RADARSAT is your flexible source of geographic information. As Canada's first Earth observation satellite and the world's first operationally-oriented radar satellite, RADARSAT provides valuable information for use in environmental monitoring and natural resource management. As the exclusive distributor of RADARSAT-1 data, RADARSAT International (RSI) has prepared this document, RADARSAT Illuminated: Your Guide to Products & Services, to help you order the RADARSAT products best suited to your operation or project requirements.

With RADARSAT we see the world differently. Unlike other radar satellites, RADARSAT offers you a choice of 35 basic products; each varies with respect to the area covered and the way in which the Earth's surface is imaged. RSI offers many services to meet your specific project and analysis needs. This unique flexibility leads to a wide range of choices. Consequently, we have designed this user guide to help you select the appropriate RADARSAT products and services for your operation.

Summary of chapters and appendices

The four chapters in this guide have specific objectives, with each chapter building on the information presented in the preceding chapter. A brief description of each chapter and the six appendices is found below.

Chapter 1, Introduction, this chapter introduces you to RSI and provides an overview of Chapters 2 - 4 and Appendices A - F.

Chapter 2, RADARSAT - we see the world differently, is intended for those users who are unfamiliar with radar remote sensing and the RADARSAT satellite and program. It provides

- information about radar remote sensing and its capabilities, and
- a review of the fixed and flexible parameters of the RADARSAT satellite and program.

In this chapter, you will learn how RADARSAT views the Earth. By evaluating your operation / application requirements you will learn how your choices (on the flexible parameters of the RADARSAT satellite and program) affect what you see in your image.

Chapter 3, RADARSAT products and services, reviews the products and services offered to you. It provides

- RADARSAT product descriptions and characteristics,
- a review of the many time-sensitive services available,
- an outline of our custom products and services, and
- examples of RADARSAT-derived products.

Chapter 4, 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. Chapter 4 provides

¥ details on the information we require to fulfil your order,
¥ references to Chapters 2 and 3 for technical clarification, and
¥ important details to help you choose the optimal RADARSAT product.

Following Chapter 4 are the Appendices, the Glossary, and the Index. The Appendices provide supplemental technical information and include

Appendix A: RADARSAT program specifications
¥ the RADARSAT program and satellite specifications.

Appendix B: Application considerations for RADARSAT
¥ specific applications solution guidelines.

Appendix C: RADARSAT product specifications
¥ RADARSAT product descriptions,
¥ calibration and image quality,
¥ special features of our unique products, and
¥ the CEOS digital product format.

Appendix D: Supported map projections
¥ RADARSAT products and available map projections.

Appendix E: General terms of sale of RADARSAT International (RSI)
¥ terms and conditions for ordering RADARSAT data.

Appendix F: Selected references
¥ supplemental material about RADARSAT applications, products, and services.

Your feedback on this guide is greatly appreciated.
Please direct any comments and suggestions to the

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Email: info@rsi.ca

For additional information and updates on new products and services, please visit our corporate website at www.rsi.ca, or contact your Client Services Representative at 1-(604) 244-0400.

HOW RADARSAT CAN MEET YOUR INFORMATION REQUIREMENTS

Your information requirements are unique. The availability of data to yield the information you require must be a high priority during project planning and implementation. RADARSAT is one of many possible data sources, including optical sensors or aerial surveys, that can play an important role in your project solution.

RADARSAT data and application benefits

As one source of valuable data, RADARSAT offers a number of data and application benefits including

- current and reliable data,
- global data coverage,
- a range of product scales and resolutions,
- flexible viewing geometry,
- Near-Real Time (NRT) processing and Electronic delivery,
- digital georeferenced products that can be integrated with other data sets, and
- data continuity with the subsequent launches of RADARSAT-2 and RADARSAT-3.

This Chapter provides you with a brief technical background on synthetic aperture radar (SAR) and the RADARSAT design. Within this discussion, you will be introduced to the fixed and flexible parameters of RADARSAT and the RADARSAT program. You will learn how the choices available to you affect your image and the information you can derive from it. This will help you use Chapter 4—a step by step guide that leads you through the *RADARSAT Image Request Form*.

SAR BACKGROUND

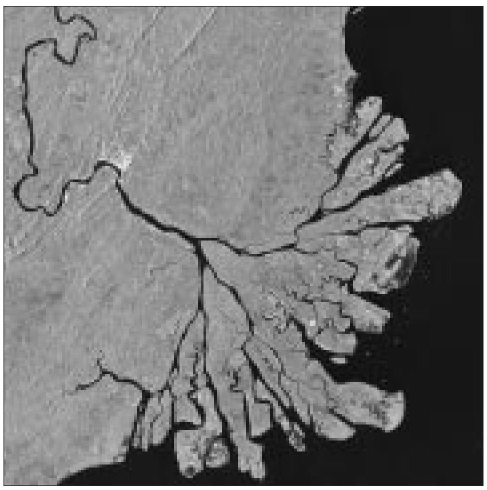
How does RADARSAT differ from optical sensors

RADARSAT differs from optical sensors in the type of data it acquires and in how this data is collected. Typical multispectral sensors, such as SPOT and LANDSAT, collect the energy reflected from the Earth’s surface at wavelengths roughly equivalent to those detected by our eyes. These sensors capture the 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 individually or in combination with other bands. Image processing techniques make it possible to combine these bands to produce a colour image of the Earth’s surface.

Radar sensors such as RADARSAT, ERS, and JERS make use of energy transmitted at microwave frequencies (not detected by the human eye). RADARSAT operates at a single microwave frequency, which generates one channel of data and, consequently, a black and white image. This “one-channel” image can be combined with multi-date RADARSAT data (e.g., for change detection) or with data from other sources to create colour images.

As an active sensor, RADARSAT’s SAR transmits a microwave energy pulse directly towards the surface of the Earth. The SAR sensor measures the amount of energy which returns to the satellite after it interacts with the Earth’s surface. Unlike optical sensors, RADARSAT’s microwave energy penetrates clouds, rain, dust, or haze, and acquires images regardless of the sun’s illumination, enabling RADARSAT to collect data under most atmospheric conditions. A RADARSAT image of Eastern Kalimantan, an area often cloud-covered, is shown in Figure 2.1.

FIGURE 2.1: RADARSAT SAR image



RADARSAT Standard beam position 6 image of the Samarinda and Mahakam River Delta, Eastern Kalimantan, Indonesia. At full resolution, this image reveals onshore geological structures, pipeline routes along the coast, and offshore rigs surrounded by ships of varying size. Also visible are small oil slicks on the ocean surface, indicative of localized pollution or natural oil seepage. RADARSAT data © Canadian Space Agency/Agence spatiale canadienne 1997. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International.

SAR’s unique features

RADARSAT was designed to respond to a diverse range of application requirements. The following Table (2.1) highlights RADARSAT’s response to various features on the Earth’s surface.

TABLE 2.1: RADARSAT responses to surface features

SURFACE FEATURES	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.
Moisture	The amount of moisture in the soil or on the vegetation affects the amount of SAR backscatter. Variable moisture levels are represented as tonal variations in the image.
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 a sharp contrast between land/water boundaries.
Anthropogenic Features	Anthropogenic features, such as buildings and ships, strongly reflect microwave energy back to the SAR sensor. These appear as bright point targets on RADARSAT images.
Topography	Radar backscatter is greater for slopes facing the radar sensor and less for slopes facing away from the sensor. This creates a “shaded relief” image from which geological and geomorphological information can be derived.

RADARSAT'S FIXED SYSTEM PARAMETERS

Several fixed parameters influence how and when RADARSAT can image the Earth. These parameters are briefly outlined below and will be described in further detail in *Flexibility offered by RADARSAT's design*. These parameters include

- the RADARSAT SAR instrument,
- RADARSAT beam modes and beam positions,
- the orbit used by RADARSAT, and
- how data is collected and transmitted.

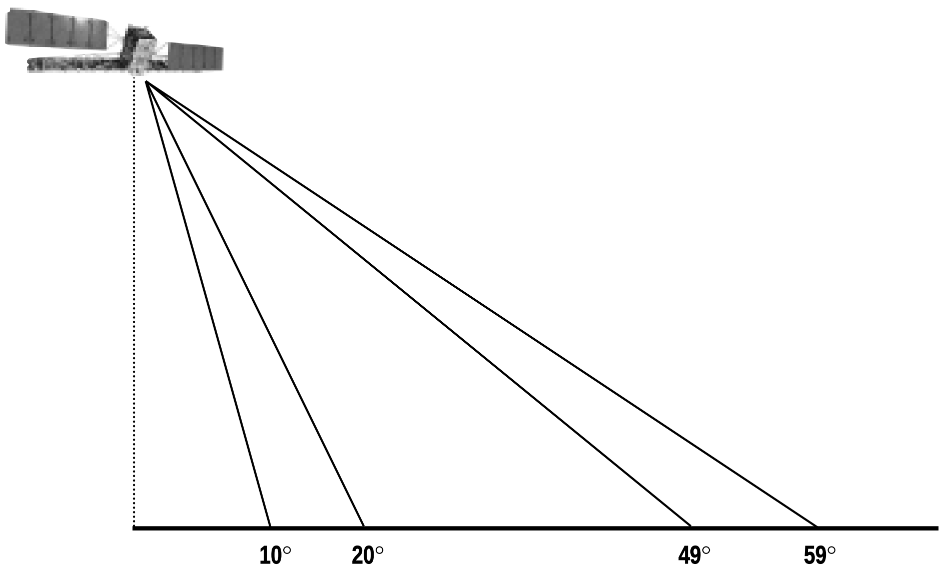
The SAR instrument

The RADARSAT antenna operates in the microwave frequency known as the C band (5.3 GHz frequency or 5.6 cm wavelength), which is able to penetrate clouds and precipitation. RADARSAT transmits and receives this energy in a horizontal orientation (polarization). This is known as HH polarization. Variations in the returned signal (backscatter) are the result of changes in the surface roughness and topography as well as physical properties such as moisture content and electrical properties. A detailed description of RADARSAT's SAR sensor is provided in Appendix A.

RADARSAT beam modes and beam positions

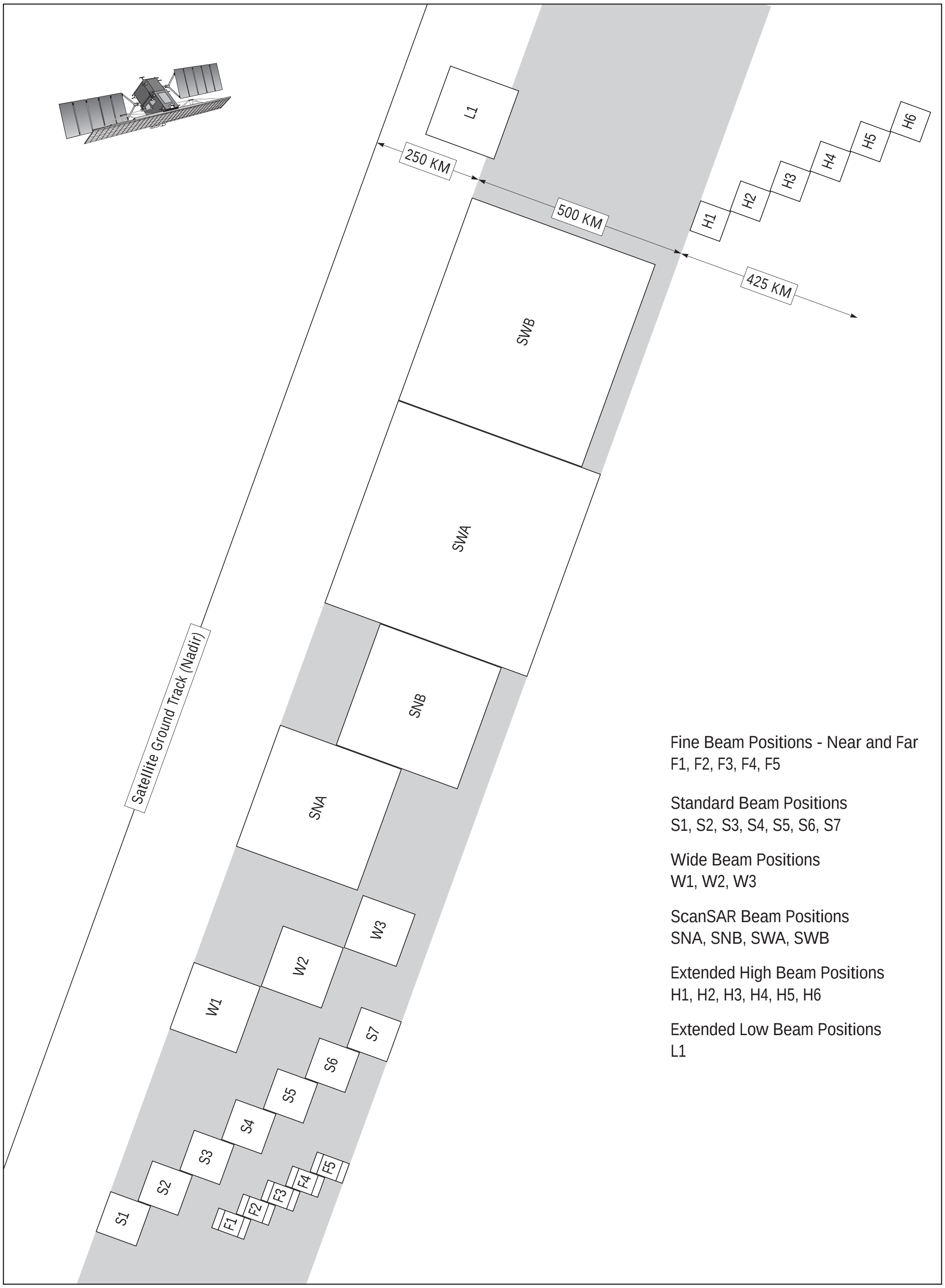
The RADARSAT satellite was designed with seven SAR imaging options, or beam modes. Each beam mode offers a different areal coverage (from ~50 km x 50 km / scene to ~500 km x 500 km / scene) and resolution (from 8 m to 100 m). The RADARSAT instrument also offers a range of incidence angles from 10° - 59° (see Figure 2.2) allowing you to choose from a selection of beam positions within each beam mode (see Figure 2.3).

FIGURE 2.2: **RADARSAT range of incidence angles**



The 35 basic product options available from RADARSAT are a result of optimal combinations of beam mode and beam position. See *Your choice of beam mode* & *Your choice of beam position* for further detail.

FIGURE 2.3: RADARSAT beam modes and positions

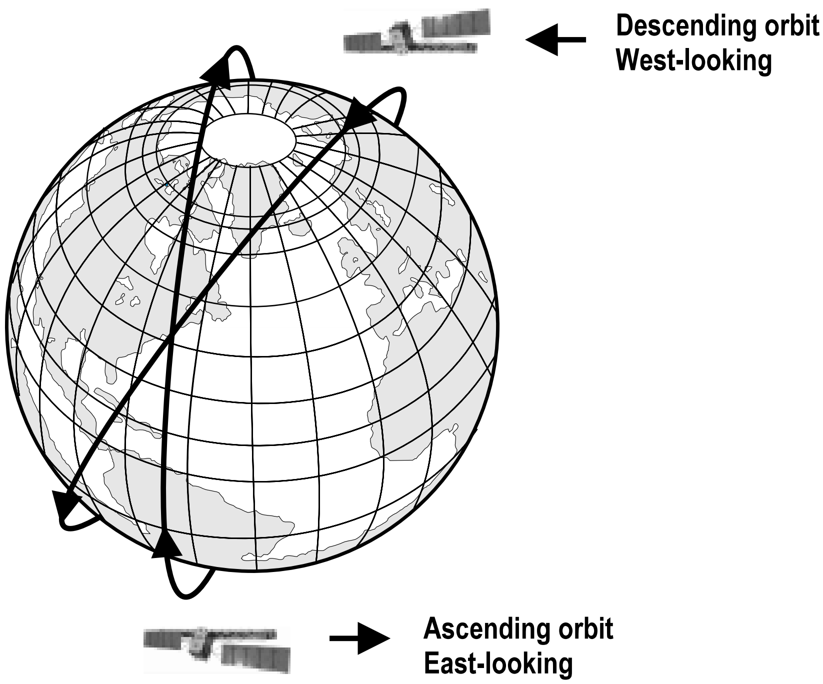


NOTE:
RADARSAT assigns its beam positions by pre-defined incidence angle ranges. An incidence angle is the angle between the radar beam and a flat Earth surface.

The RADARSAT orbit

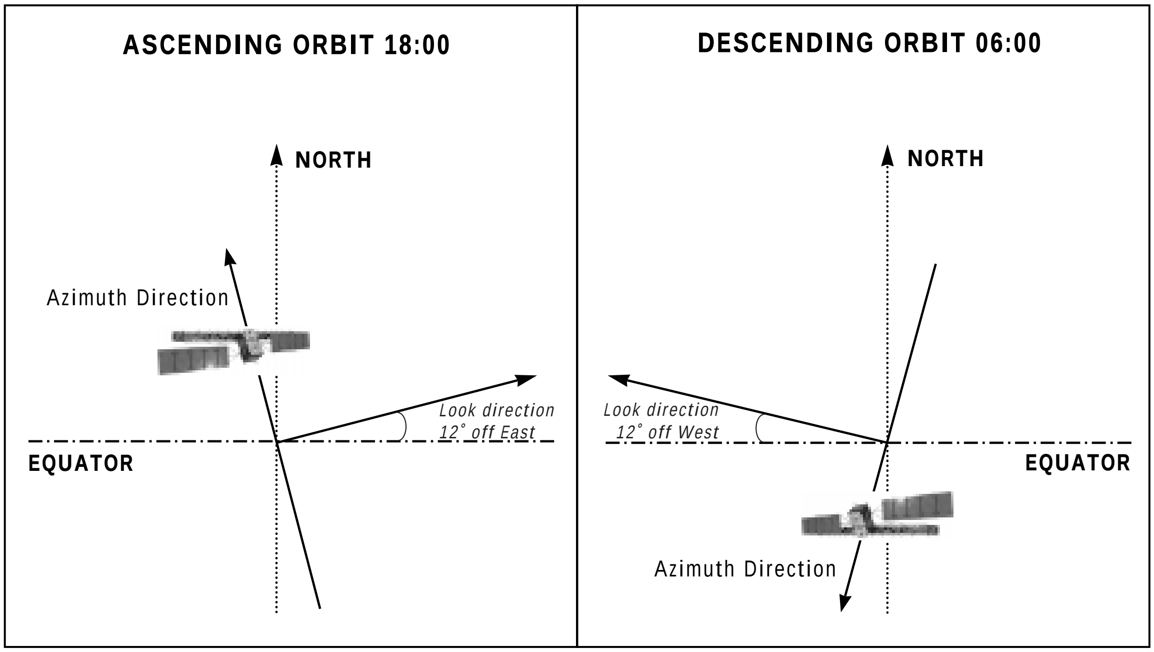
RADARSAT orbits the Earth fourteen times a day, using a sun-synchronous, dawn-dusk orbit. On the descending orbits, the satellite crosses the equator at approximately 6:00 a.m. local time, and on the ascending orbits, the satellite crosses the equator at approximately 6:00 p.m. local time (± 15 minutes). The actual time that the satellite passes over a given location will vary with latitude.

FIGURE 2.4: RADARSAT ascending and descending orbits



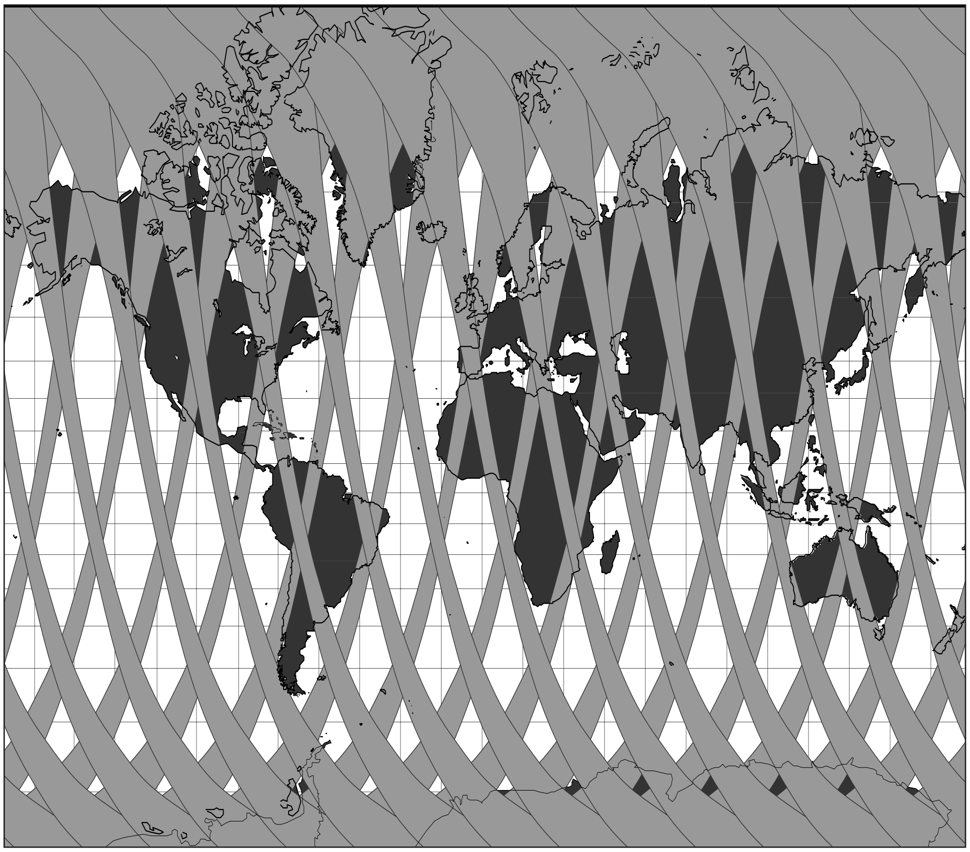
As a result of its dawn-dusk orbit, RADARSAT offers two look directions from which to view the Earth. As RADARSAT descends from the North Pole (a descending orbit pass), it views the Earth from a west-looking direction. As it ascends from the South Pole (an ascending orbit pass), it views the Earth from an east-looking direction (see Figure 2.4). On the ascending pass, the look direction is approximately 12° off East, and on the descending pass the look direction is approximately 12° off West (see Figure 2.5). The look direction controls the orientation of the radar beams with respect to the alignment of structures on the Earth's surface. See *Your choice of look direction* for more details.

FIGURE 2.5: RADARSAT look direction



RADARSAT requires 24 days to return to its original orbit path. This means that for all geographic regions, it takes 24 days to obtain exactly the same image (i.e., same beam mode, same beam position, and same geographic coverage). However, by using RADARSAT's multiple beam modes, images can be acquired on a more frequent basis. For example, the ScanSAR beam mode can view a location as frequently as once a day in high latitudes, and in less than five days at the equator (see Figure 2.6).

