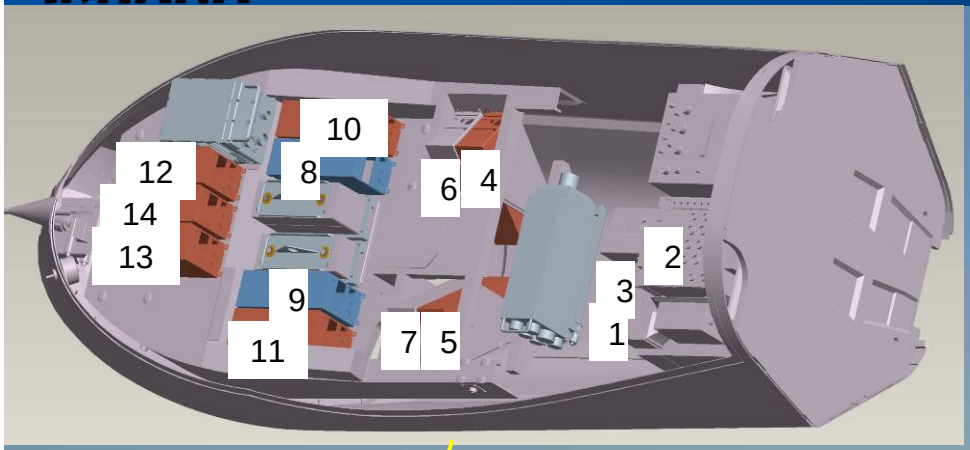
NASA
2007 Western States Fire Missions (WSFM)

Greg Buoni
NASA Dryden Flight Research Center
January 16, 2008

GENERAL ATOMICS
AERONAUTICAL SYSTEMS

Western States Fire Mission Modifications

IKHANA



Back-up battery power increased to 3 hours

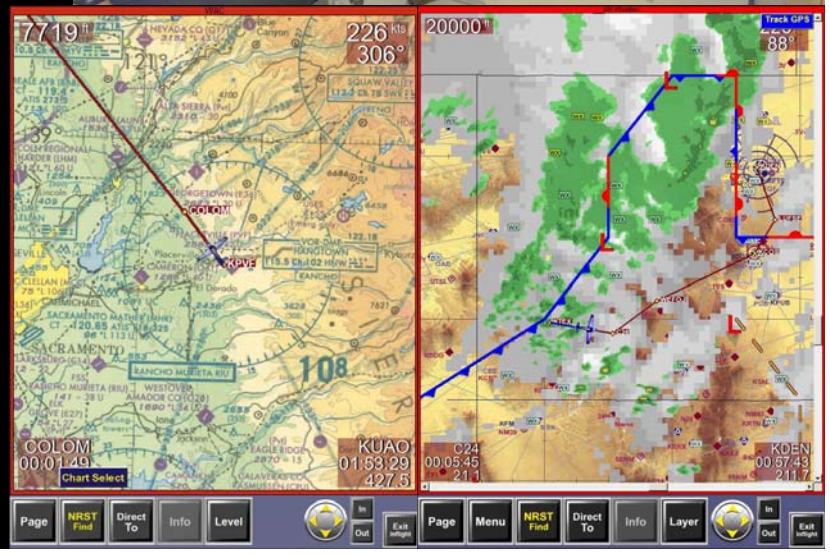
Wiring connections from pod to power distribution, GPS antenna, and SatCom system

Infrared Wildfire Scanner

Ground Systems

IKHANA

- Mobile Ground Control Station
  - Dual pilot control station
  - Electronic navigation charts
  - Weather
  - 6 Engineering/Science workstations
  - Range safety workstation
  - Intercom system throughout
  - Overhead mission displays
  - Telephones
  - Remote video from aircraft start-up/shut-down site
  - Downlink video and data recording
- Mobile 2.4m Ku SatCom Antenna
  - Dual redundant receiver/transmitters



