.

When you need images of a large area, it will be necessary to mosaic several RADARSAT images together. Mosaicking should follow the geometric correction process. Various image analysis packages can be used to join RADARSAT images and adjust the radiometric properties to produce a seamless mosaic.

There are a number of approaches to data integration (data fusion), and the approach you choose will be determined by the types of data you intend to integrate. Approaches to consider include:

- co-registration of images,
- digital image fusion techniques, and
- overlaying point, vector, or grid data.

Co-registration entails the linking of two or more images by registering a point on one image to a matching point on another image. If the images are the same product (e.g., two Standard beam mode RADARSAT images acquired at different times over the same area), a pixel on one image can be registered to a matching pixel on the other image. If images of different resolutions are to be co-registered, you will need to first register the images to a map base and then use the associated coordinate system to re-sample and co-register the two images.

Images can be fused using multi-channel image combination techniques. One technique known as an IHS (Image-Hue-Saturation) Transformation is a common method to fuse both optical and radar images. Three channels of optical or other data are represented as Red-Green-Blue (RGB) channels in a digital image. Using image analysis software, the RGB image is converted to an IHS image. The intensity channel (I) is then replaced with the radar image while the optical data remains in the hue (H) and saturation (S) channels. The result retains most of the multi-spectral information while the radar image accentuates terrain features.

Although a RADARSAT image consists of an array of pixels, utilization of the image in a Geographic Information System (GIS) will probably require that vector and point information such as roads, rivers, or political boundaries be matched to the data. In this case, co-registration is based on registering both images and vectors to a common coordinate system (map projection).

OUTPUT

Hardcopy output from digital files can be produced in a number of ways, and we can assist you by providing a high quality transparency from which prints can be made. Please call your Client Services representative for more information.

APPENDIX A

RADARSAT PROGRAM SPECIFICATIONS

The RADARSAT Program

RADARSAT is a sophisticated Earth observation satellite developed by Canada, and provides the world with the first operationally-oriented radar satellite system capable of timely delivery of large amounts of data. RADARSAT was developed under the management of the Canadian Space Agency (CSA) in cooperation with NASA / NOAA, provincial governments, and the Canadian private sector. CSA manages the program and operates the Mission Management Office. The Canada Centre for Remote Sensing (CCRS) receives the data at the Gatineau, Québec and Prince Albert, Saskatchewan ground receiving stations. RADARSAT International (RSI), a private sector company, has the exclusive rights to distribute the data worldwide, and operates the processing facilities in Gatineau, Québec and Richmond, British Columbia, Canada. NASA and NOAA launched RADARSAT in exchange for access to data and private sector participation in data distribution.

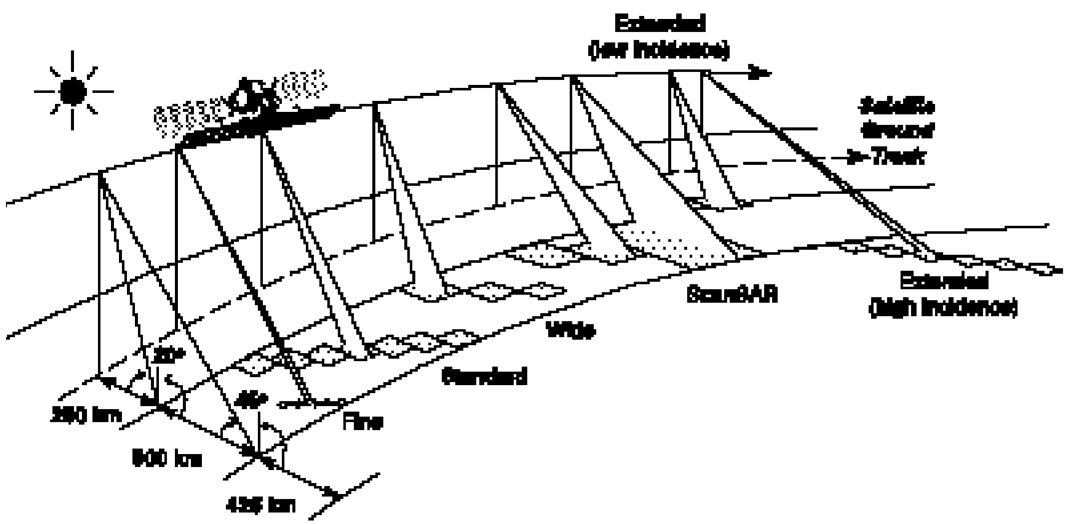
The governments of British Columbia, Saskatchewan, Ontario, and Québec have contributed funding to the program. New Brunswick, Nova Scotia, Prince Edward Island, Manitoba, and Alberta have pre-purchased data.

RSI was formed by three of Canada's leading aerospace companies including SPAR Aerospace of Toronto, Ontario, Canada; COM DEV of Cambridge, Ontario, Canada; MacDonald Dettwiler and Associates of Richmond, British Columbia, Canada. An American investor, Lockheed Martin Astronautics of Denver, Colorado, United States, bought equity in the company in 1994. RSI has its headquarters in Richmond, British Columbia and maintains a branch office in Ottawa, Ontario, Canada.

The SAR antenna

RADARSAT is equipped with an advanced Synthetic Aperture Radar (SAR) using:

- C-band wavelength (5.6 cm)
- HH polarization (Horizontally transmitted, Horizontally received)
- Right looking, steerable antenna
- ScanSAR capability for wide area coverage
- Multimode image capabilities



COURTESY RADARSAT PROGRAM OFFICE / CANADIAN SPACE AGENCY

The RADARSAT SAR can be steered to image over a 500 km swath using a number of imaging modes. This provides users with superb flexibility in acquiring images with a range of resolutions, incidence angles, and coverage areas. Specifications for RADARSAT images and products are outlined in Appendix C.

RADARSAT data handling system

RADARSAT's SAR will not be collecting data continuously. The satellite will be programmed to use specific beam positions only when a request to collect data has been made.

The payload computer can store 20 beam positions at one time. The payload computer will be programmed to define which 20 positions are accessible. It can be reprogrammed if a user request for a different beam position is made.

As the RADARSAT data is collected, it will either be transmitted to a participating ground reception station or stored on a tape recorder and later downlinked to a ground station. Real time and tape recorded downlinks can be executed simultaneously through two X-band RF links. All auxiliary data that is available on the satellite and is necessary for data processing, image quality monitoring, and calibration will be included in the downlink.

Tape recorded data

RADARSAT has two onboard tape recorders which are primarily used to store data over areas which do not have participating ground reception stations. Only one tape recorder at a time is used; each tape recorder can store 10 minutes of SAR data. The second acts as a back-up in case the first fails.

The tape recorder is capable of playing back the signal data at a rate of 85 Mb/s (compared to the real time downlink of 105 Mb/s). This results in reduced coverage for some beam mode products. Table A.1 summarizes beam mode size reductions when using tape recorded data.

TABLE A.1: Differences in swath coverage:
Real time downlink and tape recorded downlink

BEAM MODE	NOMINAL REAL TIME DOWNLINK SWATH (KM)	NOMINAL TAPE RECORDED DOWNLINK SWATH (KM)
Fine	50	43
Standard	100	100
Wide 1	165	164
Wide 2	150	138
ScanSAR Narrow	300	292
ScanSAR Wide	500	447
Extended High	75	70
Extended Low	170	170

SAR on-time and switching

The SAR instrument can collect 28 minutes of data per orbit. During one orbit, there may be more than one beam position which must be collected. The following describes how the system operates when beam positions have to be switched:

- one minute (or approximately 400 km along the orbit track) is the minimum length of a data acquisition (clients only purchase what they need);
- the SAR is designed to permit six on and off cycles per orbit;
- it takes approximately five seconds to switch between SAR off, standby, and an operating mode; and
- it takes less than five seconds to switch between beam modes and positions.

The RADARSAT orbit

RADARSAT will be placed in a near-polar, sun-synchronous orbit 798 km above the earth. It has a dawn-to-dusk orbit, meaning it crosses the equator at dawn and dusk, and is rarely in eclipse or darkness. The orbit characteristics are:

Geometry	Circular, sun-synchronous (dawn-dusk)
Altitude	798 km
Inclination	98.6°
Period	100.7 minutes
Repeat Cycle	24 days
Orbits Per Day	14

RADARSAT system specifications

Frequency	5.3 GHz
Wavelength	5.6 cm (C-band)
RF Bandwidth	11.6, 17.3 or 30.0 MHz
Sampling Rate	12.9, 18.5 or 30.0 MHz
Transmit Pulse Length	42.0 µs
Pulse Repetition Frequency	1270 - 1390 Hz
Transmitter Peak Power	5 kW
Transmitter Average Power	300 W (nominal)
Average Radar Data Rate	73.9 - 100.0 Mb/s
Sample Work Size	4 bits each I and Q
Antenna Size	15.0 x 1.5 m
Antenna Elevation Phase Shifter Quantization	8 bits

Satellite dimensions

Launch Mass	2750 kg
Solar Array	3.5 kW
Batteries	3 x 48 Ah NiCd
Design Lifetime	5 years

APPENDIX B
APPLICATION CONSIDERATIONS FOR RADARSAT

The following tables represent some general application information which may help you in defining:

- where RADARSAT will be useful,
- the type of information RADARSAT can provide, and
- suggested beam mode / beam position combinations for an application.

