A Spaceborne Coastal and Inland Water Color Hyperspectral Imager

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Outline

- Joint Feasibility Study
- Progress Timeline
- Main Payload Requirements
- Payload Design Approaches
- Developed Payload Concept
- Excepted Performance
- Conclusion

Joint Feasibility Study

A Coastal and Inland Waters Hyperspectral Imager (Canadian WaterSat)

Canada has been developing since 2014 a VNIR hyperspectral imager with 100 m GSD specifically designed to image coastal areas, estuaries and lakes.

A Feasibility Study done in Partnership

The Canadian Space Agency (CSA) teamed with the US Naval Research Laboratory (NRL), which built the Hyperspectral Imager for the Coastal Ocean (HICO) to respond to the NASA's Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) science team need for coastal science questions. The plan was for Canada to build a **Coastal Ocean Color Imager (COCI)** payload while the U.S. would provide the imager pointing mechanism, accommodation on the spacecraft and operations.

This opportunity had obtained significant User support in Canada (Government and Academia) and in the U.S.

… that is until the NASA's PACE mission status became uncertain.

Progress Timeline

- **Schedule Highlights:**
  - KOM – April 24th 2014 at CSA;
  - MCR – December 18th 2014;
  - MRR – March 31st 2015;

Canadian WaterSat

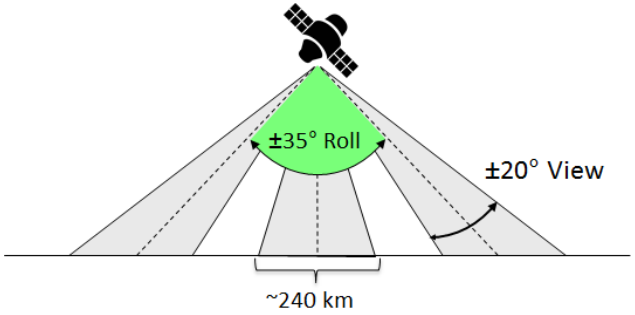
  - NRL visit at CSA – March 15-16th 2016;
  - Kick-off Meeting (KOM) and U&ST Meeting #1 - June 1st & 2nd 2016 at NASA GSFC;
  - U&ST Meeting #2 - July 21-22th 2016 at DFO in Ottawa;
  - U&ST Meeting #3 – Nov. 29-30th 2016 at NRCan in Ottawa;
  - Mission Concept Review (MCR) - March 20-21st 2017 at NASA GSFC.

Joint Study COCI

- **Now supported by identified Needs and Documented Business Case:**
  - URD and Business case (Draft) are now ready for disclosure.

Main Payload Requirements

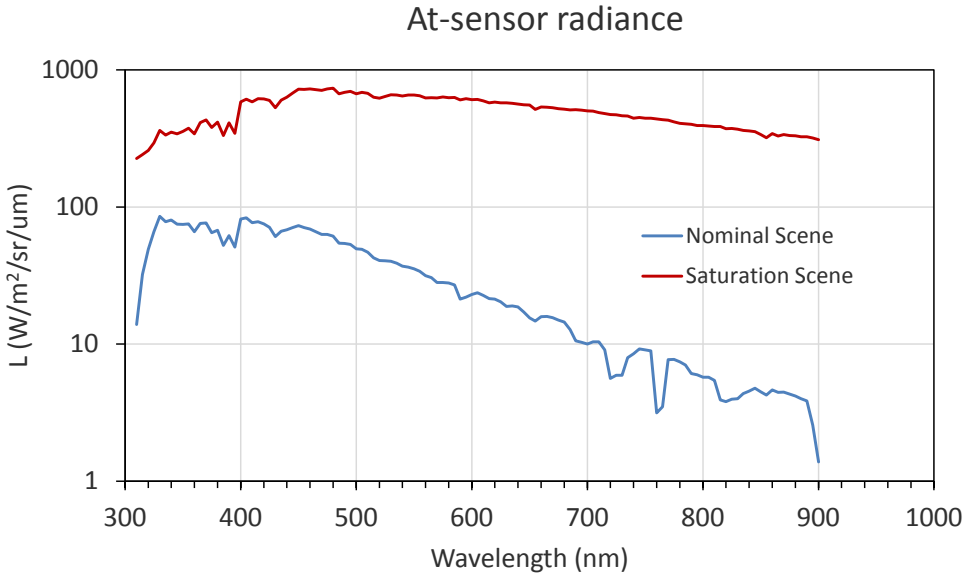
Swath width:	**≥ 240 km at an orbit of 675 km**
	Fore & aft scanning ± 20°
	Cross-track pointing ± 35°
Spatial sampling (nadir):	**100 m (threshold: < 150 m)**
Spectral range:	**350 nm to 1000 nm (goal)**
	400 nm to 865 nm (threshold)
Spectral sampling interval:	**≤ 5 nm**
Sensitivity:	**Peak SNR > 400 for water surfaces, 30° SZA (goal: > 900)**
	SNR > 50 for water surfaces, 30° SZA
Saturation scene:	**~90% albedo**
Polarization sensitivity:	**< 3%**



