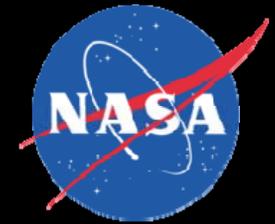


# Large UAS Operations in the NAS

## The NASA 2007 Western States Fire Missions (WSFM)



Greg Buoni  
NASA Dryden Flight Research Center  
26th ICAS/8th ATIO  
September 2008



# Aircraft Systems

## IKHANA

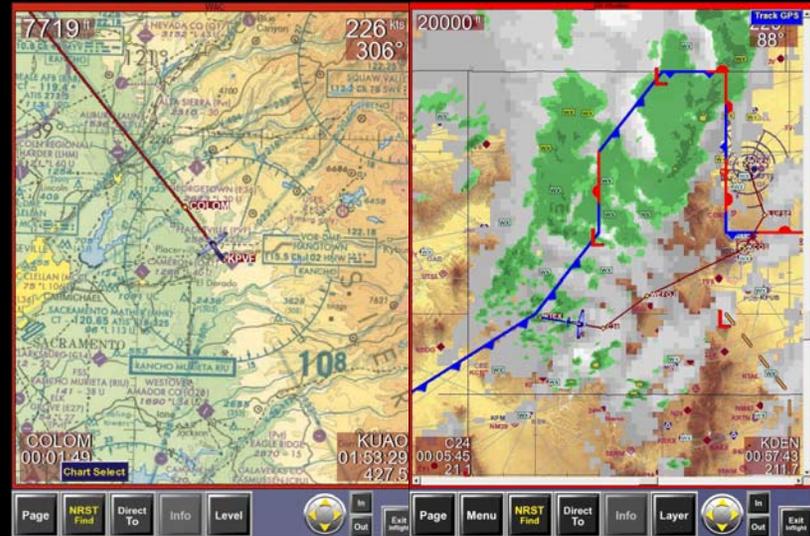


NASA Ames – Autonomous Modular Sensor (AMS)



# Ground Systems

## IKHANA



26th ICAS/8th ATIO, Large UAS in the NAS - NASA 2007 WSFM



## *2007 Western States Fire Mission Objectives*

**IKHANA**

- Demonstrate capabilities of UAS to overfly and collect sensor data on wildfires throughout Western US.
- Demonstrate long-endurance mission capabilities (20+ hours).
- Image multiple fires (greater than 4 fires per mission), to showcase extendable mission configuration and ability to either linger over key fires or station over disparate regional fires.
- Deliver real-time imagery to (within 10-minutes of acquisition).



# Certificate of Authorization (COA) Boundary Request

**IKHANA**

## 3 Operational Zones

Each zone includes no more than 3 FAA ARTCC areas

All, or parts of:  
California, Nevada,  
Oregon, Washington,  
Utah, Montana,  
Wyoming, Idaho,  
Colorado, Arizona,  
New Mexico





# Range Safety Protection Zones

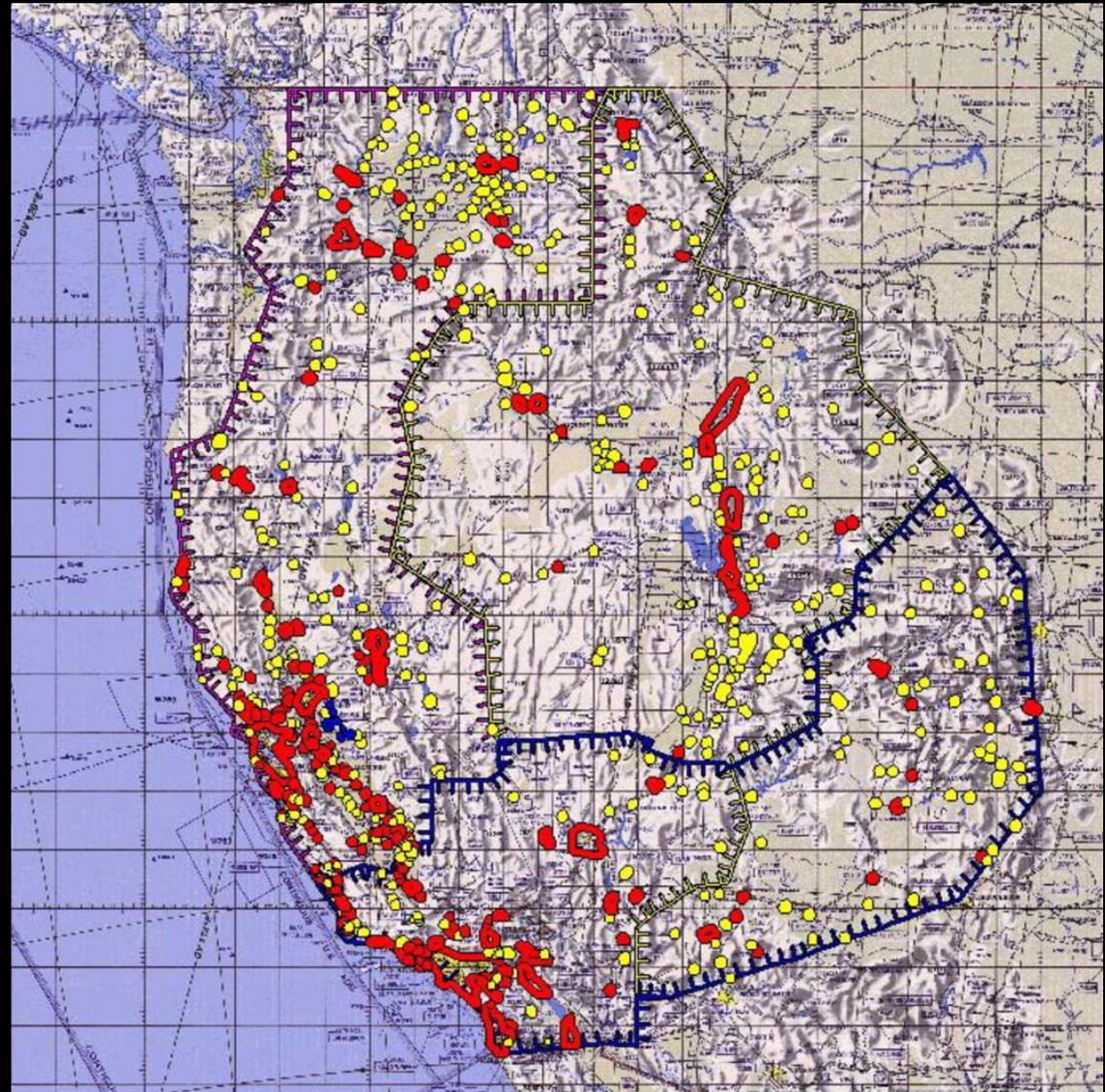
**IKHANA**

## KEEP-OUT ZONES

Defined and "Owned"  
by DFRC Range Safety

Can be changed or  
updated before or  
during flight with DFRC  
Range Safety  
concurrence