FIGURE 2.6: **A 24-hour RADARSAT orbital cycle using ScanSAR Wide beam mode**



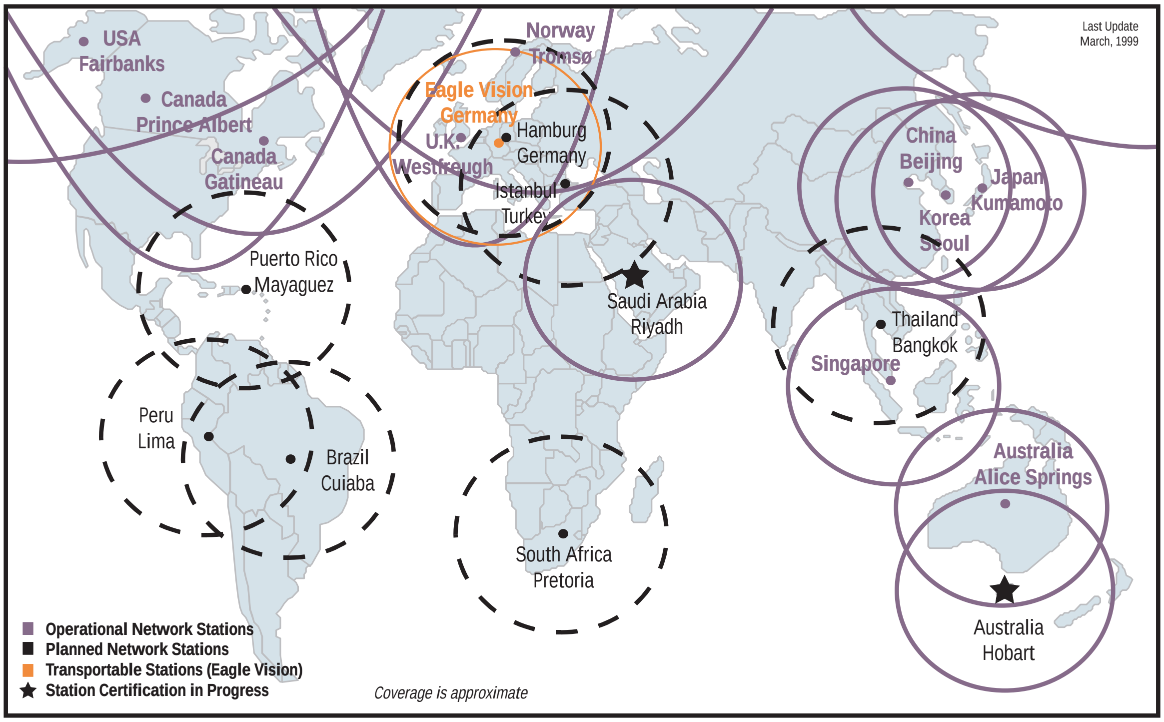
Courtesy of the Canadian Space Agency

Data collection and transmission

RADARSAT can acquire SAR data of nearly any location in the world. Data collected by RADARSAT is either directly transmitted to a local network station or stored on one of RADARSAT's two on-board tape recorders for later downlink to a RADARSAT Canadian network station.

RADARSAT downlinks its data to the network stations at different times than other Earth observation satellites (most of which use a mid-day orbit). Consequently, conflicts with other satellites are reduced for the network stations.

FIGURE 2.7: **RADARSAT network stations**



Please contact your local RADARSAT distributor or Client Services Representative for the coverage of new RADARSAT network stations.

FLEXIBILITY OFFERED BY RADARSAT'S DESIGN

Before choosing your RADARSAT product or service, the requirements and constraints of your project / application will need to be carefully evaluated. The following variables will be most important in your assessment:

- scale or level of detail required,
- geographic area and type of terrain,
- information required from the data,
- quality and reliability of the data sources (e.g., revisit period and acquisition dependability),
- how quickly the data is needed, and
- required data format (i.e., processing level).

The remainder of this chapter will help you evaluate the first four points and examines how RADARSAT can respond to your unique data requirements. The fifth and sixth point will be covered in Chapter 3 under *Processing of RADARSAT data* and *Services available to you*.

YOUR CHOICE OF BEAM MODES - THE LEVEL OF DETAIL REQUIRED

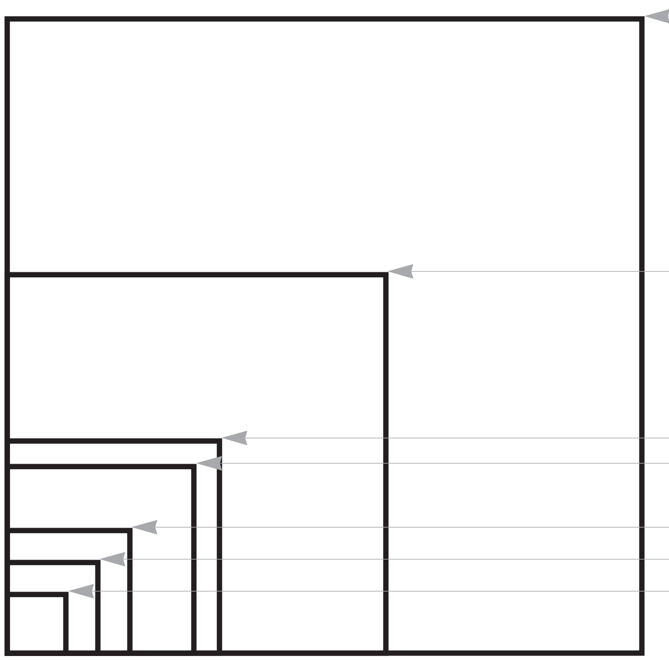
The success of deriving useful information from a data source depends on the level of detail supplied by that data source as compared to the required information. RADARSAT data has the advantage of providing a range of product scales and resolutions to facilitate a match with your project requirements. RADARSAT has seven beam modes with which to acquire data.

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

- the size of your area, and
- the type of feature(s) you wish to image.

Each beam mode is defined by the area it covers and the level of detail (resolution*) available (see Figure 2.8). RADARSAT offers a selection of beam modes ranging from Fine (which covers a 50 x 50 km nominal area) to ScanSAR Wide (which covers a 500 x 500 km nominal area). The Wide and Standard beam modes are useful for small scale (1:1,000,000 to 1:100,000) monitoring and mapping programs, while the Fine beam mode provides an additional level of detail for projects requiring larger scales (1:250,000 to 1:50,000).

FIGURE 2.8: Area coverage of RADARSAT beam modes



BEAM MODE	NOMINAL AREA COVERED (km)	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	25
EXTENDED HIGH	75 X 75	25
FINE	50 X 50	8

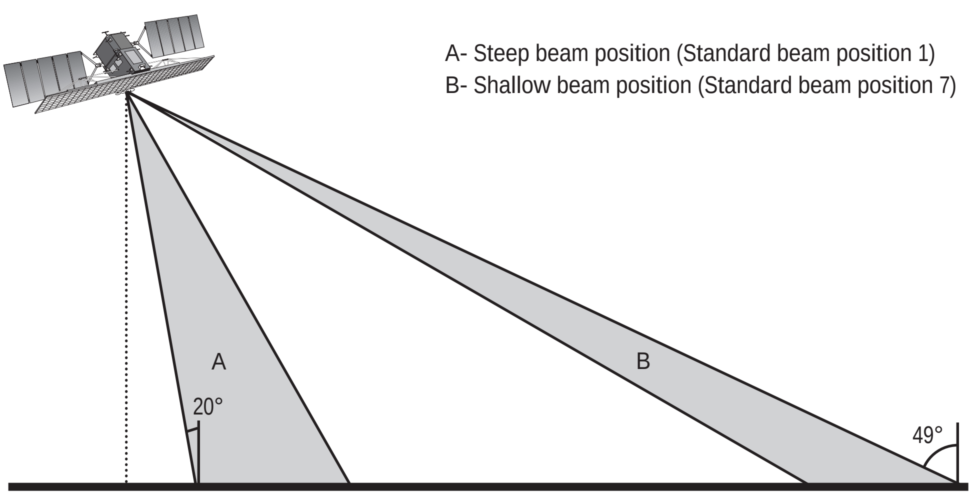
The ScanSAR beam mode, a feature unique to RADARSAT, provides repeat coverage of large areas and yields critical information for strategic operations planning, such as routing ships through polar regions or monitoring coastlines. ScanSAR provides information for scales on the order of 1:5,000,000 to 1:250,000.

*The terms resolution, pixel size, and pixel spacing are related terms but cannot be used interchangeably. The resolution is a measure of the smallest possible discernible distance between two adjacent objects using a specific sensor or beam mode. The pixel size refers to the length and width of the pixel projected on the ground, while the pixel spacing is the distance from the centre of one pixel to that of its neighbour and is generally used when the pixels are square. Resolution is determined by the acquisition parameters, and pixel spacing is determined by the processing parameters.

YOUR CHOICE OF BEAM POSITIONS - YOUR TERRAIN AND APPLICATION

A number of incidence angles are available within each RADARSAT beam mode and these are called beam positions. For example, the Standard beam mode has seven beam positions, each with its defining incidence angle range. By specifying a Standard beam position, one of seven accessible 100 x 100 km images within a 500 km swath will be collected. Variable beam positions give you the option to choose between steep or shallow angles (see Figure 2.9).

FIGURE 2.9: Standard beam mode incidence angles



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

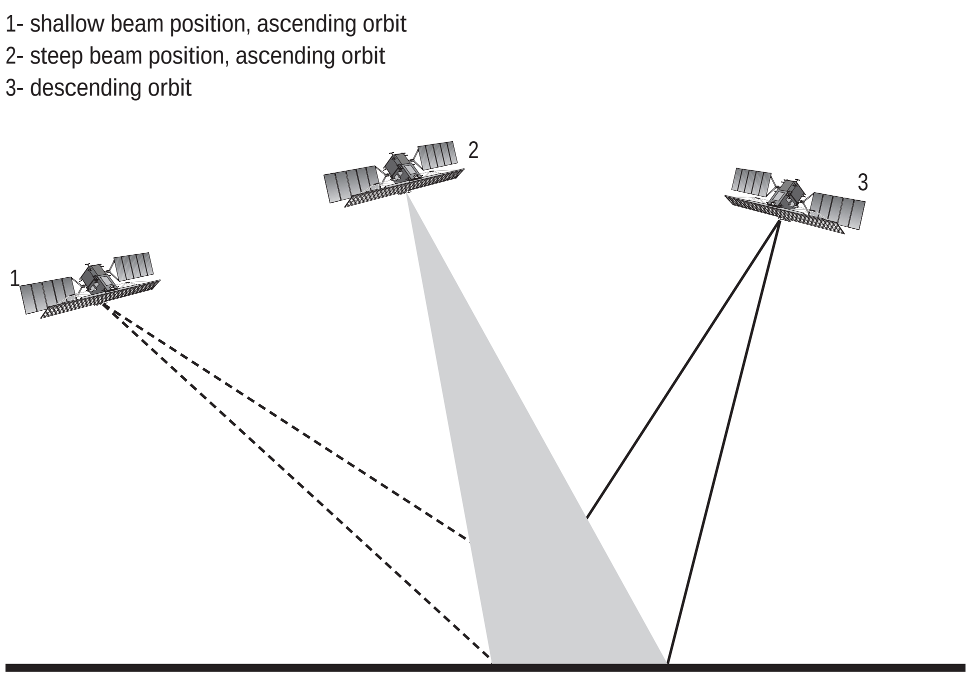
NOTE:
RADARSAT assigns its beam positions by pre-defined incidence angle ranges. An incidence angle is the angle between the radar beam and a flat Earth surface.

The addition of ten new Fine beam positions in early 1997 greatly increased RADARSAT's imaging flexibility and improved coverage efficiency, especially near the equator. To increase the available number of positions, a "near" and a "far" position were added to each of RADARSAT's original Fine beam positions.

When choosing a beam position, several factors need to be considered:

- 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.

FIGURE 2.10: RADARSAT beam position flexibility



Application sensitivity

Some surfaces will vary in appearance depending on which beam position is used. For example, point targets, such as ships, are best viewed using shallow incidence angles. Ocean features, such as oil seeps are best viewed using steep incidence angles. More information on selecting the appropriate beam positions for specific applications is found in Appendix B.

Type of terrain being imaged

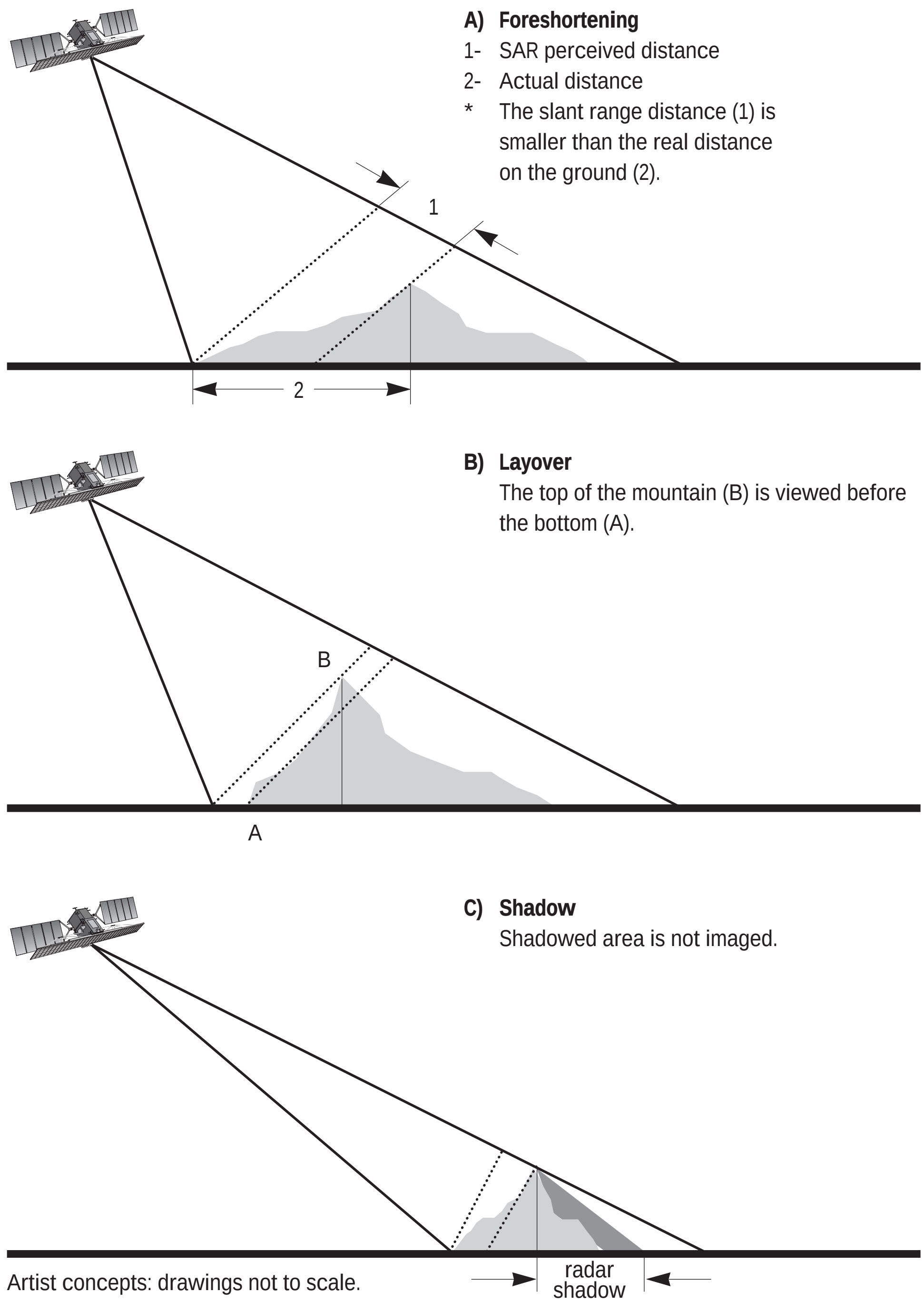
When a SAR sensor acquires data, it is measuring the time it takes for the microwave energy to leave the satellite, interact with the Earth's surface, and return to the satellite sensor. This measurement of time is then converted to a ground distance. Depending on the topography of the area, some relief displacement may occur on the resulting image. Foreshortening, layover, and shadows are examples of terrain-induced distortions that can occur on SAR images.

Foreshortening is the effect by which the SAR-facing slopes of hills and mountains appear to be compressed (see Figure 2.11A). The image of foreslopes will therefore appear brighter than other features on the same image. The greatest amount of foreshortening occurs where the slope is perpendicular to the incoming radar beam.

Foreshortening can be minimized by using a shallower incidence angle, but this can lead to increased shadow. An extreme case of foreshortening occurs when the top of a mountain is imaged before its base, and the image of the mountain appears to lean towards the direction of the radar antenna (see Figure 2.11B). This is known as layover.

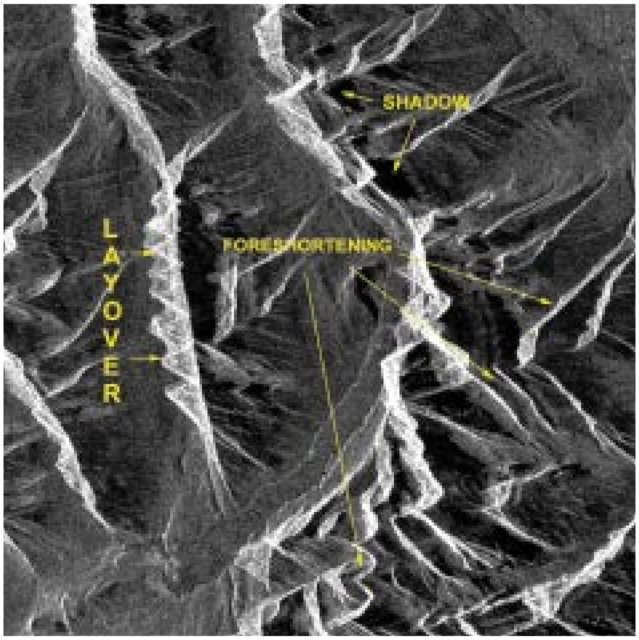
Shadows are non-imaged areas which occur on the lee sides of mountains and result in dark or black areas on an image (see Figure 2.11C). Shadows enhance structural features by highlighting changes in feature orientation.

FIGURE 2.11: Effects of terrain relief on viewing geometry



These terrain distortions can clearly be seen in the RADARSAT image near Calgary, Alberta, Canada (see Figure 2.12).

FIGURE 2.12: Terrain relief effects on SAR imagery: Calgary, AB, Canada



The effects of layover, foreshortening, and shadows are clearly illustrated in this RADARSAT image depicting mountainous terrain near Calgary, AB, Canada. Standard beam position 1: acquired February 12, 1996, area: 20 x 20 km subscene. RADARSAT data © Canadian Space Agency/Agence spatiale canadienne 1997. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International.

Stereo imagery requirements

RADARSAT's range of beam positions offers you an opportunity to acquire pairs of images for stereo analysis. Stereo pairs allow you to create digital elevation models (DEMs) and to show relationships between landforms, vegetation, mineral outcrops, and drainage systems, which may not be obvious from a single radar image. Stereo viewing with traditional stereoscopes is easily achieved using two beam positions (e.g., S2 and S7) and can greatly enhance the image interpretation. It is also possible to collect stereo pairs by viewing the same area from an ascending and a descending orbit pass (see *The RADARSAT orbit*).

Repeat coverage requirements

The RADARSAT orbit has a 24-day repeat cycle, meaning RADARSAT images the same location with the same geometry every 24 days. Fortunately, RADARSAT's beam can be programmed (or "steered") to provide more frequent coverage of a site. This is particularly useful when your application is time-sensitive and when it is important to acquire images on specific dates. We will provide you with your coverage options by assessing

- the dates or timeframe during which your image must be acquired,
- the flexibility to change beam positions,
- the satellite's orbit during that timeframe, and
- the exact latitude / longitude of your area of interest.

YOUR CHOICE OF LOOK DIRECTION - HIGHLIGHTING TERRAIN FEATURES

RADARSAT offers two look directions—east and west-looking—from which to view the Earth. On RADARSAT's descent from the North Pole, RADARSAT views the Earth from a west-looking direction. On RADARSAT's ascent from the South Pole, RADARSAT views the Earth from an east-looking direction.

RADARSAT's look direction is always perpendicular to the azimuth direction and varies with latitude. The RADARSAT azimuth is calculated from true North in a clockwise direction. At the equator, RADARSAT's azimuth is 188.6° (descending mode) and 351.4° (ascending mode).

Choosing an east or west-looking direction is important when

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

High relief vs. flat relief terrain

Selecting an appropriate beam position depends on the terrain and the application. For flat terrain, the incidence angle position will likely be unaffected by terrain-induced distortions. Conversely, for high relief terrain you can expect

- a steep beam position to produce severe layover but decrease shadows (Figure 2.11b), and
- a shallow beam position to minimize layover but increase shadows (Figure 2.11c).

By obtaining imagery from the ascending and descending passes of the satellite, both sides of the mountain can be imaged to provide a more complete data set. Knowledge about the terrain of your project area will help you select the appropriate beam position to highlight topographic features (using shadowing) and to minimize layover.

Feature orientation

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

- linear features are enhanced when aligned near-perpendicular to the look direction of the satellite, and
- linear features can be suppressed when aligned parallel to the look direction of the satellite.

Acquisition times

For certain applications, environmental conditions such as dew, snow, rain, or wind can influence when imagery should be collected. Seasonal and diurnal variations in the local environment can affect the information you are able to extract from your RADARSAT imagery. For example, studies suggest that data collection for clearcut assessment in Boreal forests is optimal during winter months. For assistance when calculating the time of day that RADARSAT passes over your area of interest, please contact your Client Services Representative.

Large-area RADARSAT mosaics

When mapping large areas, you will likely require more than one RADARSAT image. Often, images are mosaicked together to produce one full-coverage map. When obtaining the images for a mosaic, all the imaging must be carried out from the same look direction (i.e., using all ascending orbits). This ensures that the geometric and radiometric properties of each image will be similar, thereby producing an appealing and easily interpreted final product.

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

In review, RADARSATÕs many featurs, both fixed and flexible, offer solutions for acquiring data almost anywhere in the world. The following Table 2.2 highlights how RADARSAT sees the world differently.

TABLE 2.2: Seeing the world differently

TYPE OF ENVIRONMENT	CHALLENGE	RADARSAT SOLUTION
Remote	Accessibility for data collection.	Global coverage and data 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 for mapping shorelines or flood extent.	HH polarization and oblique viewing angles are favourable for land/water delineation.
Equatorial	High sun angle hinders the interpretation of terrain features.	RADARSATÕs 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 allows imaging regardless of illumination conditions.
Disasters	Volcanic eruptions or weather-related flooding create atmospheric conditions, which hamper data collection by optical sensors.	C-band microwave energy penetrates atmospheric dust as well as cloud and rain. RADARSAT provides Near-Real Time processing and Electronic delivery to satisfy time-sensitive requirements.