The information in these tables is based on research and experience gained without the benefit of actual RADARSAT data. These are general guidelines and do not take into consideration local conditions. For detailed information on specific applications, please see Selected References in Appendix F or call your Client Services representative for additional assistance.

In this document, the definitions of mapping scales are:

- Large Scale - 1:50,000
- Medium Scale - 1:50:000 to 1:100,000
- Small Scale - 1:250,000 +

Shallow incidence angles refer to beam positions in the far range (Fine, S5 to S7, or Extended) of RADARSAT's 500 km swath.

Steep incidence angles refer to beam positions in the near range (S1 to S4, or W1) of RADARSAT's 500 km swath.

Agriculture / land use

APPLICATION	TYPICAL ACTIVITIES / PARAMETERS REQUIRED
Crop Assessment	Determination of crop type and area. Assessment of vegetation biomass; crop damage.
Compliance Monitoring	Assessment of farming activity. Differentiation between tilled and cropped land.
Land Use Monitoring	Evaluation of land use patterns and temporal change.
Soil Condition Monitoring	Assessment of soil moisture and erosion by wind and water.

General guidelines

- Standard beam mode is useful for crop area estimation and crop type discrimination.
- Fine beam mode is useful for assessing crop damage.
- In deciding on a beam mode, it is advisable to match the resolution with the size of the agriculture field being imaged.
- Shallow incidence angles are useful for delineation of land use activities.
- Shallow incidence angles may be more useful for crop type monitoring.
- Steep incidence angles may be more useful for vegetation and soil moisture studies.
- Selecting an appropriate look direction (ascending versus descending orbit passes) is important when row crops are being imaged. Choose the look direction which will provide the most oblique view of the crop rows.
- Multitemporal imagery is effective for crop type classification and growth stage/change monitoring.
- If imaging time is important, (e.g., early morning if the presence of dew is desired), you can use either an ascending or a descending orbit pass. RADARSAT crosses the equator in descending mode at 6 a.m. and in ascending mode at 6 p.m. (18:00H).

Cartography

APPLICATION	TYPICAL ACTIVITIES / PARAMETERS REQUIRED
Base Mapping	Mapping of terrain form and land use, land cover and cultural features.
Topographic Mapping	Mapping of terrain elevation, X, Y, Z coordinates.

General guidelines

- Fine and Standard beam modes are effective for mapping at medium scales.
- Wide and ScanSAR beam modes are effective for small scale base mapping and terrain mapping.
- Imaging an area using more than one beam position provides different look angles. These can be used for stereo matching in topographic mapping.
- Shallow incidence angles are recommended to avoid terrain distortions in mountainous areas, particularly when no DEMs are available.
- Shallow incidence angles accentuate land cover variations and are effective for mapping terrain form.
- Terrain relief is a factor in beam mode and incidence angle selection.

  Low relief - Incidence angle selection is not critical; medium and small scale mapping is possible with Wide, Standard, and Fine beam modes.

  Moderate relief - Shallow incidence angles are preferable; medium and small scale base mapping is possible with Wide, Standard, and Fine beam modes. Small scale topographic mapping is possible.

  High relief - Shallow incidence angles are preferable; acquisition of ascending and descending pass images should be considered to eliminate radar shadow; medium to small scale base mapping is possible with Wide and Standard beam modes. Small scale topographic mapping is possible with Standard and Fine beam modes.
- For base mapping and correction of imagery using DEMs, ground control points are required to optimize accuracy.
- For base map updating, Standard and Fine beam modes are most effective.

Coastal zone

APPLICATION	TYPICAL ACTIVITIES / PARAMETERS REQUIRED
Coastal Zone Mapping	Identification of water-land boundaries, coastal vegetation, coastline changes, and human activities. Monitoring zones of high erosion or accretion.
Ship Detection	Detection of ships and ship wakes. Ship surveillance.
Oil Spill Detection and Monitoring	Monitoring illegal dumping of oil from ships. Strategic support for oil spill emergency response decisions. Identification of natural oil seepage areas.
Aquaculture Site Detection	Identification and monitoring of aquaculture sites. Identification of potential new sites.
Bathymetry	Hydrographic mapping for updating hydrographic charts and shipping corridors.

Oceans

APPLICATION	TYPICAL ACTIVITIES / PARAMETERS REQUIRED
Mesoscale Features	Mapping of mesoscale currents and regional circulation patterns. Identification of frontal zones, internal waves, eddies, upwellings, shears, and wind fronts.
Wave Spectra	Synthesized wave spectra from SAR spectra for forecast/ numerical models.

- The success of RADARSAT in detecting various coastal and ocean parameters will depend not only on the beam mode and position, but also on environmental and weather related conditions. It may be useful to collect auxiliary information (such as wind speed) on the date of the RADARSAT acquisition to help you in your interpretation.

- Wide and ScanSAR beam modes are useful for small scale monitoring and mapping activities. ScanSAR is effective for mapping mesoscale ocean features.

- Standard beam mode is effective for monitoring small to medium scale oil spills and ship detection.

- Fine beam modes is useful for monitoring aquaculture sites.

- Increased temporal coverage over selected areas can be achieved by varying the beam position and using extended beam modes.

- Fine beam modes and steep incidence angles are preferred for wave spectra applications.

- Wave spectra applications require information on local wind direction to eliminate the 180° ambiguity in the wave direction.

- Shallow incidence angles improve the detection of oil spills. Detection will also depend on the spill size and the resolution of the beam mode.

- The detection of oil spills is also affected by the ability to discriminate between oil-induced backscatter and ambient background noise. This is influenced by environmental parameters such as wind speed, wave conditions, and oil type.

- The probability of detecting ships increases using shallow incidence angles.

- The detection of ships is also affected by ship length, ship travel speed, wind speed, and to some extent, the travel direction of the ship with respect to the satellite's look direction. In general, the probability of detecting ships increases with ship length and decreases with high wind speeds. The detection of ship wakes improves as the speed of the vessel increases and as the speed of the wind decreases.

- The detection of aquaculture cages and weirs depends on the size versus the resolution of the beam mode. Detection increases using shallow incidence angles and when wind speeds are low.

- Differences in sea bottom topography can be inferred when the ocean depth is less than 10 -15 m.

Forestry

APPLICATION	TYPICAL ACTIVITIES / PARAMETERS REQUIRED
Clear Cut Mapping	Identification and delineation of logging roads and forest clear cuts from uncut forest.
Deforestation Mapping	Identification and mapping of all types of forest disturbances.
Broad Forest Type Mapping	Identification of general forest classes.

General guidelines

- Fine and Standard beam modes are effective for deforestation mapping at medium scales.
- Wide and ScanSAR beam modes are effective for small scale overview forest mapping.
- Shallow incidence angles are preferred for clear cut and general deforestation mapping because land cover variations are accentuated.
- In mountainous terrain, avoid geometric distortions by using shallow incidence angles. Radar shadow can be reduced or eliminated if images from both ascending and descending orbits are obtained.
- Data acquisitions should be planned for periods of maximum difference between the condition of the cut blocks and the forest, e.g., high humidity in the forest canopy and drier conditions in the cut blocks.
- In temperate regions, it is preferable to plan acquisitions when snow cover is present. Cut blocks have a darker return because the snow pack has a surface roughness smoothing effect and decreases the radar backscatter.
- Species discrimination and broad forest type mapping may require multi-date acquisitions.
- RADARSAT shows good potential for forest base map updating (change detection and forest monitoring) when base information exists.

Geology

APPLICATION	TYPICAL ACTIVITIES / PARAMETERS REQUIRED
Geologic Mapping	Mapping of geological structure, lithology, and lineaments.
Quaternary Mapping	Delineation of landforms and assessment of surface material.
Mineral Exploration	Identification of linear and curvilinear features such as dykes, faults, lithological charts, structures, alteration zones, and high fracture zones.
Hydrocarbon Exploration	Mapping of bedrock stratigraphy, structure, sedimentology, strikes and dips, and lineaments.
Geologic Hazard Identification	Identification of seismic zones and fracture systems. Assessment of landslide hazards and coastal erosion.

General guidelines

- RADARSAT's multiple imaging modes permit flexibility and offer a selection of optimum resolutions and coverages for specific applications.
- Standard and Fine beam modes provide optimal information for geological structure mapping.
- Wide and ScanSAR beam modes can be used to obtain broad overview coverage, particularly for the definition of major structural patterns and landforms.
- Ability to select shallow (>40°) incidence angles may be useful for optimization of structural definitions.
- Given the orientation of structural features, care should be taken in the selection of ascending versus descending orbit passes. Detection is enhanced when features are aligned near-perpendicular to the satellite's look direction.
- For moderate to high relief terrain, consider acquisitions of both ascending and descending passes to maximize the number of structural features that can be identified.
- Merging RADARSAT data with geophysical data provides surface and sub-surface information.
- Beam mode and position performance will be influenced by topography (see Table B.1).

Hydrology

APPLICATION	TYPICAL ACTIVITIES / PARAMETERS REQUIRED
Soil Moisture	Run-off estimates. Watershed modelling.
Flood Mapping	Mapping spatial extent of flooding. Tactical support for emergency response to flooding in critical areas.
Freshwater Ice Mapping	Detection of ice in rivers and lakes.
Snow Mapping	Delineation of the extent of the snow-pack. Measurement of snow water equivalent and snow wetness.