-  **NOMINAL AIRCRAFT**
-  **UNHEALTHY AIRCRAFT**





# Routes A, B, C

## IKHANA

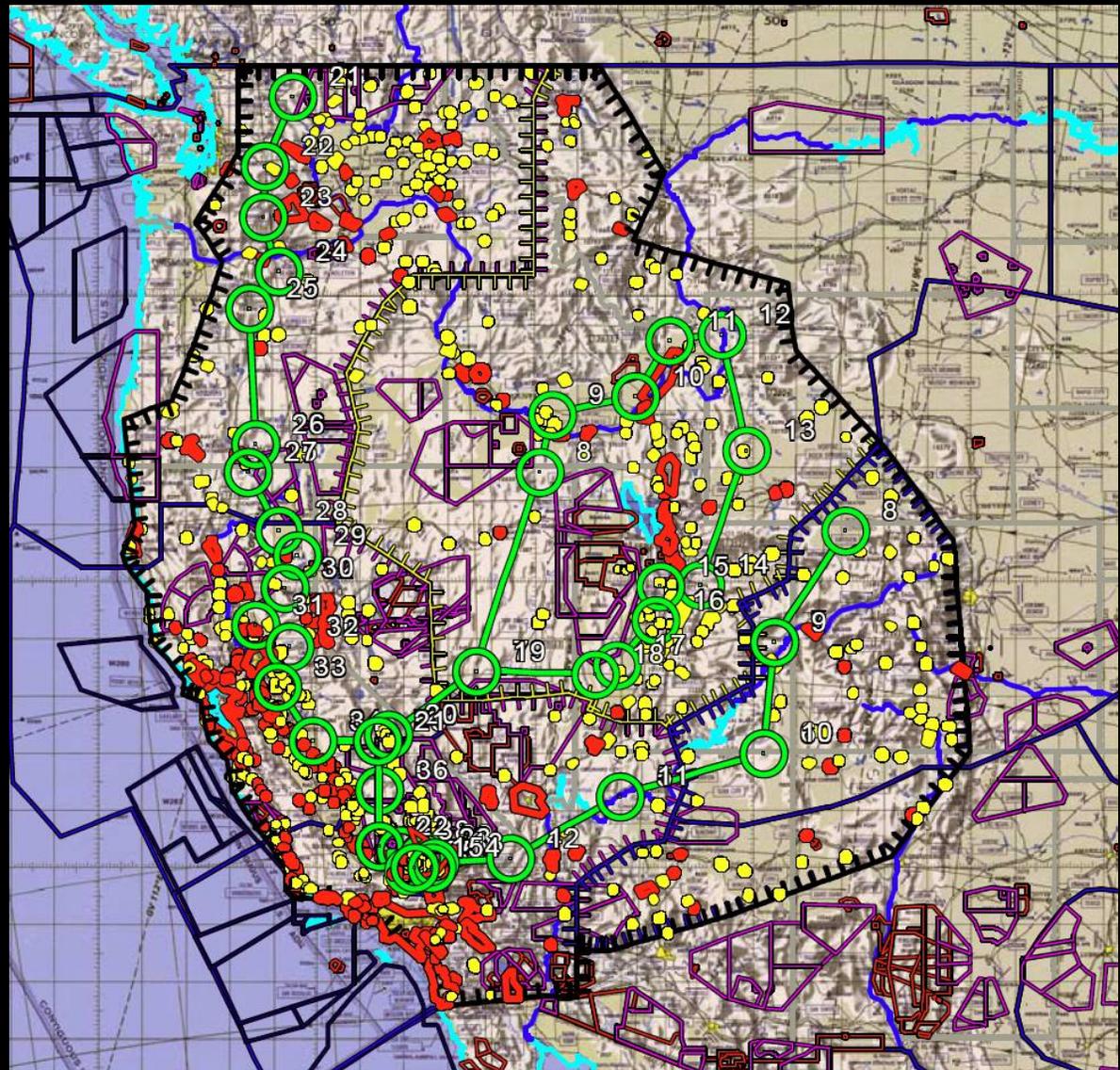
Defined Routes for each Zone

Over/near forested areas

Avoid population areas

Avoid directly above mountains when possible

- Weather when lost link





# Primary Emergency Landing Sites

**IKHANA**

Radius = 400 nm

Landing agreements negotiated with each site





# Secondary Emergency Landing Sites

**IKHANA**

**Radius = 50 nm**

**Over 280 sites identified**

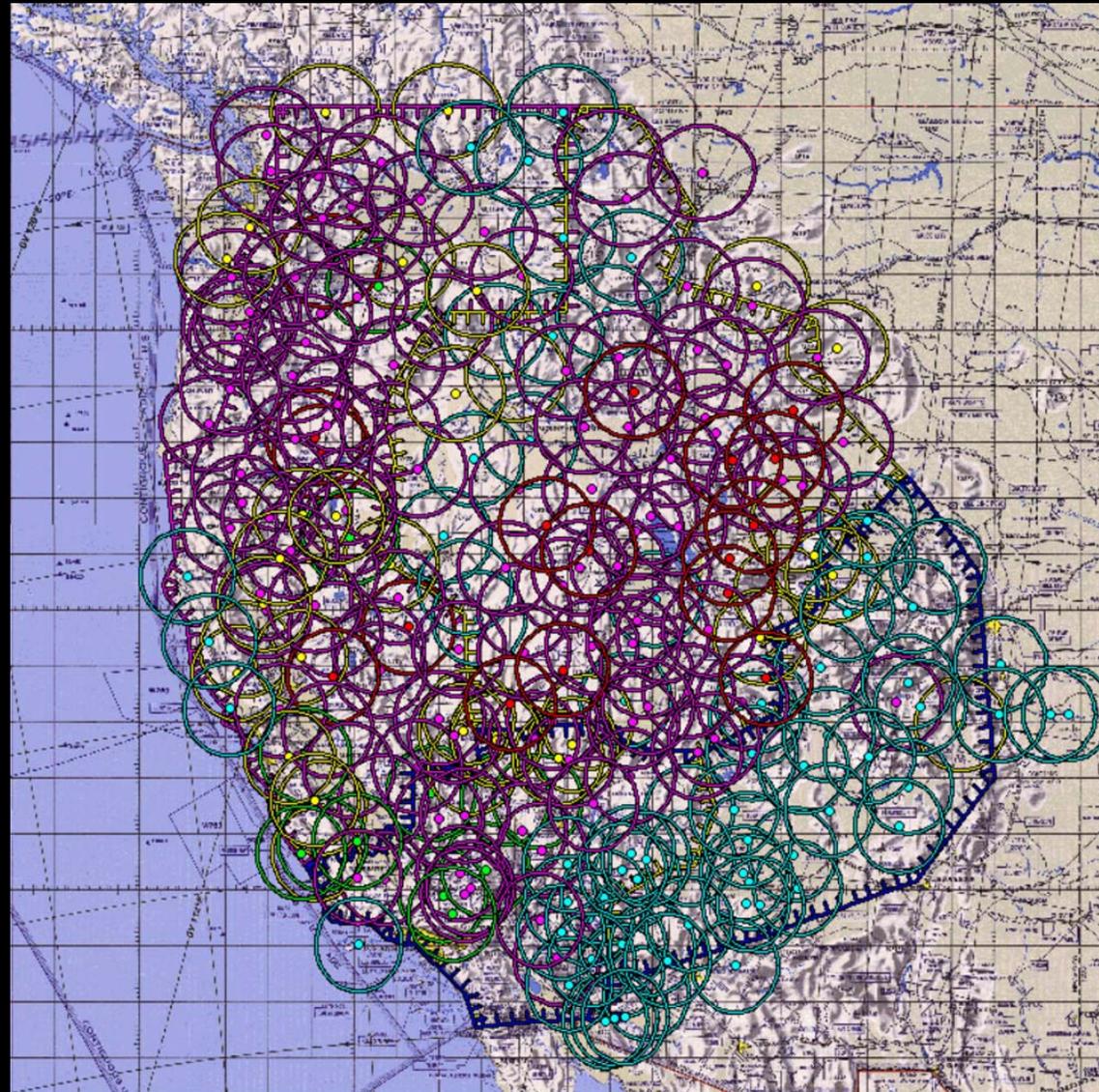
**Categorized Green, Yellow,  
Purple, Red by pilots**

**Selected in unpopulated  
areas. Abandoned runways,  
dry lakebeds, flat ground,  
ditch areas**

**Primary purpose is to  
protect public**

**Actively managed during  
each mission**

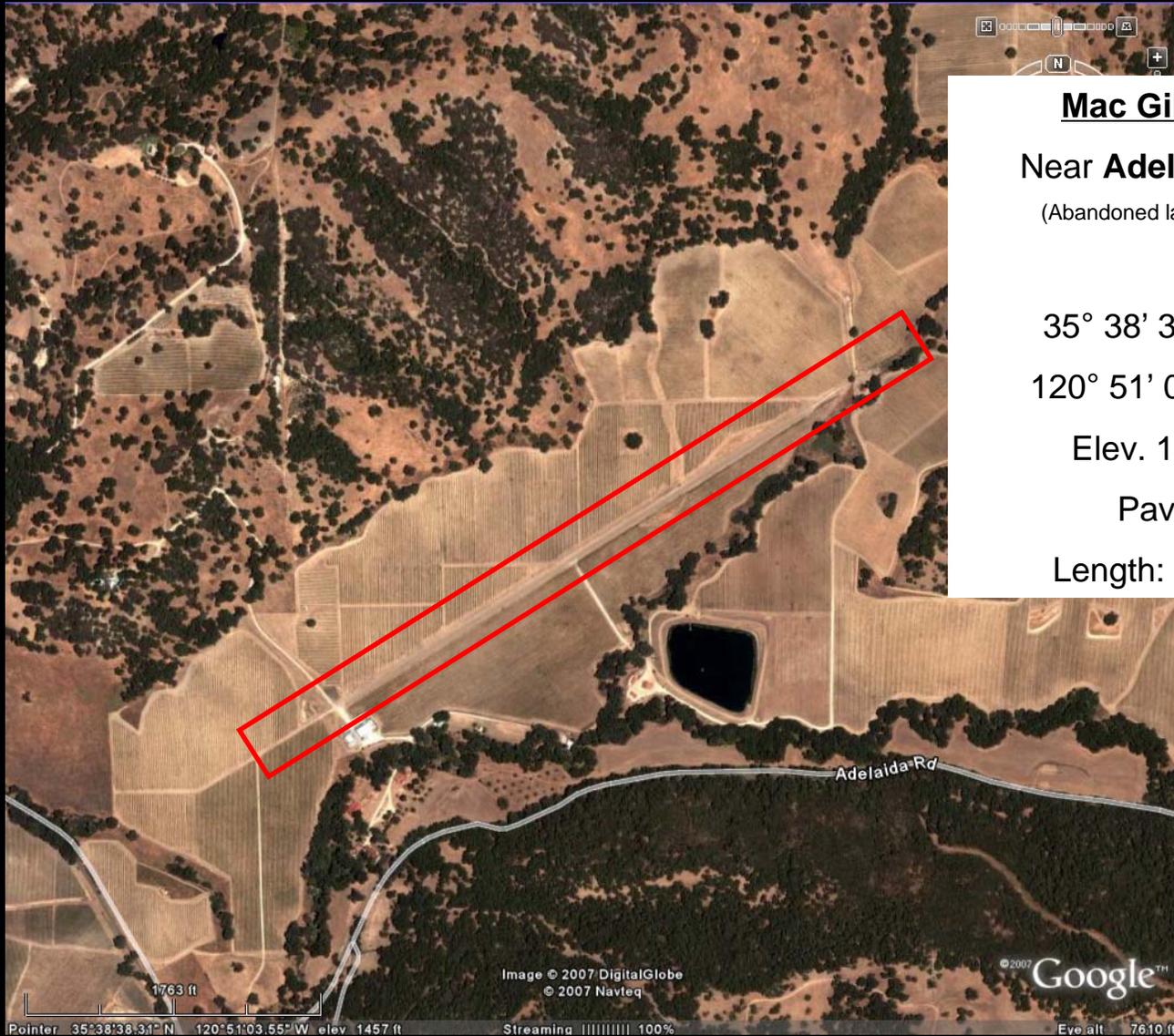
**“Owned” by DFRC Range  
Safety and changeable**





