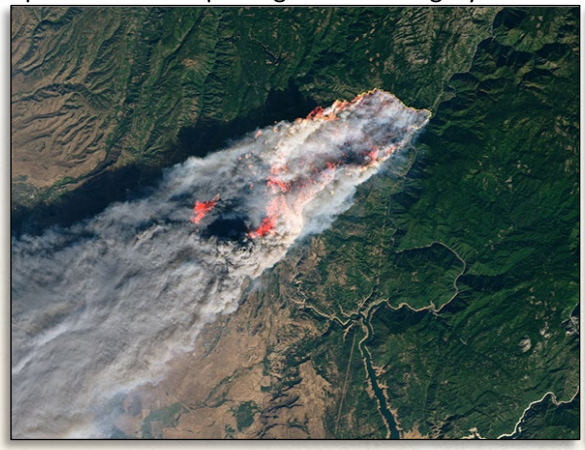
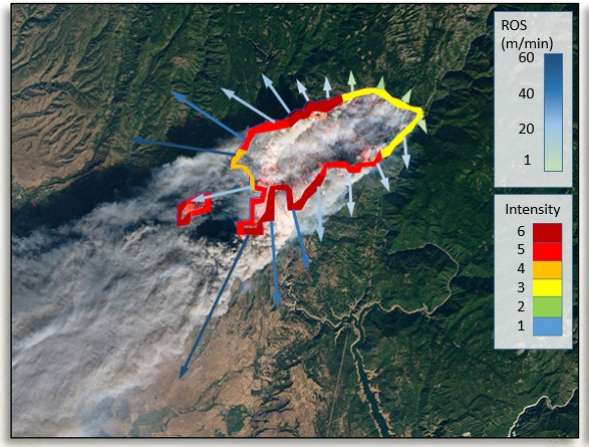
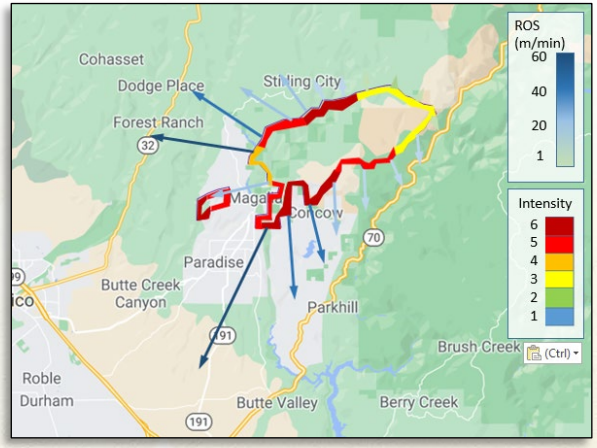
*product mock-up using Landsat imagery







WildFireSat

Canadian Operational Mission Overview

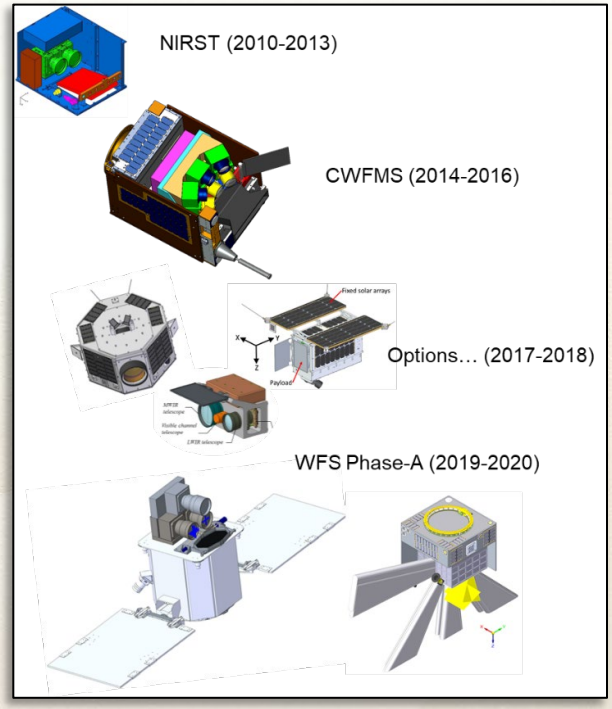
GOFC-GOLD Fire IT / GWIS Meeting
June 21-23, 2022

