

Atlantic Reclamation Conference 2016, Halifax, NS

9<sup>th</sup> Nov 16

# LAND RECLAMATION ASSESSMENT BY SATELLITE

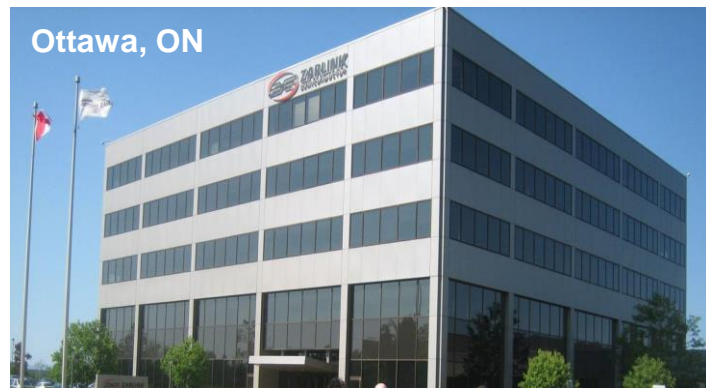
***PAUL ADLAKHA<sup>(2)</sup>, NADIA ROCHDI<sup>(1)</sup>, MARK KAPFER<sup>(2)</sup>, CHRIS HARDY<sup>(2)</sup>, KARL  
STAENZ<sup>(1)</sup>, ASHLEY BRACKEN<sup>(1)</sup>, JOHN BENNETT<sup>(2)</sup>, ZHAOHUA CHEN<sup>(2)</sup>, NEIL CATER<sup>(2)</sup>***

***<sup>(1)</sup>ALBERTA TERRESTRIAL IMAGING CENTRE (ATIC)***

***<sup>(2)</sup> C-CORE***

# About C-CORE

- Canadian R&D corporation
  - Est. 1975, ~100 staff
  - O&G, mining, gov't markets
  - World leading expertise

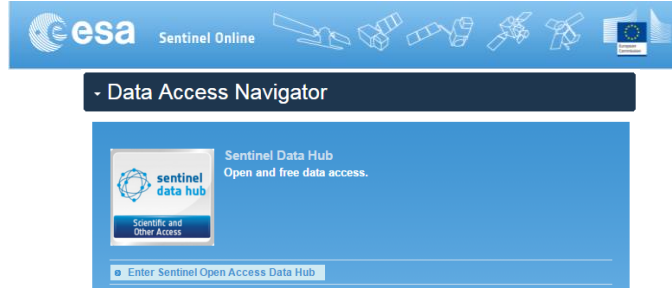


- » Remote sensing, ice and geotechnical engineering
- » Two centres of innovation: resource sector applications of remote sensing, and research & development of offshore resources



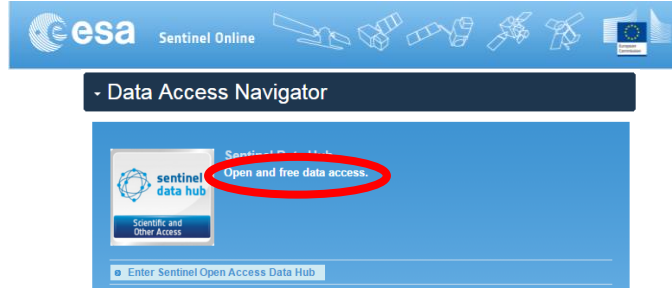
# Industry Trends

- Data policy
  - Sentinel, RADARSAT Constellation
- Agile missions
  - Cubesats

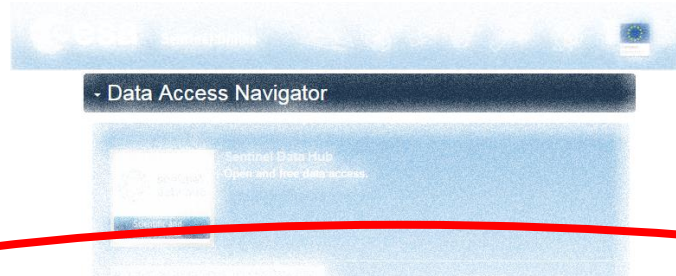


# Industry Trends

- Data policy
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# Industry Trends



