COINAtlantic
COASTAL AND OCEAN INFORMATION NETWORK

ACZISC
ATLANTIC COASTAL ZONE INFORMATION STEERING COMMITTEE

Inventory of Remote Sensing Technologies for Coastal Zone Management

Version 1.0 - 27 February 2015

Prepared by the ACZISC Secretariat for Environment Canada

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Introduction

The following tables were developed for remote sensing technologies applicable to coastal zone management. Two basic types of technologies are described. Active technologies illuminate the surface using radar, light, or sound both terrestrially and underwater. Passive technologies depend on the sensing of electromagnetic radiation from the surface in the visible range and beyond the visible. The technologies are further divided by the platform on which the sensor resides including satellites, aircraft, vessels or autonomous vehicles.

The tables provide a brief description of the technology, sensor characteristics, routine and in some cases emerging applications of the technology, important considerations to when using the technology and in some cases information about sources and costs. Many tables contain a bibliography and useful website links.

The table were developed using experts in each technology. The experts are listed in the acknowledgement section below.

This inventory will be accompanied by a report with recommendations on moving forward with the acquisition and application of remote sensing technologies.

Acknowledgements

The following experts were contracted to provide input to the inventory:

Herb Ripley, Hyperspectral Imaging Limited (Airborne Technologies)

Dirk Werle, Ærde Environmental Research (Satellite Technologies)

Taylor Davis, Terra Remote Sensing Inc. (Terrestrial LiDAR)

Todd Mitchell, Fugro Pelagos - Ventura (Bathymetric LiDAR)

Emma Mathieson, Leading Edge Geomatics (Aerial Photography)

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1. Airborne Passive Technologies

The following sets of technologies are passive sensors that capture data mounted on an aircraft. Some sensors could possibly be mounted on an autonomous vehicle (e.g. drones) if power demand is low and an appropriate level of positioning accuracy is provided.

1.1 Hyperspectral Technologies

Hyperspectral technologies include sensors that collect information from across the electromagnetic spectrum. Hyperspectral technologies divide the spectrum into many bands. This technique of dividing images into bands is commonly extended beyond the visible. In hyperspectral imaging, the recorded spectra have fine wavelength resolution and cover a wide range of wavelengths. Some sensors have fixed spectral bands; others have programmable spectral bands which can be programmed for specific applications.

Table 1.1: AISA Eagle

Name of the Sensor / Platform AISA Eagle
Brief Description of the technology Passive Airborne Hyperspectral Imager.
Sensor Characteristics – Pushbroom scanner – Spatial resolution 0.2 – 5.0 m. – Spectral resolution 3.3 nm. – Spectral range 400 – 970 nm. – 288 spectral bands
Routine / common applications of the technology for coastal and ocean remote sensing – Bathymetry – coral reef mapping – coastal plumes – coastline mapping – currents and fronts – flooding – slick detection – phytoplankton – coastal wetlands – Gelbstoff mapping
Emerging applications of the technology
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Requires clear sky conditions

- Small areas may be targeted for time specific data collection
- band width and locations are programmable
- Utilization of Inertial Measurement Units (IMU) means high spatial mapping accuracy

Suppliers of data / data products

Several private firms available to be contracted for data collection.

Range of costs to acquire

Costs will vary based on both size and duration of the survey as well as type of analysis required.

Additional information

The operator can create application specific band configurations, and quickly change from one mode or configuration to others in flight operation

Bibliography

Evaluating the potential for remote bathymetric mapping of a turbid, sand-bed river: 2. Application to hyperspectral image data from the Platte River Carl J. Legleiter , Paul J. Kinzel, Brandon T. Overstreet

High resolution seaweed mapping with hyperspectral airborne remote sensing . Mehrtens, Christina , Bartsch, Inka , Tardeck, F. , Graser, Nora and Borowy, C.

Macroalgae and eelgrass mapping in Great Bay Estuary using AISA hyperspectral imagery. Pe'eri et al., Center for Coastal Ocean Mapping

Useful websites http://specim.fi/files/pdf/aisa/datasheets/AisaEAGLE_datasheet_ver1-2013%281%29.pdf

Name of the Sensor / Platform AISA Fenix

Brief Description of the technology

Passive Airborne Hyperspectral Imager

Sensor Characteristics

- Pushbroom scanner
- Spatial resolution 1.0 – 5.0 m.
- Spectral resolution 3.5 nm (VNIR) and 12.0 nm (SWIR).
- Spectral range 380 – 2500 nm.
- 348 (VNIR) and 274 (SWIR) spectral bands
- Swath width 384 pixels

Routine / common applications of the technology for coastal and ocean remote sensing

- Bathymetry

- coral reef mapping
- coastal plumes
- coastline mapping
- currents and fronts
- flooding
- slick detection
- phytoplankton
- coastal wetlands
- Gelbstoff mapping,

Emerging applications of the technology

Important considerations in acquiring / using this technology

- Requires specially equipped aircraft
- Requires clear sky conditions
- Small areas may be targeted for time specific data collection
- band width and locations are programmable
- Utilization of Inertial Measurement Units (IMU) means high spatial mapping accuracy

Suppliers of data / data products

Several private firms available to be contracted for data collection.

Range of costs to acquire

Costs will vary based on both size and duration of the survey as well as type of analysis required.

Additional information

The operator can create application specific band configurations, and quickly change from one mode or configuration to others in flight operation

Bibliography

Evaluating the potential for remote bathymetric mapping of a turbid, sand-bed river: 2. Application to hyperspectral image data from the Platte River   Carl J. Legleiter , Paul J. Kinzel, Brandon T. Overstreet.

High resolution seaweed mapping with hyperspectral airborne remote sensing . Mehrtens, Christina , Bartsch, Inka , Tardeck, F. , Graser, Nora and Borowy, C.

Macroalgae and eelgrass mapping in Great Bay Estuary using AISA hyperspectral imagery. Pe'eri et al., Center for Coastal Ocean Mapping.

Useful websites http://www.specim.fi/files/pdf/aisa/datasheets/AisaFenix_ver3-2013.pdf

Table 1.2: Itres CASI550

Name of the Sensor / Platform	Itres CASI550
Brief Description of the technology Passive Airborne Hyperspectral Imager	
Sensor Characteristics – Pushbroom scanner – Spatial resolution 0.2 – 5.0 m. – Spectral resolution 2.4 nm – Spectral range 400 – 1000 nm. – 288 bands – swath width 550 pixels	
Routine / common applications of the technology for coastal and ocean remote sensing – Bathymetry – coral reef mapping – coastal plumes – coastline mapping – currents and fronts – flooding – slick detection – phytoplankton – coastal wetlands – Gelbstoff mapping,	
Emerging applications of the technology	
Important considerations in acquiring / using this technology • Requires specially equipped aircraft • Requires clear sky conditions • Small areas may be targeted for time specific data collection • band width and locations are programmable • Utilization of Inertial Measurement Units (IMU) means high spatial mapping accuracy	
Suppliers of data / data products Private firms available to be contracted for data collection.	
Range of costs to acquire Costs will vary based on both size and duration of the survey as well as type of analysis required.	
Additional information	

The operator can create application specific band configurations, and quickly change from one mode or configuration to others in flight operation
Bibliography Habitat mapping in the Farasan Islands (Saudi Arabia) using CASI and QuickBird imagery. G.P. Rowlands, S. Purkis Estimating the coverage of coral reef benthic communities from airborne hyperspectral remote sensing data: multiple discriminant function analysis and linear spectral unmixing. Sarah Hamylton The cover of living and dead corals using airborne remote sensing. **Mumby PJ**, Hedley JD, Chisholm JRM, Clark CD, Jaubert J (2004)**Coral Reefs** 23: 171-183
Useful websites **http://www.formosatrend.com/Brochure/CASI-550.pdf**

Table 1.3: Itres CASI1500

Name of the Sensor / Platform	Itres CASI1500
Brief Description of the technology Passive Airborne Hyperspectral Imager	
Sensor Characteristics – Pushbroom scanner – Spatial resolution 0.2 – 5.0 m. – Spectral resolution 2.4 nm – Spectral range 365 – 1050 nm. – 288 bands – swath width 1500 pixels	
Routine / common applications of the technology for coastal and ocean remote sensing – Bathymetry – coral reef mapping – coastal plumes – coastline mapping – currents and fronts – flooding – slick detection – phytoplankton – coastal wetlands – Gelbstoff mapping,	
Emerging applications of the technology	
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Requires clear sky conditions – Small areas may be targeted for time specific data collection – band width and locations are programmable – Utilization of Inertial Measurement Units (IMU) means high spatial mapping accuracy	
Suppliers of data / data products Several private firms available to be contracted for data collection.	
Range of costs to acquire Costs will vary based on both size and duration of the survey as well as the type of analysis required.	
Additional information	

The operator can create application specific band configurations, and quickly change from one mode or configuration to others in flight operation
Bibliography Habitat mapping in the Farasan Islands (Saudi Arabia) using CASI and QuickBird imagery. G.P. Rowlands, S. Purkis Estimating the coverage of coral reef benthic communities from airborne hyperspectral remote sensing data: multiple discriminant function analysis and linear spectral unmixing. Sarah Hamylton The cover of living and dead corals using airborne remote sensing. **Mumby PJ**, Hedley JD, Chisholm JRM, Clark CD, Jaubert J (2004)**Coral Reefs** 23: 171-183
Useful websites **http://www.itres.com/wp-content/uploads/2014/10/CASI_1500H1.pdf**

Table 1.4: HYMAP

Name of the Sensor / Platform	HYMAP
Brief Description of the technology Airborne hyperspectral imager	
Sensor Characteristics – whiskbroom scanner – Spatial resolution 2.0 – 10 m. – Spectral resolution 10 -20 nm – Spectral range 440 nm – 2.5 µm, 3 – 5 10 µm, 8 – 10 µm – 128 bands – swath width 600 pixels	
Routine / common applications of the technology for coastal and ocean remote sensing – Bathymetry – coral reef mapping – coastal plumes – coastline mapping – currents and fronts – flooding – slick detection – phytoplankton – coastal wetlands – Gelbstoff mapping,	
Emerging applications of the technology	
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Requires clear sky conditions – Small areas may be targeted for time specific data collection – band width and locations are programmable – Utilization of Inertial Measurement Units (IMU) means high spatial mapping accuracy	
Suppliers of data / data products HyVista Corporation (Australia)	
Range of costs to acquire Costs will vary based on both size and duration of the survey as well the type of analysis required.	
Additional information	

The operator can create application specific band configurations, and quickly change from one mode or configuration to others in flight operation
Bibliography THE HYMAP AIRBORNE HYPERSPECTRAL SENSOR: THE SYSTEM, CALIBRATION AND PERFORMANCE T. Cocks, R. Jenssen, A. Stewart, I. Wilson* and T. Shields* 1st EARSEL Workshop on Imaging Spectroscopy, Zurich, October 1998 HYMAP: AN AUSTRALIAN HYPERSPECTRAL SENSOR SOLVING GLOBAL PROBLEMS – RESULTS FROM USA HYMAP DATA ACQUISITIONS F. A. Kruse, J. W. Boardman, A. B. Lefkoff, J. M. Young, K.S. Kierein-Young
Useful websites http://www.hyvista.com

Table 1.5: AISA Hawk

Name of the Sensor / Platform	AISA Hawk
Brief Description of the technology Passive Airborne Hyperspectral Imager. Production of instrument ended in 2014 but is still commonly used.	
Sensor Characteristics – Pushbroom scanner – Spatial resolution 1.0 – 5.0 m. – Spectral resolution 8.5 nm. – Spectral range 970 – 2450 nm. – 254 spectral bands	
Routine / common applications of the technology for coastal and ocean remote sensing – coastal plumes – coastline mapping – currents and fronts – flooding – slick detection – phytoplankton – coastal wetlands – Gelbstoff mapping,	
Emerging applications of the technology	
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Requires clear sky conditions – Small areas may be targeted for time specific data collection – band width and locations are programmable – Utilization of Inertial Measurement Units (IMU) means high spatial mapping accuracy	
Suppliers of data / data products Several private firms available to be contracted for data collection.	
Range of costs to acquire Costs will vary based on both size and duration of the survey as well as type of analysis required.	
Additional information The operator can create application specific band configurations, and quickly change from one mode or configuration to others in flight operation	

Bibliography Evaluating the potential for remote bathymetric mapping of a turbid, sand-bed river: 2. Application to hyperspectral image data from the Platte River Carl J. Legleiter , Paul J. Kinzel, Brandon T. Overstreet High resolution seaweed mapping with hyperspectral airborne remote sensing . Mehrtens, Christina , Bartsch, Inka , Tardeck, F. , Graser, Nora and Borowy, C. Macroalgae and eelgrass mapping in Great Bay Estuary using AISA hyperspectral imagery. Pe'eri et al., Center for Coastal Ocean Mapping
Useful websites **https://www.ufz.de/export/data/1/18881_aisa_Hawk_datasheet.pdf**

Table 1.6: Itres SASI-600

Name of the Sensor / Platform	Itres SASI-600
Brief Description of the technology Passive Airborne Hyperspectral Imager	
Sensor Characteristics – Pushbroom scanner – Spatial resolution 1.0 – 3.7 m. – Spectral resolution 15.0 nm – Spectral range 950 – 2450 nm. – 100 bands – swath width 600 pixels	
Routine / common applications of the technology for coastal and ocean remote sensing – coastal plumes – coastline mapping – currents and fronts – flooding – slick detection – phytoplankton – coastal wetlands – Gelbstoff mapping	
Emerging applications of the technology	
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Requires clear sky conditions – Small areas may be targeted for time specific data collection – band width and locations are programmable – Utilization of Inertial Measurement Units (IMU) means high spatial mapping accuracy	
Suppliers of data / data products Itres Research Limited	
Range of costs to acquire Costs will vary based on both size and duration of the survey as well as the type of analysis required.	
Additional information The operator can create application specific band configurations, and quickly change from one mode or configuration to others in flight operation	
Bibliography Various related articles available upon request from Itres Research Limited	
Useful websites http://formosatrend.com/Brochure/SASI-600.pdf	

1.2 Other Airborne Passive Sensors

In this section a diverse group of additional passive airborne sensors are described including aerial photography (both vertical and oblique) and orthophotography.

