RADARSAT Constellation Mission Serving Canadians

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Abstract

The RADARSAT Constellation mission consist of three identical C-band SAR satellites flying in a constellation which will provide complete coverage of Canada's land and oceans offering an average daily revisit, as well as a potential daily access to 95% of any location on the globe. The main objective of the RADARSAT Constellation Mission is on meeting Government of Canada User Department's needs and requirements in Core Use Areas such as Maritime Surveillance, Disaster Management, Ecosystem Monitoring and Northern Development.

Background and Relevance

Earth Observation (EO) is a major thrust of the Canadian Space Program (CSP). In the 1980's Canada pioneered Synthetic Aperture Radar (SAR) technology through the development and extensive use in field trials around the world of a sophisticated radar imaging system deployed in aircraft as a simulator to Canada's future satellite system. Canadian technological advances were integrated into spaceflight hardware flown on the European Space Agency ERS-1 and ERS-2 radar demonstrator satellites launched respectively in 1991 and 1995. Having attained space flight heritage, Canada launched its own radar Earth observation satellite, RADARSAT, in 1995. RADARSAT was primarily driven by a requirement to better manage navigation through Canada's ice infested waters. Operating independent of daylight or weather conditions, Synthetic Aperture Radar (SAR) sensors provide global coverage of the Earth's surface. Since 1995, RADARSAT, later re-named RADARSAT-1, provides operational service to both government and commercial users worldwide through a network of 47 ground receiving stations. It has given Canada a world leadership position in space-borne SAR systems (Table 1) for data use and value-added products and services.

	Imaging frequency	Spatial resolution	Polarization	Repeat Cycle (Coherent change detection)
RADARSAT-2	C-Band, 5.405 GHz	<3 to 100 m	Single, Dual, Polarimetric	24 days
RADARSAT-1	C-Band, 5.3 GHz	10 to 100 m	Single (HH)	24 days
RCM (3 satellites)	C-Band, 5.405 GHz	<5 to 100 m	Single, Dual, Polarimetric (exp)	12 days / sat (4 days)
Envisat ASAR	C-Band, 5.331 GHz	30 to 1000 m	Single, Dual	35 days
ALOS PALSAR	L-Band, 1.27 GHz	10 to 100 m	Single, Dual, Polarimetric (exp)	46 days
COSMO SkyMed (4 satellites)	X-Band 9.6 GHz	1 to 100 m	Single, Dual	16 days / sat (5 days)
TerraSAR-X	X-Band, 9.650 GHz	1 to 15 m	Single, Dual, Polarimetric (exp)	11 days

Table 1: SAR Satellites Characteristics Summary

The RADARSAT Constellation Mission (RCM) will ensure SAR data and imagery continuity for RADARSAT-2 users, as well as adding a new series of applications enabled through the constellation approach. It will provide all-weather day and night data in support of Canadian sovereignty and security, environmental monitoring, natural resources management and other government priorities, such as Northern development. The three-satellite constellation provides average daily coverage of most of Canada and its surrounding waters. Coverage increases significantly in Canada's North. The constellation will provide coverage three to four times daily of the Northwest Passage. With the increased frequency of revisit, emerging applications such as land deformation and operational disaster management can be further exploited. http://asc-csa.gc.ca/eng/satellites/radarsat/default.asp

Description of the RADARSAT Constellation Mission

The mission is designed to respond to core needs at the highest level which can be summarized as:

- Daily coverage of Canada's territorial and adjacent waters to support maritime surveillance, including ice monitoring, marine wind monitoring, oil pollution monitoring and ship detection; and,
- Ability to monitor all of Canada for disaster mitigation on a regular basis (monthly to twice-weekly) to assess risks and identify damage prone areas; and,
- Regular coverage of Canada's land mass and inland waters, up to several times weekly in critical periods, for resource and ecosystem monitoring.
- The RADARSAT Constellation will provide on average 15 minutes of imaging time per orbit per satellite, with peak imaging of 25 minutes per orbit per satellite outside the eclipse season.