General guidelines

- Wide and ScanSAR beam modes provide small scale coverage for flood mapping.
- Fine beam mode is effective for monitoring narrow lakes, rivers, and relatively small areas in great detail.
- Increased temporal coverage permits frequent observations of time-sensitive activities such as flood monitoring.
- Steep incidence angles are preferred for soil moisture studies.
- Mapping of snow depends on the degree of snow wetness.
- The backscatter characteristics of freshwater ice are similar to sea ice. However, the detection of freshwater ice can be hampered by the smaller size of some lakes and rivers (as compared to the size of the ocean).

Sea ice / icebergs

APPLICATION	TYPICAL ACTIVITIES / PARAMETERS REQUIRED
Sea Ice Mapping	Regional scale mapping of ice concentration, edge location, ice type, motion, and surface topography.
Marine Transportation Support	Tactical identification of leads, ice type, and surface topography.
Fisheries Support	Identification of ice edge.
Iceberg Monitoring	Detection and tracking of icebergs.

General guidelines

- ScanSAR provides regional mapping capability for sea ice concentration, ice edge, motion, and ice type classification.
- ScanSAR may be useful for tactical navigation depending on the actual ice environment.
- Standard beam mode provides detail for medium scale mapping and tactical navigation support.
- Incidence angle is not a critical factor in sea ice monitoring, however, shallow angles are more effective in highlighting surface topography.
- Shallow incidence angles can improve detection of icebergs.
- RADARSAT's polar orbit enhances coverage for ice environments.
- Guaranteed SAR coverage supports frequent monitoring and short notice acquisitions.
- RADARSAT's HH polarization differentiates between open water and ice better than VV polarization.
- The appearance of a given ice feature may differ significantly in wet versus dry conditions. When surface meltwater is on the ice or near the ice edge where ocean spray may occur, feature brightness may differ from dry conditions.
- When wet surface conditions prevail, it is useful to have a reference image acquired before the onset of melt conditions.

TABLE B.1: RADARSAT SAR beam mode performance guidelines

		Fine					Standard							Wide		ScanSAR	
	Beam position	F1	F2	F3	F4	F5	S1	S2	S3	S4	S5	S6	S7	W1	W2	SN	SW
	Resolution (m)	10x9	10x9	10x9	10x9	10x9	25x28	25x28	25x28	25x28	25x28	25x28	25x28	48x30	32x30	50x50	100x50
	Nominal swath width (km)	50	50	50	50	50	100	100	100	100	100	100	100	165	150	300	500
	Incidence angle (degrees)	37-40	39-42	41-44	43-46	45-48	20-27	20-27	20-27	20-27	20-27	20-27	20-27	20-31	31-40	20-40	20-50
Agriculture	Crop Type, Acreage	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3
	Soil Moisture	3	3	3	3	3	2	2	2	3	3	3	3	3	3	2	2
	Crop Yield, Biomass	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Soil Conservation	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2
Cartography	Base Map Production	2	2	2	2	2	3	2	2	2	2	2	2	3	2	3	3
	Topographic Mapping	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	DEM	2	2	2	2	2	3	3	2	2	2	2	2	3	2	3	3
Coastal Zone	Coastal Zone Mapping	2	2	2	2	3	2	2	2	2	2	3	3	2	2	2	2
	Ship Detection	2	2	2	2	2	3	3	2	3	2	2	2	3	2	2	3
	Oil Slick Det./Mon.	2	2	3	3	3	2	2	2	3	3	3	3	3	3	3	3
	Effluent	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Erosion Mapping	3	3	3	3	3	3	3	2	2	2	2	2	2	2	3	3
	Aquaculture Site Det.	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3
	Estuary Outflow	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Bathymetry	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Forestry	Deforestation	2	2	2	2	2	3	3	3	2	2	2	2	3	3	3	3
	Broad For. Type Map.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Species Determination	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Clearcut Mapping	2	2	2	2	2	3	3	2	2	2	2	2	3	3	3	3
	Timber Yield	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Geology	Structure	1	1	1	1	1	3	2	1	1	1	1	1	3	2	3	3
	Lithology	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Surficial Material	2	2	2	2	2	3	3	2	2	2	2	2	3	2	3	3
	Geobotany	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Terrain/Landform	2	2	2	2	2	3	3	3	2	2	2	2	3	2	2	2
Hydrology	Soil Moisture	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Flood Mapping	1	1	1	1	1	3	2	1	1	1	1	1	3	2	3	3
	River/Lake Ice Mapping	2	2	2	2	2	3	2	2	2	2	2	2	3	2	3	3
	Snow Mapping	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Ice	Ice Motion	2	2	2	2	2	2	2	1	1	1	1	1	2	1	1	1
	Iceberg Tracking	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Ice Concentration	2	2	2	2	2	2	2	1	1	1	1	1	2	1	1	1
	Ice Classification	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2
Land Use	Land Cover	2	2	2	2	2	3	2	2	2	2	2	2	3	2	3	3
Oceans	Mesoscale Features	3	3	3	3	3	2	2	2	2	2	2	2	2	3	2	2
	Wave Spectra	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	n/a

Beam Mode Performance: 1- very good standalone information 2- good standalone information 3- complementary information

NOTE:
Beam mode performance will vary depending on local conditions and on other factors such as the use of multi-date data.

APPENDIX C
RADARSAT PRODUCT SPECIFICATIONS

This Appendix is divided into three sections, highlighting key specifications for RADARSAT images and products which may be important to your application.

The first section, RADARSAT comparable products identifies:

- RADARSAT products, and
- comparable products from the Landsat, SPOT, and ERS satellites.

The second section, RADARSAT image quality specifications, describes the expected quality of all RADARSAT products including:

- radiometric accuracies, and
- positional accuracies.

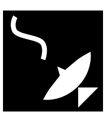
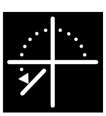
The third section, Product specifications, identifies and provides information on two unique product features of the RADARSAT system:

- ScanSAR, and
- Path Image and Path Image Plus.

Following these descriptions, Product specification tables identify for each beam mode:

- variations in specifications between beam positions,
- variations in specifications between processing levels, and
- digital file specifications.

TABLE C.1: RADARSAT comparable products

	RADARSAT	ERS (Europe)	ERS (North America)	SPOT	Landsat
	PATH IMAGE (SGF)	PRECISION IMAGE GEOREFERENCED (PRI)	GEOREFERENCED FINE RESOLUTION (SGF)	1B	PATH ORIENTED SYSTEMATIC OR PRECISION CORRECTION
	PATH IMAGE PLUS (SGX)	N/A	N/A	N/A	N/A
	MAP IMAGE (SSG)	GEOCODED IMAGE (GEC)	SYSTEMATICALLY GEOCODED (SSG)	2A	MAP ORIENTED SYSTEMATIC CORRECTION
	PRECISION MAP IMAGE (SPG)	TERRAIN GEOCODED IMAGE (GTC)	PRECISION GEOCODED (SPG)	2B	MAP ORIENTED PRECISION CORRECTION
	SIGNAL DATA	RAW[1]	RAW[1]	1A[2]	RAW[2]
	SINGLE LOOK COMPLEX (SLC)	SINGLE LOOK COMPLEX (SLC)	SINGLE LOOK COMPLEX (SLC)	N/A	N/A

NOTES:

1 SAR Signal Data (RADARSAT, ERS) cannot be viewed as an image.

2 Optical RAW data (SPOT, Landsat) can be viewed as an image.

RADARSAT image quality specifications

One of the key attributes of the RADARSAT program is that RADARSAT image products are fully calibrated. Image quality control is applied end-to-end, including the SAR instrument, data handling systems, and the processor. The RADARSAT system and processing facility in Gatineau, Québec, Canada has been designed to meet specific image quality characteristics which are outlined in Tables C.2 and C.3.

TABLE C.2: RADARSAT radiometric / image quality parameters

Radiometric Accuracy (goals)	
Within one scene	< 1.0 db
Within one orbit	< 1.5 db
Over three days	< 2.0 db
Over life of satellite	< 3.0 db
Radiometric Error	< 12.0 db
Radiometric Linearity	> .97
Total Signal Dependent Noise Ratio	< -9.2 db
Azimuth Ambiguity Ratio	< 22.0 db
Range Ambiguity Ratio	<-18.0 db
Peak Side Lobe Ratio	<-20.0 db
Global Dynamic Range	30.0 db (approx).

There are two fundamental requirements for radiometric calibration:

- relative radiometric calibration stability, and
- absolute radiometric calibration knowledge.

The relative calibration stability refers primarily to the electrical stability of the radar sensor and its ability to provide repeatable measurements over time. The RADARSAT system is designed to achieve the goals listed in Table C.2. Absolute radiometric calibration is required so that the magnitude of the digital processed data can be related to the radar backscatter coefficients. To achieve this accuracy, detailed measurements of the radar and processing system performance are made on a regular basis.

A network of calibrated reference targets includes:

- precision active transponders set to a known radar cross section,
- passive corner reflectors, and
- areas of known distributed target backscatter coefficients.

These are used to ensure image quality by providing corrections for SAR antenna gain and pattern, system performance, and processor focus and efficiency.

The final step in producing a radiometrically calibrated product is an adjustment of the output scaling of the processor to ensure optimum use of the 16-bit dynamic range. Any offsets and look up tables applied to the data are provided in the CEOS Radiometric Data Record included with each product (except Signal Data). This provides all the information necessary to extract radar backscatter values from the imagery. All RADARSAT products are calibrated except Signal Data.