Table 1.7 AVIRIS

Name of the Sensor / Platform AVIRIS
Brief Description of the technology Airborne Visible/Infrared Imaging Spectrometer
Sensor Characteristics – Whiskbroom scanner – Spatial resolution 4 m (low altitude) or 20 m (high altitude) – Spectral resolution 10 nm – Spectral range 400 – 2500 nm – 224 bands – swath width 550 pixels
Routine / common applications of the technology for coastal and ocean remote sensing – coastal plumes – coastline mapping – currents and fronts – flooding (areas affected by flooding) – slick detection – coastal wetlands – thermal pollution
Emerging applications of the technology
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Requires clear sky conditions – Long lead time required to arrange a data acquisition – band width and locations are programmable
Suppliers of data / data products NASA
Range of costs to acquire Costs will vary based on both size and duration of the survey as well as type of analysis required.
Additional information The operator can create application specific band configurations, and quickly change from one mode or configuration to others in flight operation
Bibliography AVIRIS SURFACE REFLECTANCE PROCESSING AND PRODUCTS. D. R. Thompson AVIRIS WORKSHOP PROCEEDINGS – 1988 through 2004 http://aviris.jpl.nasa.gov/proceedings/index.html
Useful websites http://aviris.jpl.nasa.gov/data/newdata.html

Table 1.8: Geovantage BUILD III

Name of the Sensor / Platform	Geovantage BUILD III
Brief Description of the technology Airborne digital camera system	
Sensor Characteristics – digital camera system – Spatial resolution 25 cm – 1.5 m. – Spectral resolution 20 nm – Spectral range 400 – 950 nm (approximate) – 4 bands – swath width 1600 pixels	
Routine / common applications of the technology for coastal and ocean remote sensing – Bathymetry – coral reef mapping – coastal plumes – coastline mapping – currents and fronts – flooding – slick detection – phytoplankton – coastal wetlands – Gelbstoff mapping	
Emerging applications of the technology	
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Requires clear sky conditions – Small areas may be targeted for time specific data collection – band location and width is controlled by physical filters before the lens. Ensure adequate lead time to identify and locate suitable filters – Utilization of Inertial Measurement Units (IMU) means high spatial mapping accuracy	
Suppliers of data / data products Geovantage (USA) www.geovanatge.com	
Range of costs to acquire Costs will vary based on both size and duration of the survey as well as the type of analysis required.	
Additional information The operator can create application specific band configurations using spectral band pass filters	
Bibliography Various publications available upon request from Geovantage Limited	
Useful websites http://geovantage.com	

Table 1.9: Geovantage BUILD IV

Name of the Sensor / Platform	Geovantage BUILD IV
Brief Description of the technology Airborne digital camera system	
Sensor Characteristics – digital camera system – Spatial resolution 25 cm – 1.5 m. – Spectral resolution 20 nm – Spectral range 400 – 950 nm (approximate) – 4 bands – swath width 4800 pixels	
Routine / common applications of the technology for coastal and ocean remote sensing – Bathymetry – coral reef mapping – coastal plumes – coastline mapping – currents and fronts – flooding – slick detection – phytoplankton – coastal wetlands – Gelbstoff mapping	
Emerging applications of the technology	
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Requires clear sky conditions – Small areas may be targeted for time specific data collection – band location and width is controlled by physical filters before the lens. Ensure adequate lead time to identify and locate suitable filters – Utilization of Inertial Measurement Units (IMU) means high spatial mapping accuracy	
Suppliers of data / data products Geovantage (USA) www.geovanatge.com	
Range of costs to acquire Costs will vary based on both size and duration of the survey as well as the type of analysis required	
Additional information The operator can create application specific band configurations using spectral band pass filters	
Bibliography Various publications available upon request from Geovantage Limited	
Useful websites http://geovantage.com	

Table 1.10: Geovantage BUILD V

Name of the Sensor / Platform	Geovantage BUILD V
Brief Description of the technology Airborne digital camera system	
Sensor Characteristics – digital camera system – Spatial resolution 25 cm – 1.5 m. – Spectral resolution 20 nm – Spectral range 400 – 950 nm (approximate) – 6 bands – swath width 4800 pixels	
Routine / common applications of the technology for coastal and ocean remote sensing – Bathymetry – coral reef mapping – coastal plumes – coastline mapping – currents and fronts – flooding – slick detection – phytoplankton – coastal wetlands – Gelbstoff mapping	
Emerging applications of the technology	
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Requires clear sky conditions – Small areas may be targeted for time specific data collection – band location and width is controlled by physical filters before the lens. Ensure adequate lead time to identify and locate suitable filters – Utilization of Inertial Measurement Units (IMU) means high spatial mapping accuracy	
Suppliers of data / data products Geovantage (USA) www.geovanatge.com	
Range of costs to acquire Costs will vary based on both size and duration of the survey as well as the type of analysis required.	
Additional information The operator can create application specific band configurations using spectral band pass filters	
Bibliography Various publications available upon request from Geovantage Limited	
Useful websites http://geovantage.com	

Table 1.11: Itres TASI-600

Name of the Sensor / Platform	Itres TASI-600

Brief Description of the technology
Passive Thermal Airborne Spectrographic Imager

Sensor Characteristics

- Pushbroom scanner
- Spatial resolution 1.0 – 3.7 m.
- Spectral resolution 125.0 nm
- Spectral range 8 – 11.5 microns
- 32 bands
- swath width 600 pixels

Routine / common applications of the technology for coastal and ocean remote sensing

- coastal plumes
- currents and fronts
- flooding (areas affected by flooding)
- ships
- slick detection
- surface temperatures

Emerging applications of the technology

Important considerations in acquiring / using this technology

- Requires specially equipped aircraft
- Requires clear sky conditions
- Small areas may be targeted for time specific data collection
- band width and locations are programmable
- Utilization of Inertial Measurement Units (IMU) means high spatial mapping accuracy

Suppliers of data / data products
Itres Research Limited

Range of costs to acquire
Costs will vary based on both size and duration of the survey as well as with the type of analysis required

Additional information

Bibliography
Various articles available upon request from Itres Research Limited

Useful websites
http://formosatrend.com/Brochure/TASI-600.pdf

Table 1.12: Itres MASI-600

Name of the Sensor / Platform	Itres MASI-600
Brief Description of the technology Passive Midwave Airborne Spectrographic Imager (Thermal)	
Sensor Characteristics – Pushbroom scanner – Spatial resolution 1.0 – 3.7 m. – Spectral resolution 32.0 nm – Spectral range 3 – 5 microns – 64 bands – swath width 600 pixels	
Routine / common applications of the technology for coastal and ocean remote sensing – coastal plumes – currents and fronts – flooding (areas affected by flooding) – ships – slick detection – surface temperatures	
Emerging applications of the technology	
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Requires clear sky conditions – Small areas may be targeted for time specific data collection – band width and locations are programmable – Utilization of Inertial Measurement Units (IMU) means high spatial mapping accuracy	
Suppliers of data / data products Itres Research Limited	
Range of costs to acquire Costs will vary based on both size and duration of the survey as well as with the type of analysis required.	
Additional information	
Bibliography Various related articles available upon request from Itres Research Limited	
Useful websites http://formosatrend.com/Brochure/MASI-600.pdf	

Table 1.13: Star SaFire HD

Name of the Sensor / Platform	Star SaFire HD

Brief Description of the technology
Passive Thermal Airborne Imager

Sensor Characteristics
- thermal imager
- Spectral range 3 - 5 microns
- swath width 640 pixels

Routine / common applications of the technology for coastal and ocean remote sensing
- coastal plumes
- currents and fronts
- flooding (areas affected by flooding)
- ships
- slick detection
- surface temperatures

Emerging applications of the technology

Important considerations in acquiring / using this technology
- Requires specially equipped aircraft
- all weather operation
- Small areas may be targeted for time specific data collection

Suppliers of data / data products
FLIR Corporation

Range of costs to acquire
Costs will vary based on both size and duration of the survey as with the type of analysis required.

Additional information

Bibliography
Various articles available upon request from FLIR Corporation

Useful websites http://www.flir.com/uploadedFiles/Brochure_StarSAFIREHD.pdf

Table 1.14 Aerial Photography

Name of the Sensor / Platform
Vexcel UltraCam Lp, Applanix DSS
Brief Description of the technology (platform base, start and end dates availability (satellite))

Large and medium Format digital aerial cameras are specifically designed for vertical imagery acquisition. The camera is installed in a dedicated imagery acquisition aircraft using a mission-appropriate mount, including a high-quality optical port, inertial compensation and navigation system. All cameras and lenses will have a current (less than three years old) calibration report. The valid calibration reports include those produced by the original equipment manufacturers, USGS, or NRC.

Vexcel UltraCam Lp: The system is a fully integrated, directly georeferenced (using on board GPS / IMU), airborne digital camera system. UltraCam Lp features:

- 92 megapixels (11,704 x 7,920 pixels pan)
- Latest internal camera electronics allow for high forward overlaps
- 1:2.20 pan-to-colour ratio provides brilliant true-colour and colour-infrared (CIR image quality with unmatched radiometric range
- High level of detail with no blur due to Forward Motion Compensation (FMC)
- Gyro stabilized camera mount
- Applanix POSTrack airborne Global Positioning System and Inertial Measurement Unit provides for directly georeferenced imagery aligned to the mapping grid
- Panchromatic focal length 70mm

Applanix DSS: 22 megapixel camera, The system is a fully integrated, directly georeferenced (using on board GPS / IMU), airborne digital camera system.
Applanix DSS is unique compared to many medium format cameras as it has been certified by the United States Geological Survey for metric mapping. The USGS certification ensures that the deliverable product will meet the strictest geometric and radiometric requirements. A copy of the USGS certification is available upon request, and additional information is available from the USGS website: http://calval.cr.usgs.gov/manufacturers_certification.php .

Applanix DSS	Model 322
Array Size	22.2 MP 4092 along flight line x 5436 cross flight line
Pixel Size	0.009mm
Filter Array	Colour (VIS) or ColourIR (CIR)
60mm Lens	Focal length 60.2mm, F/3.5, FOV crosstrack 44.2, alongtrack 34.0, diagonal 53.9 (CIR and VIS)
40mm Lens	Focal length 40.8mm, FOV crosstrack 67.9 alongtrack 48.6,

	diagonal 73.8 (CIR and VIS)
Exposure Control	Aperture priority (calibrated) Manual or shutter priority
Shutter	Electronically controlled focal plane
Shutter speed	125-4000
Exposure Compensation	+/- 2 EV in 1/3 steps
Max Exposure Rate	2.5sec
Azimuth Mount	< 0.5 deg RMS, absolute correction range +/- 40deg

Instrumentation Calibration Standards
All LEG mapping cameras are calibrated prior to survey using the Applanix Calibration and Quality Control software package. This is accomplished by flying over photo identifiable survey control points under similar conditions to those used on the mapping mission. This software is used to compute the bore site, camera, and datum calibration parameters for a number of images. The camera bore site is the misalignment of the vector generated by the optical axis of the camera, and the inertial measurement unit. LEG will provide up-to-date calibration reports for each system used.

Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)

The above listed sensors are passive. The range of on the ground resolutions depend on flying heights.
The Vexcel UltraCam Lp can collect data at a resolution of: 7-30cm
The Applanix DSS can collect data at a resolution of: 7-30cm

Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)

- Coastal Monitoring
- Coastal Erosion
- Flood Monitoring: Rapid Response
- Floodplain mapping
- Habitat Monitoring
- Vegetation Monitoring
- Regional Planning
- Ports and harbours monitoring
- Water Quality Monitoring
- Oil and Toxic Spill Planning/Mitigation/Identification
- Wet Areas Mapping

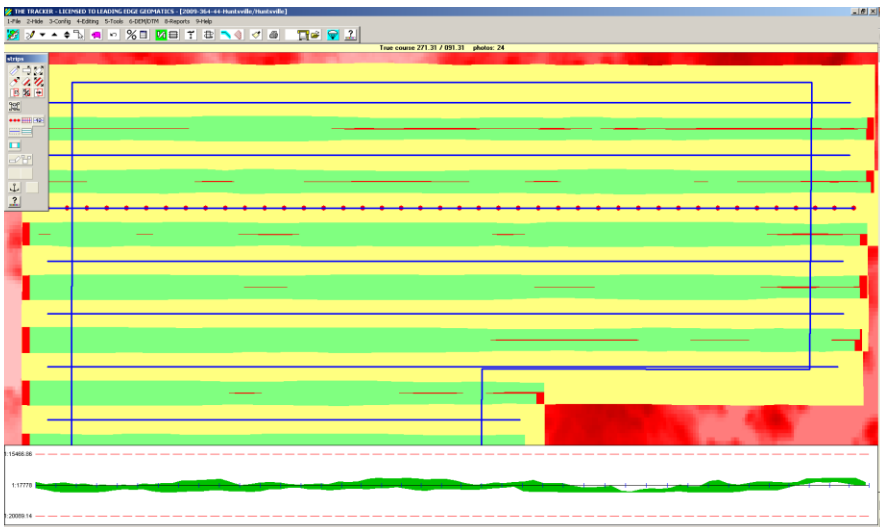
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts(include a few references in bibliography below)

The 4 band (RGBI) can help monitor coastal vegetation and change through the IR capability of the

Ultracam.
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)

Survey/Flight Planning: Airborne survey requires extensive planning. Expert planners are required, and must be familiar with project specifications, sensors and aircraft, local airspace, airports (for landing and fuel), as well as local climate, and sun angle.

When available, flight planning should be done using a Digital Elevation Model (DEM) to ensure that planned forward and side overlaps will be achieved. The image below shows our flight planning software with the forward overlaps in yellow and the sidelap coverage in green. The red hypsometric image in the background is derived from elevation data and provides the information required to draw the profile of the flight line as shown at the bottom.

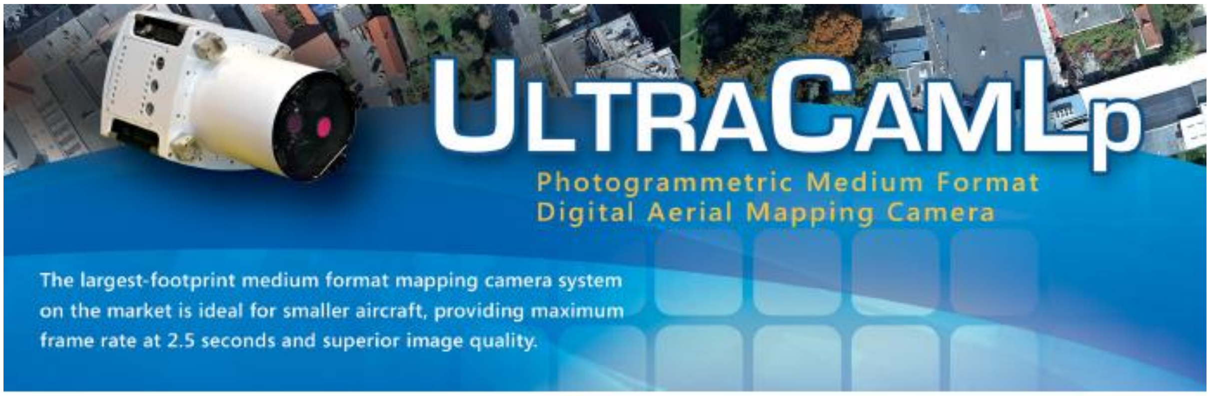


Acquisition: Weather is a major factor in conducting surveys. Acquisition may be delayed due to temperature, precipitation, sun angle, and cloud. Though this may not affect the flight operations directly, project specifications often require clear, haze, cloud and smoke free conditions for acceptable data. Therefore, it is important to account for possible weather delays when planning acquisition time frames. Sun Angle is also a major consideration in planning and acquisition. Projects may dictate minimum sun angle, which should be calculated using the National Research Council of Canada online calculator. Adherence to these times should be monitored using the GPS time as reported by the airborne position and orientation system.

Data Processing: Data processing effort is dependent on the complexity of deliverables requested. Projects flown over a longer period of time will take longer to process as the projects will be larger in regards to how much data there is to process, and also will require more colour-balancing and mosaicking, both time-consuming tasks. Higher resolution projects will also take longer in regards to processing.