Data continuity with RADARSAT-2 and -3

RADARSAT-1 was designed to have a minimum five-year lifespan; however, it is currently expected to exceed this projection and continue operations until at least the year 2007. The subsequent launches of RADARSAT-2 (in late 2005) and RADARSA T-3 ensure that RADARSAT will be able to offer you a full range of products and services well into the next millennium. The dependability of RADARSAT data for monitoring applications will be strengthened with the availability of data today and in the future.

HOW RADARSAT PRODUCTS AND SERVICES MEET YOUR DATA AND TIME REQUIREMENTS

A range of products and services has been developed by RSI to meet the needs of our clients. This chapter describes each product and introduces the many time-sensitive services we offer. The details provided in this chapter will help you complete the *RADARSAT Image Request Form* described in Chapter 4.

PROCESSING RADARSAT DATA

Your RADARSAT product is a combination of satellite parameters (beam mode and position) and the level of geographic data processing you require. SAR processing typically involves

- forming an image from the signal data,
- removing SAR-related distortions generated by the SAR system or the motion of the satellite,
- radiometric compensation and calibration to produce an image that is visually appealing while preserving quantitative measurements,
- calculating the latitude and longitude for each line of data (i.e., georeferencing the image to geographic coordinates),

and, at the user's request

- providing the image in the map projection of choice, and
- improving the positional accuracy of the image using ground control points (GCPs) and, if available, digital elevation data.

RAW Data, Path-Oriented and Map-Oriented products

Three main categories of data products are available - RAW Data, Path-Oriented and Map-Oriented products.

- **RAW Data** products are unprocessed radar signals formatted to the Level 0 CEOS format. RAW data products are available for all RADARSAT beam modes, and are also referred to as "Level 0" data.

- **Path-Oriented** data products are oriented in the geometry of the swath. Points on the Earth are determined from the orbital data. These products are available from each of RADARSAT's seven beam modes and are provided in the CEOS format.

- **Map-Oriented** products provide map coordinates with "North Up" (map North). Points on the Earth are located more precisely by using GCPs. Geocoded products are available for all RADARSAT single beam modes (i.e., all but ScanSAR beam modes).

The following section describes the products available from RSI's processing centre, the Canadian Data Processing Facility (CDPF) in Gatineau, Québec, and from our production centre in Richmond, British Columbia. Products involving map orientation and orthocorrection are produced in Richmond, British Columbia. Some products are only produced at the CDPF or in Richmond, British Columbia because they are not yet offered directly from the RADARSAT network stations. RADARSAT products have been named by RSI. Table C.1 in Appendix C provides a summary of comparable naming standards and processing levels used by other satellite systems. See Appendix C regarding calibration issues.

RAW Data products

Signal Data

Signal Data (or RAW data) cannot be viewed as a scene. It is an unprocessed matrix of time delays that has been repackaged to fit into standard CEOS format. Clients will require SAR processing capabilities to use Level 0 CEOS-formatted Signal Data.

Path-Oriented products

Single Look Complex

At the Single Look Complex processing level, data is stored in slant range, has been corrected for satellite reception errors, and includes latitude and longitude positional information. In addition, Single Look Complex data retains the optimum resolution available for each beam mode and the phase and amplitude information of the original SAR data. Data cannot be directly viewed as images by all software. Interferometric applications will benefit from this RADARSAT product. Data from all beam modes, with the exception of ScanSAR, can be processed to this product.

Path Image

Path Image products are recommended for individuals and organizations experienced in image processing or for those who do not require an image in map projection geometry. Path Image processing aligns the scene parallel to the satellite's orbit path. The data is distributed in a 16-bit dynamic range. Latitude and longitude positional information is included in the data and represents the first, mid and last pixel positions of each line of data. Data from all beam modes can be processed to this product level. ScanSAR products are available only in 8 bit.

Path Image Plus

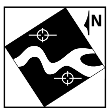
Path Image Plus uses smaller pixel spacing than Path Image to retain full RADARSAT beam mode resolution. This will enhance your ability to make detailed analyses of point targets (e.g., ships, isolated buildings), linear features (e.g., pipelines, drainage networks), or to obtain subsequent spatial information if required. However, it will create a digital file that 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-Oriented products

Map Image

Map Image processing orients the scene with “North Up” and corrects the scene to a client-requested map projection. We offer these products in a wide variety of map projections (see Appendix D). The positional accuracy of the Map Image product depends on the terrain relief, beam mode, and the accuracy of the sensor-derived positional information. This product is ideal for those clients who lack the time to transform their image to fit a map projection. Data from all single beam modes can be processed to this product (i.e., all but ScanSAR beam modes). Map Image products are offered as 8-bit or 16-bit data products.

Precision Map Image



Precision Map Image processing orients the scene with “North Up” and may provide even greater positional accuracy than Map Image processing. Ground control points (GCPs) as well as a map projection are used to spatially align the scene. (Note: Suitably scaled maps or GCPs must be provided by the client for most areas outside of Canada.) Data from all single beam modes can be processed to this product (i.e., all but ScanSAR beam modes). Precision Map Image products are offered as 8-bit or 16-bit data products.

Ortho-Image

Ortho-Image processing removes terrain distortions inherent in satellite imagery, particularly in areas of high relief. The scene is oriented to a standard map projection, corrected with a DEM and GCPs. DEM and suitably scaled maps must be provided by the client as required.

APPLYING A LOOK-UP TABLE

After processing the data, certain RADARSAT network stations apply a Look-Up Table (LUT). LUTs are similar to linear enhancements and are designed to improve the appearance of the processed image. All LUTs apply a range-dependent gain correction to the output product in order to

- optimize the radiometric scaling of the main feature of interest (while optimizing the available dynamic range in the output product), and
- compensate for changes in the radar backscatter with changing incidence angles (for the main feature of interest to the user).

The result of applying an LUT is an image in which the main feature of interest has digital number (DN) values that are well distributed within the available dynamic range and ensures constant DN values for similar surface types across the image range. This means a print of this data would have good contrast and a uniform grey scale over the entire image.

If you wish to extract radiometric calibration data, the LUT scaling operation can be reversed to derive the calibrated brightness value for each pixel in the image. LUT values used during the product generation are stored as auxiliary data in the Radiometric Data Record in the CEOS Product (SAR Header file). It should also be noted that not all RADARSAT network stations use these application LUTs. For additional LUT information, and to learn how the pixel DN values can be converted to radar brightness values (ß°) and scattering coefficients (∂°), refer to the *RADARSAT Data Products Specifications* document (RSI-GS-026).

TABLE 3.1: RADARSAT LUTs used at the CDPF

LOOK-UP TABLES	RECOMMENDED USAGE	NOTES
POINT TARGET	Imaging of calibration transponders or large corner reflectors.	Flat range independent gain designed for non-saturating imaging of high-level point targets.
SEA	Imaging of oceans.	Optimized for ocean images. Land area in images using this LUT may show saturation, particularly at steeper incidence angles.
LAND	Imaging of flat terrain target with relatively low dynamic range.	Optimized for lower ß° values. Saturation may occur in areas of high relief or in urban areas.
MIXED	Imaging of land that may include higher reflectivity targets such as urban areas, or which may include areas of high relief.	Same range variation as the land LUT but allows for higher (ß°) values. Use for land scenes if in doubt about high reflectivity.
ICE	Imaging of new and multi-year ice fields.	Land areas in images may show saturation.
UNITY	Negating the effect of an LUT.	Applies the value of 1 throughout.

ANALYSIS AND SOFTWARE/HARDWARE REQUIREMENTS FOR RADARSAT

Choosing an appropriate RADARSAT product will strongly depend on how you intend to use the data. Table 3.2 summarizes the characteristics of RADARSAT products and describes the suggested software / hardware capabilities needed to utilize RADARSAT digital data.

TABLE 3.2: Product characteristics

PROCESSING LEVEL	RADARSAT MNEUMONIC	GENERAL CHARACTERISTICS	SOFTWARE/HARDWARE REQUIREMENTS
Signal Data	RAW	Unprocessed radar signal. Level 0 CEOS-formatted.	SAR processor.
Single Look Complex	SLC	Amplitude and phase are preserved. Data remains in slant range. Data is calibrated.	Sophisticated image processing software (radar modules).
Path Image	SGF	Data is converted to ground range and multi-looked processed. Image remains oriented in direction of orbit path. Image is calibrated.	Image processing software or print media.
Path Image Plus	SGX	Data is converted to ground range. Image remains oriented in direction of orbit path. Data has finer pixel spacing than Path Image. Image is calibrated.	Image processing software or print media to accommodate larger file size.
Map Image	SSG	Image is corrected to a map projection.	GIS software and/or image processing software.
Precision Map Image	SPG	Image is corrected to a map projection. Client-provided GCPs are used to improve positional accuracy.	GIS software and/or image processing software.
Ortho-Image	ORI	Terrain distortions are removed. Orthocorrected using client-supplied DEM and maps.	GIS software and/or image processing software

SERVICES AVAILABLE TO YOU: FACTORS AFFECTING THE DELIVERY OF DATA

RSI and your RADARSAT distributor offer a number of services:

- satellite programming or RADARSAT archive searches,
- RADARSAT data processing,
- a selection of product storage media, and
- delivery options.

Remember, the choices you make affect how quickly the final product is in your hands.

PROGRAMMING AND ARCHIVE SEARCHES

Before programming the satellite, we will confirm with you, and offer advice if needed, which RADARSAT beam mode, position, and look direction you require for your particular application. We offer five programming services, which you can select from depending on how quickly your image is needed and how flexible you are on the acquisition date. All programming services are subject to the availability of satellite resources. In some cases, a search of the RADARSAT archive may be a viable choice.

Programming services

Basic: Your programming request must be finalized at least fourteen days prior to data acquisition. In the event of a programming conflict, priority may be given to another client. Data is acquired on a best-effort basis. This service is suitable for less time-sensitive applications.

Priority: Your programming request is received and finalized by RSI at least fourteen days prior to data acquisition. These requests are suitable for time-sensitive applications such as marine or crop monitoring and allow you to reserve your acquisition dates in advance.

Express: Your programming request is received by RSI and finalized at least seven to thirteen days prior to data acquisition.

Urgent: Urgent acquisitions are collected on the first available satellite pass. Your programming request must be finalized at least two to six days prior to data acquisition. This service is suitable for time-sensitive applications that cannot be planned in advance, such as flood monitoring.

Emergency: Qualifying emergency acquisitions are collected on the first available satellite pass. Your programming request must be received by RSI and finalized at least 29 to 48 hours prior to data acquisition.

RADARSAT archive searches

The RADARSAT archive contains all successfully downlinked images from 19:00 UTC on May 23, 1996 to the present. The archive includes imagery from all of the ground receiving stations participating in the RADARSAT program and is updated on a weekly basis.

If you decide to order from the archive, consider that

- you will likely receive your images more quickly than if the satellite were to be programmed (with Basic programming and Regular processing), and
- trade-offs may occur regarding your optimum beam mode, position, and look direction.

If the archive data does not suit your needs, please contact your Client Services Representative to discuss programming options.

PROCESSING SERVICES FOR RADARSAT PRODUCTS

Once data has been acquired, it can be processed to one of seven products depending on the beam mode used (as discussed in *Processing RADARSAT data*). Processing converts the downlinked SAR signal into an image product, and each product represents a different level of geographic processing.

RSI offers three time-sensitive processing service options to meet your time requirements:

Regular: This standard level of service is recommended when there is no urgency in receiving your imagery. Digital products are processed within fourteen days of reception at CDPF or a RADARSAT network station.

Rush: This level of service is recommended for time-sensitive applications (e.g., crop monitoring or flooding applications). Processing is completed within 48 hours of the data arriving at CDPF or a network station capable of providing this service. All Path-Oriented and RAW Data products are available for Rush processing.

Near-Real Time (NRT): This level of service is recommended when products are required for immediate decision-making (e.g., disaster response or ship monitoring programs). The data is processed within hours of arriving at a processing centre capable of providing this service. All Path-Oriented and RAW Data products are available for NRT processing.

NOTE:
The positional accuracy of Path Image and Path Image Plus products using Rush and NRT processing may vary slightly from products using Regular processing. Regular processing uses the definitive satellite positional information (available 24 - 48 hours after data acquisition), while Rush and NRT processing use the predicted satellite positional information.

DELIVERY

The standard method of delivering your RADARSAT product is by courier. If you require a faster turnaround, certain RADARSAT products can be delivered electronically using the Internet or a telecommunications satellite. Electronic delivery has specific system requirements. Contact your Client Services Representative to find out which methods of delivery are available in your area.

Courier

RADARSAT products are typically delivered to you by courier from the network station where they were processed. Courier services can take from two to seven working days for most major cities. Please contact your Client Services Representative for an estimated courier delivery schedule to your destination.

Electronic delivery

In order to respond quickly to our clients' needs, electronic delivery of your product is available from most RADARSAT network stations. This option enables you to receive and analyze time-critical information about your region of interest within hours of data acquisition and downlink.

File sizes for data delivered via the Internet are usually smaller than those for data delivered on CD-ROM or 8 mm data cartridge. This allows you to retrieve your products in a reliable and timely manner. Data files may be reduced by either providing subscenes or overview files. Data volume is decreased in the overview files using decimation, block averaging, or wavelet compression. Standard data formats for Internet delivery are TIFF or JPEG, with GeoTIFF and TIFF World formats available in certain cases from the CDPF. Tables are available from RSI which provide you with transmission time estimates for each Path Image product by beam mode, bandwidth (modem speed), and compression technique.

The electronic data transfer is followed by delivery by courier of the full product (on either CD-ROM or 8 mm data cartridge) the next business day. To utilize this electronic delivery service, you must have an Internet connection that will support at least 56 Kbps data transfer for extended periods. Data delivery speeds cannot be guaranteed.

STORAGE MEDIA OPTIONS

RADARSAT products are available on a number of media:

Digital

- CD-ROM,
- 8 mm data cartridge, or
- 9-track computer compatible tape (CCT).

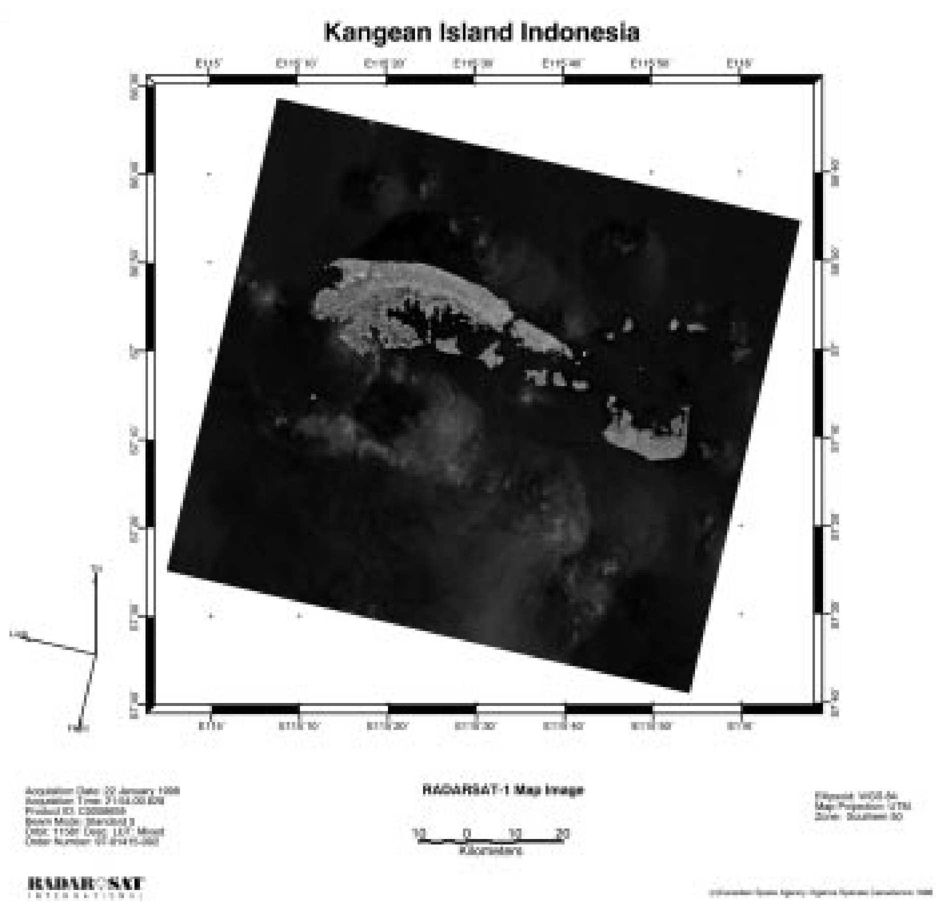
Hardcopy

- film negative or film positive, and
- print.

RADARSAT HARDCOPY PRODUCTS

Your RADARSAT product is delivered to you in digital format on the medium of your choice. Should you wish a print of your image, a film negative can be purchased from which a print can be made. Film negatives / positives are produced in our Richmond, B.C. production facility. Keep in mind that output scales are dependent on beam mode and processing level. Hardcopy RADARSAT products contain the RADARSAT image plus auxiliary information as shown in Figure 3.1.

FIGURE 3.1: **RADARSAT hardcopy film annotation**



RADARSAT DIGITAL PRODUCTS

The CEOS format

Digital RADARSAT products are stored in the standard CEOS format (see Table C.4 in Appendix C). You can read the CEOS format using most leading commercial image analysis software packages. The RADARSAT Endorsement Program (Appendix C) ensures that RADARSAT data can be imported into the endorsed companies' software.

Additional viewing information is now delivered with your RADARSAT digital product from the CDPF*. The following features are currently included on your CD-ROM:

- a software viewer called ProView™,
- improved output descriptions,
- instructions for loading and viewing the image,
- an overview of the image, and
- software to read the CEOS fields.

*Other RADARSAT network stations may or may not have similar features.

CUSTOMIZED PRODUCTS AND SERVICES

RSI is committed to responding to our clients needs by developing new products and services to support specific application and project requirements. New services are also developed for projects which may have some of the following characteristics:

- large data volume requirements,
- time-sensitive delivery needs,
- periodic assessments needs, and
- weather-dependent criteria.

Our new services

Monitoring Service

RADARSAT has the dependable ability to acquire imagery on a daily, seasonal, or annual scale regardless of weather and sun illumination conditions. Applications for this service include coastal monitoring, oil spill monitoring, ice tracking, agricultural monitoring, surveillance / change detection, and disaster monitoring. Cost-effective pricing is available for a minimum order size of fifty RADARSAT scenes.

Large Area Coverage

Special $ / km^2 pricing is available for large volume orders of Fine, Standard, and Wide beam mode data. This offer applies to contiguous coverage in a single order. Large Area Coverage is suitable for deriving thematic information for base mapping, as well as land cover and geological mapping.

Emergency Response Service

The Emergency Response Service is a proactive service which enables clients to receive information to support the development and management of disaster / emergency relief plans and to respond effectively to catastrophic events.

The Emergency Response Service is a one-year commitment that provides a suite of services to prepare and assist you in the management of your preparedness and response to natural disasters and emergency situations. This subscription includes on-site operational training, development of operational scenarios and response plans, pre-planning of acquisitions, an operational simulation, and a data block (3 RADARSAT scenes using any beam mode). Additional data blocks can be ordered at any time. This service provides Emergency programming, Near-Real Time processing and Electronic delivery of data (Path Image processing only). In this manner, time-sensitive information critical for the management and response of emergencies is made available to you when you need it.

Offshore Exploration Service

The Offshore Exploration Service caters specifically to clients with offshore areas of interest (e.g., offshore hydrocarbon exploration and well-head and rig location identification). This service is a renewable one-year subscription for a minimum commitment of fifty RADARSAT scenes per year. Scenes can be selected either by using a programming service or by accessing the RADARSAT worldwide archive. Substantial savings in the cost of data and Meteorological programming are afforded the client.

Meteorological programming

The Meteorological programming service was introduced to meet the needs of users working with weather-dependent offshore applications—primarily oil seep detection. Meteorological programming recognizes that the usefulness of the RADARSAT data depends on the environmental conditions at the time the image was acquired. A non-recoverable programming fee offers the user up to three imaging attempts over a site. Data is only processed when you confirm the acceptability of the meteorological conditions. This service includes Path Image processing of data.

The client must contact RSI with weather information immediately after each acquisition attempt. If the weather conditions prove acceptable on the first attempt, the second acquisition attempt will be dropped unless a second, separate acquisition is requested / ordered.

Stereo Data

RADARSAT stereo data is competitively priced (with a minimum of 60% overlap) for all beam modes. Clients can choose from mixed modes (e.g., Standard beam mode with Fine beam mode) and flexible beam positions to ensure their information requirements are met. RADARSAT's range of resolutions and swath widths offers a variety of mapping scales. Use this service for terrain interpretation and to generate anaglyphs and DEMs.

Our new customized and off-the-shelf products

RADARMaps

RADARMaps are pre-processed 1:250 000 scale indexed map sheets derived from our ScanSAR Narrow mosaics. Each indexed map sheet measures 1° latitude by 1.5° longitude and has 50 m resolution. RADARMaps are available as basic or orthorectified products with a standard cartographic surround. Each RADARMap is delivered to you in digital and hardcopy format.