For Map Image and Precision Map Image processing which spatially resamples the data, some changes to the radiometric calibration may occur. Projects which require detailed radiometric analysis should use Path Image or Path Image Plus products.

Positional accuracy and geometric calibration

Positional accuracies will depend on the quality of the satellite positional information used to correct the data and the terrain being imaged. Geometric calibration is the process of measuring various geometric errors within an image or set of images. The accuracy can be separated into absolute error terms (those referenced to a fixed map coordinate system) and relative error terms (errors within a single image).

Relative positional error is characterized by image scale and skew errors. Image scale accuracy is the error between the length of a line in the image relative to the length of line within a map coordinate system. Skew errors refer to errors between a given angle in the image (e.g., a road intersection) relative to the axis of the map coordinate system.

Absolute error is characterized by two factors:

- absolute positional accuracy which relates to the uncertainty of the location of an image pixel relative to a map coordinate system, and
- image orientation which relates to the uncertainty of a line on an image relative to the axis of the map coordinate system.

The absolute positional accuracy will depend on the accuracy of the satellite orbit information. For Rush and Near-Real Time processing service products, predicted satellite information (which is downlinked with the data from the satellite) is used. For Regular processing service products, the satellite positional information is provided by the ground Telemetry, Tracking and Command stations. This information has greater accuracy and will increase the absolute positional accuracy of the image (see Table C.3).

TABLE C.3: Levels of RADARSAT geometric accuracy

RADARSAT IMAGE PRODUCT *CHARACTERISTICS*	SPECIFICATION	ESTIMATE	RELATIVE GEOMETRIC ERROR*	BEAM MODES SUPPORTED
Path Image (Rush / Near-Real Time service)	< 1.5 km	< 630 m	< 40 m	Standard, Fine, Wide, ScanSAR
• *Image is aligned along the satellite path (approx. 8° from North).* • *Image corrected for systematic errors related to satellite movement, the SAR instrument and processor, and data reception.* • *Predicted satellite positional information used.*				
Path Image Plus (Regular service)	< 1.5 km	< 250 m	< 40 m	Standard, Fine, Wide, ScanSAR
• *Image is aligned along the satellite path (approx. 8° from North).* • *Image corrected for systematic errors related to satellite movement, the SAR instrument and processor, and data reception.* • *More precise satellite positional information used.*				
Map Image	< 1.5 km	< 250 m	< 40 m	Standard, Fine, Wide
• *Image can be related to a map base without rotation or translation.* • *Image corrected for systematic errors.*				
Precision Map Image	< 40 m	< 40 m	< 40 m	Standard, Fine, Wide
• *Image can be related to a map base.* • *Precision corrected using Ground Control Points.* • *For scenes with high terrain relief, a Digital Elevation Model can optionally be applied.*				

* Assumes a flat terrain with no elevation differences.

Topography related positional error

Elevation differences within an image may introduce additional relative positional errors. These can be particularly severe in areas of high relief (i.e., mountains). Distortions related to elevation differences can be readily calculated, and are a function of the elevation of a feature and the beam incidence angle used to image the feature. The expected displacement of a feature from its actual location is summarized by the following equation:

Displacement = Elevation difference x beam TSF

where Beam TSF is a Topographic Scaling Factor reflecting the beam mode and incidence angle used.

Guindon (1993) provided a formula for calculating TSF values, taking into account the earth's curvature, satellite altitude, and other parameters. Table C.4 provides an approximation of these values for each beam position.

TABLE C.4: Topographic scaling factors (TSF) for RADARSAT beam positions

BEAM MODE	BEAM POSITION						
	1	2	3	4	5	6	7
Standard	2.3	1.9	1.5	1.3	1.2	1.1	0.9
Fine	1.3	1.2	1.1	1.0	0.9		
Wide	1.7 - 2.7	1.2 - 1.7					
ScanSAR Narrow	1.2 - 2.7	1.0 - 1.7					
ScanSAR Wide	0.8 - 2.7						
Extended High	0.8	0.8	0.7	0.7	0.6	0.6	
Extended Low	2.4 - 5.7						

* TSF values will vary across an image due to incidence angle variations from near to far edge. Average values are shown. A range of scaling factors is shown for beams with the greatest variations. TSF values are approximated using the co-tangent of the incidence angle.

ScanSAR beam mode

ScanSAR is unique to the RADARSAT system. Its ability to image large areas of up to 500 km is achieved by switching between two to four single beam modes (Wide and Standard). The speed at which RADARSAT switches between sequential beam modes ensures the coverage is acquired. However, it is achieved at the expense of spatial resolution.

The beam mode combinations for the two ScanSAR modes are:

	BEAM POSITION	BEAM MODE COMBINATIONS	SWATH WIDTH (KM)
ScanSAR Narrow	SN1	W1 + W2	300
	SN2	W2 + S5 + S6	300
ScanSAR Wide	SW1	W1 + W2 + W3 + S7	500
	SW2	W1 + W2 + S5 + S6	450

ScanSAR SN1 and SN2 cover areas in the near and far range respectively. The difference between ScanSAR SW1 and SW2 is less obvious. The on-board tape recorder does not have the ability to downlink the full 500 km of data. Therefore the SW1 beam is restricted to direct data downlink. The SW2 beam provides reduced area covered (450 km) all of which can be downlinked from the tape recorder to a ground station.

Because of the unique nature of the ScanSAR beam modes, special processing is required which combines the individual beam modes into a single scene. Presently, only the Signal Data and Path Image processing levels are available for ScanSAR.

More details on the ScanSAR product specifications are found in Tables C.8 and C.9.

Path Image and Path Image Plus

Both Path Image and Path Image Plus are georeferenced products. The key difference between the two is the pixel spacing used to produce the product. Path Image Plus uses a smaller pixel dimension than Path Image to ensure the pixel dimension does not exceed one half of the radar resolution for all regions of the image. This smaller pixel spacing ensures that no information is lost from the original signal data. The final product achieves the best possible image resolution and retains all the input image information but at the expense of the product's digital file size. Path Image Plus will benefit applications such as point target analysis which requires the best possible resolution.

TABLE C.5: Product specifications - Fine beam mode

Satellite beam specifications

	F1	F2	F3	F4	F5
AVAILABLE INCIDENCE ANGLE POSITIONS	37 - 40	39 - 42	41 - 44	43 - 46	45 - 48
RESOLUTION (ground range products)* (range x azimuth) (M)	9.1 x 8.4	8.7 x 8.4	8.4 x 8.4	8.1 x 8.4	7.8 x 8.4
RESOLUTION (Single Look Complex) (range x azimuth) (M)	6.0 x 8.9	6.0 x 8.9	6.0 x 8.9	6.0 x 8.9	6.0 x 8.9
NOMINAL SWATH RANGE FROM NADIR OFFSET (KM)	250 -300	295 - 345	340 - 390	385 - 435	420 - 470

Processing image specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS	MAP IMAGE	PRECISION MAP IMAGE
NOMINAL IMAGE SIZE (KM)	50 x 50	50 x 50	50 x 50	50 x 50	50 x 50
PIXEL SPACING (M) (range x azimuth) (M)	4.6 x 5.1	6.25 x 6.25	3.125 x 3.125	6.25 x 6.25	6.25 x 6.25
NUMBER OF LOOKS (range x azimuth) (M)	1 x 1	1 x 1	1 x 1	1 x 1	1 x 1

Digital file specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS	MAP IMAGE	PRECISION MAP IMAGE
FILE SIZE (MB)	426	128	512	64	64
FILE SIZE (pixels x lines)	10,870 x 9,805	8,000 x 8,000	16,000 x 16,000	8,000 x 8,000	8,000 x 8,000
BITS / PIXEL	16 - I 16 - Q	16	16	8	8

NOTE:
Image size will be reduced if collected on tape recorder. The estimated image width is 43 km. See Table A.1 in Appendix A for more information.

* Resolution (ground range products) refers to Path Image and Path Image Plus. Map Image and Precision Map Image processing may alter the resolution slightly.

TABLE C.6: Product specifications - Standard beam mode

Satellite beam specifications

	S1	S2	S3	S4	S5	S6	S7
AVAILABLE INCIDENCE ANGLE POSITIONS	20 - 27	24 - 31	30 - 37	34 - 40	36 - 42	41 - 46	45 - 49
RESOLUTION (ground range products)* (range x azimuth) (M)	26 x 27	22 x 27	27.6 x 27	25.7 x 27	24.2 x 27	22.1 x 27	20.09 x 27
RESOLUTION (Single Look Complex) (range x azimuth) (M)	10.5 x 8.9	10.5 x 8.9	15.7 x 8.9	15.7 x 8.9	15.7 x 8.9	15.7 x 8.9	15.7 x 8.9
NOMINAL SWATH RANGE FROM NADIR OFFSET (KM)	0 - 100	60 - 160	140 - 240	210 - 310	280 - 380	340 - 440	400 - 500

Processing image specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS	MAP IMAGE	PRECISION MAP IMAGE
NOMINAL IMAGE SIZE (KM)	100 x 100	100 x 100	100 x 100	100 x 100	100 x 100
PIXEL SPACING (M) (range x azimuth) (M)	11.6 x 5.1	12.5 x 12.5	8 x 8	12.5 x 12.5	12.5 x 12.5
NUMBER OF LOOKS (range x azimuth) (M)	1 x 1	1 x 4	1 x 4	1 x 4	1 x 4

Digital file specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS	MAP IMAGE	PRECISION MAP IMAGE
FILE SIZE (MB)	676	128	312.5	64	64
FILE SIZE (pixels x lines)	8,620 x 19,610	8,000 x 8,000	12,500 x 12,500	8,000 x 8,000	8,000 x 8,000
BITS / PIXEL	16 - I 16 - Q	16	16	8	8

* Resolution (ground range products) refers to Path Image and Path Image Plus. Map Image and Precision Map Image processing may alter the resolution slightly.

