Seeing a Better World from Space

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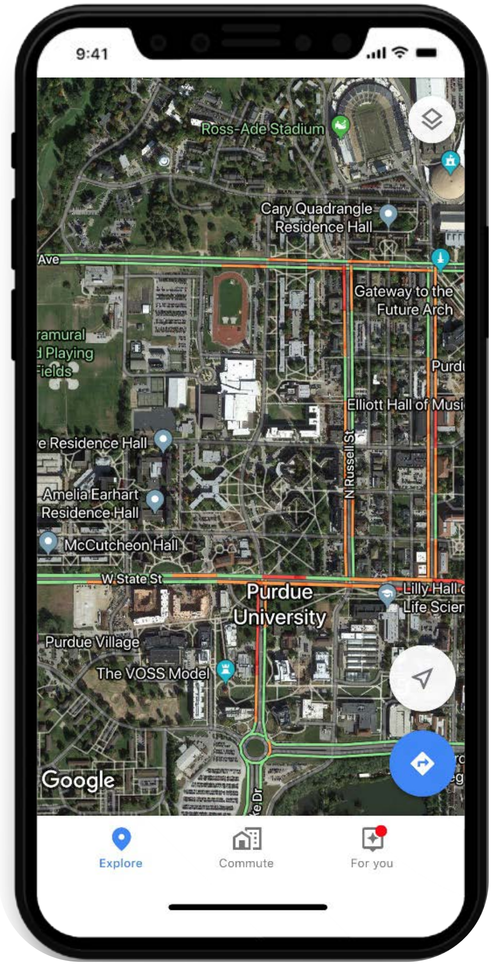
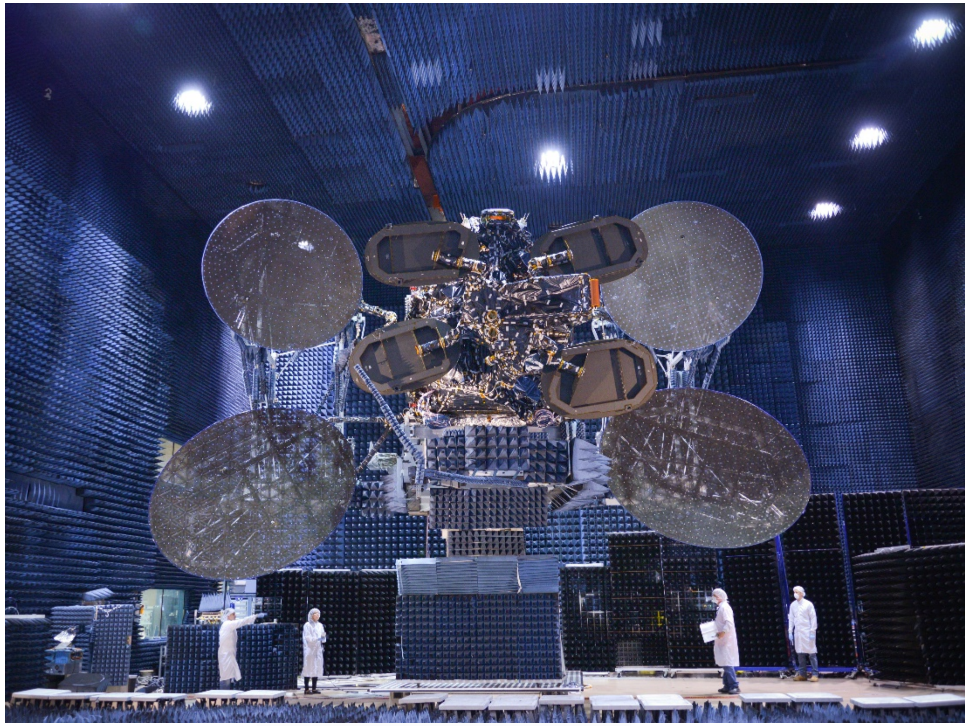
7 November, 2019

Who is *Maxar*?






"All the News That's Fit to Print"

The New York Times

National Edition

VOL. CLXVI ... No. 57,707

FRIDAY, SEPTEMBER 1, 2017

Fiery Explosions Elevate Fears for Chemical Plants Flooded by Texas Storm

A Vast Industry Around Houston, Producing Compounds Vulnerable to Heat

Disaster With 'No Boundaries' Devastates Rich and Poor Alike

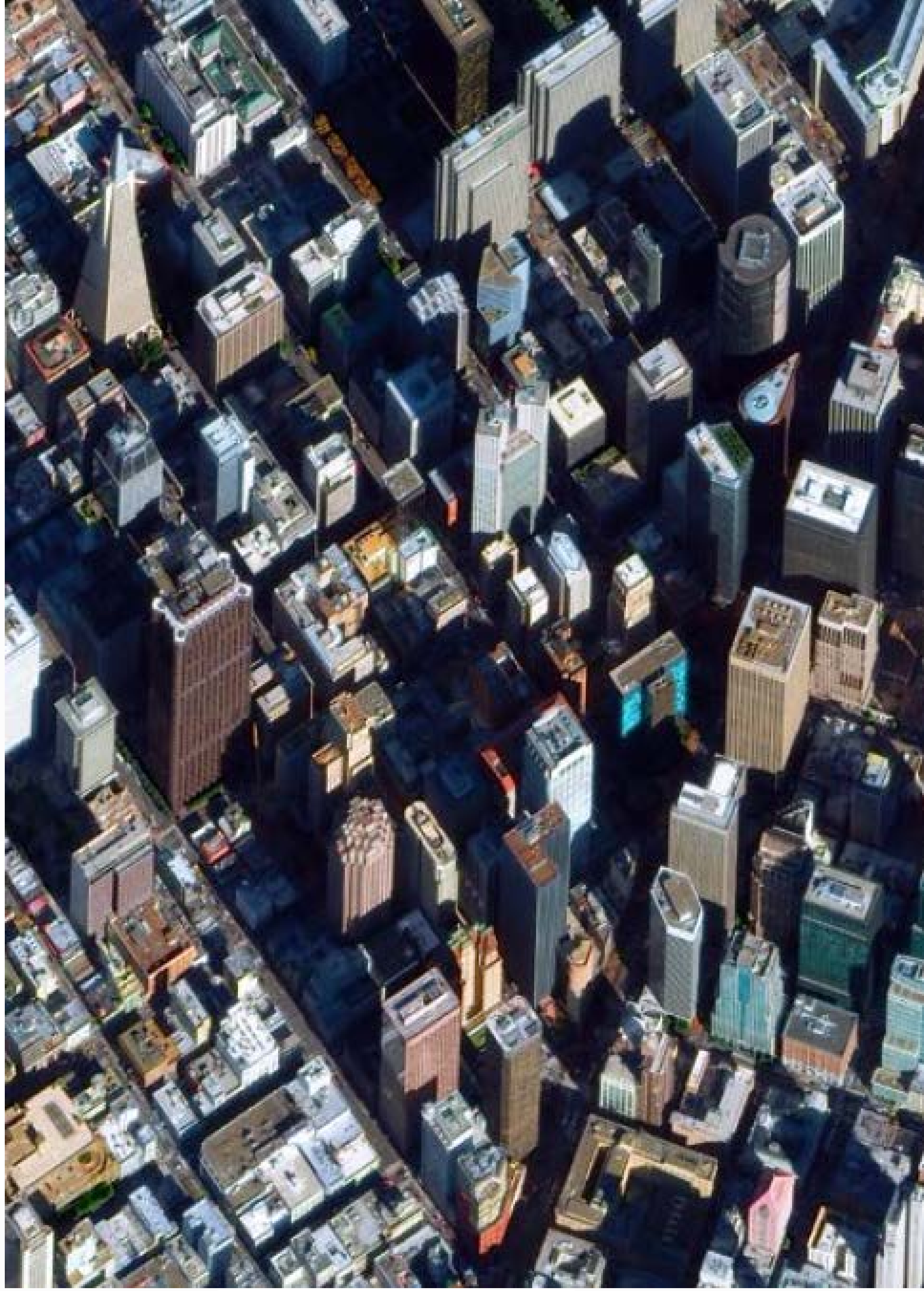
Neighborhoods United in Soggy Duress Face a Tough Recovery

Storm Shifts Political Winds In Capital

Gas Prices Rise As Oil Refiners Race to Recover

Powering accurate navigation for transportation apps

- Uber relies on Maxar for high-resolution imagery refresh to ensure their mapping applications are up-to-date and accurate. Faster than using public records, this helped Uber increase reliability with more accurate pick-up/drop-off locations and better service
for passengers.



Protecting the world's most high-profile events

The highest-quality imagery, 3D elevation models and comprehensive human landscape data helped security teams and local authorities plan emergency responses and mitigate potential threats at the Olympic Games. And with all of those resources available in the cloud, security planners had the access they needed to confidently coordinate public safety for the world's largest sporting event.


RIO VECTOR DATA

Eradicating disease with reliable maps

- The Bill & Melinda Gates Foundation turns to Maxar for current, high-resolution imagery that reveals uncharted roads and villages in Africa. With up-to-date maps, health workers can access the answers they need to reach disease-affected areas and deliver life-saving medical supplies.

ORIGINAL MAP OF MAMOU

MAP OF MAMOU DERIVED FROM MAXAR IMAGERY

MAXAR

Enabling cost-effective risk assessments

As a location data service provider, PSMA Australia wanted to build a single comprehensive, continent-wide dataset by capturing the entire built environment of Australia.

PSMA partnered with us to quantify, in detail, all 13.5 million addresses coast-to-coast – delivering a revolutionary new platform for location intelligence – using our advanced geospatial technology.

- Our organization has more than 60 years of experience in **geospatial information and analytics**, **satellite technology,** and **space systems**.
- As a trusted partner and innovator in **Earth Intelligence** and **Space Infrastructure**, we deliver disruptive value to government and commercial customers to help them monitor, **understand and navigate our changing planet**; deliver global broadband communications; and explore and advance the use of space.

30

Global office locations

5900

Team members

100+

Petabyte optical imagery archive

Integrated solutions for complex challenges

Maxar simplifies access to critical information about our planet, empowering customers to answer complex questions that impact environments, economies, and lives.

Space platforms

Ground systems

Information layers

Analytics

Robotics

Satellite imagery

Expertise

Direct & online access

Integrated solutions for complex challenges (continued)

Maxar simplifies access to critical information about our planet, empowering customers to answer complex questions that impact environments, economies, and lives.

- 280 satellites built & launched
- Long-term provider of Canada defence systems
- 40 million building footprints digitized per month
- Powered by 100+ petabytes worth of data
- Space robotics used on the ISS for 18 years
- Collecting more than 3 million sq km per day
- 1,000 cleared developers, analysts & data scientists
- Reaching more than 250,000 users in the USG

MAXAR

Satellite imagery

Optical and radar satellite imagery with diversity in temporal, spectral, and spatial resolution, plus unparalleled accuracy.

- Native 30 cm resolution for industry leading clarity and information density
- Advanced multispectral capabilities see beyond what’s visible to the human eye
- Time-lapse data library dates back to 1999, creating a living digital inventory of change on the Earth’s surface

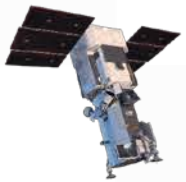
The world’s most advanced constellation

Maxar’s constellation supports a wide range of applications across defense & intelligence, civil government, and a variety of commercial industries









IKONOS	QuickBird	WorldView-4	WorldView-1	GeoEye-1	WorldView-2	WorldView-3	RADARSAT-2*	WorldView Legion
82 cm resolution	65 cm resolution	31 cm resolution	50 cm resolution	41 cm resolution	46 cm resolution	31 cm resolution	1.0 m resolution	Specifics not yet announced
9.0 m CE90	23 m CE90	5.0 m CE90	5.0 m CE90	5.0 m CE90	5.0 m CE90	5.0 m CE90	< 15 m CE90	
6.0 m RMSE	10.8 m RMSE	3.7 m RMSE	3.0 m RMSE	2.7 m RMSE	3.0 m RMSE	2.5 m RMSE		2021

Available in archive (IKONOS, QuickBird, WorldView-4)

Currently imaging in orbit (WorldView-1, GeoEye-1, WorldView-2, WorldView-3, RADARSAT-2*)

*Owned & Operated by MDA Geospatial Services Inc.

Pointing Accuracy is not applicable to RADARSAT-2

WorldView Legion

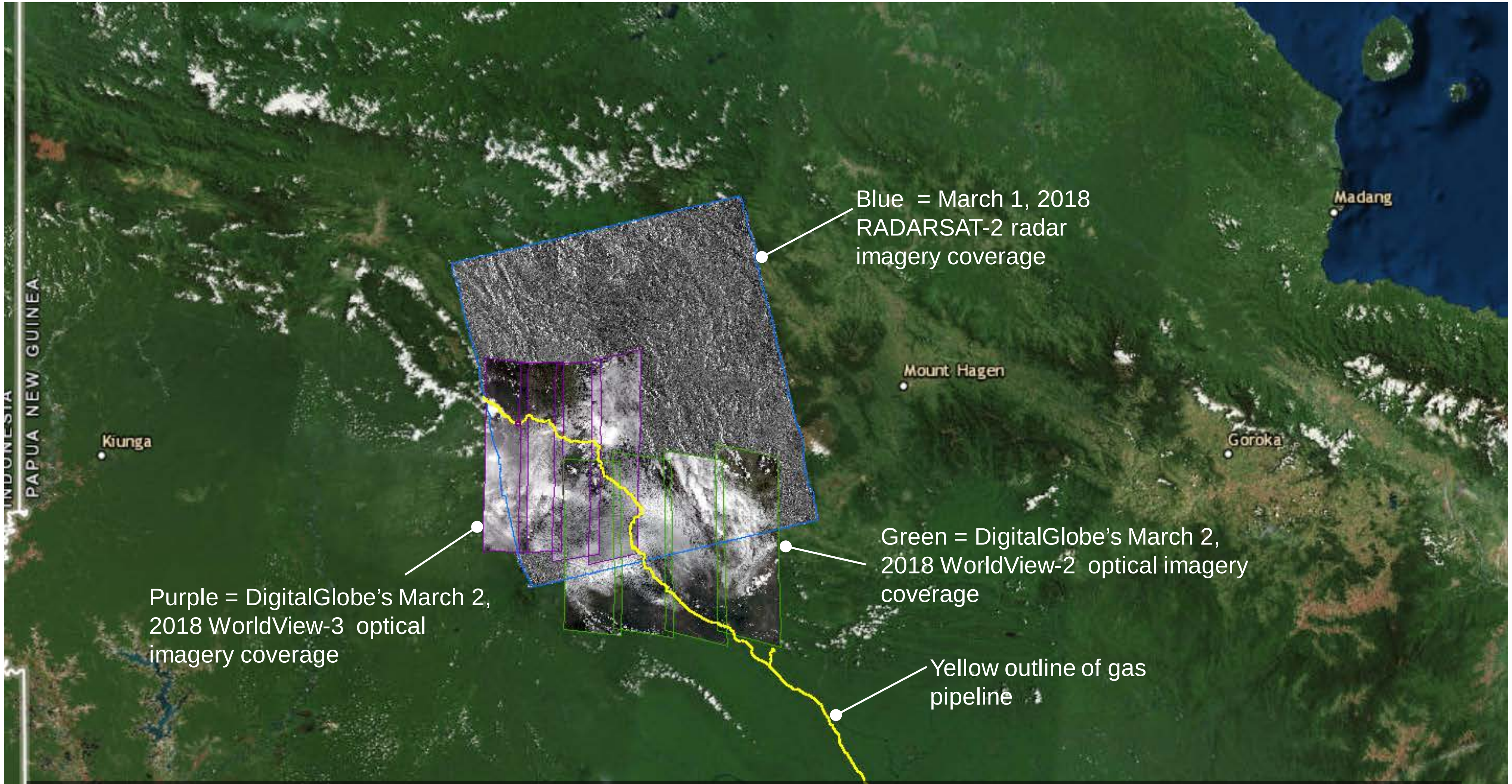
A next-generation low Earth orbit constellation, using the most innovative and flexible imaging satellite for exceptional on-orbit performance, value, and reliability.