Digital Elevation Models

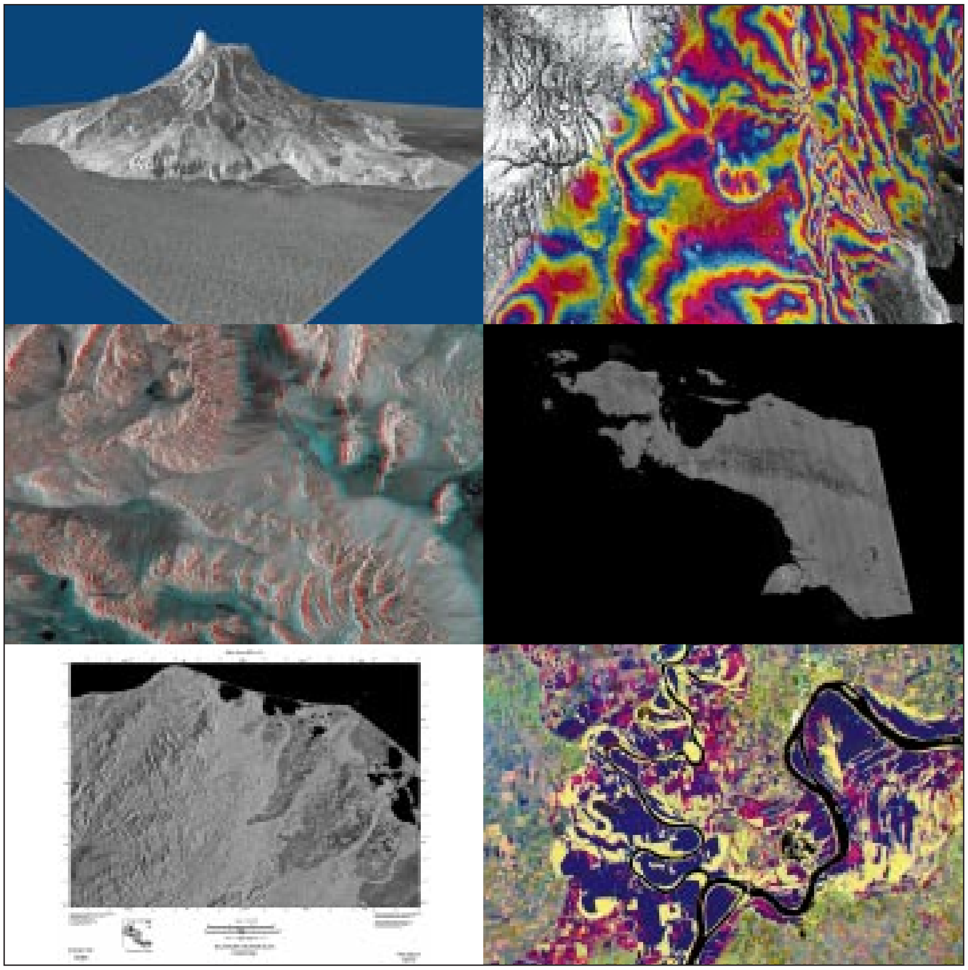
RADARSAT digital elevation models (DEMs) are ideal for use in terrain analysis and geometric correction of airborne and satellite data. Stereo pairs from RADARSAT can be used to produce high quality, competitively priced DEMs of an accuracy compatible with DTED Level 1 specifications. DEMs play a critical role in geological interpretations, telecommunications, engineering, and in the creation and updating of topographic maps.

ScanSAR Mosaics

ScanSAR mosaics are pre-processed black and white image mosaics that cover large, pre-defined areas. These mosaics have 50 m resolution and are suitable for mapping at scales up to 1:200 000. These mosaics provide you with synoptic coverage at cost-effective prices. ScanSAR mosaics are available as basic or orthorectified products.

For further details and updates on any custom or off-the-shelf products or services, please contact your Client Services Representative.

FIGURE 3.2: **RADARSAT products**



A	D
B	E
C	F

A DEM
Heard Island, Australia

B Anaglyph
Death Valley, California, USA

C RADARMap
Central America

D Interferogram
Bathhurst Island, NWT, Canada

E Mosaic
Irian Jaya, Indonesia

F Multitemporal Merge
Ohio River Flood, USA

 (A) DEM by Intermap Technologies. (D) Interferogram by CCRS.
(C & E) RADARMap and mosaic by RGI. (B & F) Anaglyph and multitemporal merge by RSI.

INTRODUCTION 1

HOW RADARSAT SEES THE WORLD 2

RADARSAT PRODUCTS AND SERVICES 3

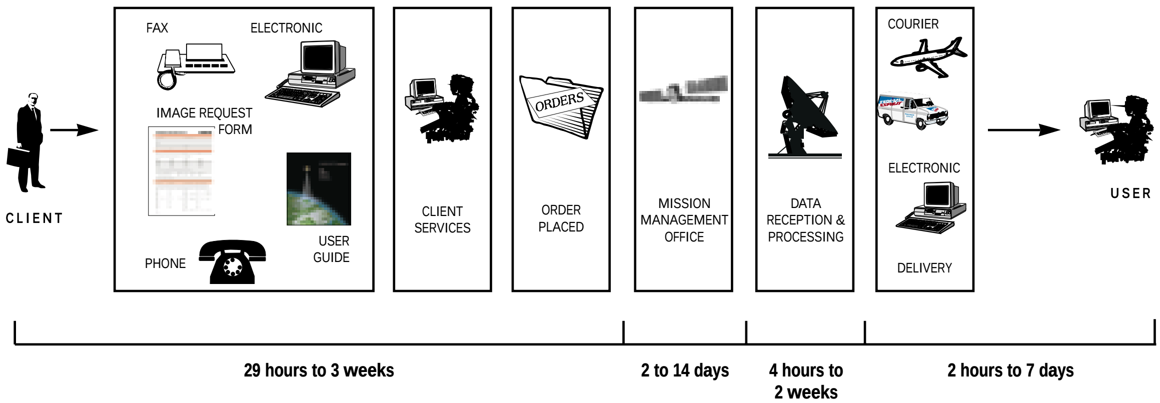
ORDERING YOUR RADARSAT PRODUCT 4

REFERENCE MATERIALS

ORDERING YOUR RADARSAT PRODUCT

This chapter focuses on the ordering process and the information we require to successfully deliver your RADARSAT products. We will guide you through a basic RADARSAT order and provide you with a step-by-step guide to filling out the *RADARSAT Image Request Form*. You may wish to refer to Chapters 2 and 3 for greater detail on the choices available to you.

FIGURE 4.1: **The RADARSAT ordering process**



WHO DO I CONTACT TO ORDER MY RADARSAT PRODUCT?

RADARSAT International (RSI) has the exclusive distribution rights for RADARSAT-1 data to the worldwide user community. 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 the RADARSAT network stations, which receive and process RADARSAT data. To exclusively serve the Canadian and USA Governments, three order desks have been set up (for Canada: the Canada Centre for Remote Sensing and the Canadian Space Agency, and for the USA: the Alaska SAR Facility).

A list of the current RADARSAT distributors and participating RADARSAT network stations can be found on the RSI website (www.rsi.ca). You can order RADARSAT products directly from RSI's Client Services department or from your local distributor.

A number of steps are involved from ordering to delivering a RADARSAT product. Figure 4.1 presents an itemized timeline of the process and illustrates each of the steps and the level of input required from you.

Planning the acquisition and ordering your product

After contacting your Client Services Representative, or distributor, the next 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. Consult your local distributor or an RSI Client Services Representative **one to two weeks** before you plan to submit a basic order. To facilitate this process we suggest you review this user guide and see the *RADARSAT Image Request Form* at the back of this guide or in Figure 4.2.

FIGURE 4.2: The RADARSAT image request form

RADARSAT-1 Image Request Form

RADARSAT INTERNATIONAL

CLIENT

Contact .... Date of Request ....
Organization ....
Address ....
....
Country .... Postal/Zip Code .... Phone # ....
Fax # .... E-mail .... URL ....

APPLICATION AND GEOGRAPHIC LOCATION OF PROJECT

Application description (e.g., oil seep detection, geological mapping, crop monitoring):
....
....

Level of detail required (resolution): ❑ 8 m ❑ 25 m ❑ 30 m ❑ 50 m ❑ 100 m
Terrain relief / other specific considerations:
....

Geographic coordinates of area of interest* (in latitude/longitude with degrees and minutes):

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

** Please provide a map if the shape of the area is complex*

BEAM MODE AND BEAM POSITION OF CHOICE

Please indicate your preferred **beam mode***: ....
Please indicate your preferred **beam position*** if known: ....
** See attached RADARSAT-1 Beam Modes and Positions Reference Sheet*

LOOK DIRECTION

Look Direction: ❑ Not important ❑ Descending pass (West-looking) ❑ Ascending pass (East-Looking)

PRODUCTS AND SERVICES

Archive and Programming Services

Archive search: ❑ Yes ❑ No
Programming request: ❑ Basic ❑ Priority ❑ Express ❑ Urgent ❑ Emergency
Dates of interest: from .... to ....
from .... to ....
from .... to ....

Special project timeline requirements: ....
....
....

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RADARSAT Products

RAW Data Products	Path-Oriented Products	Map-Oriented Products
❑ Single Look Complex	❑ Path Image	❑ Map Image
❑ Signal Data	❑ Path Image Plus	❑ Precision Map Image*
		❑ Ortho-Image*

** Suitably scaled maps or ground control points must be provided for Precision Map Image products*
** DEM and suitably scaled maps must be provided for Ortho-Image products*

Processing Services

❑ Regular ❑ Rush ❑ Near-Real Time

Media Options

Digital: ❑ CD-ROM ❑ CCT ❑ Data Cartridge
Film: ❑ Yes ❑ No
Print*: ❑ Yes ❑ Requested scale:
** In order to produce a print, the digital data and a film must be purchased.*

Delivery Services

❑ Courier ❑ Electronic delivery
Contact ....
Organization ....
Address ....
....
Country .... Postal/Zip Code ....
Phone # .... Fax # .... E-mail ....

SPECIAL INSTRUCTIONS / NOTES

....
....
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....

RADARSAT INTERNATIONAL
Tel: 1-(604) 244-0400 or Fax: 1-(604) 244-0404
e-mail: info@rsi.ca www.rsi.ca

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At this time you will need to provide your distributor or Client Services Representative with the information outlined on the *RADARSAT Image Request Form*. Your contact will help you by

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

Once the *RADARSAT Image Request Form* has been completed and reviewed you will receive a Preliminary Assessment based on the information you have provided. This phase should take place no less than two weeks before the planned acquisition. The Preliminary Assessment is sent to you by fax or email and indicates

- the number of images required to cover your area of interest, and
- possible coverage scenarios.

You should carefully review the Preliminary Assessment to ensure it meets all your requirements. Modifications to the information provided on the *RADARSAT Image Request Form* and Preliminary Assessment are encouraged to promote optimal scene acquisition.

Once you are satisfied with the plan, we will issue a Technical Proposal and a Financial Proposal, which require your signature and pre-payment unless prior approved credit has been arranged. The acquisition plan is then provided to the Mission Management Office (MMO) in Québec, who is responsible for programming the RADARSAT satellite. After the Technical and Financial Proposals are signed, **you are bound to purchase the data acquired on your behalf.** See Appendix E for our General Terms of Sale.

RADARSAT data acquisition

Once the order has been placed, the Canadian Space Agency (CSA) 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 will be applied in order to determine the final programming of the satellite:

- satellite health and safety, orbit, and altitude maintenance,
- a CSA declared Emergency,
- paid programming services, and
- basic programming services.

The custom services offered by RSI (see Chapter 3 *Custom Products and Services*) such as the Offshore Exploration Service and the Monitoring service have their distinct levels of programming priority that fit in with the above-mentioned guideline.

If a conflict does occur, your distributor or Client Services Representative will contact you immediately.

After the satellite is programmed with your request, the data will be collected and directly downlinked to a nearby RADARSAT network station. If a network station is unavailable, the data will be stored on one of RADARSAT's two on-board tape recorders. The recorded data will be later downlinked to an available RADARSAT network station. See Appendix A for additional information.

RADARSAT data processing

Once the data has been received at a network station, it is archived as Signal Data. The data is then processed to the product indicated on the Financial Proposal. Processing may be performed at one of the RADARSAT network stations or at the RSI processing facility in Gatineau, Québec. Additional processing such as geocoding and film production is performed at the production facility in Richmond, British Columbia. Once the processing is completed and the payment terms are met, the data will be delivered to you. You may contact your Client Services Representative at any time to obtain an updated status of your acquisition or order.

Obtaining data from the RADARSAT archive

Data can be ordered directly from the RADARSAT archive by completing the *RADARSAT Image Request Form*. On this form you will be asked to provide your geographic coordinates, the range of desired beam modes, and the dates for which the archive should be searched. Your Client Services Representative will search the archive for your specific data range or for all acquisitions from May 23, 1996 to the present. A list of available archive data will be provided to you. Once you choose the data you wish to purchase, a Technical and Financial Proposal will be issued for your signature. If the archive data is unsuitable, you may wish to place a programming request. See Chapter 3—*RADARSAT archive searches* for greater detail.

Once the Technical and Financial Proposals have been signed, you are contractually obligated to purchase the archive data. After you have supplied your Client Services Representative with this documentation, the data is shipped from the archive to the appropriate processing facility and processed to the product requested.

The RADARSAT archive is updated weekly. You can download information on image availability from the RSI ftp site (ftp://ftp.rsi.ca/archive).

THE RADARSAT IMAGE REQUEST FORM

The following sections examine in sequence the options available to you on the *RADARSAT Image Request Form*. When filling out this form, feel free to contact your distributor or Client Services Representative for assistance or additional information. When you have completed this form, fax or mail it to your RADARSAT contact. Additional copies of the form can be obtained from your distributor or Client Services Representative.

A detailed description of your application will assist us when recommending the best RADARSAT product for your project or operation. Some examples of specific application descriptions are provided in Table 4.1.

TABLE 4.1: List of RADARSAT applications

APPLICATION	SUB-APPLICATION
AGRICULTURE	• Crop compliance monitoring • Soil moisture studies • Harvest prediction • Rice crop monitoring
COASTAL / OCEANS	• Ocean features detection • Wave spectra • Aquaculture monitoring • Coastline mapping • Oil spill monitoring
FORESTRY	• Harvest mapping • Broad class mapping • Clearcut detection
GEOLOGY	• Geological mapping • Terrain mapping • Petroleum exploration • Structural mapping • Oil seep detection
HYDROLOGY	• Wetlands mapping • Watershed management • Flood monitoring
MAPPING	• Base mapping • Land use/land cover mapping • Topographic mapping • DEM creation
SEA ICE	• Regional mapping • Ship routing • Ice type classification
SURVEILLANCE	• Point target detection • Terrestrial surveillance • Maritime surveillance (e.g., ship detection and monitoring)

Additional information, such as project scale, terrain relief (the elevation range within the area indicated in metres), or other considerations (e.g., the need for imagery during a particular season) will help us define the optimal product and acquisition time. The more detailed information you can provide to us, the better we can serve you.

FIGURE 4.3: Ship routing using RADARSAT ScanSAR Wide beam mode

This RADARSAT ScanSAR Wide beam mode image of the Gulf of St-Lawrence was acquired March 6, 1996 on an ascending orbit pass. The displayed pixel spacing is 250 metres. RADARSAT data © Canadian Space Agency/ Agence spatiale canadienne 1996. Received by the Canada Centre for Remote Sensing (CCRS). Processed and distributed by RADARSAT International. Imagery enhancement and interpretation by CCRS.

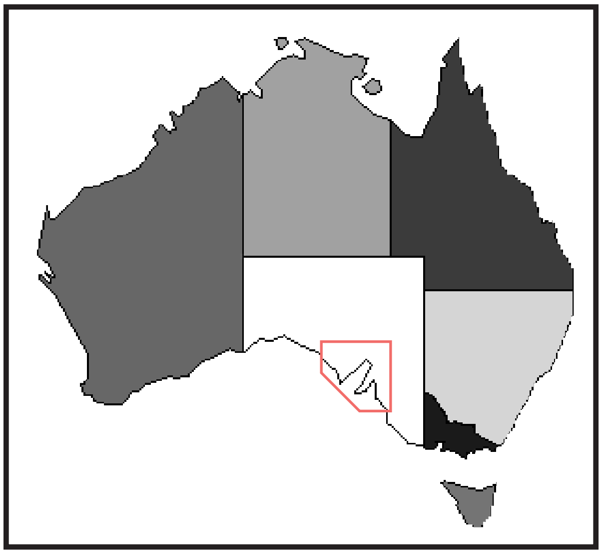
GEOGRAPHIC LOCATION

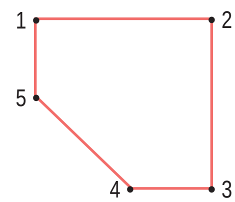
We will need to know the geographic location of your area of interest. The location is defined by both the political boundaries (country or region) in which it falls and by the set of latitude / longitude coordinates which bound the area. We use these latitude / longitude coordinates in the RADARSAT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

RADARSAT does not use a Path / Row or K / J reference system like LANDSAT and SPOT. The aforementioned sensors essentially have fixed scene sizes, making it easier to develop and employ the Path / Row reference system. RADARSAT has variable scene widths (50 km to 500 km) and incidence angles (10° to 60°), making a Path / Row system inappropriate.

You may wish to provide us with a map of your area of interest, particularly if the area has an unusual shape (e.g., an island). This will allow your Client Services Representative to target your area more specifically. Figure 4.4 shows an example of a study site requiring RADARSAT coverage.

FIGURE 4.4: Specifying latitude/longitude coordinates





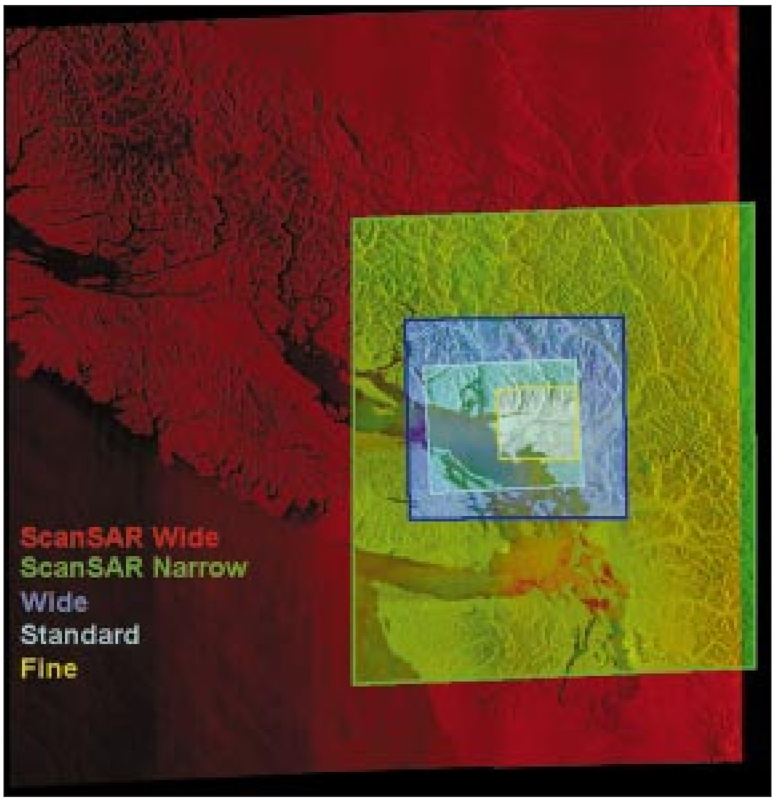
1. S 32° 0' E 134° 40'
2. S 32° 0' E 140° 0'
3. S 37° 30' E 140° 0'
4. S 37° 30' E 139° 0'
5. S 34° 30' E 134° 40'

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.

To choose the most appropriate beam mode, you will need to consider

- the size of your area,
- the features you are trying to see, and
- the final output scale desired. See Chapter 2 for more details.

FIGURE 4.5: **Area coverage of RADARSAT beam modes**



Your selection of beam modes will be made in conjunction with your selection of beam positions. Figure 4.5 illustrates the areal coverage provided by each of the RADARSAT beam modes. Specific information is provided in Table 4.2. 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 supplies detailed information on RADARSAT beam modes and product specifications. If you are in any doubt, call your Client Services Representative or distributor for assistance.

BEAM POSITION SELECTION

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 require coverage of the area. See Chapter 2 and Appendix B for more details.

Table 4.2 summarizes the incidence angle ranges and the beam positions available for each beam mode. RSI will need to know the optimum beam position that you require for your project. To help you choose an appropriate beam position, remember to provide us with as much information as possible about your specific application and the terrain conditions.

TABLE 4.2: RADARSAT beam position characteristics

BEAM MODE	BEAM POSITION	INCIDENCE ANGLE RANGE (°)	APPROXIMATE RESOLUTION (m)	NOMINAL AREA (km)
Fine	F1 near	36.4 - 39.6	8	* 50 x 50
	F1	36.8 - 39.9		
	F1 far	37.2 - 40.3		
	F2 near	38.8 - 41.8		
	F2	39.2 - 42.1		
	F2 far	39.6 - 42.5		
	F3 near	41.1 - 43.7		
	F3	41.5 - 44.0		
	F3 far	41.8 - 44.3		
	F4 near	43.1 - 45.5		
	F4	43.5 - 45.8		
	F4 far	43.8 - 46.1		
	F5 near	45.0 - 47.2		
	F5	45.3 - 47.5		
	F5 far	45.6 - 47.8		
Standard	S1	20 - 27	25	100 x 100
	S2	24 - 31		
	S3	30 - 37		
	S4	34 - 40		
	S5	36 - 42		
	S6	41 - 46		
	S7	45 - 49		
Wide	W1	20 - 31	30	165 x 165
	W2	31 - 39		* 150 x 150
	W3	39 - 45		130 x 130
ScanSAR Narrow	SNA	20 - 40	50	300 x 300
	SNB	31 - 46		
ScanSAR Wide	SWA	20 - 49	100	500 x 500
	SWB	20 - 46		450 x 450
Extended High	H1	49 - 52	25	75 x 75
	H2	50 - 53		
	H3	52 - 55		
	H4	54 - 57		
	H5	56 - 58		
	H6	57 - 59		
Extended Low	L1	10 - 23	35	170 x 170

* *tape recorded data may cover smaller area*

NOTE:
The numbers shown in the table are approximations.
The actual resolutions will vary slightly and are defined in Appendix C.
Nominal areas take into account ± five kilometre cross-track drift. Thus the image will be ± five kilometres from what is shown on the SPA Technical Proposal.
Extended High and Low beam modes operate outside of the optimum scan range of the antenna.
W3 has a consistent nadir ambiguity (narrow vertical, white line) that affects its appearance. For many applications the nadir ambiguity does not affect the usefulness of the data.

In some cases, more than one beam position can satisfy your application requirement, so we recommend that you specify a range of beam positions. This gives us increased flexibility to meet your requirements and to optimize the number of scenes required to cover your area.

LOOK DIRECTION

RADARSAT provides two look directions, which correspond to the satellite's ascending and descending orbit passes: the ascending orbit pass is "east-looking", and the descending orbit pass is "west-looking".

Choosing between an east or west-looking 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 early morning or early evening acquisition times, and
- the output from the project will be a mosaic of numerous RADARSAT images. See Chapter 2 for more details.

Specifying "not important" on the *RADARSAT Image Request Form* will double the number of opportunities to acquire imagery over your area.

PRODUCTS AND SERVICES

The Products and Services section of the *RADARSAT Image Request Form* provides you with the opportunity to select the level of service that best meets your data needs and project time requirements.

ARCHIVE AND PROGRAMMING SERVICES

1) **Archive searches:** Computer searches of previously-acquired data stored in the RADARSAT archive.
2) **Programming services:** The satellite is programmed to collect data. Programming depends on the availability of satellite resources. A choice of five programming services exists:

Basic	• Your order is finalized at least fourteen days in advance of data acquisition. • In the event of a programming conflict, priority may be given to another client.
Priority	• Your programming request is received and finalized at least fourteen days prior to data acquisition. • This service is suitable for time-sensitive applications such as monitoring (reserve your acquisition dates).
Express	• Your order is finalized seven to thirteen days in advance of data acquisition.
Urgent	• Images are acquired on a first available opportunity basis. • Order is finalized two to six working days prior to data acquisition.
Emergency	• The situation must qualify as an emergency • Images are acquired on the first available satellite pass. • Your order is finalized by RSI at least 29 to 48 hours prior to data acquisition.