# Secondary Emergency Landing Site – Example 1

**IKHANA**

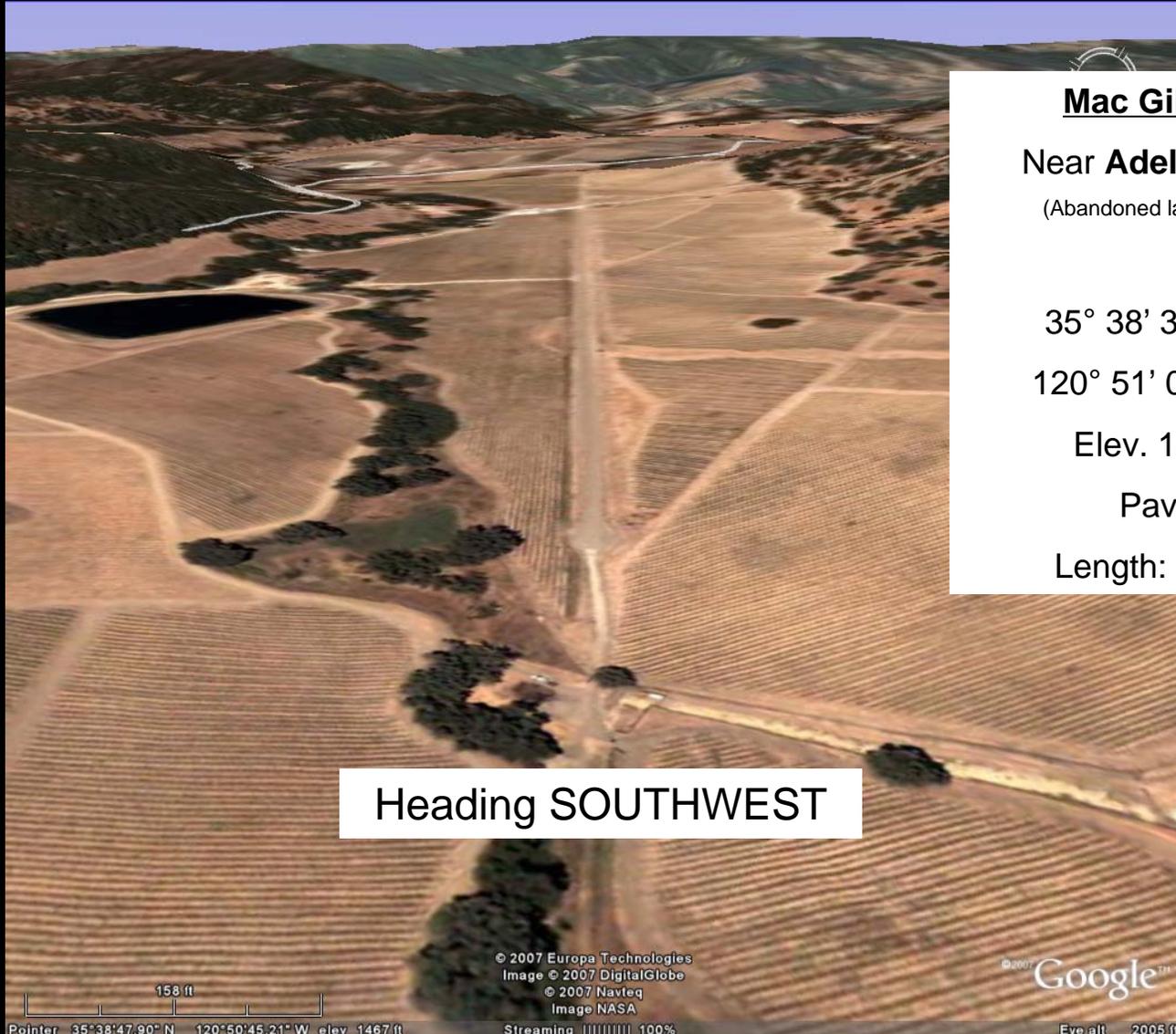


**Mac Gillivray**  
Near **Adelaida, CA**  
(Abandoned landing strip)  
  
35° 38' 39.52" N  
120° 51' 01.37" W  
  
Elev. 1454 ft  
Paved  
Length: 3000 ft



# Secondary Emergency Landing Site – Example 2

**IKHANA**



**Mac Gillivray**

Near **Adelaida, CA**

(Abandoned landing strip)

35° 38' 39.52" N

120° 51' 01.37" W

Elev. 1454 ft

Paved

Length: 3000 ft

Heading SOUTHWEST

© 2007 Europa Technologies  
Image © 2007 DigitalGlobe  
© 2007 Navteq  
Image NASA  
Streaming 100%  
Pointer: 35:38:47.90" N 120:50:45.21" W elev. 1467 ft  
Eye alt: 2005 ft  
Google™



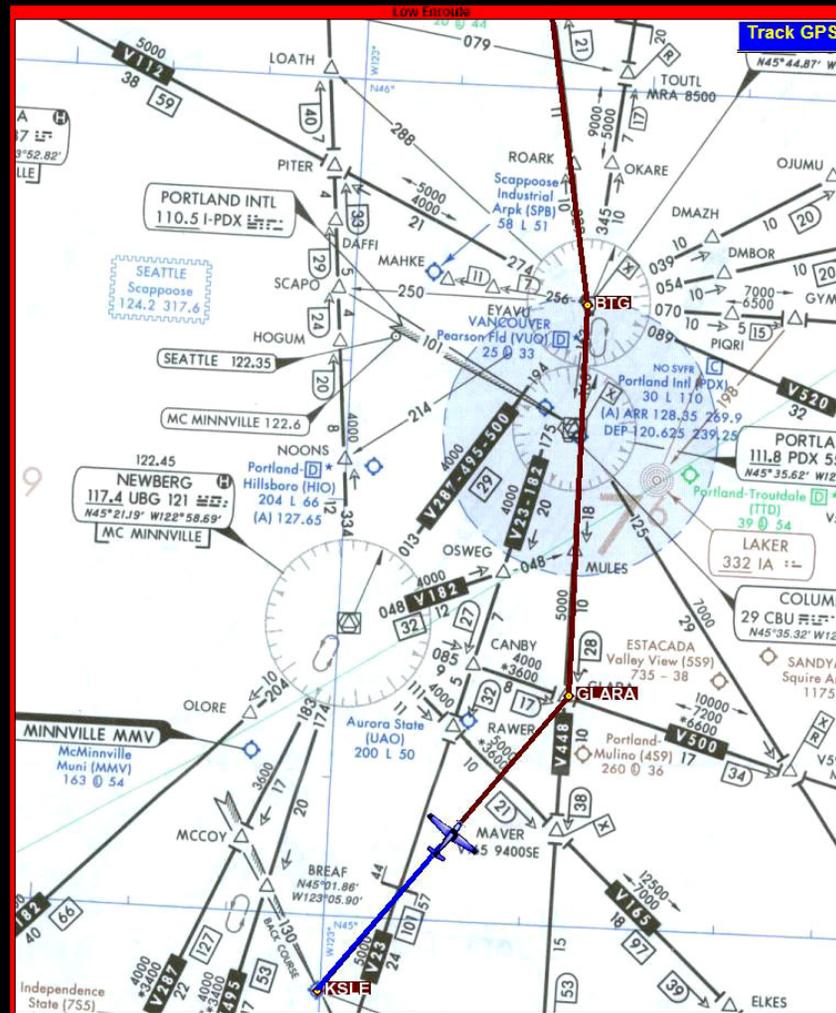
# EFB: ChartCase Professional™

## IKHANA



Page NRST Find Direct To Info Level

In Out Exit Inflight



Page Menu NRST Find Direct To Info Layer

In Out Exit Inflight





## *COA Application Provisions*

### **IKHANA**

- Only for “4-5” flights, 1 per week
  - But... wildfire emergencies could occur that would require quick turnaround and possibly more flights
- Stay 5 nm away from Zone boundaries
- Stay 10 nm away from International borders
  - Canada, Mexico
- Public Use aircraft
- NASA self-certifies for airworthiness