TABLE C.7: Product specifications - Wide beam mode

Satellite beam specifications

	W1	W2	W3
AVAILABLE INCIDENCE ANGLE POSITIONS	20 - 31	31 - 39	39 - 45
RESOLUTION (ground range products)* (range x azimuth) (M)	35.5 x 27	26.6 x 27	22.8 x 27
RESOLUTION (Single Look Complex) (range x azimuth) (M)	15.7 x 8.9	15.7 x 8.9	15.7 x 8.9
NOMINAL SWATH RANGE FROM NADIR OFFSET (KM)	0 - 160	145 - 295	290 - 420

Processing image specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS	MAP IMAGE	PRECISION MAP IMAGE
NOMINAL IMAGE SIZE (KM)	150 x 150	150 x 150	150 x 150	150 x 150	150 x 150
PIXEL SPACING (M) (range x azimuth) (M)	11.6 x5.1	12.5 x 12.5	10 x 10	12.5 x 12.5	12.5 x 12.5
NUMBER OF LOOKS (range x azimuth) (M)	1 x 1	1 x 4	1 x 4	1 x 4	1 x 4

Digital file specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS	MAP IMAGE	PRECISION MAP IMAGE
FILE SIZE (MB)	1,521	288	450	144	144
FILE SIZE (pixels x lines)	12,930 x 29,410	12,000 x 12,000	15,000 x 15,000	12,000 x 12,000	12,000 x12,000
BITS / PIXEL	16 - I 16 - Q	16	16	8	8

NOTE:
Image size will be reduced for W2 if collected on tape recorder. The estimated image width will be 138 km. See Table A.1 in Appendix A for more information.

* Resolution (ground range products) refers to Path Image and Path Image Plus. Map Image and Precision Map Image processing may alter the resolution slightly.

TABLE C.8: Product specifications - ScanSAR Narrow beam mode

Satellite beam specifications

	SN1		SN2		
AVAILABLE INCIDENCE ANGLE POSITIONS	20 - 40		31 - 46		
BEAM MODE COMBINATIONS	W1	W2	W2	S5	S6
RESOLUTION (range x azimuth) (M)	73.5 x 47.8	55.1 x 53.8	55.1 x 71.1	50.1 x 71.9	45.7 x 78.8
NOMINAL SWATH RANGE From Nadir Offset (KM)	0 - 300		145 - 440		

Processing image specifications

	PATH IMAGE
NOMINAL IMAGE SIZE (KM)	300 x 300
PIXEL SPACING (M) (range x azimuth) (M)	25 x 25
NUMBER OF LOOKS (range x azimuth) (M)	2 x 2

Digital file specifications

	PATH IMAGE
FILE SIZE (MB)	144
FILE SIZE (pixels x lines)	12,000 x 12,000
BITS / PIXEL	8

NOTE:
ScanSAR Narrow products are created using a number of Wide and Standard beam modes. See Table A.1 in Appendix A for more information. Image size will be reduced for ScanSAR Narrow if collected on tape recorder. The estimated image width will be 292 km.

TABLE C.9: Product specifications - ScanSAR Wide beam mode

Satellite beam specifications

	SW1				SW2			
AVAILABLE INCIDENCE ANGLE POSITIONS	20 - 49				20 - 46			
BEAM MODE COMBINATIONS	W1	W2	W3	S7	W1	W2	S5	S6
RESOLUTION (range x azimuth) (M)	146.8 x 93.1	110.1 x 104.7	94.5 x 117.3	86.5 x 117.5	146.8 x 93.1	110.1 x 104.7	100.0 x 106.0	91.3 x 117.6
NOMINAL SWATH RANGE From Nadir Offset (KM)	0 - 500				0 - 450			

Processing image specification

	PATH IMAGE	PATH IMAGE
NOMINAL IMAGE SIZE (KM)	500 x 500	450 x 450
PIXEL SPACING (M) (range x azimuth) (M)	50 x 50	50 x 50
NUMBER OF LOOKS (range x azimuth) (M)	2 x 4	2 x 4

Digital file specifications

	PATH IMAGE	PATH IMAGE
FILE SIZE (MB)	100	100
FILE SIZE (pixels x lines)	10,000 x 10,000	10,000 x 10,000
BITS / PIXEL	8	8

NOTE:
ScanSAR Wide products are created using a number of Wide and Standard beam modes. See Table A.1 in Appendix A for more information. SW1 products are available only as a direct downlink to a ground station. SW2 is tailored for storage on the tape recorder.

TABLE C.10: Product specifications - Extended High Incidence beam mode

Satellite beam specifications

	H1	H2	H3	H4	H5	H6
AVAILABLE INCIDENCE ANGLE POSITIONS	49 - 52	50 - 53	52 - 55	54 - 57	56 - 58	57 - 59
RESOLUTION (ground range products)* (range x azimuth) (M)	19.8 x 27.0	19.4 x 27	19.1 x 27	18.5 x 27	18.2 x 27	18.0 x 27
RESOLUTION (Single Look Complex) (range x azimuth) (M)	15.7 x 8.9	15.7 x 8.9	15.7 x 8.9	15.7 x 8.9	15.7 x 8.9	15.7 x 8.9

Processing image specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS	MAP IMAGE	PRECISION MAP IMAGE
NOMINAL IMAGE SIZE (KM)	75 x 75	75 x 75	75 x 75	75 x 75	75 x 75
PIXEL SPACING (M) (range x azimuth) (M)	11.6 x 5.1	12.5 x 12.5	8 x 8	12.5 x 12.5	12.5 x 12.5
NUMBER OF LOOKS (range x azimuth) (M)	1 x 1	1 x 4	1 x 4	1 x 4	1 x 4

Digital file specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS	MAP IMAGE	PRECISION MAP IMAGE
FILE SIZE (MB)	380	72	176	36	36
FILE SIZE (pixels x lines)	6,465 x 14,705	6,000 x 6,000	9,375 x 9,375	6,000 x 6,000	6,000 x 6,000
BITS / PIXEL	16 - I 16 - Q	16	16	8	8

NOTE:
Extended High Incidence beam mode operates outside the optimum scan angle range of the SAR antenna. Some minor degradation in the quality of the image can be expected as compared to images produced using Standard beam mode. If data is stored on the tape recorder, its image size is expected to be 70 km. See Table A.1 in Appendix A for more information.

* Resolution (ground range products) refers to Path Image and Path Image Plus. Map Image and Precision Map Image processing may alter the resolution slightly.

TABLE C.11: Product specifications - Extended Low Incidence beam mode

Satellite beam specifications

	L1
AVAILABLE INCIDENCE ANGLE POSITIONS	10 - 23
RESOLUTION (ground range products)* (range x azimuth) (M)	36.3 x 27.0
RESOLUTION (Single Look Complex) (range x azimuth) (M)	10.5 x 8.9

Processing image specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS	MAP IMAGE	PRECISION MAP IMAGE
NOMINAL IMAGE SIZE (KM)	170 x 170	170 x 170	170 x 170	170 x 170	170 x 170
PIXEL SPACING (M) (range x azimuth) (M)	8.1 x 5.1	12.5 x 12.5	10 x 10	12.5 x 12.5	12.5 x 12.5
NUMBER OF LOOKS (range x azimuth) (M)	1 x 1	1 x 4	1 x 4	1 x 4	1 x 4

Digital file specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS	MAP IMAGE	PRECISION MAP IMAGE
FILE SIZE (MB)	2,800	370	578	185	185
FILE SIZE (pixels x lines)	20,990 x 33,300	13,600 x 13,600	17,000 x 17,000	13,600 x 13,600	13,600 x 13,600
BITS / PIXEL	16 - I 16 - Q	16	16	8	8

NOTE:
Extended Low Incidence beam mode operates outside of the optimum scan angle range of the SAR antenna. Some minor degradation in the quality of image can be expected as compared to images produced using Standard beam mode.

* Resolution (ground range products) refers to Path Image and Path Image Plus. Map Image and Precision Map Image processing may alter the resolution slightly.

SUPPORTED MAP PROJECTIONS

Map projections

Our processor supports a large number of projections which can be user defined for Map Image and Precision Map Image products.

The most frequently requested projection is Universal Transverse Mercator (UTM). For UTM projections, the earth is divided into 60 zones, each representing 6° of longitude. A standard zone numbering system is established where Zone 1 starts at 180°W to 174°W through to Zone 60 at 174°E to 180°E. This zone number is used as input to the processor. Client Services can help you determine your zone number if required.

Other common projections include:

- Lambert Conformal Conic which requires user input as to the two standard parallels (latitudes) and the projection origin (latitude and longitude).
- Transverse Mercator which requires a projection origin (latitude and longitude) and a scale factor (used to reduce distance distortions and typically a value close to 1).

