CSA Report on Earth Observation

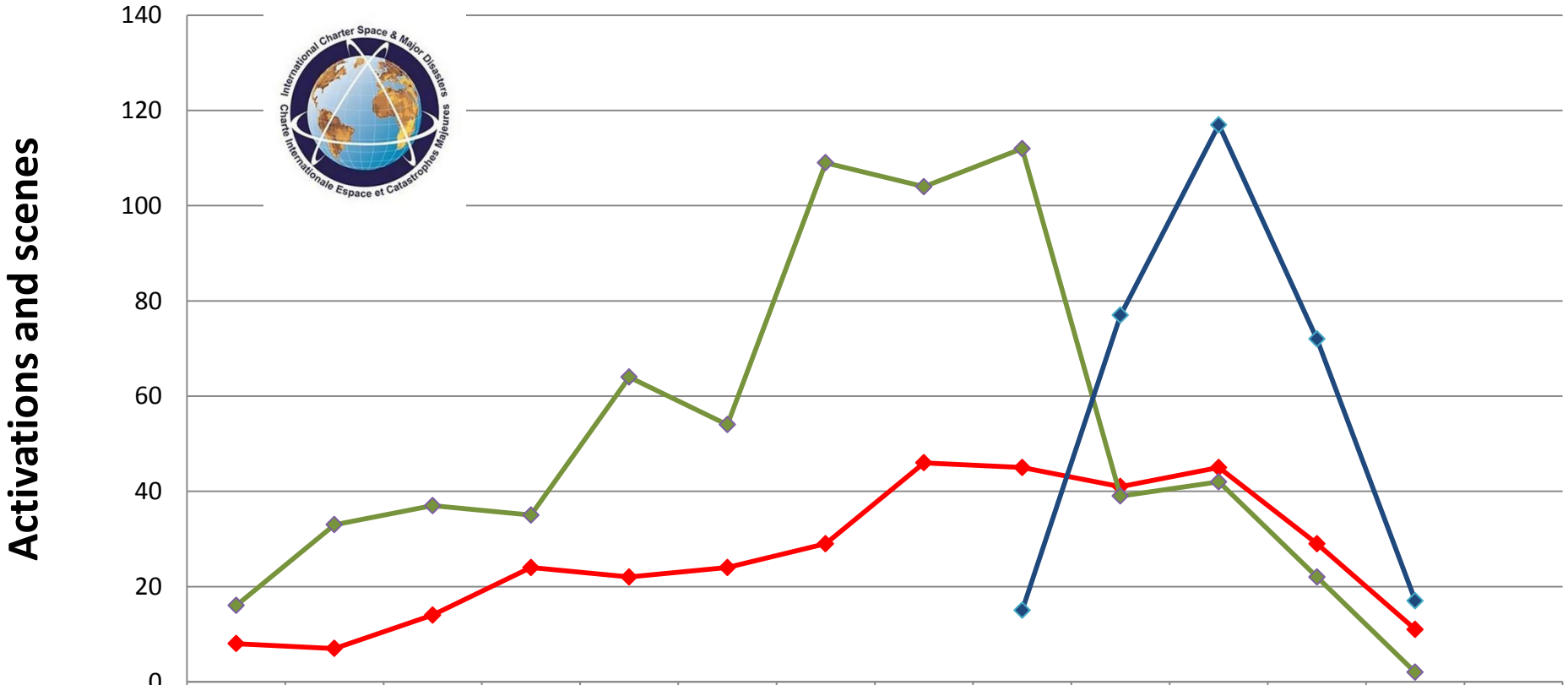
Presented at
CEOS WGCV 35th Plenary
Hyderabad, India
September 24 – 28, 2012

Dr. Satish K. Srivastava
WGCV Vice-chair &
CSA Member of WGCV
Canadian Space Agency

RADARSAT-1 Mission Status

- Current funding for RADARSAT-1 operation lasts March 31, 2013.
- Spacecraft operation is nominal.
- Data has been received and processed at 50 ground stations with 32 archive facilities globally, meeting a fast turnaround time of less than two hours for time critical acquisitions.
- As of August 27, 2012, completed 87,768 orbits, planned 354,006 user requests corresponding to a total acquisition of 662,271 minutes of SAR data.
- Average system performance maintained better than 95%.

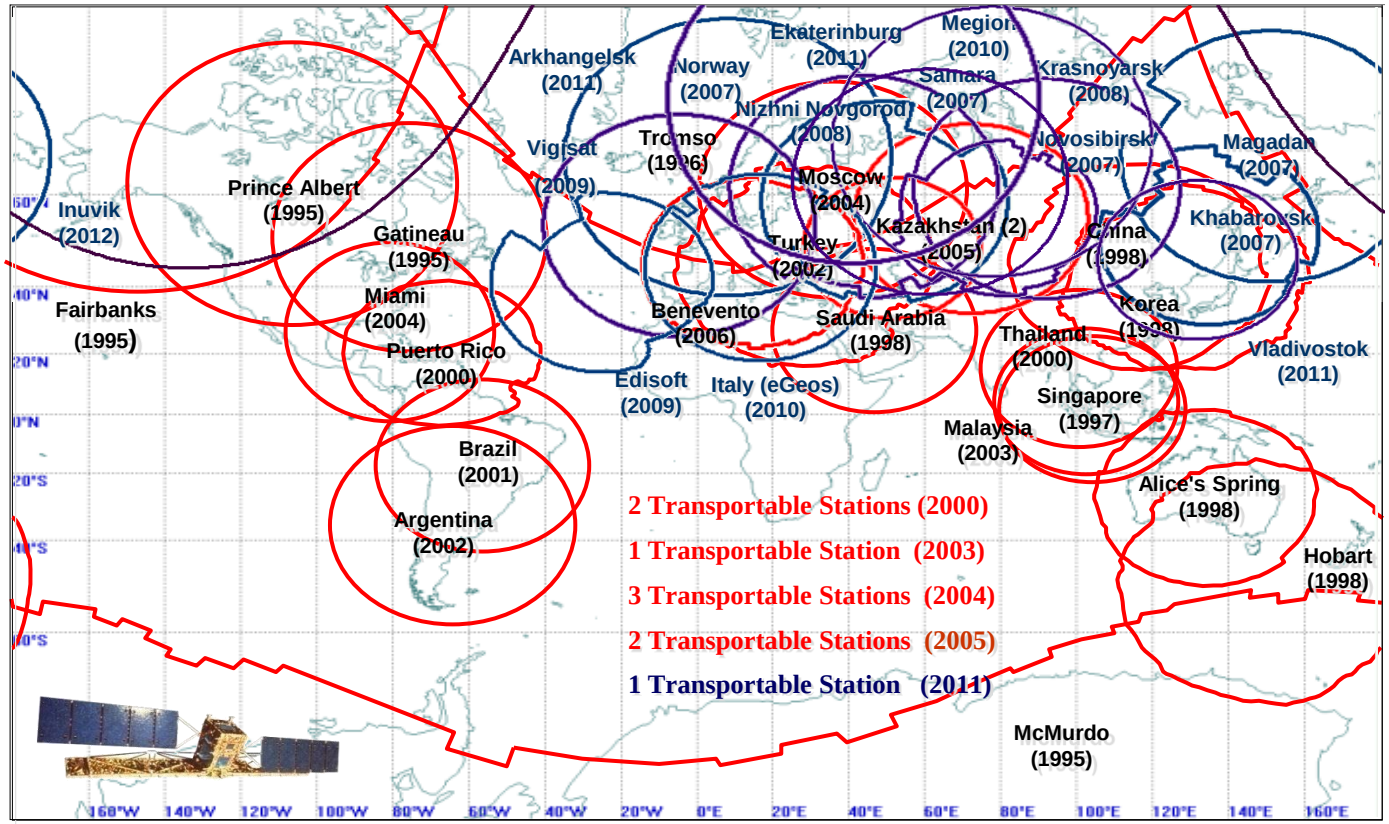
International Charter
R1 and R2 activations and scenes, 2000-2012



	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013*	
Activations	8	7	14	24	22	24	29	46	45	41	45	29	11	
Scenes R1	16	33	37	35	64	54	109	104	112	39	42	22	2	
Scenes R2									15	77	117	72	17	

RADARSAT-1 Reception Coverage

2012
2011
2010
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997
1996
1995

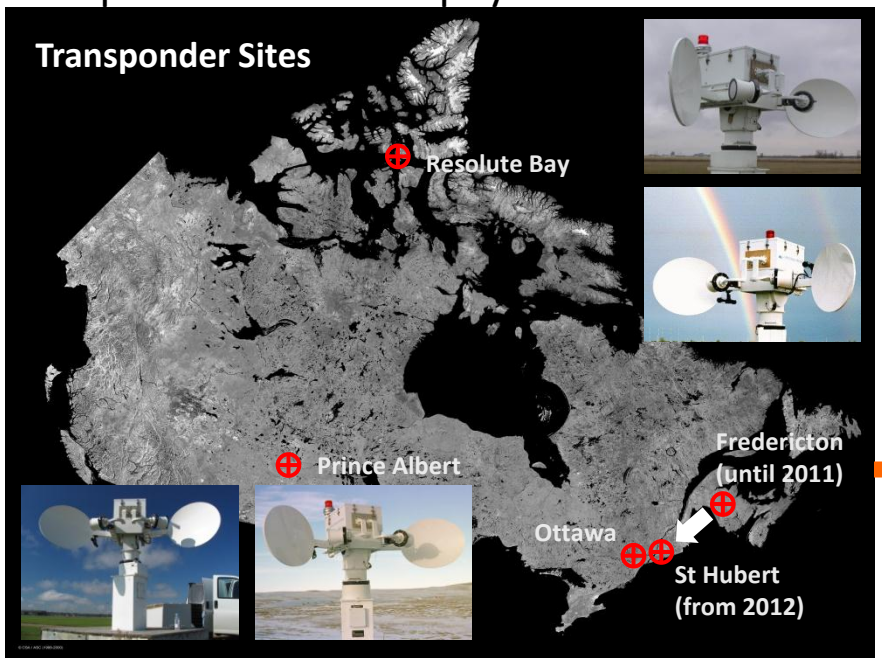


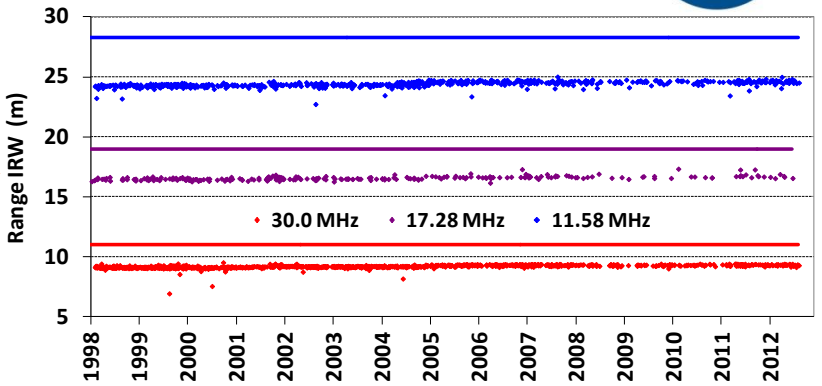
- **Certified Reception Facilities: 50 (including 9 transportable stations)**
- **Active Reception Facilities: 33**
- **Data Archiving Facilities: 32**

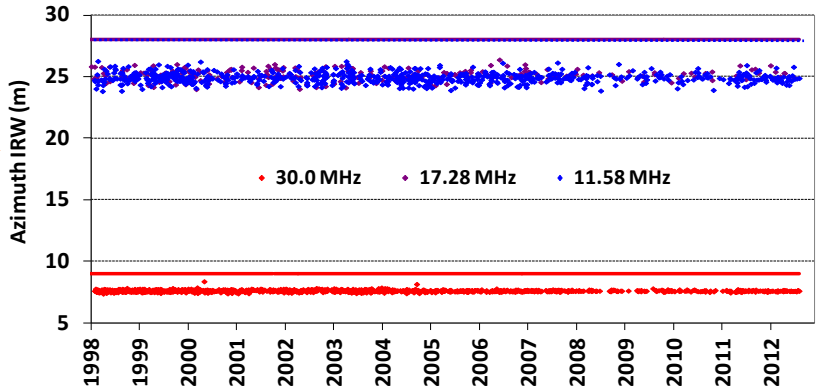
RADARSAT-1 SAR Image Quality

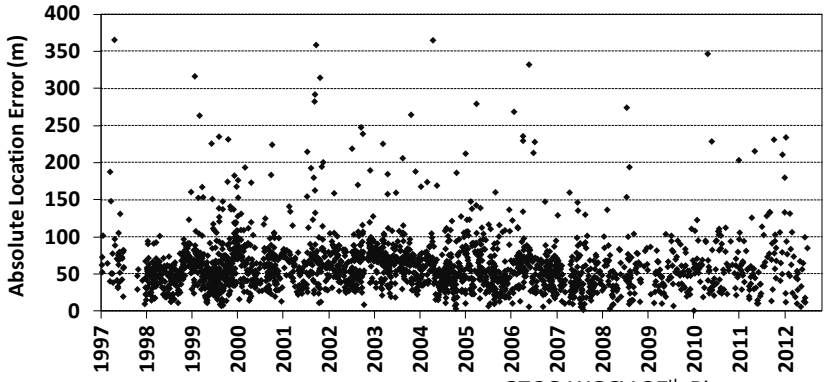
More than 15 years of successful maintenance image quality