Natural Resources Canada | Ressources naturelles Canada

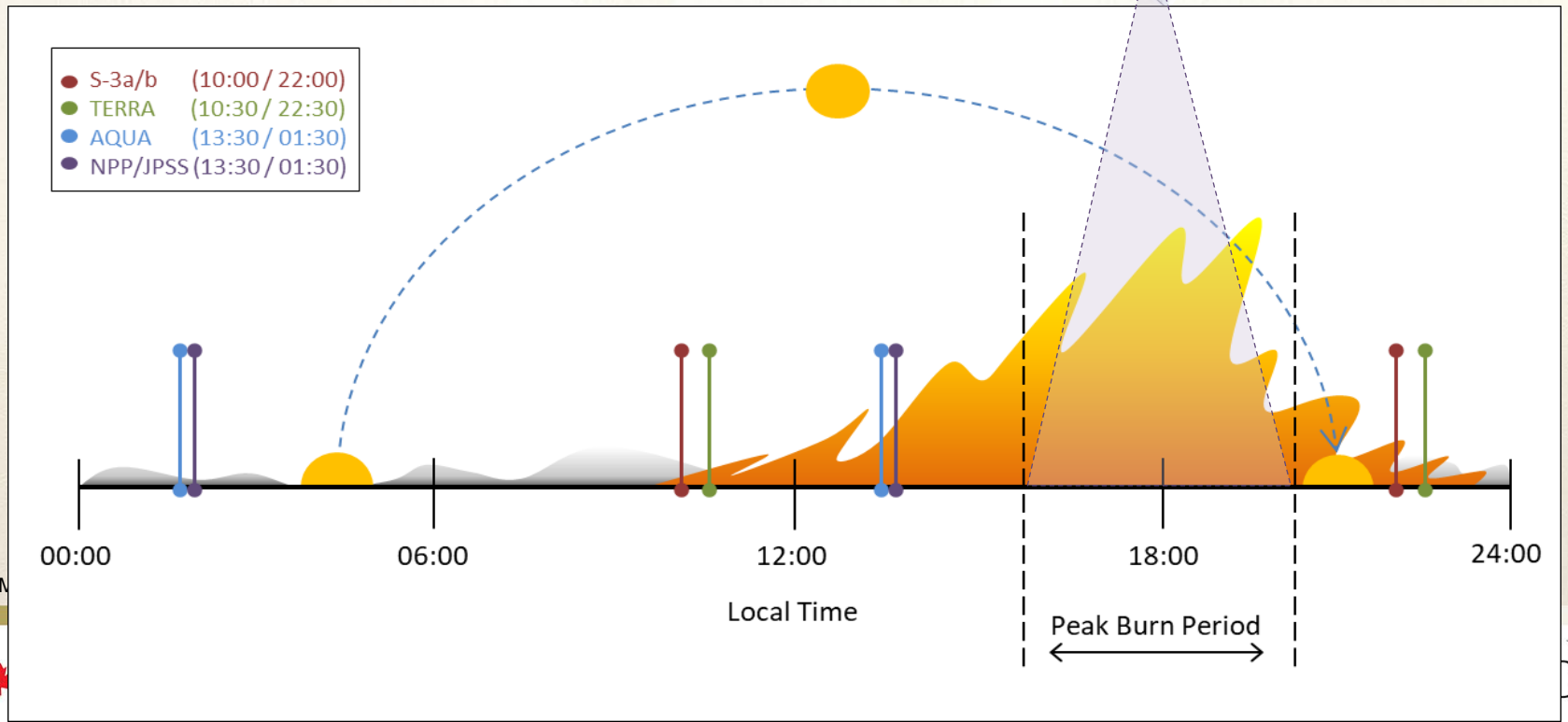
Canada

WildFireSat Origins

- Unique Canadian sensor technology has enabled small-scale wildfire monitoring satellite systems
  - CFS involvement dates back to 2010
- Phase-0 of CWFMS completed in 2016
- “WildFireSat” mission began in 2018 to develop an operational wildfire and smoke monitoring system
  - Wildfire and Emergency management in Canada
  - Air quality monitoring and forecasting, and
  - Carbon accounting
- Phase-A of the mission completed in November 2020
  - One solution for space system was deemed optimal for the User Requirements
  - A significant funding gap remained, and the mission was reprofiled as a Pathfinder
- In April 2022, the Government of Canada awarded end to end funding for the Canadian operational WFS Mission