2007 Western States Fire Mission Objectives

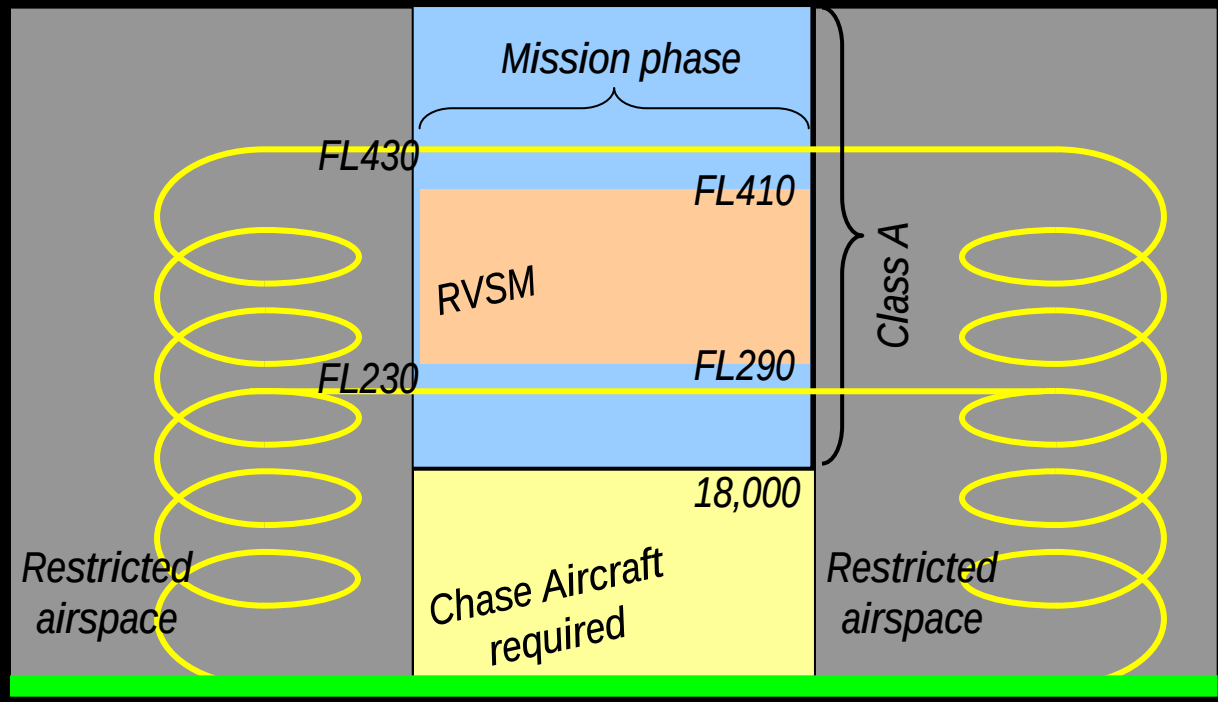
IKHANA

- Demonstrate capabilities of UAS to overfly and collect sensor data on widespread fires 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.
- Demonstrate new UAV-compatible, autonomous sensor for improved thermal characterization of fires.
- Provide automated, on-board, terrain and geo-rectified sensor imagery over OTH satcom links to national fire personnel and Incident commanders.
- Deliver real-time imagery to (within 10-minutes of acquisition).
- Demonstrate capabilities of OTS technologies (GoogleEarth) to ‘serve’ and display mission-critical sensor data, coincident with other pertinent data elements to facilitate information processing (WX data, ground asset data, other satellite data, R/T video, flight track info, etc).

Operations Concept

IKHANA

- Chase aircraft required below 18k in the U.S. National Airspace (NAS)
- Air traffic control (ATC) used for collision avoidance above 18,000 ft
- NASA Dryden uses restricted airspace to climb to cruise altitude before exiting into the NAS
- Since Ikhana not qualified for Reduced Vertical Separation Minima (RVSM), operations are limited to 18,000 ft to FL 290 or above FL 410
- Transponder and radio communication required



