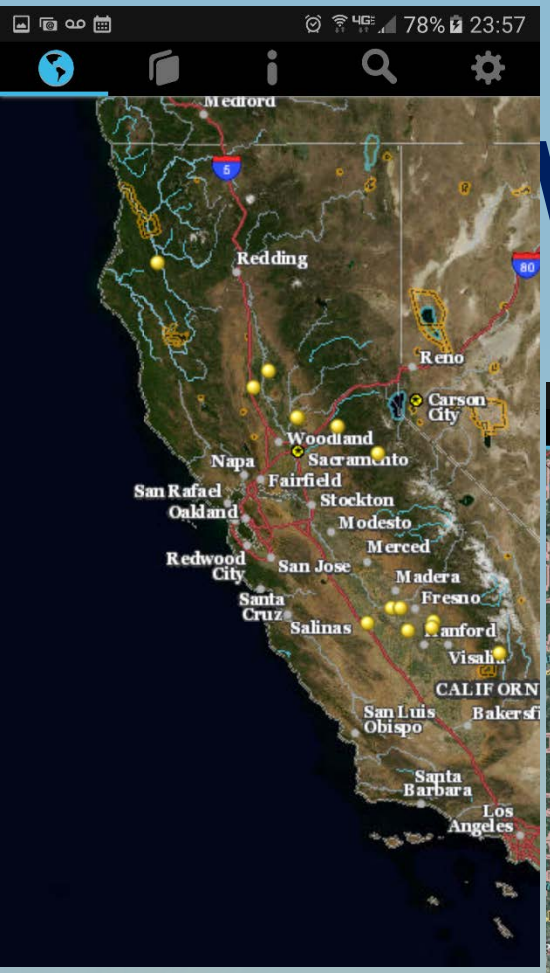
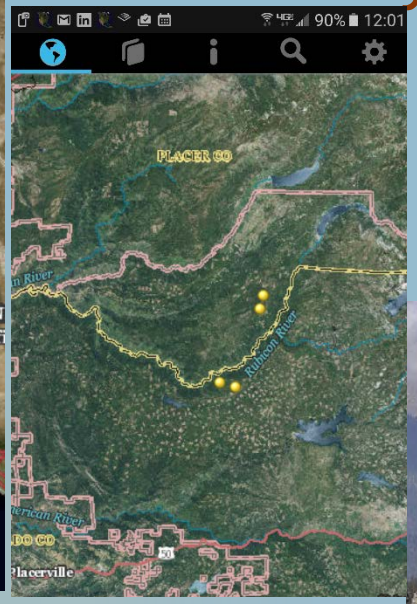


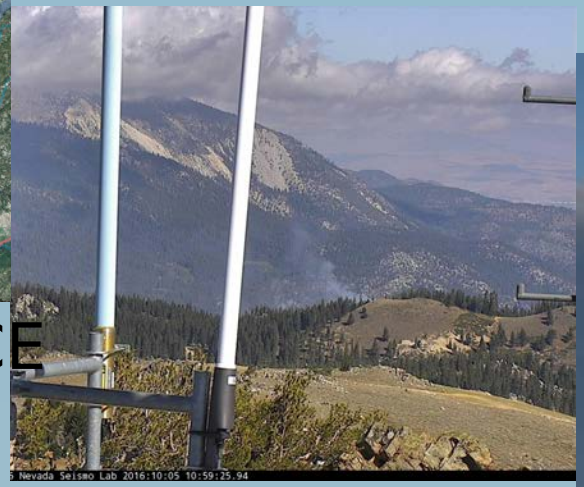


Wildland Fire Intelligence

Carl Pennypacker, Lawrence Berkeley National Lab (LBNL)
Tim Ball, Fireball International

October 16, 2018

FUEGO



- ACTIONABLE INTELLIGENCE
- EARLY DETECTION
- DEEP LEARNING ANALYSIS (FIRE & FUELS)
- IMPROVED SIMULATION => PRIORITIZATION

The Intelligence Cycle

Where information is collected and transformed to actionable intelligence in support of all aspects of operations

Wise & Nimble Strategy/Tactics

Safe & Effective Operations

Prioritized Tasking

Commander's Priority Intel Requirements

DISSEMINATION

Multi-source Collection

Verified, Traceable, Analyzed Information packaged for action

Analysis:

Synthesis, Synchronization & Production

Processing & Exploitation to sharable form

Infamous Fires Fuego Could Have Minimized

Two Examples of Delayed Fire Detection

Corral LAC/CDF Nov 24, 2007
Malibu Bowl

Cause: Bonfire at The Cave at top of Malibu Bowl

Initial Report: 3:29 AM, 100 acres

Weather: 59°F, RH 8%, 27 MPH, G36, Northerly.
RED FLAG conditions. Bonfire detectable so LACoFD Patrol could have suppressed.

Totals: 4901 Ac, 49 Residence, 31 other structures, 27 Structures Damaged, 10,000 people evacuated

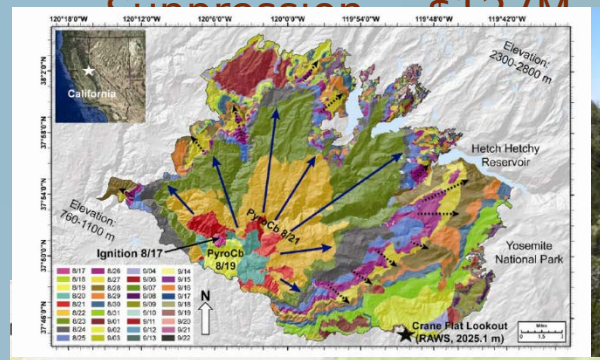
Rim USFS-STF Aug 17, 2013
Tuolumne River Drainage

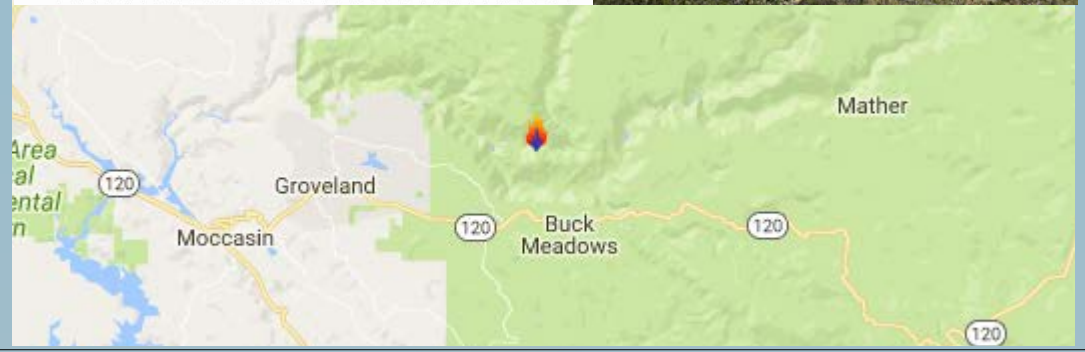
Cause: Hunter's Cooking Fire

Initial Report: 3:25 PM, Air Tanker Pilot, 40 acres.