- Impulse Response Width (IRW) and other indicators still at, or better than, initial specifications
- Stability of end-to-end SAR system, from processor to SAR payload



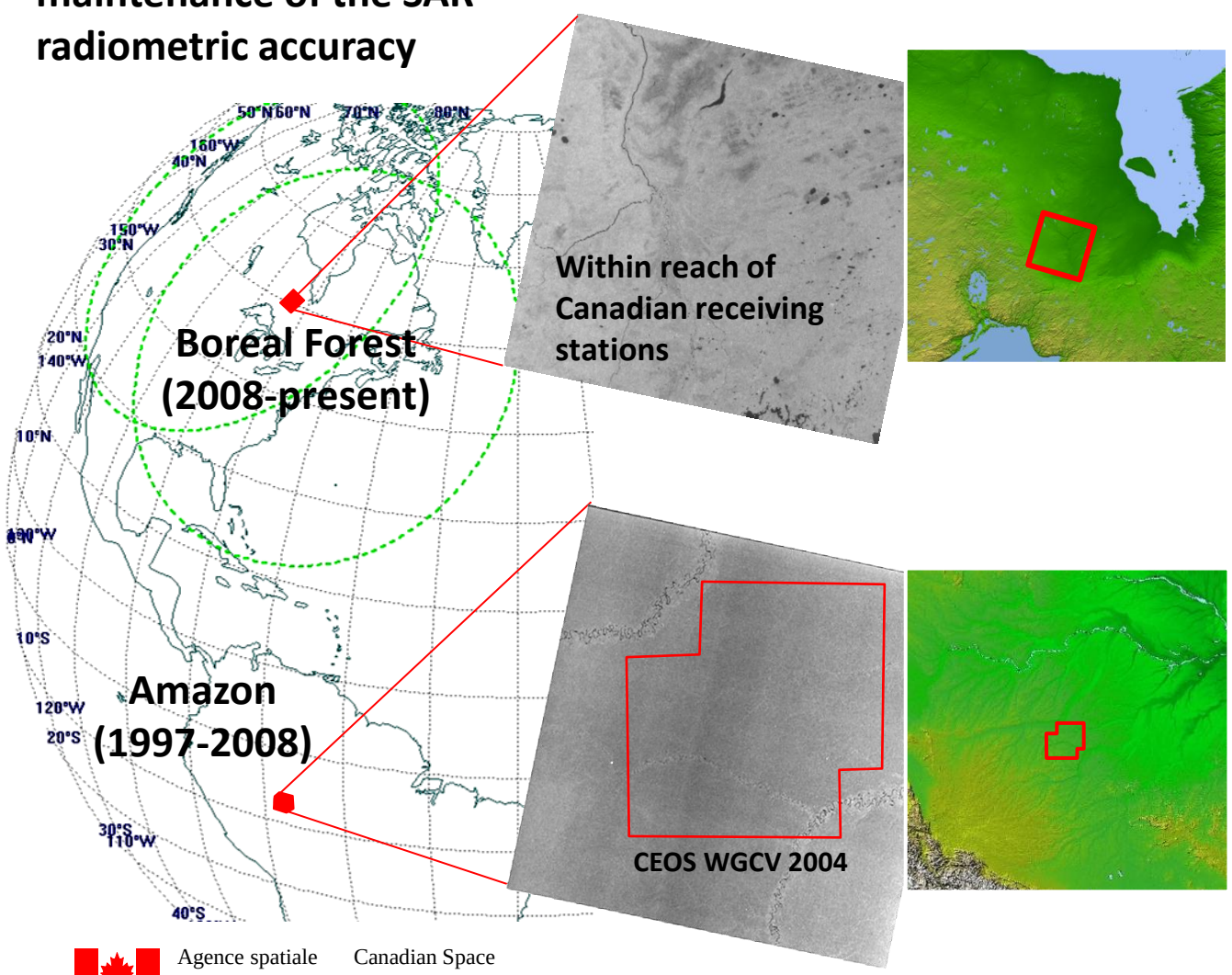






RADARSAT-1 SAR Radiometric Calibration

Fifteen years of successful maintenance of the SAR radiometric accuracy



1997-2008:

- Utilization of Amazon for on-orbit antenna pattern measurements
- Relative radiometric accuracy maintained to within 1 dB

2008:

- End of R1 On-Board Recorder operations

2008-2012:

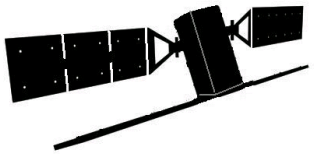
- Utilization of Boreal Forest site, within reach of reception masks
- Relative radiometric accuracy maintained to within 1 dB (80% central part of swath)

Agence spatiale Canadienne | Canadian Space Agency

RADARSAT-2 Mission Status

Spacecraft Health and Anomalies

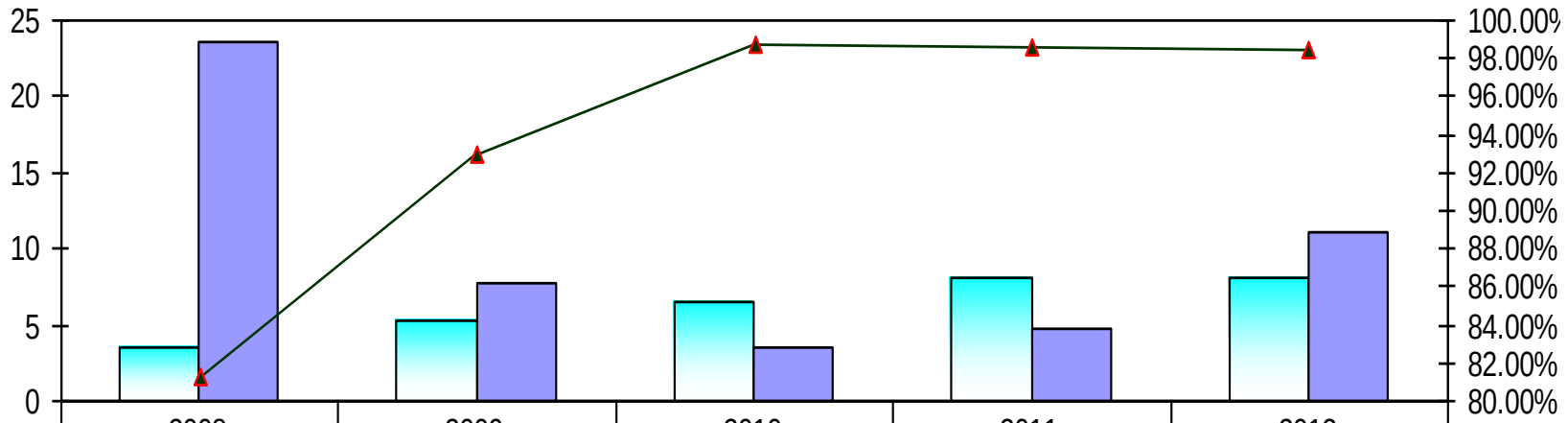
System	Status
Thermal	About 3°C increase in 4 years. A few monitoring sensors failed with no impact
Power	Battery and Solar array: No sign of degradation Re-calibrated the battery charging algorithm end of 2011 as recommended by manufacturer
AOCS	Attitude and orbit well within specifications
Propul-sion	Well within specifications. Fuel margin greater than expected
Data Handling	Well within specifications. All systems nominal.
Payload	One Hardware failure (CDU#3 heater). Software patch available to mitigate the impact in a redundant heater failure scenario.



Many Bus and Payload anomalies related to Single Event Upset

When not SEU related, most anomalies are managed through monitoring and recovery using pre-prepared and, in some cases, automatic recovery procedures.

Performances



	2008	2009	2010	2011	2012
Minute SAR/Orbit	3.5	5.2	6.5	8.1	8.1
Hours of outage	23.65	7.68	3.48	4.7	11.08
Acq success rate	81.22%	92.91%	98.72%	98.57%	98.48%

Note: Outage figure includes anomalies and planned outage such as during beam upload

Major Improvements

Alternate Downlink:

- Summer 2011: limitations identified in the overall downlink time available with the Canadian receiving stations.
- User will be able to specify up to four alternate sites to downlink the data

Web Service development for ordering interfaces:

•Developing ordering Web Services compliant with the OGC standard

Electronic Interface for Ordering from Foreign Receiving Stations:

To facilitate generation of product received by foreign station, an electronic interface is being implemented from the Order Desk

New and Enhanced Beam modes:

- Next mode is Extra Fine = Compromise between wide swath (105-170km) and resolution (5m)
- Work in progress to extend coverage for Ultrafine and Spotlight from 49.54 to 54.2°.
- Continuous R&D and testing for new improvements

PDHT Timeout:

•Reduced frequency of one of the most recurring payload anomaly by 40%

Enhanced Definitive Orbit:

•Work in progress to improve accuracy of definitive orbit accuracy.

- Promising results in Interferometry

Envisat Loss: Foreseen increase in volume of data delivered to the ENVISAT user community to cover the data provision gap until Sentinel is launched

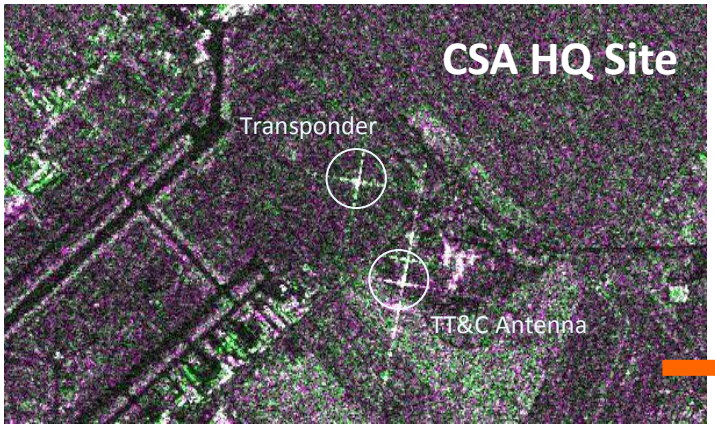
RADARSAT Point Target Facility at CSA HQ

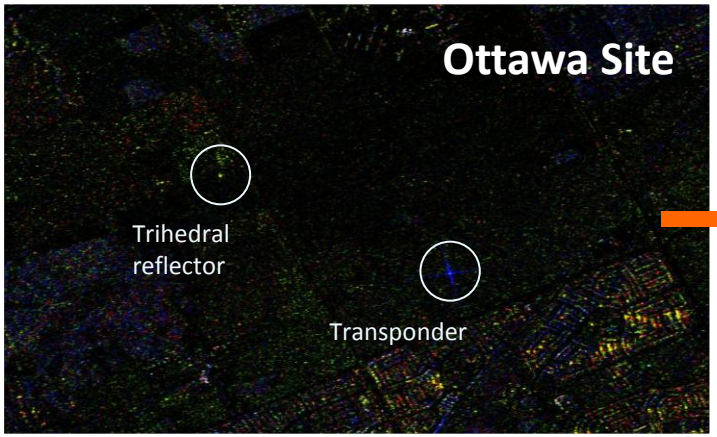
- In operations since spring 2012
- Upgraded RADARSAT-1 precision transponder: RADARSAT-1 and RADARSAT-2 operation
- For the R2 Quality Assurance mandate of the GoC, operates in conjunction with another upgraded R1 instrument in Ottawa