- Launch in 2021-2022
- Triples Maxar's 30 cm resolution collection capacity
- 500 kg class spacecraft bus

Providing even greater insights into global events of significance, for critical decision-making when time is of the essence.

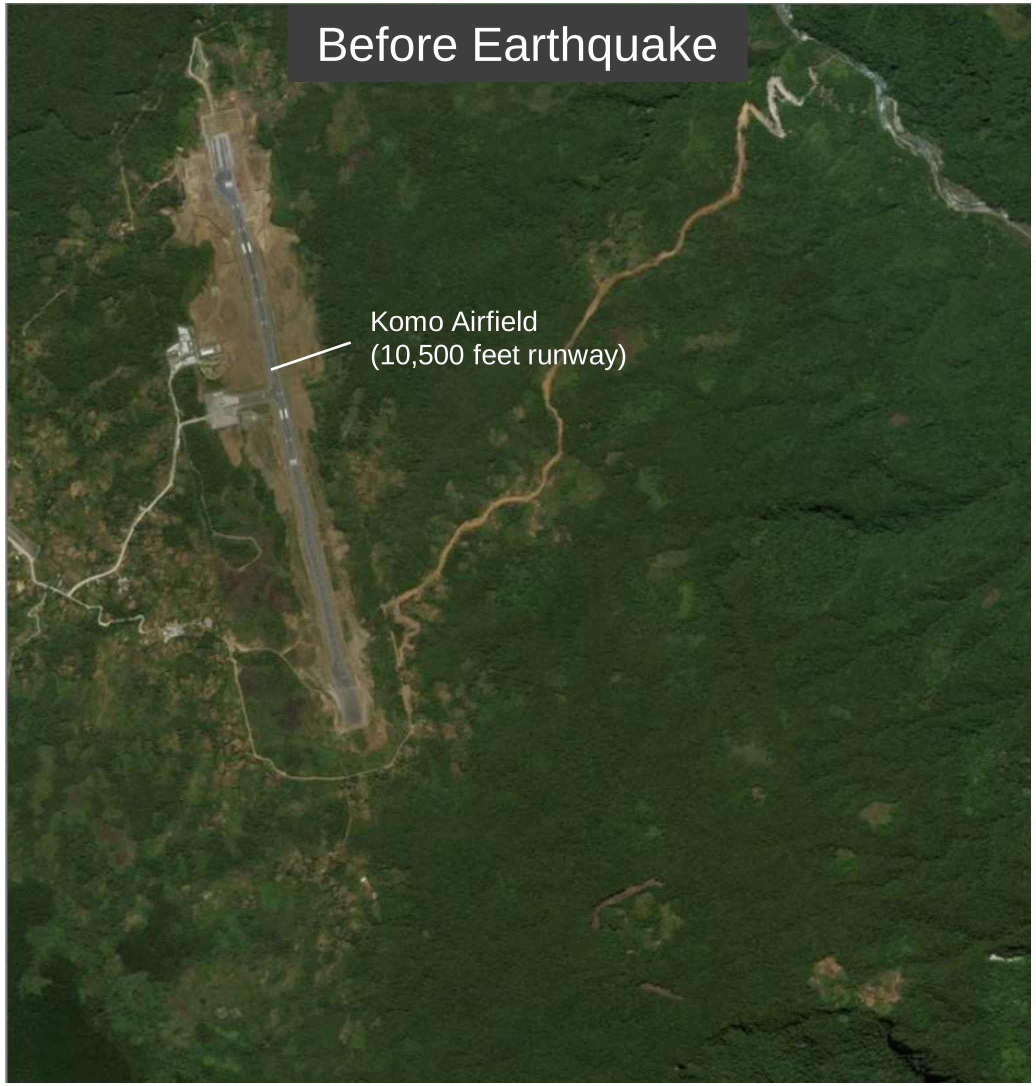
MAXAR

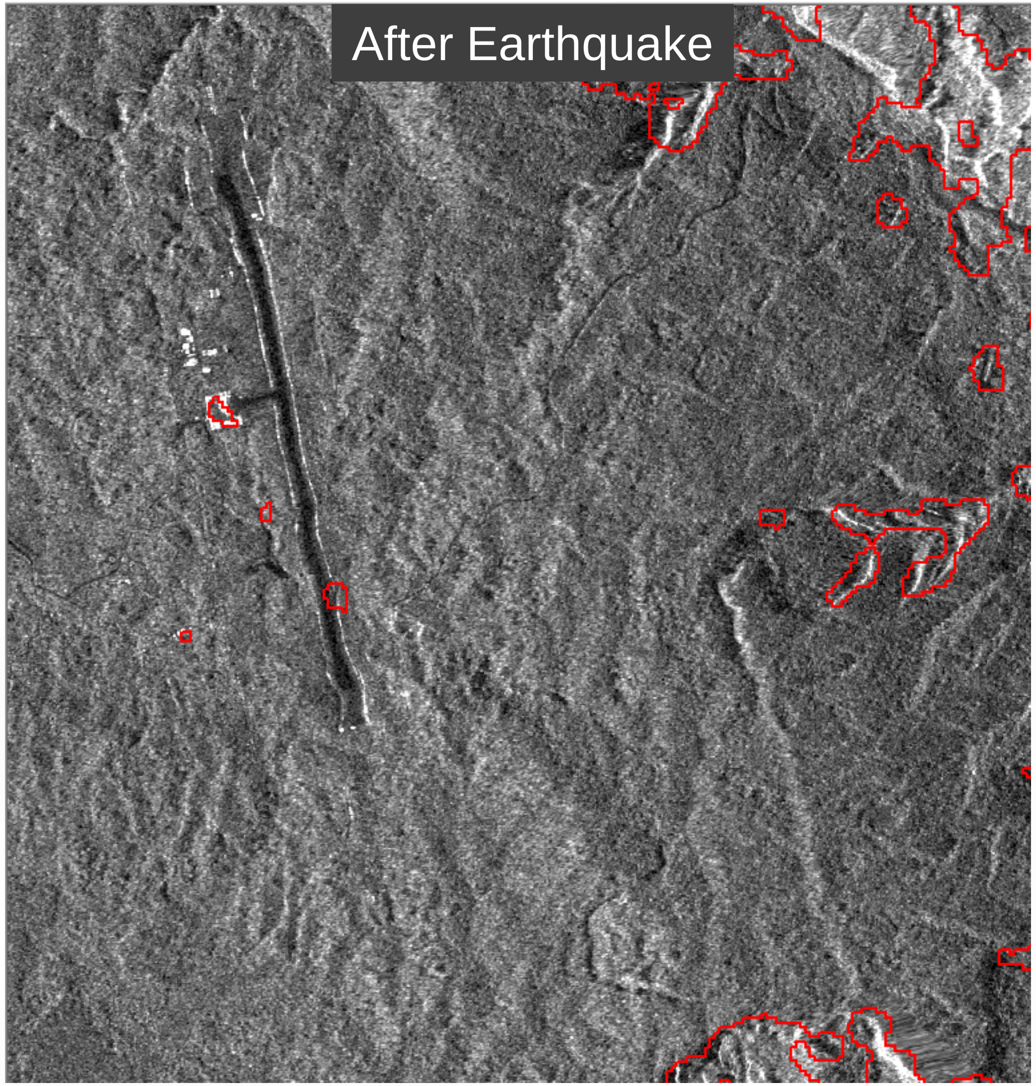
Optical vs SAR



MDA RADARSAT-2 and DigitalGlobe Satellite Imagery Coverage | March 1, 2018 | Papua New Guinea Earthquake Aftermath

Optical vs SAR (continued)





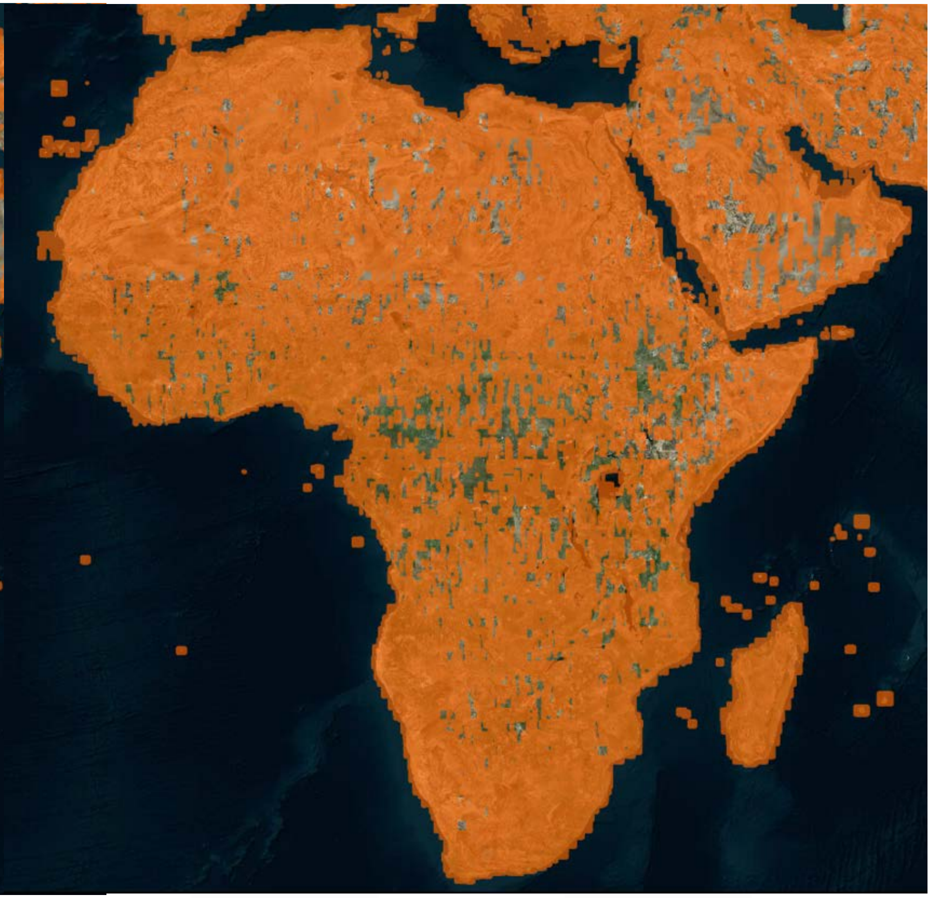
So how do we do this?

Image Collection :

Over 30 days

Over 6 months

Over 1 year



MAXAR

There are many ways we deliver imagery

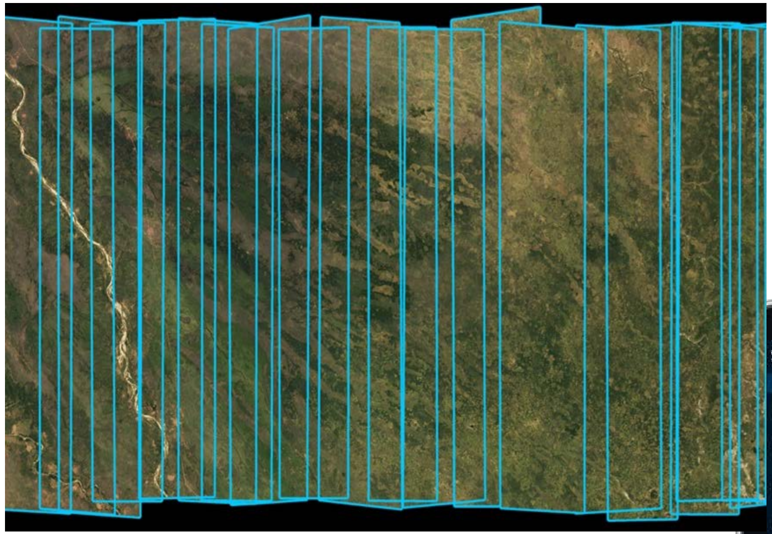
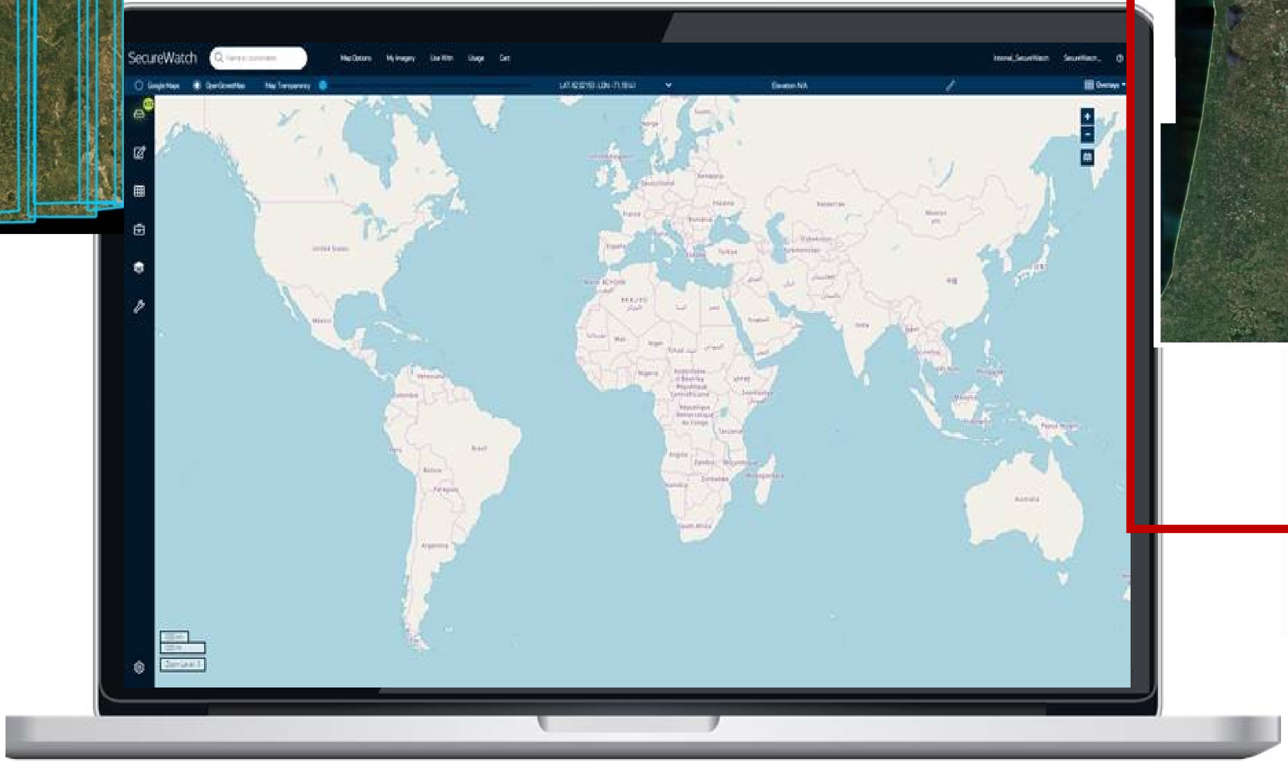