Weather: 87°F, RH 17%, 15 MPH, G21, Westerly

Totals: 257,314 Ac, 11Residence, 98 Outbuildings, 3 Commercial Buildings,





FIREBALL

Intelligence in Time

Exportable Wide Area Surveillance with Real Time Exploitation Military and Civil Applications

Shinjuku Cocoon, Tokyo

Fireball Leadership

J. Timothy Ball

President

B.A. & M.A. Biological Sciences, Univ. of California, Santa Barbara.
Ph. D. Biological Sciences, Stanford University.

Experience:
15 Years professor at the Desert Research Institute.
19 years CEO Fireball

Research:
Linkage of ecosystem and atmospheric process through remote sensing; Fire Ecology Fire Behavior.

Ryan C. Dotson

Vice President

B.S. Mathematics &
M.S. Applied Mathematics,
University of Nevada, Reno

Experience:

20 years in the software industry

19 years Vice President, COO of Fireball

Research:
Numerical Modeling, Statistics, and their use in Image Processing and Navigation

John C. Arvesen

Senior Collaborator

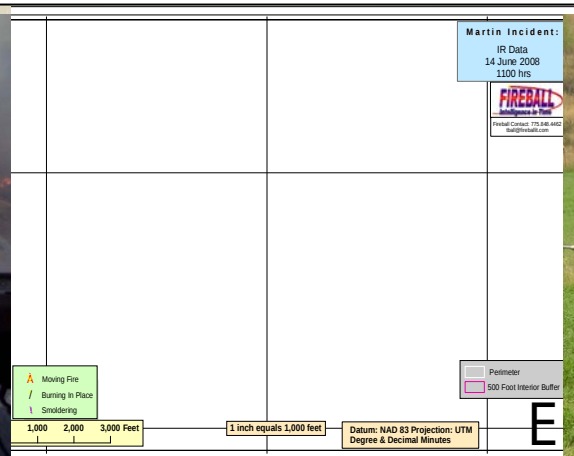
B.S. Engineering Physics, Univ. of California Berkeley.
M.S. Mechanical Engineering, Stanford University.

Experience:

35 years at NASA

20 years with NASA U-2/ER-2 High Altitude Branch.

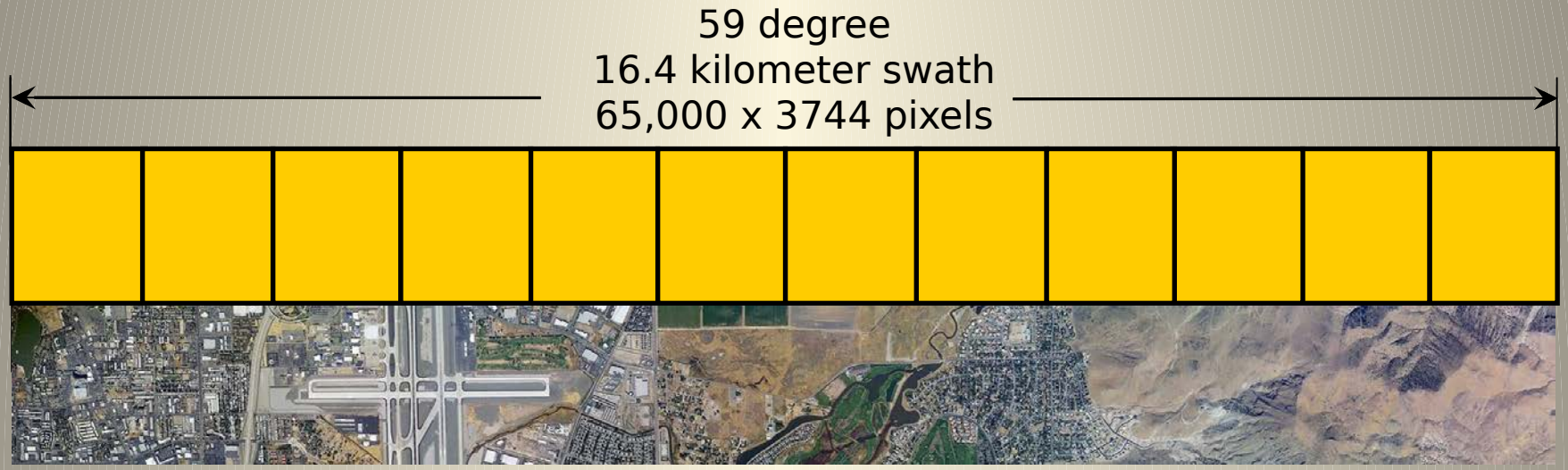
Long tenure as Branch Chief included characterization of atmospheric chem... Ozone Hole and development of many airborne sensor systems.



ARGUS Surveillance System on NASA WB-57

Designed for One Standard WB-57 Pallet

--50,000 feet



Standard Configuration (400 mm lenses)

Altitude	System Swath	Nadir GSD	Outer GSD	Ground Speed	Forward Overlap	Side-lap	Frame interval	Max Map Rate	Practical Map Rate	Nominal mapping duration	Area/Flight
15,200 m 50,000 ft	59 deg. 16.4 km 9.3 mi	24 cm 9.6 in	37 cm 14.8 in	325 kts	39%	20%	3.3 s	9900 sqkm/hr	6,400 sq. km/hr.	3.25 hours	20,000 sq. km 7,700 sq. mi.

Ultra-wide Configuration (Mix of 400, 200, 100, 85 mm lenses)

Altitude	System Swath	Nadir GSD	Outer GSD	Ground Speed	Forward Overlap	Side-lap	Frame interval	Max Map Rate	Practical Map Rate	Nominal mapping duration	Area/Flight
15,100 m 50,000 ft.	138 deg 18.4 km 11.4	1.2 m 47 in	1.2 m 47 in	350 kts	70%	20%	5 s	23,880 sq.km/hr	15,533 sq km/hr	3.25 hours	50,483 sq. km 19,491 sq. mi.