## *COA: Special Provisions*

### **IKHANA**

- Remain within 75 nm of 'backbone' route
- 3 business day mission notification to FAA
  - With "specific routes" identified
- IFR Flight Plan submitted 24 hours in advance
- Flight Plan
  - Point to point is acceptable
  - in FRD format (fix-radial-distance)
  - No more than 48 elements (fixes + loiter times)
- Mission Planning telecon with affected ATC Centers 24 hours prior to mission



## *COA: Special Provisions (con't)*

### **IKHANA**

- No flight into forecasted “moderate or severe” turbulence
- No flight in area where convective SIGMET has been issued
- No flight in area of known or forecast icing
- No flight in area of affected by GPS testing, solar storms or RAIM outages
- Contact list maintained for all ATC Centers and Ikhana GCS



## COA: Special Provisions (con't)

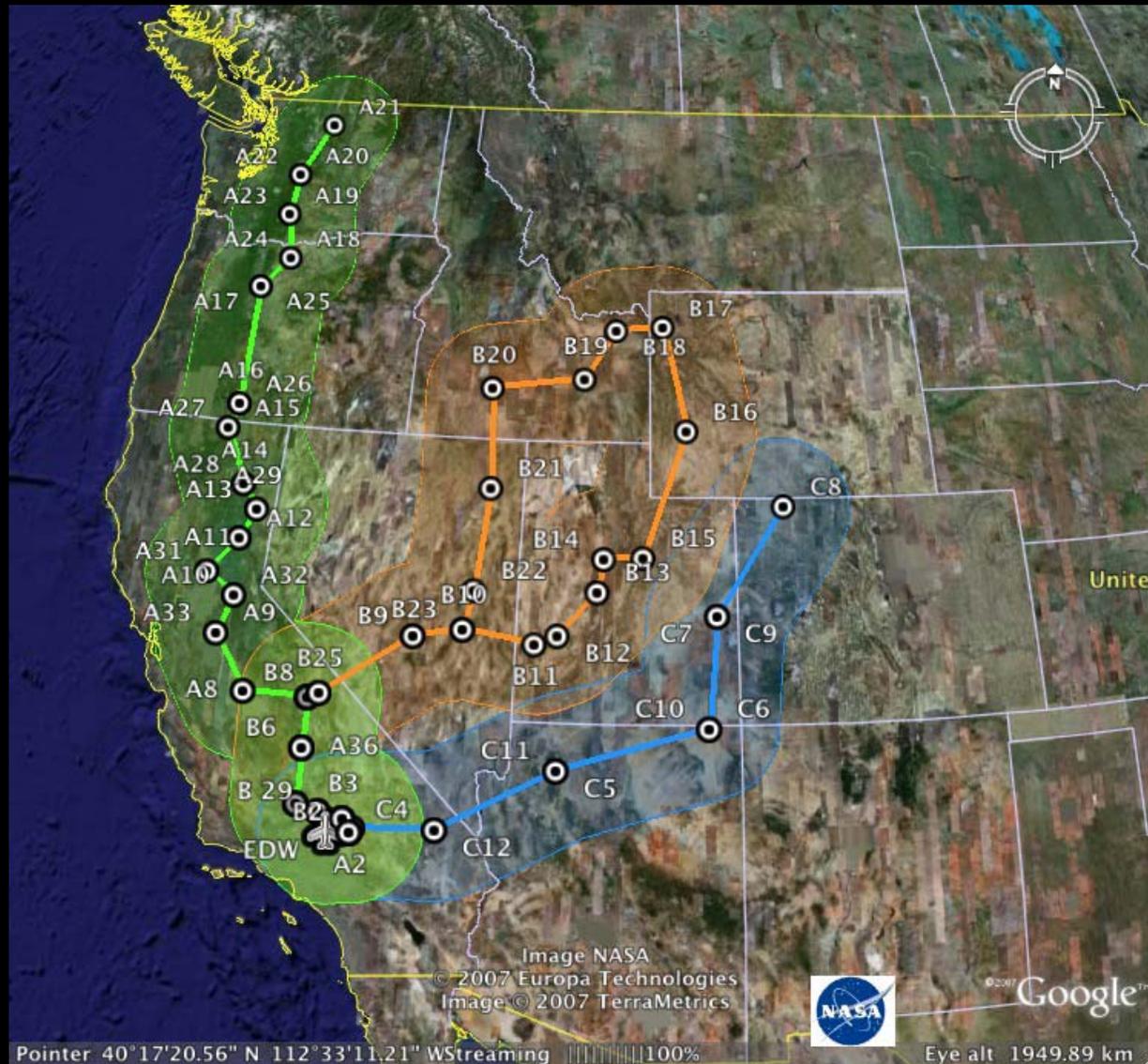
### IKHANA

- Lost link procedure
  - Maintain altitude
  - Continue on filed flight plan (the route) for 15 min
    - Does not mean “keep going straight ahead for 15 minutes”
    - If in a loiter area, stay in there for at least 15 minutes
  - Squawk 7600
  - Aircraft will turn right, if it has to retrace the flight plan
  - Aircraft will return to R-2508/R-2515 the way it came out (usually)