Active-fire LEO Coverage



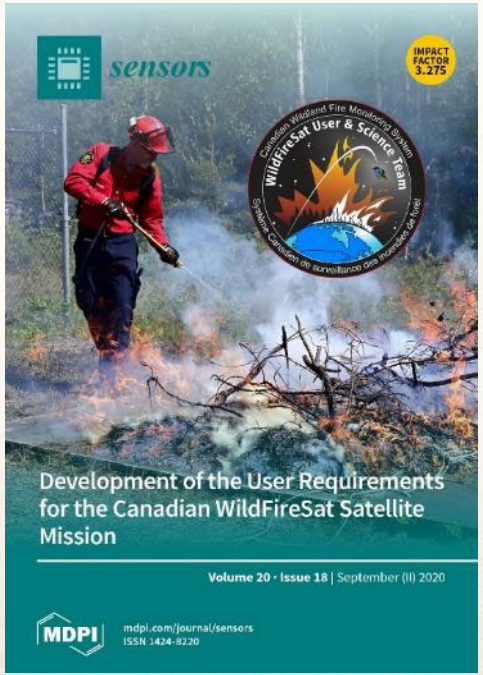
WildFireSat

Key Features:

- VIS/NIR (200 m)
- MWIR/LWIR (400 m);
- Daily peak burn overpass;
- FRP optimised;
- Detection capacity at 15 x 15 m fire;
  - *open canopy (Johnston et al, 2018)
- 30 min data latency.

Fire Monitoring Capability:

- Near-real-time data delivery;
- Early detection (remote access fires);
- Active perimeter mapping and progression;
- Perimeter mapping of ROS (m min^{-1}) when combined with VIIRS (Johnston, 2016);
- Perimeter mapping of FI (kW m^{-1}), (Johnston et al, 2017);
- Mapping of Fuel Consumption (kg m^{-2});
- Near-real-time measurements of carbon emissions and smoke plume dynamics.



(Johnston *et al*, 2020)

Products

Tier 1: Satellite L-1B data

Product	outputs
Cloud mask	Mask of cloud contaminated pixels
Contextual Fire Detection	Mask of fire effected pixels, and confidence, false positive rejection
Characterisation	FRP (MW) Effective Fire Area (ha) Effective Fire Temp (K)
AI Detection*	Cloud mask: Mask of fire effected pixels, and confidence, false positive rejection

Tier 2: Data synthesis with VIIRS etc

Product	outputs
Clustering of fire pixels	Differentiation of pixels contributing to a single fire or adjacent fires (similar the M3 CWFIS product)
Rate and Direction of Spread	Mean ROS (m/min) over the afternoon period. Generalized mean direction of travel for all moving regions of the perimeter
Fire Intensity	Mean FI (kw/m) for the subpixel perimeter.
Burned Area Map	Map of disturbed forest area
Fire Severity Map	Map of relative severity of fire effected area
Smoke plume ID	Re-characterisation of portions of the cloud mask as smoke.
Fire Arrival Time Map	Burned area map tagged with the first satellite observation of each cell. Similar to Parks day of burn map, possibly omitting interpolation.