Deciding when to acquire your RADARSAT images will be influenced by

- your application and operational requirements,
- whether you need to collect supporting data, and
- RADARSAT's orbit characteristics. See Chapter 2 for more details.

Please indicate if data must be acquired on a specific date due to field work or other application requirements. If not, 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 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 minimize the possibility of conflicts.

You are encouraged to plan multitemporal image acquisitions well in advance. 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.

RADARSAT data can be processed to one of seven products depending on the RADARSAT beam mode you have selected. Your product choice will depend on

- your analysis requirements,
- your hardware and software capabilities,
- how quickly you need the data, and
- the beam mode you have selected. See Chapter 3 for more details.

The characteristics of each product are summarized in Table 4.3 and the availability of processing levels for the various beam modes is summarized in Table 4.4.

NOTE:
Map-Oriented products are not available with Rush and Near-Real Time processing services.

TABLE 4.3: RADARSAT product characteristics

PRODUCT NAME	PRESENTATION PLANE	IMAGE ORIENTATION	CLIENT 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, GCPs
Ortho-Image	Ground range	To map	Map projection, GCPs, DEM

For Map Image products, the map projection and related parameters (see Appendix D) need to be specified. For Precision Map Image products, GCP information is required. You must provide us with good quality maps. You can also provide Global Positioning Satellite (GPS) information to be used for ground control points. Ortho-Image products require user-supplied GCPs and DEMs. Product specifications for each beam position and processing level are found in Appendix C.

TABLE 4.4: RADARSAT beam mode and processing level availability

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

*ScanSAR Narrow and ScanSAR Wide products are processed to a level similar to Path Image; however, these products are 8 bit only and are mirror images (i.e., flipped North-South or East-West).

PROCESSING SERVICES

RSI offers three levels of data processing:

Regular
- Digital products are processed within 14 days of data reception at a RADARSAT processing facility.

Rush
- Digital products are processed within 48 hours of data reception at the CDPF or a RADARSAT network station with this capability.

Near-Real Time
- Digital products are processed within hours (~ 4) of reception at the CDPF or a RADARSAT network station with this capability.

NOTE:
Map-Oriented products, including films and prints, are not available with Rush and Near-Real Time processing services.

MEDIA OPTIONS

Your RADARSAT product will be delivered on a CD-ROM unless you specify otherwise. Digital products are also available on computer compatible tape (CCT) and 8 mm data cartridge. Please indicate the digital medium you prefer. Hardcopy products are generated on request, in addition to the digital products. Prints can be made from film at client-defined scales. Limited processing of the imagery is carried out before a film transparency is created. A histogram stretch ensures that maximum contrast is achieved in the imagery. For film or print prices as well as suitable map scales, please contact your Client Services Representative or refer to the RADARSAT Price List.

DELIVERY SERVICES

Your delivery options include:

Courier	• Product is typically delivered by courier from the network station where is was processed. Courier delivery can take from two to seven working days for most major cities.
Electronic delivery	• Product is electronically delivered within hours from the CDPF or a network station capable of this service.

NOTE:
The delivery time begins when the RADARSAT product is ready for shipping and excludes possible delays encountered when clearing customs. RADARSAT image products can ONLY be sent to a street address—not to a P.O. Box.

If you have any questions or comments, please contact us at 1-(604)244-0400,
fax: 1-(604)244-0404, or visit our website at www.rsi.ca.

APPENDIX A
RADARSAT PROGRAM SPECIFICATIONS

The RADARSAT-1 program

RADARSAT is a sophisticated Earth observation satellite. Developed by Canada, RADARSAT provides the world with the first operationally-oriented radar satellite system. RADARSAT was conceived as a partial solution to Canada's energy needs in response to the late 1970s oil crisis. During this time, Canada conducted an extensive drilling program in the Beaufort Sea as part of its search for alternative sources of oil. To aid in this research, a synthetic aperture radar (SAR) sensor was designed. SAR was used as it could provide information regardless of sun illumination or atmospheric conditions (long periods of darkness in the winter months and clouds and haze in the summer months). Today, RADARSAT is providing SAR data worldwide for applications such as crop monitoring, ice reconnaissance, geological mapping, oil seep detection, disaster management, and land use management.

RADARSAT was developed under the management of the Canadian Space Agency (CSA) in cooperation with NASA / NOAA, the Canadian provincial governments, and the Canadian private sector.

RADARSAT International (RSI), a private company established in 1989 as the marketing arm of the RADARSAT program, has the exclusive rights to distribute RADARSAT-1 data. RSI's partners include an international network of more than seventy distributors, nine network stations, and seven resource centres.

RADARSAT-2 is currently being developed by MacDonald Dettwiler and Associates Ltd. (Richmond, British Columbia) and is scheduled for launch in early 2002.

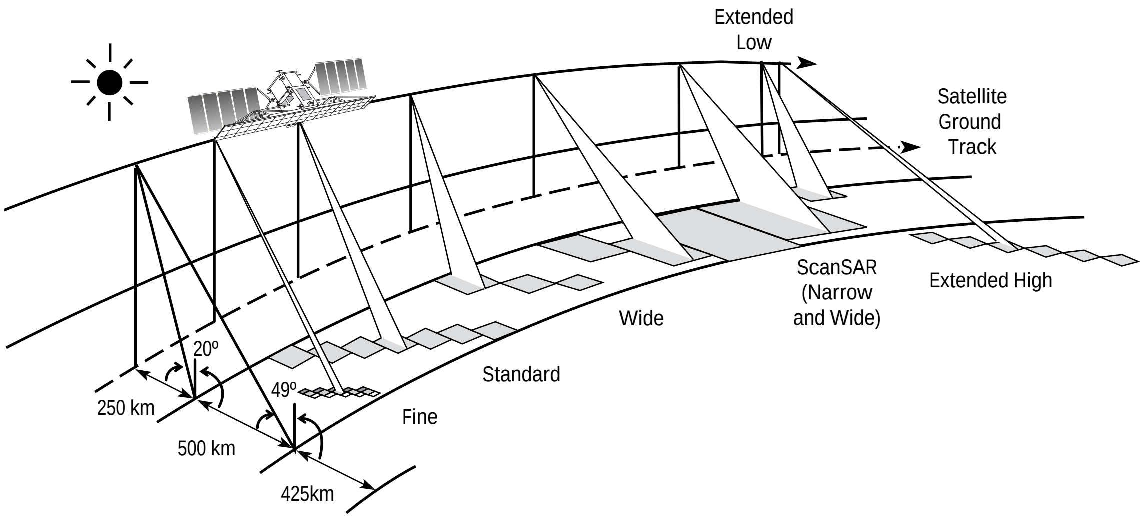
RADARSAT satellite specifications

The SAR antenna

RADARSAT is equipped with an advanced SAR:

- C-band wavelength (5.6 cm),
- HH polarization (horizontally transmitted, horizontally received),
- right-looking, steerable antenna,
- ScanSAR capability for wide area coverage, and
- multi-mode imaging capabilities.

FIGURE A.1: RADARSAT beam modes



The RADARSAT SAR can be "steered" to image over a 925 km swath using 7 beam modes. This superb flexibility allows users to acquire 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 systems

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

The payload computer can store 23 beam positions at one time. The Fine, Standard, Wide, and ScanSAR beam positions are always loaded, while four of the seven Extended beam positions are selectively loaded.

As the RADARSAT data is collected, it is either transmitted directly to a participating network station or stored on an on-board tape recorder (OBR) for later downlink to a RADARSAT network 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 is included in the downlink.

Tape-recorded data

RADARSAT has two on-board tape recorders (OBRs) with 10 minutes of SAR on-time per tape recorder. The OBRs are primarily used to store data over areas that do not have participating network stations. Only one tape recorder is used at a time; the second OBR acts as a back-up.

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). The tape recorders also have the capacity to record 48

Standard beam mode images or 480,000 km^2 in the North-South direction for each 10-minute imaging session. The use of the OBRs results in reduced coverage for some beam mode products. Table A.1 summarizes beam mode size reductions when using the OBR.

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	*38 - 45
Standard	100	100
Wide 1	165	165
Wide 2	150	138
ScanSAR Narrow	300	295
ScanSAR Wide B	450	450
Extended High	75	75
Extended Low	170	170

* tape-recorded swath width varies with beam position

TABLE A.2: Real-time and tape-recorded swath coverage information from the CDPF

BEAM POSITION	REAL-TIME INCIDENCE ANGLE	TAPE-RECORDED INCIDENCE ANGLE	REAL-TIME DISPLAYED (SPA) BEAM WIDTH (KM)	TAPE-RECORDED DISPLAYED (SPA) BEAM WIDTH (KM)	REAL-TIME AVERAGE PRODUCT BEAM WIDTH (KM)	TAPE-RECORDED AVERAGE PRODUCT BEAM WIDTH (KM)	REMARKS
Fine 1 Near	36.4 - 39.5	36.3 - 38.9	58	45	58	46	See NOTE
Fine 1	36.8 - 39.9	37.2 - 39.6	57	45	57	45	
Fine 1 Far	37.2 - 40.3	38.0 - 40.3	57	44	57	44	
Fine 2 Near	38.9 - 41.8	38.9 - 41.1	56	43	56	43	
Fine 2	39.3 - 42.1	39.6 - 41.8	56	42	56	43	
Fine 2 Far	39.6 - 42.5	40.3 - 42.5	55	42	56	42	
Fine 3 Near	41.1 - 43.7	41.1 - 43.1	52	39	52	39	
Fine 3	41.5 - 44.0	41.8 - 43.7	51	39	52	39	
Fine 3 Far	41.8 - 44.3	42.5 - 44.4	51	38	51	38	
Fine 4 Near	43.2 - 45.5	43.2 - 45.0	50	38	50	38	
Fine 4	43.5 - 45.8	43.8 - 45.6	50	37	50	37	
Fine 4 Far	43.8 - 46.1	44.4 - 46.1	50	37	50	37	
Fine 5 Near	45.0 - 47.3	45.0 - 46.8	49	39	49	39	
Fine 5	45.3 - 47.5	45.6 - 47.3	49	38	49	38	
Fine 5 Far	45.6 - 47.8	46.2 - 47.8	49	38	49	38	
Standard 1	19.4 - 26.8	= realtime	104	= realtime	114	= realtime	See NOTE
Standard 2	24.1 - 30.9	= realtime	104	= realtime	113	= realtime	
Standard 3	31.0 - 37.0	= realtime	101	= realtime	111	= realtime	
Standard 4	33.6 - 39.4	= realtime	103	= realtime	112	= realtime	
Standard 5	36.4 - 41.9	= realtime	103	= realtime	112	= realtime	
Standard 6	41.7 - 46.5	= realtime	100	= realtime	109	= realtime	
Standard 7	44.7 - 49.2	= realtime	102	= realtime	112	= realtime	
Wide 1	19.3 - 30.2	= realtime	159	= realtime	184	= realtime	See NOTE
Wide 2	30.1 - 38.9	31.4 - 38.8	149	127	161	137	
Wide 3	38.9 - 45.1	= realtime	125	N/A	112	N/A	not recommended due to nadir ambiguity
ScanSAR Narrow A	19.3 - 38.9	19.3 - 38.8	307	289	335	315	composite of W1 & W2
ScanSAR Narrow B	30.1 - 46.5	= realtime	304	= realtime	299	= realtime	composite of W2, S5 & S6
ScanSAR Wide A	19.3 - 49.2	N/A	524	N/A	518	N/A	composite of W1, W2, W3 & S7
ScanSAR Wide B	19.3 - 46.5	= realtime	461	= realtime	481	= realtime	composite of W1, W2, S5 & S6
Extended Low 1	10.4 - 22.0	= realtime	154	= realtime	167	= realtime	SGF products only See NOTE
Extended High 1	49.0 - 52.4	= realtime	85	= realtime		= realtime	See NOTE
Extended High 2	50.0 - 53.5	= realtime	90	= realtime		= realtime	
Extended High 3	51.2 - 54.6	= realtime	90	= realtime	102	= realtime	SGF products only
Extended High 4	54.4 - 57.1	= realtime	80	= realtime	90	= realtime	SGF products only
Extended High 5	55.5 - 58.2	= realtime	80	= realtime		= realtime	
Extended High 6	56.9 - 56.4	= realtime	80	= realtime	93	= realtime	SGF products only

NOTE:
Average product width of Fine beams is equal to displayed width in SPA, use overlap to account for +/- 5 km satellite drift.
Average product width of Standard beams is 10 km greater than displayed width in SPA to account for +/- 5 km satellite drift.
Average product width of Wide beams is 10 km greater than displayed width in SPA to account for +/- 5 km satellite drift.
Average product width of Extended beams is 10 km greater than displayed width in SPA to account for +/- 5 km satellite drift.

SAR on-time and switching

The SAR instrument can collect 32 minutes of data per orbit. During one orbit, more than one beam position may need to be used. The following describes how the system operates when beam positions are 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 a minimum of 13.5 seconds to switch between beam modes and positions.

The RADARSAT orbit

RADARSAT is placed in a near-polar, sun-synchronous orbit 798 km above the Earth. It has a dawn-dusk orbit and is rarely in eclipse or darkness. The orbit characteristics are:

Geometry	near-polar, 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 to 1390 Hz
Transmitter Peak Power	5 Kw
Transmitter Average Power	300 W (nominal)
Average Radar Data Rate	73.9 to 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
Expected Lifetime	7 years

APPENDIX B
APPLICATION CONSIDERATIONS FOR RADARSAT

This appendix is divided into a series of application overview tables and general guidelines to help you select the appropriate RADARSAT beam mode and position for your application.

The information in these tables is based on research and experience gained from pilot studies and research projects for which RADARSAT data has been used since launch. These guidelines are general and do not take local conditions into consideration. For certain applications, complementary data is recommended to fully exploit your RADARSAT data. For detailed information on specific applications, please see the Selected References in Appendix F or contact your Client Services Representative.

In this document, the definitions of mapping scales are as follows:

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

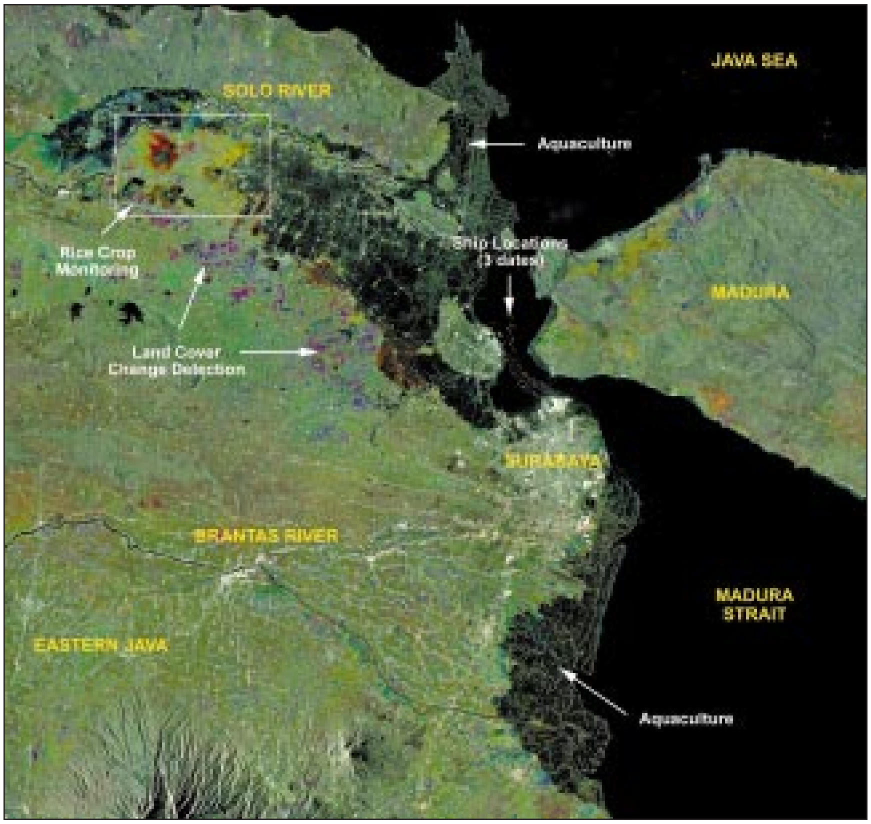
TABLE B.1: Agriculture/land use

APPLICATION	TYPICAL ACTIVITIES	RADAR RESPONSE
Crop Assessment	Crop type determination	Different crops have unique roughness and moisture levels. Radar is sensitive to differences in these parameters resulting in contrasting backscatter.
	Crop damage assessment	Damage to crops alters the geometric structure of plant and canopy surface roughness. Damaged areas have different geometric structure/roughness than surrounding areas, therefore producing contrasting backscatter.
Compliance Monitoring	Farming activity assessment	Different crops have unique geometric structure, canopy roughness, and moisture levels. Radar is sensitive to these differences resulting in contrasting backscatter.
	Land use evaluation	Agricultural land use is associated with the presence or absence of certain crops. Different crops have unique geometric structure, canopy roughness, and moisture levels. Radar is sensitive to these differences and helps differentiate between tilled and cropped land.
Land Use Monitoring	Temporal change evaluation	Canopy roughness and moisture content vary over the growing season. Radar is sensitive to these differences allowing for the temporal evaluation of changes in backscatter and thus changes in crop parameters.

Soil Condition Monitoring	Tillage practice determination	Different tillage practices produce unique soil surface roughness. Radar is sensitive to differences in surface roughness resulting in contrasting backscatter.
	Soil moisture assessment	Variations in soil moisture produce changes in dielectric properties of soil. This contrast results in increasing backscatter with increasing soil moisture.

General guidelines

- Standard beam mode is useful for crop area estimation and crop type discrimination.
- Fine beam mode is useful for assessing crop damage.
- Shallow incidence angles are useful for delineation of land use activities and estimating soil erosion.
- Shallow incidence angles may be more useful for crop type monitoring.
- Steep incidence angles may be more useful for soil moisture studies.
- Selecting an appropriate look direction (ascending or descending orbit pass) is important when row crops are being imaged. Choose the look direction that will provide the most oblique view of the crop rows. A look direction perpendicular to row direction maximizes backscatter from the crop canopy and may yield soil information.
- If imaging time is important, you can use either an ascending or descending orbit pass. RADARSAT crosses the equator on a descending pass at 6 a.m. (06:00 H) and on an ascending pass at 6:00 p.m. (18:00 H). An ascending pass (18:00 H) may be preferred to minimize the presence of morning frost or dew, which may decrease interpretation and classification accuracy.
- When selecting image specifications, it is advisable to match the resolution with the size of the agricultural fields being imaged. The beam mode resolution should be several times smaller than the size of the agricultural fields.
- In areas of convection related to evaporation, the descending pass (dawn orbit) may be preferred to reduce the effects of rain events.



Coastal land use mapping of Surabaya, Eastern Java, Indonesia using a multi-date RADARSAT merge. RADARSAT data © Canadian Space Agency/Agence spatiale canadienne 1997. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International.

TABLE B.2: Coastal and oceans

APPLICATION	TYPICAL ACTIVITIES	RADAR RESPONSE
Coastal Zone Monitoring	Water-land boundary delineation	The smooth surface of a water body (specular reflector) greatly contrasts to a rough land surface (diffuse reflector). As a result, open water surfaces will have a dark tone in radar imagery, while land will have a lighter tone. Shallow incidence angles are recommended for better land/water discrimination.
	Coastal vegetation identification	Vegetation can be discriminated on the basis of structural parameters and canopy roughness resulting in changes in radar texture and tone. Vegetated areas have a brighter return than non-vegetated areas or standing water. Multitemporal data acquired using different incidence angles can improve the discrimination between vegetated and non-vegetated areas.
	Coastline change evaluation	Shallow incidence angles provide a greater backscatter contrast, which improves the discrimination of the water-land boundary. Open water surfaces will appear dark in comparison to the brighter returns from land. Shoreline detection and the identification of areas of erosion/sedimentation can be improved by acquiring multitemporal data using the same beam mode and look direction.

Ocean Circulation Mapping	Mesoscale ocean feature identification	Mesoscale ocean features may be identified on an image by characteristic patterns of natural surfactants or surface roughness modulation related to wind-current interaction at the current shear or convergence zones. Bathymetric features can be detected by local changes in the surface roughness pattern related to underwater topography.
Ship Target Detection	Ships and ship wake location	A ship acts as a bright point target against the generally dark ocean background. Ship detection depends on ship size and type, and wind speed. As wind speeds increase, the clutter from the ocean background also increases, making it difficult to distinguish the return from a bright point target. The presence of a wake can be used to determine ship heading and speed. Shallow incidence angles are recommended for ship detection.
Oil Spill Monitoring	Oil spill detection and mapping Oil spill emergency response	The presence of oil on water reduces the backscatter over the area of the spill, due to attenuation of the Bragg scale waves and a reduced signal return to the sensor. On the image, the oil spill has a darker tone than the surrounding water. Wind shadows near land, regions of low wind speed, natural surfactants, and grease ice can be mistaken for oil spills, and ancillary or multitemporal information is sometimes needed to discriminate the oil spill from other phenomena. Steep incidence angles are recommended for oil spill detection.
Aquaculture Site Monitoring	Aquaculture site location and mapping	Anthropogenic structures provide higher signal returns than the surrounding water. The smooth surface of the water (darker tone) contrasts with the brighter return from the structures, permitting the delineation of the aquaculture pen or fish pond.

General guidelines

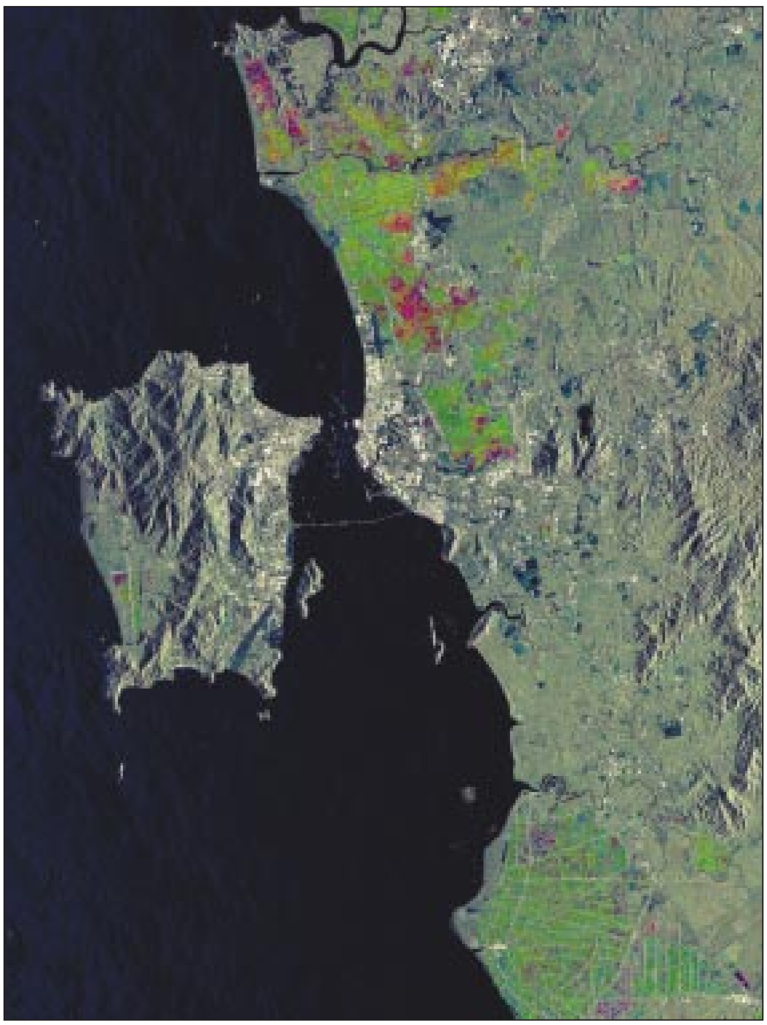
- Large area coverage (Wide and ScanSAR beam modes) is useful for monitoring and surveillance applications, including ship traffic, fisheries monitoring, oil spill mapping, and ocean circulation mapping.
- Intermediate area coverage (Standard and Wide beam modes) is useful for monitoring ship traffic and near-shore fisheries activities, and mapping oil spills and inter-tidal features.
- Small area coverage (Fine beam mode) is useful for harbour traffic monitoring, aquaculture site location, and small spill mapping.
- High-frequency temporal coverage over selected areas can be achieved by varying the beam position and using the Extended beam modes.
- Wave spectra applications require information on local wind direction to eliminate the 180° ambiguity in the wave direction. Steep incidence angles (e.g., Extended Low 1, Standard 1 to 3) are preferred for wave spectra applications.