# Approved COA Area

## IKHANA





# WSFM #1 - #4 Flight Tracks

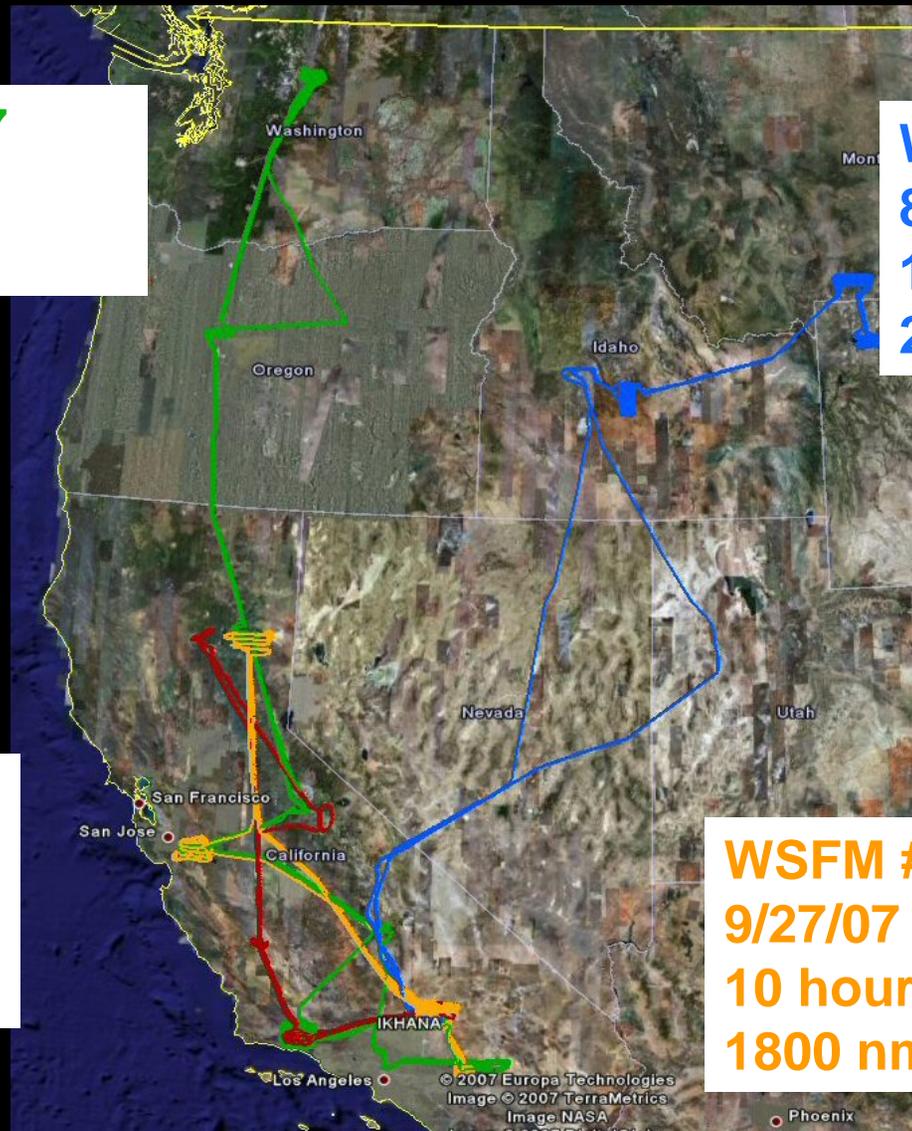
**IKHANA**

**WSFM #3 9/7/07**  
20 hours  
3200 nmi

**WSFM #2 8/29/07**  
16.1 hours  
2500 nmi

**WSFM #1 8/16/07**  
9.5 hours  
1400 nmi

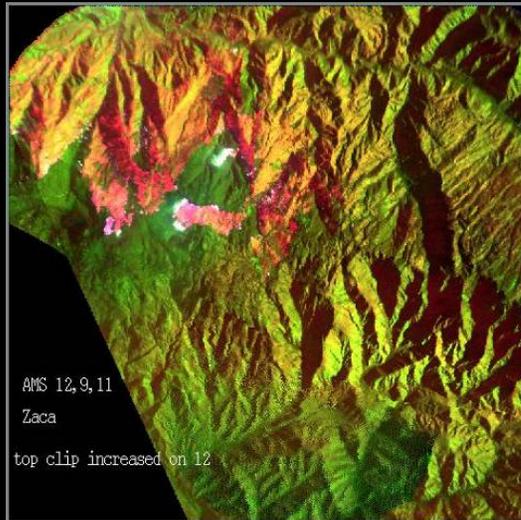
**WSFM #4 9/27/07**  
10 hours  
1800 nmi



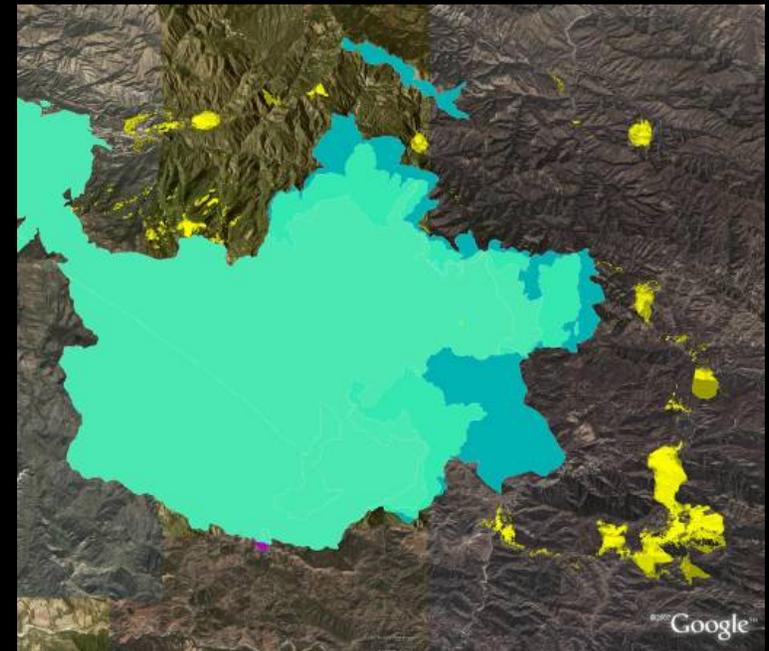


# WSFM #1 – Aug. 16, Zaca Fire

**IKHANA**



- Delivered near real-time data to the Incident Command Center for the Zaca fire  
“ Our conversation surrounded the "fog of war" existing due to an inversion on the southeast corner of the fire... the incident management teams did not know where the fire was, and that information was critical to modify their strategy and initiate action. The intel provided by the UAV, real time and geospatially oriented, answered that critical question and saved precious hours. Yes, indeed, it was a success...”

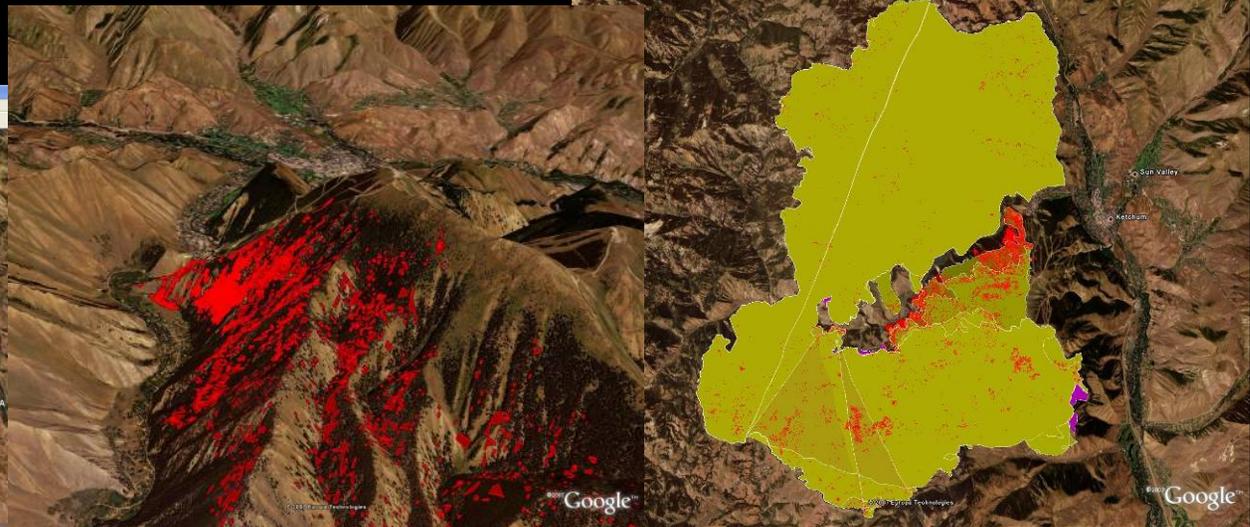
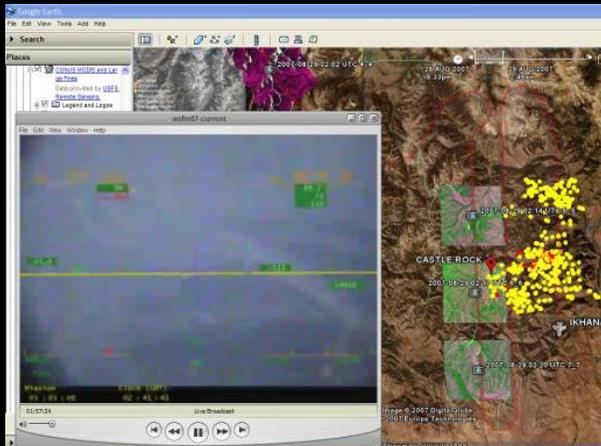
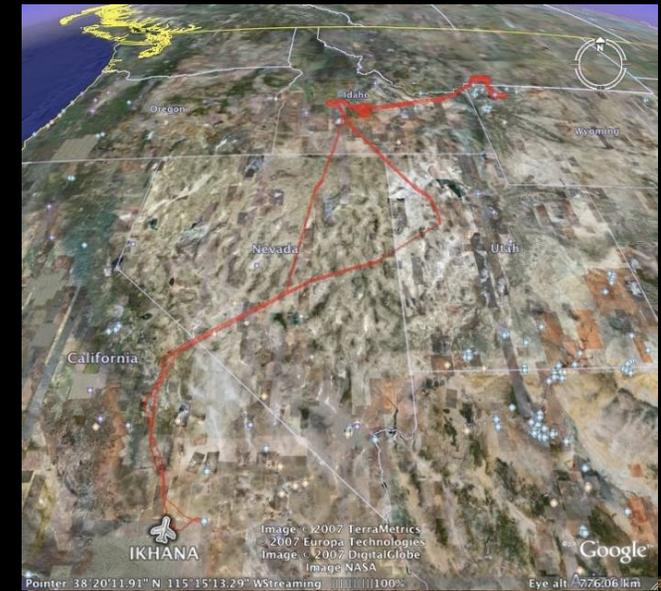




# WSFM #2 – Aug. 29-30

## IKHANA

- Real-time ATC routing around poor weather saved the mission
- Collected and transmitted real-time fire data on eight fires spread through CA (Jackrabbit), ID (Trapper Ridge, Castle Rock, Granite Creek, and Hardscrabble), MT (WH Fire), and WY (Columbine Fire).
- Made repeat passes over each, spending most time over Castle Rock, as this was a high priority fire for US, threatening Ketchum and Sun Valley, ID.
- Delivered near real-time data to Incident Command on Castle Rock; used for operations and redeployment of resources on the fire based on the data.
- Collected coincident UAV data with a MODIS satellite data overpass on Castle Rock...major science accomplishment
- Tremendous amount of national publicity for NASA, USFS, and the FAA.