Argus, Aware® and Tsunami Cooperate

t Recognition, Localization, and Analysis

Fireball's Argus Large Area High Res Camera

AWARE® Real Time Image Exploitation Software

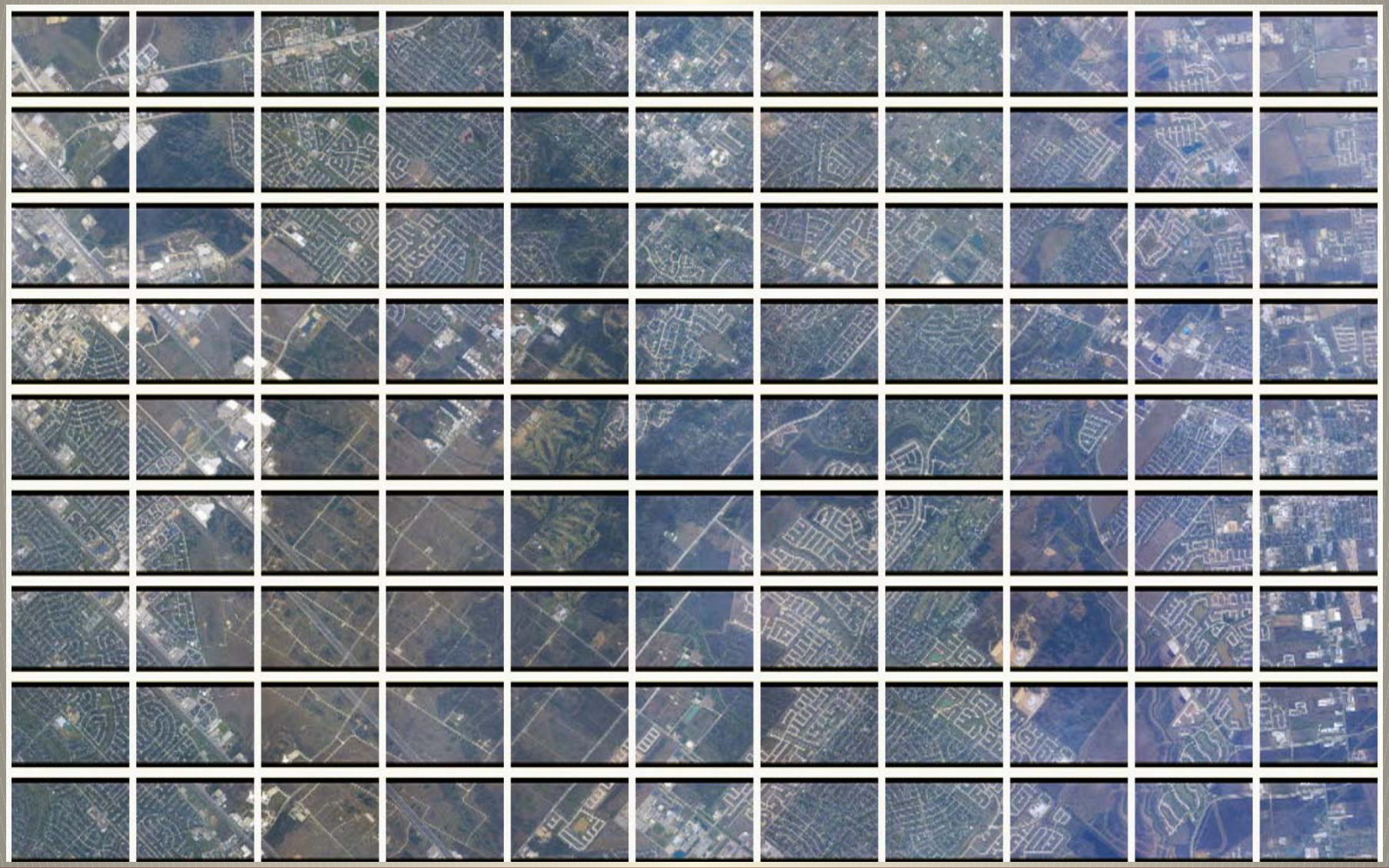
- Image "*Waterfall*" display
- Image Geo-referenced
- Image enhanced
- Full Res display of selected location
- Image "chipped" to relevant size
- Image "geo-chip" transmitted off aircraft via multiple networks
- Target coordinates passed to telescope
- Recall of image from Database by location or time (for comparison).
- Geo-Context images transmitted

Tsunami Telescope
slews to coordinates provided by Argus

Telescope Still Frame and Video transmitted
via Mil-Star

Argus in Operation:

35 seconds of imagery from 65,000 feet. Houston
12 inch GSD; 9 miles along-track, 13 miles cross-track 75,000 acres




National Soccer Stadium,
Bamako, Mali

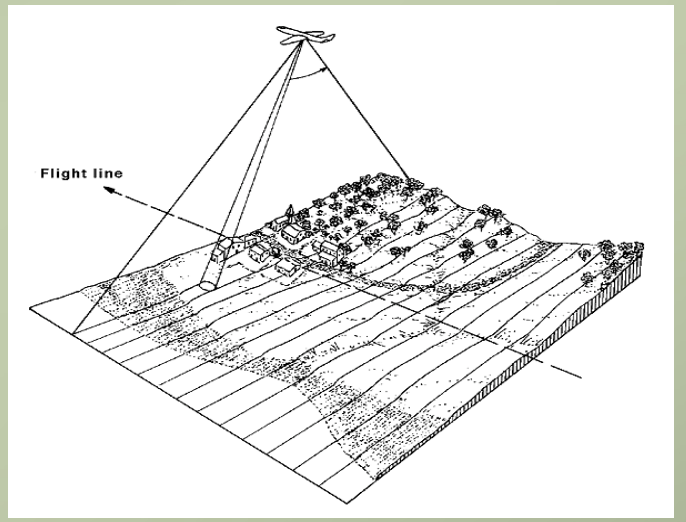
NATIONAL INFRARED OPERATIONS

The U.S. Forest Service National Infrared Operations (NIROPS) Program:

2016 NIROPs Closeout

November 02, 2016

PHOENIX System Specifications



Two channel thermal IR line scanner, 1680 pixels per scan line

- 3-5 µm band for intense heat (A channel, mid-wave)
- 8-12 µm band for background terrain (B channel)

No absolute calibration

Detections from kA-B

k is < 1 and varied by operator to subtract background from the mid-wave.