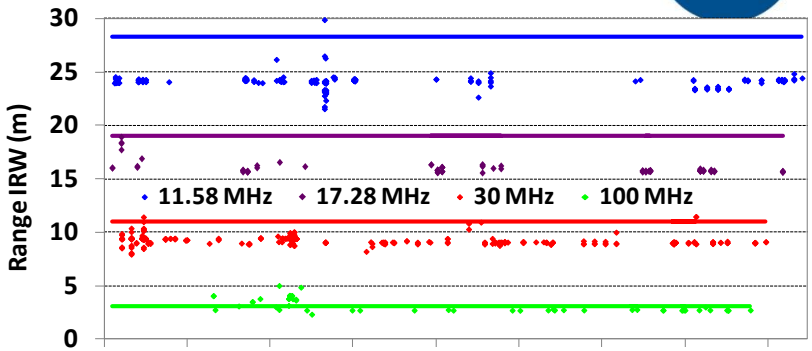
RADARSAT-2 Image Quality Assurance

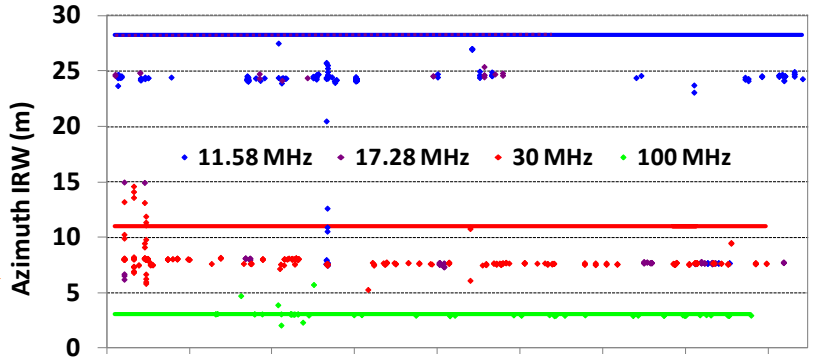
CSA executes the mandate of the Government of Canada to monitor R2 SAR performance

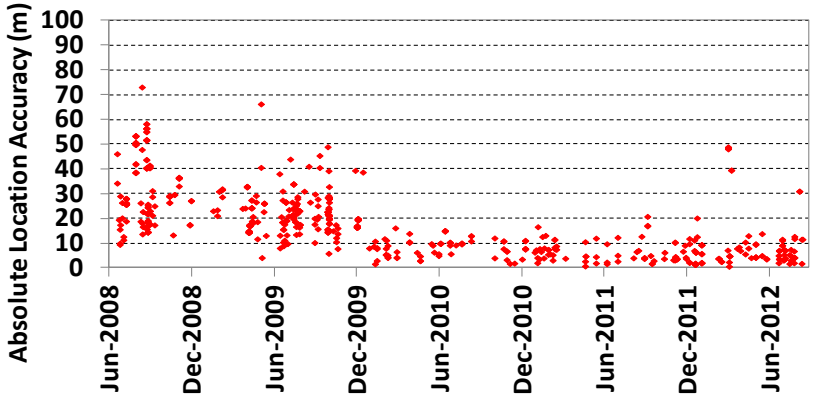
- **Excellent overall image quality results: IRW, georeference**



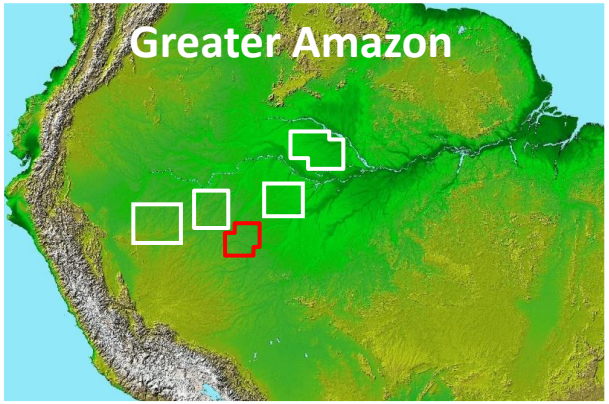








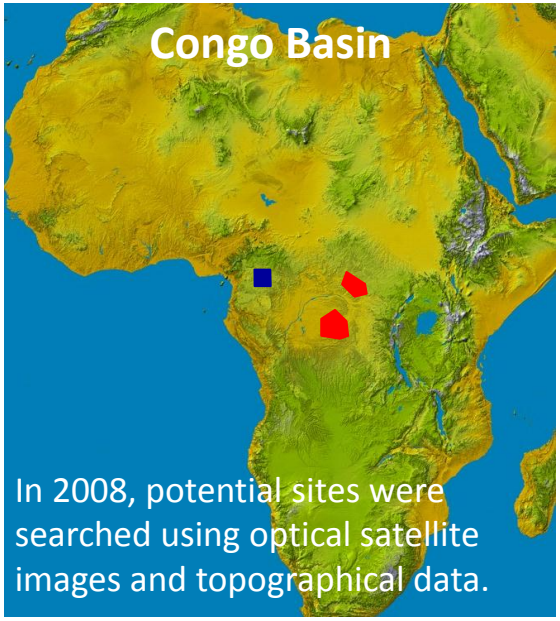
Monitoring of RADARSAT-2 SAR Radiometric Calibration



In 2006-07, RADARSAT-1 was utilized to search and validate alternate areas in the Amazon basin for future use for RADARSAT-2 cal-val.

Scenes were acquired over a year-long period for beam pattern measurements.

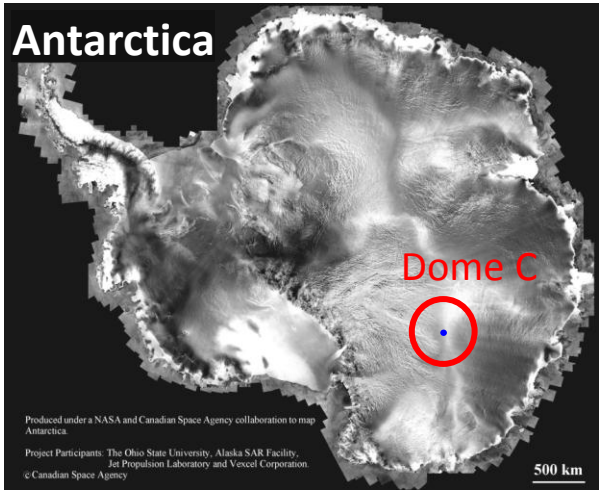
Results were consistent with RADARSAT-1 primary area (in red)



Three potential areas were identified, two of which are in protected reserves.

Areas were validated with RADARSAT-2.

Boumba Bek National Park (blue) is now exploited by the CSA in the monitoring of RADARSAT-2.



Potential site for microwave sensors (CEOS WGCV Microwave Sensor Subgroup 2008, Mark Drinkwater, ESA).

In 2008, site was surveyed with RADARSAT-1 and -2 data.

Stable, smooth backscatter range profiles, found suitable for beam pattern monitoring. Area and applicability to be better circumsbribed

Natural SAR cal-val sites as seen by RADARSAT-2

Amazon

Well characterized (backscatter variation with incidence, backscatter levels, seasonal variations)

Flat terrain uniform vegetation coverage on a very large scale

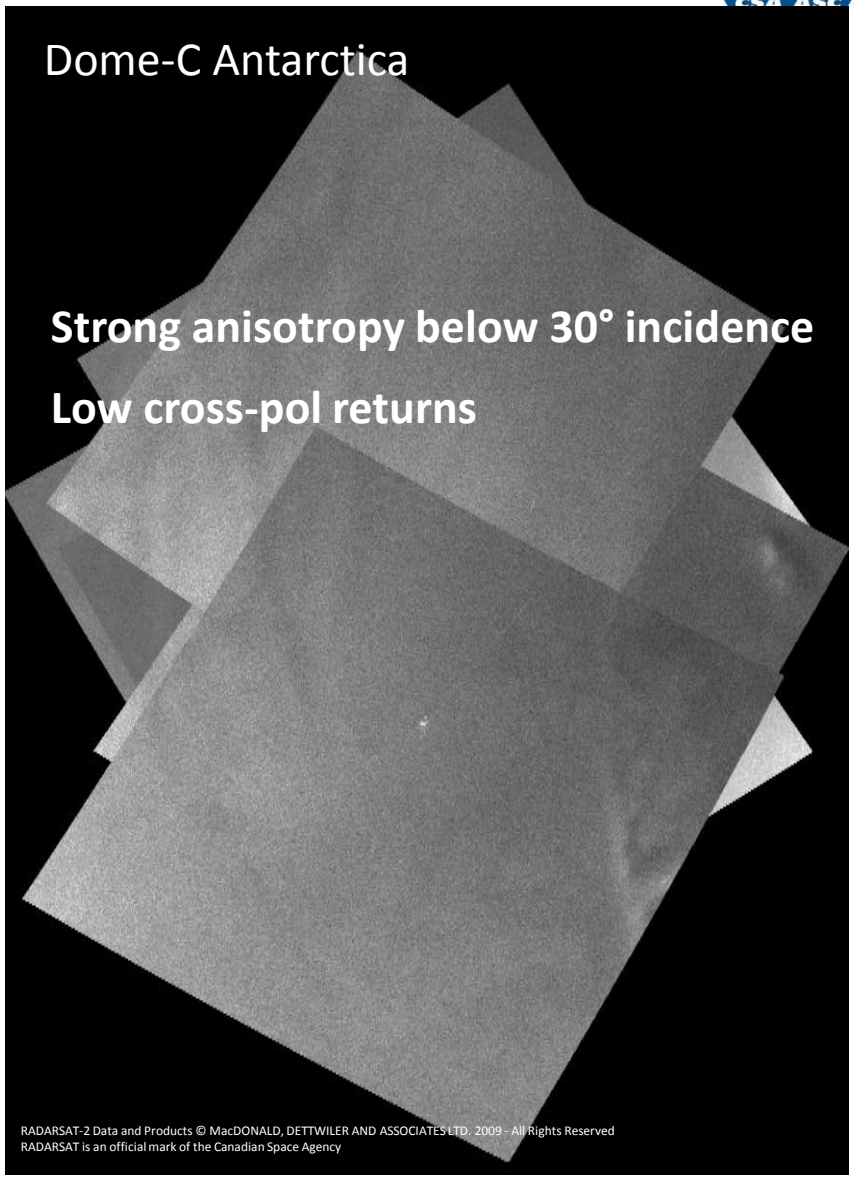
Deforestation nearby exploited areas

Cameroon: Boumba Bek National Park

Backscatter characteristics similar to the Amazon (backscatter variation with incidence, backscatter levels)

Hilly terrain, less uniform vegetation coverage may affect beam pattern measurements for smaller swaths images