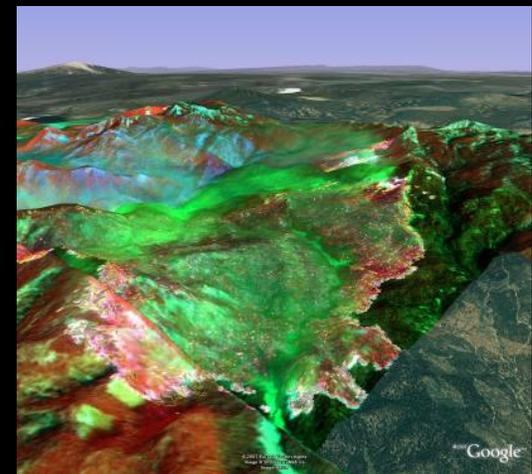
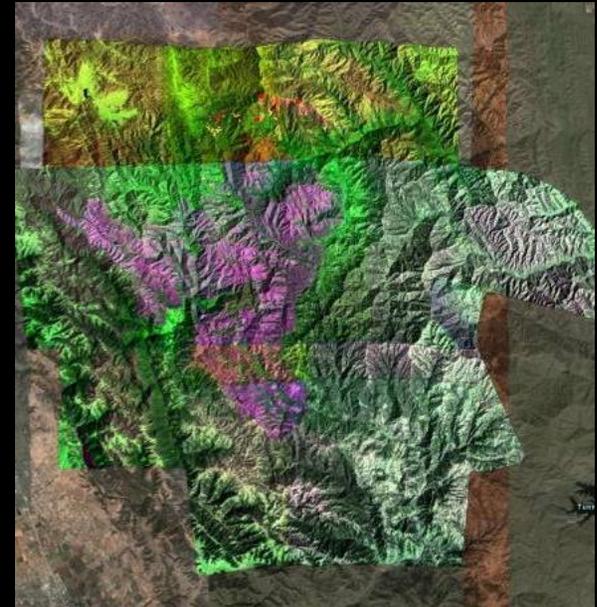
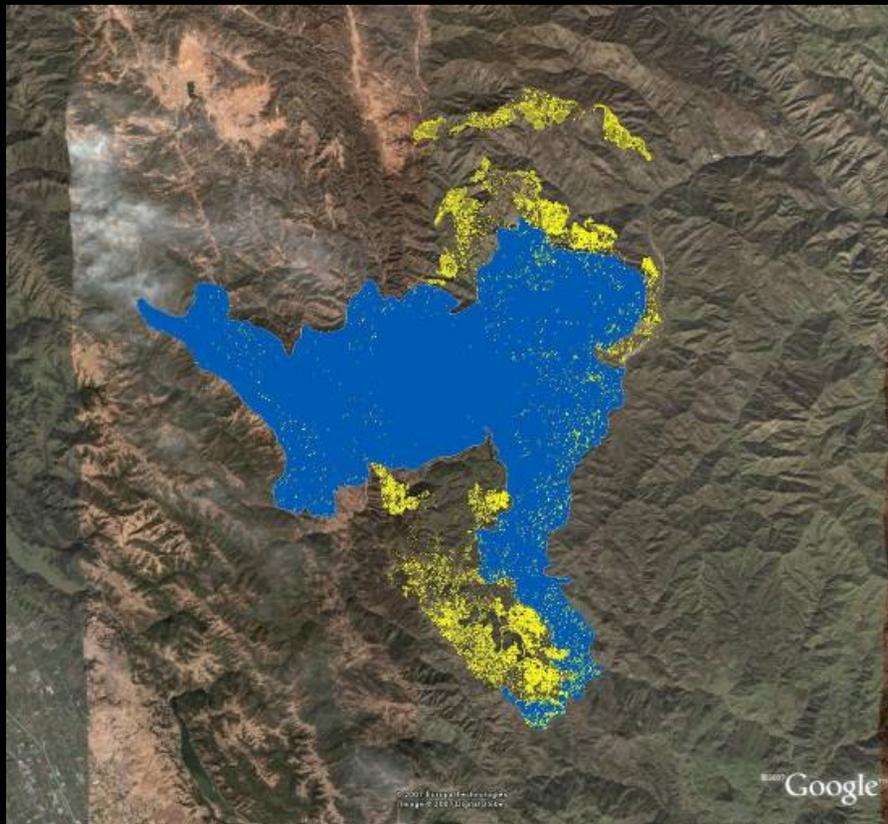




# WSFM #3 - September 7-8

## IKHANA

- Collected and transmitted near real-time fire data on eleven fires spread through CA (Butler, North, Fairmont, Grouse, Lick, Bald, Moonlight, Zaca), OR (GW & Big Basin Fires), and WA (Domke Lake and South Omak Fires),
- Made repeat passes over most, (total of 18 fire visits) spending significant time over high priority fires (Lick, Moonlight, and GW)

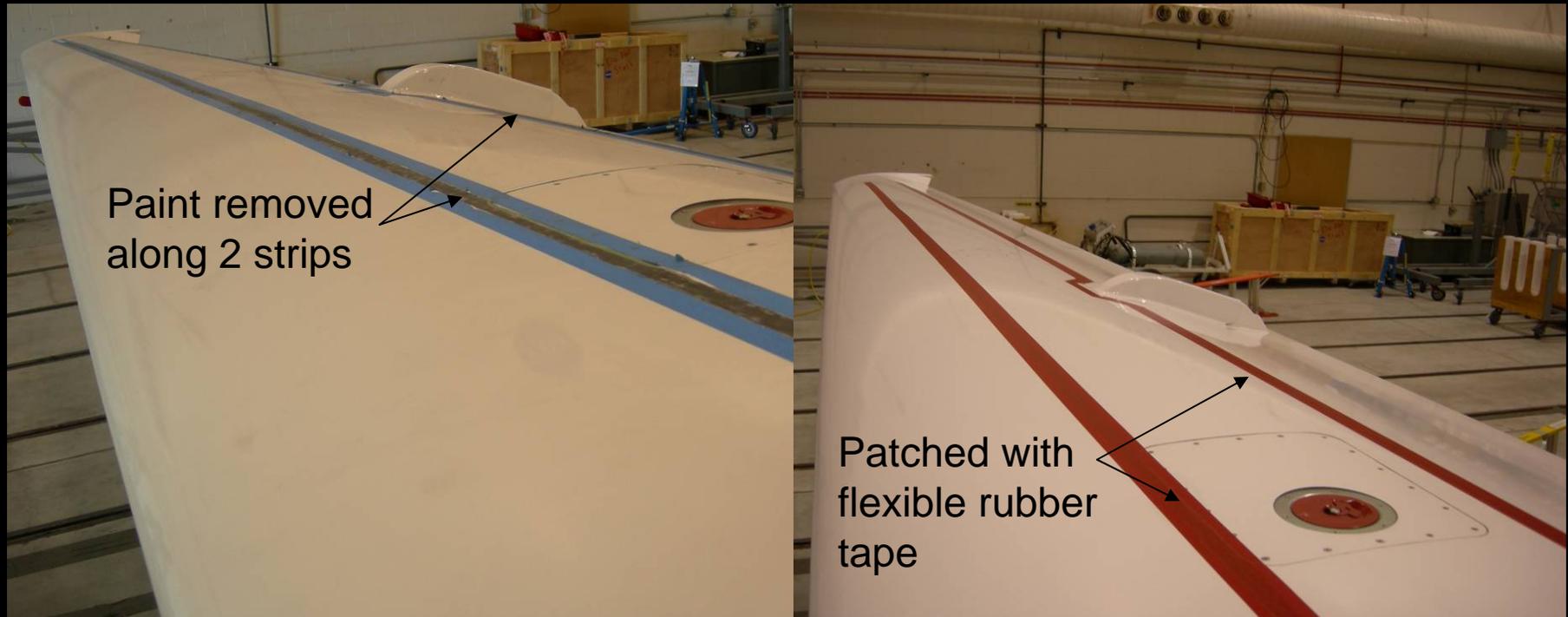




# California Emergency Wildfire Response

## IKHANA

- Oct 20-21: Wildfires start and spread in southern California
- Oct 22<sup>nd</sup>: Ikhana team began preparation for a possible fire mission
  - Two impediments
    - Failed hard drive in the wildfire sensor
    - Ikhana wings being modified for another experiment.
- Oct 24<sup>th</sup>: 1<sup>st</sup> Emergency response mission (WSFM #5)