Existing Standards:
Sensors/Platforms: As there are no Canadian standards in place, When seeking aerial photography services, it should be mandated that the proposed sensor is approved/certified by an organization such

as USGS or ASPRS. **Testing of Spatial Accuracy**: The National Spatial Standards for Reporting Spatial Accuracy (NSSDA) methodology should be used to assess the final deliverables and report in the metadata. **Certifications:** Department of Transportation Canada issues certifications for aircraft to perform aerial survey.
Suppliers of data / data products
Leading Edge Geomatics acquires aerial photography and produces related products/deliverables to client specifications.
Range of costs to acquire (per scene, per square kilometre)
$70-$1,500/km² based on project size, location, specifications and deliverables.
Additional information
Bibliography (references from sections above and additional important references)
http://infraredsolutions.co.nz/wp-content/uploads/2013/09/Sea-Water-Pollution.pdf http://calval.cr.usgs.gov/documents/The_USGS_and_IADIWG_Plan9.pdf http://www.asprs.org/a/society/committees/standards/Procurement_Guidelines_w_accompanying_material.pdf
Useful websites
http://books.google.com/books/about/Remote_Sensing_of_Coastal_Aquatic_Enviro.html?id=iD8WAXO8p4QC http://proceedings.spiedigitallibrary.org/proceeding.aspx?articleid=1018566



Overview

Based on the UltraCamL, the UltraCamLp features the same advanced technical specifications but boasts an even larger format collection at 92 megapixels (11,704 x 7,920 pixels pan) compared to the UltraCamL 64 megapixel format, making it the largest-footprint medium format mapping camera system on the market and ideal for smaller aircraft and local projects that require a rapid response. With new electronics, the UltraCamLp allows for a larger footprint than the UltraCamL without sacrificing cycle rates. The result is 43% more image at the same frame rate, allowing for the following possible benefits:

- Data collection at higher flight speeds
- Increase of potential forward overlap for a given GSD and speed
- Data collection at higher resolutions with the same forward overlap and speed

With superior image quality, the UltraCamLp can be used on smaller airplanes, and thus operated at lower cost. Smaller mapping companies have an affordable option for offering a digital platform and expanding their aerial services. The UltraCamLp is also ideal for larger mapping firms who need to cost-effectively fly small projects or collect digital data in conjunction with lidar or other data. The UltraCamLp provides the same high geometric accuracy, broad dynamic range, matching and stereo capabilities, and full metric capabilities, as the large format cameras. The image data are suitable for DSM (digital surface model) production, aerotriangulation, ortho mapping and 3D technical vector mapping.

Features

- *Largest-footprint medium format mapping camera system on the market with an even larger format collection at 92 megapixels (11,704 x 7,920 pixels pan)*
- *New camera electronics provide the same maximum frame rate at 2.5 seconds, which increases the forward overlap at a given GSD and speed*
- *1:2.20 pan-to-color ratio delivers brilliant true-color and color-infrared (CIR) image quality with unmatched radiometric range*
- *Short frame interval allows multi-ray photogrammetry even for large-scale mapping at low altitude and high aircraft speed; forward overlaps of 80% are achieved at a 10 cm pixel size at 110 knots*
- *High level of detail with no blur due to Forward Motion Compensation (FMC) using Time Delayed Integration (TDI)*
- *Pixel size on the ground (GSD) at flying height of 900 m is 8 cm (at 500 m is 4.3 cm)*
- *Removable storage units provide two benefits: the length of missions is limited only by the constraints of the aircraft; ground time is minimized*
- *Maximum use of legacy environments; supports ALL standard gyro-stabilized camera mounts (PAV-30, Z/I-TAS, GSM3000) and most common GPS/IMU systems*
- *Utilizes only a sensor head with integrated sensor and computing sub-systems, integrated computing sub-system and integrated solid-state devices (storage sub-system) for maximum reliability; no additional computing or storage units are required*
- *Weight of UltraCamLp sensor head is approximately 55 kg*
- *Panchromatic Focal Length: 70 mm, Color and NIR 33 mm*

Camera Types and Models

The project area will be acquired using the Applanix Digital Sensor System (DSS), consisting of a 22 mega pixel camera (or better). The system is a fully integrated, directly georeferenced (using on board GPS / IMU), airborne digital camera system.

Applanix DSS is unique compared to many medium format cameras since it has been certified by the United States Geological Survey for metric mapping. Many camera systems flown in tandem with LiDAR sensors are not certified by an independent government agency. The USGS certification is assurance that the deliverable product will meet the strictest geometric and radiometric requirements.

-Taken from the USGS Certificate

"The United States Geological Survey (USGS) certifies that the Digital Sensor System (DSS) manufactured by the Applanix Corporation, of Richmond Hills, Ontario, Canada meets the claims of the manufacturer and is capable of providing quality, consistent image data to support civil government mapping and ortho-photography product development.

The USGS provides this certificate to Applanix Corporation for successful completion of the USGS Manufacturer Certification process which included presenting and providing all appropriate information to address the certification requirements as define in the USGS Quality Assurance of Digital Aerial Imagery plan and the USGS Manufacturer Certification Checklist".

Additional information regarding camera certifications is available from the USGS website at the following web address: http://calval.cr.usgs.gov/manufacturers_certification.php

Additional information is available from the USGS website at the following web address: http://calval.cr.usgs.gov/manufacturers_certification.php

Table 1.15: Orthophotography

Name of the Sensor / Platform

Vexcel UltraCam Lp, Applanix DSS

Brief Description of the technology (platform base, start and end dates availability (satellite))

Large and medium Format digital aerial cameras are specifically designed for vertical imagery acquisition used for orthophotography. Cameras are installed in a dedicated imagery acquisition aircraft using a mission-appropriate mount, including a high-quality optical port, inertial compensation and navigation system. All cameras and lenses will have a current (less than three years old) calibration report. The valid calibration reports include those produced by the original equipment manufacturers, USGS, or NRC.

Vexcel UltraCam Lp: The system is a fully integrated, directly georeferenced (using on board GPS / IMU), airborne digital camera system. UltraCam Lp features:

- 92 megapixels (11,704 x 7,920 pixels pan)
- Latest internal camera electronics allow for high forward overlaps
- 1:2.20 pan-to-colour ratio provides brilliant true-colour and colour-infrared (CIR image quality with unmatched radiometric range
- High level of detail with no blur due to Forward Motion Compensation (FMC)
- Gyro stabilized camera mount
- Applanix POSTrack airborne Global Positioning System and Inertial Measurement Unit provides for directly georeferenced imagery aligned to the mapping grid
- Panchromatic focal length 70mm

Applanix DSS: 22 megapixel camera, The system is a fully integrated, directly georeferenced (using on board GPS / IMU), airborne digital camera system.

Applanix DSS is unique compared to many medium format cameras as it has been certified by the United States Geological Survey for metric mapping. The USGS certification ensures that the deliverable product will meet the strictest geometric and radiometric requirements. A copy of the USGS certification is available upon request, and additional information is available from the USGS website: http://calval.cr.usgs.gov/manufacturers_certification.php .

Applanix DSS	Model 322
Array Size	22.2 MP 4092 along flight line x 5436 cross flight line
Pixel Size	0.009mm
Filter Array	Colour (VIS) or ColourIR (CIR)
60mm Lens	Focal length 60.2mm, F/3.5, FOV crosstrack 44.2, alongtrack 34.0, diagonal 53.9 (CIR and VIS)

40mm Lens	Focal length 40.8mm, FOV crosstrack 67.9 alongtrack 48.6, diagonal 73.8 (CIR and VIS)
Exposure Control	Aperture priority (calibrated) Manual or shutter priority
Shutter	Electronically controlled focal plane
Shutter speed	125-4000
Exposure Compensation	+/- 2 EV in 1/3 steps
Max Exposure Rate	2.5sec
Azimuth Mount	< 0.5 deg RMS, absolute correction range +/- 40deg

Instrumentation Calibration Standards
All LEG mapping cameras are calibrated prior to survey using the Applanix Calibration and Quality Control software package. This is accomplished by flying over photo identifiable survey control points under similar conditions to those used on the mapping mission. This software is used to compute the bore site, camera, and datum calibration parameters for a number of images. The camera bore site is the misalignment of the vector generated by the optical axis of the camera, and the inertial measurement unit. LEG will provide up-to-date calibration reports for each system used.

Orthorectification Process

Imagery Processing Software
LEG uses the full suite of Trimble Inpho Photogrammetric software (http://www.inpho.de/) including:

Aerial Triangulation	Match-AT
DTM Extraction	Match-T
DTM Editing	DTMaster with Stereo
Orthorectification	Orthomaster
Mosaicking	Orthovista

All collected or provided images will be individually orthorectified and used to create the final mosaic tiles. *Inpho Orthomaster* allows for intelligent handling of the images to allow for the most nadir section of the image to be retained in the final mosaic. This process does not simply clip a fixed percentage off; it analyzes the neighboring images in relation to the center of the image and determines the most nadir section in relation to all neighboring images, thereby minimizing building lean.

Mosaic Process
Once all images have been processed by Inpho Orthomaster and individually orthorectified they are passed to Orthovista for colour balancing and tile generation. The individual tiles will comprise the nadir sections of all individual orthoimages that are contained within the bounds of the tile.

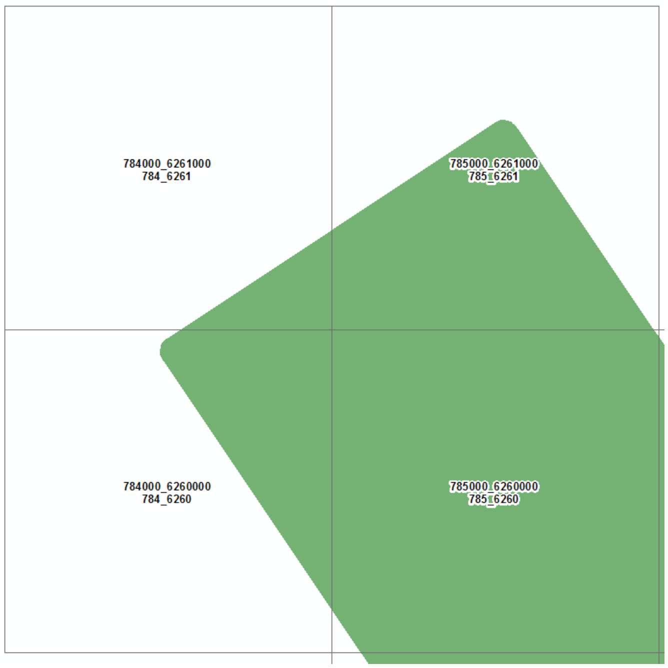
Colour Balancing

LEG uses Inpho OrthoVista to compensate for a wide range of image intensity and color variations originating from the imaging process. OrthoVista computes radiometric adjustments that compensate for visual effects within individual images, such as hot spots, lens vignetting and color variations.

Initially OrthoVista performs a block wide color balancing by adjusting adjacent images to match in color and brightness, after this step the operator can graphically select individual images to adjust manually. This process is done on screen and in real time to allow the operator to preview the final results without having to commit to a long process.

Imagery Tiling

The orthoimagery is typically delivered as spatial tile which are segmented into 1km x 1km tiles named for the lower left corner coordinate using UTM 20/21 NAD83 (CSRS) in the graphic below. A typical tile will have the coordinates Easting 784000, Northing 6261000 and the alias of 784 6261. There will be a small collar between photo tiles. Please see example below.



Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)

The above listed sensors are passive. The range of on the ground resolutions depend on flying heights.
The Vexcel UltraCam Lp can collect data at a resolution of: 7-30cm
The Applanix DSS can collect data at a resolution of: 7-30cm

Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)

- Coastal Monitoring
- Coastal Erosion
- Flood Monitoring: Rapid Response
- Floodplain mapping
- Habitat Monitoring
- Regional Planning
- Ports and harbours monitoring
- Water Quality Monitoring
- Oil and Toxic Spill Planning/Mitigation/Identification
- Wet Areas Mapping

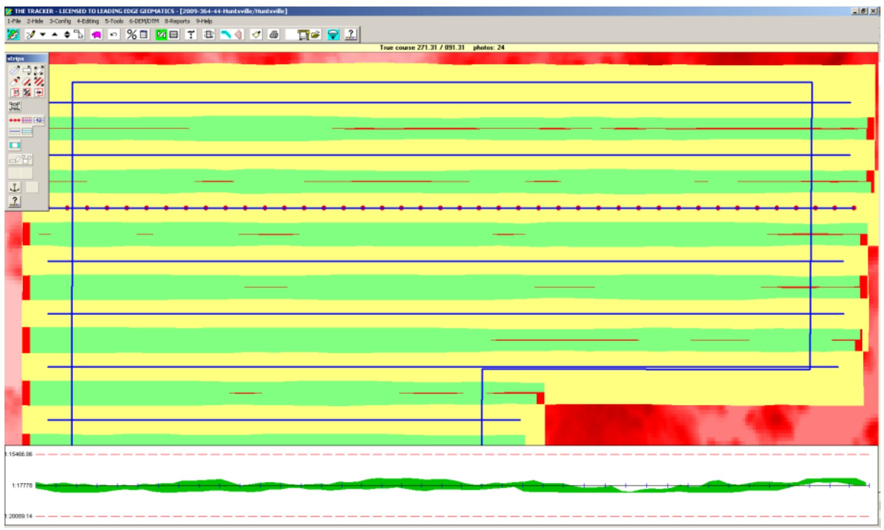
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts(include a few references in bibliography below)

The 4 band (RGBI) can help monitor coastal vegetation and change through the IR capability of the Ultracam.

Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)

Survey/Flight Planning: Airborne survey requires extensive planning. Expert planners are required, and must be familiar with project specifications, sensors and aircraft, local airspace, airports (for landing and fuel), as well as local climate, and sun angle.

When available, flight planning should be done using a Digital Elevation Model (DEM) to ensure that planned forward and side overlaps will be achieved. The image below shows our flight planning software with the forward overlaps in yellow and the sidelap coverage in green. The red hypsometric image in the background is derived from elevation data and provides the information required to draw the profile of the flight line as shown at the bottom.



Acquisition: Weather is a major factor in conducting surveys. Acquisition may be delayed due to temperature, precipitation, sun angle, and cloud. Though this may not affect the flight operations directly, project specifications often require clear, haze, cloud and smoke free conditions for acceptable data. Therefore, it is important to account for possible weather delays when planning acquisition time frames. Sun Angle is also a major consideration in planning and acquisition. Projects may dictate minimum sun angle, which should be calculated using the National Research Council of Canada online calculator. Adherence to these times should be monitored using the GPS time as reported by the airborne position and orientation system.

Data Processing: Data processing effort is dependent on the complexity of deliverables requested. Orthorectified projects evidently take longer to process than basic aerial photography as they require each image to be individually orthorectified (see *Orthorectification Process* above). Projects flown over a longer period of time will take longer to process as the projects will be larger in regards to how much data there is to process, and also will require more colour-balancing and mosaicking, both time-consuming tasks. Higher resolution projects should also be expected to take longer in regards to processing due to the enhanced level of detail.

Existing Standards:
Sensors/Platforms: As there are no Canadian standards in place, When seeking aerial photography services, it should be mandated that the proposed sensor is approved/certified by an organization such as USGS or ASPRS.