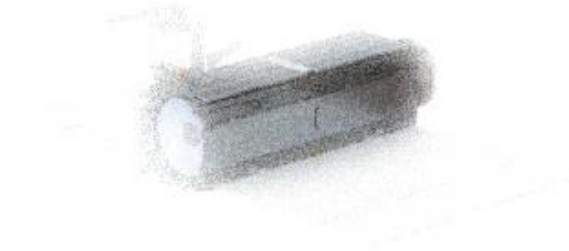
- Data policy

- Sentinel

**Open and free data access.**

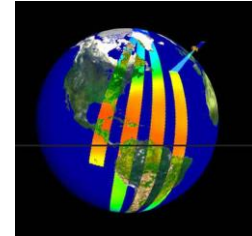
- Agile missions

- Cubesats



# Industry Trends

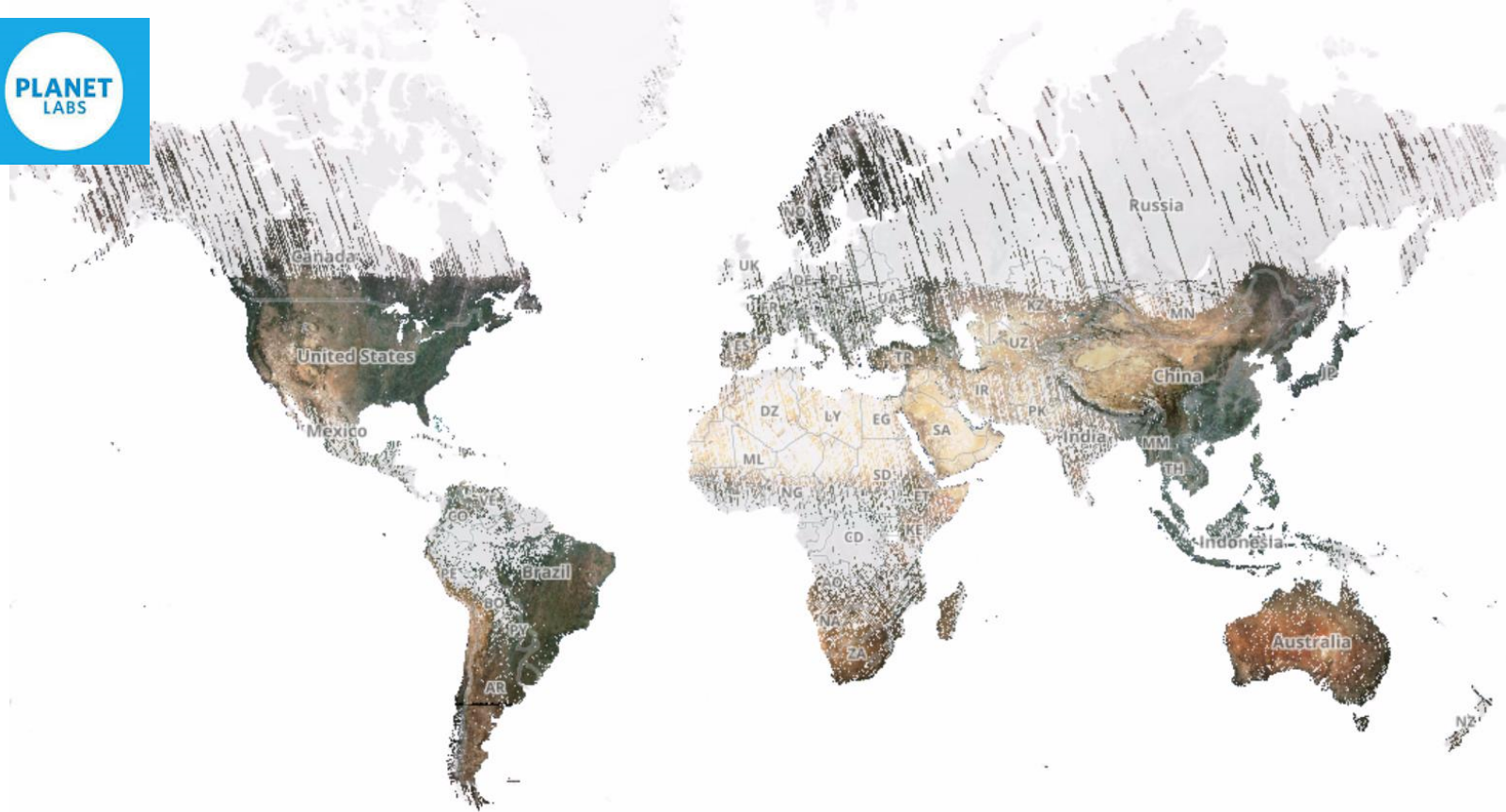
- Emergence of Cubesats
  - Accelerated development timelines
    - 1 year cycles vs 5 – 10 years
  - High density constellations
  - Flexible price structures
  - Launch current sensors, new data management approaches, cloud-based access and processing



# Example Missions

Mission	#satellites	Sensors	Revisit	Resolution
Planet Labs	150 – 200	HR EO	Daily, global	5m and lower
BlackSky Global	60	HR EO	70+ daily	1m
Satellogic	300	HR EO, video HS, Thermal IR	5 – 10 min	1m, 30m, 90m
<i>SkyBox Imaging</i>	16	HR EO, video	?	1m
UrtheCast	16	X & L band SAR Video, HR EO		1.5m, 5m 1m
Spire	16	S-AIS +	15min	n/a

# Planet Labs – Mosaic Archive





# BlackSky Global

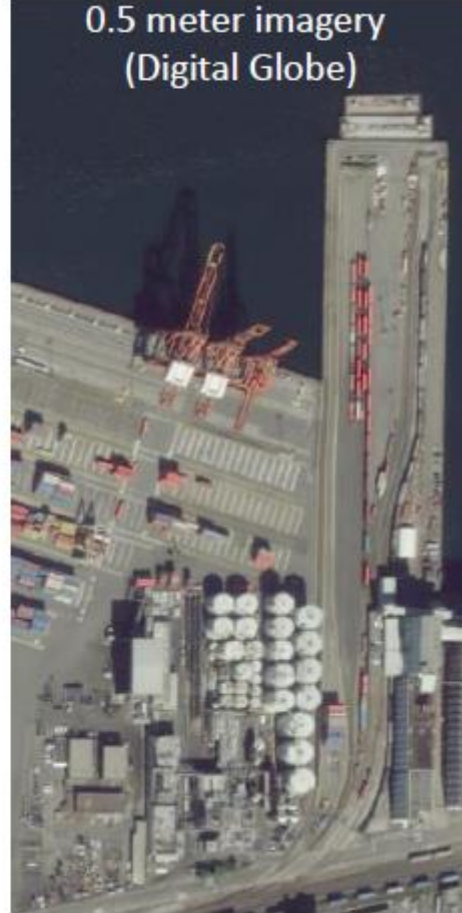
5 meter imagery  
(Planet Labs)



