RADARSAT-1 Satellite

Summary:

RADARSAT-1 is an advanced Earth observation satellite project developed by the Canadian Space Agency (CSA) to monitor environmental change and to support resource sustainability. NASA launched RADARSAT-1 in exchange for access to the satellite on a pro rata basis through its Alaska SAR Facility (ASF). At the heart of RADARSAT-1 is an advanced radar sensor called Synthetic Aperture Radar (SAR). SAR is a microwave instrument which sends pulsed signals to the Earth and processes the received reflected pulses. RADARSAT-1's SAR-based technology provides its own microwave illumination and thus will operate day or night, regardless of weather conditions. RADARSAT-1 was placed into a sun-synchronous polar orbit in order to provide global coverage. Research emphasis will be on the polar regions, though on-board tape recorders will allow imaging of any region, world-wide. Data downlinked to NASA's stations (McMurdo, Antarctica and ASF in Fairbanks, Alaska) will be made available through the Alaska SAR Facility.

Some potential applications of RADARSAT-1's data include: sea-ice monitoring - daily ice charts; extensive cartography; flood mapping and disaster monitoring in general; glacier monitoring; forest cover mapping; oil spill detection; assessment of the likelihood of mineral, oil and gas deposits; urban planning; crop production forecasts; coastal surveillance (erosion); and surface deformation detection (seismology, volcanology). Some of the large RADARSAT-1 activities include: the Antarctic mapping mission; "Arctic Snapshots" showing the complete Arctic ice extent at given times (4 snapshots every 24 days); a Geophysical Processor System (RGPS) to provide derived data sets such as sea ice motion products; and a global set of stereographic SAR images. RADARSAT-1 was launched November 4, 1995 and has a design lifetime of 5.25 years.

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1. Source/Platform or Data Collection Environment Overview:

Source/Platform or Data Collection Environment Long Name, Source/Platform Acronym:

RADARSAT-1, RADAR Satellite

Source/Platform Introduction:

At the heart of RADARSAT-1 is an advanced radar sensor called Synthetic Aperture Radar (SAR). SAR is a microwave instrument which sends pulsed signals to Earth and processes the received reflected pulses. RADARSAT-1's SAR-based technology provides its own microwave illumination and thus will operate day or night, regardless of weather conditions. RADARSAT-1 offers a variety of beam selections; the satellite's SAR will have the unique ability to shape and steer its beam from an incidence angle of less than 20 degrees to more than 50 degrees, in swaths from 35 to 500 kilometers, with possible resolutions from 10 to 100 meters. The RADARSAT-1 SAR image swath can cover much of the Arctic daily and most of Canada every 72 hours, depending on the beam selected. The entire Earth could be covered every 24 days using the standard 100-kilometer beam mode. Data will be downlinked in real time or stored on one of the tape recorders until the spacecraft is within range of a receiving station. Data is expected to be available for users a few hours after the satellite passes over an area. Receiving stations are located at Prince Albert, Saskatchewan; Gatineau, Quebec; Tromso, Norway; and Fairbanks, Alaska. Additional ground stations are also developing the capability to support the RADARSAT mission.

Collection Environment:

Polar-orbiting, sun-synchronous satellite

Source/Platform Program Management:

Under the aegis of CSA , Canada is responsible for the design and integration of the overall system, for its control and operation in orbit, and for the operation of the data reception and processing stations located in Prince Albert, Saskatchewan and Gatineau, Quebec. NASA launched RADARSAT-1 in exchange for the right to access the satellite on a pro rata basis and is responsible for its data reception and processing station - the Alaska SAR Facilty in Fairbanks, Alaska.

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Source/Platform Mission Objectives:

Some of NASA's stated mission objectives include:

1. Mapping all of the Antarctic ice sheet

NASA scientists will use RADARSAT-1 data to compile, for the first time, a high-resolution map of all of Antarctica, a largely unexplored continent that is bigger than the continental United States. Repeated surveys should reveal changes in the ice sheet that may ultimately lead to a rise in global sea levels. The first mapping is planned for late 1997.