These two characteristics are among those that forces human interpretation precluding real-time data utilization

Instantaneous Field of View: 1.25 milliradian						Total Field of View: 120 degrees						Cross-track pixels: 1680	
								Spatial Detection Limit at 1000 degrees F					
Altitude			Nadir	Nadir		Outer	Outer		Night time NADIR		Outer		Swath, km	Swath, miles
	Ft, AGL		GSD, m	GSD, ft		GSD, m	GSD, ft		Sq. cm	Sq. Inches	Sq. cm	Sq. Inches		
Nominal	10,000		3.8	12.5		6.6	21.6		322	50	963	149	10.6	6.6
Usual	15,000		5.7	18.75		9.9	32.5		724	112	2168	336	15.6	9.9

GSD = Ground sample Distance, the length of the sides of one pixel projected to the ground; AKA pixel size

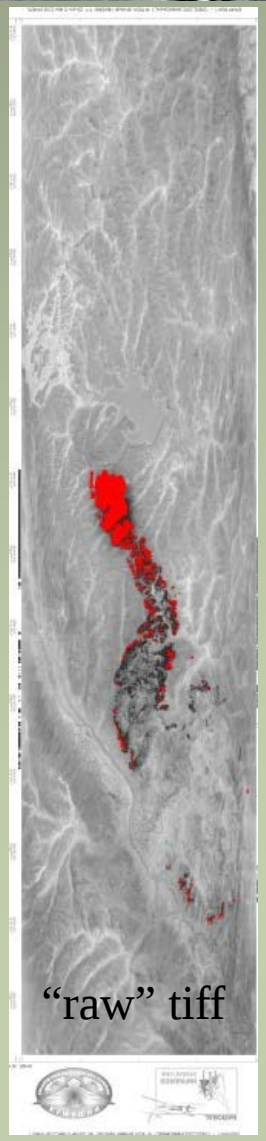
Phoenix Spatial Specifications

Instantaneous Field of View: 1.25 milliradian			Total Field of View: 120 degrees			Cross-track pixels: 1680					
			Spatial Detection Limit at 1000 degrees F								
Altitude, Ft	Nadir	Nadir	Outer	Outer		Night time NADIR		Outer		Swath, km	Swath, miles
	GSD, m	GSD, ft	GSD, m	GSD, ft		Sq. cm	Sq. Inches	Sq. cm	Sq. Inches		
10,000	3.8	12.5	6.6	21.6		322	50	963	149	10.6	6.6
15,000	5.7	18.75	9.9	32.5		724	112	2168	336	15.6	9.9

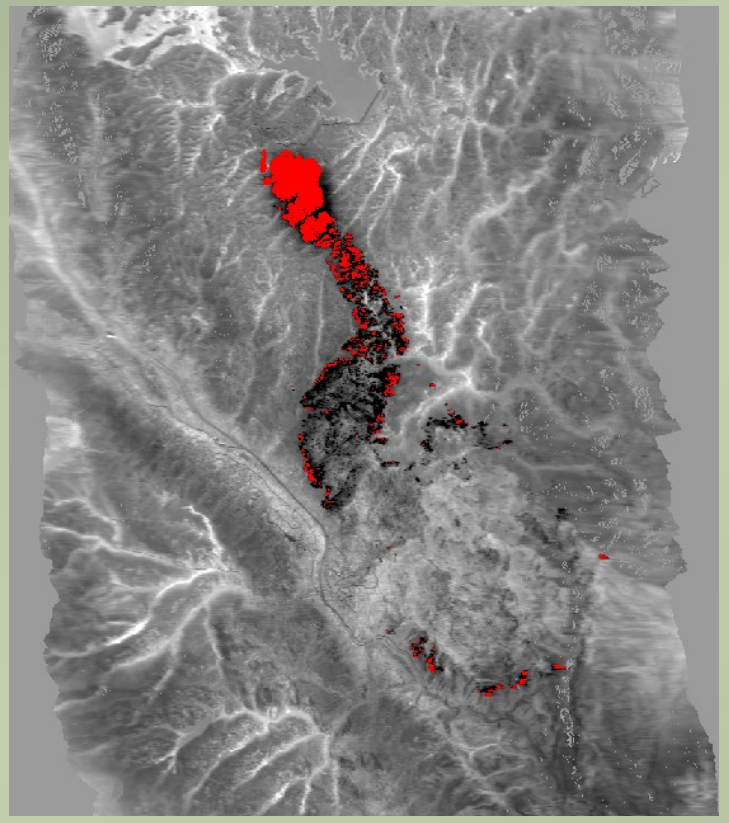
Two Mid-wave Fireball Fire Finder

Instantaneous Field of View: 0.66 milliradian			Total Field of View: 87 degrees			Cross-track pixels: 2300					
			Spatial Detection Limit at 800 degrees F								
Altitude, Ft	Nadir	Nadir	Outer	Outer		Day & Night NADIR		Outer		Swath, km	Swath, miles
	GSD, m	GSD, ft	GSD, m	GSD, ft		Sq. cm	Sq. Inches	Sq. cm	Sq. Inches		
10,000	2	6.6	2.7	8.8		88	13.6	160	25	4.9	3.7
15,000	3	9.8	4.1	13.4		198	30	369	57	7.4	5.2