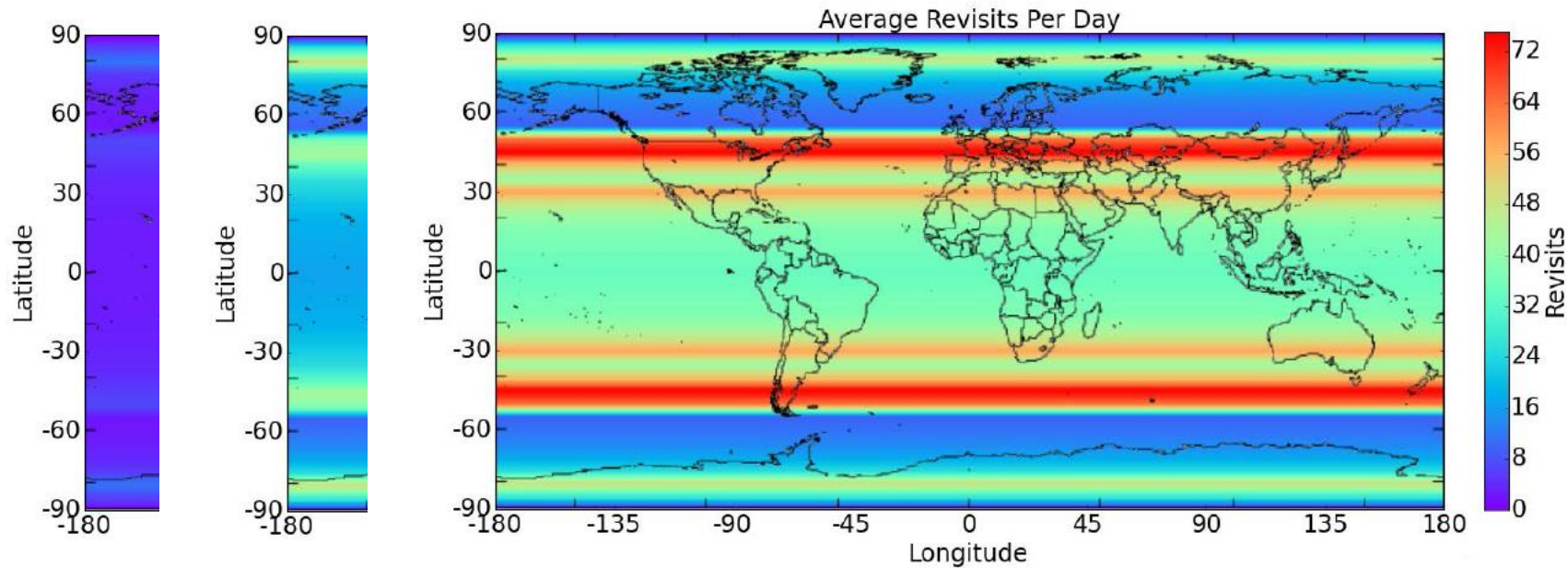
1 meter imagery  
(BlackSky)



0.5 meter imagery  
(Digital Globe)



# Revisit potential



# ROADMAP

2013-2015



**3 Satellites Launched**

Constellation Prototype  
Successful system test

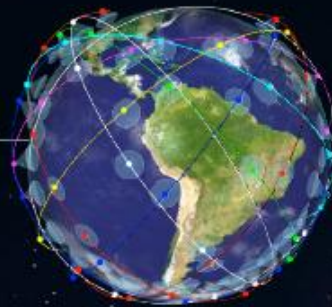
2016-2017



**16 Satellites**  
**2hr revisit times**

1m resolution MS  
30m resolution HySp  
90m resolution TIR  
1m resolution video

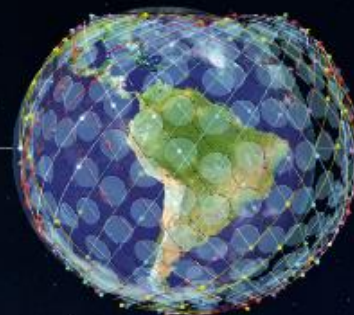
2017-2018



**100 Satellites**  
**15m revisit times**

Improved spectral,  
geometric and radiometric  
resolutions.

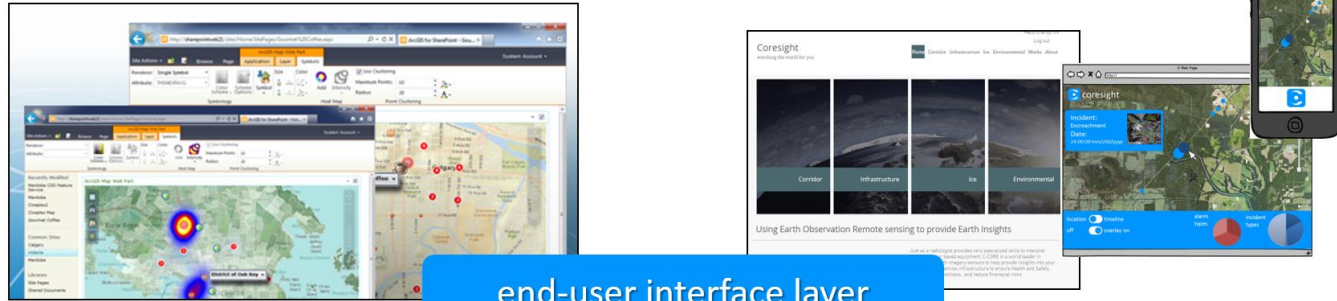
2018-2020



**300 Satellites**  
**5m revisit times**

Improved Capabilities  
5th Generation

# Technology



- Data management

- Ingest volumes

- Extract only info

- automate processes

- Web delivery, user access, integrated with GIS



# Land Reclamation Service

**The Land Management/Reclamation Service is a web based remote sensing solution that provides regular reporting on the health status of various remote properties.**

**For...** Government Regulators with mandates to audit properties granted certification but have limited resources as well as industry members with managers who require the tools to better assess and distribute resources in order to meet regulatory reporting requirements with their properties

**Who...** require timely, broad area, reliable, regular ongoing information on the status and health of reclaimed properties or who require historical analysis of their properties

**The product is...** a timely and cost effective alternative that utilizes a web based remote sensing solution for integrating layers of relevant data and indicators and delivering a customizable product

**That provides...** a suite of derived products based on the themes of Land, Water and Stability to better identify higher risk candidate, assess properties based on a variety of indicators, provide information required to properly guide decision making and focus ground surveys to higher risk candidate areas

**Complementary to...** ground surveys, airborne and surface sensors

**Our product...** efficiently and economically covers larger, remote areas with all-weather capabilities and integrates everything into a simple, stand alone web-based delivery system.