2. Monitoring sea-ice cover for climate research and navigation purposes

The regular coverage of far northern oceans will allow scientists to apply automated techniques for tracking ice floes, and will allow them to study the motion of ice across the entire Arctic. Further analysis should reveal the rates at which Arctic sea ice opens and closes, from which the science team can estimate the rates at which new ice forms and study the effects of ice cover on climate change. For example, see the data products which will be produced by the RADARSAT-1 Geophysical Processor System.

3. Identifying and mapping land cover and assessing how it changes over time

NASA will use RADARSAT-1 to study the Earth's forests. The data can be used to estimate the kinds of vegetation in a forest, the extent of flooding (which plays a role in the exchange of chemicals between the forest and the atmosphere) and the amount of vegetation covering an area.

Some of the CSA's stated mission objectives:

1. To ensure data availability for environmental monitoring

2. To create daily sea ice maps based on SAR data collected over the Arctic

3. To collect SAR data over selected portions of the globe for the purpose of crop forecasting

4. To obtain periodic SAR data coverage of Antarctic sea ice distribution, subject to receiving station or tape recorder availability

5. To collect a global set of stereographic SAR images for mapping

6. To obtain the first comprehensive map of the Antarctic continental ice sheet based on SAR images

7. To collect site and time specific SAR data in support of approved research studies or application demonstrations sponsored either individually or jointly by the parties involved

8. To collect site and time specific SAR data for experiments sponsored by the parties through an EAO

9. To collect and make available global data to any persons, on a non-discriminatory basis

10. To develop applications of SAR data in a pre-operational environment

11. To promote globally the utilization of RADARSAT-1 SAR data and data products and related information of the Earth's surface in such areas as:

* Global ice reconnaissance
* Ocean monitoring
* Monitoring of renewable and non-renewable land resources
* Monitoring of the natural environment
* The protection of human life and property from natural disasters

12. To contribute to the overall development of a national and international commercially viable remote sensing industry

13. To contribute to the maintenance and improvement of the Canadian industry's capability and its high quality profile in the field of remote sensing

Source/Platform Parameters:

RADARSAT-1 was launched on 4 November 1995 by a McDonnell-Douglas Delta II-7920 from the Western Range, Vandenberg Air Force Base, California. RADARSAT-1 has an design lifetime of 5.25 years. Primary sponsors are the Canadian Space Agency through the Canadian federal government, Canadian Provinces (Saskatchewan, British Columbia, Quebec, and Ontario), NASA, NOAA, and RADARSAT-1 International Corporation. Industrial partners included:

* Spar Aerospace (Montreal)
  - Primary Contractor

* Ball Aerospace, Space Systems Division
  - Spacecraft Bus

* McDonnell-Douglas
  - Launch Vehicle (Delta II-7920)

* MacDonald Dettwiler & Associates/SED/BALL
  - Mission Control System

* CAL Corporation
  - SAR Antenna

* COMDEV
  - Low Power Transmitter, Receiver, Calibration Subsystems and Phase Shifters

* DORNIER
  - High Power Microwave Circuit

* ODETICS
  - High Data Rate Tape Recorders

along with Astro Aerospace, First Mark Technologies, Fleet Industries, IMP, MPB Technologies, Prior Data Sciences, SED Systems, SAFT, FIAR, Loral, GORE, TST, COI, Gulton INP, Barnes, South West Research, Allied Signal, Adcole, SEAKR Schoeastedt, FRE Composites, and British Aerospace.