Certificate of Authorization (COA) Boundary Request

IKHANA

3 Operational Zones

Each zone includes no more than 3 ARTCC areas

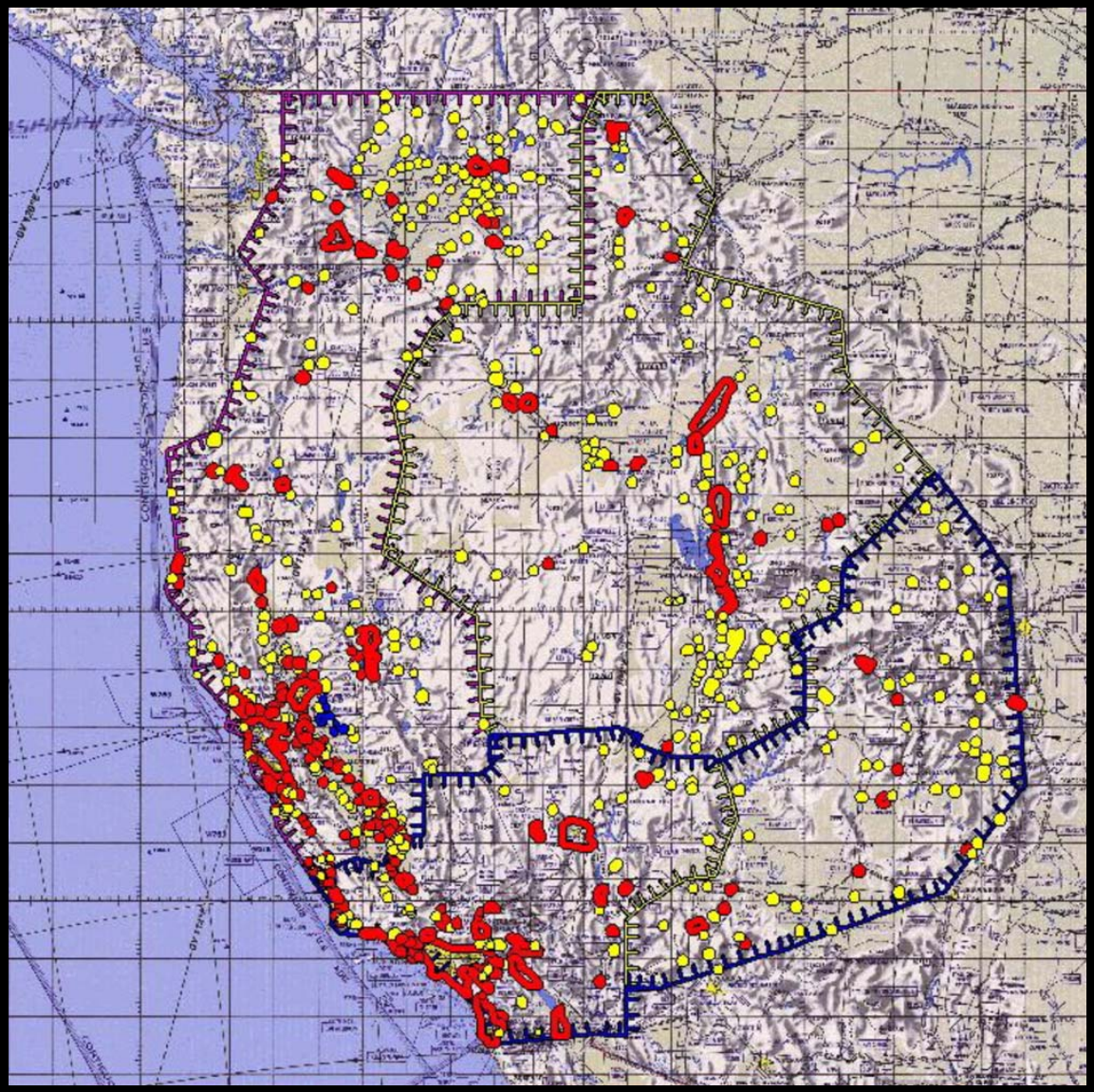
Range Safety Protection Zones

IKHANA

KEEP-OUT ZONES

Defined and “Owned” by DFRC Range Safety

Can be changed or updated before or during flight with concurrence of a DFRC Range Safety Officer (RSO)