Image Strips

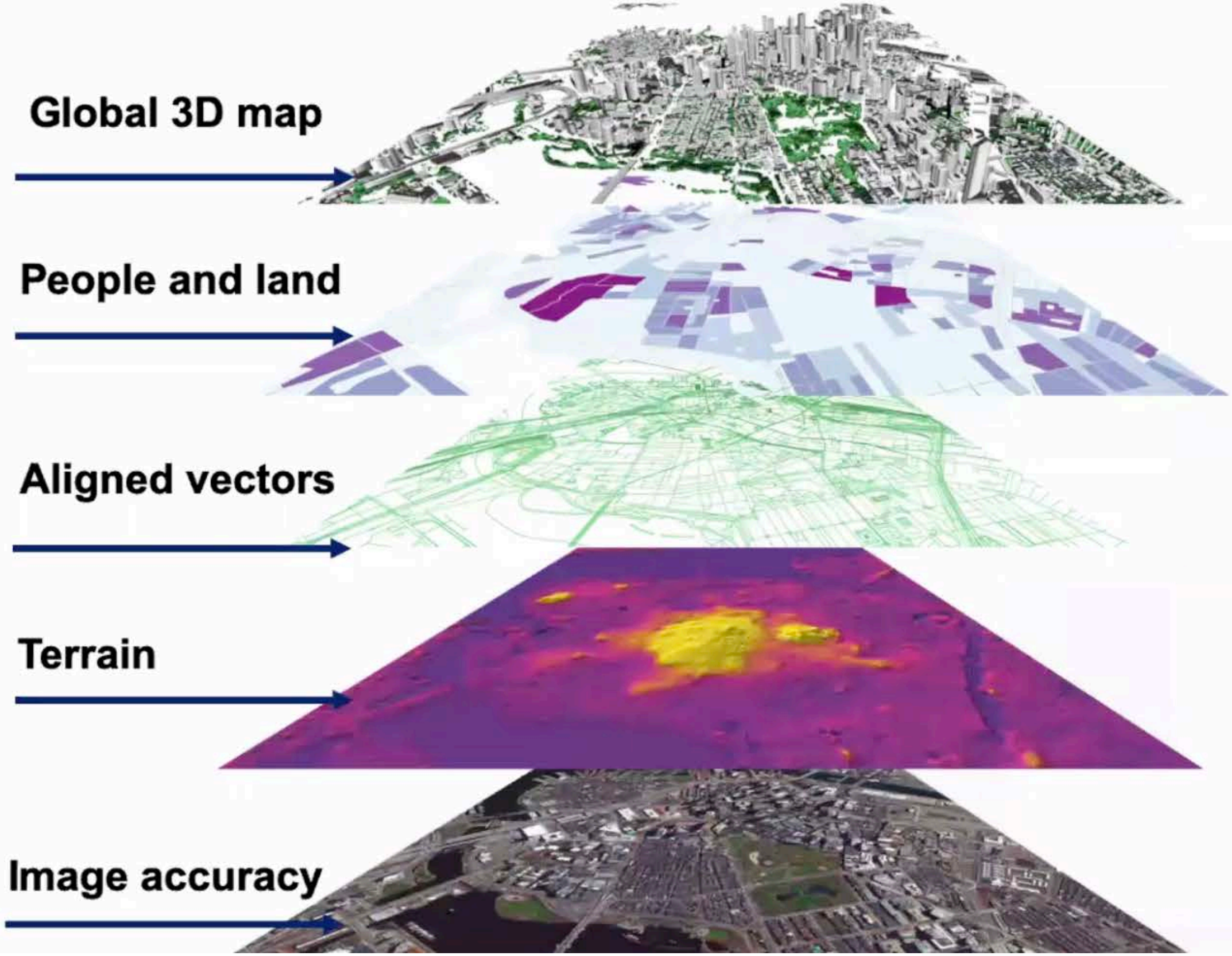
Services



Mosaics

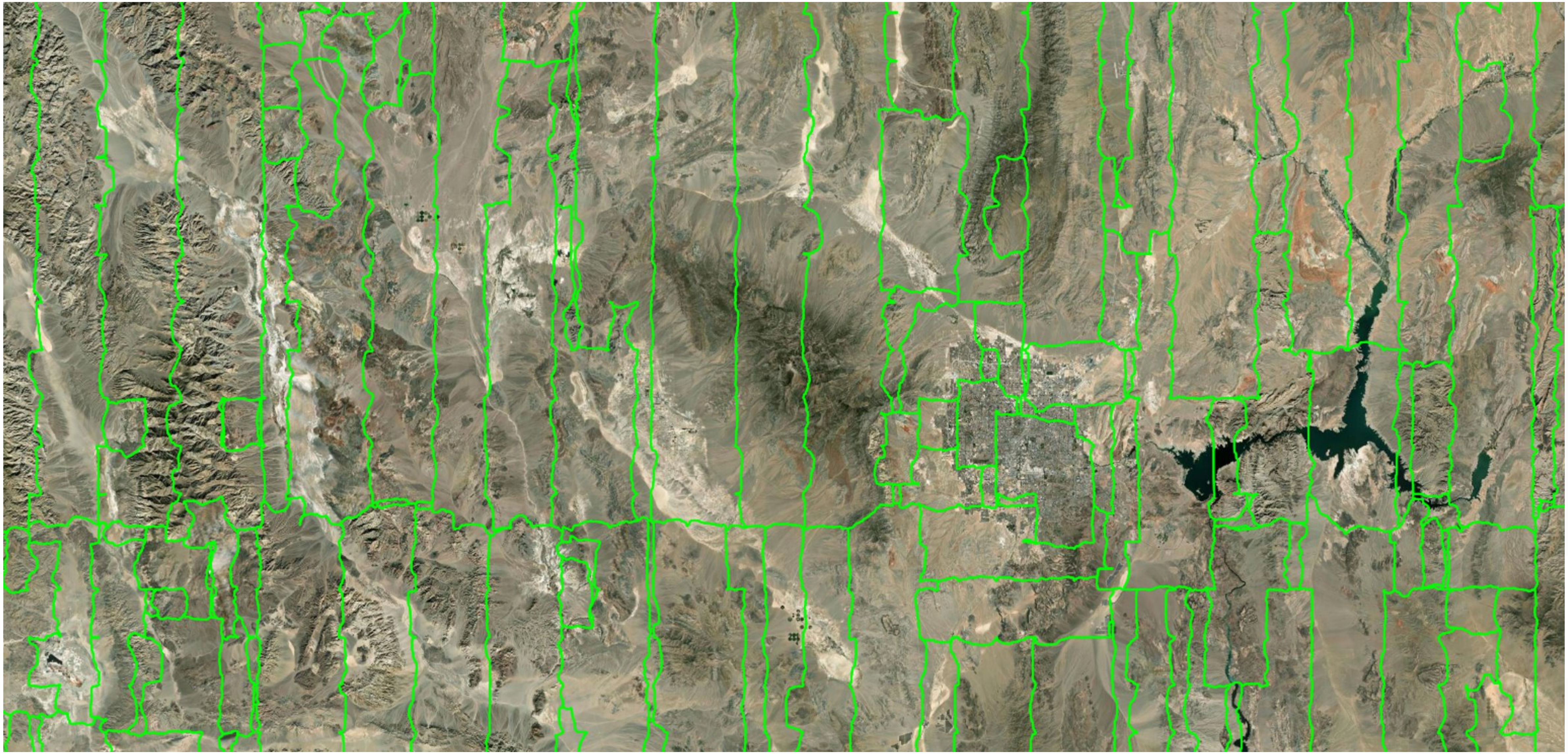
MAXAR

Image mosaics are the global 2D mapping foundation



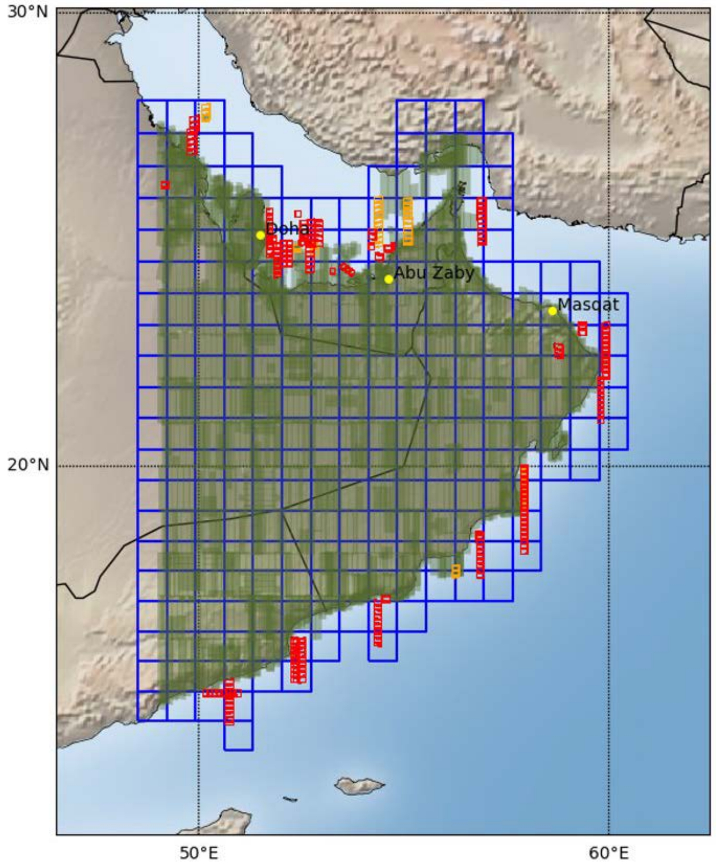
- Accurate
- Current
- Analysis ready
- Global scale

Large Area Mosaics are made of a lot of images…



Creating an imagery mosaic

Atmospheric Compensation

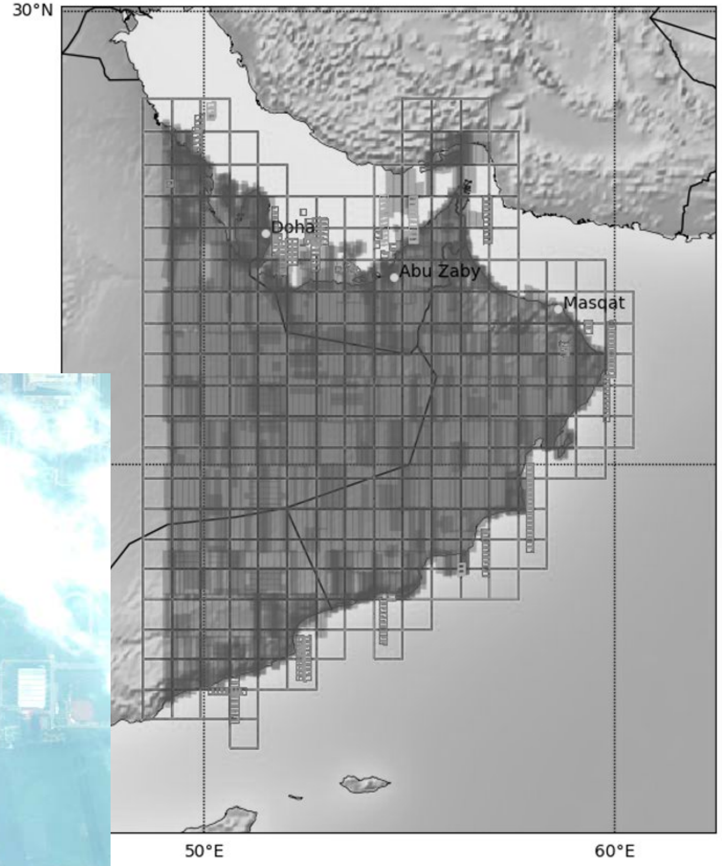


Bundle Block Adjustment

FLAME

Creating an imagery mosaic (continued)

Atmospheric Compensation



Bundle Block Adjustment

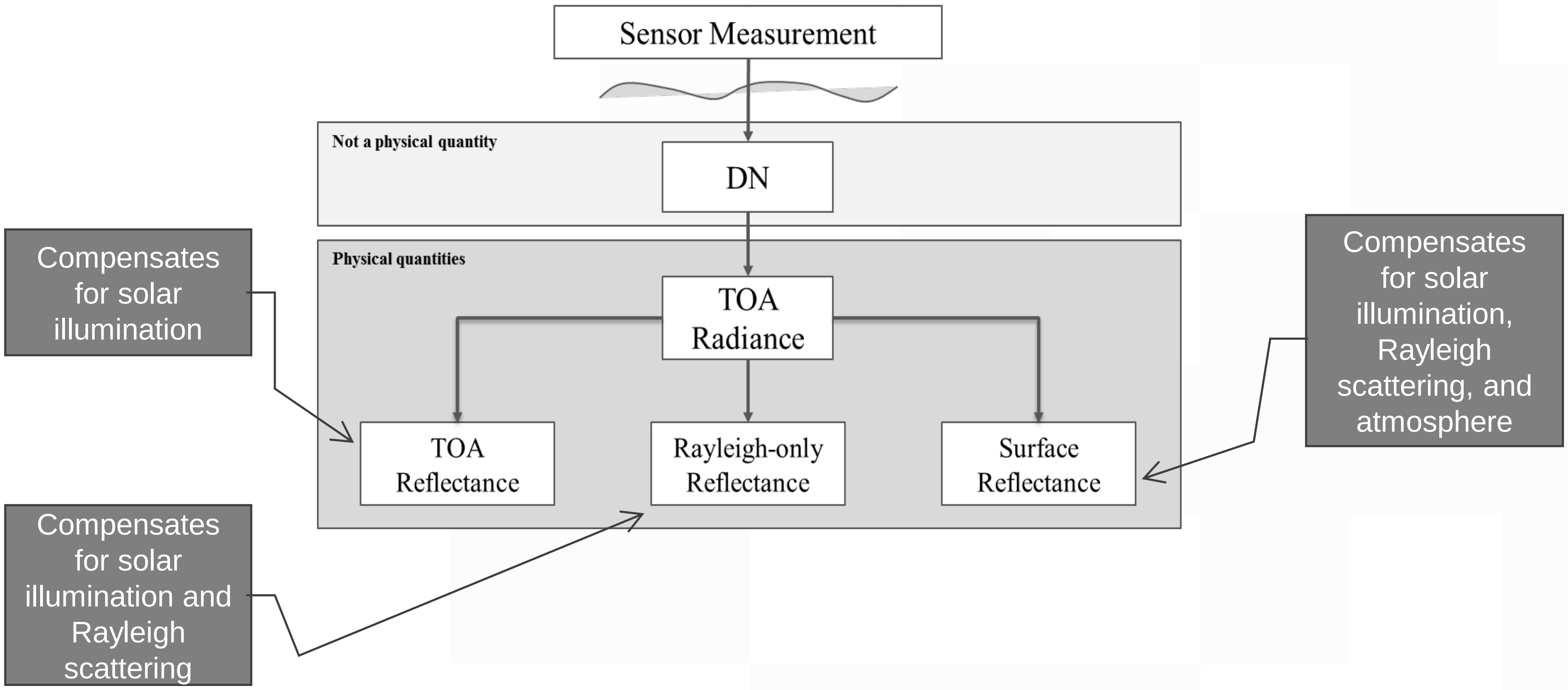
FLAME

The atmosphere affects ALL satellite images

The atmosphere affects ALL satellite images

How to minimize the effects of the atmosphere?

- Physical property of a viewed surface that is independent of lighting and atmospheric conditions
- Compensate the images to be consistent with viewing the area from the ground



Maxar's Atmospheric Compensation (Acomp)

- **Quantitative analysis** (spectral analysis, band ratios, etc.) requires measures of physical units (surface reflectivity) rather than an observed quantity
- **AComp** is a **fully automated, physics-based** framework for atmospherically compensating very high spatial resolution images
- Advantages:
  - Determines aerosol optical depth (AOD) and water vapor from image
  - Works on PAN, VNIR, and SWIR imagery (all current Maxar satellites)
  - facilitates cross-sensor processing
  - improves performance of multi-temporal data analysis
  - enables the extraction of information using physical quantities, not just image statistics
  - fully automated (no human in the loop), thus suitable for large-scale production
- Validation results indicate that AComp is **more accurate** than other software like FLAASH or QUAC

How to minimize the effects of the atmospheric?