Payload Design Approaches

Design Challenges

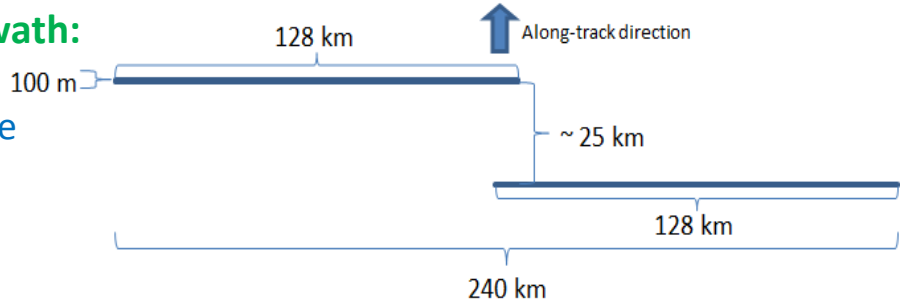
- **Wide Swath**
  - **Required 240 km swath and 100 m GSD**
    → **> 2400 across-track elements**
    ~20° FOV
- **High dynamic range (ratio up to 140) caused Saturation**
  - **Reference scene is relatively faint (clear water)**
  - **High SNR desired (900:1)**
  - **Bright scene can be Saturated**



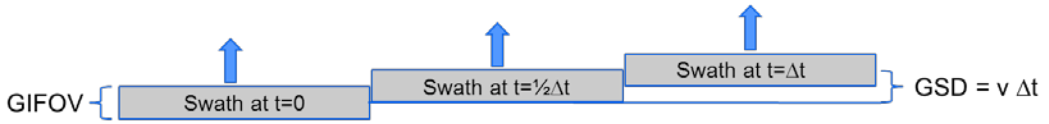
Payload Design Approaches

Spatial acquisition scheme selected to deal with wide swath:

- Split the swath into two equal halves
- Feed two identical spectrometers with a common telescope
  - Require a smaller detector array
  - Reduce the divergence in the spectrometers, and
  - Reduce the total volume of the aft optics



- Oversampling in time
  - Acquire for half the smear distance, twice
  - Combine after acquisition



Spectral acquisition scheme to deal with high dynamic range:

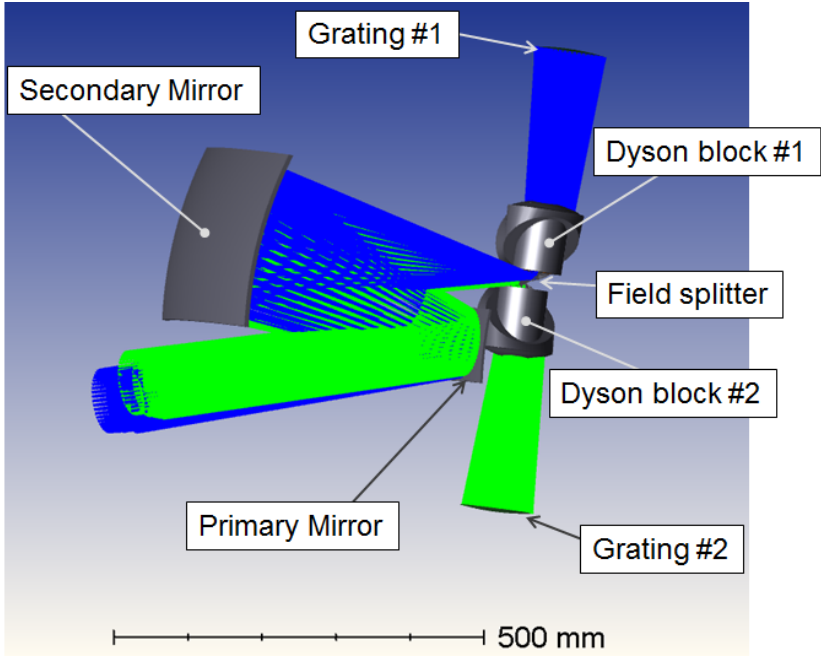
- Sampled every 1.25 nm
  - Take advantage of available detector rows
  - Further reduction of saturation