The RADARSAT Constellation will provide a four-day exact revisit, allowing coherent change detection using an InSAR mode. It will also provide an average daily global re-look capability in medium 50 m resolution mode. Most of the applications considered require re-look at least daily and an exact revisit once to twice weekly (interferometric change detection applications). Very frequent re-look capability is critical to certain disaster management applications.

The timelines and data latency requirement is highly variable according to the application area. For many ecosystem monitoring applications, data delivered several days or in some cases several weeks later may be sufficient. However, maritime surveillance and disaster monitoring have much more demanding timeliness requirements. For ship detection in Canadian and adjacent waters within Canadian ground station masks, RADARSAT Constellation will provide 10 minute data latency from acquisition to delivery of data, and 30 minutes for other maritime surveillance applications. For global and Canadian disaster management applications, the Constellation will provide 2 hour data latency from downlink to data delivery, and for ecosystem monitoring applications, 24 hour data latency from downlink to data delivery will be provided.

RCM is designed as a scalable constellation of three small satellites (Figure 1). With a constellation, the time between successive imaging of the same part of the Earth (revisit time) is significantly reduced. The creation of a three-satellite constellation will increase the frequency of available information, as well as the reliability of the system, making it better suited to operational requirements of Government Departments. In the event of a satellite failure, the other satellites can continue to provide a certain level of service. The lower cost of individual satellites facilitates the replacement and makes the system scalable.