NOMINAL AIRCRAFT

UNHEALTHY AIRCRAFT

Routes A, B, C

IKHANA

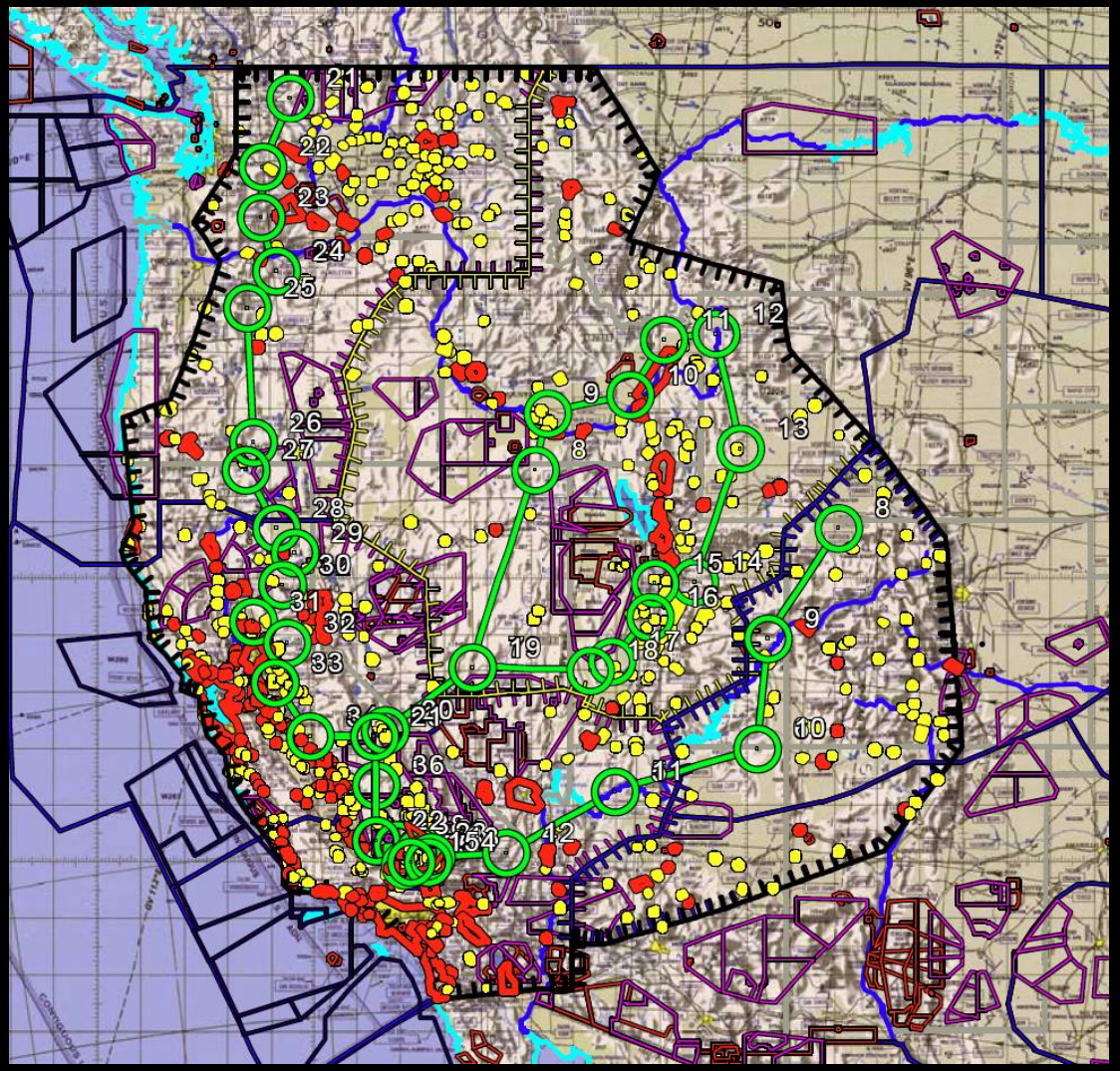
Defined Routes for each Zone

Over/near forrested areas

Avoid population areas

Avoid directly above mountains when possible

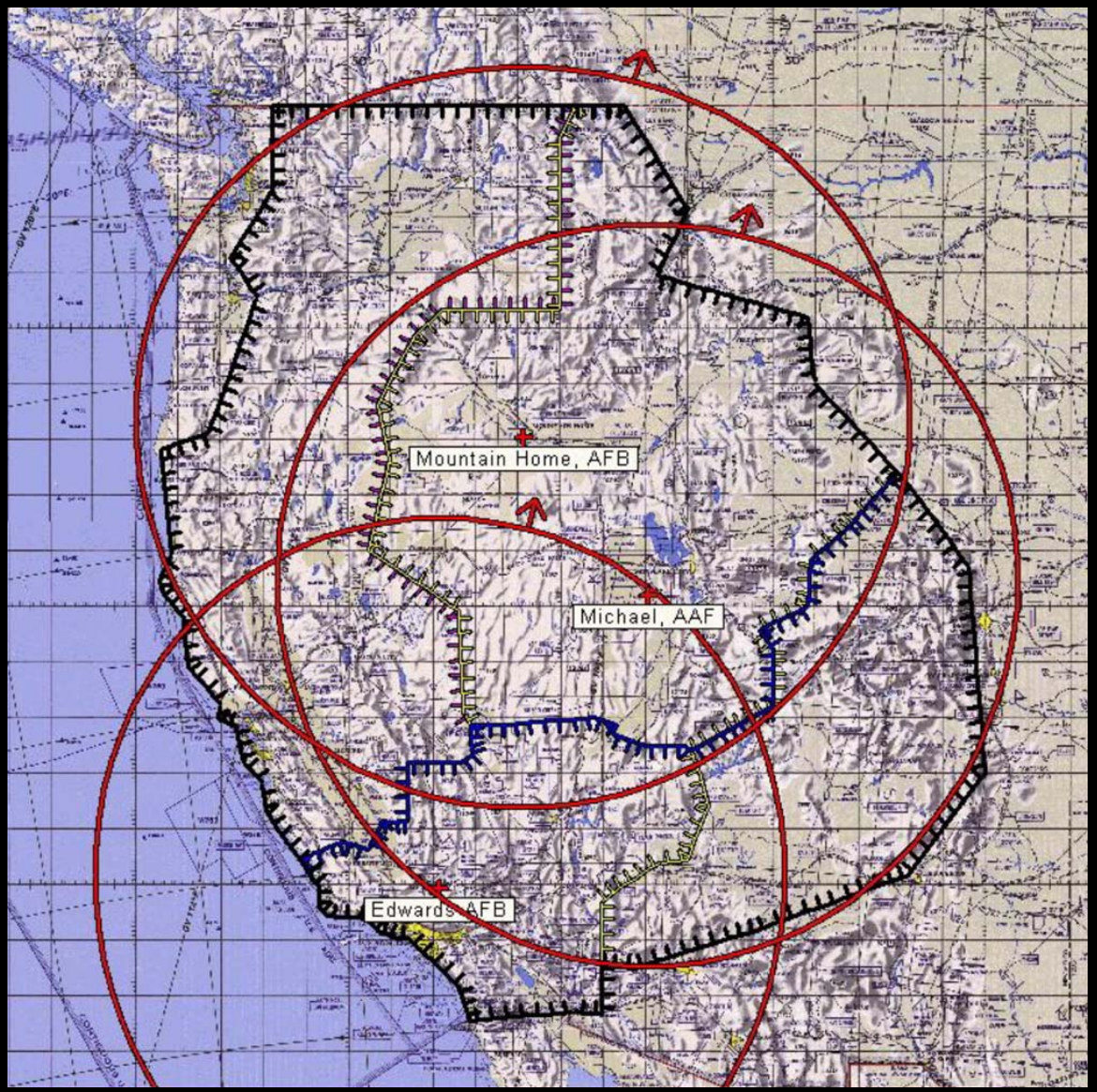