Tier 3: T1, T2 + ancillary data and models

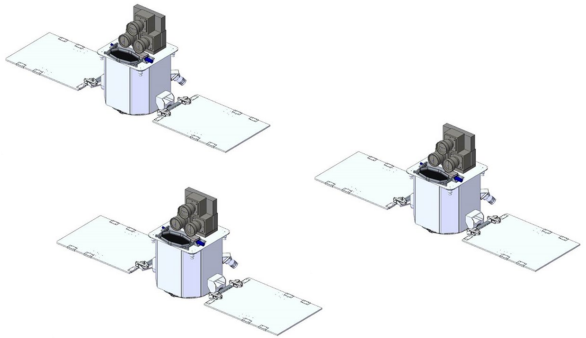
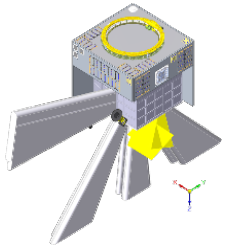
Product	outputs
Proximity and threat to interface	Distance to values and estimated time of arrival at the interface zone. Based on observed rate and direction of spread from Tier 2, and national WUI maps
Fire Growth Model (FGM) projection	This could be using Bigfoot, or local agency FGM, or BurnP3, (TBD)
Fire Growth Model data assimilation	R&D required – open FGM which can update coefficients in spread equations based on observations
Fuel grid verification	Local to the FGM AOI
Risk/threat	Where this fire falls in the context of risk assessment (e.g. how it ranks on a relative scale)
Torchlight trigger point	Automated approval of Torchlight deployment
Suppression potential/effectiveness	Map of potential suppression method options based on observed fire behaviour (i.e. can we action this fire?)
Land surface change	Vector or raster representation of land surface change (e.g., Lake ice cover, vegetation change, etc.)

Supplemental:
Cloud forecast for 18:00 local, released at 12:00

Phase-A Mission Configuration

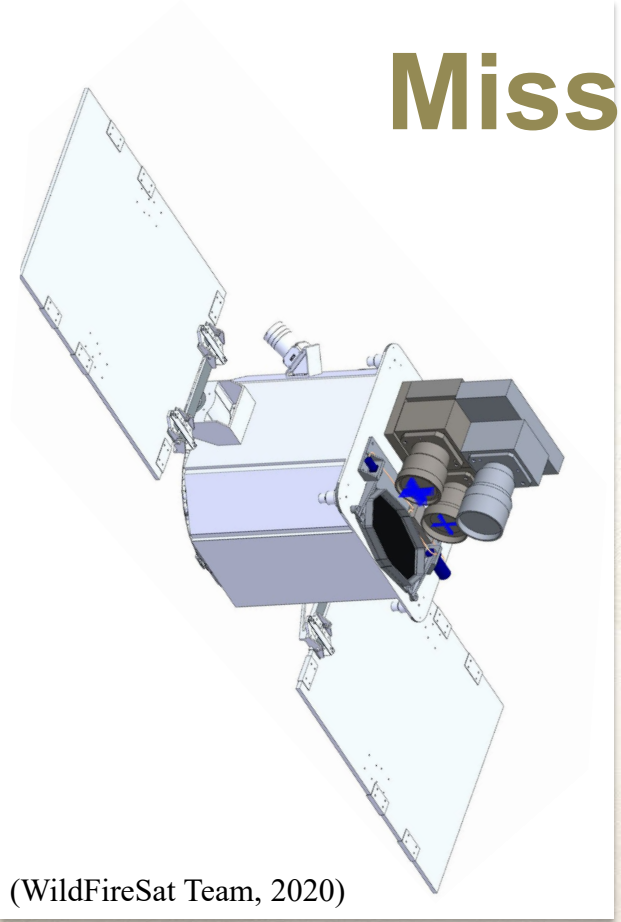
Outcome of Phase-A

- Two industrial contractors were tasked for a daily monitoring system
- Resulted in two different design concepts: 3-sat system versus 1-sat system

Honeywell: 3-satellite system	MDA: 1-satellite system
	

- The 3-sat design was adopted based on advantages in technical feasibility, data quality, modularity, and potential for graceful degradation

Mission Specifications



(WildFireSat Team, 2020)

Criteria	WildFireSat-COM
Orbit	Sun-synchronous
LTAN	1800 local
Altitude	650 km
Spacecrafts	3 with 90deg phased separation
Downlinking	Bent-pipe
Data latency	~ 30 min
Revisit over Canada	12hr
Swath	400km (for each satellite)
Bands	6
Max co-elevation angle	20 deg off nadir