- Steep incidence angles (e.g., Standard 1 to 3, Wide 1) are optimum for oil spill detection. Detection will also depend on the spill size, sea state conditions, and image resolution. With the better-than-expected noise performance of RADARSAT, beam modes that have higher incidence angles can also be considered. It may be useful to collect auxiliary information (such as wind speed, wave conditions, and oil type) on the date of the RADARSAT acquisition to help in your interpretation.

- Shallow angles (i.e., Standard 4 to 7, Wide 3, Extended High 1 to 6, ScanSAR Narrow B) are optimum for ship target detection. Detection depends on ship size and type, ship heading with respect to look angle, sea state conditions, and beam mode selected at the time of imaging. In general, the probability of detecting ships increases with ship length and decreases with high wind speeds.

- Shallow incidence angles are optimum for the detection of aquaculture cages and weirs. Detection will also depend on the size and configuration of the pens, and sea state conditions at the time of imaging.

- The effects of bathymetry are visible in near-shore regions under light wind conditions. Shallow incidence angles are better suited to imaging inter-tidal features, such as mudflats, shoals, and sandbars. Differences in sea bottom topography can be inferred when the ocean depth is less than ~30 m.



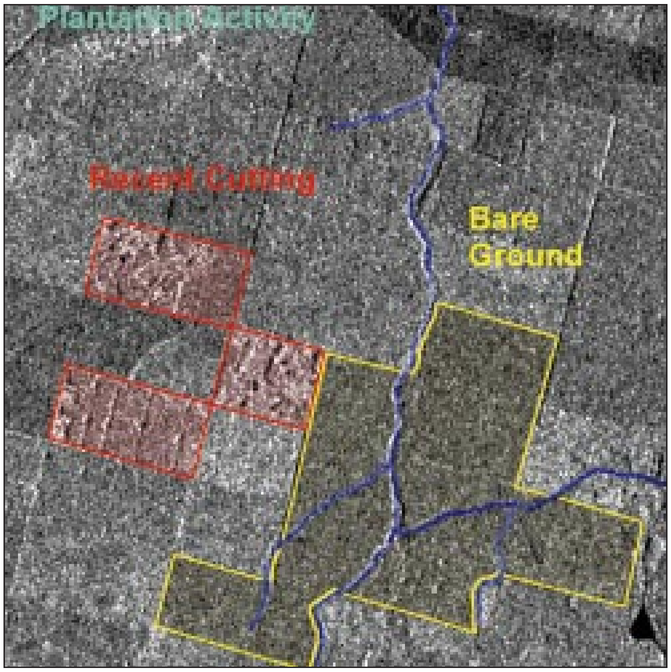
Coastal zone mapping of Penang, Malaysia using a multitemporal merge of three RADARSAT scenes. RADARSAT data © Canadian Space Agency/Agence spatiale canadienne 1996, 1997. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International.

TABLE B.3: Forestry

APPLICATION	TYPICAL ACTIVITIES	RADAR RESPONSE
Reconnaissance Mapping	Terrain analysis	The ability to image topographic relief is a result of the side-looking configuration of radar, which highlights topographic differences. Different forest types can often be inferred from terrain analysis.
	Forest cover type discrimination	In some cases, different forest types may have unique geometric structures, canopy surface roughness, and moisture levels. Radar is sensitive to these parameters resulting in contrasting backscatter.
Commercial Forestry	Mapping of cleared forest areas	The relatively smooth surface of clearcuts produces little backscatter compared to the rougher canopy of the uncut forest. These differences in backscatter allow forest clearcuts to be delineated from uncut forest.
	Burn delineation	After a forest fire, the affected area dries out and debris is left on the ground. Thus, a contrast in moisture levels and structure exists between the burn area and surrounding forest. Radar is sensitive to differences in these parameters resulting in a contrast in backscatter.

General guidelines

- Intermediate to large-scale imagery at intermediate to high resolutions (Fine and Standard beam modes) are effective for deforestation mapping at medium scales.
- Intermediate to small-scale imagery at intermediate resolutions (Wide and ScanSAR beam modes) are effective for regional overview forest mapping.
- Shallow incidence angles are preferred for clear-cut mapping and general deforestation mapping because land cover variations are accentuated.
- In mountainous terrain, geometric distortions can be reduced by using shallow incidence angles. Radar shadow can be reduced or eliminated if images from both ascending and descending orbits are obtained for the same area.
- Data acquisition should be planned to maximize the contrast between the clear-cut areas and the forest.
- In temperate regions it is preferable to plan acquisitions when snow cover is present as the snowpack has a surface roughness smoothing effect and decreases the radar backscatter.
- Species discrimination and broad forest type mapping may require multi-date acquisitions.
- Radar data shows good potential for forest base map updating (change detection) when base map information exists.
- Accurate forestland mapping requires geometric correction of radar data using a digital elevation model (DEM).
- RADARSAT can detect burn areas after the “ripening time” because the tonal contrasts increase as the trees dry up and lose their moisture content.



Multitemporal merge of RADARSAT Standard beam mode data of North Island, New Zealand. RADARSAT data © Canadian Space Agency/Agence spatiale canadienne 1996, 1997. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International.

TABLE B.4: Geology

APPLICATION	TYPICAL ACTIVITIES	RADAR RESPONSE
Geological Mapping	Geological structure mapping	Geological structures often have characteristic forms, which if located near the Earth's surface are highlighted by the side-looking configuration of radar. Underlying topography often manifests itself in the treetop canopy, which can be detected by radar.
	Surficial bedrock geological mapping	Depending on the type of physical weathering, surficial bedrock may fracture and produce characteristic fragment sizes (as a function of rock fabric, texture, and mineral composition). Different rock units may break down differentially, resulting in unique surface roughnesses, which are distinguishable on radar imagery because of contrasting backscatter.
Quaternary Mapping	Landform delineation	Landforms often have characteristic shapes, which may be manifested as topographic relief. The ability to image landforms is a result of the side-looking configuration of radar, which highlights relief.
	Surficial material assessment	Non-vegetated, unconsolidated surficial material contains different fragment sizes, which may produce a characteristic soil roughness and soil moisture-holding capacity. Radar is sensitive to differences in roughness and moisture resulting in contrasting backscatter between different surficial units.

Mineral Exploration	Lineament identification	Lineaments, such as folds and faults, may be manifested as topographic relief. The ability to image lineaments is a result of the side-looking configuration of radar, which highlights lineaments.
Hydrocarbon Exploration	Geological structure mapping	(see Geological Mapping above)
	Sedimentology mapping	Unconsolidated sediments, such as those deposited by glaciers, are often manifested as topographic relief. The ability to image sedimentological units is a result of radar's side-looking configuration. Different sediments also have characteristic grain sizes, which have different moisture holding capacities or may produce a characteristic surface roughness. Radar is sensitive to differences in moisture and roughness resulting in contrasting backscatter between different sediments.
Geologic Hazard	Seismic zones identification	Seismic zones are often characterized by the presence of faults, which are manifested topographically. The ability to image seismic zones is a result of the side-looking configuration of radar, which highlights this topography.
	Landslide hazard assessment	Landslide hazard areas are defined through the detection of past landslide events. Landslides alter the landscape through the transportation of vegetation and soil. Affected areas have different canopy and soil roughnesses than surrounding unaffected areas. Radar is sensitive to differences in roughness resulting in contrasting backscatter between affected and unaffected areas.
	Coastal erosion assessment	The smooth surface of a water body causes specular reflection, resulting in low backscatter values. This contrasts with the rougher surface of the land, which causes diffuse scattering and produces relatively high amounts of backscatter. Comparison of backscatter on several dates allows the evaluation of backscatter change over time and thus the assessment of coastal erosion.

General guidelines

- Detailed-scale imagery (Fine beam mode) provides the highest resolution information for geological mapping but is restricted to viewing angles of 36° to 48°.
- Intermediate-scale imagery (Wide and Standard beam modes) can be used to obtain large area coverage for the definition of major structural patterns and landforms over a range of incidence angles (20° to 49°).
- The choice of incidence angles depends on the surface topography and land cover characteristics.
- In mountainous terrain, large incidence angles varying from 40° to 59° are suitable for structural and geomorphic mapping.

- In moderate terrain, small incidence angles ranging from 20° to 31° are suitable for landform identification.

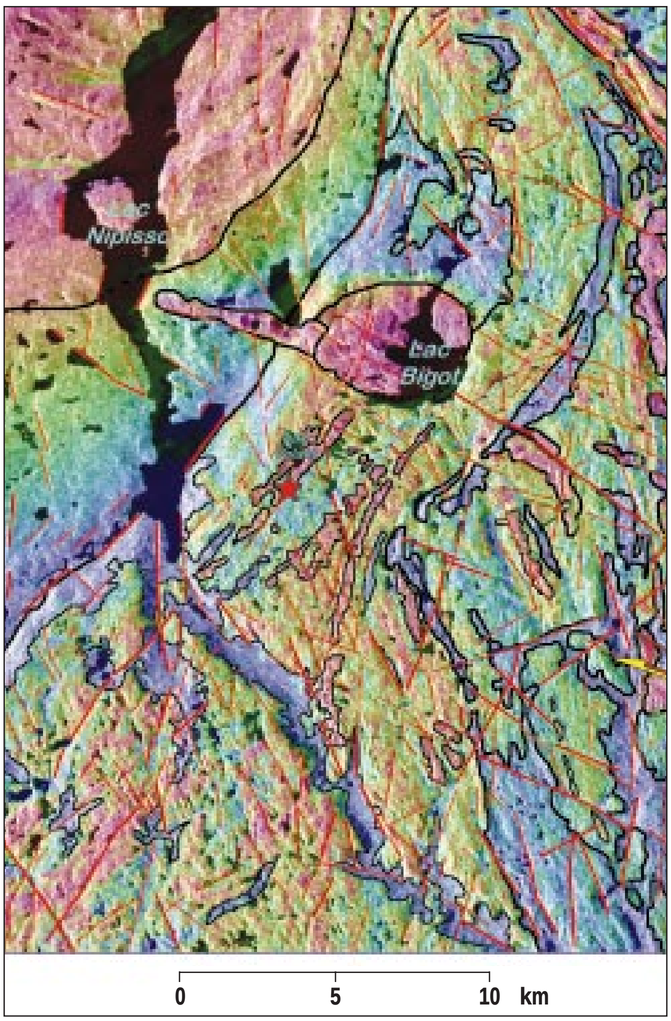
- In flat and rolling terrain, a wide range of incidence angles are suitable for terrain mapping (25° to 45°).

- Structural features are enhanced when their principle trends are near-perpendicular to the satellite's look direction.

- Same-side stereo pairs (ascending/ascending or descending/descending) can be viewed stereoscopically with conventional optical stereoscopes (without geometric corrections applied to the data), which greatly improves the interpretation of the area.

- Acquisition on both ascending and descending orbit passes over the same area provides opposing views of the terrain morphology thus maximizing the possibility of revealing geological features.

- Merging radar data with geophysical data provides surface and subsurface information.



RADARSAT SAR imagery with geophysical aeromagnetic data of Lac Volant, Québec. Image enhancement and interpretation by the Canada Centre for Remote Sensing (CCRS), Geology Division. High-resolution MAG image enhancement and interpretation by MIR Teledetection Inc. RADARSAT data © Canadian Space Agency/Agence spatiale canadienne 1996. Received by CCRS. Processed and distributed by RADARSAT International.

TABLE B.5: Hydrology

APPLICATION	TYPICAL ACTIVITIES	RADAR RESPONSE
Watershed Modelling	Soil moisture estimation	Radar is sensitive to variations in soil moisture because of the changes in the dielectric properties of soil produced by changes in water content. The sensitivity to these differences produces a change in backscatter values.
	Mapping land cover	Land cover is associated with natural cover and anthropogenic objects, which differ in geometric structure, roughness, and moisture content. The sensitivity of radar to these differences produces a change in the backscatter.
	Wetland condition determination	Radar is sensitive to variations in soil moisture associated with wetlands as a result of changes in the dielectric properties of soil (produced by changes in the water content). The sensitivity of radar to these differences produces the change in backscatter values.
	Snowpack condition determination	Snowpack conditions are determined in part by water content variations. The sensitivity of radar to these differences produces tonal contrasts.
Flood Mapping	Mapping flood extent	The smooth surface of water bodies acts as a specular reflector, which results in low backscatter return. This contrasts with the rougher surface of the land, which is a diffuse scatterer and produces relatively high amounts of backscatter.
Fresh Water Ice Mapping	Evaluation of ice conditions in rivers and lakes	Due to its rough surface and fine microstructure, ice in rivers and lakes results in high backscatter. In contrast, low wind conditions result in low backscatter from the smooth water surface of rivers and lakes.

General guidelines

- Small and intermediate-scale imagery (Wide and ScanSAR beam modes) provides coverage for flood mapping at a watershed level in low-land environments.
- High-resolution imagery (Fine beam mode) is effective for mapping narrow lakes, rivers, and relatively small areas in greater detail, facilitating the use of GCPs for accurate registration of radar imagery to existing maps.
- Increased imaging frequency permits observation of time-sensitive activities such as flood monitoring.
- Steep incidence angles are preferred for soil moisture studies. Steep incidence angles may provide greater microwave penetration of the forest canopy, thus improving the delineation of flooded vegetation.
- Mapping of snow depends on the snow liquid water content. Wet snow has a very low return while dry snow is basically transparent to microwave energy. Effective image interpretation depends on environmental conditions at the time of acquisition.

- The detection of freshwater ice can be hampered by the smaller size of some lakes and rivers, particularly on small and intermediate-scale images.

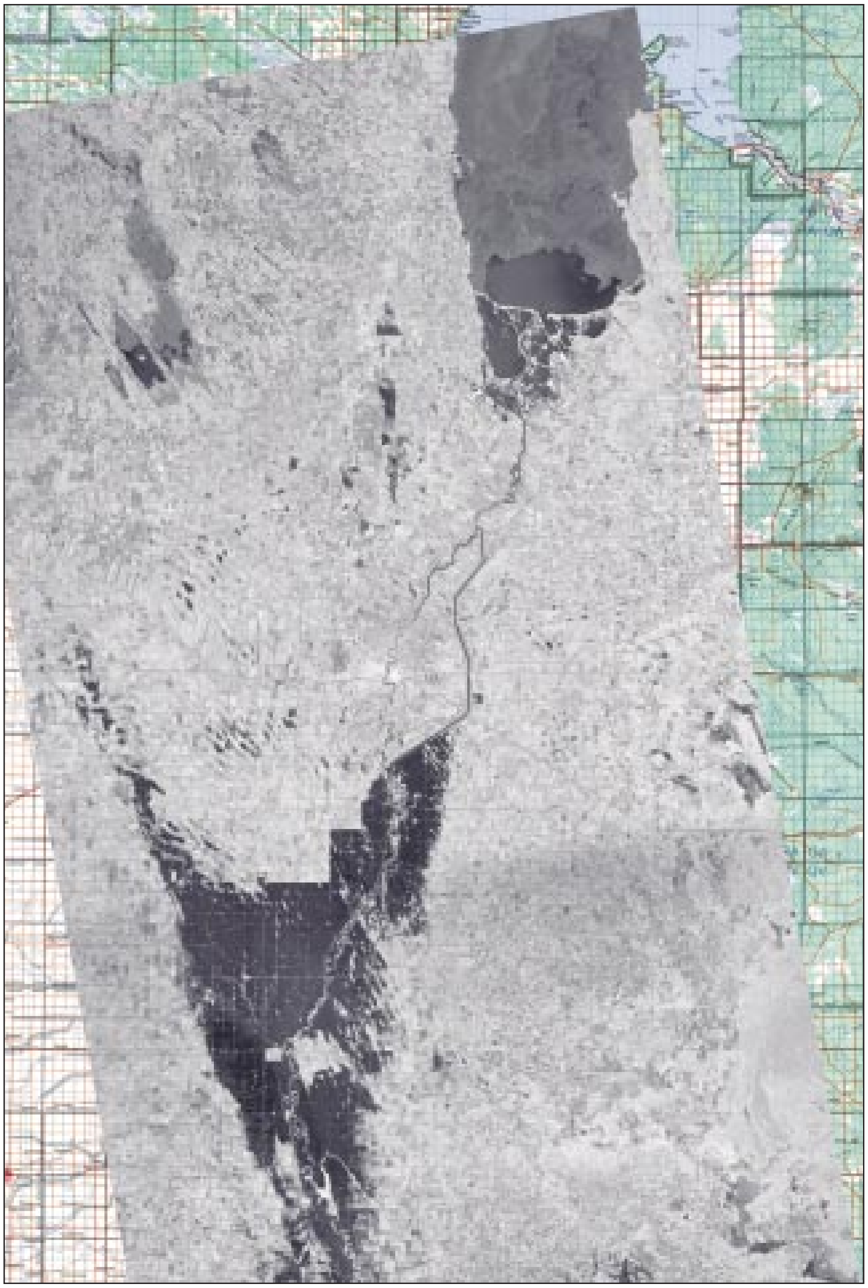


Image map of the Red River flood in Manitoba, Canada. Produced by the Mapping and Charting Establishment, Department of National Defence, Canada © 1997. Her Majesty the Queen in Right of Canada. RADARSAT data © Canadian Space Agency/Agence spatiale canadienne 1997. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International.

TABLE B.6: Mapping

APPLICATION	TYPICAL ACTIVITIES	RADAR RESPONSE
Base Mapping	Mapping land use and land cover	Land use and land cover are associated with natural cover and anthropogenic objects, which differ in geometric structure, roughness, and moisture content. Radar is sensitive to differences in these parameters resulting in contrasting backscatter.
	Mapping of cultural features	Cultural features are those created by humans and which may differ from natural features in geometric structure and roughness. Radar is sensitive to differences in these parameters resulting in contrasting backscatter values.
Land Use Monitoring	Temporal change evaluation	The unique geometric structure, roughness, and moisture content of different types of land cover and land use change over time. Radar is sensitive to these differences and the comparison of backscatter through time allows for the evaluation of temporal change.
Topographic Mapping	Mapping terrain elevation (x,y,z coordinates)	RADARSAT's variable viewing angles highlight topographic information and can be used for stereo viewing, anaglyphs, and DEM generation.

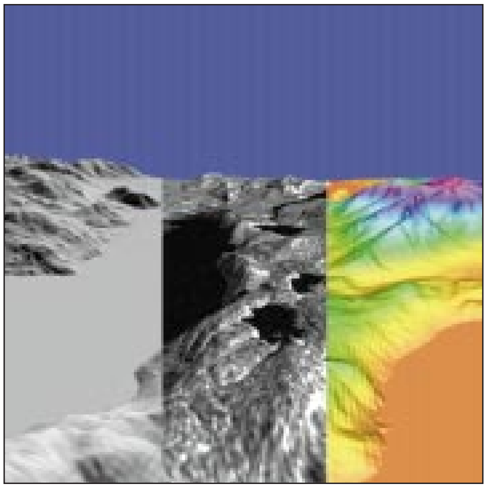
General guidelines

- Terrain relief is a factor in beam mode and incidence angle selection.
- In low relief, incidence angle is not critical but does depend on the application.
- In moderate relief, shallow incidence angles are preferable.
- In high relief, shallow incidence angles are preferable. Images acquired on the ascending and descending orbit pass should be considered to eliminate radar shadow.
- Intermediate-scale and intermediate-resolution imagery (Standard beam mode) is useful for land use and land cover delineation.
- Large-scale and high-resolution imagery (Fine beam mode) is useful for detailed studies on specific areas or land cover.
- Wide and ScanSAR beam modes are effective for small-scale land cover mapping and terrain mapping.
- Shallow incidence angles are preferred for the delineation of land use activities.
- Steep incidence angles are more useful for vegetation and soil moisture studies.
- When imaging linear features such as row crops or forest plantations, choose a look direction that maximizes backscatter (generally perpendicular to the row direction).
- Multi-date, time-sequenced imagery is effective for vegetation classification and growth stage/change monitoring.

- Imaging an area using more than one beam position (ie., different look angles) can be used for stereo matching in topographic mapping.

- Shallow incidence angles are recommended to avoid terrain distortions in mountainous areas, particularly when DEMs are not available.

- For base mapping and correction of imagery using DEMs, GCPs are required to optimize geographic and elevation accuracy. For base map updating, intermediate to large-scale and high-resolution imagery is most effective.



DEM, ortho-image and shaded relief of Mission, British Columbia, Canada. RADARSAT data © Canadian Space Agency/Agence spatiale canadienne 1997. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International.

TABLE B.7: Sea ice

APPLICATION	TYPICAL ACTIVITIES	RADAR RESPONSE
Sea Ice Mapping	Ice edge determination	The ice edge is normally distinguishable from open water by a higher backscatter response. In rough seas or at steep incidence angles this contrast is reduced making the ice edge difficult to detect.
	Ice concentration estimation	Based on the ability to distinguish ice from open water (above), the proportion of the ocean surface covered in sea ice may be estimated.
	Ice type determination	Different ice types (newly formed ice vs. first and multi-year ice) have very different physical properties (salinity, microstructure, moisture content, and surface roughness). Radar is sensitive to differences in these parameters, which produce differential backscatter. The shape, size, and location of the ice floes give important clues to the physical structure and thickness of the floes. These features may be visually interpreted from radar imagery.
	Ice motion estimation	Distinct physical properties (salinity, microstructure, moisture content, and surface roughness) of different ice types produce contrasting backscatter, which allows floes to be differentiated on a single date.