- **Weather when lost link**



Primary Emergency Landing Sites

IKHANA

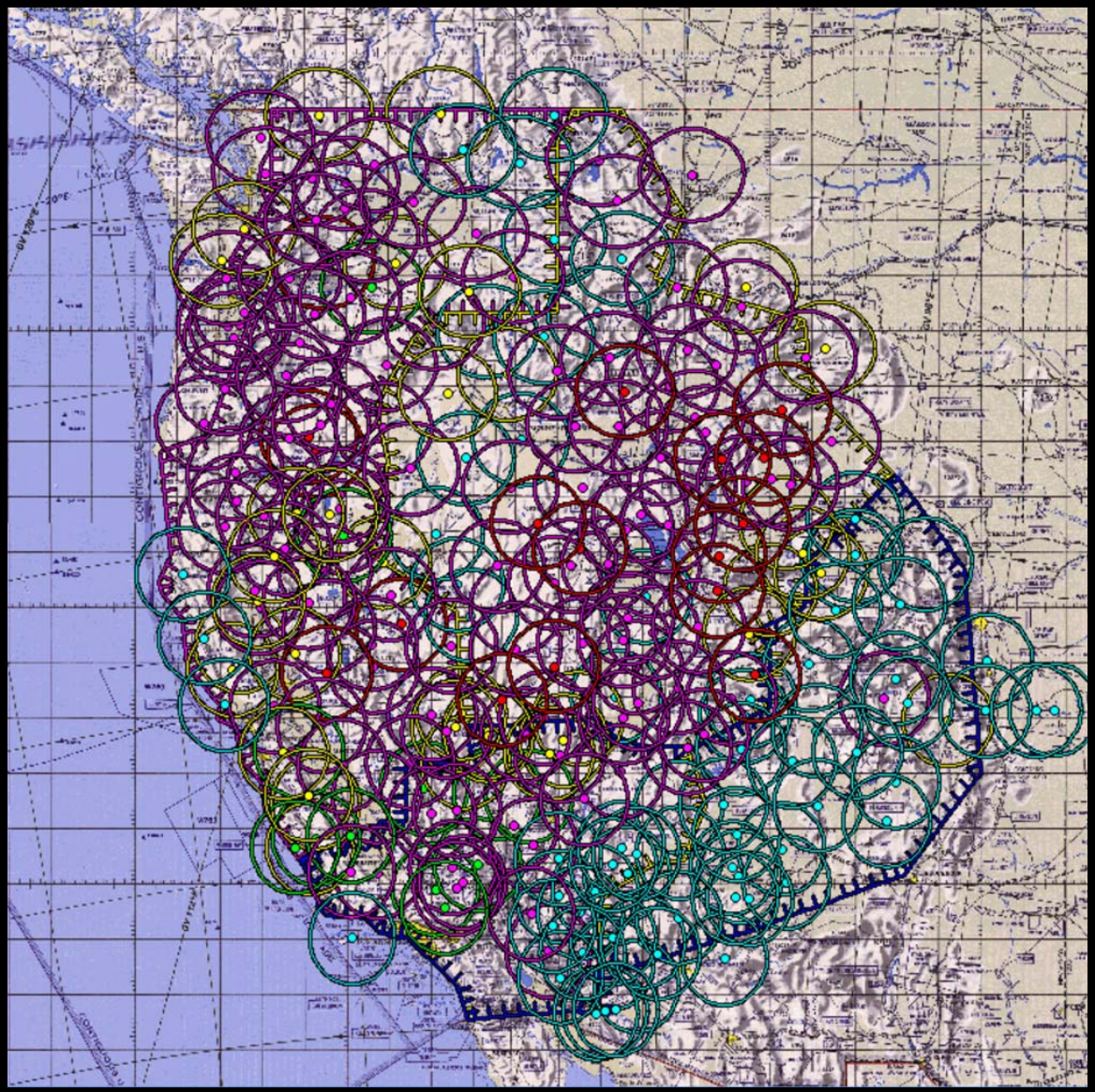
- Radius =400 nmi
- Minimum Range on Battery Power
- Aircraft has single generator
- Landing agreements negotiated with each site