TOA reflectance

Rayleigh-only reflectance

Surface reflectance

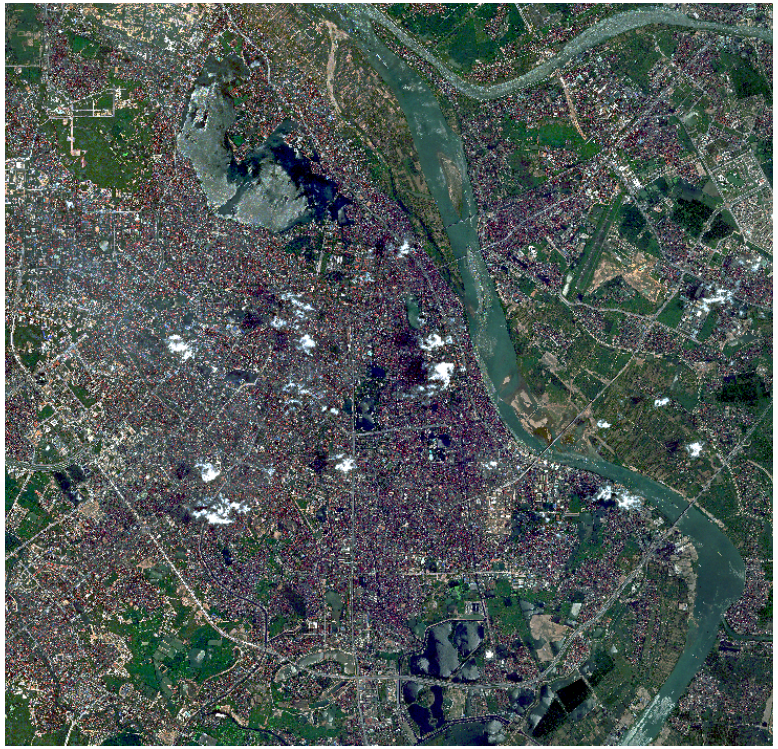
Normal visibility (about 40 km)

How to minimize the effects of the atmospheric?

TOA reflectance

Rayleigh-only reflectance

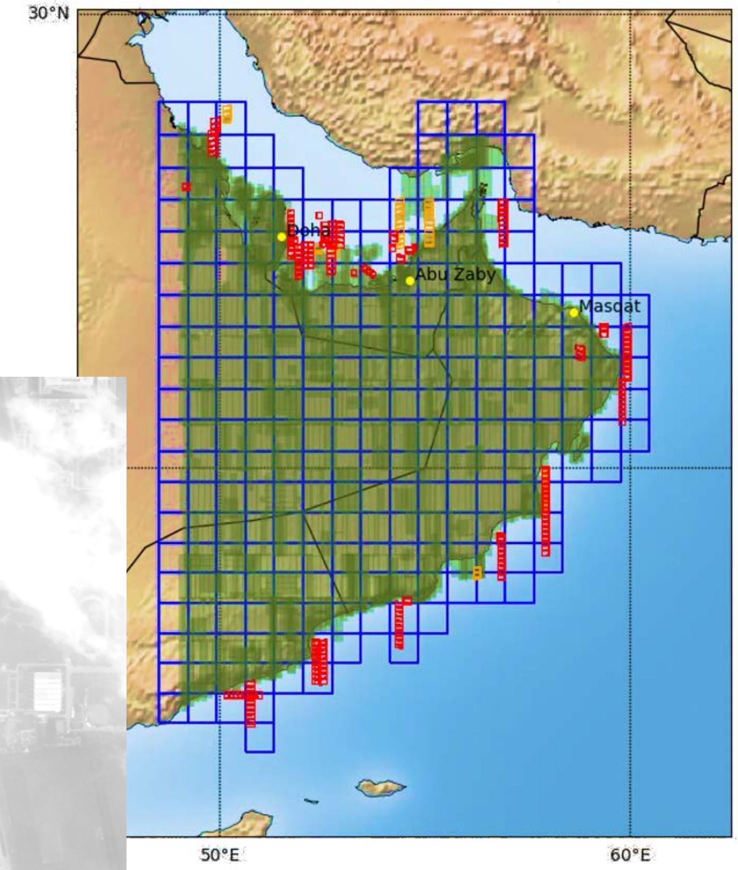
Surface reflectance



Low visibility (about 1 km)

Creating an imagery mosaic (continued)

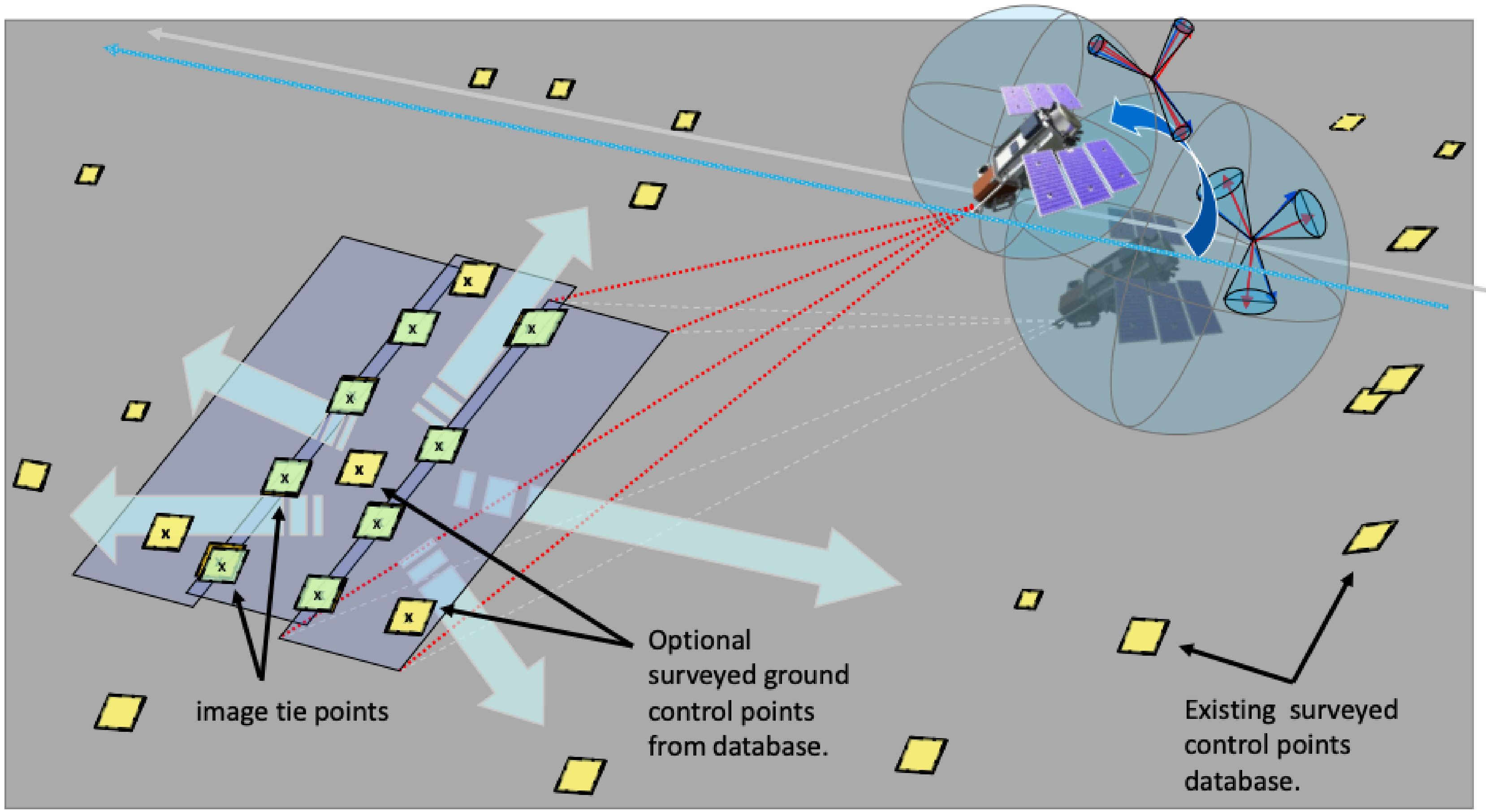
Atmospheric Compensation



Bundle Block Adjustment

FLAME

Bundle Block Adjustment (BBA) for improving geolocation accuracy



Multiple overlapping images are adjusted to a "best fit" using tie points between images.

- Reduce shear in large area ortho-mosaics
- Produce single blocks for entire nations or regions
- Improved absolute accuracy over large contiguous regions of imagery
- Improved spatial precision for vector overlay or feature extraction
  - Predictable Absolute Accuracy of 3 to 4 meters CE90.
  - Predictable Relative Accuracy of 1 to 2 pixels.
- Fully Automated Workflow.
- Massively Scalable – Runs in AWS.

BBA Methodology

- Use pointing information from multiple images
  - Attitude and ephemeris
- Generate tie-points with Atp (Auto-tie-point)
  - find interest points using machine vision
  - cluster into tie-points in image overlaps
  - correlate points in images
  - score points and select the best
- Find an optimal solution to pointing information
  - least-squares solver
  - minimize position residuals
  - rigorous camera model
  - iterative solution to remove blunders

Before BBA | After BBA

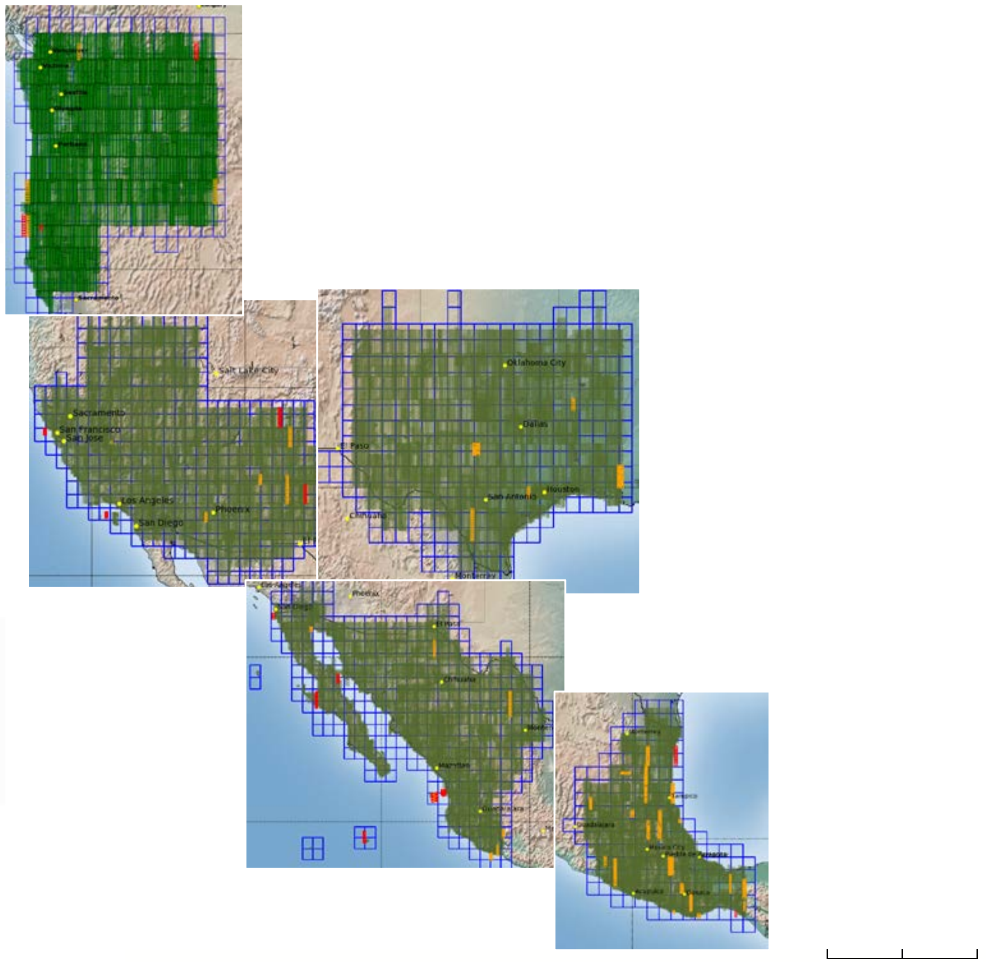
Why do BBA?

Benefits

- Improves positional geolocational accuracy
- Customers trusts that object in image is where it’s located on the ground
- Better visual quality

Example: Creating a mosaic of North America

- Divided landmass into grids; assign each partition its own AWS EC2 compute instance
- Hundreds of simultaneous instances using machine vision to find tie-points
- Results saved into AWS S3 storage
- 1-2 million km2 complete in 6-10 hours

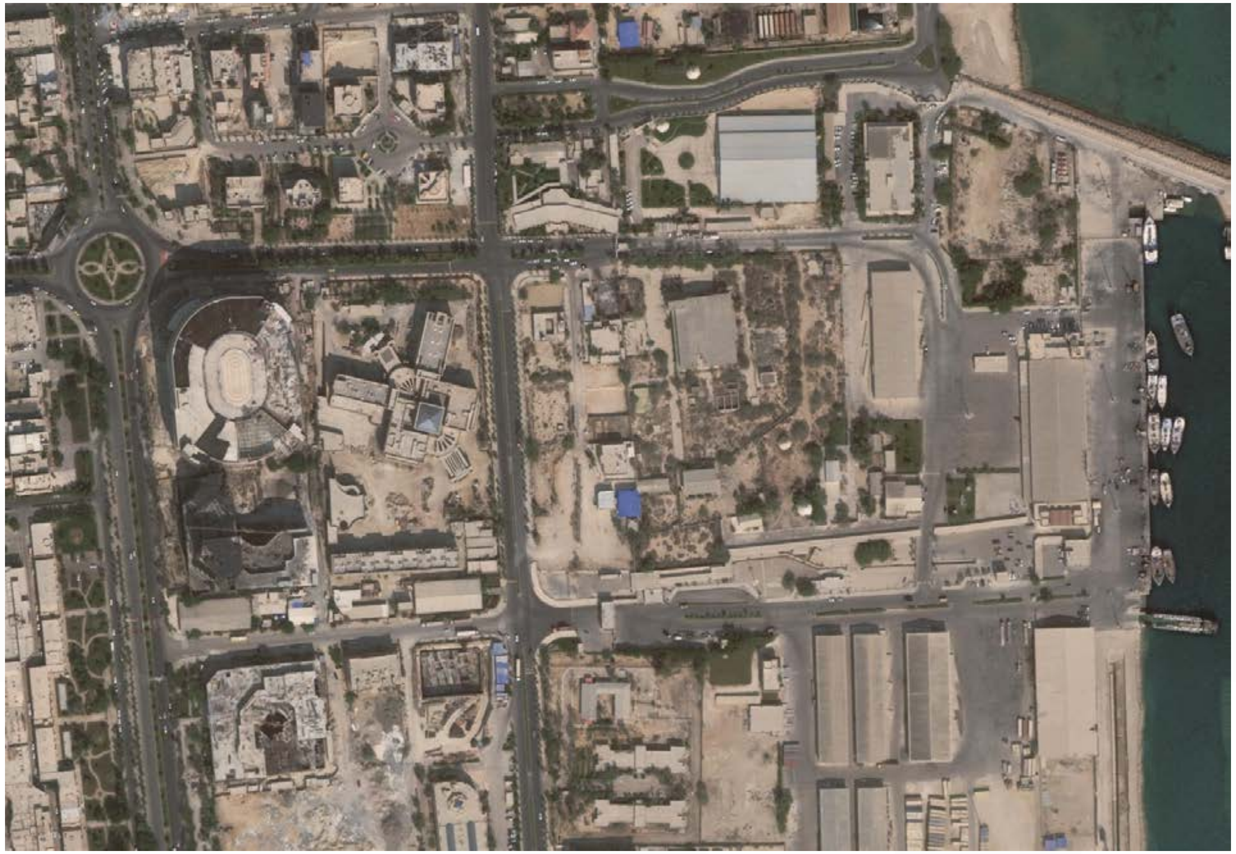


Automated bundle adjustment at scales not previously possible in WorldView-class imagery.