Dome-C Antarctica



Strong anisotropy below 30° incidence

Low cross-pol returns

Natural Site Diversification: a Strategic Asset in Future Cal-Val Plans

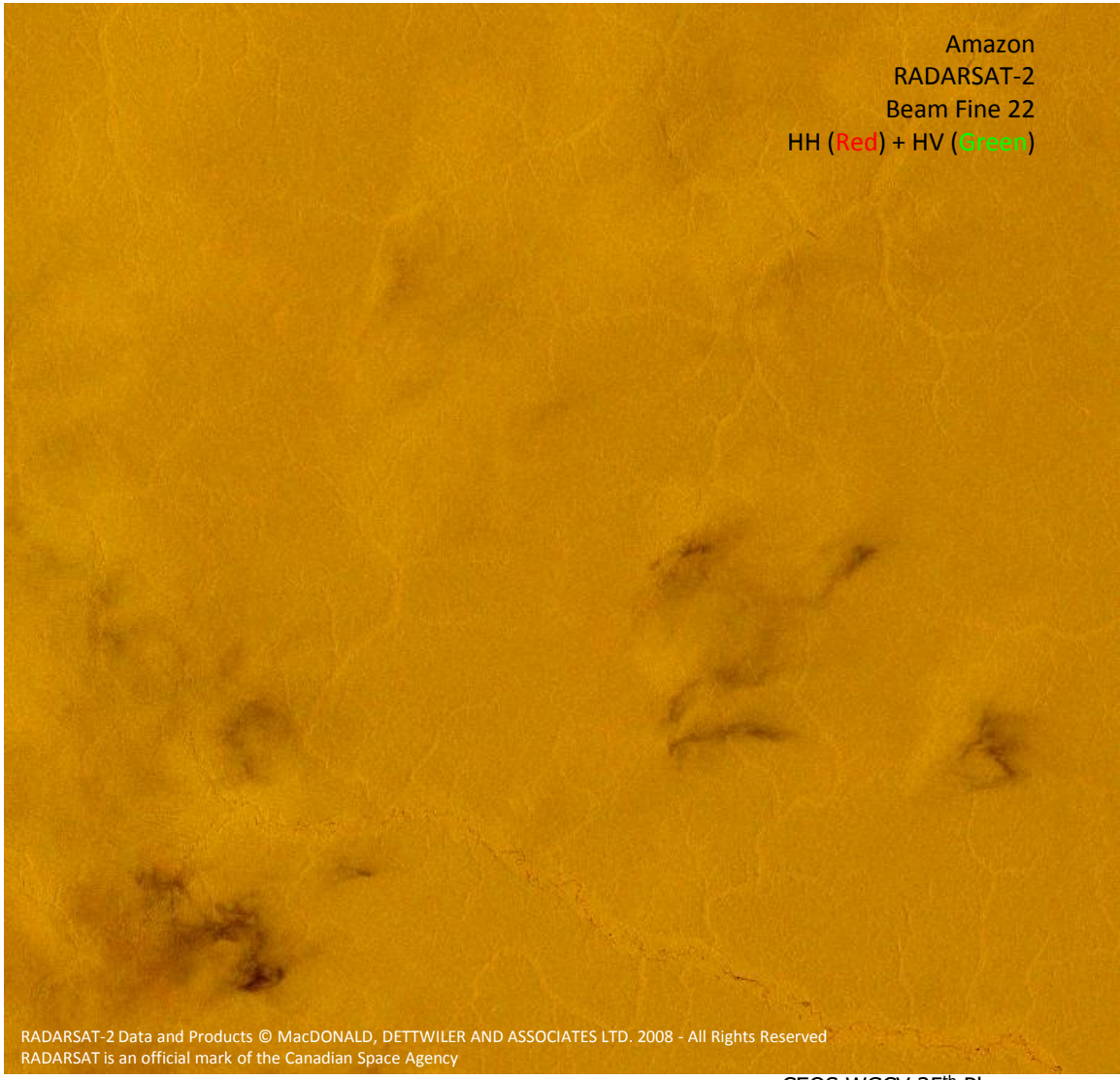
Trends are observed in current and future SAR EO satellites which contribute to a more intensive exploitation of a restricted set of distributed target sites for cal-val:

- Increasing number of SAR imaging modes
- Widened incidence range
- Polarimetric diversity

Hence, CSA endeavours to diversify the number of natural calibration sites for:

- Enhanced planning flexibility, increased revisit
- Increased robustness of cal-val plans and results

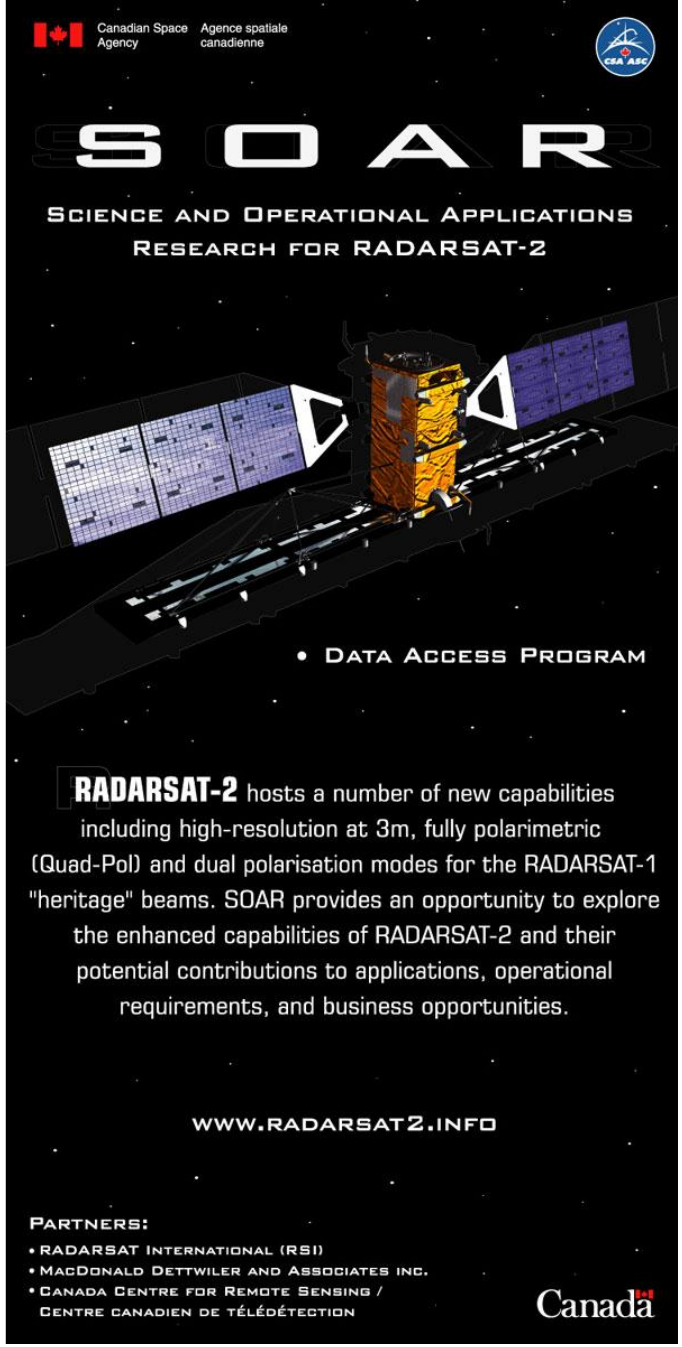
A direct benefit for the future RADARSAT Constellation Mission (3 satellites)



Coordinates of the Amazon areas and boreal forest site can also be obtained from the www.ceos.org page

Distributed Target Sites	Satellite	Modes (tested by CSA)	Lat-Lon Polygon	Used by	Comments
Amazon Prime area	RADARSAT-1 RADARSAT-2	All	6.617092S 68.471545W 7.893549S 68.446272W 7.884001S 66.886225W 7.407580S 66.887274W 7.397836S 66.562979W 6.103395S 66.557360W 6.096117S 67.922924W 6.608517S 67.923008W	MDA	Area was used by CSA as the prime area for RADARSAT-1 for about 10 years. Well-characterized and accepted as an international area in 2004 by the Committee on Eart Observation Satellites, SAR Cal/Val Working Group. Is also the prime area for RADARSAT-2 for absolute radiometric calibration (MDA). JAXA (Japan), ESA and DLR have areas that contains this area, and have been contained by this area.
Greater Amazon 1-E	RADARSAT-2	All	4.976390S 71.190000W 4.976390S 74.000000W 7.246940S 74.000000W 7.246940S 71.190000W	MDA CSA	Area validated by CSA with RADARSAT-1 in 2006 in support of MDA, to enlarge the valid Amazonian calibration sites in anticipation of the large number of RADARSAT-2 modes to be monitored.
Greater Amazon 1-W	RADARSAT-2	All	4.362500S 70.208890W 6.377780S 70.204440W 6.384440S 68.278330W 4.362500S 68.278330W	MDA CSA	Area validated by CSA with RADARSAT-1 in 2006 in support of MDA, to enlarge the valid Amazonian calibration sites in anticipation of the large number of RADARSAT-2 modes to be monitored.
Greater Amazon 2-E	RADARSAT-2	All	1.109720S 62.805000W 1.109720S 64.916670W 2.551110S 64.916670W 2.551110S 63.966670W 3.205280S 63.966670W 3.205280S 62.009170W 1.550000S 62.009170W 1.550000S 62.805000W	MDA CSA	Area validated by CSA with RADARSAT-1 in 2006 in support of MDA, to enlarge the valid Amazonian calibration sites in anticipation of the large number of RADARSAT-2 modes to be monitored.
Greater Amazon 2-W	RADARSAT-2	All	4.362500S 70.208890W 6.377780S 70.204440W 6.384440S 68.278330W 4.362500S 68.278330W	MDA CSA	Area validated by CSA with RADARSAT-1 in 2006 in support of MDA, to enlarge the valid Amazonian calibration sites in anticipation of the large number of RADARSAT-2 modes to be monitored.
Canadian Boreal Forest	RADARSAT-1	Wide Standard Extended High	51.266667N 84.607778W 49.655556N 85.248056W 49.291667N 82.760556W 50.891944N 82.022778W 51.266944N 84.583611W	CSA	Validated since 2003, used as the prime RADARSAT-1 site since 2008 after the loss of the RADARSAT-1 On-Board Recorder, which allowed cost-efficient data acquisition over the Amazon. Amazon is out of reach of any active and certified receiving facility. This Boreal Forest site near Hearst, Ontario, is within reach of both Prince Albert and Gatineau facilities.
Cameroon	RADARSAT-2	All (under validation)	4.14129N 13.48798E 4.13572N 13.48798E 4.15119N 12.19741E 2.59908N 12.26637E 2.61134N 13.53829E	CSA	Area under validation
Dome-C	RADARSAT-2	All (under validation) Co-pol only	73.75806S 123.35000E 73.83250S 121.70222E 74.04917S 120.21111E 74.38667S 119.03028E 74.81083S 118.30222E 75.27500S 118.14667E 75.72472S 118.63444E 76.10167S 119.75889E 76.35333S 121.40556E 76.44167S 123.35000E 76.35333S 125.29444E 76.10167S 126.94111E 75.72472S 128.06556E 75.27500S 128.55333E 74.81083S 128.39778E 74.38667S 127.66972E 74.04917S 126.48889E 73.83250S 124.99778E	CSA	Area under investigation

Science and Operational Applications Research (SOAR)



The SOAR Program

- The SOAR Program offers **access to RADARSAT-2** data for **research and testing**

- The SOAR Program provides an opportunity to **explore the enhanced capabilities of RADARSAT-2** and expand development of applications through the loan of RADARSAT-2 data for research projects.

- The SOAR umbrella Program uses **Announcements of Opportunity** to raise interest and access to RADARSAT-2 data for R&D purposes by stakeholders other than the Government of Canada.

- SOAR is a living, evolving program with new initiatives in response to interest in collaborative efforts on the part of space agencies around the world, and to specific requests from the E.O. community.

The SOAR Initiatives

The CSA's **Earth Observation** programs, alone or in partnership with national or international organizations, issue announcements of opportunity.

Previous Opportunities

- SOAR-DLR: Joint initiative with DLR: RADARSAT-2/TerraSAR-X
- SOAR-EU: Joint initiative with ESA
- SOAR-I: International (Pre-launch)

Current Opportunities

- SOAR-AF: Africa
- SOAR-CPT: Canadian Provinces and Territories
- SOAR-E: Education Canada
- SOAR-JECAM: (Crop Area monitoring)

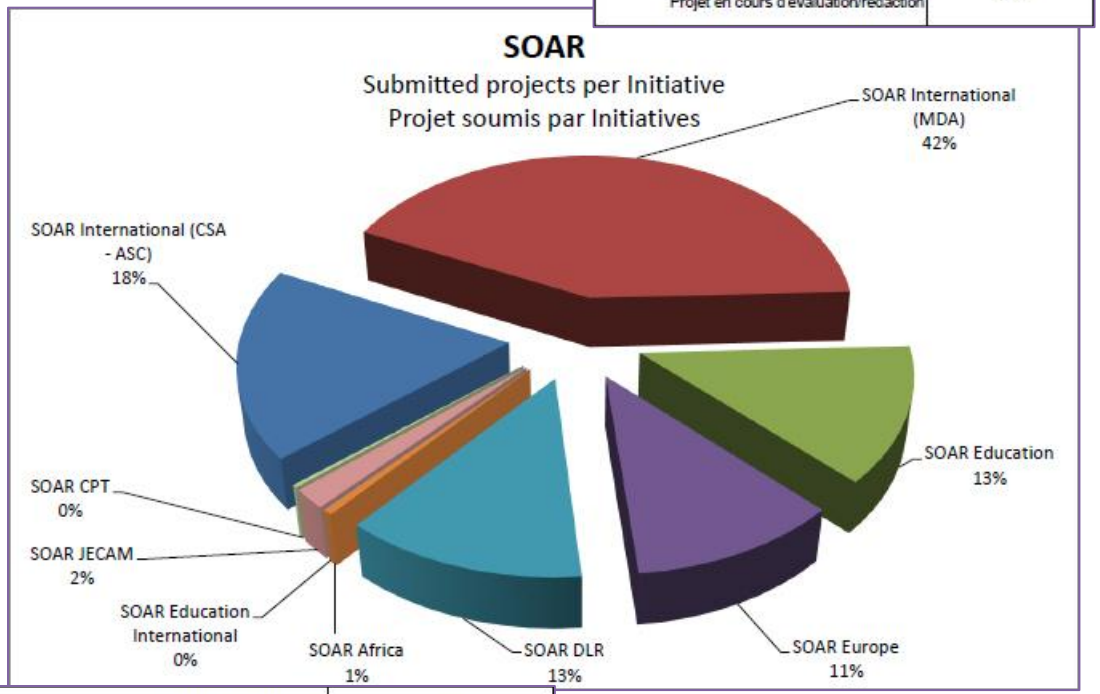
Opportunity in Development

- SOAR-EI: Education International
- SOAR-FCT: (Forest Carbon Tracking)
- SOAR-E G&C

Opportunities in initial negotiation

- Japan - DLR (phase 2)
- India - ESA (phase 2)
- Korea
- Italy

Submitted Projects Projets soumis	375
Accepted Projects Projets acceptés	284
Rejected Projects Projets rejetés	54
Projects cancelled by PI Projets annulés par le IP	13
Projects in evaluation/writing stage Projet en cours d'évaluation/rédaction	24



Scenes requested Scènes demandées	4301
Scenes acquired & delivered Scènes acquises et livrées	1954
Scenes to be acquired Scènes à être acquises	2347

SOAR Education International

- Principal Investigators: researchers in the International education community; Canadians may participate as co-investigators.
- Oriented towards fundamental and applied research; focus on development of applications. Could be with thematic or specific mode.
- Announcement of Opportunity will be open for a limited two month-period for the submission of proposal. On-line: Fall 2012.
- Project support is for Research activities i.e. operational and commercial project will not be supported.
- Project acquisition duration for 3 years maximum; with a mid-review after 2 years and a 1 year extension based on results and justifications.
- Projects are limited to 2 areas of interest.
- Maximum of 20 scenes provided.
- Proposal will be evaluated by MDA.