Spacecraft Parameters:

Design Lifetime:	5.25 years
Spacecraft Mass:	3100 kg (vs 2750 kg)
Bus Mass:	1560 kg
Payload Mass:	1540 kg

Average Power:

Requirement:	1500 W
Total Solar Power:	2500 W
Batteries:	3 48 Ah NiCd
Available (after 3 years):	1900 W

Hydrazine:

Yaw Maneuver:	67 kg

Orbit Parameters:

Geometry:	Circular, sun-synchronous (dawn-dusk)
Altitude:	798 km (793-821)

Inclination:	98.6 degrees
Period:	100.7 minutes, 14 orbits/day
Repeat Cycle:	24 days, 343 orbits
Local mean solar time of ascending node:	18:00 GMT
Argument of perigee:	90.0 degrees

Coverage Information:

Data will be downlinked to receiving stations at: Prince Albert, Saskatchewan; Gatineau, Quebec; McMurdo, Antarctica; and ASF in Fairbanks, Alaska. The North American stations can obtain real-time data within their station masks - an area within approximately 3000 km of each station. McMurdo's coverage mask is more limited due to the surrounding mountains. Data may also be recorded over the desired location and later downlinked later - receiving station. Using the maximum swath width of 500 km, the following may be obtained:

* Daily coverage in areas north of 70 N, excepting a small portion at the pole

* Coverage every 4 days for regions between 48 N and 70 N

* Coverage every 6 days for locations north of 80 S

* Daily coverage in areas south of 80 S, excepting a portion at the pole (put something about Antarctic mappings)

Also see the Canadian Space Agency's information regarding RADARSAT-1 coverage.

Attitude Characteristics:

(Orbit parameters listed above.) RADARSAT-1 is 3-axis stabilized.

Position Errors:

Along-Track:	+/- 1430 meters
Cross-Track:	+/- 36 meters
Radial:	+/- 26 meters

Velocity Errors:

Along-Track:	+/- 0.75 m/s
Cross-Track:	+/- 1.5 m/s
Radial:	+/- 1.5 m/s

Rotation Measurement Errors:

Roll:	+/- 0.1 degrees
Pitch:	+/- 0.1 degrees
Yaw:	+/- 0.1 degrees

(from 0.05 degrees long term bias, 0.05 degrees short term random errors for each)

Drift Rates:

Roll:	+/- 0.001 degrees/second
Pitch:	+/- 0.001 degrees/second
Yaw:	+/- 0.001 degrees/second

Antenna Pointing Errors:

Elevation/Azimuth Pointing Errors:	0.5 degrees
Elevation/Azimuth Drift Rates:	0.01 degrees/second

Data Collection System:

The S-band command and telemetry link will permit simultaneous reception of commands and transmission of telemetry between the RADARSAT-1 satellite and the Telemetry, Tracking, and Control Stations (TTCS) at ST.-Hubert and Saskatoon. SAR data will currently be downlinked to the Canadian stations and Gatineau and Prince Albert and the U.S. station at Fairbanks, Alaska. Other ground receiving stations may be added in the future.

Communication Links:

An S-band link is used for telemetry, tracking, and control. Two X-band links are used to downlink SAR information: one for real-time data aquisition and transmission, and the other to downlink recorded data. Both X-band links may be used at the same time. Note that all auxiliary data available in the satellite which is necessary for data processing, image quality monitoring, and calibration will be included in the downlinked data stream. The X-band links' characteristics are as follows:

Carrier Frequencies:	8.105 GHz (RT Data), 8.230 GHz (Recorded Data)
Number of Channels:	2
Modulation:	QPSK
Signal Quantization:	4 bits (I and Q)

Data Rates:	105 Mbps (Realtime) 85 Mbps (Recorded)
RF Power:	22 Watts/channel
Bit Error Rate:	.00001
Ground Station G/T:	31.9 degrees, dB per degrees Kelvin
Spacecraft Antenna Beamwidth:	124 degrees
Polarization:	Right-Hand Circular Polarization (RHCP)

List of Sensors/Instruments:

Synthetic Aperture Radar (SAR)

2. Ground Segment Information:

Tracking and Control:

The Telemetry, Tracking and Control Stations (TTCS) at St.-Hubert and Saskatoon use the weekly and daily planning schedules provided by the MCF/SSCM (Mission Control Facility/Spacecraft Scheduling & Command Management). Orbit elements provided by the MCF are used by the TTCSs to calculate the antenna tracking angles required to locate the spacecraft in its orbit. The TTCS operates in the standard Earth-to-space and space-to-Earth S-band frequencies.