Product
Landscape disturbance inventory
DEM
Trend analysis
Land cover map
Vegetation monitoring
Field correlation index
Status indicator
Biomass monitoring
Water quality indicator
Water areal extent
Water level
Ground cover stability
Berm/dam stability
Acid draining/leaching
Anomaly analysis

# Project Outline

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1. Context
2. A Web-Based Monitoring System for Enhancing the Provincial Mapping and Monitoring Capability
3. Summary and future directions

# Outline

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## 1. Context

2. A Web-Based Monitoring System for Enhancing the Provincial Mapping and Monitoring Capability
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# Alberta's Energy Resources

## Natural gas

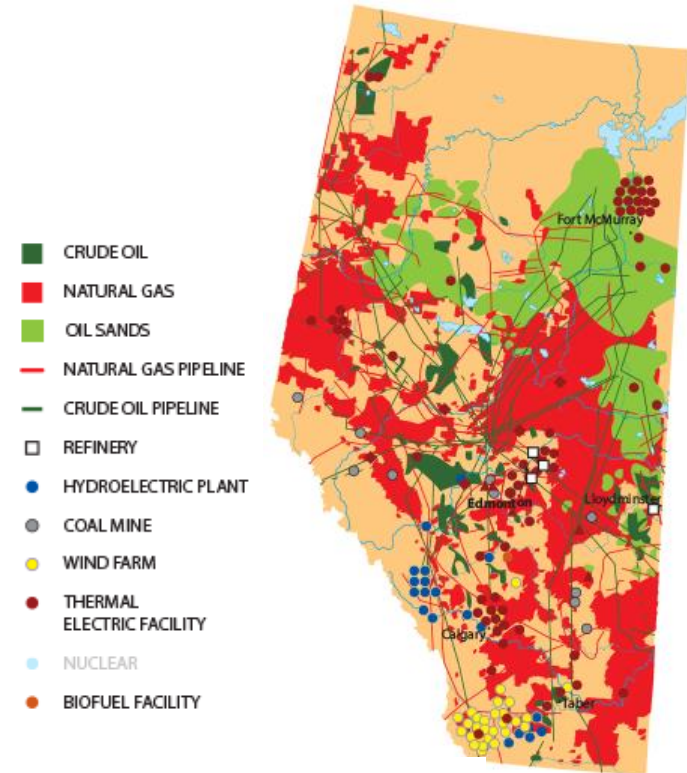
70.9% of the marketed natural gas produced in Canada in 2011.

## Crude Oil

Alberta's reserves totalled 1.49 billion barrels or about 36% of Canada's total in 2010

## Oil Sands

70% of Alberta's total crude oil and equivalent production and about 50% of all crude oil and equivalent produced in Canada in 2011.



Source: [centreforenergy.com](http://centreforenergy.com)



# Oil and Gas Exploration

## Land Use Footprint



**Open-pit mine**

*Source: mining.com*



**Wellsite**

*Source: Cenovus Inc.*



**Pipeline**

*Source: pipelineinternational.com*

# Reclamation and Certification

- **Land Reclamation** - Restoring disturbed land to an “equivalent land capability” (*Environment and Enhancement Plan Act - EEPA*)
- **Reclamation Certification** - issued by the Alberta Energy Regulator (AEP – up to 2014) to attest reclamation standards are met.



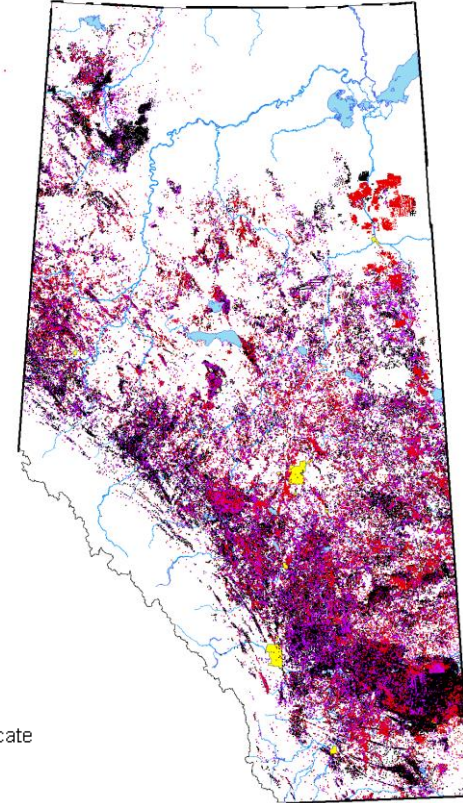
Source: [blog.transcanada.com](http://blog.transcanada.com)



Source: [capp.ca](http://capp.ca)