Testing of Spatial Accuracy: The National Spatial Standards for Reporting Spatial Accuracy (NSSDA) methodology should be used to assess the final deliverables and report in the metadata. **Certifications:** Department of Transportation Canada issues certifications for aircraft to perform aerial survey.
Suppliers of data / data products
Leading Edge Geomatics acquires aerial photography and produces related Orthophotography products/deliverables.
Range of costs to acquire (per scene, per square kilometre)
$70-$1,500/km² based on project size, location, specifications and deliverables.
Additional information
Bibliography (references from sections above and additional important references)
http://www.asprs.org/a/society/committees/standards/Procurement_Guidelines_w_accompanying_material.pdf http://calval.cr.usgs.gov/documents/The_USGS_and_IADIWG_Plan9.pdf http://infraredsolutions.co.nz/wp-content/uploads/2013/09/Sea-Water-Pollution.pdf
Useful websites
http://coast.noaa.gov/digitalcoast/publications/coastal-remote-sensing

Table 1.16 Oblique Aerial Photography

Name of the Sensor / Platform
LEG does not have an oblique sensor/platform readily available, however we lease a multi-camera oblique system as required.
Brief Description of the technology (platform base, start and end dates availability (satellite))
Many Oblique systems include multiple cameras to allow for acquisition from an angle, rather than nadir, producing oblique images. Example system: Leica RCD30 Oblique: http://www.leica-geosystems.com/downloads123/zz/airborne/RCD30_Oblique/Flyer/Leica_RCD30_Oblique_FLY_en.pdf
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Passive Sensor with resolutions varying depending on flying height.
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
• Coastal Monitoring • Coastal Erosion • Emergency Management Planning • First Response • Storm Relief • Navigation Planning • Flood Monitoring: Rapid Response • Habitat Monitoring • Vegetation Monitoring • Regional Planning • Ports and harbours monitoring • Wet Areas Mapping
Emerging applications of the technology
Currently being used extensively for municipal asset management, real estate, property valuation and emergency response.
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
Survey Planning: Airborne survey requires extensive planning. Expert planners are required, and must be familiar with project specifications, sensors and aircraft, local airspace, airports (for landing and fuel), as well as local climate. **Acquisition:** Weather is a major factor in conducting surveys. Acquisition may be delayed due to temperature, precipitation, and cloud. Though this may not affect the flight operations directly, project specifications often require clear, haze, cloud and smoke free conditions for acceptable data. Therefore, it is important to account for possible weather delays when planning acquisition time frames. **Data Processing:** Data processing effort is dependent on the complexity of deliverables requested. Projects flown over a longer period of time will take longer to process as the projects will be larger in

regards to how much data there is to process, and also will require more colour-balancing and mosaicking, both time-consuming tasks. Higher resolution projects will also take longer in regards to processing. **Existing Standards:** **Sensors/Platforms:** As there are no Canadian standards in place, When seeking aerial photography services, it should be mandated that the proposed sensor is approved/certified by an organization such as USGS or ASPRS. **Testing of Spatial Accuracy**: The National Spatial Standards for Reporting Spatial Accuracy (NSSDA) methodology should be used to assess the final deliverables and report in the metadata. **Certifications:** Department of Transportation Canada issues certifications for aircraft to perform aerial survey.
Suppliers of data / data products
Sanborn Imaging: http://www.sanborn.com/products/oblique
Range of costs to acquire (per scene, per square kilometre)
Additional information
Bibliography (references from sections above and additional important references)
Useful websites
http://coastal.er.usgs.gov/hurricanes/oblique.php http://oceanservice.noaa.gov/news/jul14/oblique.html http://sanctuarysimon.org/obsregistry/reg_simon/reg_PDF.php?projectID=100189 http://www.eagleview.com/

2. Active Airborne Sensors

The technologies in this section are active sensors using microwave energy or light energy from lasers to illuminate the surface or seafloor and recording the reflected energy and waveform.

2.1 Synthetic Aperture Radar

Table 2.1: PALS

Name of the Sensor / Platform **PALS**
Brief Description of the technology Passive/Active L/S-band dual-polarized sensor
Sensor Characteristics PALS is a combined polarimetric radiometer and NASA licensed radar sharing a rotating planar array antenna. The PALS instrument includes a combined L-band radiometer and scatterometer , operating at 1.413 GHz and 1.26 GHz respectively. It was designed and built to investigate the benefits of combining passive and active microwave sensors for Ocean salinity and Soil moisture remote sensing. It is the prototype for the Aquarius and SMAP missions and its' flexible design is compatible with many aircraft.
Routine / common applications of the technology for coastal and ocean remote sensing – ocean salinity – soil moisture – currents and fronts
Emerging applications of the technology
Important considerations in acquiring / using this technology – Requires specially equipped aircraft
Suppliers of data / data products NASA
Range of costs to acquire Costs will vary based on both size and duration of the survey
Additional information
Bibliography Ocean Surface Salinity Remote Sensing With A Passive/Active L-/S-Band Microwave Instrument . Simon H. Yueh, William J. Wilson, Fuk K. Li, and S. Howden
Useful websites http://airbornescience.jpl.nasa.gov/instruments/pals

2.2 Bathymetric LiDAR

Table 2.2: Airborne LiDAR Bathymetry

Name of the Sensor / Platform
Airborne LiDAR Bathymetry (ALB) – can be deployed using a fixed-wing or rotary-wing aircraft. High-powered sensors (for deeper penetration), require a turboprop engine to generate sufficient power to operate the system.
Brief Description of the technology (platform base, start and end dates availability (satellite))
Airborne LiDAR Bathymetry uses the base principals of Light Detection and Ranging (LiDAR) to measure ranges from the sensor to the terrain surface (in this case the seabed). The sensor is mounted in an aircraft which flies over the area of interest. A Global Navigation Satellite System (GNSS aka GPS) is integrated with an Inertial Measuring Unit (IMU, also sometimes referred to as an Inertial Navigation System (INS)) which are key for recording the precise position of the aircraft as well as its orientation. A highly precise clock is also required in order to correlate the LiDAR observation to the location/orientation data. Applying the range observation of the LiDAR unit to the position and orientation of the system allows for the calculation of a coordinate on the terrain surface.
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Bathymetric LiDAR systems are equipped with a blue/green laser (532 nm wavelength), which allows optimal penetration of the water column under the broadest range of coastal water conditions (Jerlov, N.G., 1976. Marine Optics, Elsevier Scientific Pub. Co., Amsterdam, 231 pp). Many ALB systems are also equipped with an infra-red (conventional) topographic LiDAR scanner as well. The reason for this is the critical need to identify the portion of the ALB range observation that is below the water surface, as that portion must be corrected for the effects of water on the observation, principally refraction. Some sensors rely upon information captured in the blue/green pulse to identify the water surface. Both system types are capable of collecting topographic data in addition to bathymetry. Although penetration depth is often expressed as a maximum in meters, water clarity has a tremendous impact on this figure. Therefore, it is more accurate to express depth of penetration in a multiplier of Secchi Disk depth (a Secchi Disk, created by Angelo Secchi in 1865, is a 30 cm diameter disk used to measure water transparency. When lowered into a body of water, the depth at which the disk is invisible is the Secchi depth. Transmissometer (light meter) values offer the most dependable optical range results however as they do not include the objectivity of the observer. ALB sensors are generally grouped into two classes – 'coastal' and 'topo-bathy'. Coastal systems use a high power laser and a low pulse rate (i.e. fewer observations) in order to achieve maximum penetration (the low pulse rate is a function of the heat generated – and mitigation thus applied - with such high-power lasers). These systems can generally achieve from 2 to 3 times the Secchi Disk depth in penetration. Shallow penetration systems are relatively new and operate a lower power laser and collect orders of magnitude more observations per second. However, the trade-off is in the reduction in penetration – these sensors generally collect from 1 to 1.5 times the Secchi depth. For 'coastal' systems this equates to depths up to 50+ meters in optimal water conditions and about 10-15 meters as a typical maxima for the topo-bathy systems. All ALB sensors are capable of measuring both coastal land (topo) and seabed, allowing for seamless land-sea data to be collected. ALB sensors not only capture ranging information, but also capture a measurement of the amount

returned energy (reflectance). Reflectance data can be used to produce panchromatic imagery of the terrain. Although somewhat analogous to sonar back-scatter data (which is a measure of reflected sonar pulse signal strength), as it is a measure of reflected light, the results are not the same. Work has been done on some projects (principally in the USA, Canada, Australia, Middle East and in Brazil) to correlate ALB reflectance to seafloor classification.
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
ALB technology was principally developed for safely and efficiently producing navigational charts in shallow water areas. Conventional hydrographic survey techniques (sonar) collect data from a vessel. When operated in shallow water environments, the efficiency of collecting complete seabed coverage is hindered. Multibeam echosounder systems collect swaths of data that are a function of the water depth below the sensor (typically 3x to 4x water depth). Vessels also travel relatively slowly (~7.5 km/h – sometimes more slowly when the area is previously uncharted and there is risk of the vessel running aground or striking a shoal.
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts(include a few references in bibliography below)
The Canadian Hydrographic Service (under the Department of Fisheries and Oceans) has been employing ALB technology for projects in several locations since 2011 totalling more than 2200 km^2 of surveys. The principal objective has been for hydrographic charting to supplement the work conducted by CHS' survey vessels. One project was used as a study case for DFO to assess eel grass and oyster habitat using not only the bathymetric data, but also using that data to evaluate seabed roughness as well as the reflectance data for habitat mapping. Habitat classification and mapping is a potential deliverable from any ALB project, although it does require field investigations in order to perform supervised classification. Habitat classification can potentially be improved upon through the fusion with multi-spectral imagery. Whether captured from the aircraft during ALB collection, captured by an independent aircraft or via satellite imagery, the additional spectra of light that can penetrate the water column potentially add reflectance information not available from ALB alone. The key limitation is the water column penetration. As imagery is a passive remote sensing technique, spectral reflectance will be more limited than with the active ALB sensor, and to varying degrees due to the water column's effect on the spectral band in question.
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
As most ALB surveys are principally used for Nautical Charting, they are typically required to comply with the International Hydrographic Organization standards (published in IHO Standards for Hydrographic Surveys – document S-44). The specific needs of the survey should dictate the appropriate order for the accuracy of the survey. Compliance with the appropriate order to support the appropriate Nautical Charting is strongly advised. Critical to success for ALB is consideration of water clarity – specifically suspended sediments and aeration of the water column hinder the performance of ALB. Weather is also an important

consideration, not only in that fog, clouds and precipitation prevent data collection, but wind can create effects on the water surface that negatively affect data collection.

Therefore it is critical to consider weather and climate conditions as well as site depth when planning an ALB survey. This can best be managed through a desktop study that evaluates seasonal water clarity for a region, available depth information (which may be historical, gravity or satellite based) and historical weather conditions. The desktop study will also often include flight line planning.

Due to the environmental constraints, it is often highly advantageous for stakeholders to plan multiple locations for data collection in a campaign – particularly where multiple stakeholders can collaborate on multiple projects in a region. The local conditions affecting one site may not impede data collection at alternate sites, therefore the equipment and crew are less likely to be unutilized on a given day providing a better cost benefit long term.

When collecting aerial imagery, collection of ALB data becomes restricted to daylight-only collection, which reduces operational efficiency by 50% - perhaps more. Therefore, it is important to consider the cost-effectiveness of simultaneous collection.

Suppliers of data / data products

Currently, there are few agencies and private sector companies equipped to carry out deep-water ALB surveys (*) and marginally more collecting shallow-water:

- Fugro Pelagos*
- Fugro LADS*
- Airborne Hydrography AB*
- US Army Corps of Engineers*
- Japan Coast Guard*
- Pelydryn*
- Royal Australian Navy* (technical contractor support provided by Fugro LADS)
- Applied Geomatics Research Group, Nova Scotia Community College
- University of Texas
- US Geological Survey
- Quantum Spatial
- Woolpert

Range of costs to acquire (per scene, per square kilometre)

As there are many options to choose: deep-water penetration, shallow-water penetration (which has a less rigorous aircraft requirement), both simultaneously, the Order of Accuracy/point density required, and with/without coincident collection of aerial imagery; there is significant range in acquisition costs.

Compound the selection of required technology with the location of the project (which in Canada, can be extremely remote, limited by appropriate runways and aviation fuel) and again pricing becomes more difficult to estimate.

Projects also benefit significantly from increased size (to amortize mobilization/demobilization costs) and to allow for multiple options for data collection at varying sites.

Finally, proper assessment of site conditions (water clarity, weather) and schedule planning can mean the difference between a successful and failed project.

As rough orders of magnitude for data collection (and not including mobilization), it is possible to estimate that shallow-water penetration ALB surveys may be of the order of $200/square kilometer up as high as $3000/square kilometer. Deep-water penetration ALB surveys may be of the order of $500/square kilometer up to $5,000/square kilometer. Again, the difference in costs can often be managed better through good planning and scheduling.

Additional information

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"Data Acquisition; Maintenance, and Dissemination", Amar Nayegandhi, CP, CMS(RS), GISP Director of Remote Sensing. MAPPS 2014 Proceedings. http://c.ymcdn.com/sites/www.mapps.org/resource/resmgr/Docs/MAPPS_TMAC_Presentation_(12-.pdf

"Multi-Wavelength Airborne Laser Scanning", Martin Pfennigbauer & Andreas Ulrich, ILMF 2011 Proceedings. http://www.riegl.com/uploads/tx_pxpriegldownloads/Paper_ILMF_2011_RIEGL_Multiwavelength_ALS.pdf

"Airborne LiDAR Bathymetry – Sea, Shore and More", Bill Gutelius, LiDAR Magazine Vol. 2. No. 6.

http://www.LiDARnews.com/PDF/LiDARMagazine_Gutelius-LiDARBathymetry_Vol2No6.pdf
Useful websites
http://shoals.sam.usace.army.mil/Publications.aspx

Table 2.3: Optech AQUARIUS

Name of the Sensor / Platform	Optech AQUARIUS
Brief Description of the technology Airborne Bathymetric LiDAR	
Sensor Characteristics – Simultaneous land/water depth measurement capability – Available as a complete solution or as a sensor head addition to the Gemini – “Drop-in” sensor design enables small portal installations and unrestricted use of FOV – Discrete and/or waveform-derived elevation measurements – Pseudo-reflectance measurement capability – Integration with additional digital imaging sensors – Programmable density irrespective of altitude – Production-focused workflow – Automated LiDAR rectification – Platform design with 15 years of field-proven results	
Routine / common applications of the technology for coastal and ocean remote sensing – Bathymetry – coastline mapping – currents and fronts – coastal wetlands – environmental	
Emerging applications of the technology	
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Small areas may be targeted for time specific data collection	
Suppliers of data / data products Several private firms available to be contracted for data collection.	
Range of costs to acquire Costs will vary based on both size and duration of the survey	
Additional information Data collection survey plans prepared in advance	
Bibliography A list of publications may be obtained by contacting Optech, www.optech.com	
Useful websites http://specim.fi/files/pdf/aisa/datasheets/AisaEAGLE_datasheet_ver1-2013%281%29.pdf	

Table 2.4: Optech CZMIL

Name of the Sensor / Platform Optech CZMIL
Brief Description of the technology Airborne Bathymetric LiDAR
Sensor Characteristics – Seamless, simultaneous high-resolution topographic/bathymetric imaging – Depth penetration of 2.5 × Secchi depth, up to 80 m – Excellent performance in shallow or turbid water – Detects objects as small as 1 meter cube in water up to 25 meters deep – Green and IR frequencies available in a single system – Superior land/water discrimination and depth resolution – Optimized coverage, spatial density and survey rate – Sampling rate of 10 kHz in hydrographic mode and up to 70 kHz in topographic mode
Routine / common applications of the technology for coastal and ocean remote sensing – Disaster Management – Coastal & Shoreline – Shallow, Turbid & Muddy Water – Submerged Object Detection – Environmental
Emerging applications of the technology Optech HydroFusion, a powerful end-to-end software suite, handles data from all three sensors—from mission planning to post- processing, delivering fused LiDAR and imagery datasets, bottom classifications, and even submerged object detection.
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Small areas may be targeted for time specific data collection
Suppliers of data / data products Optech provides project specific data collection services.
Range of costs to acquire Costs will vary based on both size and duration of the survey
Additional information Data collection survey plans prepared in advance
Bibliography A list of publications may be obtained by contacting Optech, www.optech.com
Useful websites http://specim.fi/files/pdf/aisa/datasheets/AisaEAGLE_datasheet_ver1-2013%281%29.pdf