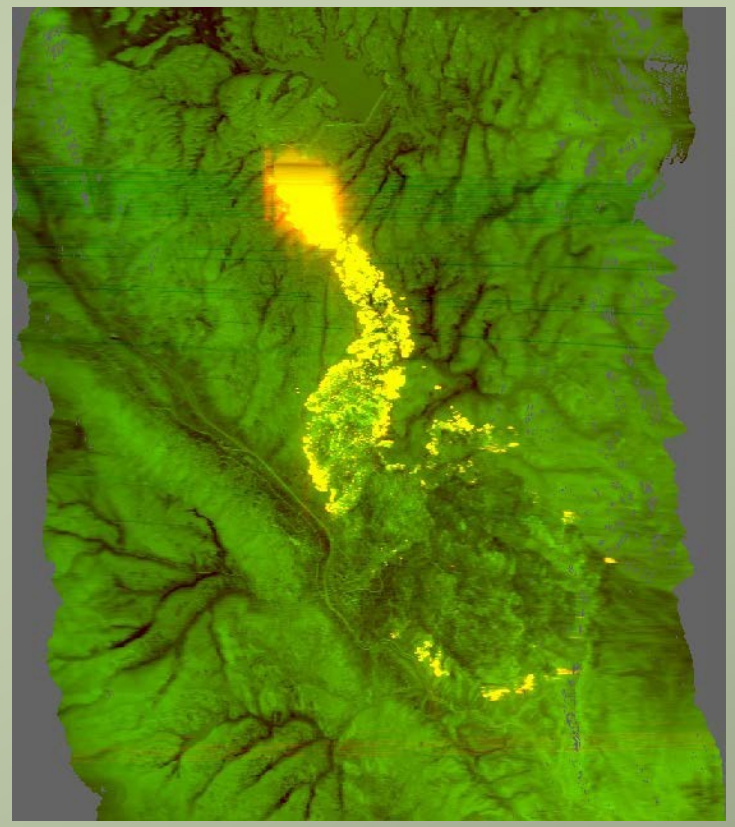
IR Data delivered from plane



"raw" tiff

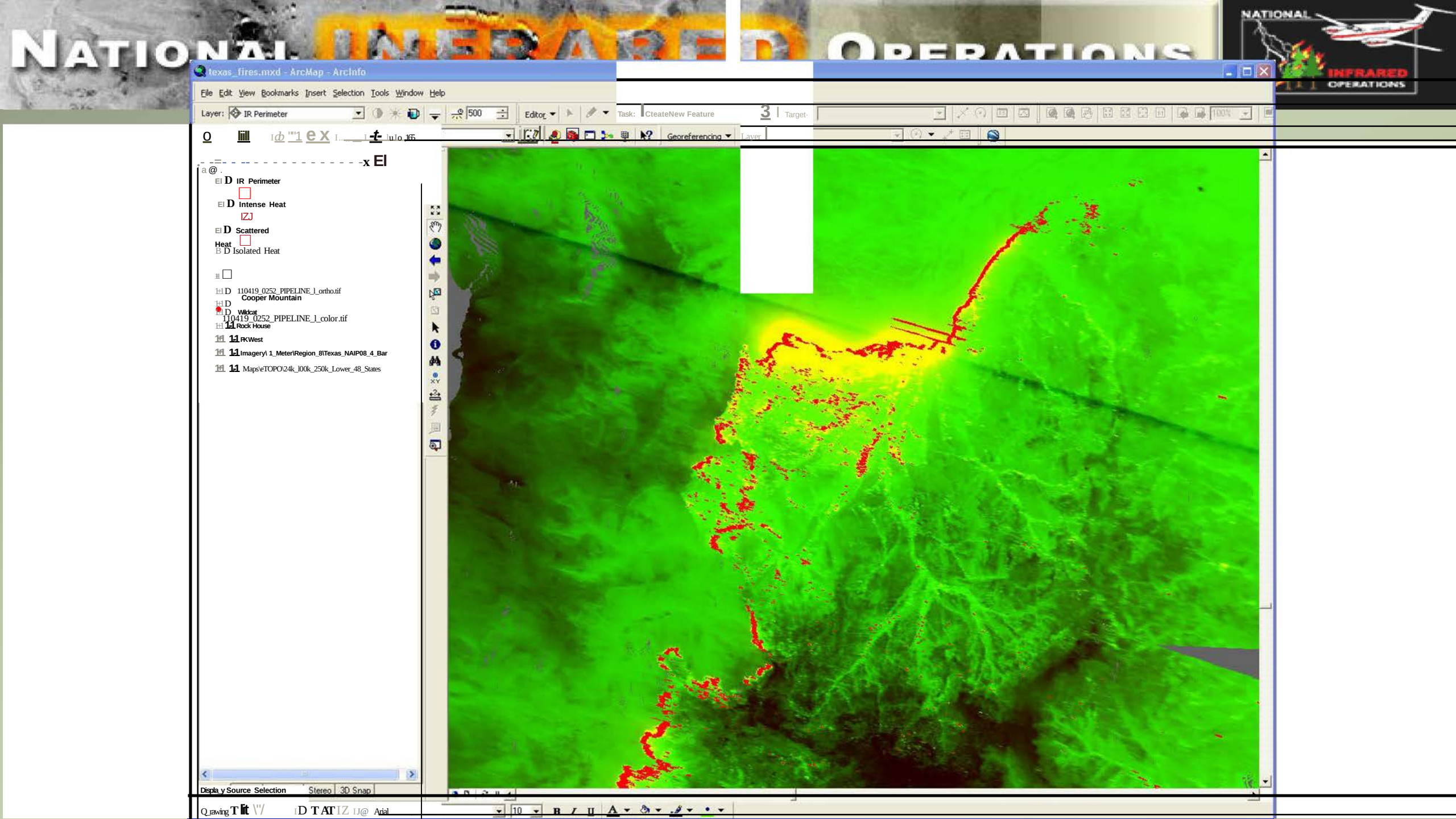


Orthocorrected tiff w/ fire detects



Orthocorrected color tiff

Waldo Canyon Fire June 25, 2012, 2253 hrs


NATIONAL INFRARED OPERATIONS
texas_fires.mxd - ArcMap - ArcInfo
File Edit View Bookmarks Insert Selection Tools Window Help
Layer: IR Perimeter
Editor
Task: CteateNew Feature
Target
Georeferencing
IR Perimeter
Intense Heat
Scattered Heat
Isolated Heat
110419_0252_PIPELINE_l_ortho.tif
Cooper Mountain
Wildcat
110419_0252_PIPELINE_l_color.tif
Rock House
RKWest
Imagery\ 1_Meter\Region_8\Texas_NAIP08_4_Bar
Maps\eTOPO\24k_l00k_250k_Lower_48_States
Display Source Selection
Stereo
3D Snap
Drawing
Arial

NATIO

NATIONAL INFRARED OPERATIONS

texas_fires.mxd - ArcMap - ArcInfo

File Edit View Bookmarks Insert Selection Tools Window Help

Editor Task: Create New Feature Target:

1:30,165 Georeferencing Layer:

Layers
- IR Perimeter
- Intense Heat
- Scattered Heat
- Isolated Heat
- 110419_0252_PIPELINE_1_color.tif
- 110419_0252_PIPELINE_1_ortho.tif
- Cooper Mountain
- Wildcat
- Rock House
- PK West
- Imagery\1_Meter\Region_8\Texas_NAIP08_4_Band
- Maps\eTOPO\24k_100k_250k_Lower_48_States

Infrared Interpreter(s)