Payload Concept - Overview

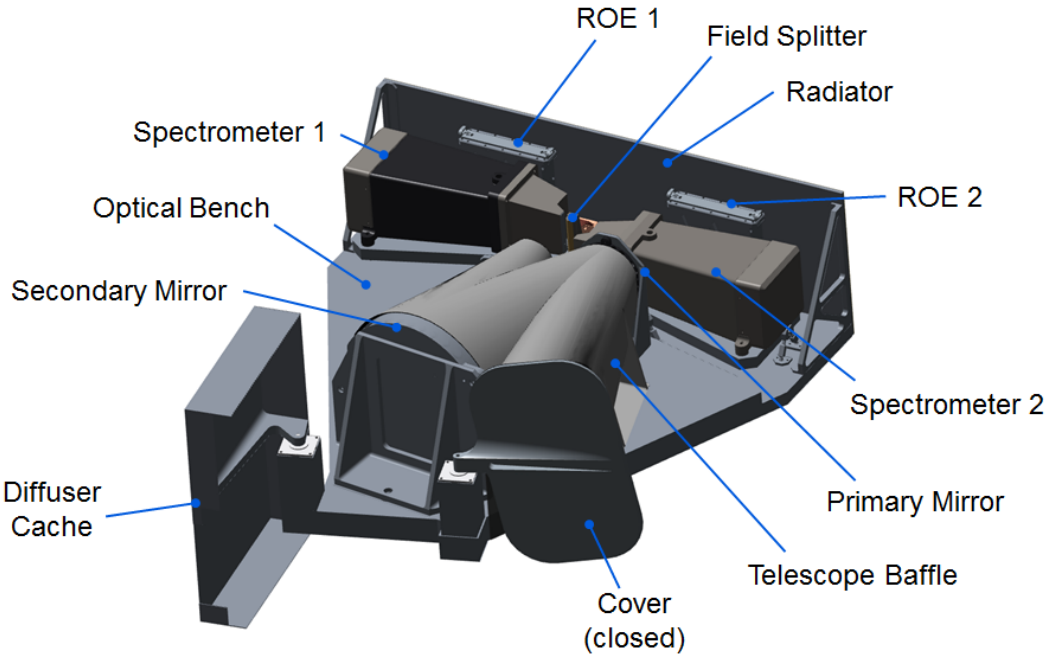
- One common telescope
- Two spectrometers to cover the full swath
  - Dyson spectrometers
  - One detector array 1280 × 480 per spectrometer
- Optical layout and coatings to reduce polarization sensitivity
- Onboard radiometric references
  - Shutter and solar diffuser
- Onboard along-track spatial binning (2:1 to achieve 100m GSD)
- Onboard spectral binning (depending on operation mode, e.g. 5nm by 4:1 pinning)
- Payload mounted on rotating platform (±35°) for sun glint avoidance and scanning (±20°)

Payload Concept

Optical layout



Instrument Outlook



Performance Summary

Parameter	Value	Notes
Altitude	675 km	
FOV	20.2° × 4.2°	
Swath width	240 km	
GIFOV at nadir	100 m × 100 m	
IFOV	0.148 mrad × 0.148 mrad	
GSD	Across-track: 100 m Along-track: Sampled at 50 m then binned to 100 m	
F / #	2.38	
Integration time per sample	5.88 ms	
Integration period	7.35 ms	
Spectral range	360 nm to 910 nm	
Spectral sampling interval (raw)	1.25 nm	
Spectral resolution (FWHM)	< 6.5 nm	4 spectral elements binned
Peak SNR (dim scene 5% albedo)	900 at 450 nm	For 10 nm sampling, 100 m × 100 m
Saturation level	80% with maximum scene	
Estimated Enveloppe	Optical head: 37 cm × 80 cm × 112 cm E-Box: 23 cm × 33 cm × 17 cm	Excluding gimbal
Estimated mass	Optical head: 57 kg E-Box: 19 kg	Excluding gimbal 25% contingency
Estimated power	119 W peak (when repointing)	Including gimbal 35% contingency
Data rate when imaging	169 Mbits /s	100 m and 5 nm Assuming 2:1 compression