There are a many other projections available. These are listed in Table D.1, along with the required user inputs. Contact Client Services if you require assistance in selecting a projection.

The Ellipsoid or Radius of the earth is another input which the user can define within the projection. Table D.2 provides a partial list of the most commonly used Ellipsoids and the geographical region to which they apply. You can provide us with the name of the ellipsoid you prefer.

The Map Image and Precision Map Image products are provided to you in CEOS format. The CEOS Map Projection Data Record provides the latitude / longitude and projection coordinates of the top left and bottom right corners of the complete image. Map origins and projection parameters such as standard parallels are also included in the Map Projection Data Record.

TABLE D.1: Available projections and required inputs

The following are the projections supported for Map Image and Precision Map Image products. Inputs which you are required to provide are indicated by a "Y".

Name	Standard Parallels 1 parallel	Standard Parallels 2 parallels	Projection Origin Latitude	Projection Origin Longitude	Scale Factor	Zones
Albers Conical Equal Area	Y	Y	Y	Y	N	N
Azimuthal Equidistant	N	N	Y	Y	N	N
Equidistant Conic Type A	Y	N	Y	Y	N	N
Equidistant Conic Type B	Y	Y	Y	Y	N	N
Equirectangular	See next page					
General Vertical Near-Side Perspective	See next page					
Gnomic	N	N	Y	Y	N	N
Lambert Azimuthal Equal Area	N	N	Y	Y	N	N
Lambert Conformal Conic	Y	Y	Y	Y	N	N
Hotine Oblique Mercator Type A	See next page					
Hotine Oblique Mercator Type B	See next page					
Mercator	See next page					
Millar Cylindrical	N	N	N	Y	N	N
Orthographic	N	N	Y	Y	N	N
Polar Stereographic	See next page					
Polyconic	N	N	Y	Y	N	N
Sinusoidal	N	N	N	Y	N	N
State Plane Coordinate System	N	N	N	N	N	Y
Stereographic	N	N	Y	Y	N	N
Superficial Conic						
Transverse Mercator	N	N	Y	Y	Y	N
Universal Transverse Mercator	N	N	N	N	N	Y
Van der Grinton I	N	N	N	Y	N	N

All projections can also have false map origins applied in both eastings and northings coordinates.

Equirectangular

Projection Inputs:
- projection origin longitude
- latitude of true scale

General Vertical Near-Side Perspective

Projection Inputs:
- projection origin longitude
- projection origin latitude
- height of perspective point above surface (in metres)

Hotine Oblique Mercator Type A

Projection Inputs:
- projection origin latitude
- latitude of first point on central line
- latitude of second point on central line
- longitude of first point on central line
- longitude of second point on central line
- scale factor at centre of projection

Hotine Oblique Mercator Type B

Projection Inputs:
- projection origin latitude
- longitude of point on central line where azimuth is measured
- scale factor at centre of projection
- azimuth angle east of north of central line

Polar Stereographic

Projection Inputs:
- latitude of true scale
- longitude straight down from North Pole or up from South Pole

TABLE D.2: Earth models (ellipsoid)

Many earth models can be used; this is only a partial list.

NAME	DATE	USE
1.0000382*Clarke	1866	
Airy	1849	
Bessel	1841	Central Europe, Chile, Indonesia
Clarke	1880	
Clarke	1880	Africa, France
Clarke	1866	N. America, Philippines
Everest	1830	India, S. Asia
Fischer	1960	S. Asia
Fischer	1968	
GRS-80	19870	N. America
Helmert	1907	
IAU	1965	Australia, S. America
International Sphere		
International/Hayford	1924/1909	entire world, excluding N. America & Africa
Krasovsky	1940	USSR, East Europe
Malayan		Malaysia
Modified Bessel	1841	Sweden
NAD-27	1927	North America
NAD-83	1983	North America
WGS-66	1966	(NWL-9D)
WGS-72	1972	PEI, Canada, NASA

APPENDIX E
GENERAL TERMS OF SALE OF RADARSAT INTERNATIONAL (RSI)

1. General provisions

All sales of products by RADARSAT International (RSI) are governed by these General Terms. No contrary terms or conditions shown on the buyer's purchase order or its correspondence are binding on RSI unless specifically accepted in writing by RSI.

2. Orders

All orders must clearly identify the name of the buyer.

A. Archived Images
RSI's acknowledgement of an order containing all the order's specifications shall be order confirmation by RSI and deemed acceptance of the General Terms of Sale by the buyer. Production of archived images will commence immediately following order acknowledgement. No modification or cancellation of the order will be accepted after the order acknowledgement has been issued.

B. Images to be Acquired
A programming request is deemed to be an order and, once acknowledged by RSI as noted below, binding upon the buyer in accordance with the General Terms of Sale. Upon receipt of the programming request, RSI shall endeavour to secure the requisite programming slots. Upon receipt of programming confirmation from the satellite operator, RSI shall acknowledge the programming request. In the event that the scenes ordered are not obtained, the buyer shall only be entitled to a refund of amounts paid in respect of such scenes not obtained and no more.

RSI reserves the right to refuse any order.

3. Delivery

Production and delivery of products are done on a best effort basis. Failure to meet Rush processing times by RSI will result in no Rush charges being applied but does not entitle the buyer to refuse delivery of the products or to other compensation whatsoever. If RSI cannot deliver the products as ordered, the customer is only entitled to a refund of the price paid, without additional compensation of any kind.

4. Prices

The price applicable to each order shall be the price in effect at the date of order acknowledgement. Unless otherwise stipulated in writing by RSI, all prices are exclusive of shipping, taxes and duties, Ex-Works RSI Richmond, British Columbia, and/or Gatineau, Québec, Canada (1990 I.C.C. Incoterms) and include standard packaging. Prices are subject to change without prior notice.

5. Shipping

The products are shipped at the buyer's risk, notwithstanding that RSI may as agent for the buyer negotiate and sign on his behalf a transport contract. Accordingly, it is the buyer's responsibility to advise the carrier within the legal time limit of any lost, stolen or damaged products.

If the data and data products are transmitted by electronic device, Ex-Works Richmond and/or Gatineau delivery shall be input of the data stream to the equipment or facilities of the common carrier.

6. Complaints and inspection

No complaints relative to the quality and/or quantity of the products delivered will be accepted unless made in writing by facsimile or registered mail received within sixty (60) days of receipt of the products at the airport of destination for deliveries outside of Canada, or at the buyer's address for deliveries within Canada. Products may not be returned except with RSI's express prior authorization.

7. Payment

All orders must be prepaid unless credit has been previously established or other terms have been agreed to in writing by RSI. Any overdue sums are subject to interest charges at the rate of 1.5% per month until payment is made. Non-payment of any amount as it falls due shall cause all amounts outstanding to become immediately due and payable. RSI may require immediate payment of all outstanding invoices. In addition, payment may be requested in advance of shipment for quantities not yet delivered, or the balance of the order may be cancelled by RSI without liability to it.

8. Data license and trademarks

Use of the data delivered and the trademarks associated therewith is governed by the terms of the License Agreement included with the product and the buyer by using the products shall be deemed to have accepted and be bound by the terms of such license.

9. Termination

In the event of a breach in any of the General Terms of Sale, RSI shall have the right to terminate all orders or sales in process by providing the buyer with fifteen (15) days notice in writing. RSI shall retain any advances paid towards the cancelled sales without prejudice to all other amounts due, and costs, interest or damages that the buyer may be ordered to pay.

10. Governing law

These General Terms of Sale are governed by the laws of Canada and Province of British Columbia, and ensures to the benefit of the Canadian Space Agency and/or RSI, their successors and assigns. The parties expressly exclude the application of the United Nations convention on Contracts for the International Sale of Goods and the implementing legislation thereto.

APPENDIX F
SELECTED REFERENCES

Books/Journals

CASI, Special Issue, *RADARSAT*, *Canadian Journal of Remote Sensing*, Vol. 19, No. 4, Nov. / Dec. 1993.

RADARSAT International Inc., *Catalogue of Recent Radar Research Related to Canada's RADARSAT*, unpublished, 1992.

RADARSAT International Inc., *RADARSAT: Canada's Earth Observation Satellite*, unpublished, 1993.

Guindon, B., "Aspects of Digital Elevation Data Requirements for Operational Geocoding of RADARSAT Imagery", *Canadian Journal of Remote Sensing*, Vol. 19, No. 2, p. 132, April / May 1993.

Raney, K. et al, "RADARSAT", *Proceedings of IEEE*, Vol. 79, No. 6, June 1991.

Glossary courtesy of the Canada Centre for Remote Sensing.

A

Active system: A remote sensing system that transmits its own electromagnetic emanations at an object(s) and then records the energy reflected or refracted back to the sensor.

Active remote sensing system: A system that provides its own source of energy and illumination.

Antenna: Part of the radar system which transmits and / or receives electromagnetic energy.

Aspect angle: The geometric orientation in the horizontal plane of the object with respect to the illuminating or transmitted radar beam.

Azimuth: The angular position of an object within the field-of-view of an antenna in the plane intersecting the moving radar's line of flight. The term is commonly used to indicate linear distance or image scale in the direction parallel to the radar flight path. (In an image, azimuth is also known as the long track direction.)