Table 2.5: LADS MK3

Name of the Sensor / Platform LADS MK3
Brief Description of the technology Airborne Bathymetric LiDAR System
Sensor Characteristics – Digital Imagery, Mosaic Images • Hyperspectral Data • Seabed Reflectivity & Classification • River Survey • Satellite Imagery • Collection of Data Relative to the Ellipsoid • Portable Processing - Ground System on Laptop • Area Based Data Processing • 3000 ft, Super Swath • Extending Depth Capability • Topographic Capability • Riegl Integration for High Density Shoreline
Routine / common applications of the technology for coastal and ocean remote sensing – Bathymetry – Support of marine and coastal engineering – currents and fronts – coastal wetlands – Ecological management of fragile coastal zones, beaches and coral reefs – Production of nautical charts to International Hydrographic Organization (IHO) standards – Support of safe, cost-effective offshore oil and gas exploration and field development – Provision of data to assist climate change adaptation models
Emerging applications of the technology
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Small areas may be targeted for time specific data collection
Suppliers of data / data products FugroLADS www.fugrolads.com
Range of costs to acquire Costs will vary based on both size and duration of the survey
Additional information Data collection survey plans prepared in advance
Bibliography A list of publications may be obtained by contacting FugroLADS www.fugrolads.com
Useful websites http://www.fugrolads.com/download/datasheets/Fugro-LADS-Mk3

Table 2.6: RIEGL - VQ-820

Name of the Sensor / Platform	RIEGL - VQ-820
Brief Description of the technology Airborne Bathymetric LiDAR System	
Sensor Characteristics – excellently suited for combined land and hydrographic airborne survey – high-accuracy ranging based on echo digitization and online waveform processing with multiple target capability – high spatial resolution due to laser repetition rate up to 520 kHz, high scanning speed up to 200 scanlines/second and a wide field of view up to 60° – compact, rugged and light-weight modular configuration, compatible with standard airborne platforms. – optional waveform data output, data accessible via RiWAVELiB – seamless integration with other RIEGL ALS Systems and software packages	
Routine / common applications of the technology for coastal and ocean remote sensing – Coastline and Shallow Water Mapping – River Bed Profiling – Acquiring Base Data for Flood Prevention – Measurement for Aggradation Zones – Habitat Mapping – Surveying for Hydraulic Engineering – Monitoring of Hydraulics Laboratories – Hydro-Archaeological-Surveying	
Emerging applications of the technology	
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Small areas may be targeted for time specific data collection – ideal for surveys where conventional systems are most limited: shallow water, the land/water interface, remote and/or hazardous areas, and areas requiring rapid environmental assessment.	
Suppliers of data / data products FugroLADS www.fugrolads.com	
Range of costs to acquire Costs will vary based on both size and duration of the survey	
Additional information Data collection survey plans prepared in advance	
Bibliography A list of publications may be obtained by contacting RIEGL www.riegl.com	
Useful websites http://www.riegl.com/uploads/tx_pxpriegldownloads/DataSheet_VQ-820-G_2014-09-19.pdf	

Table 2.7: SHOALS-1000

Name of the Sensor / Platform SHOALS-1000

Brief Description of the technology
Airborne Bathymetric LiDAR System

Sensor Characteristics
- Digital Imagery, Mosaic Images
- Seabed Reflectivity & Classification
- River Survey
- Collection of Data Relative to the Ellipsoid
- Portable Processing - Ground System on Laptop
- Area Based Data Processing
- Topographic Capability

Routine / common applications of the technology for coastal and ocean remote sensing
- Hydrography & Nautical Charting
- Oil & Gas and Renewable Energy Survey Support
- Coastal Zone Mapping & Environmental Monitoring
- Habitat Mapping
- Inland Waterways
- UNCLOS Baseline Mapping

Emerging applications of the technology

Important considerations in acquiring / using this technology
- Requires specially equipped aircraft
- Small areas may be targeted for time specific data collection
- ideal for surveys where conventional systems are most limited: shallow water, the land/water interface, remote and/or hazardous areas, and areas requiring rapid environmental assessment.

Suppliers of data / data products
FugroLADS www.fugrolads.com

Range of costs to acquire
Costs will vary based on both size and duration of the survey

Additional information
Data collection survey plans prepared in advance

Bibliography
A list of publications may be obtained by contacting FugroLADS www.fugrolads.com

Useful websites **http://www.fugrolads.com/download/datasheets/SHOALS-1000T**

2.3 Airborne Terrestrial LiDAR

Table 2.8: Airborne terrestrial LiDAR

Name of the Sensor / Platform
Airborne terrestrial LiDAR (Light Detection and Ranging)
Brief Description of the technology (platform base, start and end dates availability (satellite))
Fixed wing or helicopter platforms available. Platform selection depends on the size of project area, ruggedness of terrain, required point density and airport / fuel location(s)
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
LiDAR is an active sensor that sends out a pulse of visible or near-infrared light (typically 1064nm or 1550nm), which is used to generate xyz coordinates of ground and above ground features from range measurements based on the time difference between the emitted pulse from the sensor to the return of the reflection back to the sensor. Typically 4 discrete returns from each outgoing pulse are recorded, however full waveform sensors are also commercially used. LiDAR is typically flown between 100-3000m above ground altitude. The altitude and speed of the aircraft will determine the optimal settings of the pulse repetition frequency (PRF) and the laser scan rate that should be set to obtain an equally distributed along track and cross track point spacing pattern on the surface. Generally increasing the PRF will decrease the power of each outgoing pulse necessitating lower PRF rates at higher altitudes. Increased airspeed will result in higher along track point spacing. Lasers operating in the 1064nm range are not sensitive to water, snow or ice and obtain returns from these surfaces, whereas lasers operating in the 1550nm range will not get reliable or abundant returns from water, snow or ice as the incoming energy is absorbed. Depending on the desired application, both could be advantageous in coastal mapping applications. For example, if shoreline extent was desired, LiDAR data in the 1550nm range generally demonstrates exactly where the water's edge is at the time of survey due to no returns where water is present. However, dark sands, wet vegetation, mud, tidal pools etc. can also result in void areas. Additionally areas directly under nadir can still result in returns.
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
Floodplain mapping Sea level rise studies Tsunami run up modelling Hazard assessment (3D building classification etc.) Dike assessment Shoreline erosion monitoring Sand dune migration tracking Structural ecosystem assessment Port and harbor development Pipeline crossings Electrical transmission cable crossings Fiber optic cable crossings
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts(include a few references in bibliography below)
Sea level rise studies Tsunami run up modelling Hazard assessment (3D building classification etc.) Shoreline erosion monitoring

Sand dune migration tracking Structural ecosystem assessment
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
Conditions: LiDAR is highly sensitive to aerosols and moisture (low cloud, fog, smoke etc.) so should be acquired in clear conditions with low wind speeds. Airborne terrestrial LiDAR should also be ideally acquired at low tide so as to capture the maximum exposed shoreline possible. LiDAR should not be acquired when snow or ice is on the ground, unless the objective is for an ice or snow thickness study. If the objective is purely based around LiDAR and no concurrent imagery is to be acquired, ideally LiDAR should be collected during leaf off conditions so as to maximize the chances of penetration to the bare earth. **AOI characteristics:** Depending on the sinuosity of the coastline and how far inland is to be mapped, following a complex shoreline can be made more simple and time effective using a helicopter platform, which allows data to be captured over longer lines without having to break offline and make turns, which can make a difference when trying to acquire data within a specific tidal window. For large deltas or long straight coastlines, fixed wing platforms will work well, however generally fixed wing platforms fly faster than helicopters so data density is typically lower in a single flight line than data acquired from helicopter platforms. **Accuracy considerations:** LiDAR is relied on as an accepted tool for flood plain mapping applications and FEMA has developed specific guidelines for the acquisition and validation of LiDAR data for floodplain applications. The specifications include rigorous real time kinematic (RTK) ground surveys to accompany the LiDAR surveys to aid in the positioning and validation of the data to ensure a high confidence in the data's vertical accuracy is achieved. In flat river floodplain or delta areas, a small vertical error in the LiDAR data can translate into a large horizontal error. Various provincial and federal agencies in Canada have adopted similar standards, however a range of existing standards exist that have not been officially adopted or endorsed by one governing body. Generally the ASPRS is a good source of information on current accuracy and data standards. Data density at the time of the survey, and data processing techniques both have implications on the overall accuracy of the LiDAR derived data products. Although techniques like planimetric feature capture and hydrological enforcement techniques are often used in coastal mapping applications to enhance the accuracy of the resulting digital elevation models (DEM), some aspects of resolution relating to accuracy cannot be enhanced. For example, if a LiDAR dataset is collected to achieve a 1 point / square m density, generating contours at a 50cm interval is a pointless exercise. LiDAR data classification can range from fully automated point cloud processing to intense manual classification efforts to capture a wealth of detail. For example, it is difficult for automated ground finding algorithms to distinguish between a dock and bare earth, thus, if the standards or expectations governing the project required docks to not be included in a bare earth class, these features have to be manually removed from the bare earth ground class. Additionally, if the requirements were such that a clean vegetation classification was desired, all non-vegetation objects have to be manually removed from the dataset, meaning that all lamp standards, transmission lines, boats, pilings, docks, buildings, automobiles, etc. have to be removed from the point cloud to a different class or classes. These distinctions can dramatically increase costs.

Cost considerations:
The primary factors in determining cost are the required point density, project size and data accuracy requirements. In order to lower costs, the more specific the project requirements (tidal, concurrent imagery etc.) the larger the acquisition window should be to ensure that sufficient windows of opportunity exist for data capture. In addition to higher chances of hitting time / condition windows, generally providers can offer lower cost surveys with larger project windows and flexible acquisition schedules. To lower the cost of surveys, often times some concessions have to be made to various datasets to optimize data collection efficiency. For example, if a LiDAR / Hyperspectral acquisition was desired, the hyperspectral needs high sun angles / clear sky conditions and full leaf on conditions for good vegetation study applications, which means that the LiDAR data cannot be collected during leaf off conditions.

As previously mentioned the level of detail required in the data processing also has cost implications and can vary considerably depending on the project requirements.

Suppliers of data / data products

The following list includes Canadian LiDAR providers only and was put together based on Industry Canada data:
AeroGeo
Airborne Imaging
Champlain Air Surveys Ltd.
Eagle Mapping
GeoDigital
KBM Resources Group
LaserMap
LiDAR Services International
McElhanney Consulting
North West Geomatics Ltd.
Terra Remote Sensing Inc.

Range of costs to acquire (per scene, per square kilometre)

The costs of acquiring LiDAR data are highly variable depending on numerous factors including the project data requirements, project scheduling requirements, project location, project size, project scope (multi-year change detection can lower overall costs etc.). Costs can range from $100-1000/square km.

Additional information

Bibliography (references from sections above and additional important references)

Useful websites

http://www.asprs.org/
http://coast.noaa.gov/digitalcoast/data/coastalLiDAR
http://LiDAR.cr.usgs.gov/
http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/coastal_floodplain_mapping-2011.pdf
http://www.naturalcapitalproject.org/models/coastal_protection.html
http://www.naturalcapitalproject.org/models/coastal_vulnerability.html
http://www.ngdc.noaa.gov/mgg/bathymetry/LiDAR.html
https://www.fema.gov/coastal-flood-risks-achieving-resilience-together

Table 2.9: Optech TITAN

Name of the Sensor / Platform	Optech TITAN

Brief Description of the technology

Airborne terrestrial LiDAR

Sensor Characteristics

- Three independent active imaging channels that support 532, 1064, and 1550 nm wavelengths for multispectral mapping of the earth's surface, day or night
- A high-resolution "green" channel that ensures high point density for shallow water mapping applications
- Narrow pulse widths, state-of-the-art receiver and timing electronics guarantee the highest range precision possible for maximum data quality
- A fully programmable scanner enables huge increases in point density at narrower FOVs for maximum target resolution and detail over competing sensors
- A 29 MP high-resolution, fully electronic QA camera provides passive imagery support.
- Optional embedded 80 MP RGB orthometric camera with forward motion compensation enhances image quality and improves classification. Also available with imbedded multispectral, thermal or NIR sensor options
- Realtime XYZI point display, available exclusively with Optech FMS, enables independent channel visualization during flight for true-coverage verification and collection monitoring
- Optional sensor gyro-stabilization, fully automated with Optech's comprehensive Flight Management System (FMS) for effortless operation and consistent point distribution
- The latest in tightly-coupled inertial and Virtual Reference System processing technology enables steep turns, extended GPS baselines, and the elimination of remote base stations
- Optional CenterPoint RTX provides global coverage of centimeter-level real time position accuracy, a critical consideration for bathymetric mapping in remote locations (<0.1 m XY)
- Powerful Optech LMS LiDAR processing software automates sensor calibration, maximizes laser point accuracies and quantifies project accuracy deliverables
- An Optech LMS software extension that supports water attenuation corrections for bathymetric applications

Routine / common applications of the technology for coastal and ocean remote sensing

- Bathymetry
- coastal plumes
- coastline mapping
- flooding
- slick detection
- topography
- coastal wetlands

Emerging applications of the technology

Important considerations in acquiring / using this technology

- Requires specially equipped aircraft
- Requires clear sky conditions

– Small areas may be targeted for time specific data collection
Suppliers of data / data products Several private firms available to be contracted for data collection.
Range of costs to acquire Costs will vary based on both size and duration of the survey
Additional information Data collection survey plans prepared in advance
Bibliography A list of publications may be obtained by contacting Optech, www.optech.com
Useful websites **http://www.optech.com/wp-content/uploads/Titan-Specsheet-141125-WEB.PDF**

Table 2.10: Optech PEGASUS

Name of the Sensor / Platform	Optech PEGASUS
Brief Description of the technology Airborne terrestrial LiDAR	
Sensor Characteristics – Wide FOV coupled with the highest operating altitude and detect-ability available provide s the user with high data collection efficiency – Drop-in sensor design installs in deep portals with unrestricted use of the entire FOV – High accuracy and precision deliver high-quality datasets – Multi-laser design obtains twice the collection efficiency and data density of single-laser systems – Fully-embedded, medium-format digital camera provides simultaneously-collected, high-resolution imagery	
Routine / common applications of the technology for coastal and ocean remote sensing – Natural resource monitoring – Urban mapping – Large area mapping	
Emerging applications of the technology	
Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Small areas may be targeted for time specific data collection	
Suppliers of data / data products Several private firms available to be contracted for data collection.	
Range of costs to acquire Costs will vary based on both size and duration of the survey	
Additional information Data collection survey plans prepared in advance	
Bibliography A list of publications may be obtained by contacting Optech, www.optech.com	
Useful websites **http://www.optech.com/wp-content/uploads/PEGASUS-Specsheet-140624-WEB.pdf** **http://www.optech.com/wp-content/uploads/Pegasus-HD-SpecSheet-141126-WEB.pdf**	