Display Source Selection Stereo 3D Snap

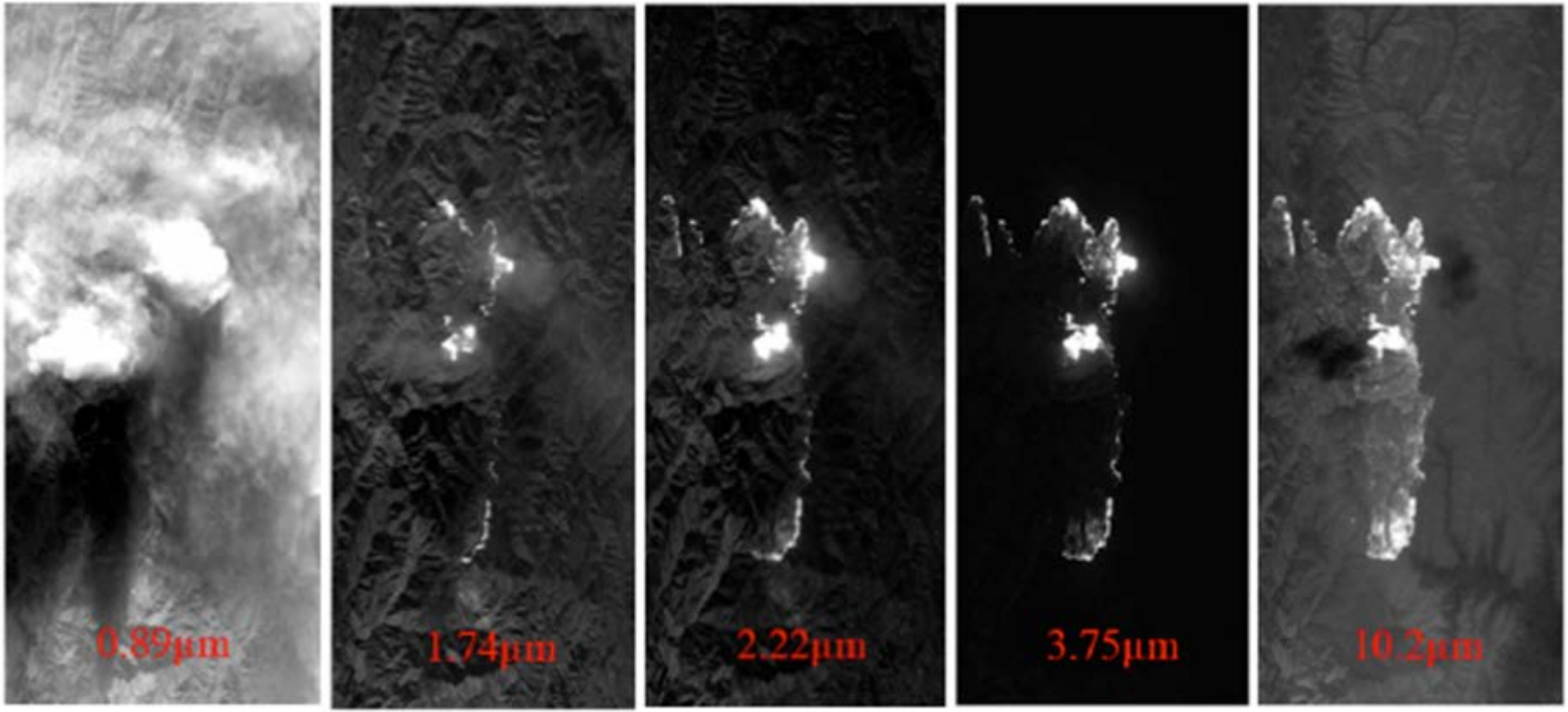
Drawing Arial 10

18401.664 3425155.378 Meters

Some Points To Remember About Phoenix Imagery

- What is captured in the imagery is the relative variation in heat across the fire area
  - No one-to-one correspondence between pixel values and ground temperature
- The technician can adjust the heat “threshold” value during runs across the fire area.
  - Doesn’t allow for automated extraction of heat areas
- There is more heat in the imagery than just the red (DN = 255) pixels!
  - Requires an Infrared Interpreter (IRIN) to derive products

These images are from one section of the Zaca Fire in Santa Barbara and Ventura Counties California (2007) taken by the Autonomous Modular Scanner (Built NASA Ames Research Center) flying on the Ikhana (Predator B) Unmanned System demonstrate the different information about a fire that can be understood at different wavelengths.