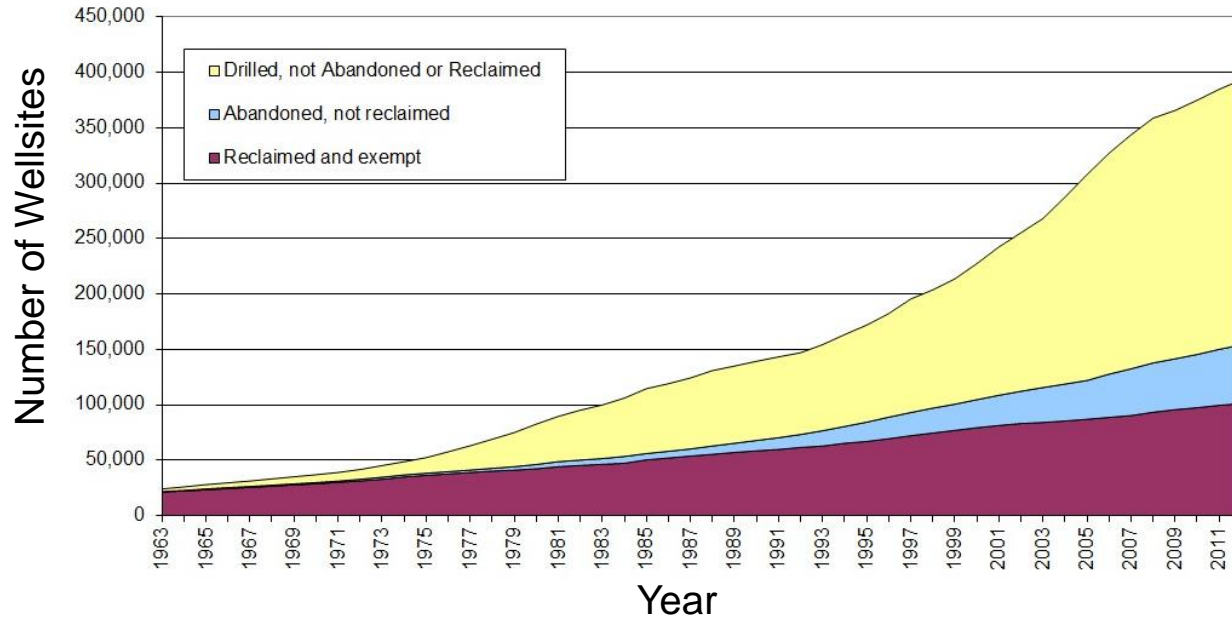
# Reclamation Assessment

- Field audit of ~15% of submitted applications for reclamation certificates.
- Vegetation condition (10%) and ground contamination (5%)
- 2010 – Reclamation Criteria for Forested, grasslands and agricultural area (Landscape, vegetation, soil)



- Abandoned - No Reclamation Certificate
- InActive
- Active

# Reclamation Monitoring



Source: Alberta Environment and Parks

**Need for a large-scale mapping and monitoring of reclamation criteria**

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# Project-1 Scope

Development of a web-based system for mapping and monitoring land disturbance and reclamation in Alberta's grassland and forested areas using remote sensing technologies.



# Project-1 Objectives

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- **Develop information extraction procedures** for deriving disturbance footprints and a set of success indicators of reclamation in native grassland and forested areas using high/medium-spatial resolution spaceborne multi-spectral sensors;
- **Develop a web-based monitoring system** that incorporates the above processing and information extraction procedures; and
- **Validation** of the developed procedures for assessing disturbance, reclamation condition and recovery trends.

# Multispectral Remote Sensing

Sensor	Spatial resolution (m)	Spectral bands	Swath (km)	Revisit Time (days)	Launch Year
Worldview-3	1.2 (VNIR) 3.7 (SWIR)	8 (VNIR) 8 (SWIR)	13.1	< 1	2014
RapidEye	6.5 (VNIR)	5 (VNIR)	77	1	2008
SPOT 7	6 (VNIR)	4 (VNIR)	60	1-3	2015
SPOT 6	6 (VNIR)	4 (VNIR)	60	1-3	2012
SPOT 5	10 (VNIR) 20 (SWIR)	4 (VNIR) 1 (SWIR)	120	2-3	2002
Sentinel-2	10/20 (VNIR) 20 (SWIR)	8 (VNIR) 2 (SWIR)	290	2-3	2015
Landsat 5/7/8	30 (VNIR/SWIR)	8 (VNIR) 2 (SWIR)	185	16	1982



# Study Areas

## Primary Sites (Field Campaigns)

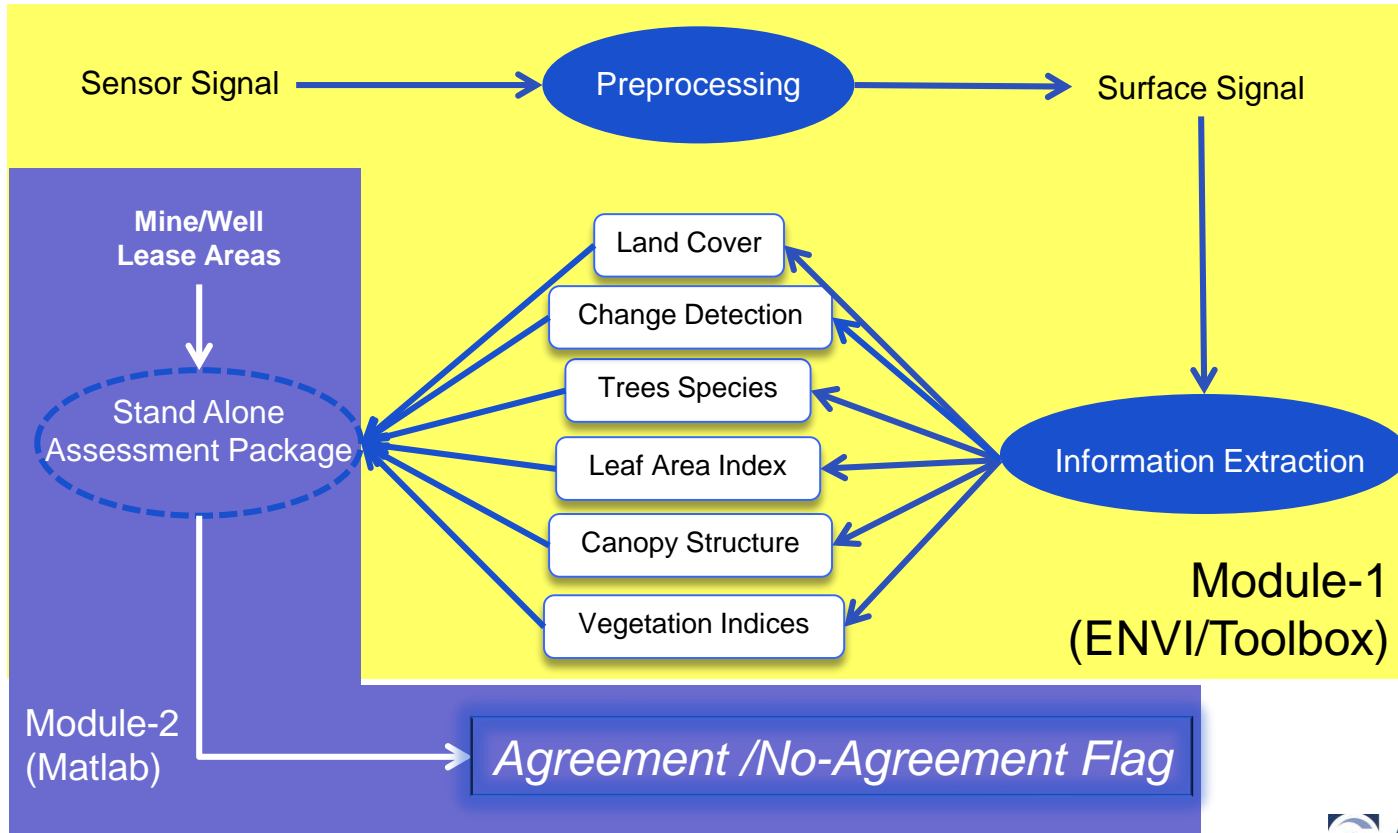
- Mattheis Ranch (Summer 2016)
  - Dry Mixedgrass