Table 2.11: Optech ORION

Name of the Sensor / Platform Optech ORION
Brief Description of the technology Airborne terrestrial LiDAR
Sensor Characteristics – High data precision delivers the high quality datasets – Compact form factor and low power requirements provide platform flexibility – Exceptional small-target detection capability captures even the smallest details – Monitor data quality and collection confidence in real-time with in-air LiDAR point cloud display and coverage maps – Output XYZI point clouds in LAS format in real-time for immediate data deliverables – Have the flexibility that only a completely programmable scanner and FOV offer, maintaining required ground point densities when collection conditions and altitudes vary from plan – Provide service differentiation by adding passive imaging capability with Optech's modular line of digital cameras (RGB, NIR, thermal, and multispectral). Tightly-integrated and fully supported from one flight management system – Flexible multi-sensor mounts for both helicopter and aircraft installations provide scalable solutions as business requirements change – Deliver consistent data quality and accuracy with production-focused workflow software with automated calibration capabilities
Routine / common applications of the technology for coastal and ocean remote sensing – Corridor and asset mapping – Defense and security – Natural resource mapping – Urban mapping
Emerging applications of the technology
Important considerations in acquiring / using this technology – May be flown in most aerial survey aircraft – Small areas may be targeted for time specific data collection
Suppliers of data / data products Several private firms available to be contracted for data collection.
Range of costs to acquire Costs will vary based on both size and duration of the survey
Additional information Data collection survey plans prepared in advance
Bibliography A list of publications may be obtained by contacting Optech, www.optech.com
Useful websites http://www.optech.com/wp-content/uploads/ORION-C-Specsheet-140624-WEB.pdf http://www.optech.com/wp-content/uploads/ORION-H-Specsheet-140624-WEB.pdf http://www.optech.com/wp-content/uploads/ORION-M-Specsheet-140624-WEB.pdf

Table 2.12: Optech GALAXY

Name of the Sensor / Platform	Optech GALAXY
Brief Description of the technology Airborne terrestrial LiDAR	
Sensor Characteristics – 550-kHz effective PRF provides on-the-ground point density and efficiency – Continuous operating envelope replaces conventional multipulse technologies for complete coverage and more consistent point densities – Up to 8 returns per pulse provides increased vertical resolution of complex targets without the need for full waveform recording and processing (waveform recorder optionally available) – Swath Tracking Mode with dynamic scan field of view enables constant swath widths and point distributions over variable terrain. – High-torque, low-inductance scanner provides superior reliability and calibration stability – Programmable scanner enables dramatic point density increases at lesser FOVs – Innovative atmospheric point inhibitor enables cleaner raw data and significantly reduces post-processing filtering – Industry-leading data precision and accuracy for the highest-quality datasets possible – Wide dynamic range enables exceptional small-target detection capability and capture of even the smallest details – In-air LiDAR point cloud display for maximum collection confidence. – Real-time XYZI point clouds in LAS format enable immediate data deliverables. – Low power requirements and compact form factor provide platform flexibility. – Tight integration with Optech’s modular line of digital cameras (RGB, NIR, thermal, and multispectral) under a single flight management system provides excellent application flexibility and scalable data deliverables – Production-focused workflow software with automated calibration and boresight capability of both LiDAR and camera within a single workflow, enabling truly coincident datasets and quantified accuracies	
Routine / common applications of the technology for coastal and ocean remote sensing • Wide-area mapping • Powerline and transportation corridor • Natural Resource management • Defense & Security • Engineering and infrastructure modeling • Urban Mapping	
Emerging applications of the technology	

Important considerations in acquiring / using this technology – Requires specially equipped aircraft – Small areas may be targeted for time specific data collection
Suppliers of data / data products Several private firms available to be contracted for data collection.
Range of costs to acquire Costs will vary based on both size and duration of the survey
Additional information Data collection survey plans prepared in advance
Bibliography A list of publications may be obtained by contacting Optech, www.optech.com
Useful websites http://www.optech.com/wp-content/uploads/Galaxy-Specsheet-141001-WEB.pdf

3. Vessel-borne Acoustic Technologies

The following technologies use sound to illuminate the seafloor and record water depth and acoustic back scatter information. Two technologies are described. Multibeam soanr has become the tool of choice for producing navigational charts. Sidescan sonar draws an acoustic picture of the bottom that in expert's hands can produce bottom character that can be a precursor to a habitat map. Newer technologies such as Synthetic Aperture Sonar and interferometric sonar can produce these pictures more efficiently and provide bathymetric information as well. Many of the newer sensors can be mounted on autonomous underwater vehicles.

Table 2.13: Multibeam Sonar

Name of the Sensor / Platform (if applicable)
Multibeam sonar / survey vessel mounted / ROV mounted / AUV mounted
Brief Description of the technology (platform base, start and end dates availability (satellite))
The benefits of multibeam echo sounders are that they map the seafloor by a fan of narrow acoustic beams, thus providing 100% coverage of the bottom. The resulting seabed maps are more detailed than those obtained using single-beam mapping. The maps are also produced faster, reducing your ship survey time. Before the reported sonar echoes can be translated into measurements of the sea floor, and before they can be compared between time slices (the hydrophone array will be in different positions and at different angles in different time slices), the motions of the hydrophone array must be measured and taken into account. This process is called motion compensation, or beam stabilization. The motions of a ship at sea and the hydrophone mounted to it are highly complex and somewhat unpredictable. Some of these motions are deliberate, such as the ship's forward progress, or turns. However, most are due to the effects of waves.
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
A wide range of multibeam sonars are manufactured from ROV/ AUV or pole mounted units (Kongsberg Maritime M3) with a 120˚ swath width to permanently mounted systems with narrower swath beam width that can be used in deeper water depths. These systems also provide sidescan or backscatter data for sea bottom classification.
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
Hydrographic charting (meeting IHO standards), bathymetric mapping, bottom classification, surficial geology mapping
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts(include a few references in bibliography below)
Fish stock estimation
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
Multibeam data collection must be conducted with either calm sea states or advanced vessel orientation systems to correct for vessel motion. The efficiency of multibeam sonar systems in shallow waters is reduced due to limited bottom coverage per survey line especially for narrow swath systems

and the prudent survey speeds required to avoid uncharted shoals. Overlap in adjacent survey lines is recommended and is required to meet IHO standards. Except in macrotidal environments, a seamless marine to terrestrial elevation surface is not obtainable and even in these environments surveys would be constrained by tide levels. For most applications, water column measurements must be taken at regular intervals to correct for temperature and salinity and to identify and compensate for water column stratification that affects the speed of sound in water and sound refraction due to water body boundaries. The raw data requires significant data processing and quality control. There are several suppliers of data processing software. Processing and interpretation of sidescan and backscatter data for bottom classification and surficial geology mapping is less routine and to date requires subject knowledge expertise and ground truthing through bottom sample collection and / or bottom camera / video imagery.
Suppliers of data / data products
MacGregor Geoscience University of New Brunswick / Ocean Mapping Group Canadian Hydrographic Service **Data processing software** CARIS HIPS / SIPS Fledermaus 3D interactive visualization Firms awarded contracts by NOAA in 2014 C&C Technologies, located in Lafayette, Louisiana David Evans and Associates, located in Vancouver, Washington eTrac, located in San Rafael, California Fugro Pelagos, located in San Diego, California Leidos, located in Newport, Rhode Island Ocean Surveys Inc., located in Old Saybrook, Connecticut TerraSond, located in Palmer, Alaska Williamson and Associates, located in Seattle, Washington
Range of costs to acquire (per scene, per square kilometre)
Additional information
Bibliography (references from sections above and additional important references)
Mapping the Ocean, The Journal of Ocean Technology, Vol. 7, Number 2
Useful websites
http://woodshole.er.usgs.gov/operations/sfmapping/swath.htm

Table 2.14: Sidescan Sonar

Name of the Sensor / Platform
Sidescan Sonar/ survey vessel mounted / ROV mounted / AUV mounted
Brief Description of the technology (platform base, start and end dates availability (satellite))
Marine researchers commonly use side-scan sonar technology to search for and detect objects on the seafloor. Side scan sonar continuously records the return echo, thus creating a “picture” of the sea floor. This picture is made up of dark and light areas. Hard objects protruding from the bottom send a strong echo and create a dark image. Shadows and soft areas, such as mud and sand, send weaker echoes, thus creating a light image. Studying these dark and light images, scientists can create accurate maps of the sea floor, and locate seafloor features and possible obstructions to navigators. Synthetic Aperture Sonar (SAS) allows for higher resolution imagery at lower frequencies than possible with conventional systems. An interferometric sidescan uses phases of the reflected sonar signal to extract other characteristics of the seafloor including elevation.
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
There is an inverse relationship between the frequency of the sonar and its spatial resolution – lower frequency sonars achieve wide swath coverage, but at a lower resolution. As a result conventional sidescan sonars offer high resolution or high coverage but not both. Combining interferometric and synthetic aperture sonar gives 5 to 10 times the improvement in bathymetric mapping efficiency over conventional side scan sonars and multibeam echosounders. Interferometric SAS is a relatively new technology, just now reaching maturity. Use of a SAS system on an AUV has additional advantages. An AUV normally has an accurate inertial navigation system and other positioning systems that provide the sensor orientation needed by the SAS. Since AUV operate below surface layers, the SAS doesn’t need to compensate for surface layer sound speed variations and surface wave effects.
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below).
Mine hunting, pipeline inspections, surficial and bedrock mapping, bathymetric mapping
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts(include a few references in bibliography below)
A combination of an SAS system with a state of the art multi-frequency multibeam echo sounder fills the gap left by the SAS at nadir.
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
Conventional and SAS sidescans normally operate close to the sea bottom requiring vigilance especially in rough terrain to prevent damage to the sonar system through collision with the bottom. To cover the

gap at the nadir overlapping survey lines are necessary if the not combined with a multibeam echosounder. Interpretation of sidescan sonar images requires experience since the image is a combination of reflections and shadows.
Suppliers of data / data products
MacGregor Geoscience **Data processing software**
Range of costs to acquire (per scene, per square kilometre)
Additional information
Bibliography (references from sections above and additional important references)
Mapping the Ocean, The Journal of Ocean Technology, Vol. 7, Number 2
Useful websites
http://woodshole.er.usgs.gov/operations/sfmapping/swath.htm

4. Satellite-based Technologies

Satellite- based technologies are dived into active and passive sensors. The active sensors included are various deployments of synthetic aperture radar. The passive sensors are a wide range of deployments including high resolution visible sensors (some of these are commercial initiatives), thermal and hyperspectral sensors. The satellites these sensors are based on are deployed by many countries, China and India being some of the latest nations involved in deploying satellites. Included also are altimeters which measure the elevation of the sea and land surface.

4.1 Synthetic Aperture Radar

Table 4.1: HY-3A, NSOAS

Name of the Sensor / Platform / Operator / Country
HY-3A, NSOAS / Chinese Academy of Space Technology, CAST, China
Brief Description of the technology (platform base, start and end dates availability (satellite))
Imaging microwave radar / synthetic aperture radar (SAR), 2015-2010
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
X-band SAR with 3 resolution modes (1, 5, 10 m) and 3 swath width (40, 80, 150 km)
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below):
High resolution radar measurements of land and ocean features; sea ice cover; ocean surface feature detection
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below):
Ocean monitoring, environmental protection, coastal zone survey.
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards):)
Data access restricted, depending on sharing agreements with Chinese Academy of Space Technology (CAST)
Suppliers of data / data products:
Data continuity secured through HY-3B/C follow-on missions from 2017 to 2027
Range of costs to acquire (per scene, per square kilometre):
Dependent on sharing agreements with CAST
Additional information

Bibliography (references from sections above and additional important references)
Useful websites
http://www.cast.cn/CastEN/index.asp

Table 4.2: HY-2A Ocean Dynamics Satellite

Name of the Sensor / Platform / Operator / Country
HY-2A Ocean Dynamics Satellite, NSOAS / CAST, China
Brief Description of the technology (platform base, start and end dates availability (satellite))
Imaging microwave radar / radar altimeter, microwave radiometer, scatterometer; 2011-2014
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Active Radar Altimeter: 16 km resolution, 16 km swath width, < 4 cm accuracy for ocean topography, wave height and spectra. Active Microwave radiometer: 18-100 km resolution, 1600 km swath Active Scatterometer: 50 km resolution, 1300 km swath width, 0.5 dB accuracy (1 – 100 cm)
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below): Radar Altimeter: ocean surface winds (horizontal wind speed) and ocean surface temperature (sea surface temperature) measurements
Radar Altimeter: ocean topography and currents (sea level, ocean dynamic topography) Microwave radiometer: ocean surface winds (horizontal wind speed) and ocean surface temperature (sea surface temperature) Scatterometer: Ocean surface winds for horizontal wind speed measurements
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below):
Ocean monitoring, detecting ocean surface temperature, wave and wind fields, and ocean surface topography.
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards):
Data access depending on sharing agreements with Chinese Academy of Space Technology (CAST)
Suppliers of data / data products: data continuity secured through HY-2B/C /D follow-on missions from 2016 to 2022
Range of costs to acquire (per scene, per square kilometre):
Dependent on sharing agreements with CAST
Additional information
http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=967 http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=973 http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=972
Bibliography (references from sections above and additional important references)
Useful websites
http://www.cast.cn/CastEN/index.asp

Table 4.3: RADARSAT-2

Name of the Sensor / Platform / Operator / Country(if applicable)
RADARSAT-2; MacDonald Dettwiler and Associates Ltd. (MDA) and Canadian Space Agency (CSA); Canada
Brief Description of the technology (platform base, start and end dates availability (satellite))
High performance and versatile imaging radar (SAR); 2007 – 2015 and ongoing
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Active C-band synthetic aperture radar with multiple polarizations and a diversity of imaging and digital processing modes and spatial resolutions; Standard Mode: 27 - 17 x 25 m (4 looks); Wide Mode: 40 - 19 x 25 m (4 looks); Fine Mode: 10 - 7 x 8 m (1 look); ScanSAR Mode (N/W): 80 - 38 x 60 m / 160 - 172 x 100 m (4/8 looks), Extended (High/Low) Mode: 18 - 16 x 25 m / 60 - 23 x 25 m (4 looks); Ultra-Fine Mode: 4.6 - 2.1 x 2.8 m (1 look, best resolution ~1 m) SAR swath width include Standard: 100 km (incidence angles: 20 - 49 deg); Wide: 150 km (inc.: 20 - 45 deg); Fine: 50 km (inc.: 30 - 50 deg); ScanSAR (Narrow/Wide): 300/500 km (inc.: 20 - 46 / 20 - 49 deg); Extended (High/Low): 75/170 km (inc.: 49 - 60 / 10 - 23 deg); Ultra-Fine: 20 km (inc.: 20 - 49 deg)
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
Environmental monitoring, physical oceanography, ice and snow, land surface. Multi-purpose imagery for clean and coastal surface winds (horizontal wind speed over sea surface), ocean topography / currents (vector surface currents, bathymetry and dynamic topography), ocean wave height and spectrum (significant wave height), sea ice cover, edge and thickness (sea-ice cover, sea-ice type), ice sheets (topography), coastal vegetation (vegetation type, land cover), coastal landscape topography (land surface topography), coastal and marine pollution (oil spill detection); marine traffic analysis (ship detection and tracking); RADARSAT-2 data is routinely used by the Canadian Ice Service, http://www.ec.gc.ca/glaces-ice/ ; Environment Canada has also developed operational services for oil spill detection and wind field analysis in near-coastal areas, http://www4.asc-csa.gc.ca/auot-eoau/eng/grip/Projects/73084.aspx and http://earth.esa.int/workshops/polinsar2009/participants/122/pres_6_DeLisle_122.pdf
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Interferometric SAR, surface coherent change detection, motion analysis
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
Ownership of RADARSAT-2 has been transferred to MDA Corporation. CSA investment in the project is paid back with the data generated by the satellite since it entered operations; Canadian government departments benefit from this block-allocation of RADARSAT-2 data under a master agreement between MDA and GoC. MDA offers several RADARSAT-2 programming services, depending on the urgency of the data acquisition request, the cost for this service may range from $120 to $3,600 per scene.
Suppliers of data / data products
MDA Geospatial Services, http://gs.mdacorporation.com/SatelliteData/Radarsat2/Radarsat2.aspx;