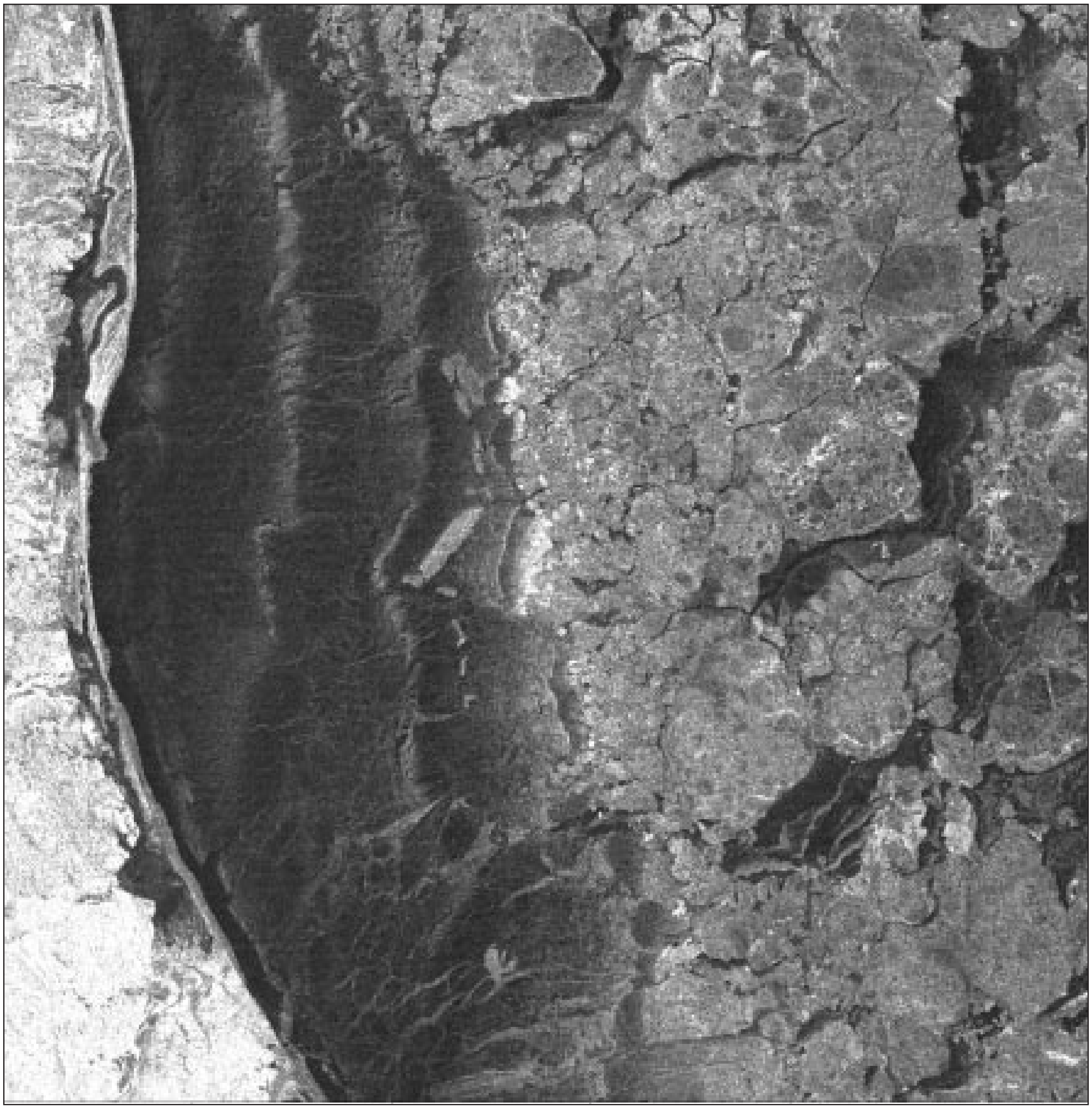
		Multitemporal acquisition allows the magnitude and direction of displacement of floes to be estimated.
	Surface topography determination	Ice topographic features (ridges, rubble fields) increase the surface roughness of the ice and produce an associated increase in radar backscatter, which contrasts from smoother surrounding features.
	Ice pressure determination	Ice pressure results in ice topographic features, which increase the roughness of the ice surface, which, in turn, increases radar backscatter.
	Ice decay estimation	Distinct physical properties (salinity, microstructure, moisture content, and surface roughness) of different ice types produce contrasting backscatter, which allows floes to be differentiated on a single date. Multi-date data comparisons allow the identification of location and estimation of rate of ice decay.
Transportation Support	Determination of leads location	Sea ice that surrounds leads produces a greater amount of backscatter, which contrasts with the smoother specular surface of the water surface of the leads.
Fisheries Support	Ice edge determination	The ice edge is normally distinguishable from open water by a higher backscatter response. In rough seas or at steep incidence angles this contrast is reduced, making the ice edge difficult to detect.
Iceberg Monitoring	Determination of iceberg/ice island locations	The low backscatter of an ocean surface contrasts with the high backscatter from icebergs. The high radar reflectivity created by an iceberg is the result of high internal scattering and corner reflections between the water and the iceberg.

General guidelines

- Small-scale imagery (ScanSAR beam modes) provides regional mapping capability for sea ice concentrations, ice edge location, ice motion tracking, and ice type classification. This information can be useful for tactical navigation depending on the actual ice environment.
- Intermediate-scale imagery (Wide and Standard beam modes) provides detail for medium-scale mapping and tactical navigation support.
- Incidence angle is not a critical factor in sea ice monitoring. However, shallow incidence angles are more effective for highlighting surface topography, separating the ice/water boundary, and detecting icebergs.
- Platforms with polar and near-polar orbits, such as RADARSAT, deliver enhanced ice environment coverage.
- Guaranteed SAR coverage supports frequent monitoring and short-notice acquisitions.
- HH polarization provides greater differentiation between open water and ice than VV polarization.
- The appearance of an ice feature may differ significantly in wet versus dry conditions. When surface meltwater is on

the ice or ocean spray is on the surface at the ice edge, feature brightness may differ from that encountered in dry conditions.

- When wet surface conditions prevail, it is useful to utilize a reference image acquired before the onset of melt conditions.



Near-shore ice dynamics can be seen in this image of the East Coast of Sakhalin Island, Russia. RADARSAT data © Canadian Space Agency/Agence spatiale canadienne 1998. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International

APPENDIX C
RADARSAT PRODUCT SPECIFICATIONS

This Appendix is divided into four sections, which review and describe RADARSAT images and products specifications.

The first section, **RADARSAT product descriptions**, 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

- network station product certification,
- radiometric accuracies, and
- locational accuracies.

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

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

The fourth section, **CEOS digital product format**, includes descriptions of

- the Volume Directory file,
- Leader and Trailer files,
- Data files,
- the Null Volume file, and
- the RADARSAT software endorsement program.

RADARSAT product descriptions

RADARSAT products are processed to one of three main levels: RAW data, Path-Oriented or Map-Oriented.

- RAW data has had no standard processing applied, and consists of frame-synchronized echo and replica data, as detected by the satellite. RAW data products are Level 0 CEOS-formatted Signal Data.
- Path-Oriented data has been processed by a SAR processor and is referenced to a standard Earth ellipsoid.
- Map-Oriented data has been processed and transformed to a true map projection.

Within each processing level, specific products are available as shown in Table C.1.

TABLE C.1: RADARSAT comparable products

RADARSAT DATA TYPES	RADARSAT MNEMONIC	ERS-1 (EUROPE)	ERS-1 (NORTH AMERICA)	LANDSAT	SPOT
RAW DATA					
Signal Data	RAW	RAW[1]	RAW[1]	RAW[2]	1A[2]
PATH-ORIENTED					
Single Look Complex	SLC	SLC	SLC	N/A	N/A
Path Image	SGF	Precision Image Georeferenced (pRI)	Georeferenced Fine Resolution (SGF)	Path Oriented Systematic or Precision Correction	1B
Path Image Plus	SGX	N/A	N/A	N/A	N/A
ScanSAR Narrow	SCN	N/A	N/A	N/A	N/A
ScanSAR Wide	SCW	N/A	N/A	N/A	N/A
MAP-ORIENTED					
Map Image	SSG	Geocoded Image (GEC)	Systematically Geocoded (SSG)	Map Oriented Systematic Correction	2A
Precision Map Image	SPG	Terrain Geocoded Image (GTC)	Precision Geocoded (SPG)	Map Oriented Precision Correction	2B

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

All single beam data products produced at the CDPF, with the exception of Signal Data (RAW), are calibrated during processing to provide both radiometric and geometric corrections to the data and to ensure compliance with the RADARSAT mission's image quality specifications (shown in Table C.2). Data processed at other RADARSAT network stations may be similarly calibrated, depending on the station's level of certification. Calibration of the Fine, Standard, Wide, ScanSAR, and Extended Low beam modes has been completed at the CDPF. Contact your Client Services Representative for the ongoing status of this work.

RADARSAT network station certification

On June 18, 1998, RADARSAT International (RSI) and the Canadian Space Agency (CSA) made revisions to the network station certification process. These revisions were made to streamline the efforts of all involved parties: network stations, network station system providers, RSI, and CSA.

The certification process now includes two mandatory certifications and an optional advanced product endorsement. All three are defined below.

1. Station Operations Certification

This is the first level achieved by a network station and verifies the station's operational and functional capabilities with respect to

- data reception,
- communications interfaces to CSA and RSI,
- data archive and catalogue,
- operational performance as a RADARSAT program network station, and
- generation of RADARSAT program compliant Level 0 products for commercial distribution (Level 0 = RAW data).

A network station can receive RADARSAT data before being Product Certified, but it may not distribute RADARSAT data to users unless the products are processed at the CDPF.

2. Product Certification

This level complements the Station Operations Certification and is also mandatory. Product Certification verifies the station's capability to generate RADARSAT-compliant Level 1 imagery products (Level 1= Path-Oriented products) with respect to

- the CEOS format standard, to the extent that products can be read and displayed as georeferenced images by commercial off-the-shelf software,
- visual radiometric and geometric criteria, and
- absolute location accuracy requirements (<750 m) of specific point targets contained in Level 1 image products.

No quantitative analysis is performed on the radiometry of the data products other than absolute location accuracy.

2A. Gold Seal Product Endorsement

This optional advanced product endorsement recognizes that products meet all RADARSAT image quality requirements, including quantitative radiometric and geometric accuracy and resolution, and that products are fully calibrated. Network Stations select the beam mode and / or product they would like to have endorsed depending on their unique market needs.

TABLE C.2: RADARSAT radiometric/image quality specifications

Relative Radiometric Accuracy for Standard beam modes	
Within one scene (100 x 100 km)	< 1.0 dB
Within one orbit	< 1.5 dB
Over three days	< 2.0 dB
Over lifetime of satellite	< 3.0 dB
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
Absolute Locational Accuracy	< 750 m
Geometric Distortion (within 100 x 100 km scene)	< 40 m

Radiometric calibration

Radiometric calibration is a process of measuring the characteristic performance of the satellite and the processor and of applying corrections to the data to ensure a consistent and qualified relationship between the backscatter of any location on the Earth's surface and its representation in the delivered RADARSAT product. Some of the corrections routinely applied to the RADARSAT data at the CDPF and RADARSAT network stations with Product Certification include the following:

- RAW signal I and Q imbalance,
- processor gain and range spreading,
- replica gain correction to compensate for radar transmitter and receiver gain fluctuations, and
- antenna pattern correction.

Fine, Standard, Wide, ScanSAR, and Extended Low beam products from the CDPF have absolute calibration. This means that a specific radar backscatter value can be determined for every pixel value (DN value) in the image. This provides many benefits to the user, such as

- applications support where radar backscatter can be related to certain geophysical (or other) parameters, such as soil moisture,
- consistency in the products over time, which allows for accurate multitemporal analyses (e.g., if an area is imaged on different days, months, or years),
- absolute calibration to ensure that any changes in measured radar backscatter are due to the target and not the system,
- consistency when comparing different products (e.g., if the user has both a Path Image and a Path Image Plus product, the absolute radar backscatter values for an area will be identical),
- the ability to compare the results of different beam modes (i.e., if an area is imaged at the same incidence angle by a Fine beam and a Standard beam, the average radar backscatter values calculated should be identical), and

- ability to analyze and compare the radar response at various incidence angles using different RADARSAT beam modes (i.e., if a target is imaged by both an S1 and an S7 and the radar backscatter is calculated in each case under stable surface conditions). The difference will be due to the incidence angle and not to any system-related phenomenon.

As a result of absolute calibration, valid comparisons can be made by using the calibrated radar backscatter even if a user intermixes data of various beam positions, processing levels, and dates.

Calibration of RADARSAT data has been conducted using point and distributed targets of known radar cross section. The point targets employed consist of a network of four Precision Active Transponders located in Canada in Resolute, Prince Albert, Ottawa, and Fredericton. The transponders are routinely imaged by the satellite, and the images are processed at the CDPF and analyzed for a variety of image quality parameters. These include generation of the impulse response function, which helps to measure the resolution of the system as well as other image quality attributes such as peak side lobe ratio (PSLR), integrated side lobe ratio (ISLR), and dynamic range.

The distributed targets used for RADARSAT calibration consist of several sites in the Amazon rainforest. This region has a known and constant radar cross section, which has been observed to be extremely consistent over time, regardless of the season. As a result, the Amazon region has been used in numerous radar-related studies to measure the beam profiles and to generate beam correction patterns. RADARSAT has used the targets in a similar manner. The result is a series of beam corrections, which are applied during the processing of the data to ensure the system response in the range direction is consistent.

As a final cross check on the accuracy of the computed values, the general response levels for RADARSAT are computed from the transponders and applied to images of the distributed targets. In order to compute radar backscatter from a RADARSAT product, the user should consult the technical document *RADARSAT Data Products Specifications* (RSI-GS-026).

Geometric calibration

Geometric calibration ensures the positional accuracy of the pixel values found in any Path-Oriented RADARSAT product. The following describes two approaches for evaluating and maintaining positional accuracy.

First, data sets containing a series of point targets of known lateral separation are processed at the CDPF and the distance between them is measured. This check ensures that the relative accuracy or distortion of the system is within specification.

Secondly, the Precision Active Transponders in Canada are routinely imaged and processed and the absolute locational accuracy is determined in each case. A summary of RADARSAT geometric specifications is given in Table C.3.

TABLE C.3: Levels of RADARSAT geometric accuracy specifications

RADARSAT IMAGE PRODUCT CHARACTERISTICS	ABSOLUTE LOCATION ERROR*	RELATIVE GEOMETRIC DISTORTION	BEAM MODES SUPPORTED
Path Image	< 750 m	< 40 m	Standard, Fine, Wide
• *Image is aligned along the satellite path (approx. 10-12° west of True North, at the equator).* • *Image is corrected for systematic errors related to satellite movement, the SAR instrument and processor, and data reception.*			
Path Image Plus	< 750 m	< 40 m	Standard, Fine, Wide
• *Image is aligned along the satellite path (approx. 10-12° west of True North, at the equator).* • *Image is corrected for systematic errors related to satellite movement, the SAR instrument and processor, and data reception.*			
Map Image	< 750 m	< 40 m	Standard, Fine, Wide
• *Image can be related to a base map without rotation or translation.* • *Image is corrected for systematic errors.*			
Precision Map Image	< 40 m	< 40 m	Standard, Fine, Wide
• *Image can be related to a map base.* • *Precision corrected using GCPs.* • *For scenes with high-relief terrain, a digital elevation model can be applied.*			

* Assumes a flat terrain with no elevation.

Topography-related positional error

Elevation differences within an image introduce additional positional errors. These errors can be particularly severe in areas of high relief (e.g., steep mountains). Distortions related to elevation differences can be readily calculated as they are a function of the elevation of a feature and the incidence angle used to image the feature.

Orbit data file source

In order to complete SAR processing and to georeference the resultant images, all RADARSAT processors make use of orbit ephemeris data. These files provide calculated 3-dimensional position and velocity measurements of the satellite for a particular orbit at eight-minute intervals. Orbit information is embedded as auxiliary data in the satellite downlink signal or is obtained via RSI from the RADARSAT Mission Control for the RADARSAT program.

Two main types of orbit data, which may affect the accuracy of the Path-Oriented product, can be selected by the user:

- Predicted Orbit files, and
- Definitive Orbit files.

All orbit data used in processing RADARSAT imagery is derived from actual orbit measurements of the spacecraft during transits over the Telemetry, Tracking and Command (TT&C) Station. Predicted Orbit files are determined in advance of a particular orbit and distributed to the various processing stations. In addition, predicted data is uploaded to the satellite and is included in the Auxiliary data subsequently downlinked to the network station. These files are used when processing products under NRT constraints. Definitive Orbit data files are prepared approximately 24 to 48 hours after the relevant orbit pass. Definitive Orbit data may be more accurate, thus reducing the absolute location error in the resulting image. No noticeable difference should be apparent in image distortion.

Application look-up tables (LUTs)

Prior to the final processed product, the CDPF applies an application LUT to all georeferenced data. Refer to Chapter 3 for detailed information on the LUTs used by RSI.

Product specifications: special features

Currently, the following RADARSAT beam modes are calibrated at the CDPF: Fine, Standard, Wide, ScanSAR, and Extended Low.

ScanSAR beam mode

ScanSAR is a product unique to the RADARSAT system. ScanSAR is intended for users requiring frequent repeat coverage or large area reconnaissance but not high resolution or precise quantitative radiometry. RADARSAT's ability to image large areas in excess of 500 km x 500 km is achieved by switching between single beam modes (Wide and Standard). The speed at which RADARSAT switches between sequential beam modes ensures contiguous ground coverage; however, this is achieved at the expense of spatial resolution.

The beam combinations for the two ScanSAR beam modes are:

BEAM MODE	BEAM POSITION	COMBINATIONS	NOMINAL SWATH WIDTH (KM)
ScanSAR Narrow	SNA	W1 + W2	300
	SNB	W2 + S5 + S6	300
ScanSAR Wide	*SWA	W1 + W2 + W3 + S7	500
	SWB	W1 + W2 + S5 + S6	450

* SWA contains a nadir ambiguity in the W3 beam position, which appears as a vertical white line on the image. This feature is most apparent over low backscattering areas (i.e., water, desert).

SNA and SNB cover areas in the near and far range, respectively, of the 500 km swath. The difference between SWA and SWB is less obvious. The on-board tape recorder does not have the ability to record a full swath of SWA data. Therefore, the SWA beam position is restricted to direct data downlink. The SWB beam position provides reduced swath width (450 km), which can be recorded on the tape recorder and downlinked later to a network station.

Due to the unique nature of the ScanSAR beam mode, special processing is required to combine the individual beam positions into a single scene. Presently, ScanSAR is available only as Signal Data or as a Path-Oriented product (SCN or SCW). The Path-Oriented product is approximately equivalent to a Path Image single-beam product, however with two notable differences.

First, ScanSAR data produced at the CDPF is only available as an 8-bit product. This limits the dynamic range available in the final product, hence precise quantitative radiometric measurements are not recommended when using ScanSAR data.

Secondly, the CDPF is designed to process ScanSAR data quickly and in continuous swaths. It does not take the time to re-orient the image so the data received from tape or disk is geographically corrected. Rather, data is processed and written in exactly the order it was collected by the satellite. As a result, all processed ScanSAR imagery will be one of two types of mirror images:

- all descending passes will be a left / right mirror image as recorded, or
- all ascending passes will be a top / bottom mirror image as recorded.

The user will be required to invert or flip the image on the horizontal axis (for ascending passes) or a vertical axis (for descending passes).

NOTE:
When viewing a ScanSAR image, you may notice that it contains black bands (or black fill) down the sides. This black area is a result of the SAR processor handling changes in the satellite's altitude as the orbit progresses. This effect occurs because the processor reserves more memory than the imaging window in order to accommodate changes in the imaging window associated with altitude changes. More details on the ScanSAR product specifications are found in Tables C.8 and C.9.

Path Image and Path Image Plus

Path Image and Path Image Plus are Path-Oriented products. The only 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). A Path Image Plus image covers the same area as a Path Image product but with a finer pixel size and hence a much larger file size. Path Image Plus benefits applications such as surveillance, where point target analysis requires the best possible resolution.

CEOS digital product format

RADARSAT digital data is distributed by RSI in a format that conforms to CEOS (Committee of Earth Observation Satellites) standards. CEOS was established as the standard format for storing SAR data on output media. The CEOS format is readable using most commercial image analysis software packages.

Each record of the CEOS format files is numbered in sequence and identified by a unique record code. CEOS products consist of five files containing various descriptive records.

The files are:

- Volume Directory - contains information on tape volume, as well as a text record, which describes the product,
- SAR Leader - contains ancillary data about products,
- SAR Data - contains imagery data records for products,
- SAR Trailer - series of records containing ancillary data, and
- Null Volume Directory.

Table C.4 provides an example of a CEOS header file.

TABLE C.4: File format for RADARSAT CEOS products

FILE	RECORD NAME
Volume Directory	Volume descriptor File pointer Text
SAR Leader	SAR leader file descriptor Data set summary Data quality summary Signal data histogram Processed data 16-bit histogram Processing parameters Map projection data Platform position data Attitude data Radiometric data Radiometric compensation data
SAR Data	Image options file descriptor Signal data Processed data
SAR Trailer	SAR trailer file descriptor Data set summary Data quality summary Signal data histograms Processed data (8-bit) histogram Processing parameters Attitude data Radiometric data Radiometric compensation data
Null Volume Directory	Null volume descriptor

Full details on the CEOS file format may be obtained from the document *RADARSAT Data Products Specifications* (RSI-GS-026).

The ancillary information includes

- geographic information,
- satellite position information,
- data source information (e.g., when and where the data was acquired),
- processing parameters,
- data quality information, and
- radiometric and calibration information.

All products offered by RSI will be available in the RADARSAT CEOS format including

- Path-Oriented products (for all RADARSAT beam modes),
- Map-Oriented products, and
- RAW data products.

The RADARSAT software endorsement program

RSI has set up an endorsement program for image processing software. Under the RADARSAT Endorsement Program, RSI supplies participating companies with sample products (containing RADARSAT data), RADARSAT product specifications, and technical support. When the vendor is able to demonstrate that the image processing software can read and manipulate RADARSAT data, RSI issues a Certificate of Endorsement. The vendor is then included in a directory of RADARSAT-compatible software suppliers. This endorsement program ensures ease of data integration into new and existing image analysis and geographic information software systems.

Endorsement is currently a three-level rating:

Display Level: Automatic loading, ingestion, and display of RADARSAT images.

Level 1: Display Level plus filters, texture analysis, edge and radiometric enhancement, image arithmetic, and plotting.

Level 2: Level 1 plus data integration, geocoding, mosaicking, and RGB to IHS conversions. At present, this is the highest level of certification RSI offers.