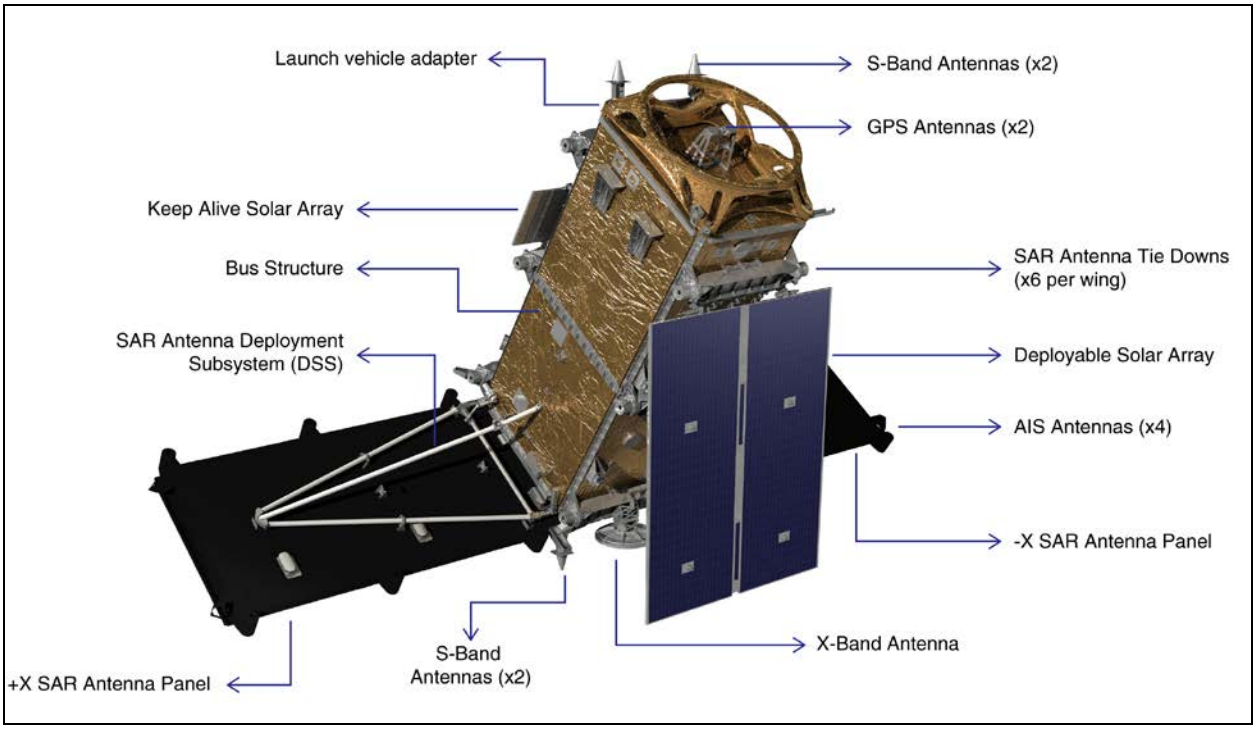

Figure 1: **RADARSAT Constellation Mission (RCM) Space Segment**

RCM involves initially flying three C-band SAR satellites in a constellation configuration, evenly spaced on the same orbit, meaning they will follow each other by 30 minutes. The satellites will

operate in a sun-synchronous low-earth polar orbit, at an altitude of approximately 600 kilometers.

RCM is designed as a wide area monitoring system, each satellite having a ground swath of about 350km, to allow monitoring the maritime approaches of Canada on a daily basis and a capacity to image any location in Canada every day.

Each spacecraft consists of a bus and two payloads: a Synthetic Aperture Radar (SAR) payload and an Automatic Identification System (AIS) payload. The bus module will provide attitude and orbit control, power generation and storage, payload commands, telemetry, thermal control and the primary support structure. The SAR payload will perform all imaging operations, store, encrypt and transmit the SAR data. The AIS payload will receive ships' identification in a wide swath, larger than the accessible swath of the SAR.

Each satellite will be capable of providing SAR imagery in a variety of imaging modes, which were selected to ensure continuity of data to RADARSAT users (Figure 2 & Table 2). In wide-area mode, it will monitor and acquire data over large areas of interest at medium resolution (from 16 to 100 meters), mostly for maritime and environmental applications. In high-resolution mode, the constellation will acquire specific on-demand images at a spatial resolution of 3 meters or 5 meters. It also has a 1 meter by 3 meters resolution in spotlight mode. The constellation has a dual polarization capability and a fully polarimetric mode as well as a compact polarization mode. Polarization options maximize the information content in the collected data. http://asc-csa.gc.ca/eng/satellites/radarsat/radarsat-tableau.asp