B

Backscatter: The (microwave) signal reflected by elements of an illuminated scene back in the direction of the radar. It is named to make clear the difference between energy scattered in arbitrary directions, and that which returns to the radar and therefore may be received and recorded by the sensor.

Band: A selection of wavelengths, or a range of radar frequencies such as the following:
C-band - the microwave band in which the wavelengths are at or near 5.6 cm.
P-band - the microwave band in which the wavelengths are at or near 75 cm.
S-band - the microwave band in which the wavelengths are at or near 10 cm.
X-band - the microwave band in which the wavelengths are at or near 3 cm.

Bandwidth: A measure of the span of frequencies available in the signal, or passed by the band limiting stages of the system. Bandwidth is a fundamental parameter of any imaging system, and determines the ultimate resolution available.

Beam: A focused pulse of energy.

Beam mode: The SAR operating configuration defined by swath width and resolution (Fine, Standard, Wide, ScanSAR or Extended).

Beamwidth: A measure of the width of the radiation pattern of an antenna. For SAR applications, both the vertical beamwidth (affecting the width of the illuminated swath) and the horizontal or azimuth pattern (which determines, indirectly, the azimuth resolution) are frequently used concepts.

Beam position: The area within the total possible swath which is actually illuminated while being governed by the characteristics of a specific beam mode (i.e., there are seven areas which can be illuminated using the Standard beam mode configuration between the incidence angles of 20° and 49°).

Brightness: Property of a radar image in which the strength of the radar reflectivity is expressed as being proportional to a digital number (digital image file) or to a grey scale (photographic image) which for a photographic positive shows “bright” as “white”.

C

C-band: Microwave band in which the wavelengths are at or near 5.6 cm (5.3 Ghz).

CCRS: Canada Centre for Remote Sensing, Ottawa, Ontario.

CCT: Computer compatible tape.

CSA: Canadian Space Agency, St. Hubert, Québec, Canada.

D

DEM (Digital Elevation Model): A quantitative model of a landform in digital form.

Dawn-dusk: The satellite’s solar array is placed in almost continuous sunlight. The solar array generates the energy for transmitting the radar.

Detection: Processing stage at which the strength of the signal is determined. Detection removes phase information from the data file.

Digital: Operating on data represented as a series of binary digits.

Doppler (frequency): Shift in frequency caused by relative motion along the line of sight between the sensor and the observed scene.

Dynamic range: The ratio of maximum measurable signal to minimum detectable signal.

E

ESA: European Space Agency, with headquarters in Paris, France.

Electromagnetic spectrum: The ordered array of known electromagnetic energy extending from the shortest rays, through gamma rays, X rays, UV, Visible, IR and including microwave and all other wavelengths of radio energy.

Electromagnetic wave: A wave described by variations in electrical and magnetic fields. All such waves move through the atmosphere at the speed of light, 3.0×10^8 m per second.

Elevation displacement: Image distortion in the range direction caused by terrain features in the scene being above (or below) the reference elevation contour, and thus in fact being closer to (or further from) the radar than their planimetric position. The effect may be used to create radar stereo images. It may be removed from an image through independent knowledge of the terrain profile. In many applications, an approximate correction may be derived through shape from shading techniques.

Ellipsoid: A solid of which all the plane sections normal to one axis are circles and all the other plane sections are ellipses.

ERS (European Remote Sensing): Satellite series (ERS-1 and -2) launched by ESA in July 1991. One instrument (AMI) includes a C-band SAR, VV polarization and 23° incidence angle.

F

Foreshortening: Spatial distortion whereby terrain slopes facing a side-looking radar's illumination are mapped as having a compressed range scale relative to its appearance if the same terrain were level. Foreshortening is a special case of elevation displacement. The effect is more pronounced for steeper slopes and for radars that use steeper incidence angles. Range scale expansion, the complementary effect, occurs for slopes that face away from the radar illumination.

Frequency: Rate of oscillation of a wave. In the microwave region, frequencies are on the order of .3 GHz - 300 GHz having wavelengths of 1 mm - 1 m respectively.

G

GCP (Ground Control Points): A geographical feature of known location that is recognizable on images and can be used to determine geometrical correction.

GHz: Gigahertz (109 cycles per second). A measure of frequency of electro-magnetic energy.

GIS (Geographical Information Systems): An organized collection of computer hardware and software designed to efficiently create, manipulate, analyze and display all types of geographically or spatially referenced data. A GIS allows complex spatial operations that are very difficult to do otherwise.

GPS (Global Positioning System): A positioning or navigation system designed to use 18 to 24 satellites, each carrying atomic locks to provide a receiver anywhere on the earth with extremely accurate measurements of its 3-dimensional position, velocity and time.

Geocoded: Geographic correction of image data to conform to a map projection. Ground control points are often used to increase the accuracy of the geocoding process.

Geomorphology: The study of the physical features of the surface of the earth and their relation to its geological structures.

Georeferenced: Relative geographical location of a scene by incorporating latitude and longitude information into the image.

Ground range: Range direction of a side-looking radar image as projected onto the nominally horizontal reference plane, similar to the spatial display of conventional maps. For spacecraft data, an Earth geoid model is used, whereas for airborne radar data, a planar approximation is sufficient. Ground range projection requires a geometric transformation from slant range to ground range, leading to relief or elevation displacement, foreshortening, and layover unless terrain elevation information is used.

H

Hertz (Hz): Named after H.R. Hertz, a 19th century German physicist. It is the standard unit for frequency, equivalent to one cycle per second.

I

Image: A pictorial representation acquired in any wavelength of the electromagnetic spectrum. For radar, the image tones represent the radar reflectivity of the scene.

Incidence angle: Defined as the viewing angle (line of sight between the radar and object) of the radar beam from the vertical. The local incidence angle takes into account the slope of the terrain at the object's location. Incidence angle can have an important influence on radar backscatter.

J

J-ERS-1 (Japanese Earth Remote Sensing): Satellite launched by Japan in February, 1992. It includes L-band SAR, HH polarization and 38.5° incidence angle.

L

L-band: Microwave band in which the wavelengths are at or near 23.5 cm.

Lambert Conformal Conic: A conformal conic projection with two standard parallels, or a conformal conic map projection in which the surface of a sphere, or spheroid, such as the earth, is conceived as developed on a cone which intersects the sphere or spheroid at two standard parallels; the cone is then spread out to form a plane which is the map.

Latitude: The angular distance on a meridian north or south of the equator, expressed in degrees and minutes.

Layover: Extreme form of elevation displacement or foreshortening in which the top of a reflecting object (such as a mountain) is closer to the radar (in slant range) than are the lower parts of the object. The image of such feature appears to have fallen over towards the radar. The effect is more pronounced for radars having smaller incidence angles.

Looks: Each of the sub-images used to form the output summed image, implemented in a SAR processor. Speckle, the radiometric uncertainty in each estimate of the scene's reflectivity, is reduced by the average implied by adding together different detected images of the same scene.

Look direction: The angle between geographic North and the direction in which the radar beam is pointing i.e. perpendicular to the flight direction.

M

Microwave: Electromagnetic wavelength 1 m - 1 mm (.3 GHz - 300 GHz). The most common imaging radars operate at frequencies between 24 cm - .85 cm (1.25 GHz - 35.2 GHz).

Mosaic: A technique whereby multiple satellite images are digitally joined, while correcting for systematic changes in radiometry and geometry thus creating a "seamless" image product.

N

NASA: National Aeronautics and Space Administration, headquarters in Washington, DC, USA.

Nadir: Points on the surface of the Earth directly below the radar source as it progresses along its line of flight.

Near polar orbit: Orbital plane within +10° of a plane containing true North (90° latitude).

Number of looks: *(see looks)*.

O

Oblique perspective: A view of the surface taken from above the Earth at an angle away from the vertical.

Optical sensor: A remote sensing system which uses the visible portion of the electromagnetic spectrum, and whose resultant image products depict the same atmospheric interference as that experienced by the human eye (i.e., an inability to see through the clouds, rain or snow.)

P

P-band: As has been adopted by the SAR community, the microwave band in which the wavelengths are at or near 75 cm.

Passive system: A sensing system that detects or measures radiation emitted by the target.

Phase: A particular appearance or state in a regularly recurring cycle of changes.

Pixel: Term derived from “picture element” in a digital representation to indicate the spatial position of a sample of an image file, which consists of a spatial array of digital numbers. A two-dimensional ensemble of pixels forms the geometric grid on which an image is built. The fundamental parameter describing this grid is the inter-pixel spacing in each of the two image directions.

Pixel Spacing: The ground distance between the centre of one pixel and the centre of its neighbour.

Polarization: Orientation of the electric (E) vector in an electromagnetic wave. Imaging radars are able to generate and receive with the same or different polarization.
H H - horizontal transmit / horizontal receive
V V - vertical transmit / vertical receive
H V - horizontal transmit / vertical receive

Processing: Sometimes denoted as “preprocessing”. It means converting the received reflected signal into an image.

Processing looks: *(See looks.)*

Pulse: A short burst of electromagnetic energy.

R

Radar: Electromagnetic sensor characterized by RAdio Detection And Ranging, from which the acronym, RADAR is derived. Predicted in the early part of the 20th century, the first important system was built in England in 1938. Basic building blocks of radar are the transmitter, the antenna (normally used for both transmission and for reception), the receiver, and the data handling equipment. A synthetic aperture radar system, by implication, includes in image processor, even though it may be remotely located in time or space from the radar electronics.