Image Alignment

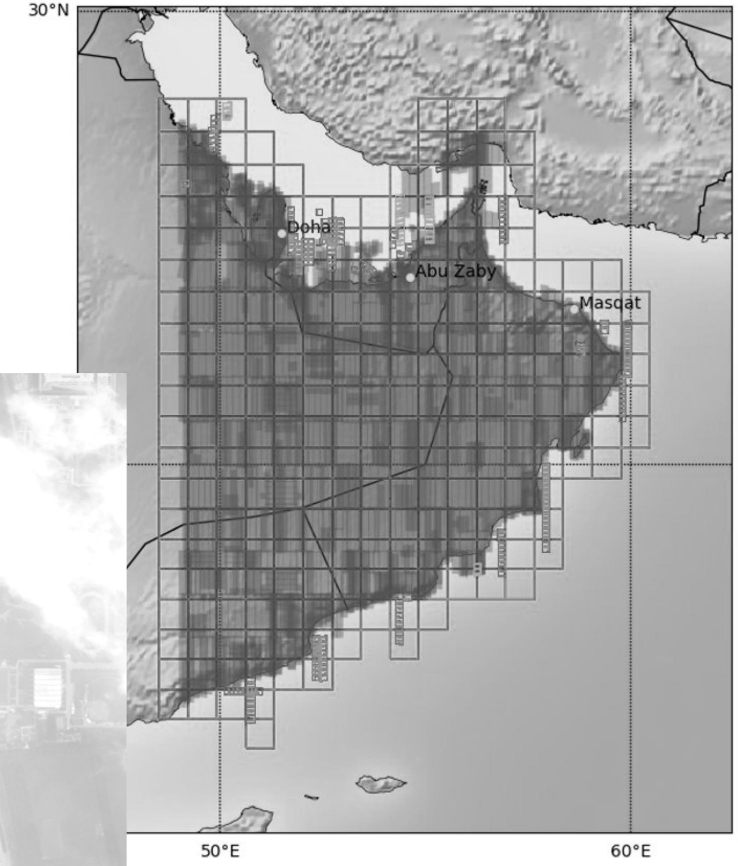
Without BBA

With BBA



Creating an imagery mosaic

Atmospheric Compensation

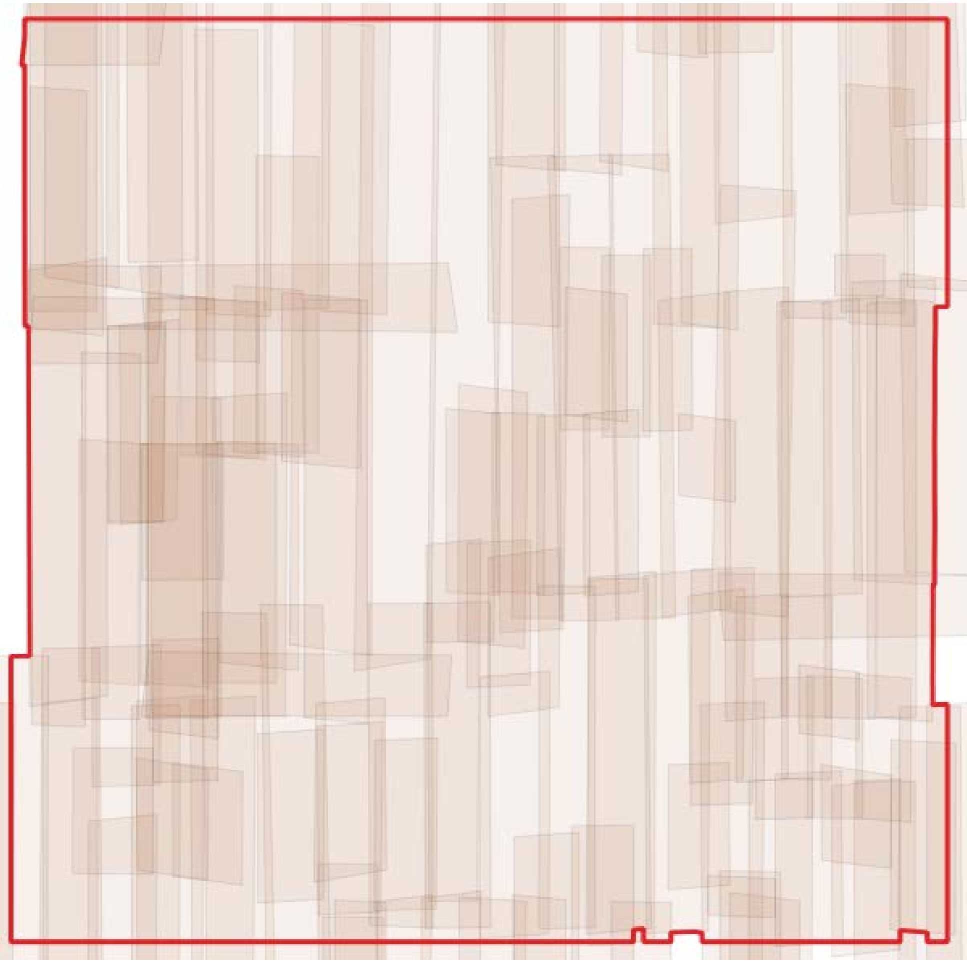


Bundle Block Adjustment

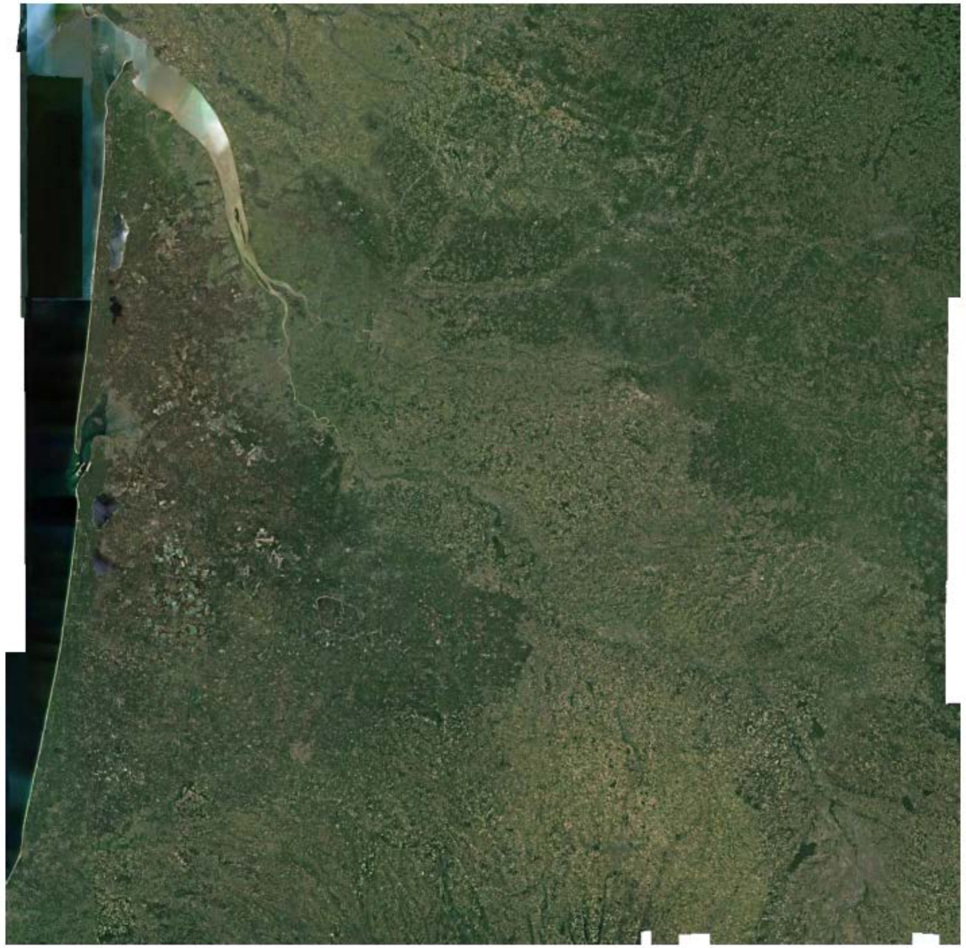
FLAME

The problem FLAME solves:

Turn a hodgepodge of satellite collects…

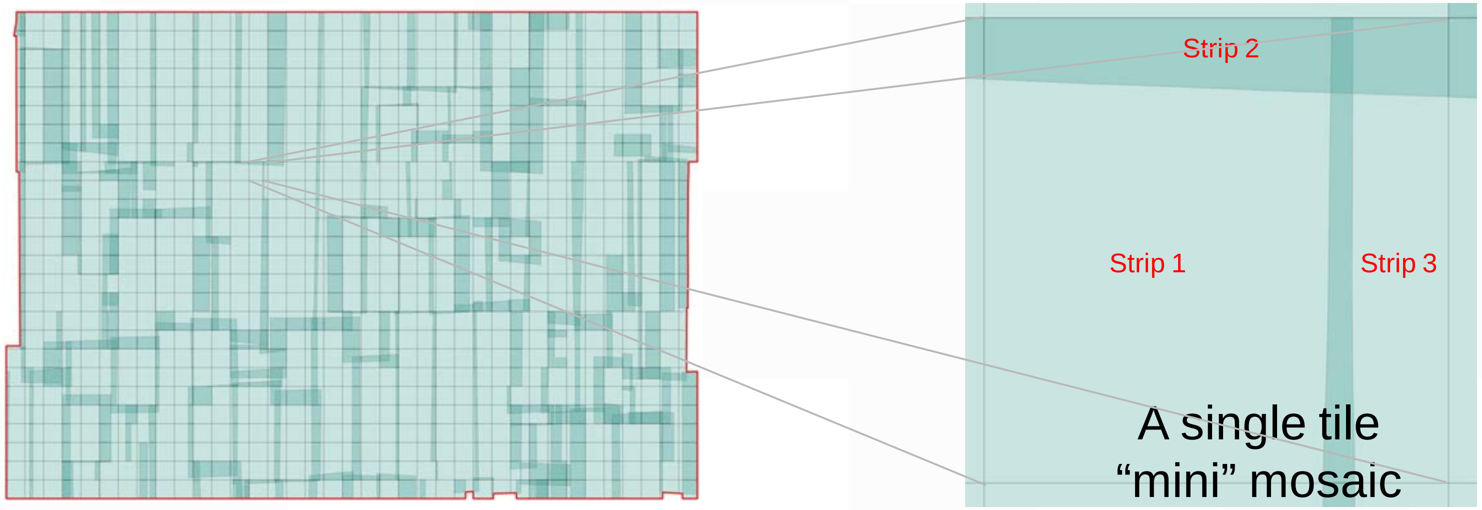


into a beautiful seamless mosaic!



What Can It Do Today?

- Scales to continent-sized mosaics
- Mixes together all the sensors that we can get imagery from
- Balances color
- Supports multiple resolutions
- Easy to update existing mosaics
- Easy to merge existing mosaics



Tonal Correction

Goal: apply a dynamic range adjustment (DRA) to each strip that maps them to 8bit RGB space such that they look tonally consistent

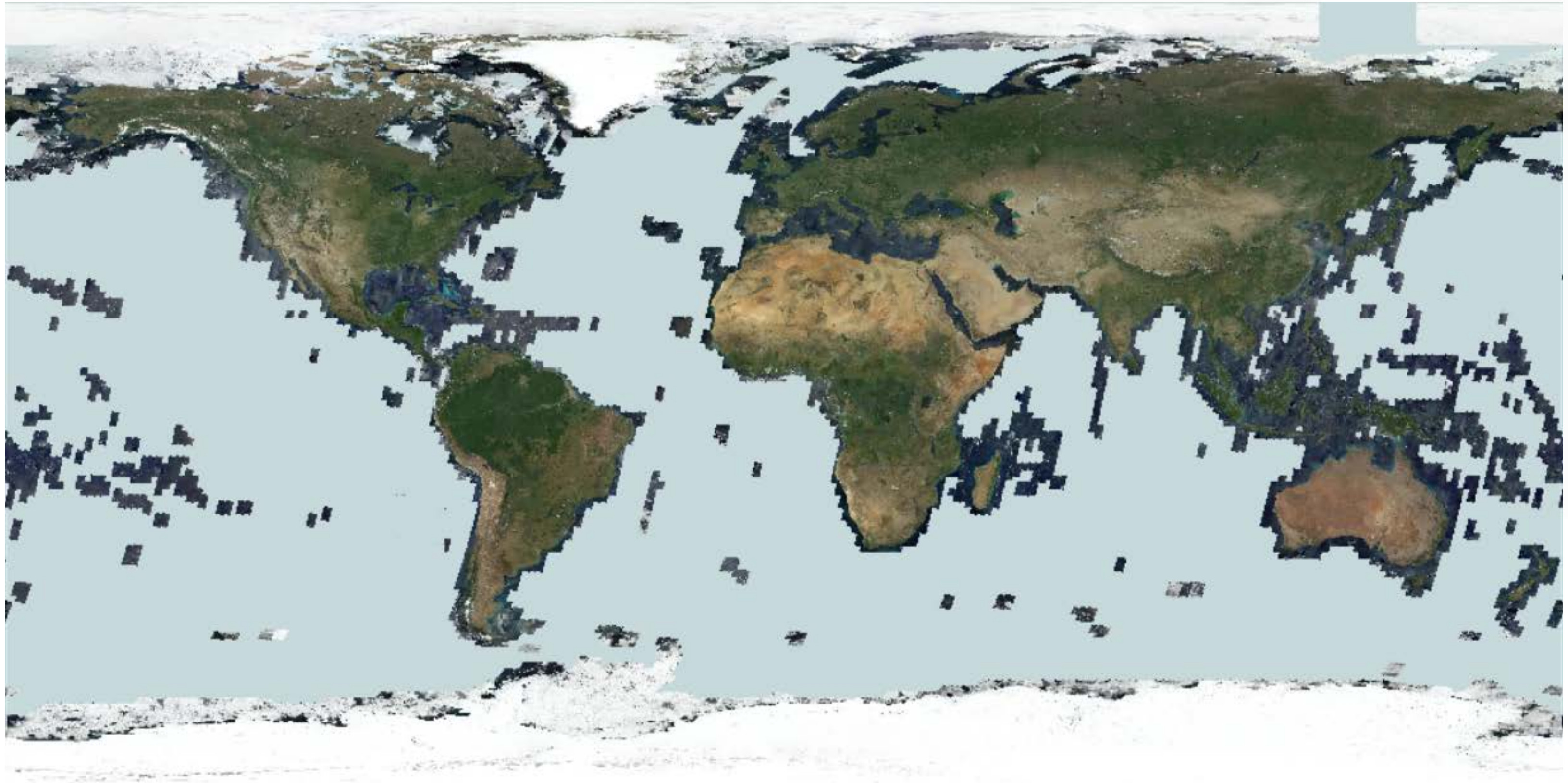
- Do it manually?
  - This is how we do small scale, high touch mosaics
  - Processing all the strips up to a certain level (through pan sharpening) and then having someone look at them in aggregate to determine a DRA for each collect is a colossal bottleneck!
- A common approach is to do a relative balance
  - Solve for gain and bias corrections for each image via least squares such that we minimize the difference in pixel intensities at some set of common points
  - Still requires all strips to be processed through a certain level, and you still have to put a final DRA on it

We needed a fully automated approach where each strip can be processed through tonal correction without any knowledge of the other strips that compose the mosaic

Baselayer Matching

Solution: match each strip to a global low resolution basemap(s)!