Visit: http://www.asc-csa.gc.ca/eng/newsletters/eo_express/editions.asp
Subscribe: eo-express@asc-csa.gc.ca

Contact information

For more information on SOAR, please contact:

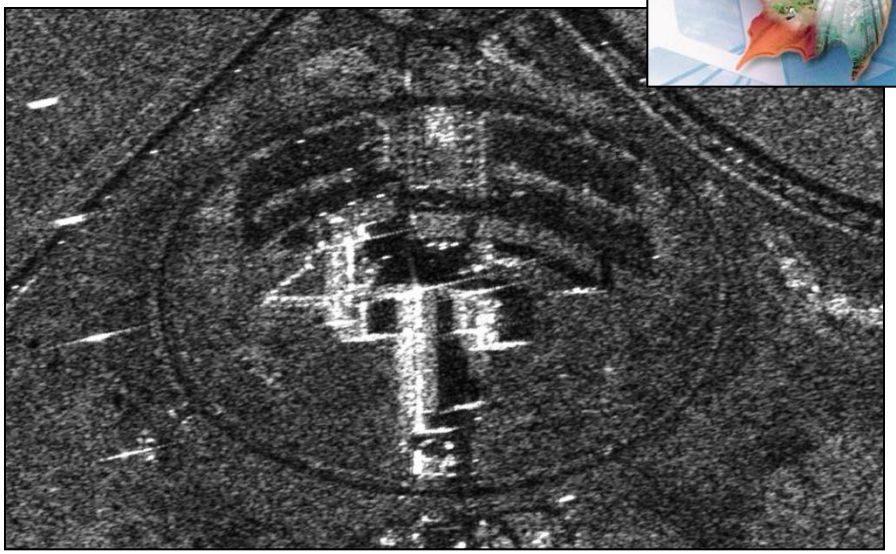
Stéphane Chalifoux, M. Sc.

SOAR Coordinator

Canadian Space Agency

E-mail : [Stephane.Chalifoux@asc-csa.gc.ca]

Government of Canada

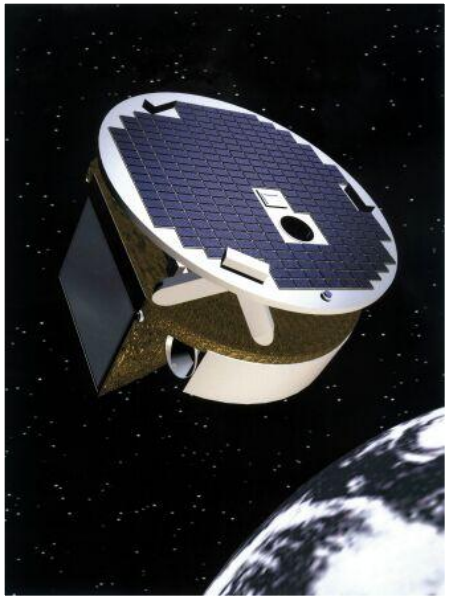


For more information:
http://www.asc-csa.gc.ca/eng/programs/soar/default.asp

SCISAT Program Status (1)

- Launched in August 2003, SCISAT satellite measures numerous trace gases, thin clouds and aerosols in the stratosphere, thereby enabling a more comprehensive understanding of the several chemical processes that play a role in stratospheric ozone depletion.

- CSA has approved continuation of SCISAT operation until March 31, 2015.

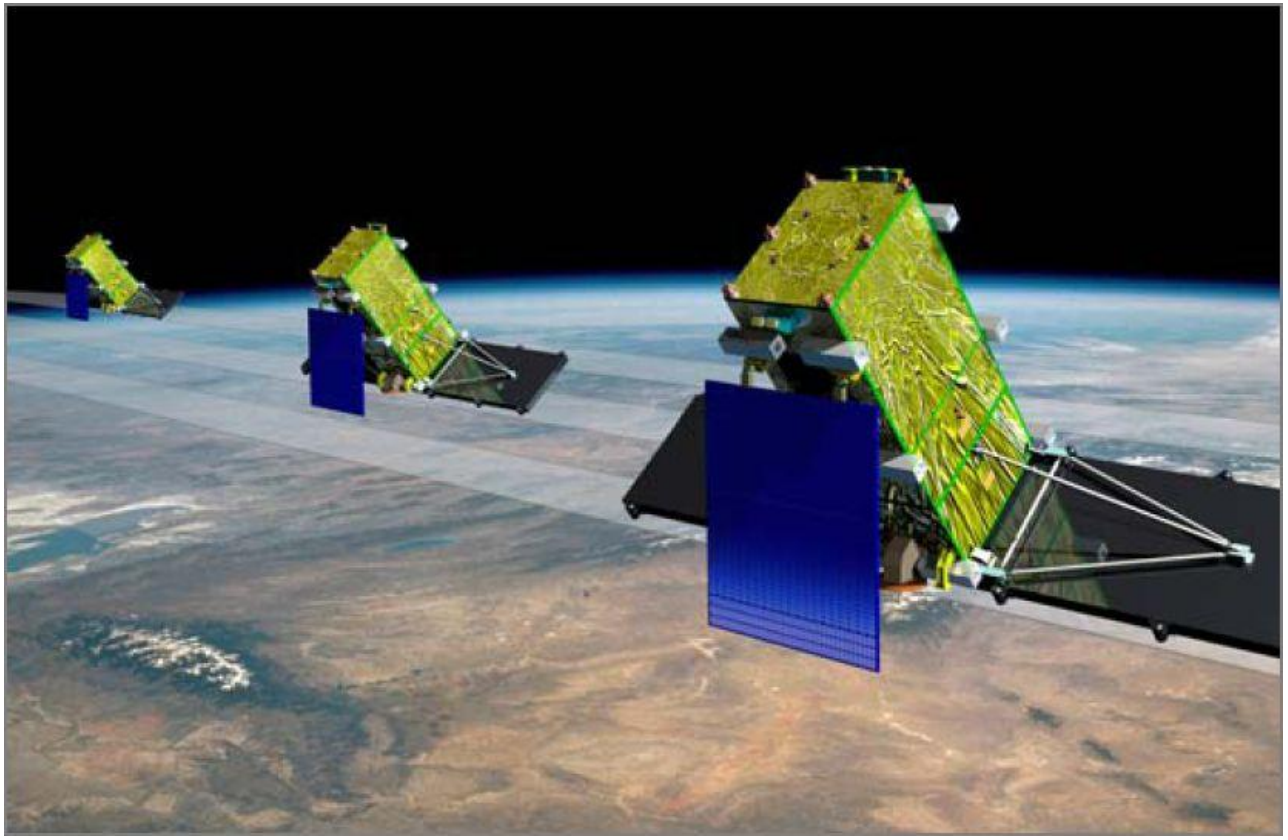


SCISAT

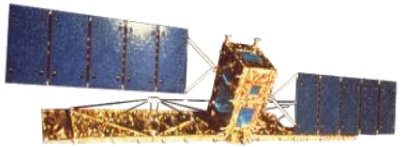
SCISAT Program Status (2)

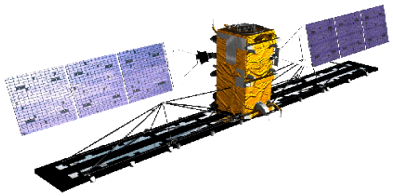
- Completed 48, 778 orbits
- Delivering data to the scientific community using stations in Canada, ESA, (support from CNES and DLR), NASA
- Science data acquired vs. Planned performance > 97%
- More than 1000 Gbytes of data provided to the science team in the fiscal year 2011-12. Over 500 Gbytes provided since April 2012.
- Intensive data analyses by scientists have produced a number of new results that have been disseminated at international scientific conferences and through the publication of peer-reviewed scientific papers

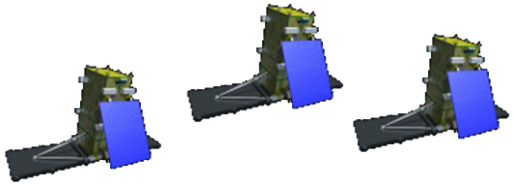
RADARSAT Constellation Mission



RADARSAT Program Evolution

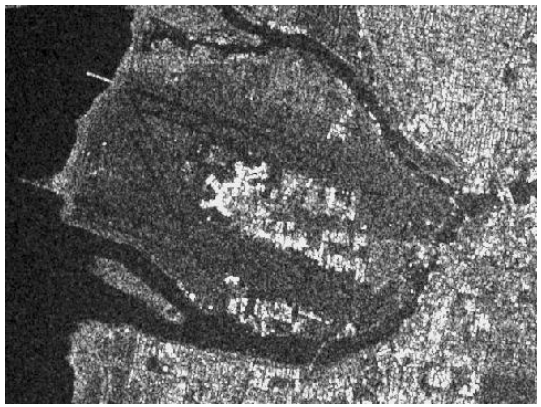






1995: RADARSAT-1

- First operational civilian SAR satellite
- Important R&D component
- GoC owned

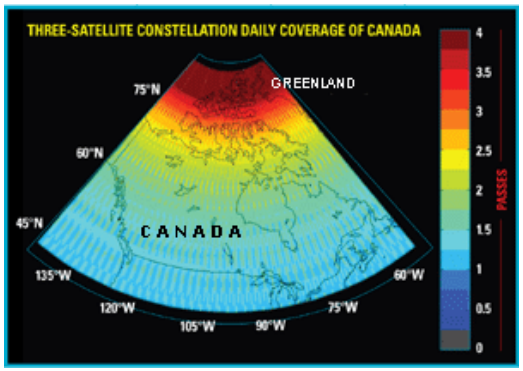


2007: RADARSAT-2

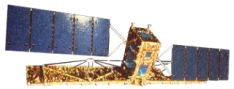
- Ops extended to DND, DFO, NRCan, and EC
- Numerous sci & ops modes
- MDA owned (PPP)

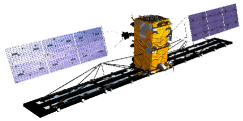
2016: 2017: RCM

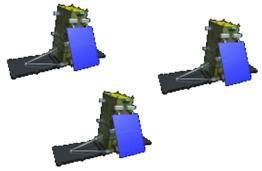
- Fully operational
- Selected R2, Compact Pol. Coherent Change Detection
- Enhanced ship detection
- GoC owned
- Fast tasking, fast delivery