## Secondary Sites (Stakeholder Data)

- Fort McMurray (ConocoPhillips)
  - Central Mixedwood
  - Lower Boreal Highlands
- Southern AB Grasslands (EMSD/ABMI)
  - Dry Mixedgrass
- Southern AB Agriculture (EMSD/ABMI)
  - Mixedgrass









# Processing flow

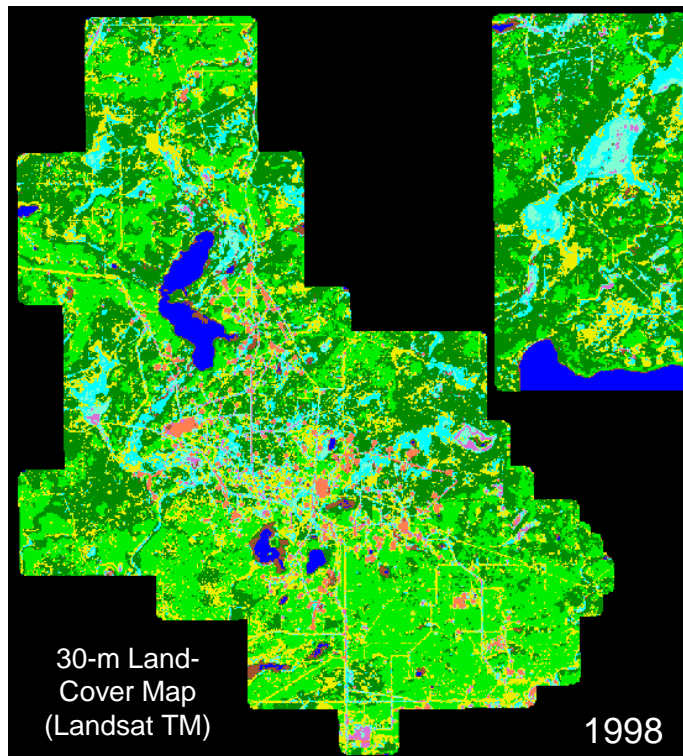


# Land Cover (1/2)



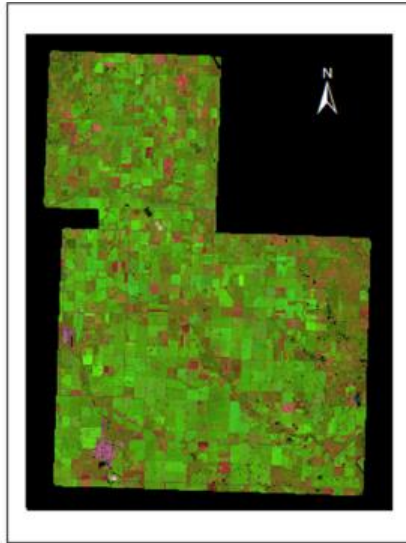
Landsat TM

- |   |  |
|---|--|
|  Deciduous forest  |  Wetlands   |
|  Coniferous forest |  Water      |
|  Herbaceous/shrubs |  Bare areas |

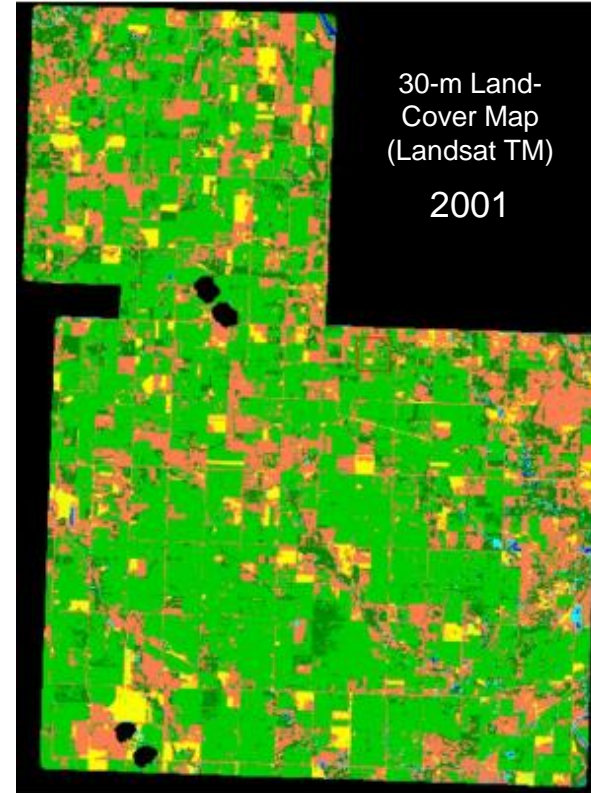
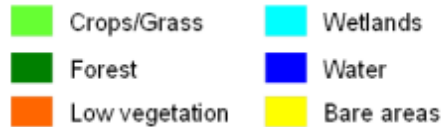