- Maxar maintains this kind of basemap built from Landsat 8



Generating Cutlines

- Cutline: the point in a mosaic when you switch from one image to another
- Types of cutlines:
  - Intra tile
  - Inter tile

Intra Cutlines

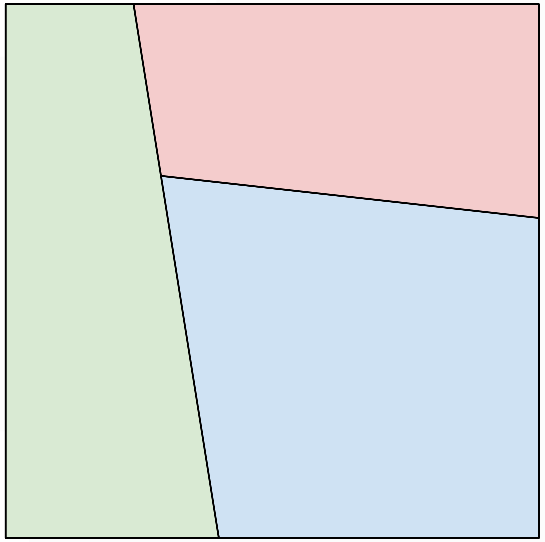
Deciding which image strips to show within a tile

To form cutlines within a tile stack, we find all pairwise default cuts and update them

This is done by:

1. Forming a cost image
2. Running Dijkstra's algorithm to find the least cost path between the start and end of the cut

To do this efficiently, we first run at low resolution and refine the result at full resolution



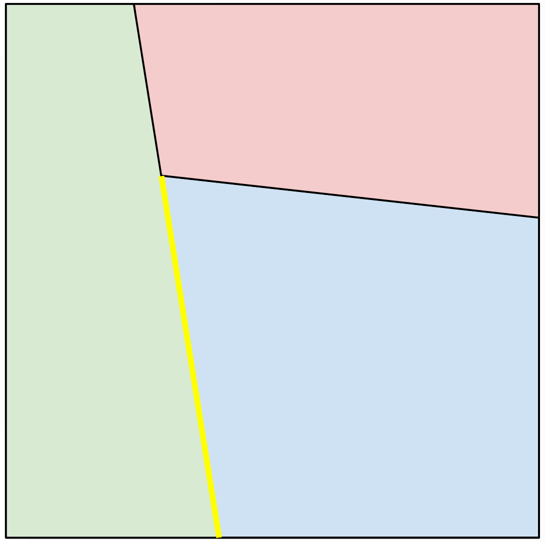
Intra Cutlines - 2

To form cutlines within a tile stack, we find all pairwise default cuts and update them

This is done by:

1. Forming a cost image
2. Running Dijkstra's algorithm to find the least cost path between the start and end of the cut

To do this efficiently, we first run at low resolution and refine the result at full resolution



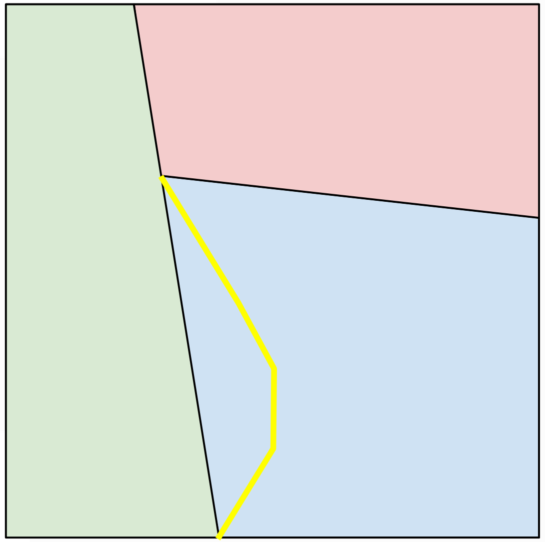
Intra Cutlines - 3

To form cutlines within a tile stack, we find all pairwise default cuts and update them

This is done by:

1. Forming a cost image
2. Running Dijkstra's algorithm to find the least cost path between the start and end of the cut

To do this efficiently, we first run at low resolution and refine the result at full resolution



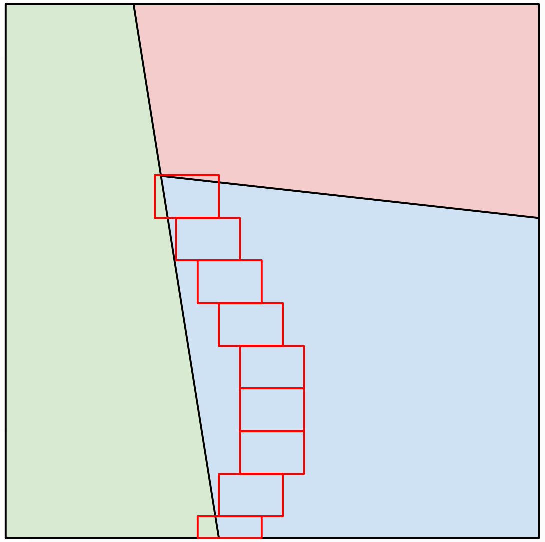
Intra Cutlines - 4

To form cutlines within a tile stack, we find all pairwise default cuts and update them

This is done by:

1. Forming a cost image
2. Running Dijkstra's algorithm to find the least cost path between the start and end of the cut

To do this efficiently, we first run at low resolution and refine the result at full resolution

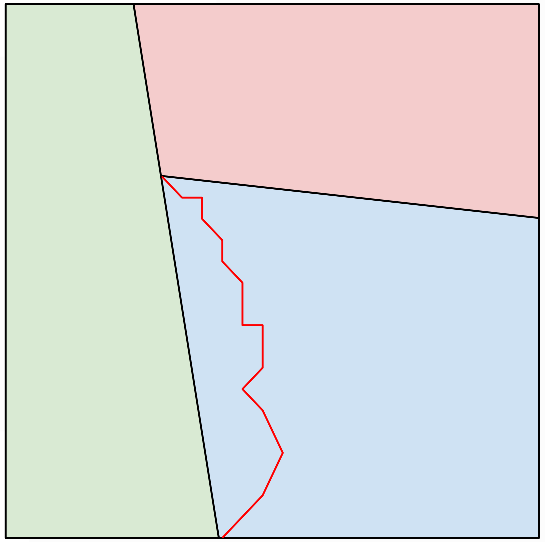


Intra Cutlines - 5

To form cutlines within a tile stack, we find all pairwise default cuts and update them

This is done by:

1. Forming a cost image
2. Running Dijkstra's algorithm to find the least cost path between the start and end of the cut



To do this efficiently, we first run at low resolution and refine the result at full resolution

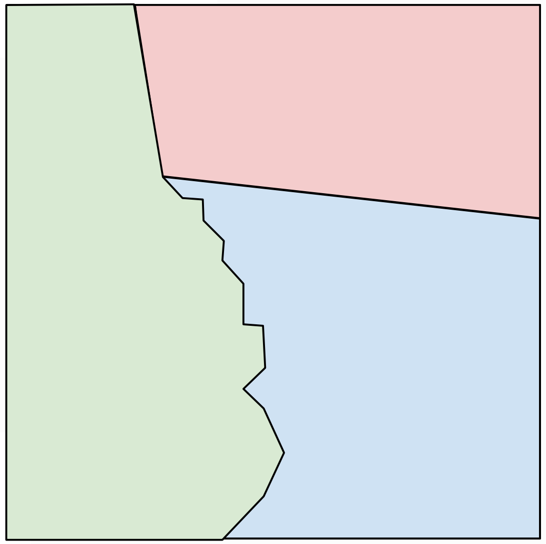
Intra Cutlines - 6

To form cutlines within a tile stack, we find all pairwise default cuts and update them

This is done by:

1. Forming a cost image
2. Running Dijkstra's algorithm to find the least cost path between the start and end of the cut

To do this efficiently, we first run at low resolution and refine the result at full resolution



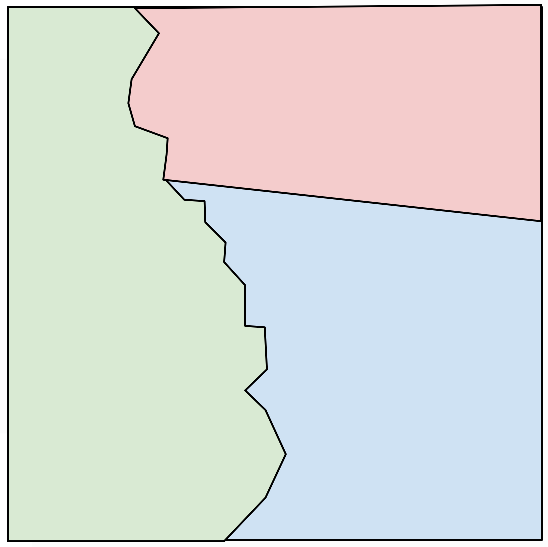
Intra Cutlines - 7

To form cutlines within a tile stack, we find all pairwise default cuts and update them

This is done by:

1. Forming a cost image
2. Running Dijkstra's algorithm to find the least cost path between the start and end of the cut

To do this efficiently, we first run at low resolution and refine the result at full resolution



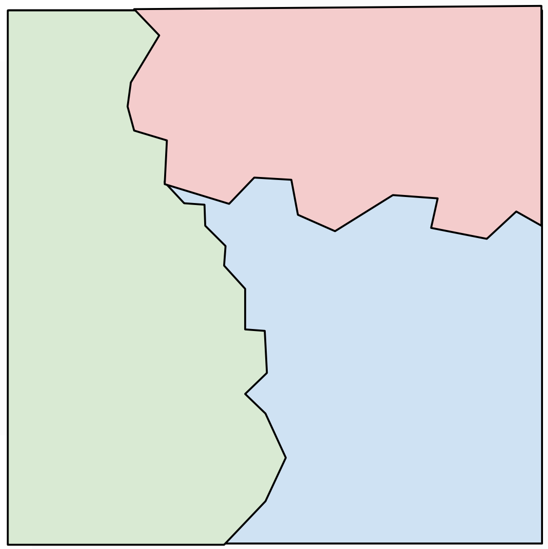
Intra Cutlines - 8

To form cutlines within a tile stack, we find all pairwise default cuts and update them

This is done by:

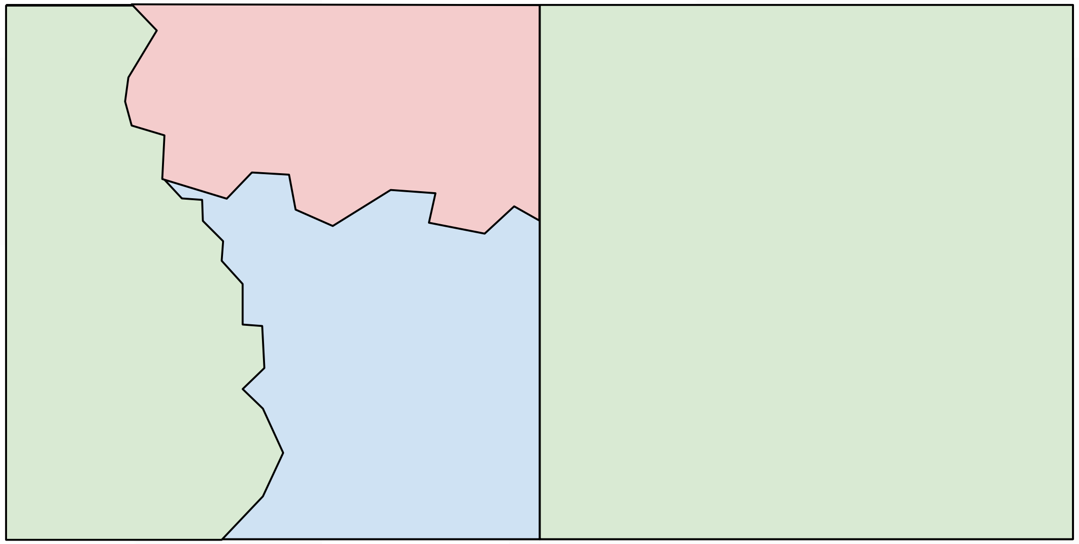
1. Forming a cost image
2. Running Dijkstra's algorithm to find the least cost path between the start and end of the cut

To do this efficiently, we first run at low resolution and refine the result at full resolution