RADARSAT Satellites Comparison

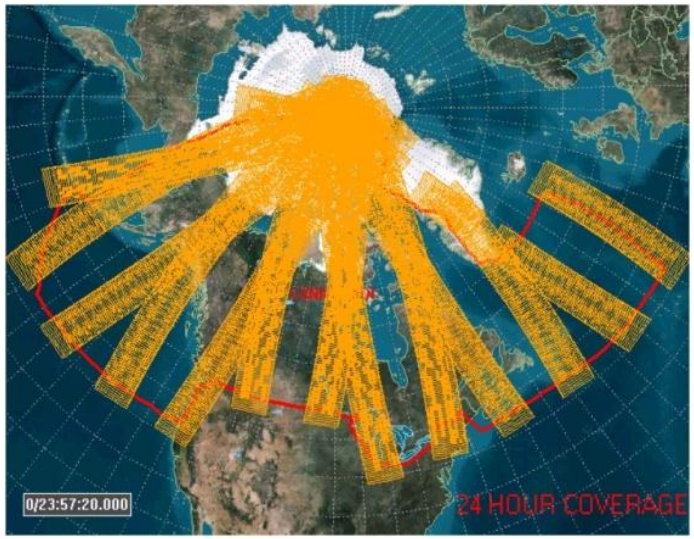


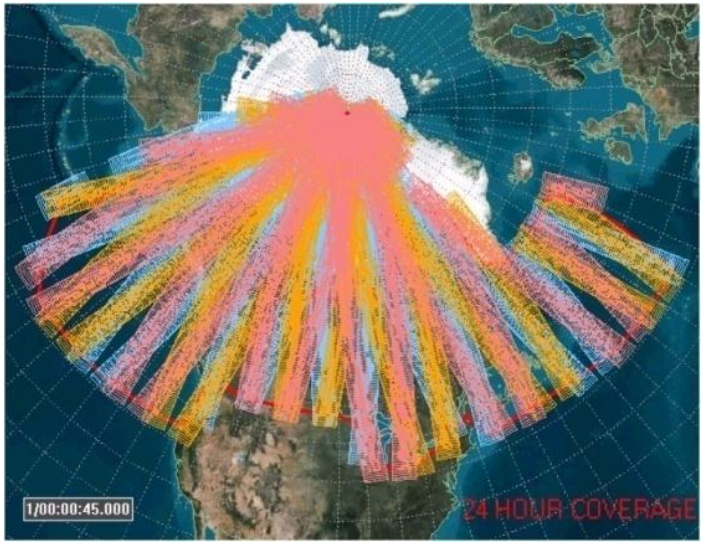




	RADARSAT-1	RADARSAT-2	RCM
Mass	• 2750 kg	• 2280 Kg	• 1400 Kg
Complete Coverage	• 2-3 days	• 2-3 days	• Daily coverage
Exact Revisit	• 24 days	• 24 days	• 4 days (12/sat)
Imaging time /orbit	• 28 min	• 28 min	• 12 min /sat
antenna span	• 15 m	• 15 m	• 6.75 m
Polarization	• Single HH	• Single, Dual, Polarimetric	• Single, Dual, Compact Pol
Altitude	• 800 km	• 800 km	• 600 km

Satellite Daily Coverage





Current coverage with RADARSAT-2

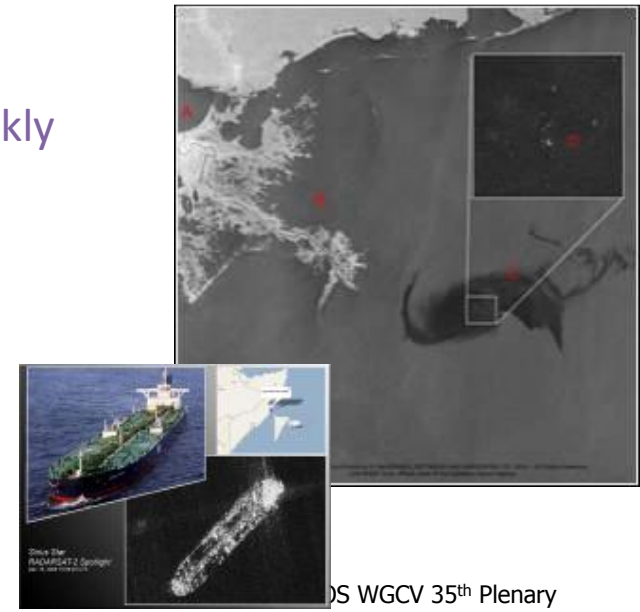
- Major gaps in maritime approaches
- Northwest Passage (NWP) coverage also incomplete
- Canadian land mass coverage lacking

Coverage with RCM

- Coverage of NWP up to 4 times daily
- Minor gaps in East and West maritime zones (completed on next day)
- Land mass coverage virtually complete

Increased Coverage Benefits

- Current situation (**1 satellite**):
  - Mapping updated every 4 days
  - Canadian land mass coverage update every 3.5 weeks
  - Insufficient coverage for operational purposes (vessels, ice, pollution)
  - Exact revisit every 24 days
  - Northern and southern coverage limited → easy avoidance of detection
- With a **3-satellite** constellation:
  - Daily coverage/mapping of Canadian areas of interest
  - Canadian land mass coverage update better than weekly
  - Operational responsiveness
  - Exact revisit every 4 days
  - Increased maritime probability of detection



RCM Objectives

System of 3 small satellites designed to:

e operational requirements of Federal departments ensuring continued access to critical RADARSAT data