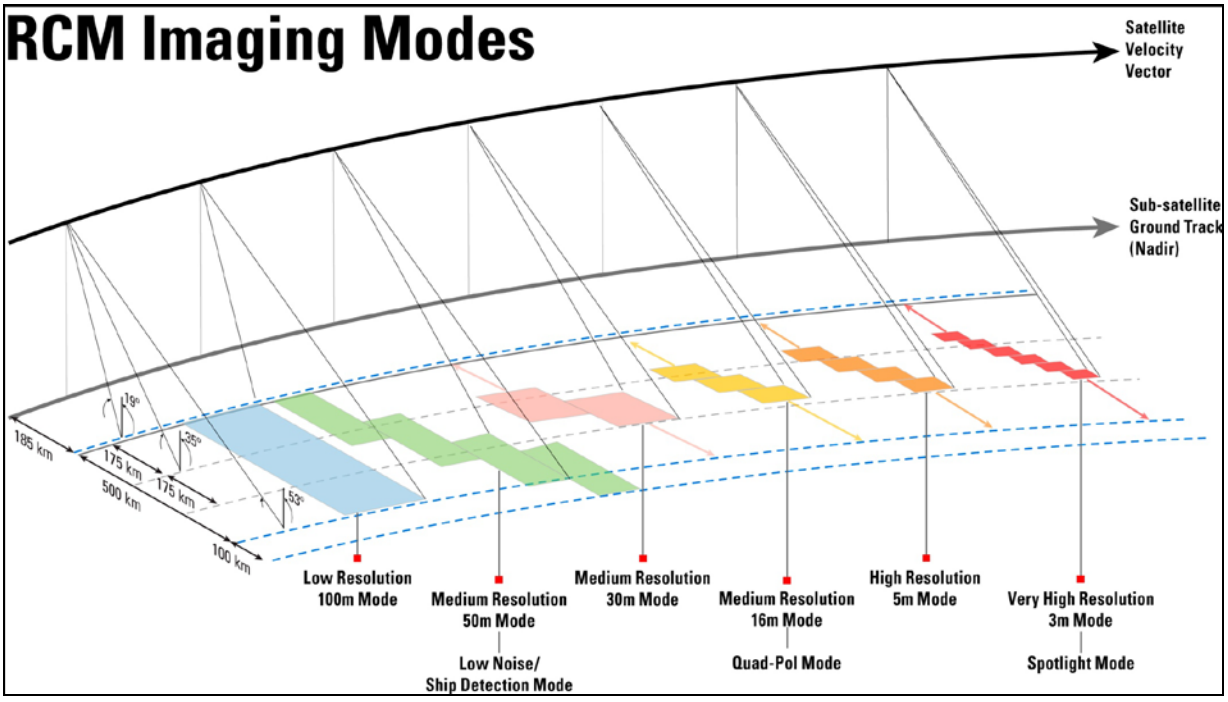

Figure 2: Visual Representation of the RCM imaging modes

Mode	Resolution for detected products m	Number of Looks for detected products rng x az	Nominal Swath Width (accessible) km	NESZ dB	Polarization Options				
					Single Pol (HH, VV, HV or VH)	Dual Pol		Compact Pol	Quad Pol (HH+VV + HV+VH)
						(HH+HV or VV+VH)	HH+VV[2]		
Low Resolution 100m	100	8x1	500 (500)	-22	✓	✓	✓	✓	
Medium Resolution 50m	50	4x1	350 (600)[3]	-22	✓	✓	✓	✓	
Medium Resolution 30m	30	2x2	125 (350)	-24	✓	✓	✓	✓	
Medium Resolution 16m	16	1x4	30 (350)	-25	✓	✓	✓	✓	
High Resolution 5m	5	1	30 (500)	-19	✓	✓	✓	✓	
Very High Resolution 3m	3 @35°	1	20 (500)	-17	✓	✓	✓	✓	
Low Noise	100	4x2	350 (600)[3]	-25	✓	✓		✓	
Ship Detection	variable	5x1	350 (350)	variable	✓	✓		✓	
Quad-Polarization[1]	9	1	20 (250)	-24					✓
Spotlight	1 (az) x 3 (grd) @35°	1	20 (350) [5km in az]	-17[4]	✓	✓		✓	

Table 2: RCM imaging modes

The satellites will also include an AIS payload. Article 19 of the 'Safety Of Life At Sea' regulation published by the International Maritime Organization (IMO) requires that all ships beyond 300 tons (Class A) transmit their identification, location, as well as bearing and velocity with an AIS transponder. The RCM onboard AIS receiver will capture the aforementioned information in across a broad expanse of open ocean, which will include the swath of the imaging area. Incorporated with the satellite imagery, this will provide a greatly enhanced information product for maritime surveillance. The AIS payload would enable the detection of illegal vessels in Canadian waters and up to 1,000 nautical miles from the shore. Having both SAR and AIS payloads on the same satellite will provide near "real time" maritime surveillance, as opposed to gathering separate data from two different systems and merging it into one piece of information. The value-added from coupling both technologies is that RCM can detect vessels that have lost their AIS signal or deliberately turned-off their AIS transmitter to avoid detection and identification. RCM would then allow for the detection of a vessel that requires assistance or alternatively, carrying out an illegal activity such as smuggling or illegal fishing within Canadian waters.