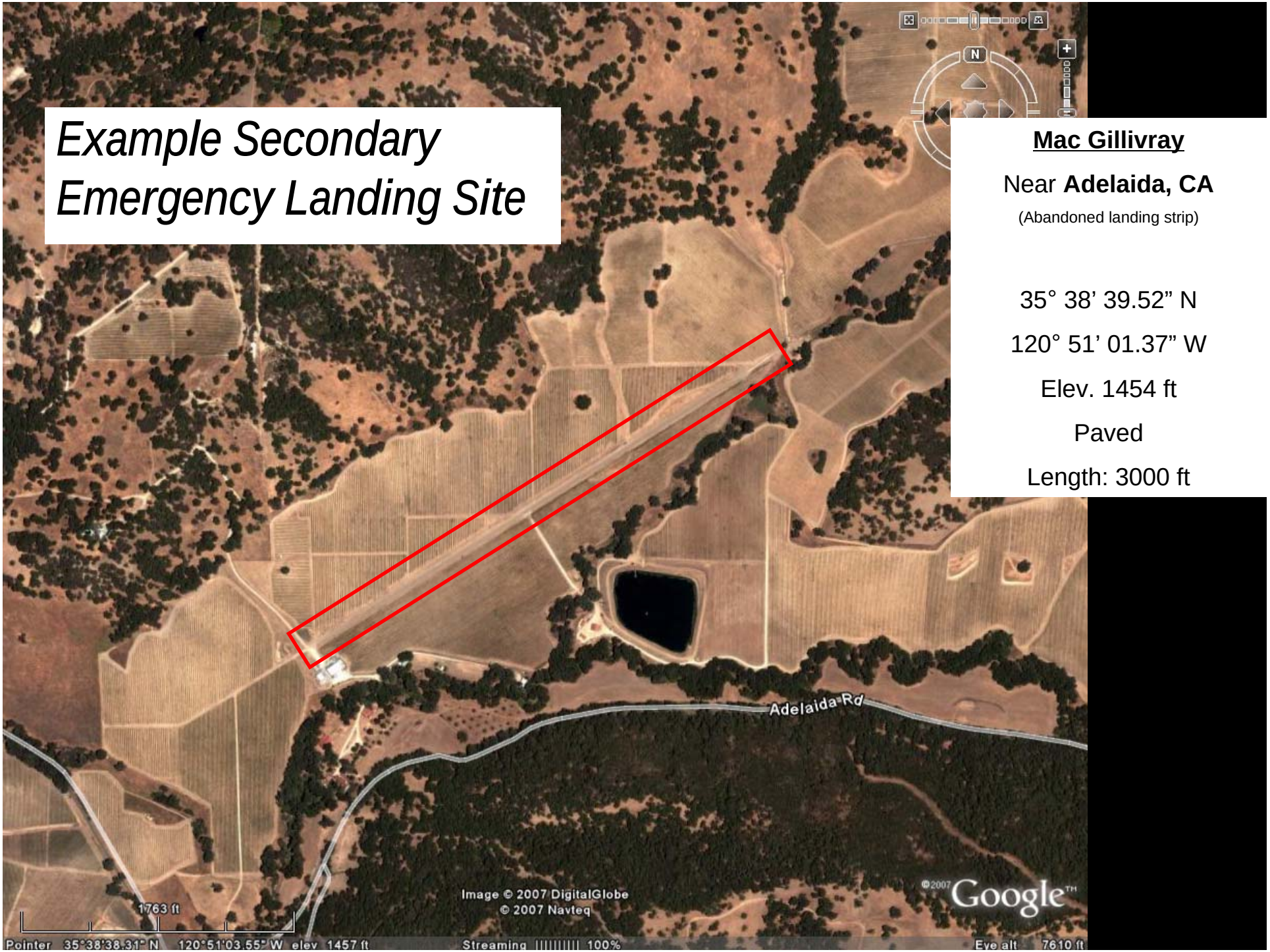


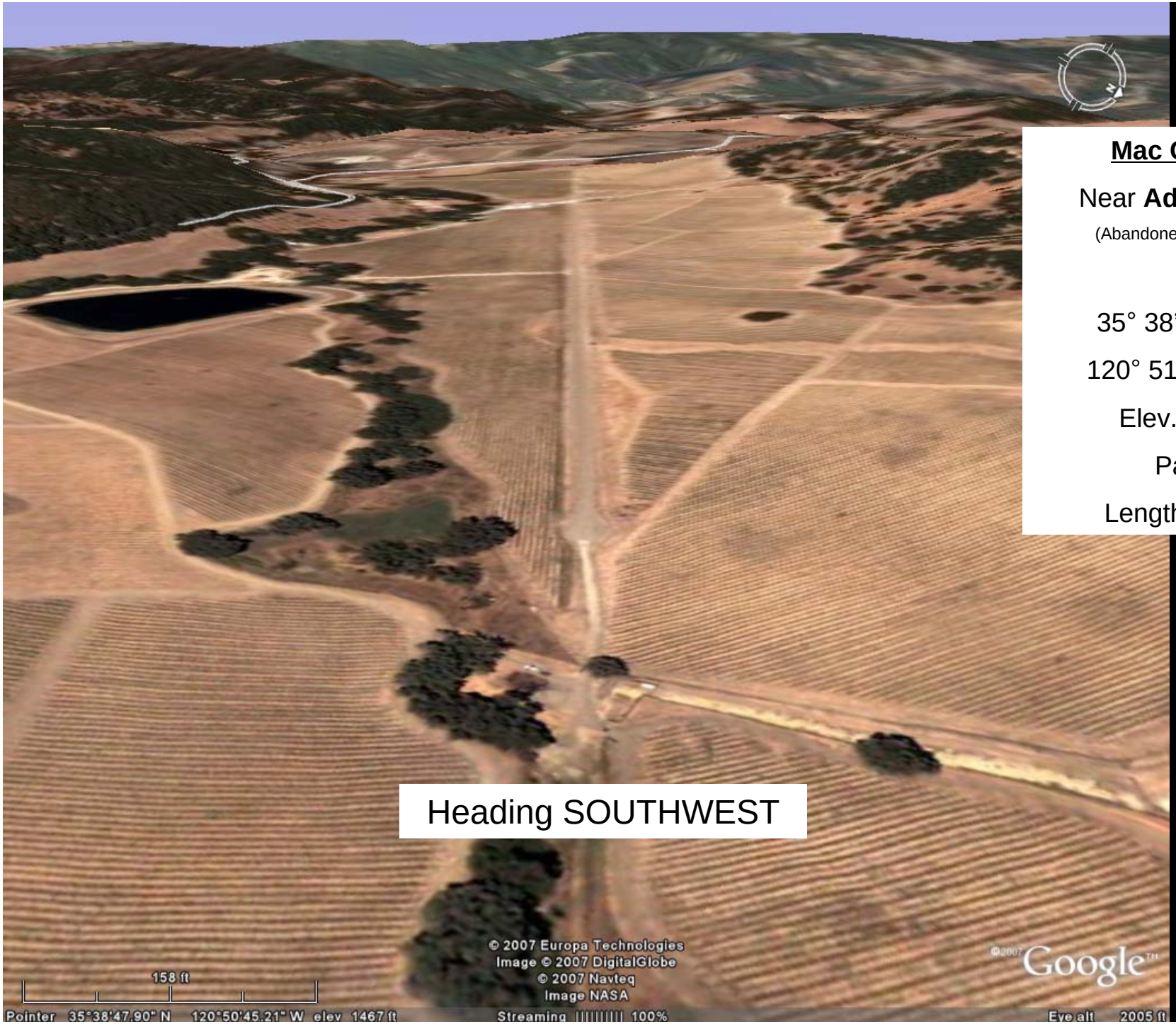
Secondary Emergency Landing Sites

IKHANA

- Radius=50 nmi (minimum glide from 23,000 ft)
- 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