Before the pass, the TTCS undergoes pre-pass tests and collects ranging calibration data. At the start of a pass, the station sweeps the uplink carrier frequency to allow the spacecraft to lock onto the doppler-shifted carrier. The station also acquires and tracks the spacecraft. During the pass, the station receives the spacecraft downlink signal, demodulates the spacecraft telemetry, and sends it to the MCF. The station also modulates the spacecraft commands received from the MCF onto the spacecraft uplink signal. On-board storage of commands by the spacecraft computer allows 24 hours of automonous operation.

The TTCS performs the spacecraft range and range rate measurements by modulating a ranging reference signal onto the spacecraft uplink signal, and comparing and time-tagging the returning ranging signal demodulated from the spacecraft downlink signal. Ranging and telemetry data is recorded, along with a time code, during a pass to allow data recovery in the event of a communication lin failure. Post-pass, the station sends the time-tagged range and range/rate measurements to the MCF.

Data Acquisition and Processing:

RADARSAT-1 SAR data will be downlinked to either the Canadian stations at Gatineau and Prince Albert or the U.S. station at Fairbanks, Alaska. (Other ground stations may be allowed to acquire RADARSAT-1's data in the future.) Data requested by U.S. investigators will be archived and processed at the Alaska SAR Facilty . All other data will be processed at the Canadian Data Processing Facility (CDPF) at Gatineau. Both centers will attempt to provide quick look (within a few hours) processing for such facilities as the National Ice Centers for forecasting sea ice conditions. Several other products will also be available. Please see the respective homepages - CSA's RADARSAT Homepage and the Alaska SAR Facility Homepage - for product availability and detailed product descriptions.

Latitude Crossing Times:

RADARSAT-1 was launched into a sun-synchronous dawn-dusk polar orbit. The satellite crosses the equator at 6 a.m. and 6 p.m.

3. References:

(Some of the information found within this document was obtained from CSA presentations and pamphlets.)

* Special Issue - RADARSAT. 1993. Canadian Journal of Remote Sensing, Vol 19(4), ISSN 0703-8992.

* The Canadian Space Agency's RADARSAT pages

* The Canadian Centre for Remote Sensing's Homepage, RADARSAT pages

4. Glossary of Terms:

See ASF's Glossary for terms related to ASF. See the EOSDIS Glossary for a more general listing of terms related to the Earth Observing System project.

5. List of Acronyms:

This list defines acronyms found within this document. See ASF's Acronym List or the EOSDIS Acronyms List for more.

Note: I had difficulty obtaining acronym expansions for many of RADARSAT-1's contractors; the acronym might be the only name. Please let me know of any corrections.

Note: When you see something like 5I, 5Q quantization, that means 5 bits of data are used to record the intensity of the signal's In-phase (cosine) and Quadrature (sine) components.

ASF:
Alaska SAR Facility

COI:
Commis. Oceanographique Intergouvernementale

CSA:
Canadian Space Agency

FIAR:
Fabbrica Italiana Apparecchiature Radioelettriche

MCF:
Mission Control Facility

MCS:
Mission Control System

NASA:
National Aeronautics and Space Administration

NOAA:
National Oceanic and Atmospherics Administration

QPSK:
Quadrature Phase-Shift Keying

RGPS:
RADARSAT-1 Geophysical Processor System

RSI:
RADARSAT-1 International

SSCM:
/Spacecraft Scheduling & Command Management

SAR:
Synthetic Aperture Radar

TT&C:
Telemetry, Tracking and Control

TTCS:
Telemetry, Tracking and Control Stations

6. Document Information:

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