aily coverage over Canada and our maritime approaches

proved and faster access to anywhere on the globe

RCM addresses Federal departments mandates

and Government priorities in the following areas

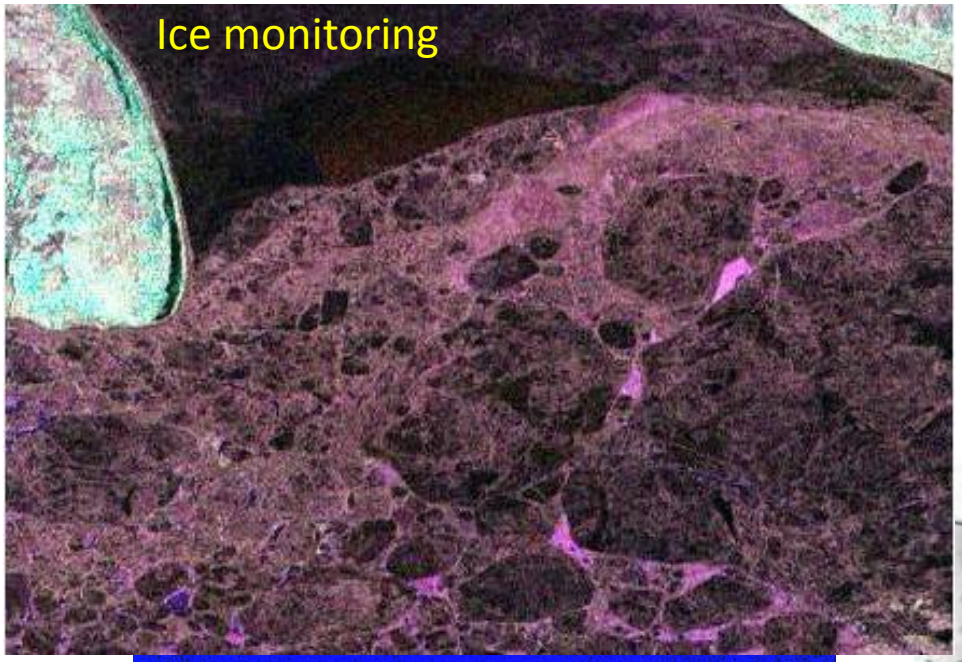
urveillance

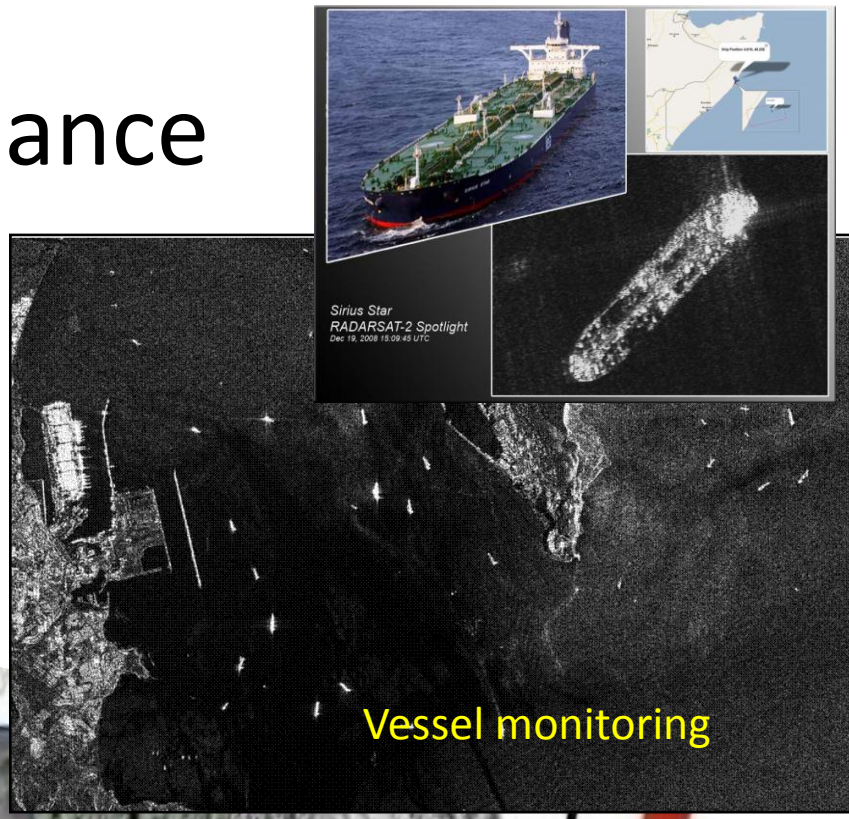
anagement

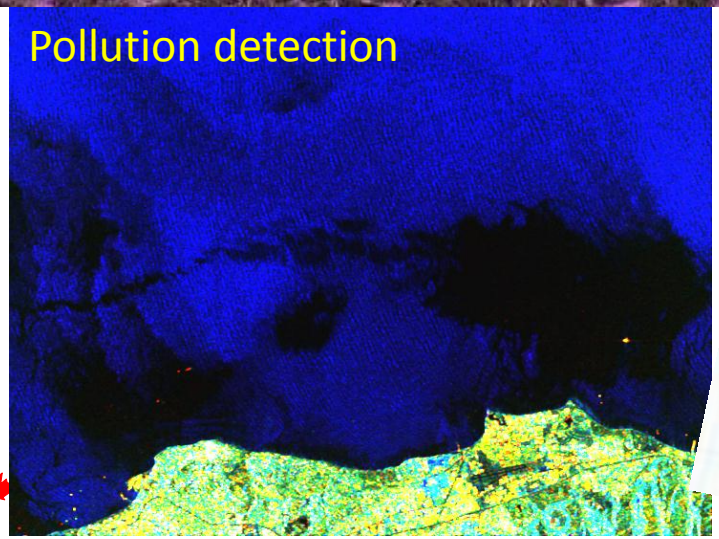
ources Management

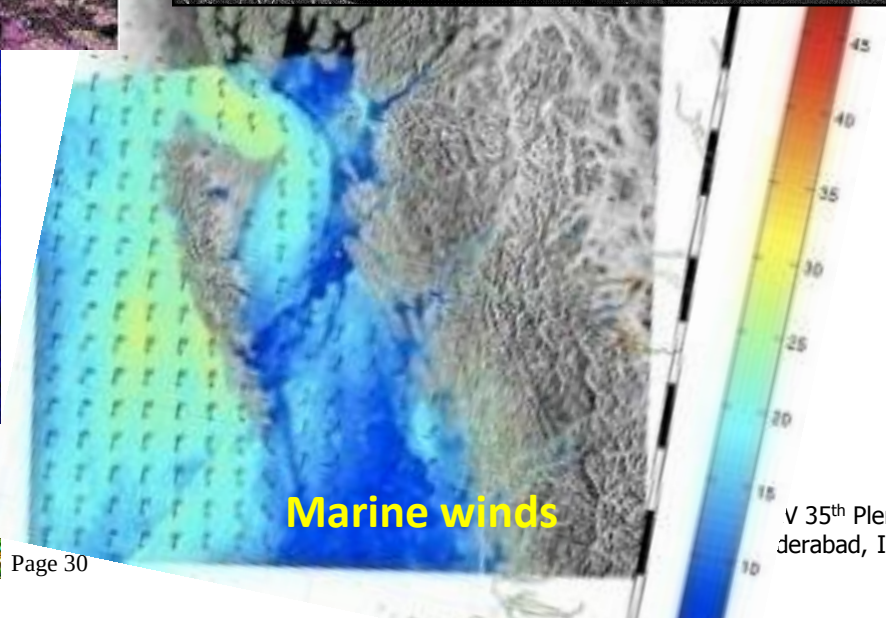
evelopment

Maritime Surveillance



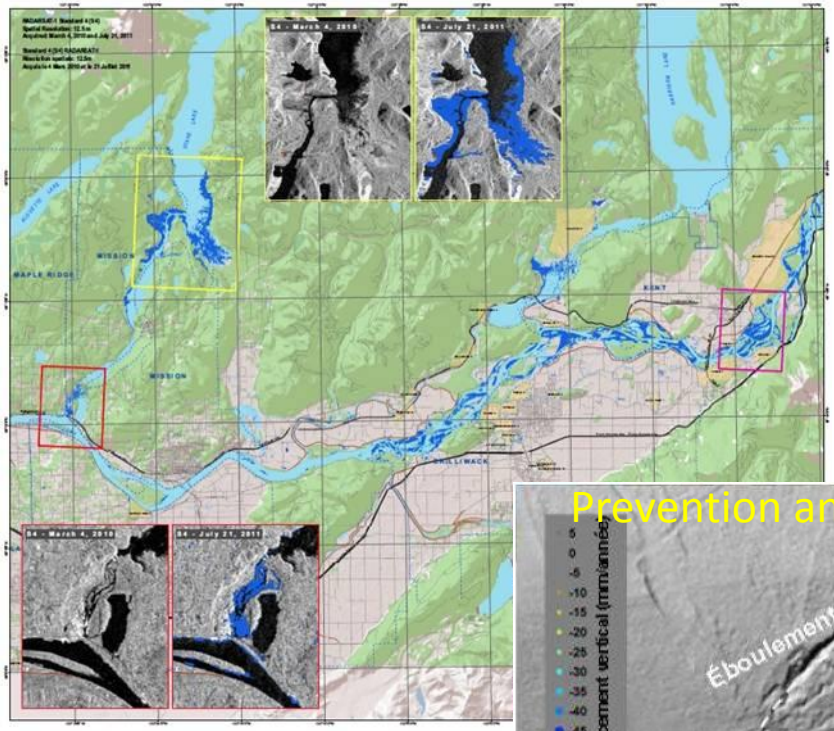




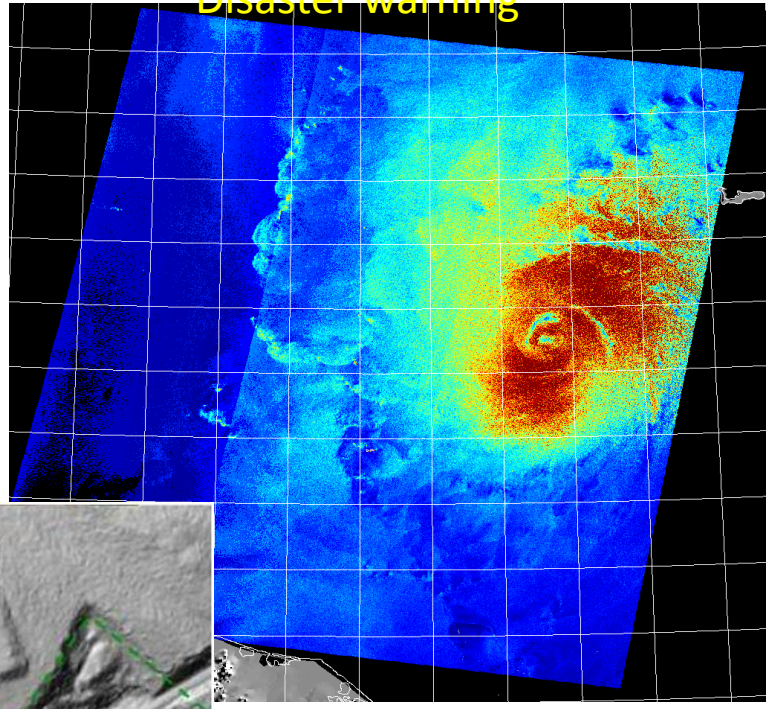


Disaster Management

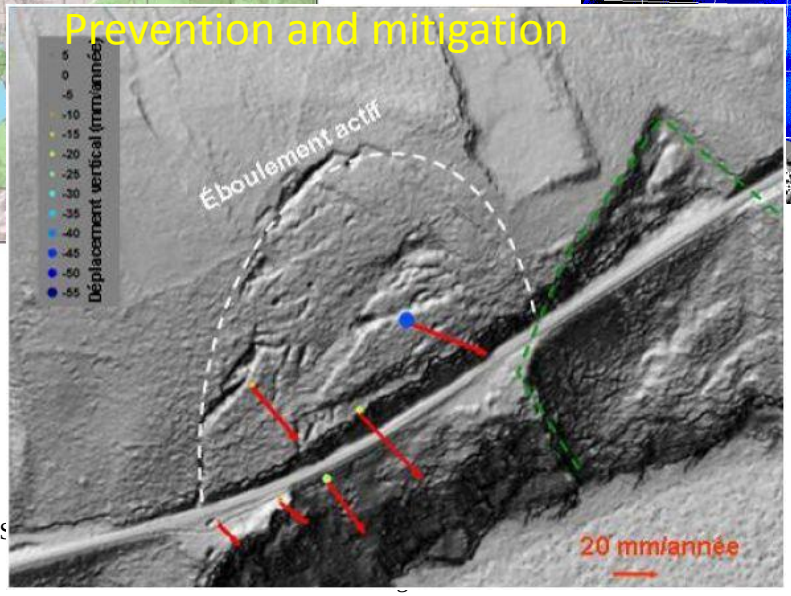
Preparedness and response



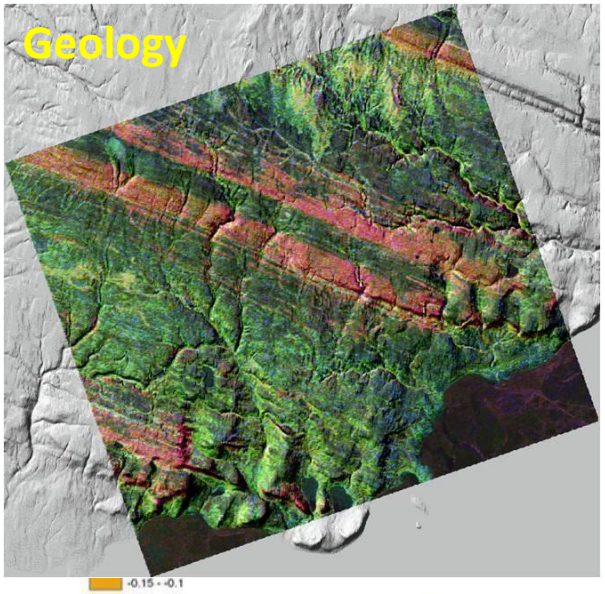
Disaster warning

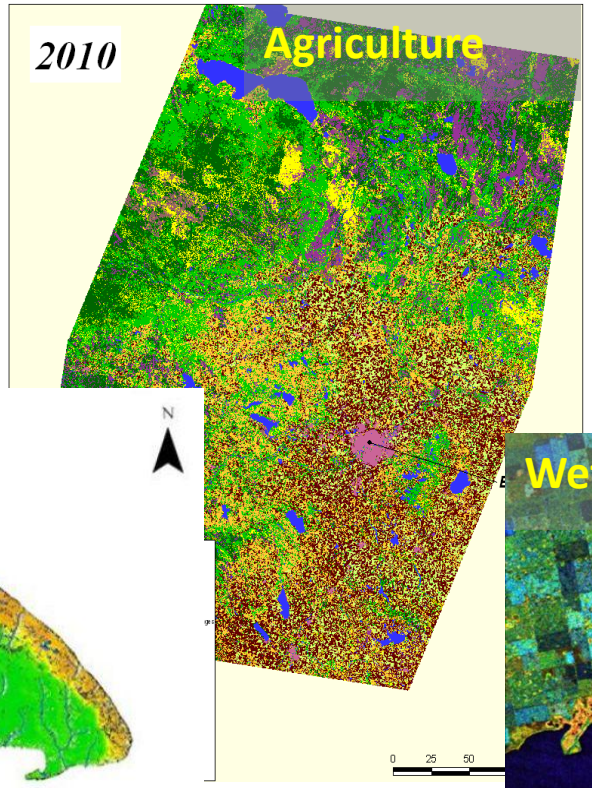


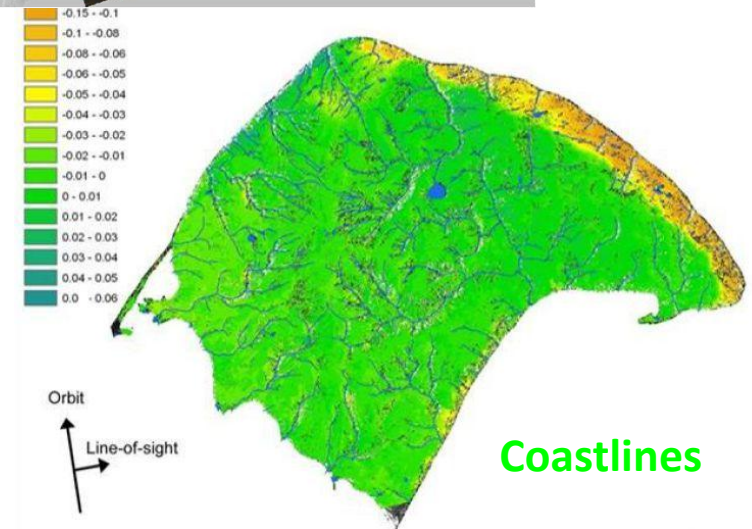
Prevention and mitigation



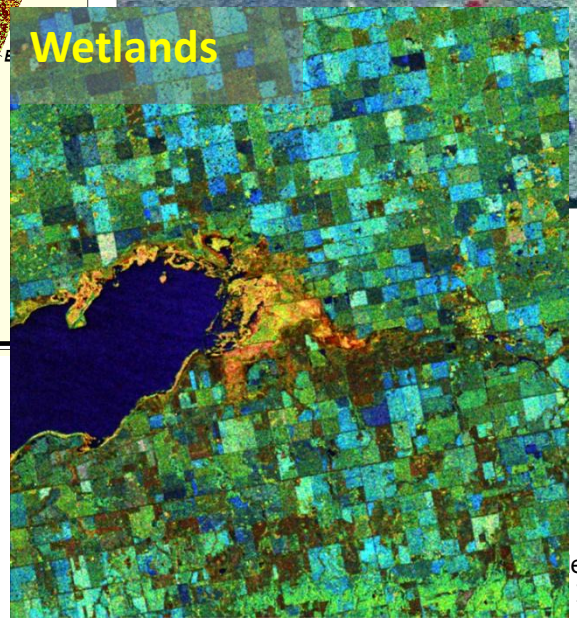
Natural Resources Management



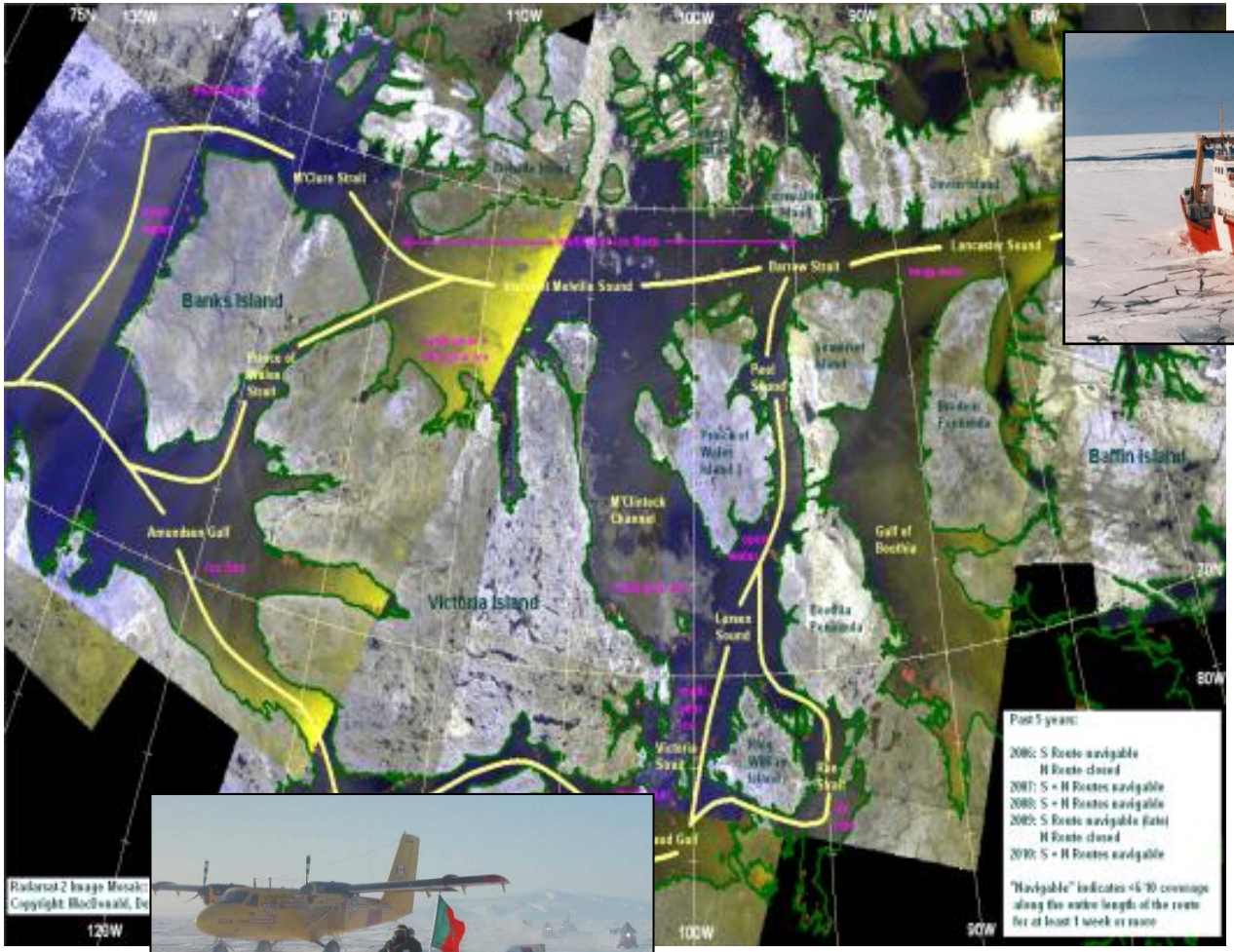




Coastlines

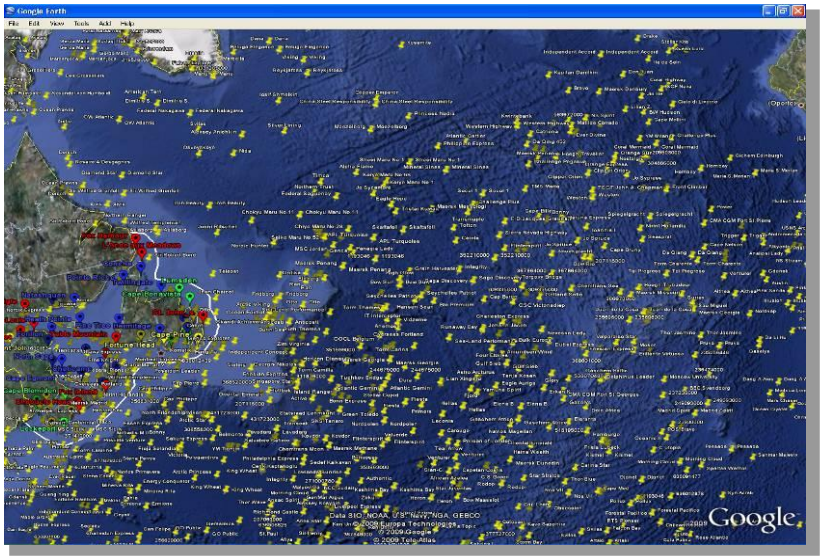