- Reclamation Assessment using similar landcover/landuse

# Land Cover (2/2)

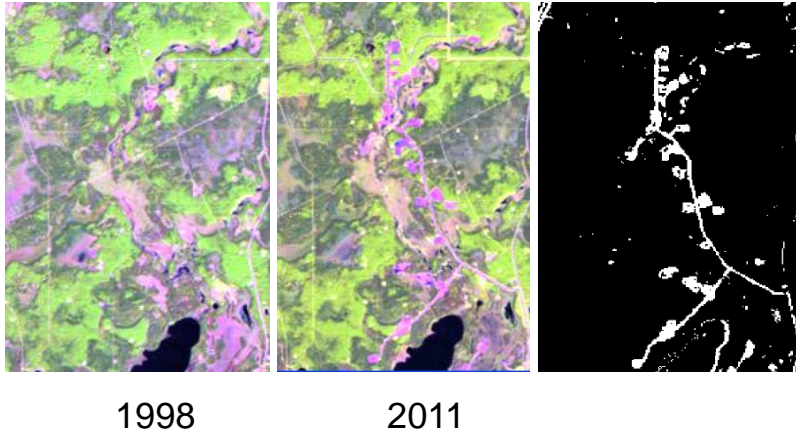


Landsat TM



- Reclamation Assessment using similar landcover/landuse types

# Change Detection



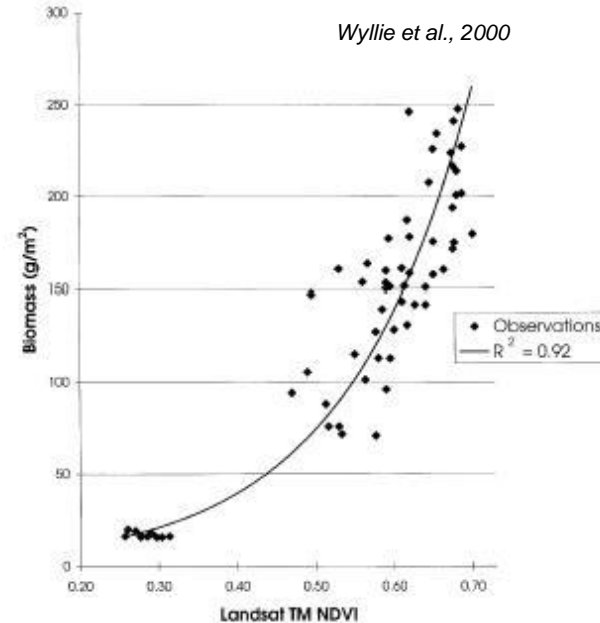
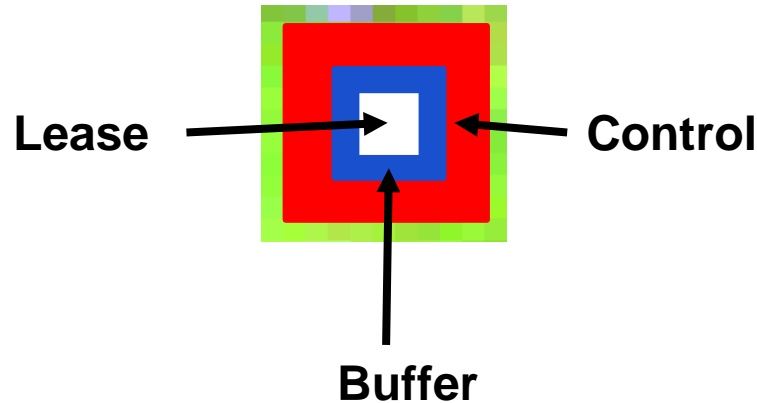
- Reclamation Assessment using undisturbed control areas



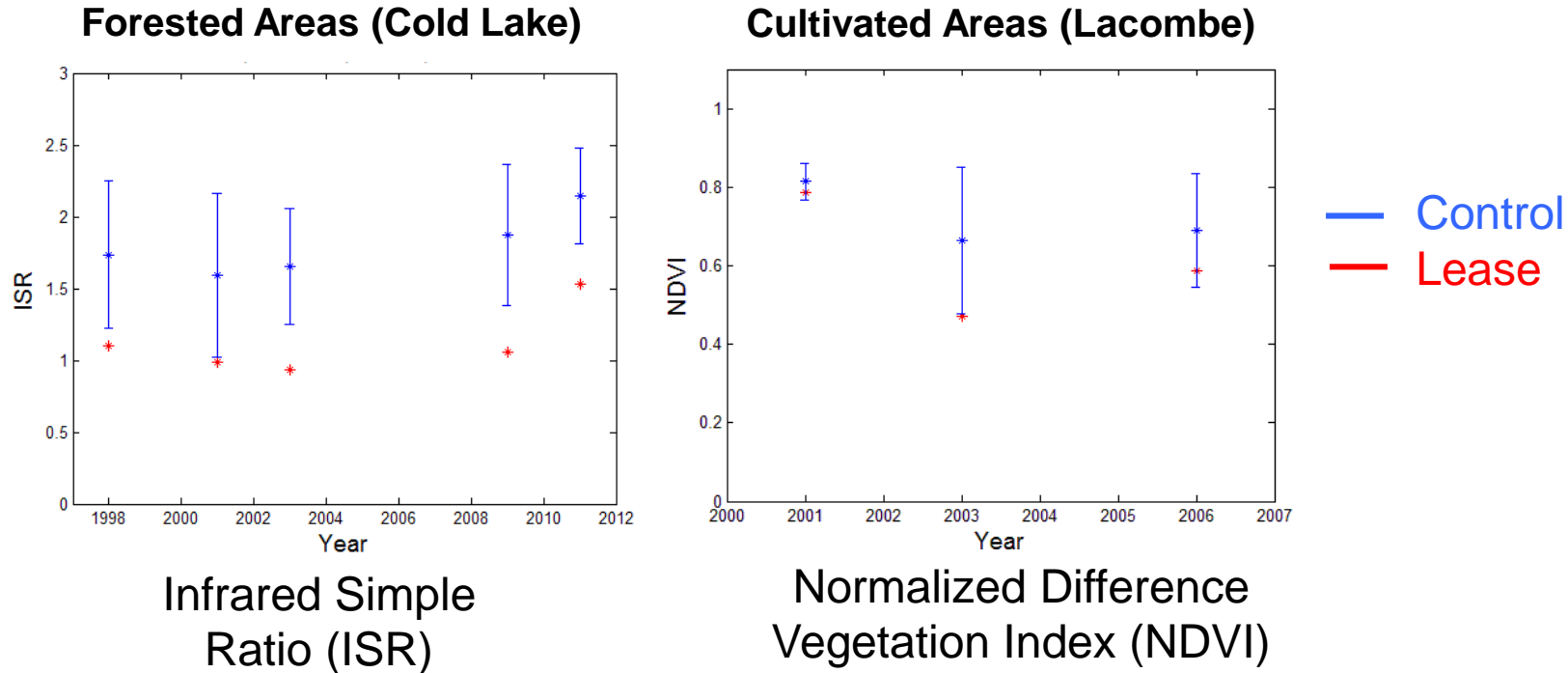
30-m Disturbance Map  
(between 1998 and 2011)