# WSFM #5 - #8 Flight Tracks

## IKHANA

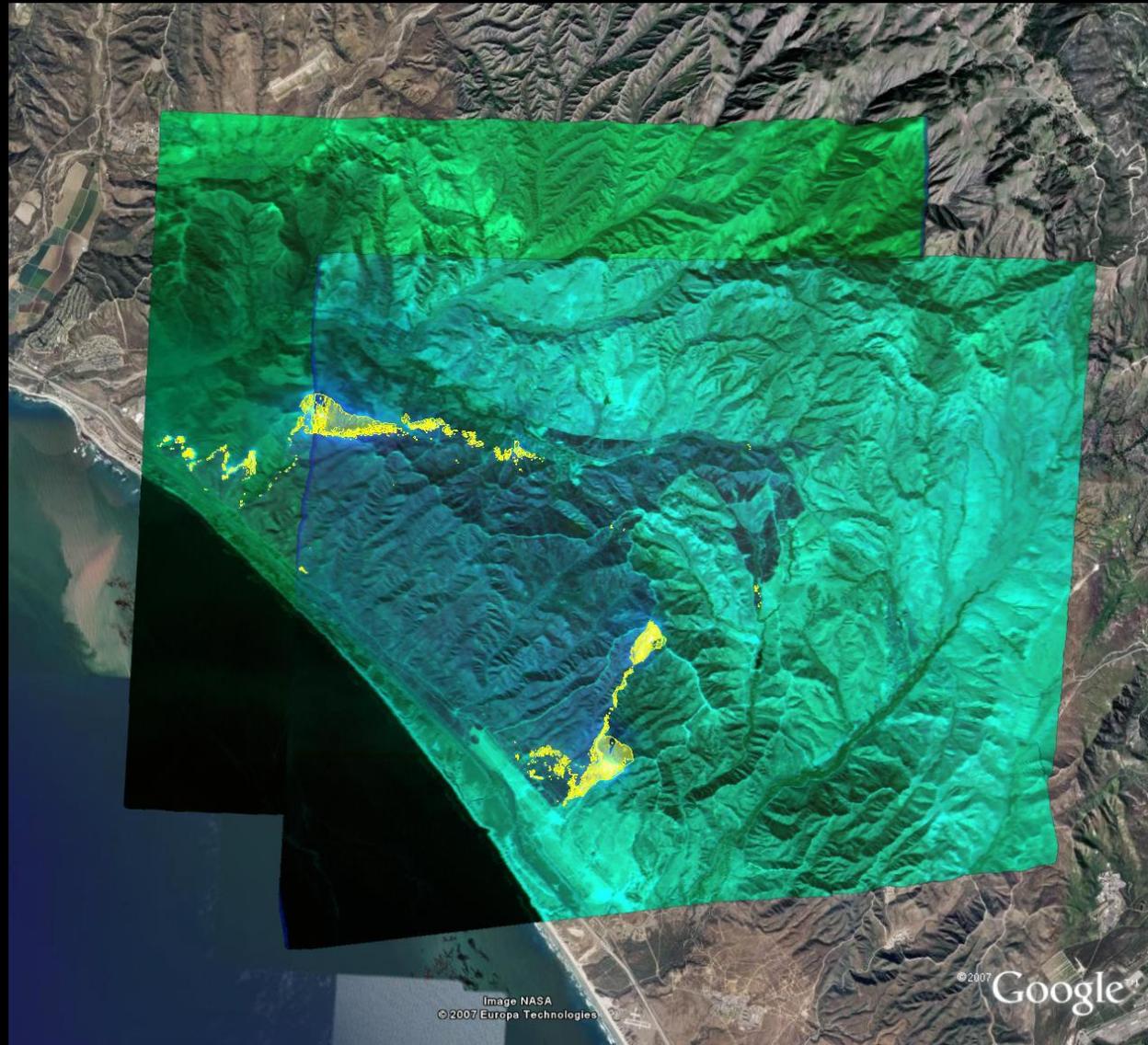




# WSFM #5 – Oct. 24<sup>th</sup>, Ammo Fire

**IKHANA**

*Hot spots in yellow*



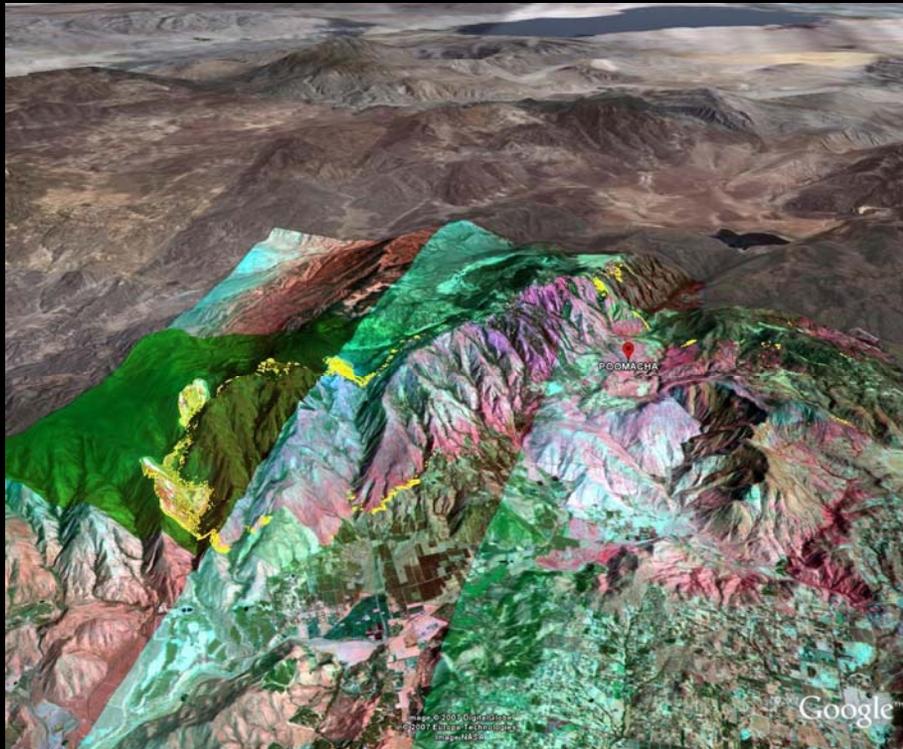


*WSFM #6 - Oct. 25<sup>th</sup>*

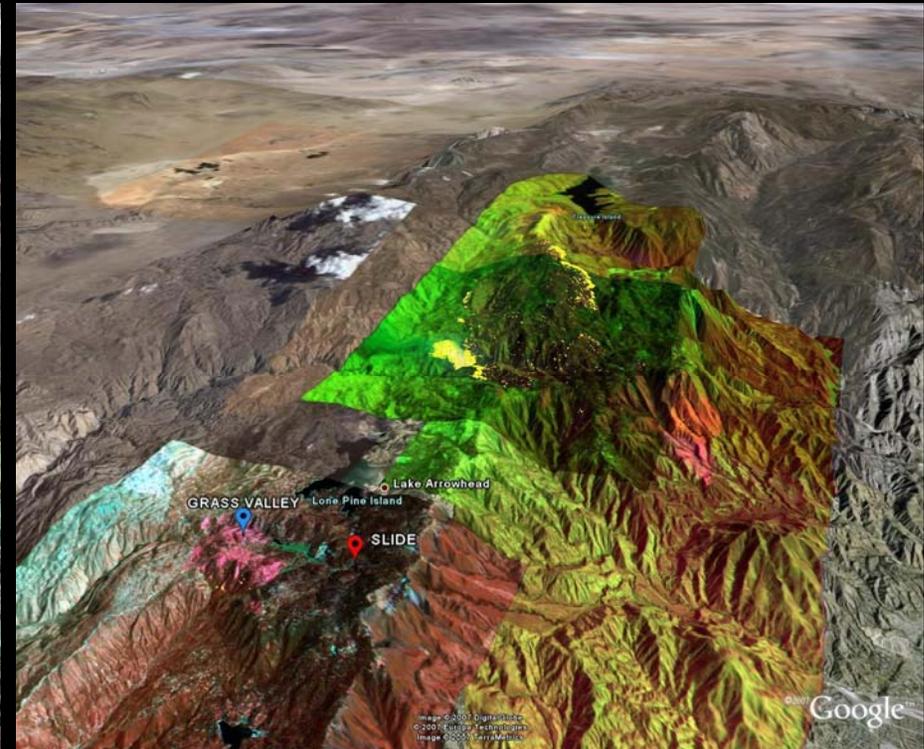
**IKHANA**

*Hot spots in yellow*

### **Poomacha / Rice Fires – 3D with Hot Detects**



### **Grass Valley / Slide Fires - 3D with Hot Detects**





**WSFM #7 - Oct. 26<sup>th</sup>**

**IKHANA**

*Hot spots in yellow*

**Santiago Fire –  
3D with Hot Detects**





# WSFM #8 - Oct. 28<sup>th</sup>, Santiago Fire

**IKHANA**

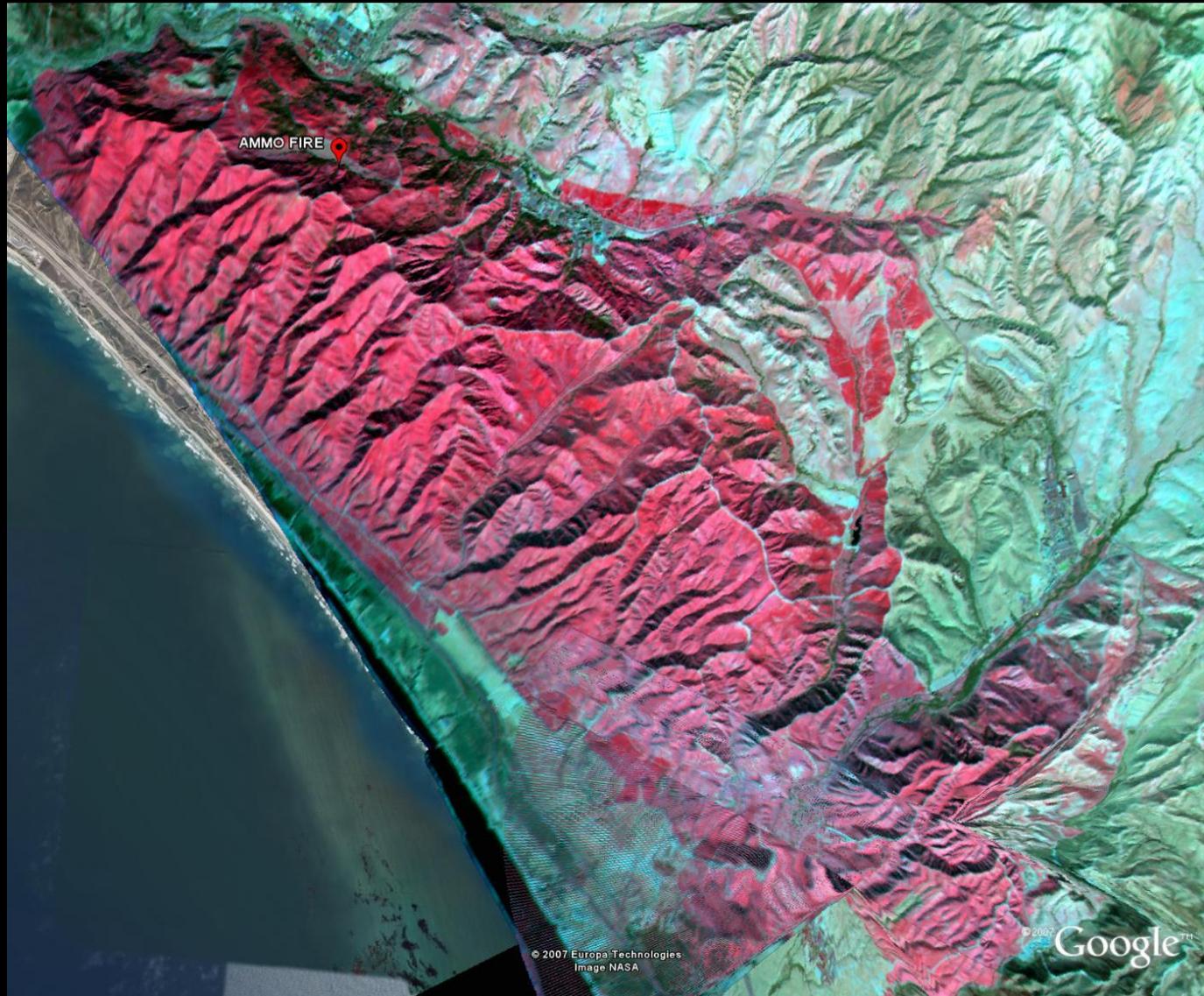




# *WSFM #8 - Oct. 28<sup>th</sup>, Ammo Burn Area*

**IKHANA**

*Sensor optimized  
for Burn Area  
Emergency  
Response (BAER)  
imagery*





## *WSFM #5 - #8 Southern California Results*

### **IKHANA**

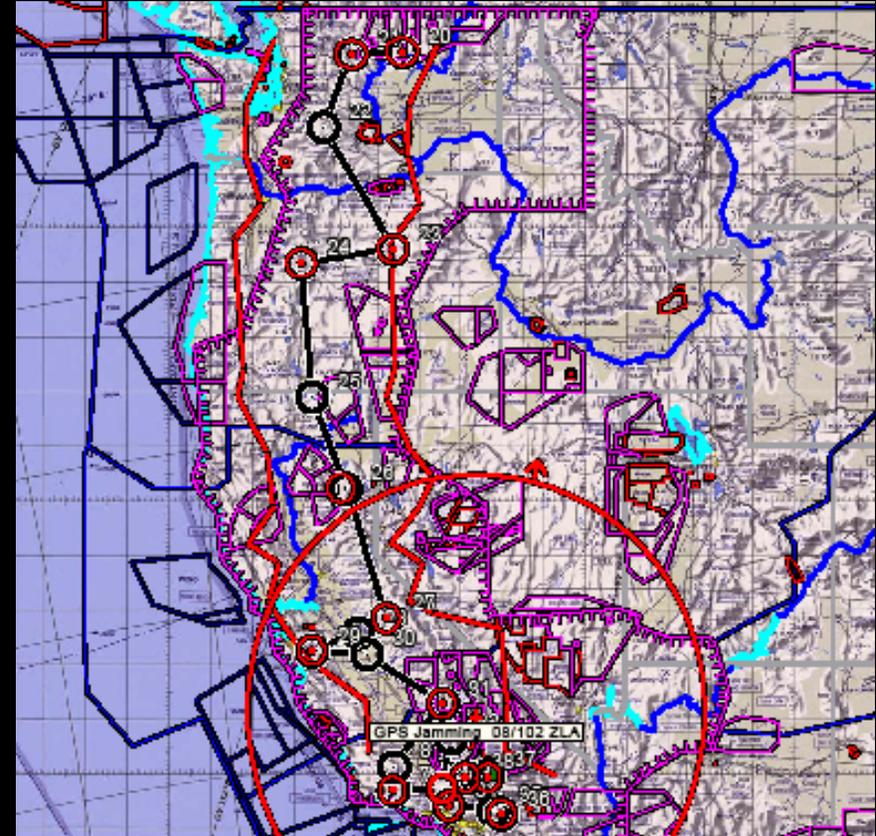
- Four 9-hr missions flown
  - 5 day period covering Wednesday, Thursday, Friday, Sunday
  - Post flight debrief with DFRC team
  - Post flight/preflight brief with FAA HQ and LA Center
- Air Traffic Control gave excellent support
  - Mission plans flown in reverse
  - Real time requests for revisits of active fires
  - Added new fire during mission
  - Moved fire loiter points as fires moved
- Thermal infrared imagery delivered in near real-time (5 to 15 minutes)
  - FEMA, NIFC, California EOC
  - Individual Fire Incident Command Centers
- Ventura County Fire Chief reported:
  - “Intel” was used tactically to fight the fires
  - “Intel” was used strategically to prioritize fires and allocate resources between fires
  - “Intel” was used to allow some fires to burn into each other



# 2007 WSFM Challenges

## IKHANA

- GPS Testing – 250+ nm RADIUS
- Command/Control frequency access
- Emergency landing site permission
- Weather
  - Wind
  - Clouds
  - Icing
  - Thunderstorms
- Long missions





## *Credit where Credit is Due*

### **IKHANA**

- THE FAA HQ UAPO (UAS) Office
  - Not possible without GREAT cooperation and communication
- FAA ATC Centers and Controllers
  - Los Angeles, Oakland, Seattle, Salt Lake, Albuquerque, Denver
- USAF
- DFRC Range Safety Office (RSO)
- General Atomics



# Questions?

## **IKHANA**