Range of costs to acquire (per scene, per square kilometre)
MDA's commercial prices per RADARSAT-2 scene range from $3,600 to $8,400, depending on processing level and Mode selection, http://gs.mdacorporation.com/SatelliteData/Radarsat2/Price.aspx ; precision map image processing (SPG product) is available for an additional $900; the Government of Canada rate per scene is on the order of several hundred dollars.
Additional information
RADARSAT-2 followed the successful RADARSAT-1 mission; CSA will be launching the RADARSAT Constellation Mission (RCM) in 2018.
Bibliography (references from sections above and additional important references)
http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=703 CASI, 2004. *Canadian J. of Remote Sensing, RADARSAT-2* Special Issue, **30**(3): 365 pp.
Useful websites
http://www.asc-csa.gc.ca/eng/satellites/radarsat2/default.asp

Table 4.4: RADARSAT Constellation Mission (RCM)

Name of the Sensor / Platform
RADARSAT Constellation Mission (RCM), Canadian Space Agency, Canada
Brief Description of the technology (platform base, start and end dates availability (satellite))
Constellation of 3 advances synthetic aperture radars (primary sensor), with addition of Automatied Identification System (AIS) space components to aid ship detection and tracking; AIS data collection system; 2018 – 2025
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
C-band SAR with multiple imaging modes and polarization, including Quad polarization imaging mode and compact polarimetry; Spatial resolution: low Resolution 100 m: 100 x 100 m (8 looks); Medium Resolution 50 m: 50 x 50 m (4 looks); Medium Resolution 16 m: 16 x 16 m (4 looks); Medium Resolution 30 m: 30 x 30 m (4 looks); High-Resolution 5 m: 5 x 5 m (1 look); Very High Resolution 1- 3 m; Swath width: Low Resolution 100 m: 500 km; Medium Resolution 50 m: 350 km; Medium Resolution 16 m: 30 km; Medium Resolution 30 m: 125 km; High-Resolution 5 m: 30 km; Very High Resolution 3 m: 20 km; Low Noise 100m: 350 km; Spotlight: 5 km; Ship Detection: 350 km. AIS for ship identification
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
SAR: Maritime surveillance (ice, wind, oil pollution and ship monitoring); disaster management (mitigation, warning, response and recovery); and ecosystem monitoring (forestry, agriculture, wetlands and coastal change monitoring) AIS: Better than 90% ship detection, for Class A ships, when ships are in view for a minimum of 5 minutes.
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Increased revisit frequency of three RCM satellites likely to improve monitoring in Canada's North (4 observations per day); increased change detection such as those induced by climate change, land use evolution, coastal change, urban subsidence and even human impacts on local environments.
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
Suppliers of data / data products
The Government of Canada will own the RCM satellites and data, and will control data dissemination. CSA is the prime authority for its operation and management. SAR data policy different from RADARSAT-2 data policy; likely open access; estricted access for AIS
Range of costs to acquire (per scene, per square kilometre)
RCM data policy
Additional information

https://earth.esa.int/documents/10174/233696/5-From_RADARSAT-2_RADARSAT_Constellation+Mission+data+continuity.pdf
Bibliography (references from sections above and additional important references)
Useful websites
http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=946 http://www.asc-csa.gc.ca/eng/satellites/radarsat/default.asp
Name of the Sensor / Platform
RISAT-1, Indian Space Research organization, ISAR; India
Brief Description of the technology (platform base, start and end dates availability (satellite))
Imaging radar, synthetic aperture radar (SAR), 2012 -2017
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Active imaging microwave radar, C-band; different imaging modes; resolutions; 3 - 6 m (FRS-1), 9 - 12 m (FRS-2), 25/50 m (MRS/CRS), best resolution: 3 m; swath width: 30 km (HRS), 30 km (FRS-1/FRS-2), 120/240 km (MRS/CRS) [Max Swath: 240 km]
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
Multi-purpose land imagery; ocean topography and currents, coastal studies
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
Suppliers of data / data products
ISRO, constrained access
Range of costs to acquire (per scene, per square kilometre)
Additional information
http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=790
Bibliography (references from sections above and additional important references)
http://www.isro.gov.in/sites/default/files/pdf/pslv-brochures/PSLVC19.pdf
Useful websites
http://isro.gov.in/Spacecraft/risat-1

Table 4.5: TerraSAR-X/TanDEM-X

Name of the Sensor / Platform / Operator / Country
TerraSAR-X/TanDEM-X, German Aerospace Center (DLR), Germany
Brief Description of the technology (platform base, start and end dates availability (satellite))
High-resolution imaging radar (SAR), 2007 – 2015(nominal)
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Active, X-Band synthetic aperture radar with a variety of imaging and polarization modes; spatial resolution: Spotlight Mode 1.2 x 1 - 4 m, Stripmap Mode 3 x 3 - 6 m, ScanSAR Mode 16 x 16 m (best resolution: 1 m); Swath width: Spotlight Mode 5-10km x 10 km, Stripmap Mode 30 km, ScanSAR Mode 100 km
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
High resolution images for monitoring of land surface and coastal processes and for agricultural, geological and hydrological applications; ocean surface currents, ship detection, sea ice.
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Provision of a world-wide DEM data set
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
Suppliers of data / data products
DLR, scientific users have the option to respond to Announcements of Opportunity (AOs); registration is required
Range of costs to acquire (per scene, per square kilometre)
Science data (COFUR) cost range from Euro 160 to 200.
Additional information
http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=697 http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10377/565_read-436/#/gallery/350 DLR maintains a TSX receiving station in Canada's Arctic
Bibliography (references from sections above and additional important references)
http://www.dlr.de/dlr/en/Portaldata/1/Resources/documents/TSX_brosch.pdf http://terrasar-x.dlr.de/
Useful websites
http://terrasar-x.dlr.de/

4.2 Other Satellite-based Sensors

Table 4.6: AIS Sat-2 / Automatic Identification System Satellite-2

Name of the Sensor / Platform / Operator / Country
AIS Sat-2 / Automatic Identification System Satellite-2, Norwegian Space Center, Norway
Brief Description of the technology (platform base, start and end dates availability (satellite))
Communication system; AIS (Automatic Identification System); July 2014 – June 2017
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Software Defined Radio / SDR for reception of VHF AIS (Automatic Identification System)
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below):
AIS signals beyond the land-based AIS system operated by the Norwegian Coastal Administration; observe ship traffic in the High North
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts(include a few references in bibliography below)
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards):
Modelling shows that the instrument should detect more than 95% of the vessels carrying AIS within the satellite's field of view in the High North each orbit.
Suppliers of data / data products
Norwegian Space Center / NSC, AISSat-3 planned for July 2015 – July 2018
Range of costs to acquire (per scene, per square kilometre)
Very constraint access; technology is relevant to Canada because Canada's RADARSAT Constellation Mission will carry AIS as part of operational ship detection and identification application development.
Additional information
http://database.eohandbook.com/database/missionsummary.aspx?missionID=714
Bibliography (references from sections above and additional important references)
Useful websites

Table 4.7: PRISMA

Name of the Sensor / Platform / Operator / Country
PRISMA (PRecursore IperSpettrale of the application mission); Italian Space Agency (ASI), Italy
Brief Description of the technology (platform base, start and end dates availability (satellite))
PRISMA is a "small" earth observation system with innovative electro-optical instrumentation that combines a hyperspectral sensor with a panchromatic, medium-resolution camera; 2017-2022
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Passive Hyperspectral/Panchromatic; resolution: 20-30 m (Hyp) / 2.5-5m (PAN); swath width: 30-60 km; spectral range: 0.4 - 2.5 µmm (Hyp) / 0.4 - 0.7 µm (PAN); ontinuous coverage of spectral ranges with 10 nm bands
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below): Experimental and limited time mission to make available to the scientific community for developing new applications for environmental risk management based on high-resolution spectral images
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below): Pollution monitoring; quality of inland waters; coastal zones and Mediterranean Sea
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards): Small-Sat technology is also being developed in Canada, and the PRISMA mission provides potentially valuable precursor experience for coastal applications in Canada
Suppliers of data / data products
ASI; Carlo Gavazzi Space, S.p.A (procurement) and Selex-Galileo Avionica S.p.A and Oerlikon Contraves Rheinmetall Italia S.p.A (principal contractor)
Range of costs to acquire (per scene, per square kilometre)
TBD
Additional information
https://directory.eoportal.org/web/eoportal/satellite-missions/p/prisma-hyperspectral http://www.asi.it/files/The%20PRISMA%20mission.pdf (2009)
Bibliography (references from sections above and additional important references)
https://directory.eoportal.org/web/eoportal/satellite-missions/p/prisma-hyperspectral (see extensive PRISMA bibliography at the end of the document)
Useful websites
http://www.asi.it/en/activity/earth_observation/prisma_ http://database.eohandbook.com/database/agencysummary.aspx?agencyID=1

Table 4.8: Sentinel-3A and 3B; ESA / EUMETSAT

Name of the Sensor / Platform / Operator / Country
Sentinel-3A and 3B; ESA / EUMETSAT; European Union
Brief Description of the technology (platform base, start and end dates availability (satellite))
Multiple sensors: Sea and Land Surface Temperature Radiometer (imaging multi-spectral radiometers, vis/IR); Ocean and Land Colour Imager, 2015 – 2024
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Sea and Land Surface Temperature Radiometer (imaging multi-spectral radiometers, VIS/IR) with Passive VNIR/SWIR, 500 m resolution; TIR 1 km resolution; max. swath width: 1675 km (near-nadir view), 750 km (backward view); 9 bands in VNIR/SWIR/TIR: VIS (~0.40 µm - ~0.75 µm), NIR (~0.75 µm - ~1.3 µm), SWIR (~1.3 µm - ~3.0 µm), and TIR (~6.0 µm - ~15.0 µm) Passive Ocean and Land Colour Imager; 300 m resolution; 1270 km swath width; 21 bands in VNIR/SWIR, VIS (~0.40 µm - ~0.75 µm), NIR (~0.75 µm - ~1.3 µm) Active C-band SAR / Ku-Band Radar Altimeter; 300 m resolution (profiler) with 3 cm (surface accuracy in range), 2 m for significant wave height;
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below):
SLSTR: multi-purpose imagery for land and ocean sensing; designated for operational application; OLCI: ocean colour/biology, ocean chlorophyll concentration, ocean suspended sediment concentration, color dissolved organic matter (CDOM) SAR / Radar Altimeter: Ocean surface winds (wind speed over sea surface, horizontal), ocean topography/currents (sea level, ocean dynamic topography), ocean wave height and spectrum (significant wave height), sea ice cover, edge and thickness (sea-ice cover, sea-ice thickness)
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below):
global land and ocean monitoring services, in particular: sea/land colour data and surface temperature; sea surface and land ice topography; coastal zones, inland water and sea ice topography; vegetation products.
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards):
Canada is a member of ESA and has certain data access privileges; the EU is making Sentinel data available to users free of charge or at nominal cost.
Suppliers of data / data products
European Space Agency / ESA, open access
Range of costs to acquire (per scene, per square kilometre)
Open data access
Additional information

http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=902 http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=896 http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=903
Bibliography (references from sections above and additional important references)
http://esamultimedia.esa.int/multimedia/publications/SP-1322_3/
Useful websites
http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-3

Table 4.9: Jason-3

Name of the Sensor / Platform / Operator / Country
Jason-3 / NASA, NOAA, CNES, EUMETSAT / USA, France
Brief Description of the technology (platform base, start and end dates availability (satellite))
Positioning Ocean Solid Earth Ice Dynamics Orbiting Navigator (Single frequency solid state radar altimeter) Poseidon-3B Radar Altimeter; 2015 – 2018 (2020)
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
C- and Ku-Band altimeters: Sea level 3.4 cm accuracy; significant wave height: 40 cm accuracy; horizontal sea surface wind speed: 1.5 m / sec.
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
Nadir viewing sounding radar for provision of real-time high precision sea surface topography, ocean circulation and wave height data.
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Refinement of coastal models (physical oceanography); climate monitoring
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
Data products are provided through NOAA's CLASS system (see URL below) http://www.class.ncdc.noaa.gov/saa/products/welcome;jsessionid=63A5CA89E32943A904998A584866C21D
Suppliers of data / data products
NASA, NOAA, CNES
Range of costs to acquire (per scene, per square kilometre)
Open access
Additional information
http://sealevel.jpl.nasa.gov/missions/jason3/
Bibliography (references from sections above and additional important references)
Useful websites
http://www.jpl.nasa.gov/missions/jason-3/ http://www.eumetsat.int/website/home/Satellites/FutureSatellites/Jason3/index.html

Table 4.10: Visible/Infrared Imager Radiometer Suite (VIIRS)

Name of the Sensor / Platform
Visible/Infrared Imager Radiometer Suite (VIIRS) / Joint Polar Satellite System (JPSS-1) / NOAA, NASA / USA ; 2017 – 2024
Brief Description of the technology (platform base, start and end dates availability (satellite))
Multi-purpose imaging VIS/IR radiometer
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
VIIRS: 400 – 1600 m resolution; 3000 km swath width, VIS - TIR: 0.4 - 12.5 µm (22 channels), VIS (~0.40 µm - ~0.75 µm), NIR (~0.75 µm - ~1.3 µm), SWIR (~1.3 µm - ~3.0 µm), MWIR (~3.0 µm - ~6.0 µm), TIR (~6.0 µm - ~15.0 µm)
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
Global observations of land, ocean, and atmosphere parameters: cloud/weather imagery, sea-surface temperature, ocean colour, land surface vegetation indices.
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Global ocean and coastal observation, sea surface temperature (SST), ocean colour (chlorophyll concentrations), sea ice cover (ice type
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
Launch date under review. Meteorological, climatic, terrestrial, oceanographic, and solar-geophysical applications; global and regional environmental monitoring, search and rescue, data collection.
Suppliers of data / data products
NASA, NOAA
Range of costs to acquire (per scene, per square kilometre)
Open access for accredited users
Additional information
http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=412
Bibliography (references from sections above and additional important references)
Useful websites
http://www.jpss.noaa.gov/

Table 4.11: VIIRS / SUOMI NPP

Name of the Sensor / Platform
VIIRS / SUOMI NPP / NASA, NOAA, USA
Brief Description of the technology (platform base, start and end dates availability (satellite))
Multi-purpose imaging VIS/IR radiometer; 2011
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Passive,
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
Various ocean parameters, including sea surface temperature, phytoplankton production, sea ice, surface wind fields and sea height
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
Suppliers of data / data products
Detailed product specifications are provided at http://viirsland.gsfc.nasa.gov/Products.html
Range of costs to acquire (per scene, per square kilometre)
Additional information
Bibliography (references from sections above and additional important references)
http://viirsland.gsfc.nasa.gov/Publications/PubsPR.html
Useful websites
http://viirsland.gsfc.nasa.gov/index.html