Please visit www.rsi.ca or contact your Client Services Representative for a current list of image processing and GIS software packages that can read and interpret the RADARSAT CEOS format.

TABLE C.5: Product specifications - Fine beam mode

Satellite beam specifications

	F1N F1 F1F	F2N F2 F2F	F3N F3 F3F	F4N F4 F4F	F5N F5 F5F
AVAILABLE INCIDENCE ANGLE POSITIONS	37 - 40	39 - 42	41 - 44	43 - 46	45 - 48
RESOLUTION (ground range products)* (range x azimuth) (m)	8.3 x 8.4	7.9 x 8.4	7.6 x 8.4	7.3 x 8.4	7.1 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
NOMINAL IMAGE SIZE (km) REAL TIME	50 x 50	50 x 50	50 x 50	50 x 50	50 x 50
NOMINAL IMAGE SIZE (km) RECORDED	45 X 50	42 X 50	39 X 50	37 X 50	38 X 50

Processed image specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS	MAP IMAGE	PRECISION MAP IMAGE
PIXEL SPACING (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	102	102
FILE SIZE (pixels x lines)	10,870 x 9,805	8,000 x 8,000	16,000 x 16,000	10,400 x 10,400	10,400 x 10,400
BITS / PIXEL	16 - I 16 - Q	16	16	8	8

NOTE:
Map-Oriented products are larger than Path-Oriented products due to rotation of image.

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

** Digital file specifications are approximate.

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)	24 x 27	20 x 27	25 x 27	23 x 27	22 x 27	20 x 27	19.1 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

Processed image specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS	MAP IMAGE	PRECISION MAP IMAGE
NOMINAL IMAGE SIZE (km) REAL TIME	100 x 100	100 x 100	100 x 100	140 x 140	140 x 140
NOMINAL IMAGE SIZE (km) RECORDED	100 x 100	100 x 100	100 x 100	140 x 140	140 x 140
PIXEL SPACING (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	102	102
FILE SIZE (pixels x lines)	8,620 x 19,610	8,000 x 8,000	12,500 x 12,500	10,400 x 10,400	10,400 x 10,400
BITS / PIXEL	16 - I 16 - Q	16	16	8	8

NOTE:
Map-Oriented products are larger than Path-Oriented products due to rotation of image.

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

** Digital file specifications are approximate.

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)	33.8 x 27	24.6 x 27	20.8 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

Processed image specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS	MAP IMAGE	PRECISION MAP IMAGE
NOMINAL IMAGE SIZE (km) REAL TIME	150 x 150	150 x 150	150 x 150	200 x 200	200 x 200
NOMINAL IMAGE SIZE (km) RECORDED	150 x 150	150 x 150	150 x 150	200 x 200	200 x 200
PIXEL SPACING (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.
W3 is not available on the tape recorder.
Map-Oriented products are larger than Path-Oriented products due to rotation of image.
* Resolution (ground range products) refers to Path Image and Path Image Plus. Map Image and Precision Map Image processing may alter the resolution slightly.
** Digital file specifications are approximate.

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

Satellite beam specifications

	SNA	NEAR RANGE	SNB	FAR RANGE	
AVAILABLE INCIDENCE ANGLE POSITIONS	20 - 31	31 - 40	31 - 49	36 - 42	41 - 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		

Processed image specifications

	PATH IMAGE	PATH IMAGE
NOMINAL IMAGE SIZE (km) REAL TIME	300 x 300	300 X 300
NOMINAL IMAGE SIZE (km) RECORDED	295 x 300	295 X 300
PIXEL SPACING (range x azimuth) (m)	25 x 25	25 x 25
NUMBER OF LOOKS (range x azimuth) (m)	2 x 2	2 x 2

Digital file specifications**

	PATH IMAGE	PATH IMAGE
FILE SIZE (MB)	144	144
FILE SIZE (pixels x lines)	12,000 x 12,000	12,000 x 12,000
BITS / PIXEL	8	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.
This product may be produced with image pixels either east-west inverted (descending passes) or north-south inverted (ascending passes) to match chronological order in which the data was collected and recorded.
** Digital file specifications are approximate.

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

Satellite beam specifications

	SWA	NEAR RANGE			SWB	FAR RANGE		
AVAILABLE INCIDENCE ANGLE POSITIONS	20 - 31	31 - 39	39 - 45	45 - 49	20 - 31	31 - 39	36 - 42	41 - 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			

Processed image specification

	PATH IMAGE	PATH IMAGE
NOMINAL IMAGE SIZE (km) REAL TIME	500 x 500	450 x 450
NOMINAL IMAGE SIZE (km) RECORDED	N/A	450 x 450
PIXEL SPACING (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 combination of Wide and Standard beam modes. See Table A.1 in Appendix A for more information.
SWA products are available only as a direct downlink to a ground station. SWB is tailored for storage on the tape recorder.
** Digital file specifications are approximate.

TABLE C.10: Product specifications - Extended High 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)	18.2 x 27	17.7 x 27	17.3 x 27	16.8 x 27	16.6 x 27	16.4 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

Processed image specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS
NOMINAL IMAGE SIZE (km) REAL TIME	75 x 75	75 x 75	75 x 75
NOMINAL IMAGE SIZE (km) RECORDED	75 x 75	75 x 75	75 x 75
PIXEL SPACING (range x azimuth) (m)	11.6 x 5.1	12.5 x 12.5	8 x 8
NUMBER OF LOOKS (range x azimuth) (m)	1 x 1	1 x 4	1 x 4

Digital file specifications**

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

NOTE:
Extended High 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 compared to images produced using Standard beam mode.
* Resolution (ground range products) refers to Path Image and Path Image Plus.
** Digital file specifications are approximate.

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

Satellite beam specifications

	L1
AVAILABLE INCIDENCE ANGLE POSITIONS	10 - 23
RESOLUTION (ground range products)* (range x azimuth) (m)	39.1 x 27.0
RESOLUTION (Single Look Complex) (range x azimuth) (m)	10.5 x 8.9

Processed image specifications

	SINGLE LOOK COMPLEX	PATH IMAGE	PATH IMAGE PLUS
NOMINAL IMAGE SIZE (km) REAL TIME	170 x 170	170 x 170	170 x 170
NOMINAL IMAGE SIZE (km) RESOLUTION	170 x 170	170 x 170	170 x 170
PIXEL SPACING (range x azimuth) (m)	8.1 x 5.1	12.5 x 12.5	10 x 10
NUMBER OF LOOKS (range x azimuth) (m)	1 x 1	1 x 4	1 x 4

Digital file specifications**

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

NOTE:
Extended Low 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 compared to images produced using Standard beam mode.
* Resolution (ground range products) refers to Path Image and Path Image Plus.
** Digital file specifications are approximate.

APPENDIX D
SUPPORTED MAP PROJECTIONS

Map Projections

RSI's processor supports a large number of map projections that can be user-defined for Map Image and Precision Map Image products. Uncorrected SAR images contain distortions just like any two-dimensional representation of the three-dimensional Earth. The selection of map projections is based upon the application and the geographic area.

The most frequently requested projection is the 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. The zone number is used as an input to the processor. Your Client Services Representative 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).

Other projections are available as listed in Table D.1. Contact your Client Services Representative if you require assistance in selecting a projection.

The ellipsoid or radius of the Earth is an input that 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

The following are the projections supported for Map Image and Precision Map Image products. You may be asked to provide standard parallels, projection origin, scale factors, and zones.

Albers Conical Equal Area
Equidistant Conic Type A
Krauss-Greuger
Lambert Azimuthal Equal Area
Lambert Conformal Conic
Space Oblique Mercator
Transverse Mercator
Universal Transverse Mercator

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

NOTE:
The map projections mentioned above are currently being used. RSI can create additional map projection(s) for customized orders. Further details can be obtained by contacting your Client Services Representative.

TABLE D.2: Earth models (ellipsoids)

The following is a partial list of the Earth models that can be used.

NAME	DATE	USE
Airy	1849	Great Britain
ARC 1950	1950	
Australian 1965	1965	Australia, S. America
Bessel	1841	Central Europe, Chile, Indonesia, Japan, S. Korea
Clarke 1858	1858	
Clarke 1866	1866	
Clarke	1880	Africa, France, Ghana
Everest	1830	India, S. Asia
Everest 2	1830	Malaysia
Fischer	1960	S. Asia
GRS-80	1980	N. America
Hayford	1924	
INDONESIA-74	1974	Indonesia
International/Hayford	1924/1909	Entire world excluding N. America and Africa
Krasovsky	1940	Russia, E. Europe
Liberia	1964	
Minna-B	N/A	Nigeria
NAD-27	1927	North America
NAD-83	1983	North America
WGS-84	1984	
WGS-72	1972	Canada and NASA

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

General Provisions

All sales of products by RADARSAT International (RSI) are governed by these General Terms of Sale. 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.

Orders

All orders must clearly identify the name of the buyer.

Once the client has decided which Data, Data Products and Services to purchase, RSI will issue a Technical and Financial Proposal for the client's signature. These two documents contain the order's technical and financial specifications and are considered to constitute a binding order in accordance with the General Terms of Sale. No modification or cancellation will be accepted by RSI once the Technical and Financial Proposals have been signed. In the event that the scenes ordered are not delivered, the buyer's recourse shall be limited to a refund of any amounts paid in advance of delivery.

RSI reserves the right to refuse any order.

Processing time

Production and delivery of products are done on a best effort basis. Failure to meet RUSH or NEAR-REAL TIME processing times by RSI will result in no RUSH or NEAR-REAL TIME 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.

Prices

The price applicable to each order shall be the price in effect at the date of order acknowledgment. Unless otherwise stipulated in writing by RSI, all prices are exclusive of shipping, taxes and duties, and include standard packaging. All prices are in Canadian dollars unless otherwise stated. Prices are subject to change without prior notice.

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 the input of the data stream to the equipment or facilities of the common carrier.

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 the deliveries within Canada. Products may not be returned except with RSI's express prior authorization.

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.

Data Licence and trademarks

Use of the data delivered and the trademarks associated herewith is governed by the terms of the Licence Agreement included with the product and is subject to the applicable satellite copyrights. The buyer by using the product shall be deemed to have accepted and be bound by the terms of such licence.

Termination

In the event of a breach in any of these 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.

Governing law

These General Terms of Sale are governed by the laws of Canada and Province of British Columbia, and, in the case of RADARSAT data, 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

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Digital resources

NAME	SOURCE	DESCRIPTION	DISTRIBUTION MEDIA
Resources in Earth Observation	CSIRO, Australia	Case studies, data, and information for schools and developing countries	CD-ROM
RADARSAT Curriculum Guideline	RSI, Canada	Overview of radar theory and RADARSAT sensor. Also includes flooding and geology case studies.	CD-ROM
The RADARSAT Mission	CSA, Canada	Overview of the RADARSAT mission objectives and sensor characteristics.	CD-ROM
RADARSAT Monitors Natural Disasters: The Red River Flood of 1997.	RSI, Canada	Overview of how RADARSAT was used to monitor the Red River Flood in Canada.	CD-ROM
SAR-101	AERDE Environmental, Canada	Interactive image library, radar theory, and radar image comparisons.	CD-ROM (English, Spanish, or Portuguese)

World wide web (www) sites

RADARSAT International	www.rsi.ca
Canada Centre for Remote Sensing	www.ccrs.nrcan.gc.ca
Canadian Space Agency	www.radarsat.space.gc.ca
NASA Education site	www.hq.nasa.gov/office/mtpe/education.html

(Glossary contributed to by the Canada Centre for Remote Sensing.)

A

Active Remote Sensing System: A system that provides its own source of energy and illumination (i.e., radar system).

AGC (automatic gain control): An adaptive change in the radar gain in the along-track direction, to compensate for changes in the average scene reflectivity. Mainly seen in coastal regions.

Amplitude: Measures the strength of a signal, in particular the strength or "height" of an electromagnetic wave.

Ancillary Data: Any data accessory (or related to the main topic) and not of remote sensing origin.

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: This term is 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 along-track direction.)

B

Band: A selection of wavelengths or a range of radar frequencies:

X-band is the microwave band in which the wavelengths are at or near 3 cm. C-band is the microwave band in which the wavelengths are at or near 5.6 cm. S-band is the microwave band in which the wavelengths are at or near 10 cm. L-band is the microwave band in which the wavelengths are at or near 23.5 cm. P-band is the microwave band in which the wavelengths are at or near 75 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.

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.

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

Beam Position: The area within the total possible swath that is actually illuminated while being governed by the characteristics of a specific beam mode (i.e., seven areas can be illuminated using the Standard beam mode configuration with a predetermined incidence angle range for each position).

Beta Nought (ß°): A radar brightness coefficient. The reflectivity per unit area in slant range, which is dimensionless.

Bit: Contraction for “binary digit”, in which digital computing represents an exponent of the base 2.

Brightness: Property of an 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: See Band.

Calibration: Process of comparing an instrument’s measurement with that of a known standard.

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

CCT: A computer compatible tape, on which digital satellite data are stored and distributed.

CDHS: Canadian Data Handling System.

CDPF: Canadian Data Processing Facility, Gatineau, Québec, Canada.

CEOS: Committee of Earth Observation Satellites. The standard data format for storing SAR data on computer compatible tapes. All RADARSAT products comply to this format.

Change Detection: A difference image prepared by digitally comparing images acquired at different times.

Corner Reflector: A combination of two or more intersecting specular surfaces that combine to enhance the signal reflected back in the direction of the radar. The strongest reflection is obtained for materials having a high conductivity (i.e., ships, bridges).

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

D

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

dB (Decibel): The decibel is a measurement of signal strength. This unit is named in honour of Alexander Graham Bell.

DEM (digital elevation model): A quantitative model of a landform in digital form, normally given as metres above sea level (including the height of the vegetation) and referenced to a geographic coordinate system.

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

DTM (digital terrain model): A quantitative model of a landform in digital form, normally given as metres above sea level, and referenced to a geographic coordinate system.

Dielectric Constant: Measure of a material's ability to conduct or reflect microwave energy.

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

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

Dynamic Range: A description of the variety of signal amplitudes available in a system. Dynamic range is specified either i) to be within minimum and maximum values or ii) with respect to the ratio of maximum to minimum values.

E

EarthWatch: A company based in Longmont, Colorado, USA, who will be launching a high-resolution, commercial imaging satellite, Quick Bird, which is equipped with a panchromatic and multispectral sensor.

Electromagnetic Spectrum: The ordered array of known electromagnetic energy extending from the shortest rays, through gamma rays, X-rays, UV, Visible, IR, microwave and radio waves.

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 x 10^8 m / sec).

Elevation Displacement: Image distortion in the range direction caused by terrain features in the scene being above (or below) the reference elevation contour, and, in fact, being closer to (or farther from) the radar than their planimetric position. The effect may be used to create radar stereo images.

Ellipsoid: A model used to describe the shape of planet Earth, which is not a true sphere but an oblate spheroid compressed along the polar axis and bulging slightly around the equator.

EOSAT: See Space Imaging.

ERS (European Remote Sensing): Satellite series (ERS-1 and -2) launched by ESA in July, 1991. One instrument (ANI) includes a C-band SAR, VV polarization, and 23° incidence angle, and 30-metre resolution.

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

F

Far Range: Portion of the radar image farthest from the flight path.

Foreshortening: Spatial distortion whereby terrain slopes facing a side-looking radar's illumination are mapped as having a compressed scale relative to its appearance, as 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.

Frequency: Rate of oscillation of a wave. In the microwave region, frequencies are on the order of 0.3 GHz-300 GHz, having wavelengths of 1 mm - 1 m respectively.

G

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

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

Georeferenced: The act of registering a map's coordinates with the ground's coordinates at true scale, also incorporating latitude and longitude information into the image.

GHz (Gigahertz): 109 cycles per second. A measure of frequency of electromagnetic energy.

GICS: Geographic Image Correction System.

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

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.

Grey Scale: The sequence of grey tones ranging from black to white.

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. 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. For spaceborne data, an Earth geoid model is used.

H

HDDT: High Density Digital Tape.

Hertz (Hz): Named after H.R. Hertz, a 19th century German physicist. It is the standard unit for measuring 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 the 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 the radar backscatter.

Interferometry: A technique that utilizes the measured differences in the phase of the return signal between two satellite passes to detect slight changes on the Earth’s surface.

IRS-1C (Indian Remote Sensing Satellite): One of a series of sensors launched in December, 1996 and one of 8 multispectral satellites planned for launch by India’s Department of Space.

ISLR: Integrated Side Lobe Ratio.

J

JERS (Japanese Earth Remote Sensing): JERS-1 satellite launched by Japan in February, 1992. It includes L-band SAR, HH polarization and 38.5° incidence angle. The operation of JERS-1 was terminated in late 1998.

L

L-band: See Band.

Lambert Conformal Conic: A conformal conic projection with two standard parallels, or a conformal conic map projection in which the surface of a sphere, such as the Earth, is conceived as developed on a cone, which intersects the sphere 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, 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 features appear to have fallen over toward the radar. The effect is more pronounced for radars having smaller incidence angles.

Look-Up Tables (LUTs): Tables of data containing reference and calibration parameters specific to certain applications.

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 mm - 1 m (0.3 GHz-300 GHz). The most common imaging radars operate at frequencies between 24 cm to 0.85 cm (1.25 GHz-35.2 GHz).

MMO: Mission Management Office, located at the CSA in St. Hubert, Québec, Canada.

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.

Multitemporal Imagery: A collection of images of the same area, obtained at different times.

N

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

Nadir Ambiguity: The superposition of the nadir return with a valid return from an earlier pulse. A feature currently seen in Wide beam position 3.

NASA: National Aeronautics and Space Administration, with headquarters in Washington, D.C., USA.

Near-Polar Orbit: Orbital plane within +10° of a plane containing true North (90° latitude).

Near Range: Refers to the portion of the radar image closest to the flight path.

NOAA: National Oceanic and Atmospheric Administration, headquartered in Boulder, CO, USA.

O

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

OBRs: On-board tape recorders.

Optical Sensor: A remote sensing system that 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).

Orbit: Path of a satellite around a body such as the Earth, under the influence of gravity. The orbit determines the orientation and timing of the acquisition of the radar beam.

P

P-band: See band.

Parallax: Displacement of the position of a target in an image caused by the shift in the observation position.

Passive System: A remote 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. Indicates the spatial position 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 the image is built.

Pixel Size: Refers to the length and width of the pixel element.

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

Polarization: Orientation of the plane of the electric field relative to the Earth's surface. Imaging radars are able to generate and receive with the same or different polarization. HH: horizontal transmit / horizontal receive, VV: vertical transmit / vertical receive, HV: horizontal transmit / vertical receive.

Processing: Sometimes denoted as "preprocessing." It means converting a received reflected signal into an image.

PSLR: Peak Side Lobe Ratio.

Pulse: A short burst of electromagnetic energy.

Q

Quick-look: Imagery produced immediately after data reception. The imagery lacks corrections, but has sufficient resolution and clarity to provide visual information for most users.

R

Radar: Acronym for Radio Detection And Ranging. First built in England in 1938. A system for detecting the direction, range, or presence of objects by sending out pulses of high-frequency electromagnetic waves, which the objects reflect.

Radargrammetry: The process of applying traditional photogrammetric techniques in the adoption of radar data for the creation of stereo models.

RADARSAT: Canada's first Earth observation satellite and the world's first operationally-oriented radar sensor. Launched in November 1995, this C-band SAR satellite includes a steerable beam, which offers users a wide selection of image scales and resolutions.

Radiometric Correction: This procedure corrects and calibrates the gain and offset variations in radar imagery.

Rain Attenuation: The process whereby electromagnetic radiation is absorbed and / or scattered when traversing rain.

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 radar's line of flight. See also Slant Range and Ground Range.

Real-Time: Images or data made available for inspection simultaneously with their acquisition.

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

Resolution: The minimum separation between two objects of equal reflectivity that enables them to appear individually in a processed radar image. 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.

RSI: RADARSAT International, with its headquarters in Richmond, British Columbia, Canada, distributes RADARSAT data, products, and services worldwide (with the exception of Canadian government requests). RSI also distributes ERS products in North America, IRS products worldwide, and SPOT, LANDSAT, and JERS products in Canada.

S

S-band: See band

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.

Scalloping: Horizontal banding visible on ScanSAR imagery, caused by difficulty in calculating the azimuth beam pattern.

Seasat: NASA satellite that was in operation from July to 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 that 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 the 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 is not illuminated by the radar energy; therefore, it 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 hardcopy.

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

SIR-C/X-SAR: A shuttle radar built for missions in 1993, 1994, and 1996 carrying a polarimetric SAR and C- and L-bands, and an X-band HH polarized SAR (contributed by Germany and Italy). It offered 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 first returned to the sensor.

Space Imaging: A remote sensing company founded in 1994 in Thornton, Colorado, USA, who will launch the world’s first one metre resolution commercial optical satellite IKONOS-1 in 1999.

Speckle: Statistical fluctuation (or uncertainty) associated with the brightness of each pixel in the image of a scene, resulting in a salt-and-pepper appearance. 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; sixty percent overlap is considered normal, fifty three percent 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 acquired at the same latitude and at the same time of the year, identical conditions of data acquisition are ensured.

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.

Topographic Inversion: An optical illusion that may occur on images with extensive shadows. Ridges appear as valleys and valleys appear as ridges. This illusion can be corrected by orienting the image so that the shadows trend from the top of the image to the bottom.

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

Transponder: A transmitter-receiver facility, the function of which is to transmit signals automatically when the proper interrogation is received.

U

Grid Universal Transverse Mercator (UTM): A 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 coordinates. Attributes may be associated with the objects. A computer image can be represented in vector format or raster format.

W

Wavelength: The microwave portion of the electromagnetic spectrum used by radar sensors. The wavelength determines the SAR's ability to penetrate cloud cover and ground surface.

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

X

X-band: See band

ACRONYMS AND ABBREVIATIONS

bpi	bits per inch
CCRS	Canada Centre for Remote Sensing
CCT	Computer Compatible Tape
CDPF	Canadian Data Processing Facility
CEOS	Committee on Earth Observation Satellites
CSA	Canadian Space Agency
dB	Decibel
DEM	Digital Elevation Model
DTM	Digital Terrain Model
GHz	Gigahertz
GB	Gigabyte
GCP	Ground Control Points
GICS	Geocoded Image Correction System
GIS	Geographic Information System
GPS	Global Positioning System
HDDT	High Density Digital Tape
ISLR	Integrated Side Lobe Ratio
LUT	Look-Up Table
MMO	Mission Management Office
N/A	Not Applicable
PSLR	Peak Side Lobe Ratio
Raw	Raw Signal Data
RAW	RAW Level 0 CEOS-formatted Signal Data
RSI	RADARSAT International
SAR	Synthetic Aperture Radar
SCN	ScanSAR Narrow
SCW	ScanSAR Wide
SGF	Path Image
SGX	Path Image Plus
SLC	Single Look Complex
SPG	Precision Map Image
SSG	Map Image
UTM	Universal Transverse Mercator