Highlight Article

RADARSAT: First Images

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RADARSAT represents Canada's entry into the arena of Earth observation satellites. Launched 4 November 1995, Canada's RADARSAT is a cooperative space project led by the Canadian Space Agency (CSA) in association with Canadian provincial governments and private sector, and the United States. From the early conceptual stages, the RADARSAT program was designed to provide remotely sensed data for operational applications on an international scale. In this respect, it will complement the capabilities and knowledge gained from existing Earth observation satellites.

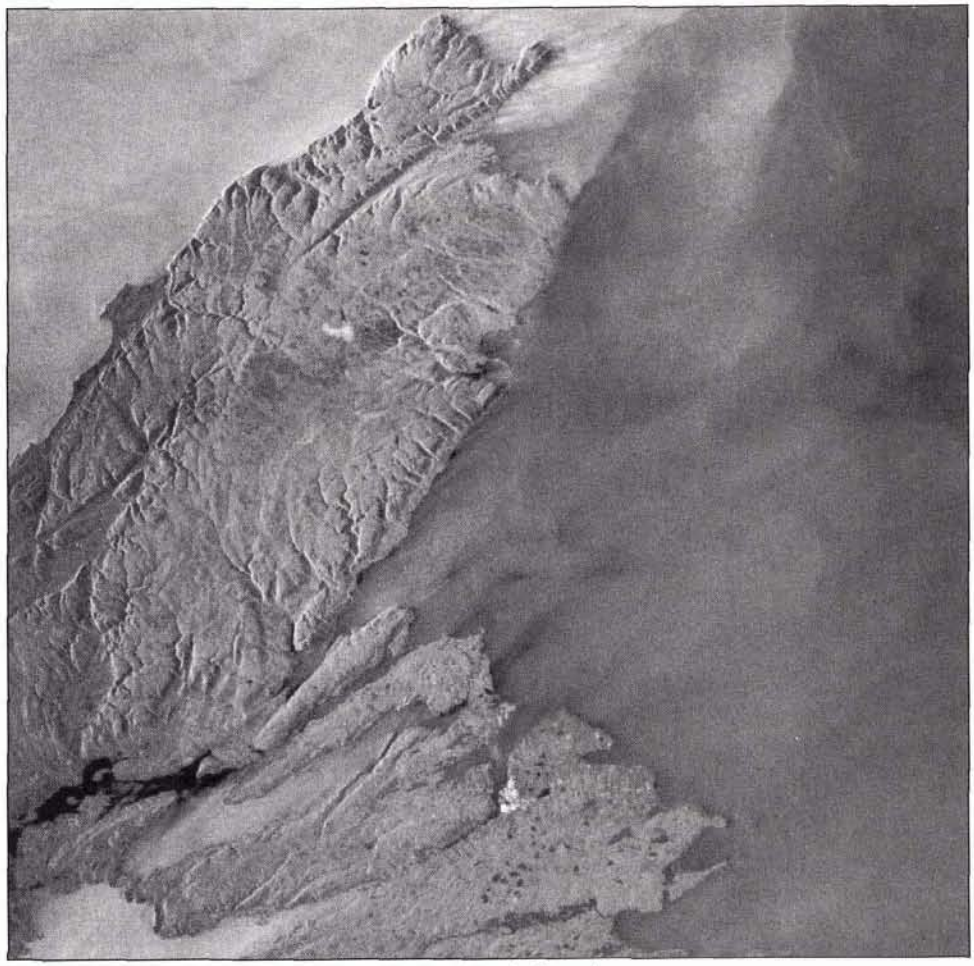

Figure 1. RADARSAT Image of Cape Breton Island, Canada.

First RADARSAT Images

The first RADARSAT image was made publicly available on 14 December 1995. The image in Figure 1 was acquired on 28 November 1995 during the initial system evaluation period. The image parameters are as follows:

- **Location:** Cape Breton Island, Nova Scotia, Canada
- **Acquisition Date:** 28 November 1995
- **Acquisition Time (local):** 1741 (2141 GMT)
- **Image Center:** N46.45, W60.31
- **Mode:** Standard 1, Ascending Pass
- **Local Incidence Angle:** 23 degrees
- **Image Resolution:** 25 meters
- **Image Size:** Range - 132 km, Azimuth - 127 km

Even under conditions of darkness, overcast skies, rain, and strong winds, this RADARSAT image provides information useful in many applications. For example, geological features, including major fault lines are clearly visible as are the remnants of glacial drumlin fields (bottom). Offshore, an inbound and outbound ship can be identified both from the bright returns of the ships themselves and from the residual ocean surface disturbance created by their wakes.