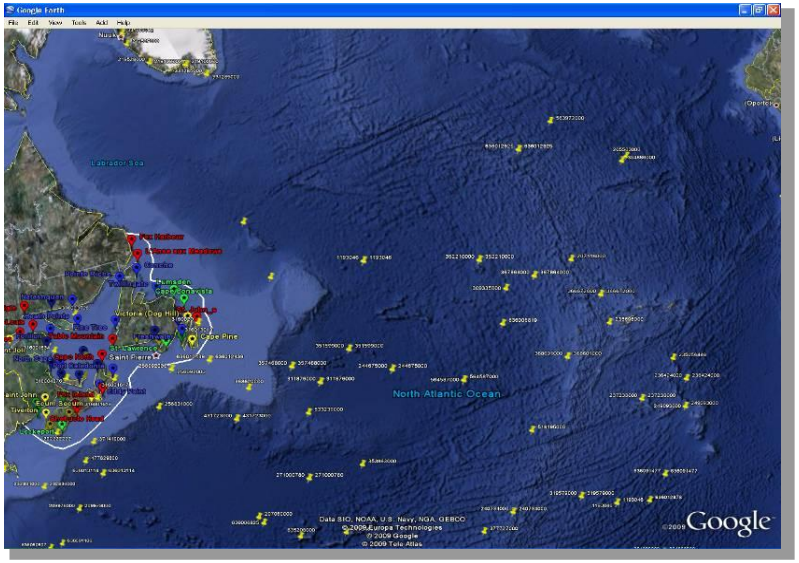
Northern Development



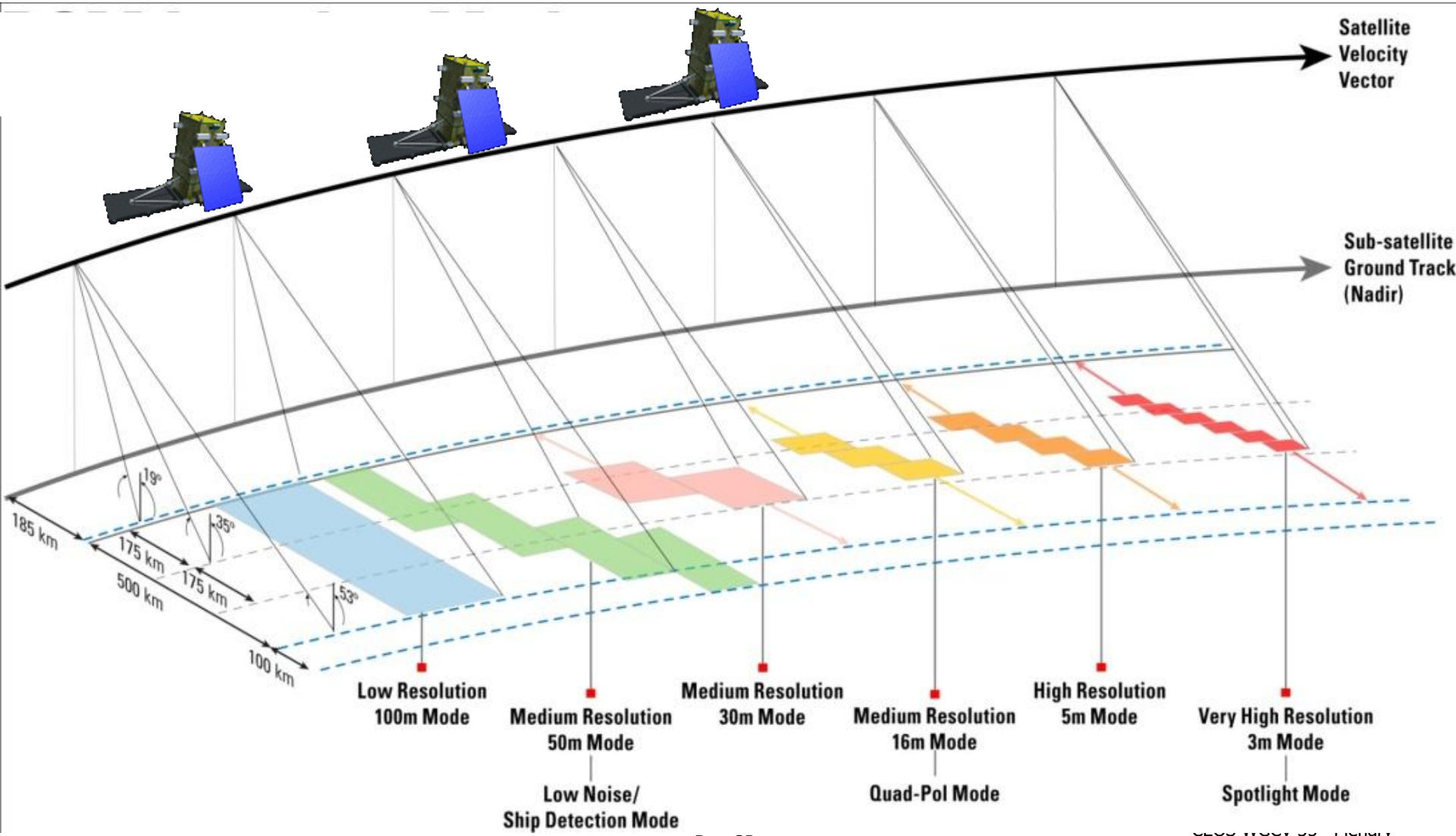
Automatic Identification System

- A 3-satellite RCM will provide a very high probability of detecting and tracking all ships approaching Canada (6000 on any given day)
- Fusion of AIS data with SAR data will enable the identification of the majority of non-compliant contacts.

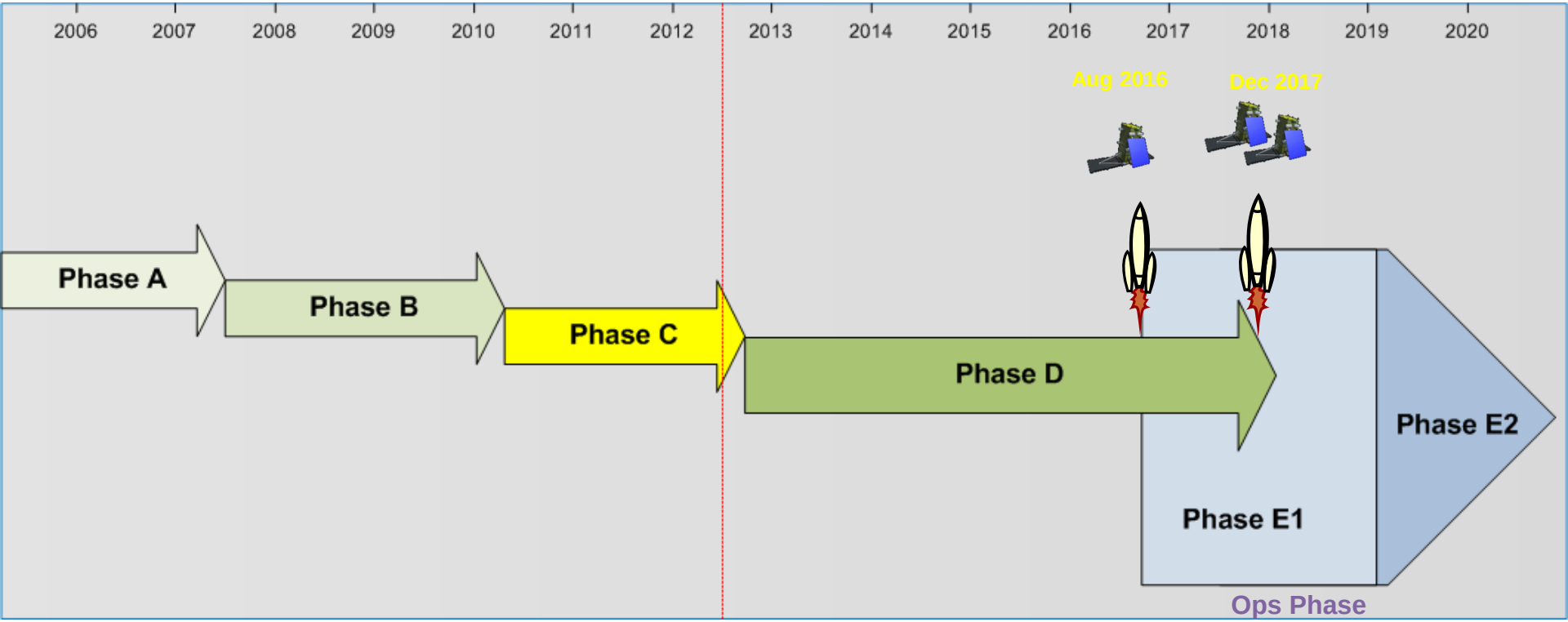




RCM Imaging Modes



Project Schedule



Summary

A RCM satellite constellation:

- Government owned and operated
- Addresses the increasing requirement for radar imagery in support of operational government programs;
- Enables daily monitoring of maritime approaches for detection of illegal vessel activity and pollution;
- Supports northern development through surveillance of the North West passage, ice monitoring and mapping
- Supports response to natural disasters
- Enables monitoring and management of natural resources and sensitive ecosystems.

Thank You!