Both the SAR and AIS payloads can be activated upon request. The data stream collected will be downlinked to ground stations for their processing.
By focusing on key requirements, the size and weight of the satellites were kept to a minimum. Each satellite will weigh approximately 1,560 kg. The use of smaller lighter satellites allows the use of less expensive launch vehicles, or the launch of several satellites on the same launch vehicle.

To achieve the technical objective, CSA is developing several critical technologies in partnership with Canadian industry, which will be used in the spacecrafts. The main areas of technology development are the small-satellite bus, the transmit/receive modules for the SAR antenna, the payload central electronics, and the SAR antenna design.

The RADARSAT Constellation will require ground stations with vast coverage over Canadian maritime zones of interest in order to provide data within ten to thirty minutes of acquisition. The ground segment is required to perform the following tasks: commanding and monitoring the satellites for navigation and imaging; receiving satellite telemetry; receiving data from the satellites' payloads; and managing the data for users.

The RCM ground segment is based on existing infrastructure, using the national Gatineau, Prince Albert, and Inuvik stations for data reception and Telemetry Tracking & Command. It will be harmonized for data reception with the upgraded Polar Epsilon coastal stations in order to support near-real time maritime surveillance. It will also include a fast tasking capability allowing access to the satellites on every orbit, likely achieved through international partnerships.

The satellites will be launched in 2018 from Vandenberg, California, on a Falcon 9 launch vehicle.

Data Utilization

In preparation prior to the RCM launch, simulated products derived from RADARSAT-2 will be made available to various Canadian Stakeholders. As such, the Science and Operational Applications Research – RCM (SOAR-RCM) is a Government of Canada initiative supported by the Canadian Space Agency (CSA) and Canada Centre for Remote Sensing, **addressed to Canadian educational organizations and research centers**. It will support scientist in the development of RCM applications and promote the use of synthetic aperture radar (SAR) remote sensing to graduate students. Project proposals can range from fundamental to applied research towards applications development using new capabilities offered by RCM.

Additionally, the project scope includes another applications development program to assist government users to make optimum use of the data when the system becomes operational. The Data Utilization and Applications Program (DUAP) provides technical assistance to federal departments to upgrade their applications and develop new ones exploiting data generated by the RCM; as well as to integrate applications into operational systems. These applications are needed to transform the data into value-added information and to assist user departments in making the transition from RADARSAT-2 to RCM data. The requirement arises because the orbiting and imaging parameters of the RCM satellites differ from those of predecessors RADARSAT-1 and RADARSAT-2, and to account for the abundance of data to be generated by the three satellites which will require high-volume automated information processing capacity at the users' premises.

The RCM Data and Use Policy is being formulated in consultation with a number of stakeholders including: Government departments, Provinces and Territories, Value-Added Services Providers, universities and associations representing the Canadian remote sensing community. The Data and Use Policy will favor public good interests and the requirements of Government users while conciliating commercial interest.

Conclusions

The RADARSAT Constellation will ensure C-band data continuity for RADARSAT users, as well as adding a new series of applications enabled through the constellation approach.

The RCM is being designed for three main uses:

- Maritime surveillance (ice, surface wind, oil pollution and ship monitoring);
- Disaster management (mitigation, warning, response and recovery); and
- Ecosystem monitoring (agriculture, wetlands, forestry and coastal change monitoring).

In addition to these core user areas, there are expected to be a wide range of ad hoc uses of RADARSAT Constellation data in many different applications within the public and private sectors, both in Canada and internationally.

For example, while the mission design initially focused on maritime security requirements, land security, particularly in the Arctic, will be dramatically enhanced. The system offers up to four passes per day in Canada's far north, and several passes per day over the Northwest Passage.

The increase in revisit frequency introduces a range of applications that are based on regular collection of data and creation of composite images that highlight changes over time. Such applications are particularly useful for monitoring climate change, land use evolution, coastal change, urban subsidence and even human impacts on local environments.