Expected Performance

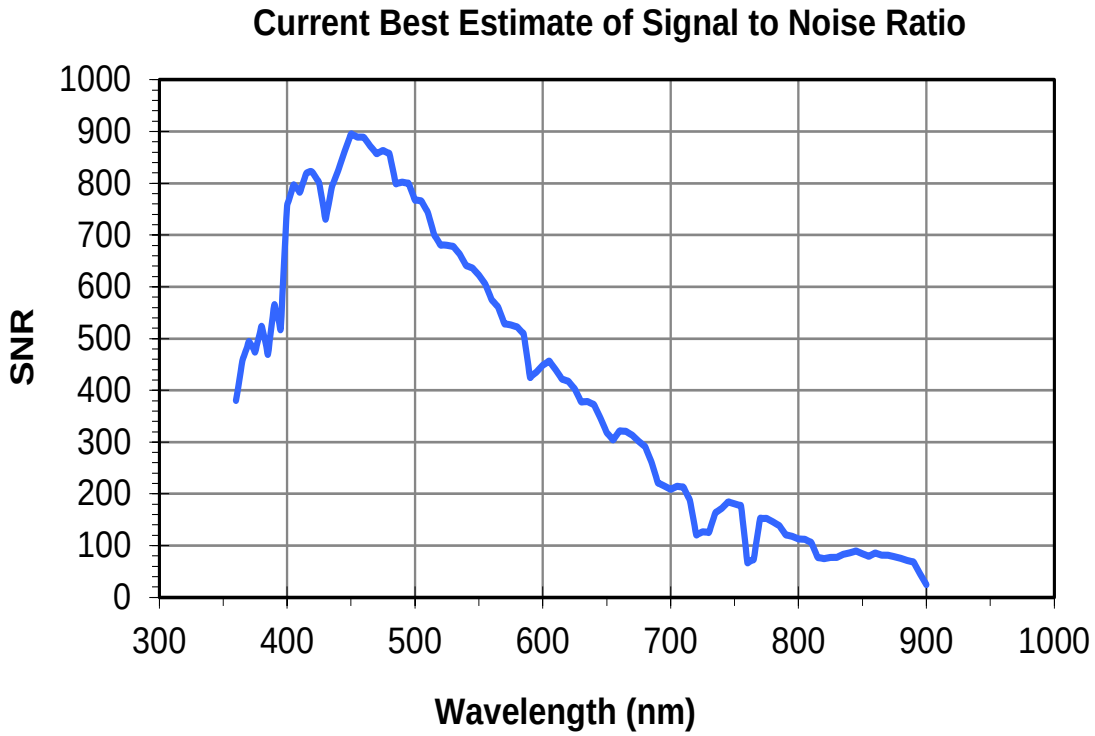
Signal-to-noise ratio

For:

Nominal scene

10 nm spectral sampling

100 m ground sampling distance

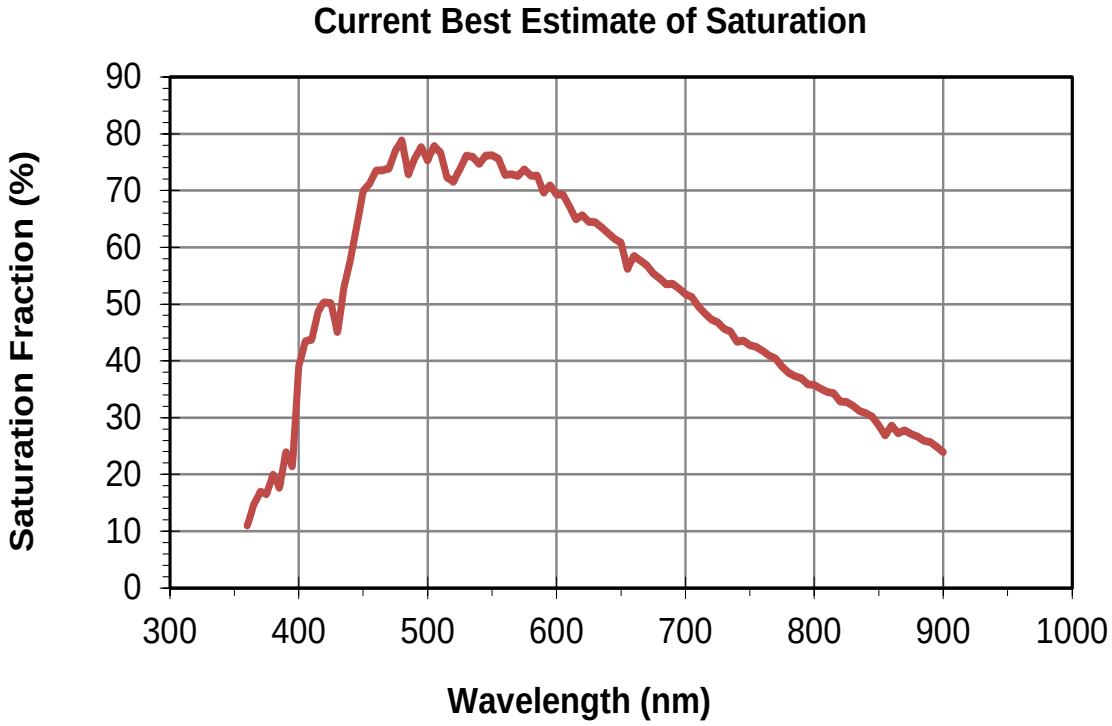


Expected Performance

Saturation

For:

Bright scene

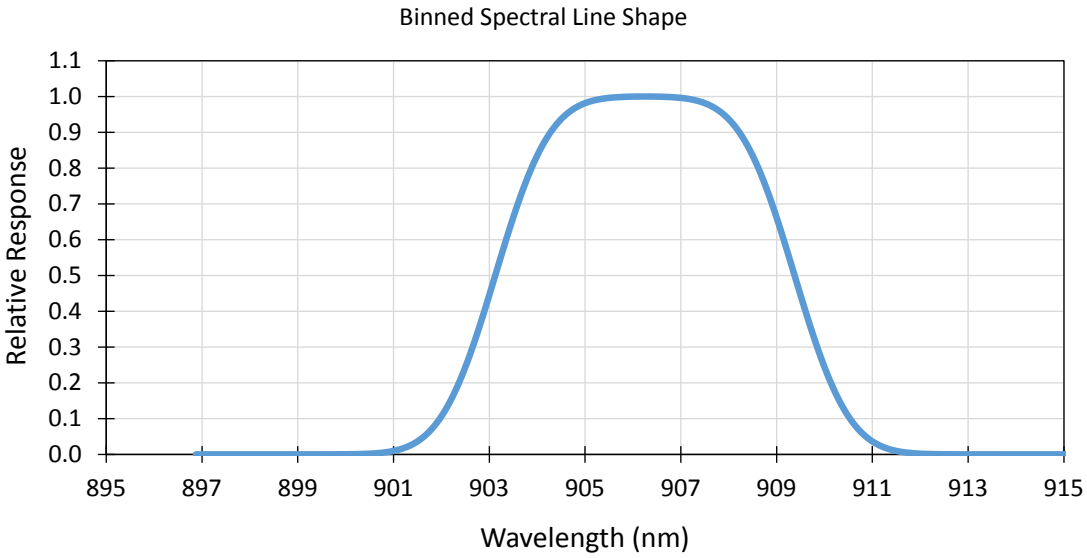


Expected Performance

Spectral Resolution

FWHM of spectral response after binning four 1.25mn native spectral bands

Wavelength	Center FoV	70% FoV	Edge FoV
360 nm	6.4 nm	6.3 µm	6.1 nm
570 nm	6.1 nm	6.1 nm	6.3 nm
910 nm	6.1 nm	6.1 nm	6.5 nm



Conclusion

- The Canadian Space Agency, in collaborating with US Naval Research Laboratory and NASA, completed a joint feasibility study for a Coastal Ocean and Inland Water Color Hyperspectral Imager
- A mature and feasible mission concept developed that addresses unmet spectral, spatial and temporal resolution requirements for environmental, water quality, and water resource management applications in coastal and inland waters
- Compliant Payload concept achieved
- Payload Concept based on existing detector model and existing technology
- Key performance parameters better than required