# Vegetation Indices (VIs)

A set of combinations of a number of spectral bands sensitive to vegetation biomass (e.g., NDVI, SR, ISR, ARVI, SAVI).



# VIs Temporal Trend



- Assess productivity as well as its temporal trend in agricultural and forested areas

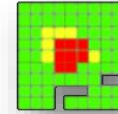


# Web-Based Monitoring System

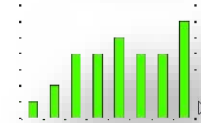


Show 10 ▾ entries

Well Site	Status	Number	Rank	Score					Lat	Long	Action
1 Agawam	MA	01001	6115	60.37489	0	12293	22.06947	73.40212	42.14098	-72.77950	◆
2 Amherst	MA	01002	975	93.59713	0	14232	68.52967	82.63116	42.36540	-72.45609	◆
3 Barre	MA	01005	6511	58.31555	0	3349	20.51971	73.19553	42.32779	-72.14520	◆
4 Belcherstown	MA	01007	3914	73.90479	0	8577	31.38627	79.61516	42.28068	-72.38873	◆
5 Blandford	MA	01008	4922	67.29552	0	945	25.79882	77.63875	42.17914	-72.94803	◆
6 Brimfield	MA	01010	4540	69.76556	0	2252	27.79751	78.36147	42.10920	-72.22135	◆
7 Chester	MA	01011	7481	53.51199	0	1352	20.97701	66.25217	42.29242	-72.96318	◆
8 Chesterfield	MA	01012		61.43032	0	353	23.22946	72.73525	42.39329	-72.81224	◆
9 Chicopee	MA	01013	16563	19.74880	0	15464	19.75281	52.71066	42.16294	-72.67040	◆
10 Chicopee	MA	01013	16563	19.74880	0	15464	19.75281	52.71066	42.16294	-72.67040	◆



Analysis



Trend



Image

Reclamation Ranking





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# Project Status

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- End of first year of project
  - Completion scheduled for Feb 2018
- Land Cover mapping being automated
- Disturbance inventory approach completed
- Field campaign completed Summer 2016
- VI's completed. Assessment for Feb. 2017

# Project Status

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- Expected accuracies
  - Land cover > 80%
  - Vegetation Indices > 80%
- Applicability
  - Methodology is transportable
  - Field validation is area/ecosystem specific

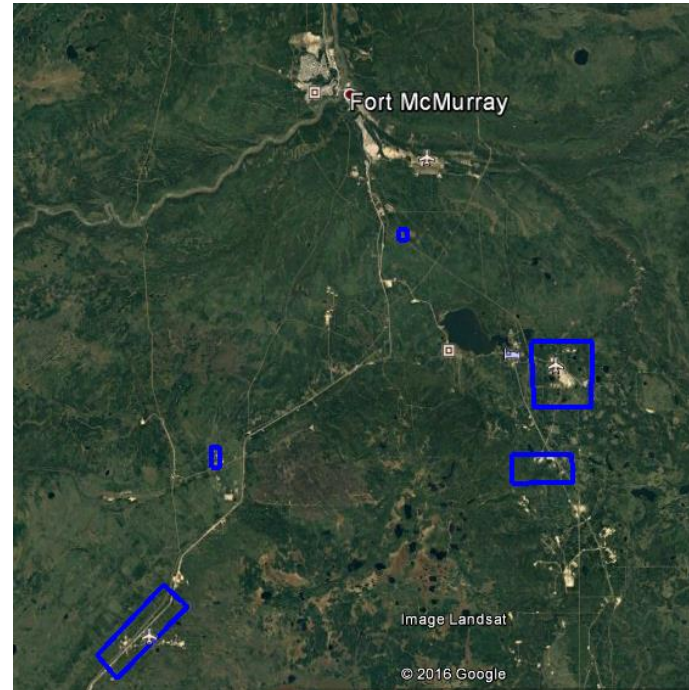
# Project-2 Objectives

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- Development of a tailored **hyperspectral-based method** to retrieve information related to vegetation type and condition
- Validation of the developed procedure using revegetated areas resulting from several reclamation strategies
- Validation of the developed procedure using Pass/Fail reclamation assessments under the new Reclamation Criteria for Wellsites and Associated Facilities in **Peatlands**.

# Airborne Hyperspectral Acquisition

- Five study sites
- Field assessment of reclamation condition
- Hyperspectral airborne acquisition (summer 2017)



# Supporting Organizations



University of  
Lethbridge



# THANK YOU

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