RADARSAT: The first Canadian remote sensing satellite which will be launched in 1995. It is a C-band SAR satellite which also includes a steerable antenna and changeable image scale or swath width. As well, it will be the first operationally oriented commercial radar satellite.

Range: Line of sight distance between the radar and each illuminated scatterer. In SAR usage, the term is also applied to the dimension of an image away from the line of flight of the radar. Slant range is the distance as measured by the radar directly, in effect along each line perpendicular to the flight vector and directly connecting the radar and each scatterer. Ground range is the same distance projected (through a geometrical transformation) onto a reference surface representing the Earth's geoid.

Real time: Time in which recording of events is simultaneous with the events. For example, the real time of a satellite is the time in which it simultaneously reports its environment as it encounters it. The real time of a computer is the time during which it is accepting data and performing operations on it.

Remote sensing: A technique of acquiring information about an area or object from a distance.

Resolution: The smallest discernable unit or the smallest unit represented. In satellite imagery it refers to the smallest object that can be discerned. Also referred to as spatial resolution. Resolution in a radar system differs in two directions: the azimuth or along-track direction and the range or across-track direction.

Roughness: Variation of surface height within an imaged resolution cell. A surface appears "rough" to microwave illumination, when the height variations become larger than a fraction of the radar wavelength. The fraction is qualitative, but may be shown to decrease with incidence angle.

S-band: Microwave band in which the wavelengths are at or near 10 cm.

SAR: Synthetic Aperture Radar. SAR systems use the motion of the aircraft / satellite and doppler frequency shift to electronically synthesize the large antennae necessary for the acquisition of high-resolution radar images.

Seasat: NASA satellite that was in operation July - September of 1978. Seasat was the first (civilian) imaging radar satellite. It operated at L-band, using horizontal polarization at 22° incidence angle.

Sensor: Any device which gathers energy (electromagnetic radiation) and presents it in a form suitable for obtaining information about the environment. Passive sensors, such as thermal infrared and optical, utilize electromagnetic radiation produced by the surface or object being sensed. Active sensors, such as radar, supply their own energy source.

Shadow: The area corresponding to that which does not get illuminated by the radar energy, and thus is also not visible in the resulting radar image. The region is filled with “no reflectivity”, which appears as small digital numbers, or a dark region in hard copy.

SIR (-A and -B): NASA sponsored radar missions in the Shuttle, each lasting about one week. SIR-A (November 1981) was at L-band, HH polarization, nominally 50° incidence angle and was optically processed. SIR-B (October 1984) was also at L-band, HH polarization, offered a variety of incidence angles from about 20° to 50°, and was digitally processed.

SIR-C / X-SAR: A shuttle radar built for missions in 1993, 1994 and 1996 and carrying a polarimetric SAR and C- and L-bands, and an X-band HH polarized SAR (contributed by Germany and Italy). It offers a variety of incidence angles, band selections, resolutions and polarization modes.

Slant Range: The line of sight between the radar and each reflecting element on the surface. This line is measured in time from when the signal is first transmitted to when it is returned to the sensor.

Speckle: Statistical fluctuation or uncertainty associated with the brightness of each pixel in the image of a scene. A single look SAR system achieves an estimate of the reflectivity of each resolution cell in the image. Speckle may be reduced, at the expense of resolution, in the SAR processor by using several looks.

Specular: A surface that is smooth at the wavelength of illumination having the qualities of a mirror.

Stereographic coverage: Photographic coverage with overlapping air photographs to provide three dimensional presentation of a picture. (60% overlap is considered normal, and 53% as a minimum).

Sun-synchronous orbit: Synchronization with the sun i.e. the angle between the satellite's orbital plane and the sun's direction is constant. For scenes at the same latitude and at the same time of year, this ensures identical conditions of data acquisition.

Surface roughness: In general a rough surface is defined as having a height variation of about half the radar wavelength. Surface roughness influences the reflectivity of microwave energy and thus the brightness of features on the radar imagery.

Swath: Width of imaged scene in the range dimension, measured either in ground range or slant range.

T

Texture: In a photographic image, the detailed spatial pattern of change and arrangement of tones.

Tone: Each distinguishable shade of grey from white to black on an image.

Transmission: Energy sent by the radar, normally in the form of a sequence of pulses, to illuminate a scene of interest.

U

UTM Grid (Universal Transverse Mercator Grid): A particular grid based upon a transverse mercator projection, according to specifications laid down by military authorities; it may be superimposed on any map.

V

Vector format: A coordinate-based data structure commonly used to represent map features. Each object is represented as a list of sequential x,y coordinates. Attributes may be associated with the objects. A computer image can be represented in vector format or raster format.

W

Wavelength: The distance traversed by a photon (particle of light) during one complete vibration (wave). The wavelength of a photon varies inversely with the energy it possesses.

Worm drives: Write-once, read many (WORM). An optical disk drive with storage capacities of up to one terabyte. This disk becomes a read-only storage medium after data is written to the disk.

X

X-Band: Microwave band with wavelengths at or near 3 cm.

RADARSAT Image Request Form

RADARSAT INTERNATIONAL

WHO?

Date of request [D/M/Y] .... Customer reference number ....

Contact ....

Organization ....

Address ....

Country .... Postal code ....

Tel # .... Fax # .... E-mail # ....

WHERE?

Country .... Region .... Area ....

Geographic coordinates of bounding area (one request form per area) ❑ Map attached

Latitude			Longitude			Latitude			Longitude		
❑N ❑S	°	"	❑E ❑W	°	"	❑N ❑S	°	"	❑E ❑W	°	"
❑N ❑S	°	"	❑E ❑W	°	"	❑N ❑S	°	"	❑E ❑W	°	"
❑N ❑S	°	"	❑E ❑W	°	"	❑N ❑S	°	"	❑E ❑W	°	"
❑N ❑S	°	"	❑E ❑W	°	"	❑N ❑S	°	"	❑E ❑W	°	"

Application description [E.G. CROP IDENTIFICATION, FLOOD EXTENT, LAND USE MAPPING : REFER TO USER'S GUIDE] ....

....

Operation scale ❑ 1:1,000,000 or more ❑ 1:500,000 ❑ 1:250,000 ❑ 1:100,000 ❑ 1:50,000 or less

– or – Resolution (level of detail) required ❑ 100 m+ ❑ 50 m ❑ 30 m ❑ 10 m

Terrain conditions / other specific considerations ....

....

WHAT?

Orbit look direction ❑ Not important ❑ Ascending [EAST FACING] ❑ Descending [WEST FACING]

BEAM POSITION	BEAM MODE	INCIDENCE ANGLE	RESOLUTION	NOMINAL AREA	BEAM POSITION	BEAM MODE	INCIDENCE ANGLE	RESOLUTION	NOMINAL AREA
❑ F1	Fine	37°- 40°	10 m	50 x 50 km	❑ W1	Wide	20°- 31°	30 m	165 x 165 km
❑ F2		39°- 42°			❑ W2		31°- 39°		150 x 150 km
❑ F3		41°- 44°			❑ W3		39°- 45°		130 x 130 km
❑ F4		43°- 46°			❑ SN1	ScanSAR narrow	20°- 40°	50 m	300 x 300 km
❑ F5		45°- 48°			❑ SN2		31°- 46°		
❑ S1	Standard	20°- 27°	30 m	100 x 100 km	❑ SW1	ScanSAR wide	20°- 49°	100 m	500 x 500 km
❑ S2		24°- 31°			❑ H1	Extended high	49°- 52°	25 m	75 x 75 km
❑ S3		30°- 37°			❑ H2		50°- 53°		
❑ S4		34°- 40°			❑ H3		52°- 55°		
❑ S5		36°- 42°			❑ H4		54°- 57°		
❑ S6		41°- 46°			❑ H5		56°- 58°		
❑ S7		45°- 49°			❑ H6		57°- 59°		
					❑ L1	Extended low	10°-23°	35 m	170 x 170 km

WHEN?

❑ Catalogue search | Programming service ❑ Urgent ❑ Priority ❑ Basic

Acquisition dates [D / M / Y] ❑ Multidate requirements

Range from .... to .... Specific date ....

Range from .... to .... Specific date ....

Range from .... to .... Specific date ....

Range from .... to .... Specific date ....

HOW?

Preferred product level	Processing service			Special processing instructions [E.G. PROJECTIONS]
	Near-Real Time	Rush	Regular	❑ map provided showing Ground Control Points (GCP)
Single Look Complex	❑	❑	❑	
Signal Data	❑	❑	❑	
Path Image	❑	❑	❑	
Path Image Plus	❑	❑	❑	
Map Image			❑	
Precision Map Image			❑	

Preferred storage media ❑ CEOS reader required

❑ CD-ROM ❑ CCT ❑ EXABYTE™ ❑ Film ❑ Print Scale ....

Image analysis system or GIS name ....

SHIPPING

Method of shipping ❑ Courier [RSI SELECT] ❑ Courier [CUSTOMER SELECT] ❑ Electronic

Contact ....

Organization ....

Address ....

Country .... Postal code ....

Tel # .... Fax # ....

E-mail # .... Courier account # ....

SPECIAL INSTRUCTIONS / NOTES

For more information contact: RADARSAT International, Client Services
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Tel: 1-(604) 244-0400 Fax: 1-(604) 244-0404

RADARSAT INTERNATIONAL