Figure 2 (page 145) shows a portion of an image acquired in the vicinity of Osaka and Kobe, Japan. Details of the full image details are:

- **Location:** Osaka, Japan
- **Acquisition Date:** 7 December 1995
- **Acquisition Time:** 2104 GMT
- **Image Center:** N34.61, E134.59
- **Mode:** Standard 3, Ascending Pass
- **Local Incidence Angle:** 34 degrees
- **Image Resolution:** 25 meters
- **Image Size:** Range - 132 km, Azimuth - 133 km

The water body (nearly black) in Figure 2 is Osaka Bay with Kobe visible along the top shore and Osaka to the right. The two reclaimed islands visible off Kobe were severely damaged during the 17 January 1995 earthquake. There is a distinct contrast between the urban areas and the steeper mountainous terrain which appear as darker tone along the north (upper) shore of Osaka Bay. Once again, numerous ships are also visible in Osaka Bay.

Overview of the RADARSAT Program

The RADARSAT program was designed to provide operational functionality to meet Canadian and international Earth observation requirements. As part of the process, considerable effort was spent addressing mission requirements from the perspective of data users (Parashar *et al.*, 1993; Canadian Space Agency, 1991). The results of this effort were incorporated into the many elements of the RADARSAT system.

The satellite is equipped with an active microwave sensor that guarantees data collection independent of weather conditions and illumination. Furthermore, RADARSAT's SAR antenna has selectable incidence (viewing) angles that can be optimized for specific applications, terrain conditions, and coverage area requirements. With its range of selectable resolutions, RADARSAT can provide a wide range of products that meet the special requirements of each user.

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Table 1. Key Beam Mode Performance Parameters

	Standard	Fine	Wide	ScanSAR (N,W)	Extended (H,L)
Nominal Swath Width (km)	100	45	150	300, 500	75, 170
Range resolution (m)	< 25	< 9	< 35	50, 100	< 20
Azimuth resolution (m)	< 28	< 9	< 28	50, 100	< 37, 27, 27
Peak impulse response sidelobe (dB)	< -20	< -20	< -20	< -20	< -20
Range ambiguity ratio (dB)			< -20		
Azimuth ambiguity ration (dB)			< -20		
Noise equivalent (dB)			< -20		
Equivalent number of independent looks	> 3.4	1	>3.4	14, 8	> 3.4
Global dynamic range (dB)			> 30		

Finally, with its different beam modes and "steerable" antenna, RADARSAT can revisit the same area on a frequent basis.

Satellite System...

RADARSAT employs a near-polar, dawn-to-dusk orbit with latitudinal crossing at approximately the same solar time (nominally 0900 and 1800 at the equator) each day. In a dawn-dusk orbit, RADARSAT remains in sunlight for longer periods, providing maximum power to operate the SAR. In addition, this orbit reduces potential downlink conflicts with other satellites (such as ERS, SPOT, and Landsat).

Data are collected continuously along a line parallel to the subsatellite track offset to the right of nadir, approximately 250 km. The normal field of view is an additional 500 km off nadir. Data collection in the azimuth direction is limited by the maximum SAR on-time of approximately 28 minutes per orbit. Although collected continuously, the data products are available on a frame-by-frame basis, with the spatial size of the frame dependent on the beam mode. Data acquisition rates for RADARSAT beam modes are consistent with the maximum 105 Mb/s real-time downlink capacity.

RADARSAT is equipped with a C-Band, horizontal-like polarized SAR system looking to the right. SAR on-time will be approximately 28 minutes per orbit, equalling about one-quarter of an orbit period (100.7 minutes/orbit or slightly more than 14 orbits per day). The repeat cycle for an orbit will be every 24 days; however, the repeat coverage for a given area ranges from every day in Arctic regions to every sixth day at the Equator. RADARSAT will also have two onboard tape recorders facilitating data acquisition over areas not covered by ground receiving stations.

RADARSAT Beam Modes...

The RADARSAT SAR has the flexibility to operate in seven beam modes (Luscombe *et al.*, 1993), providing data with varying image characteristics. RADARSAT beam modes include Standard, Fine, Wide, ScanSAR, and Extended (Table 1). For each of the beam modes, a number of beam positions can be programmed, providing users with a wide variety of acquisition options.