All parameters TBC following Phase-B

Constellation Structure

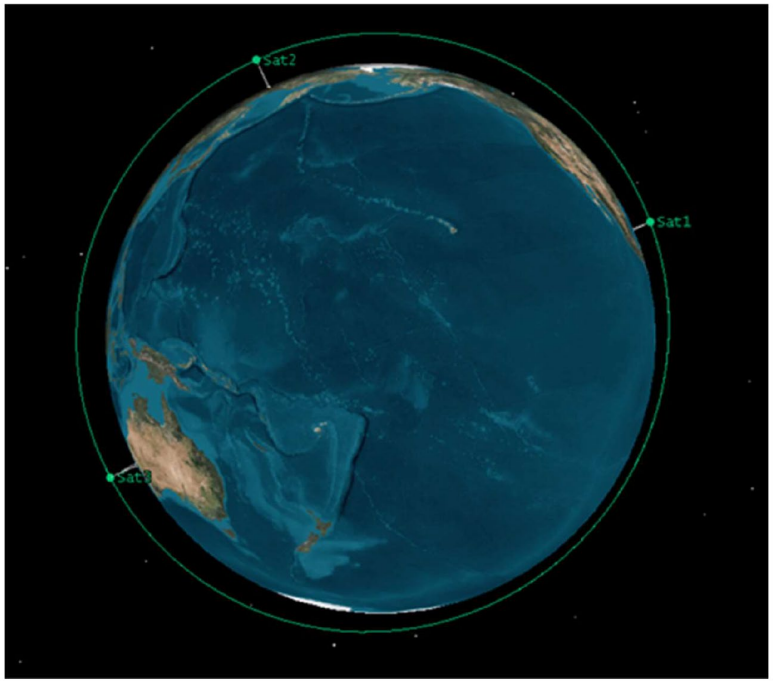


Figure 1-1 Three satellites in same orbital plane

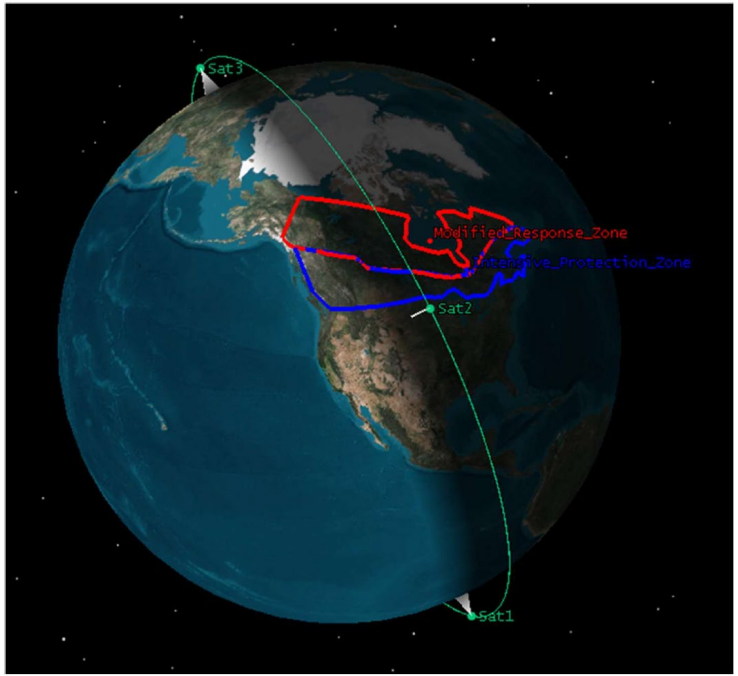
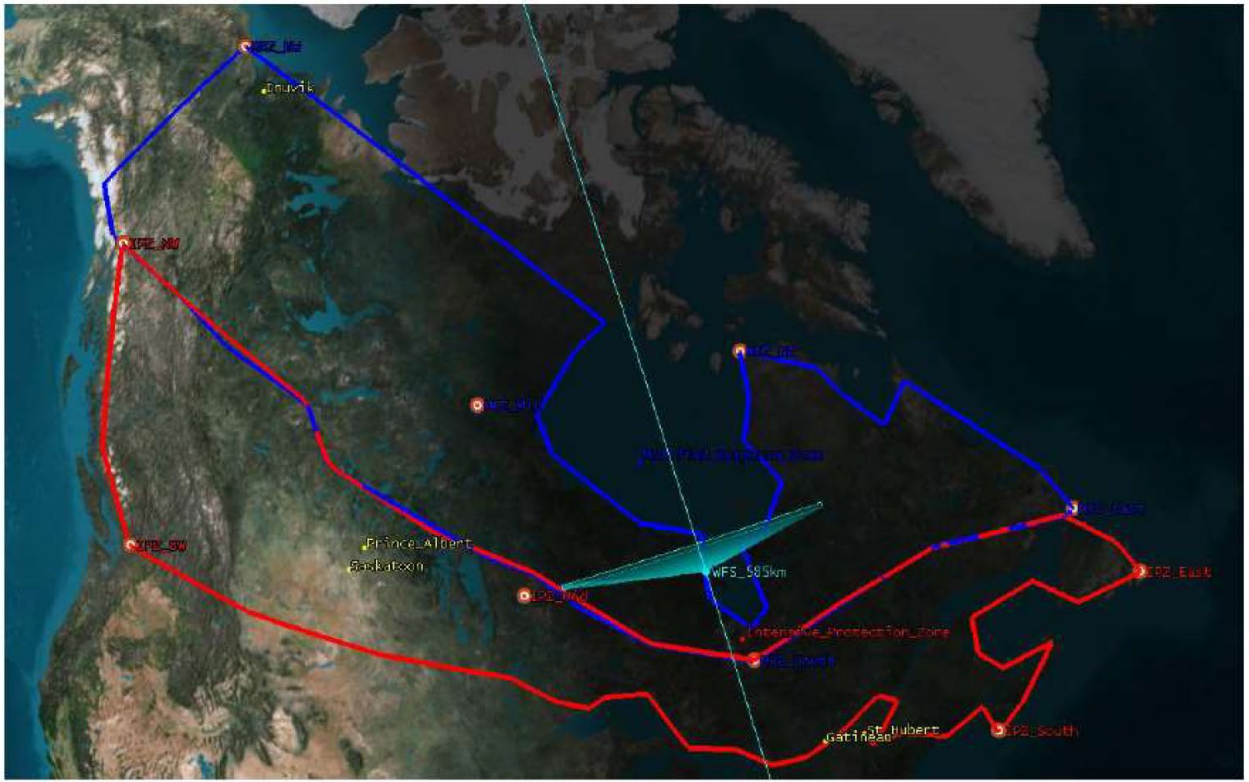


Figure 1-2 Three satellites in sequential passes over Canada showing IPZ (blue) and MRZ (red)

(WildFireSat Team, 2020)

Individual Swath



(WildFireSat Team, 2020)

Figure 3-1: WFS operation concept diagram. The ground track of a satellite is shown, along with the expected swath coverage width (teal colour). The red area is the IPZ, and the blue area is the MRZ. Yellow labels show the 5 Govt ground station locations.