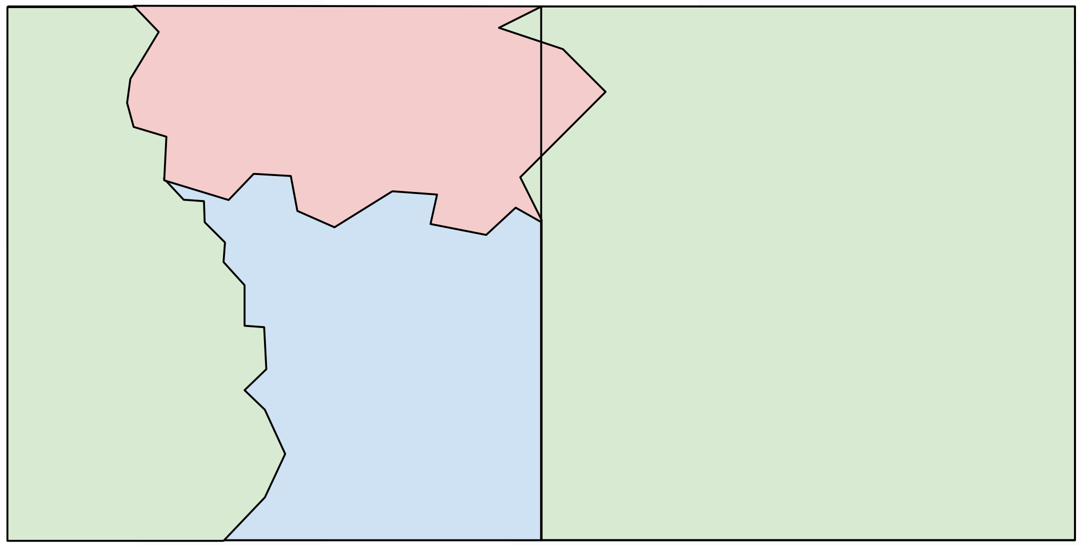
Inter Cutlines

Same idea, but neighbor tiles now



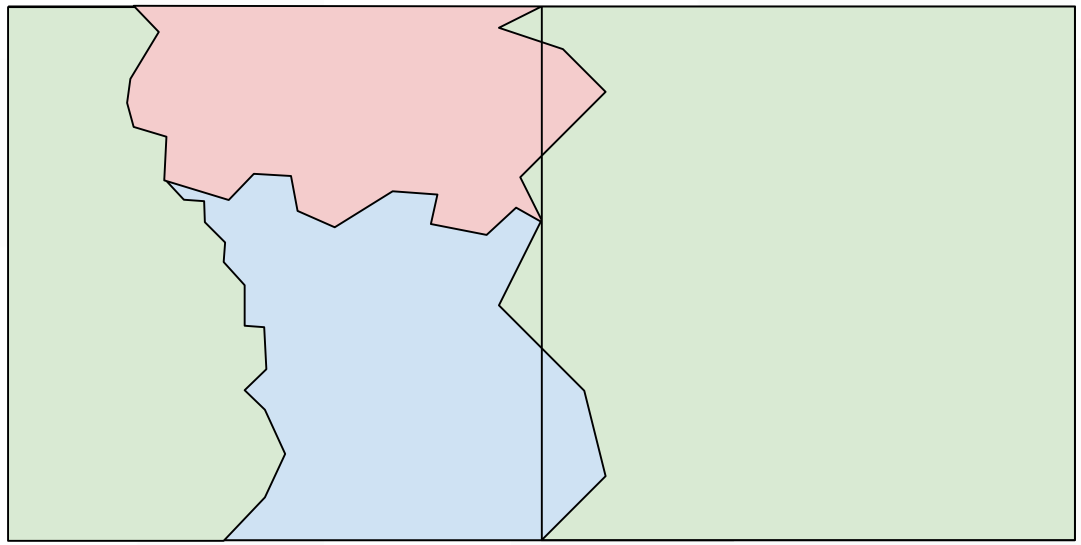
Inter Cutlines - 2

Same idea, but neighbor tiles now



Inter Cutlines - 3

Same idea, but neighbor tiles now



Cutline Blending

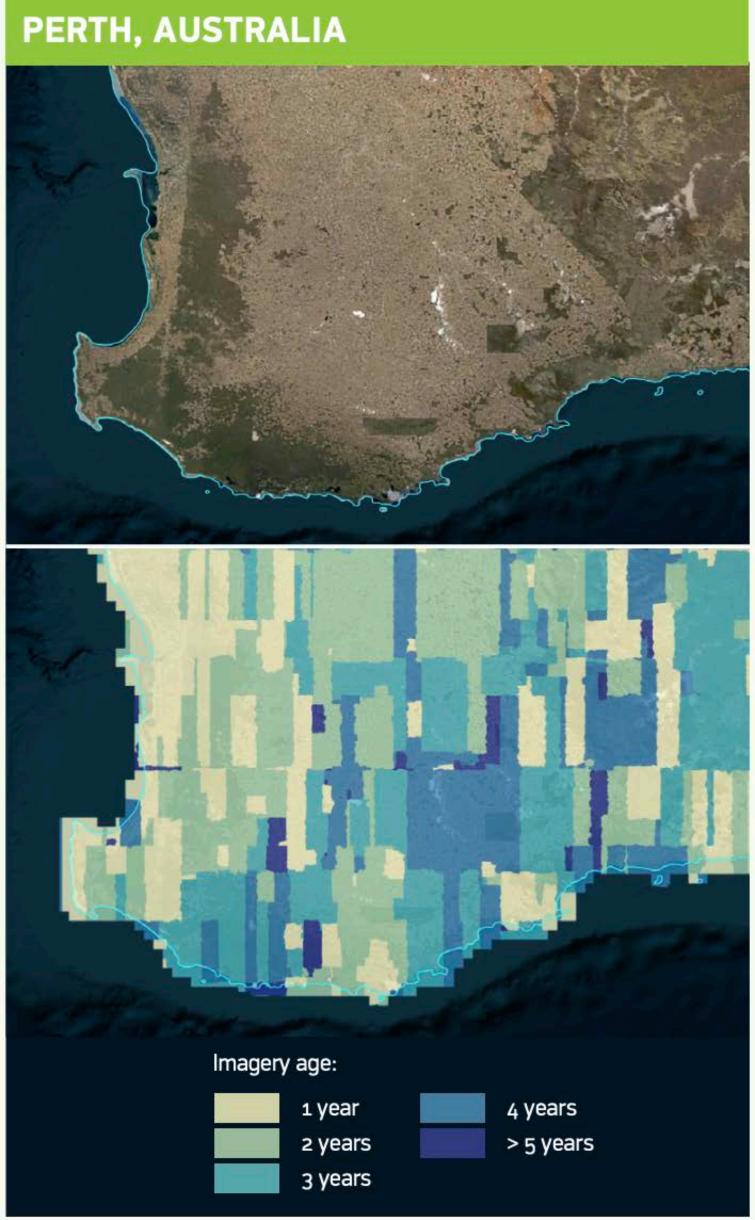
Cutline Blending (before blend)

Cutline Blending (after blend)

Leading to Unprecedented Accuracy

- At 50cm or better, Maxar Mosaics offer the clarity needed to:
  - Extract building and road features
  - Assess use and health of the landscape
  - Identify change over time

See across large areas with Vivid (top) or focus on the activity in your city with Metro (bottom)



See the most current view of the ground with a Dynamic image layer (top), and the vintage map of the Dynamic image layer shows you the collection year of the images used in the mosaic (bottom)

Seeing a Better World

Maxar's Open Data Program

- Formally launched in January 2017, the Open Data Program has been focused on open imagery to support disaster response
- Maxar's Open Data Program activated for 17 events in 2018 and 9 events so far in 2019, covering floods, hurricanes, earthquakes, mudslides and wildfires
- Estimated damages from natural disasters totaled over $155 billion in 2018[1]
- Maxar's objectives with the Open Data Program are twofold: (1) accelerate disaster response efforts with timely, actionable information and (2) foster a community of practice around satellite imagery and geospatial intelligence for disaster management

1. The Washington Post. *The Cost of Natural Disasters This Year.* 26 December 2018. https://www.washingtonpost.com/weather/2018/12/26/cost-natural-disasters-this-year-billion/?utm_term=.55cbbb481519

How do we determine which natural disasters are open events?

Criteria:

- Sudden onset natural disaster, such as earthquakes, hurricanes, typhoons, tropical storms, tsunamis
- FirstLook event service has been activated
- Disaster is categorized as a “major event”
- The internal DigitalGlobe Activation Committee agrees that the event meets the open data activation criteria based on geographic scope, humanitarian impact, and expectation of need

What’s Included

- **Imagery**
  - Pre-event imagery of area affected
  - Post-event imagery of area affected
- **Crowdsourcing Damage Data Layers**
- **Other Event-Specific Information Products (more coming)**
  - Flood layers
  - Settlement layers
  - Hotmaps
  - Radar
- *all licensed by CC BY-SA 4.0

Open Data Program Partners

HOT Humanitarian OpenStreetMap Team

UNOOSA

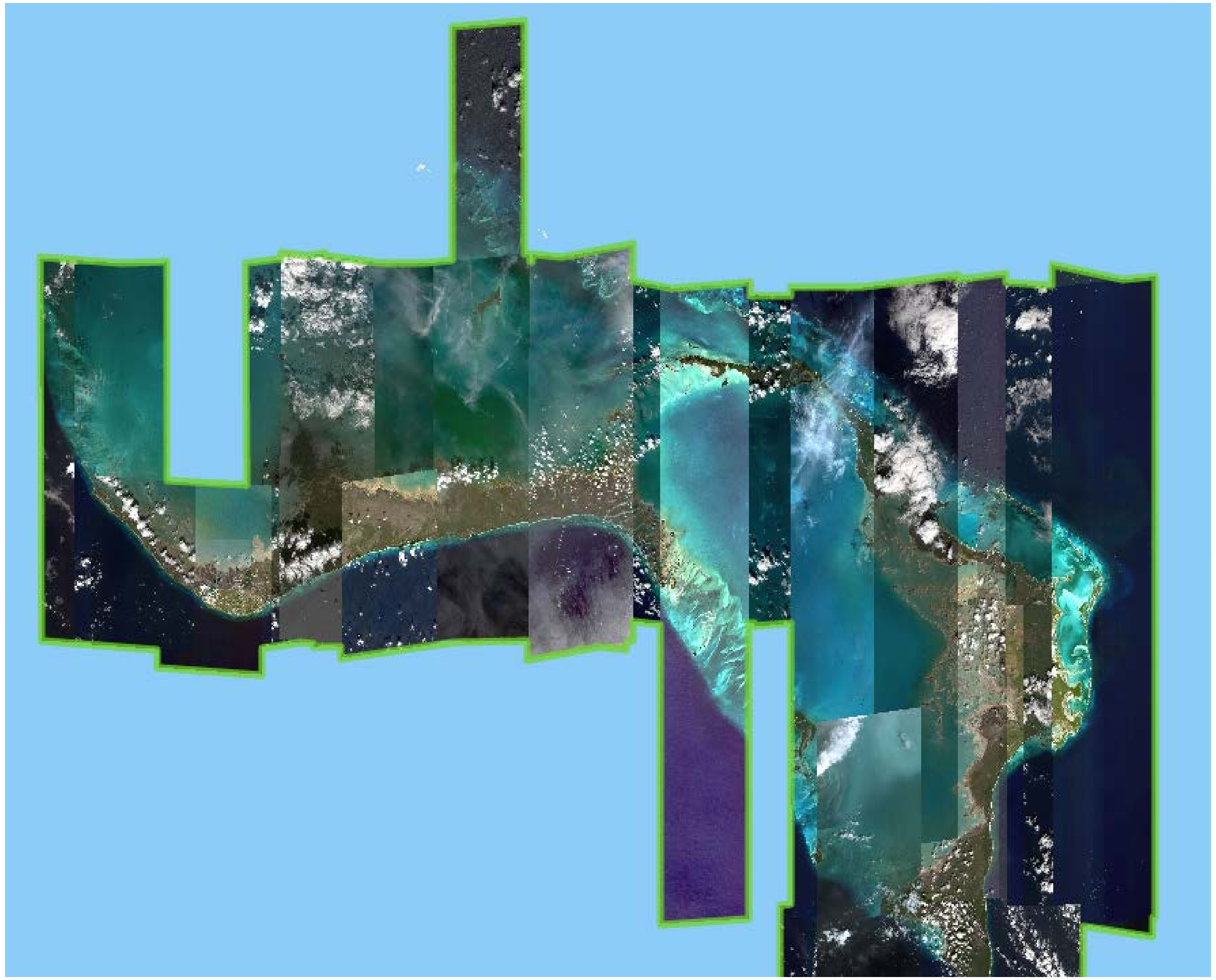
GFDRR Global Facility for Disaster Reduction and Recovery

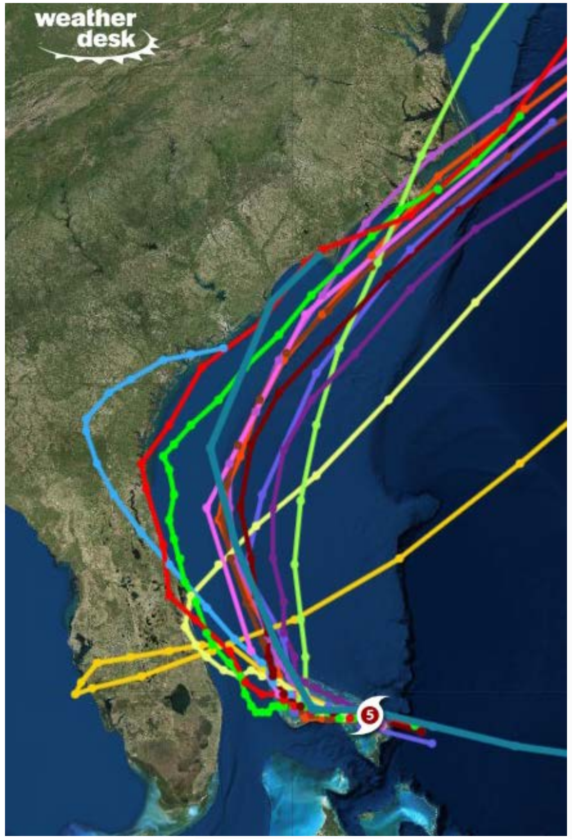
NETHOPE

Mapbox

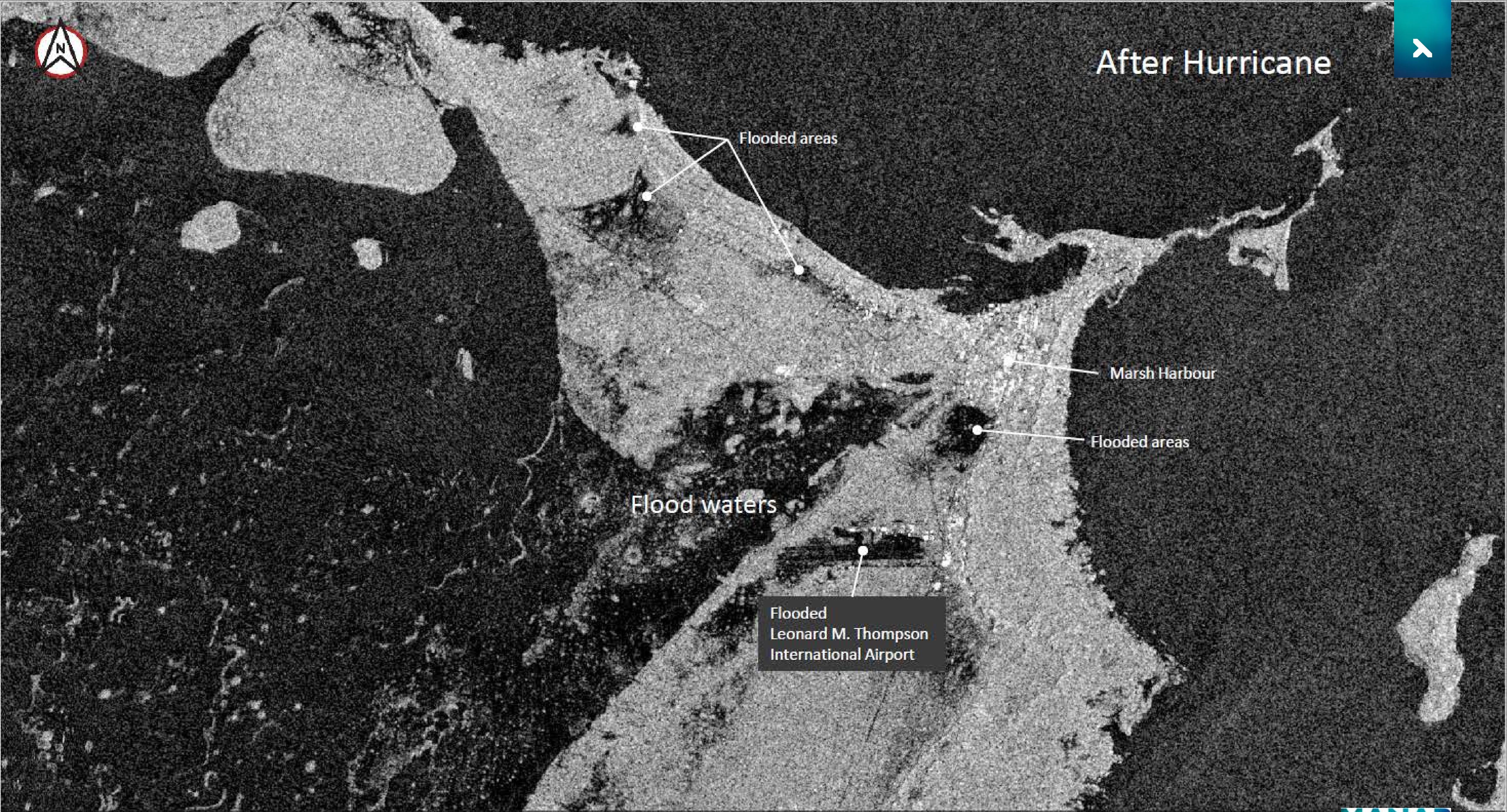
TEAM RUBICON

Hurricane Dorian






Before Hurricane
N
Marsh Harbour
Leonard M. Thompson
International Airport
Before Hurricane Dorian | Marsh Harbour, Bahamas | August 17, 2019 | Copernicus Sentinel-1 Radar Satellite Image
MAXAR



After Hurricane Dorian | Marsh Harbour, Bahamas | September 4, 2019 | Copernicus Sentinel-1 Radar Satellite Image

Camp Fire: ~2 months pre-disaster

MAXAR

Disaster Preparation (building footprints)