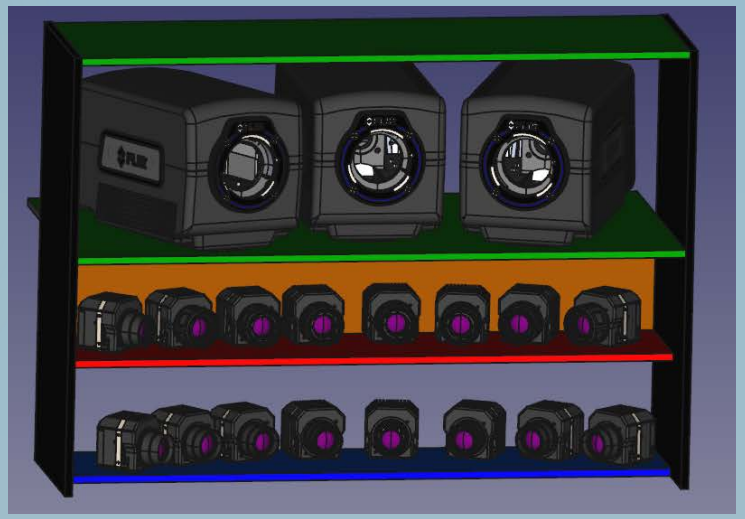


Near Real-Time, High Resolution, Day/Night Mapping and Fire Characterization

FIRE-FINDER

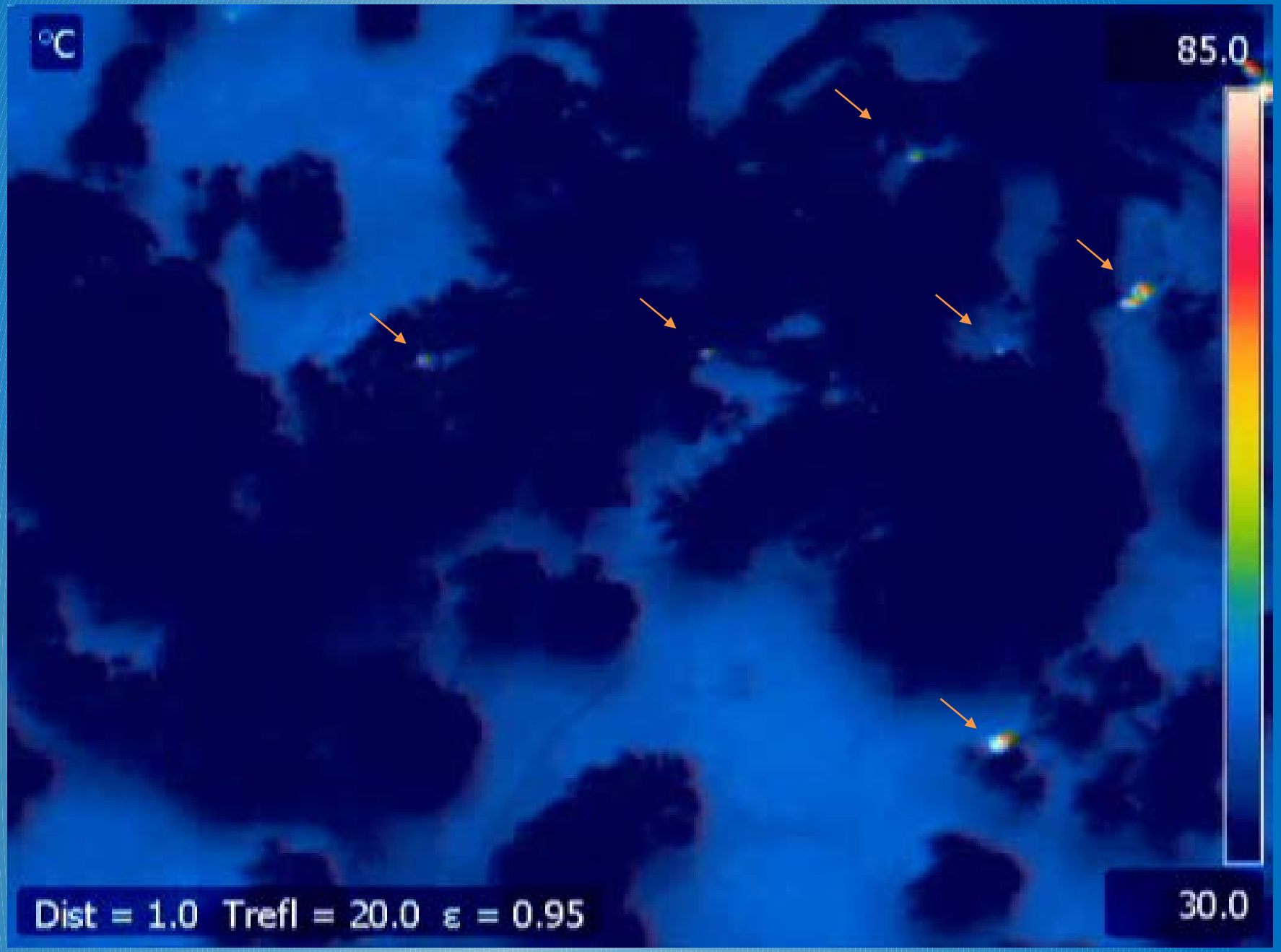
19 cameras 3 Infrared Wavelengths

Wide Swath for Perimeter & Spot Fires



SAMPLE MAPS

Real Data



Time Differential Fire Map

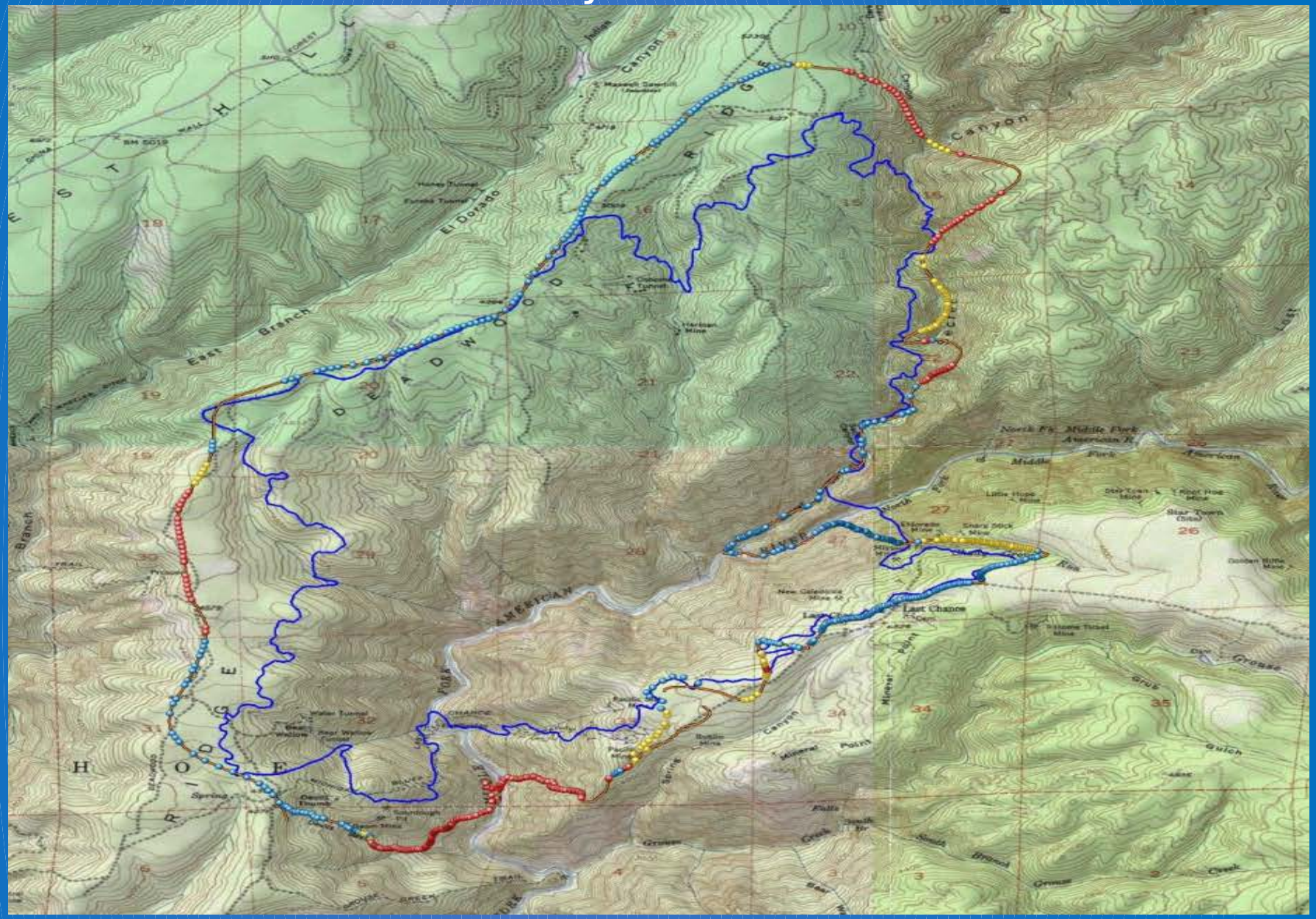
Current Perimeter and Activity vs. Previous Perimeter