Worst Case 18:00 Revisit

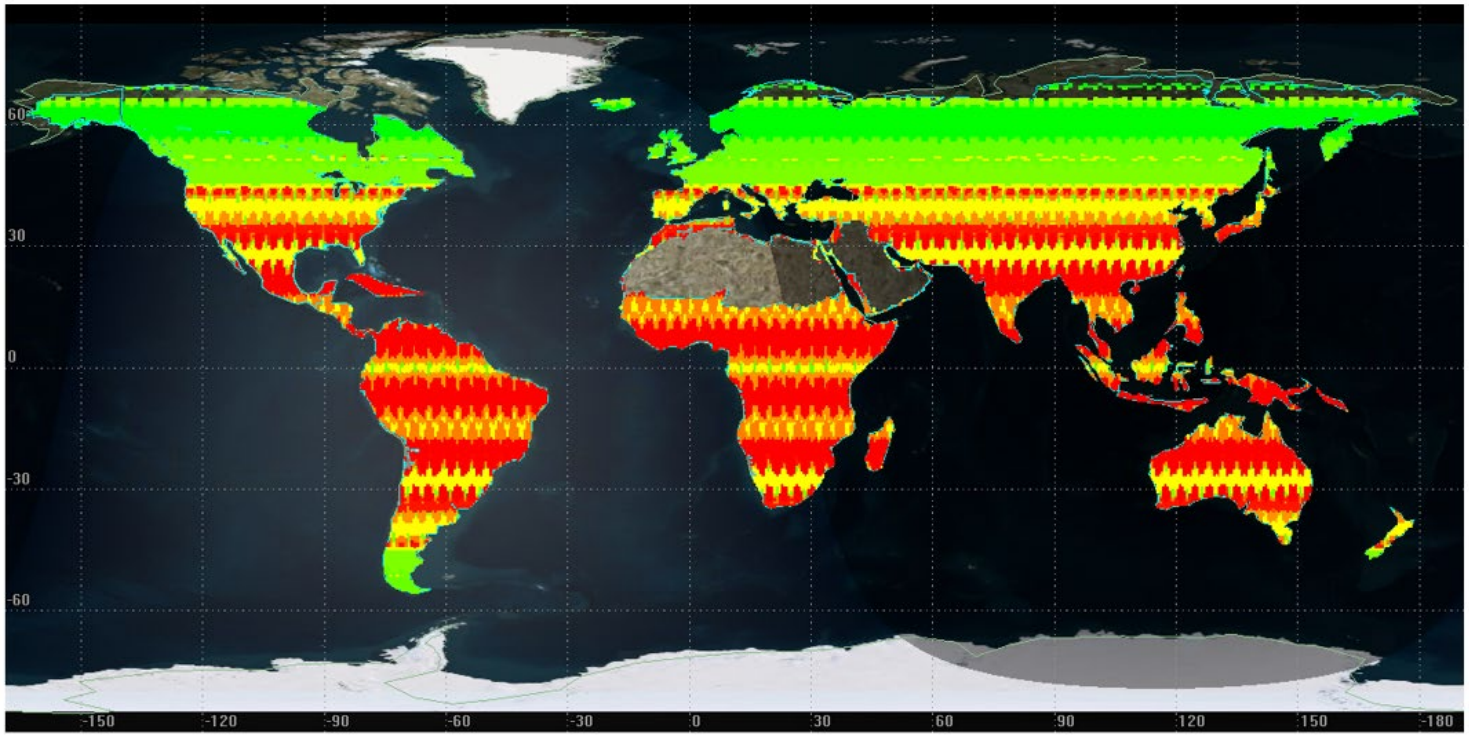


Figure 3-1: Worst-Case Revisit Time for Global AoI (dark green: less than 24 hr, red: in excess of 72 hr)

(WildFireSat Team, 2020)