The implementation of RADARSAT's ScanSAR imaging mode (Luscombe *et al.*, 1993; Raney *et al.*, 1991) is unique among spaceborne SARs and will provide a useful wide area coverage capability with total swath width of either 310 or 505 km at reduced resolution, but with no increase in the mean data downlink rate. The basic approach to ScanSAR implementation is to share SAR operational time between two or more separate subswaths in such a way as to obtain complete coverage of each sub-swath, and to allow sufficient time for the synthetic aperture to image the subswath at the required resolution. The imaging operations are formulated into a series of blocks which produce a unique return from each subswath. Beam switching is fast enough so that each sub-swath adjoins or overlaps. Depending on the sub-swath location as a function of the incidence angle, one or more pulse repetition frequencies (PRF) are required for a given sub-swath, which may cause a loss of up to nine pulses between blocks of data. A block of data is, however, typically 1,000 pulses in length; so, a nine-pulse loss is tolerable.

Although several ScanSAR beam combinations are possible, RADARSAT will routinely employ two beam modes —ScanSAR Narrow and ScanSAR Wide. For ScanSAR Narrow, imaging alternates between the three Wide swath beams to produce a swath of about 300 km. ScanSAR Wide uses two Wide swath and two Standard swath beams to produce a continuous swath of around 500 km. To achieve ScanSAR swath widths across incidence angles ranging from 20 to 49, the PRF is lower than previous satellite systems and dictates the use of the longer 15 m antenna to provide an azimuth beam width of 0.2 (nominal).

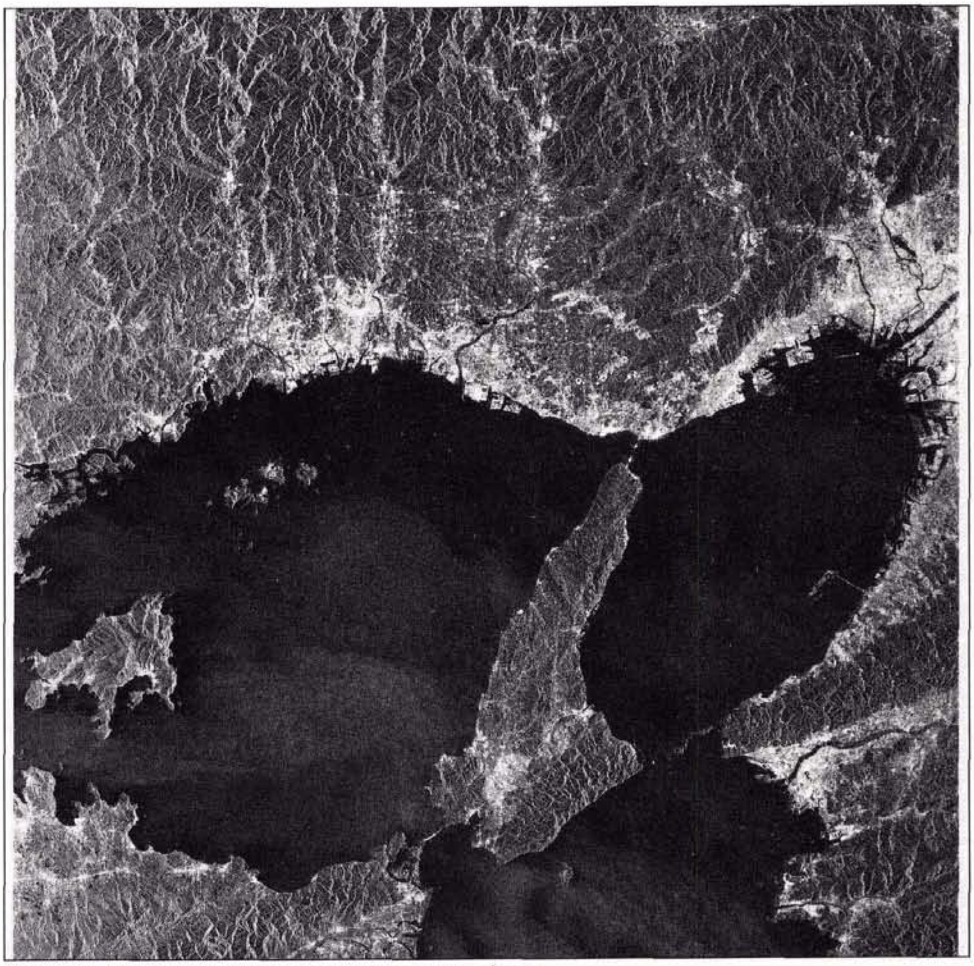

Figure 2. RADARSAT Subscene of Osaka Bay, Japan.