Table 4.12: RESOURCESAT-2

Name of the Sensor / Platform
RESOURCESAT-2, Indian Space Research Organization, ISRO, India
Brief Description of the technology (platform base, start and end dates availability (satellite))
Multi-purpose imaging VIS/IR radiometer, high resolution optical imagers
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Passive, Advanced Wide Field Sensor (AWFS), 55 m resolution, swath width 740 km; VIS: 0.52 - 0.59 µm and 0.62 - 0.68 µm, NIR: 0.77 - 0.86 µm, SWIR: 1.55 - 1.7 µm; VIS (~0.40 µm - ~0.75 µm), NIR (~0.75 µm - ~1.3 µm), SWIR (~1.3 µm - ~3.0 µm) Passive, Linear Imaging Self Scanner – III (LISS-III), 23 m resolution, 141 km swath width; VIS: Band 2: 0.52 - 0.59 µm, Band 3: 0.62 - 0.68 µm, NIR: Band 4: 0.77 - 0.86 µm, SWIR: Band 5: 1.55 - 1.75 µm, VIS (~0.40 µm - ~0.75 µm), NIR (~0.75 µm - ~1.3 µm), SWIR (~1.3 µm - ~3.0 µm) Passive, Linear Imaging Self Scanner – IV(LISS-IV), 5.8 m resolution, 70 km swath width; VIS: 0.52 - 0.59 µm, 0.62 - 0.68 µm, NIR: 0.77 - 0.86 µm; VIS (~0.40 µm - ~0.75 µm), NIR (~0.75 µm - ~1.3 µm)
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
Multi-purpose imagery (land / coastal surfaces); data used for vegetation type assessment, resource assessment, regional-scale and detailed land use and land cover change.
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
AWFS and LISS-III: Open access; LISS-IV: Constrained access; data continuity provided by planned RESOURCESAT-2A launch in 2016
Suppliers of data / data products
ISRO
Range of costs to acquire (per scene, per square kilometre)
Additional information
http://isro.gov.in/Spacecraft/resourcesat-2 http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=461 http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=934 http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=460
Bibliography (references from sections above and additional important references)
http://www.isro.gov.in/sites/default/files/pdf/pslv-brochures/PSLVC16.pdf
Useful websites
http://www.antrix.gov.in/earth_observation.html

Table 4.13: Oceansat-2

Name of the Sensor / Platform / Operator / Country
Oceansat-2, Indian Space Research Organization, ISRO, India
Brief Description of the technology (platform base, start and end dates availability (satellite))
Medium-resolution spectro-radiometer (OCM); Radar scatterometer (SCATT) 2009 – 2016
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Passive, Ocean Colour Monitor (OCM); spatial resolution 236 x 360 m; swath width 1420 km; 8 spectral bands, VIS - NIR: 0.40 - 0.88 µm (8 channels); VIS (~0.40 µm - ~0.75 µm), NIR (~0.75 µm - ~1.3 µm); Ku-Band pencil beam scatterometer (SCAT), spatial resolution 50 km; swath width 1440 km; ROSA GPS receiver for atmospheric sounding by radio occultation
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
Systematic data collection for oceanographic, coastal and atmospheric applications; OCM for ocean colour/biology (chlorophyll concentration), identification of potential fishing zones, assessment of primary productivity; SCAT for horizontal wind speed and direction;
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
SCATT no longer operational (instrument failed Feb. 2014)
Suppliers of data / data products
Open access for OCM and SCATT.
Range of costs to acquire (per scene, per square kilometre)
Additional information
http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=464 http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=752 http://isro.gov.in/Spacecraft/oceansat-2
Bibliography (references from sections above and additional important references)
http://www.isro.gov.in/sites/default/files/pdf/pslv-brochures/PSLVC14.pdf
Useful websites
http://isro.gov.in/spacecraft/earth-observation-satellites

Table 1.14: LANDSAT-8

Name of the Sensor / Platform
LANDSAT-8, US Geological Survey, NASA, USA
Brief Description of the technology (platform base, start and end dates availability (satellite))
High-resolution optical imager (OMI multispectral radiometer), Narrow-band channel IR radiometer (TIRS); 2013 – 2023
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Passive, Operational Land Imager (OMI); spatial resolution 15 m (panchromatic), VIS and SWIR 30 m; swath width 185 km; VIS - SWIR: 9 bands: 0.43 - 2.3 µm; VIS (~0.40 µm - ~0.75 µm), NIR (~0.75 µm - ~1.3 µm), SWIR (~1.3 µm - ~3.0 µm) Passive, Thermal Infrared Sensor (TIRS); spatial; resolution 100 m, swath width 185 km; TIR 10.5 µm and 12 µm.
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
Earth resources, land surface, environmental monitoring (including coastal zone), agriculture and forestry, disaster monitoring and assessment, ice and snow cover.
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
http://landsat.usgs.gov/landsat_level_1_standard_data_products.php http://landsat.usgs.gov/tools_acq.php
Suppliers of data / data products
USGS, details at http://landsat.usgs.gov/Landsat_Search_and_Download.php
Range of costs to acquire (per scene, per square kilometre)
Open access, LANDSAT Level 1 data can be accessed via Internet at no charge
Additional information
http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=1524 http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=897 http://landsat.usgs.gov/
Bibliography (references from sections above and additional important references)
Useful websites
http://landsat.usgs.gov/index.php http://www.nasa.gov/mission_pages/landsat/main/index.html http://landsat.gsfc.nasa.gov/?page_id=4071

Table 4.15: Satellite Pour l'Observation de la Terra (SPOT-5)

Name of the Sensor / Platform / Operator / Country
Satellite Pour l'Observation de la Terra (SPOT-5), CNES, France
Brief Description of the technology (platform base, start and end dates availability (satellite))
High- and medium resolution optical imagers, Multi-purpose imaging radiometer, 2002 – 2015
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
High resolution optical (HRG) with off-nadir steering capability; resolution 5 m panchromatic, 10 m multispectral; swath width 60-117 km; VIS: B1: 0.50 - 0.59 µm, B2: 0.61 - 0.68 µm, NIR: B3: 0.79 - 0.89 µm, SWIR: 1.50 - 1.75 µm, Panchromatic: 0.49 - 0.69 µm; VIS (~0.40 µm - ~0.75 µm), NIR (~0.75 µm - ~1.3 µm), SWIR (~1.3 µm - ~3.0 µm) High resolution stereoscope (HRS); resolution 10 m panchromatic; swath width 120 km; panchromatic VIS 0.49 - 0.69 µm VEGETATION multispectral radiometer; resolution 1150 m, swath width 2200 km; Operational mode: VIS: 0.61 - 0.68 µm, NIR: 0.78 - 0.89 µm, SWIR: 1.58 - 1.75 µm, Experimental mode: VIS: 0.43 - 0.47 µm
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
HRG: Multi-purpose land and coastal imaging; HGS: land surface topography; vegetation assessment and monitoring (regional scale)
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
Global coverage and fast product delivery available
Suppliers of data / data products
Satellite Imaging Corporation, http://www.satimagingcorp.com/satellite-sensors/other-satellite-sensors/spot-5/
Range of costs to acquire (per scene, per square kilometre)
Additional information
http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=759 http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=183 http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=404
Bibliography (references from sections above and additional important references)
http://www.geo-airbusds.com/files/pmedia/public/r233_9_geo_0013_spot_en_low.pdf
Useful websites
http://www.satimagingcorp.com/satellite-sensors/other-satellite-sensors/spot-5/

Table 4.16: Satellite Pour l'Observation de la Terra (SPOT-6 / 7)

Name of the Sensor / Platform / Operator / Country
Satellite Pour l'Observation de la Terra (SPOT-6 / 7), Airbus Defence and Space, France
Brief Description of the technology (platform base, start and end dates availability (satellite)
High- and medium resolution optical imagers, Multi-purpose imaging radiometer, 2012/14 – 2022/24
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Passive, High resolution multi-spectral imagery with off-nadir steering capability; resolution 1.5 m panchromatic, 6 m multispectral; swath width 60 – 120 km; Blue (0.455 µm – 0.525 µm), Green (0.530 µm – 0.590 µm), Red (0.625 µm – 0.695 µm), Near-Infrared (0.760 µm – 0.890 µm)
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
Multi-purpose land and coastal imaging, DEM generation
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
Global coverage, daily revisit capability and fast product delivery available; 120 km x 120 km bi-strip or 60 Km x 180 km tri-strip mapping in a single pass and delivery of mosaic; stereo and tri-stereo acquisition of 60 Km x 60 km scenes for production of DEM; several weather forecasts per day to optimize tasking. Rush tasking orders for satellite image data around the world are accepted in support of live events, natural disasters, global security, and various other applications.
Suppliers of data / data products
Satellite Imaging Corporation, http://www.satimagingcorp.com/satellite-sensors/other-satellite-sensors/spot-7/
Range of costs to acquire (per scene, per square kilometre)
Additional information
http://www.geo-airbusds.com/files/pmedia/public/r2928_9_geo_012_spot6-7_en_low.pdf
Bibliography (references from sections above and additional important references)
http://www.geo-airbusds.com/files/pmedia/public/r2928_9_geo_012_spot6-7_en_low.pdf
Useful websites
http://www.satimagingcorp.com/satellite-sensors/other-satellite-sensors/spot-7/

Table 4.17: WorldView-3

Name of the Sensor / Platform / Operator / Country
WorldView-3, DigitalGlobe, USA
Brief Description of the technology (platform base, start and end dates availability (satellite))
Multi-payload super-spectral high-resolution commercial satellite, 2014 – 2024
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Passive, Very high-resolution panchromatic, resolution 31 cm; multi-spectral with 13 km swath width, resolution 1.24 m, short-wave infrared resolution 3.7 m, CAVIS 30 m resolution; 4 VNIR bands added for coastal, yellow, red edge, near-IR; 12 CVAIS bands for mapping clouds, ice and snow, and aerosol and water vapour correction strip map swath width 26 – 66 km.
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
Mapping, land classification, disaster preparedness and response, change detection, environmental monitoring, bathymetry and coastal applications.
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
Direct access tasking; daily revisit capabilities, large area mono and stereoscopic data collection, 66x112 km and 26x112 km, respectively
Suppliers of data / data products
DigitalGlobe, USA (also provides archived QuickBird and GeoEye imagery); data products include high resolution individual scenes, strip maps, large area (112 km) coverage mosaics; GIS-ready basemaps;
Range of costs to acquire (per scene, per square kilometre)
Archive data: Pan: ~USD13/skm, Multi-spectral: ~USD16/skm; new acquisitions: Pan: ~USD22/skm, Multi-spectral: ~USD25/skm; http://www.landinfo.com/satellite-imagery-pricing.html
Additional information
Bibliography (references from sections above and additional important references)
http://satimagingcorp.s3.amazonaws.com/site/pdf/WorldView3-DS-WV3-Web.pdf http://www.landinfo.com/Imagery_LandInfo_Oct2014_50cm.pdf http://www.landinfo.com/buying-optical-satellite-imagery.html
Useful websites
https://www.digitalglobe.com/

Table 4.18: Aqua / Terra satellite constellation (formerly EOS PM-1 and EOS AM-1)

Name of the Sensor / Platform
Aqua / Terra satellite constellation (formerly EOS PM-1 and EOS AM-1), NASA (and other space agencies), USA
Brief Description of the technology (platform base, start and end dates availability (satellite))
Multi-sensor platforms, including AIRS, AMSR-E, AMSU-A, CERES, HiRDLS, HSB, MODIS (Aqua) and ASTER, CERES, MISR, MODIS, MOPITT (Terra) instruments, 1999 (Terra) / 2002 (Aqua) – 2015
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
MODerate-Resolution Imaging Spectroradiometer (MODIS); 250 m resolution; swath width 2330 km; VIS - TIR: 36 bands in range 0.4 - 14.4 µm; VIS (~0.40 µm - ~0.75 µm), NIR (~0.75 µm - ~1.3 µm), SWIR (~1.3 µm - ~3.0 µm), MWIR (~3.0 µm - ~6.0 µm), TIR (~6.0 µm - ~15.0 µm)
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
Multi-purpose imagery (land and ocean), ocean colour / biology (chlorophyll concentrations, suspended sediment concentration), sea ice cover, sea surface temperature, vegetation indices
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Atmospheric dynamics/water and energy cycles, atmospheric chemistry, physical and radiative properties of clouds, air-land exchanges of energy, carbon and water, vertical profiles of CO and methane volcanology.
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
https://earthdata.nasa.gov/data/near-real-time-data/rapid-response Near real-time data availability via Internet
Suppliers of data / data products
NASA, various data products and subsets of global coverage (2x per day, i.e Terra MODIS AM and Aqua MODIS PM)
Range of costs to acquire (per scene, per square kilometre)
Open access
Additional information
http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=395 http://modis.gsfc.nasa.gov/
Bibliography (references from sections above and additional important references)
http://www.nasa.gov/pdf/156292main_Terra_brochure.pdf http://oceancolor.gsfc.nasa.gov/cms/
Useful websites
http://www.nasa.gov/mission_pages/aqua/index.html http://www.nasa.gov/mission_pages/terra/index.html

Table 4.19: RapidEye Satellite Constellation

Name of the Sensor / Platform / Operator / Country
RapidEye Satellite Constellation (5 satellites, built by MDA, Canada), BlackBridge, Germany
Brief Description of the technology (platform base, start and end dates availability (satellite))
High-resolution multi-spectral imagers (push=broom scanning), commercial satellite constellation, 2008 - 2019
Sensor Characteristics (passive / active, range of on the ground resolutions, frequency sensitivities)
Passive, multi-spectral imager, resolution 6.5 m, swath width 77 km; 5 spectral bands: Blue 440-510 nm, Green 520-590 nm, Red 630-685 nm, Red Edge 690-730 nm, NIR 760-850 nm
Routine / common applications of the technology for coastal and ocean remote sensing i.e. routinely used (in Canada or worldwide) for management purposes and relevant to Canadian coasts (include a few references in bibliography below)
Energy and infrastructure, mapping, environment, security and emergency
Emerging applications of the technology i.e. under development or used in research and relevant to Canadian coasts (include a few references in bibliography below)
Important considerations in acquiring / using this technology (acquisition / survey planning, data processing effort, existing standards)
http://www.blackbridge.com/rapideye/about/resources.htm?tab=2#TabbedPanels1
Suppliers of data / data products
http://www.blackbridge.com/rapideye/upload/RE_Product_Specifications_ENG.pdf http://www.blackbridge.com/rapideye/upload/RapidEye_Mosaic_Product_Specifications.pdf BlackBridge and value-added reseller provide RapidEye basic image products, 25x25 km tile Orth products, orthorectified and radiometrically corrected mosaics, and 'persistent change detection monitoring' (PCM)
Range of costs to acquire (per scene, per square kilometre)
~USD1.28 / skm (min. 500 contiguous skm, archive; 3500 skm on-demand tasking)
Additional information
http://www.blackbridge.com/rapideye/upload/RE_Product_Specifications_ENG.pdf http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=831
Bibliography (references from sections above and additional important references)
http://www.blackbridge.com/rapideye/upload/EyeFind_UserGuide.pdf http://www.blackbridge.com/rapideye/upload/RE_Product_Specifications_ENG.pdf http://www.blackbridge.com/rapideye/upload/RapidEye_Mosaic_Product_Specifications.pdf http://www.blackbridge.com/rapideye/about/resources.htm?tab=0#TabbedPanels1 http://www.blackbridge.com/rapideye/about/resources.htm?tab=0#TabbedPanels1
Useful websites
http://www.blackbridge.com/rapideye/index.html http://is.mdacorporation.com/mdais_canada/Programs/Programs_RapidEye.aspx