Source: Ecopia Building Footprints powered by Maxar

Disaster Strikes

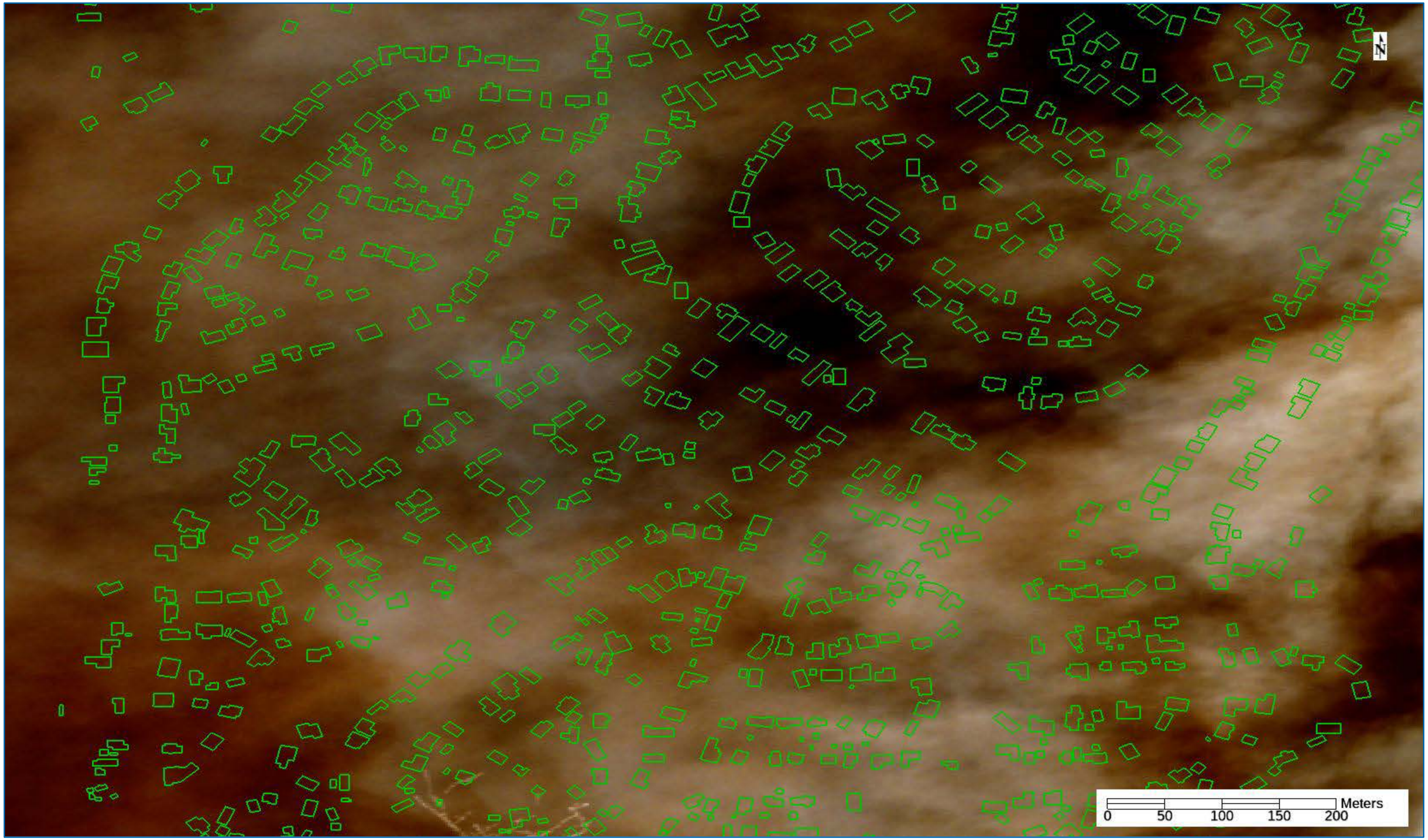
The Camp Fire was the deadliest and most destructive wildfire in California history to date.

- Started on November 8, 2018, in Northern California.
- An urban firestorm formed in the densely populated foothill town of Paradise.
- Caused at least 85 civilian fatalities.
- Destroyed 18,804 structures.

- Most of the damage occurred within the first four hours.

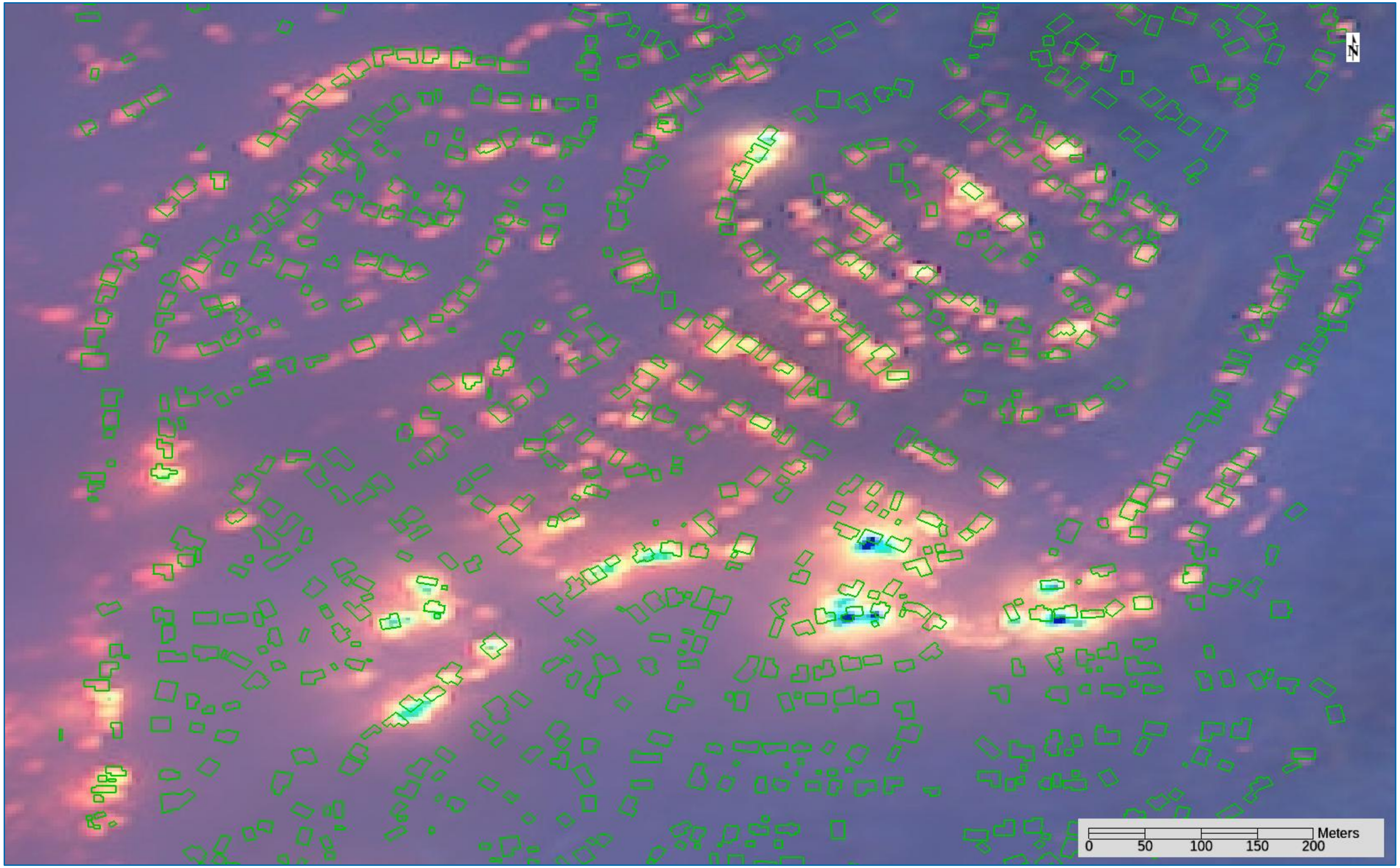
Source: Wikipedia/Camp_Fire_(2018)

Disaster Response



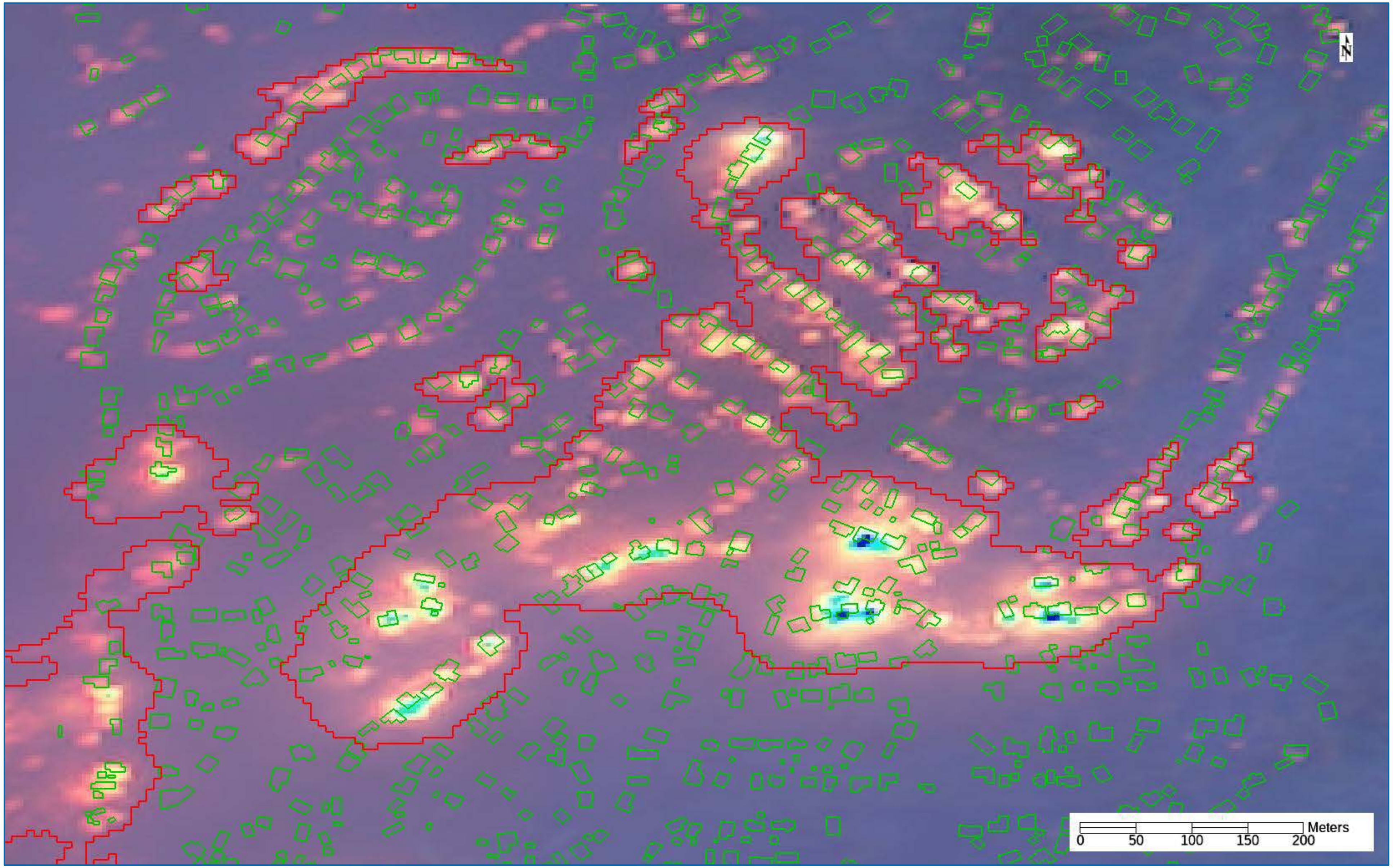
Typical Visible Imagery = SMOKE

Disaster Response (2)



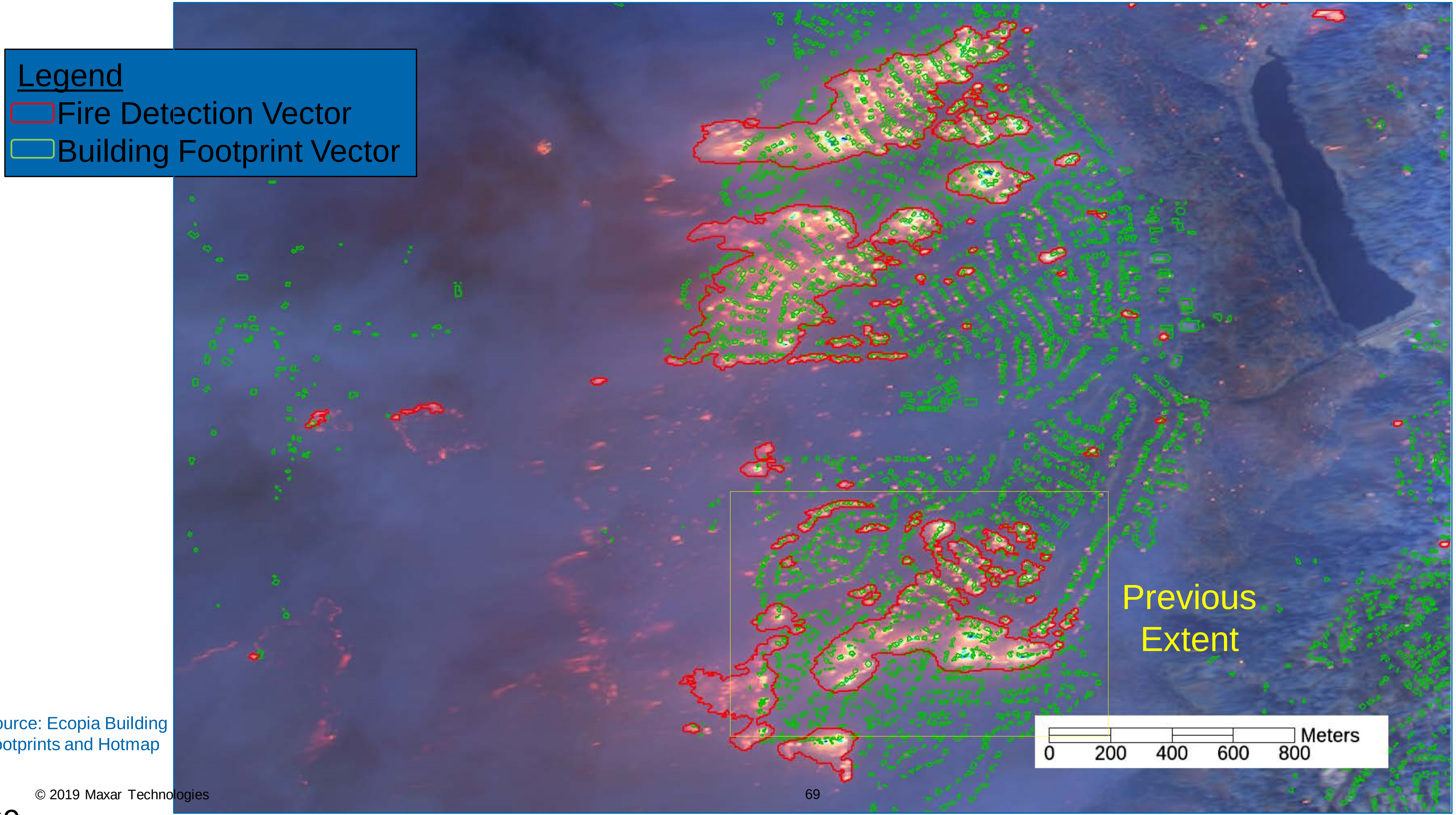
WV-3 SWIR
Imagery
=
INFORMATION

Disaster Response (3)



- WV-3 SWIR
- Hotmap SWIR Thermal Detection in **RED**
- Ecopia Building Footprints in **GREEN**

Zooming out to Region



Source: Ecopia Building Footprints and Hotmap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