Satellite Control... The satellite is controlled from ground facilities located at the Canadian Space Agency in St. Hubert, Quebec, Canada. International requests for data acquisition from RADARSAT will be coordinated through the Canadian Order and Dispatch Desk (CODD), located at the offices of RADARSAT International (RSI) in Richmond, British Columbia, Canada. RADARSAT SAR data can be downlinked in real time to two Canadian (Prince Albert, Saskatchewan and Gatineau, Quebec), one American (Alaska SAR Facility), and other foreign ground stations, or can be recorded on one of RADARSAT's tape recorders and downlinked to the Gatineau receiving station in Canada. There, it will be processed using the Canadian Data Processing Facility (CDPF). This high speed, moderate throughput processor is designed to process and deliver data in as little as four hours after receipt to serve operational users primarily located in Canada. This requirement meets the needs of the Canadian Ice Centre, which will be a major user of RADARSAT data. In the future, it is expected that similar RADARSAT SAR processors will be installed in other countries, in regions such as Europe and Asia as other ground receiving stations are added to the network. This will ensure the fastest possible turnaround of data to the user.

Radiometric Calibration... The Image Data Calibration System (IDCS) within the CDPF provides overall SAR image calibration for RADARSAT. The IDCS capability includes analysis of internal calibration measurements performed routinely by the onboard calibration subsystem and imbedded in the radar telemetry downlink, and external calibration from ground calibration sites in Canada. The ground calibration sites, including receivers and corner reflectors, measure signal strength, and transponders transmit a calibrated signal to the spacecraft. Foreign calibration ground-sites may be used if required.

The objectives of the IDCS as outlined in the RADARSAT Systems Specifications (Canadian Space Agency, 1993) are to provide calibration capacity to: 1) correct for radiometric drift calibration and range pulse distortion compensation for the SAR instrument (excluding the antenna); and 2) determine beam pattern and beam pointing information for the SAR antenna. The design goal (Brown *et al.*, 1993) applies to all RADARSAT beam modes and requires the relative radiometric error to be not greater than the following:

- 100 km scene, 1.0 dB
- one orbit, 1.5 dB
- 3 days (orbit repeat sub-cycle), 2.0 dB
- 5 years (in-orbit lifetime), 3.0 dB

Beam qualification and calibration is currently underway and operational acquisitions are expected to begin in February. Ongoing calibration will be done during the life of the satellite using the IDCS.

Near-Real Time Delivery...

One of the key benefits of a SAR sensor is guaranteed acquisition of data. Once this is achieved, it becomes possible to consider applications where reliability of information access is important. Often these applications pertain to dynamic phenomena where rapid turnaround after acquisition is also important.

Applications which must consider this issue include "disaster response" applications, such as flood monitoring. In these cases, several temporal aspects are important. There is a need to respond quickly to an event, implying a requirement for short-notice mission planning. Second, there may be a need for sustained information gathering, requiring reliability in data availability. For instance, in 1993, parts of the Mississippi River in the United States remained at or near flood levels for several months.

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The Canadian ground segment, through the CDPF, provides the capability for near-real time processing and delivery of RADARSAT data and imagery products. Table 2 summarizes the categories of turnaround time, describing product turn around times from Canadian facilities. Other reception and processing sites within the RADARSAT network may provide similar near-real time capabilities.

Data Access and Availability

The Canadian Space Agency (CSA), in cooperation with the Canada Centre for Remote Sensing (CCRS) and RADARSAT International (RSI), built and operates the Canadian ground segment which includes:

- upgrade and operation of the two existing Canadian remote sensing satellite reception stations at Prince Albert, Saskatchewan and Gatineau, Quebec to receive RADARSAT data;
- operation of several order desks for national (through CCRS, RSI and CSA channels) and international (through RSI) data needs; and,
- construction and operation of a state-of-the-art SAR data processor in Canada to process national and international data requirements.

Table 2. Product Turnaround Times

Delivery Category		Processing Time	Method of Delivery
Non Near-Real Time	Regular	2 weeks	Courier
	Rush	2 days	Courier/ Electronic
Near-Real Time		4-6 hours	Electronic

The United States federal government will operate its own order desk and will also support the RADARSAT program through operation of the Alaska SAR Facility.

RSI is a privately-owned Canadian firm whose primary role is to process, market, and distribute the data from RADARSAT on a worldwide basis, and to help pioneer the commercial use of RADARSAT data. Via RSI, users will have access to worldwide data through a network of international ground receiving stations. Additionally, RSI has the ability to utilize RADARSAT's onboard tape recorders to collect data of almost any location in the world and can download this data at the Gatineau receiving station thus providing products on a reliable basis.

Acknowledgments

RADARSAT imagery © 1995 Canadian Space Agency, received by the Canada Centre for Remote Sensing, and processed and distributed by RADARSAT International.

About the Authors

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