Fire Activity
North
American Incident
TNF-001562
16 Aug 2013
0830hrs

20130816_0830FireActivity
- Moving
- Creeping
- Smoldering
- 20130816_0830PeriPolyLine
- Roads

In a few seconds you can understand:

- ✓ where the fire is moving &
- ✓ the topography where the fire is going to be hard to catch.

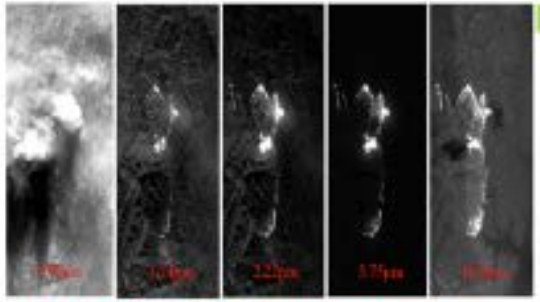


Fire-Finder is Scalable

Three Wavelength Fire Analysis & Intel Dissemination

Concept & Why it is Necessary

Detection, Accurate Localization & Characterization, Mop-up are Actionable Intel



Different Wavelengths (like different colors)

Pick the bands that tell what you need to know.

1.7µm - Flame Size
3-4 µm - Energy Release
10 µm - Smoldering

Scalable Design

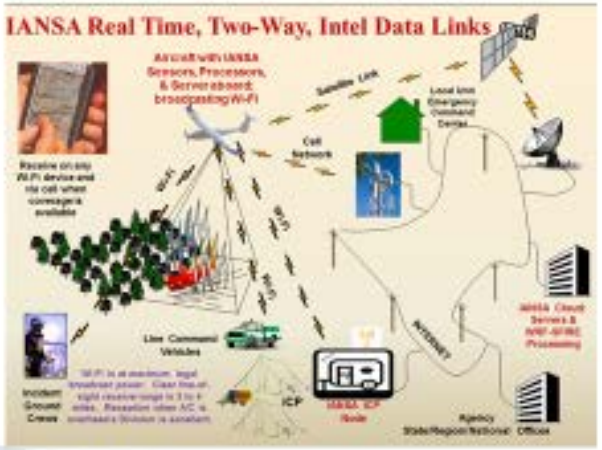
Measure as wide a swath as possible at high resolution.

Fill the payload bay as appropriate for altitude.

Analyze Data On-Board in Real Time

Extract Actionable Intel:
Perimeter Location
Fire Front Width
Fire Front Power
Rate & Direction of Spread
Put these in the context of:
Wind, Slope, Exposure, Fuel and Threat to Values

Format and Disseminate the Intel as instantly understandable product.



Be systematic ! Mow the lawn. This is not a military, zoom-in problem. Context is everything.

Fire-Finder Bullets

1. FireFinder can track fires in day and night. (NIROPS is night only.) This is accomplished using three well-chosen wave bands.

2. All cameras internally calibrated (NIST Traceable) and produce 14 bit data so that data is consistent comparable, and of science value.

3. Maps of
   a. fire perimeter
   b. total intensity (radiative energy released)
   c. flame length (safety and tactics)
   d. rate and direction of spread (simple linear projection updated each map cycle)
   e. spotting frequency and spotting distance (characterizes most dangerous rates of spread)
   generated immediately on the aircraft (no delay waiting for IR Interpreter).
   NWCG GIS standard format with additions. Can be continuous, as needed.

4. Finished maps and GIS data transmitted off the aircraft in real-time. Using all available networks, the intelligence can be “pushed” to firefighters on the ground and users on the internet. Products remaining available on the cloud.
   (Networks include, P-25 Radio, Satellite, Cellular, Wi-Fi, Military Grade Mesh Networks)

5. In mop-up the system finds smoldering materials as small as 3 square inches and down to 250°F. (For comparison NIROPS detection limits are 50 square inches and 1000°F)

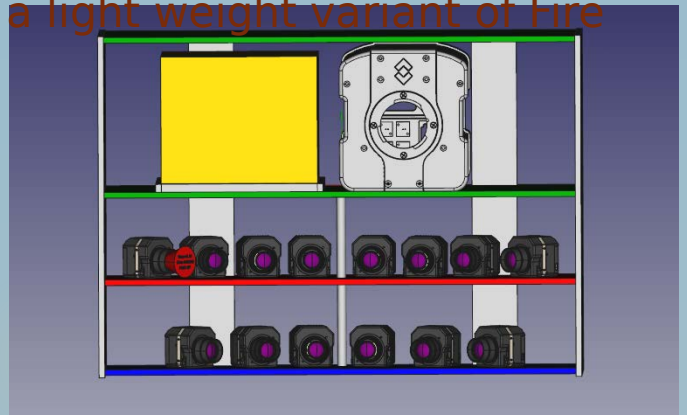
NWCG = National Wildland Fire Coordinating Group

High Altitude, Long Duration, Solar-Electric Unmanned Vehicle

- Continuous station-keeping where threat is greatest
- Patrol large areas or track fire movement
- Real-Time, High Resolution, Day/Night Mapping and Fire Characterization
- Data transmitted direct to the Fireline

Drone America, Phoebus

- ✓ Long-wing, solar, & engine variant of existing aircraft
- ✓ Initial Flight, 9 month after funding.
- ✓ Flight above the NAS.
- ✓ Balloon carries aircraft aloft.
- ✓ Well along path to FAA Altitude & BVLOS approval for decent (for different mission).
- ✓ Payload: a light weight variant of Fire Finder



Intel is a force