Downlink Coverage

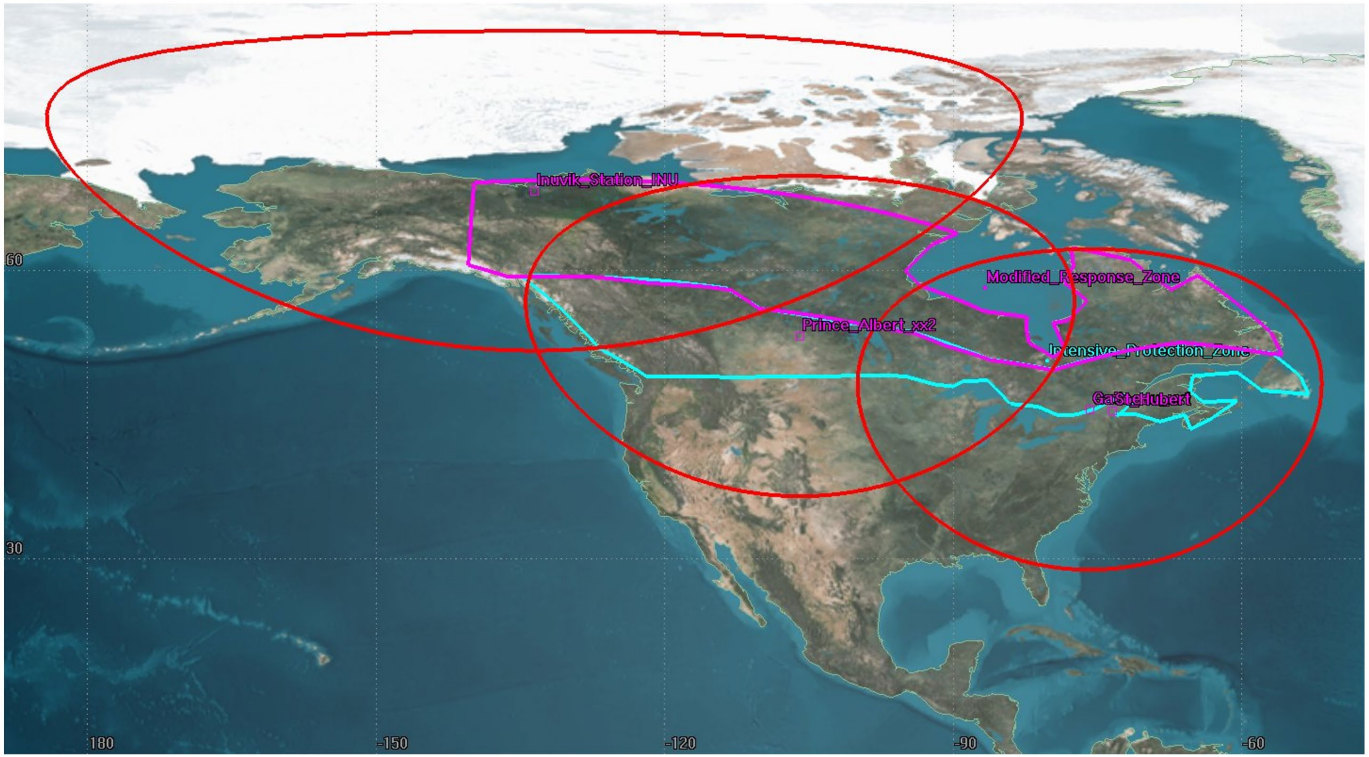


Figure 4-2 GFE Ground Station FOV with min 10 deg elevation

(WildFireSat Team, 2020)

Downlink Specifications

CCMEO Antenna Parameters

Physical Characteristics	
➢ Reflector	13 m diameter
➢ Operating Temperature	-40 C to +50 C (-50 C for Inuvik)
➢ Operating Wind	96 km/h
➢ Survival Wind	193 km/h
➢ Velocity	Azimuth: 12 deg/sec minimum Elevation: 7.5 deg/sec minimum Third Axis: 5 deg/sec maximum
➢ Acceleration	Azimuth: 10 deg/sec^2 maximum Elevation: 10 deg/sec^2 maximum
➢ Tilt Axis	7 deg from vertical
X Band Characteristics	
➢ Frequency Range	8.0 to 8.5 GHz
➢ Polarization	Data: RCHP and LHCP (simultaneous) Track: RCHP/LHCP (switch selectable)
➢ System G/T (8 GHz at 5 deg elevation, clear sky)	> 37.4 dB/K
➢ System Beamwidth	0.19 deg nominal
➢ X-Band Converter	
➢ Input Frequency	8.0 to 8.5 GHz
➢ IF Outputs	Data: 720 MHz Track: 720 MHz
➢ Bandwidth (1 dB)	500 MHz minimum (Data and Track)
➢ Gain (RF to IF)	Data: 26 dB nominal Track: 29 dB nominal
➢ Noise Figure	Data: 18 dB maximum Track: 14.5 dB maximum

Assumed WildFireSat Baseline Downlink Parameters (X-Band only)

Orbit	650 km altitude, sun-synchronous, 18h00 LTAN
Number of channels	One
Downlink frequency	*TBD end of phase B*
Polarization	RHCP
Minimum G/T	*25.4 dB/K*
Downlink Rate	128 Mbps
Modulation Schema	TBD end of phase B
Data Volume Example	***500s overpass of Canadian AoI – single satellite***
IR (MWIR + LWIR) Data	3.2MB/images/s = 6.4MB/s
VIS + NIR Data	9.6MB/image/s
Total Data Volume	16MBs = 128Mbps = ~8GB

Baseline parameters are for 1 satellite
WildFireSat-COM is 3 of these


Thank You
Questions?

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