Example Secondary
Emergency Landing Site
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
Adelaida Rd
1763 ft
Image © 2007 DigitalGlobe
© 2007 Navteq
©2007 Google™
Pointer 35°38'38.31" N 120°51'03.55" W elev 1457 ft
Streaming 100%
Eye alt 7610 ft



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

Chart Case Professional

IKHANA

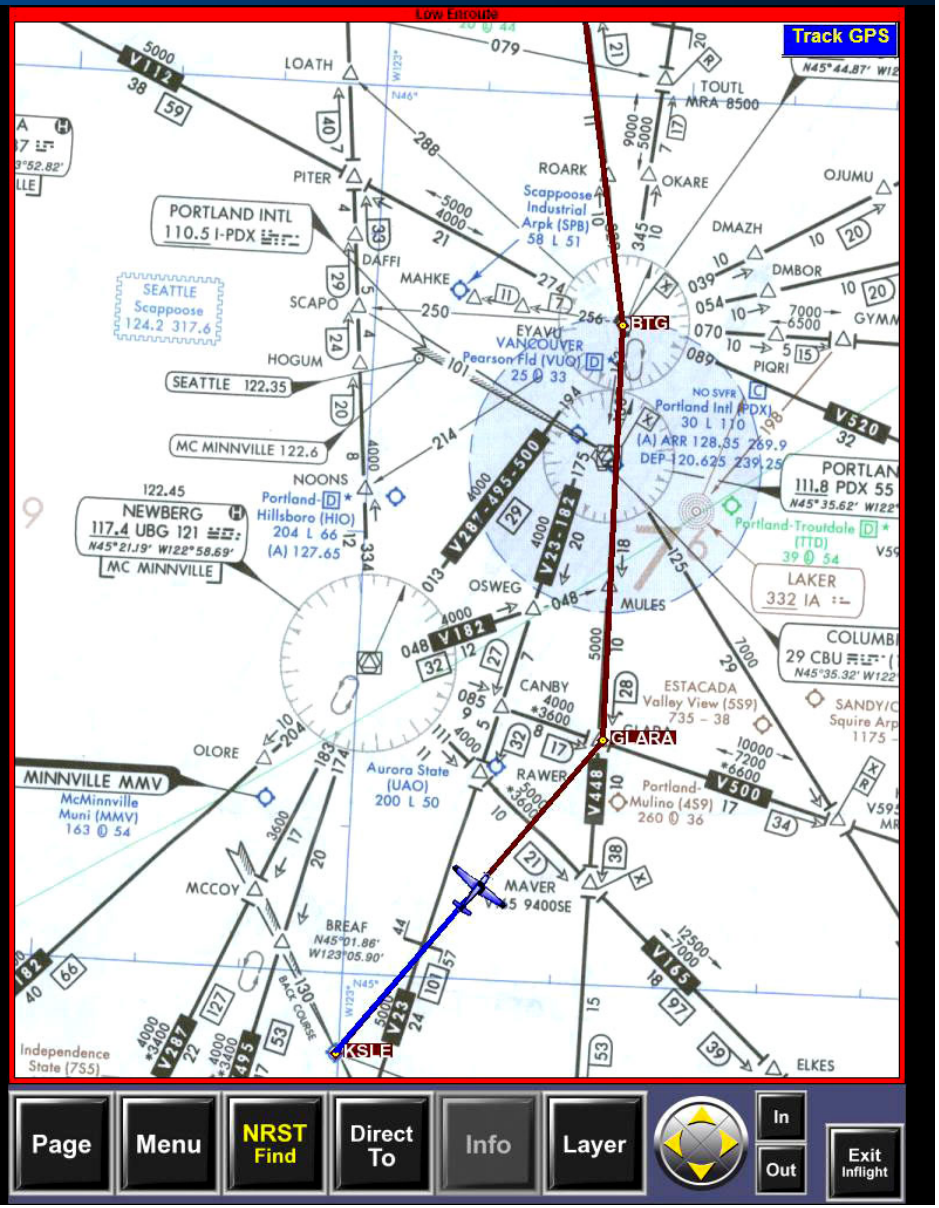
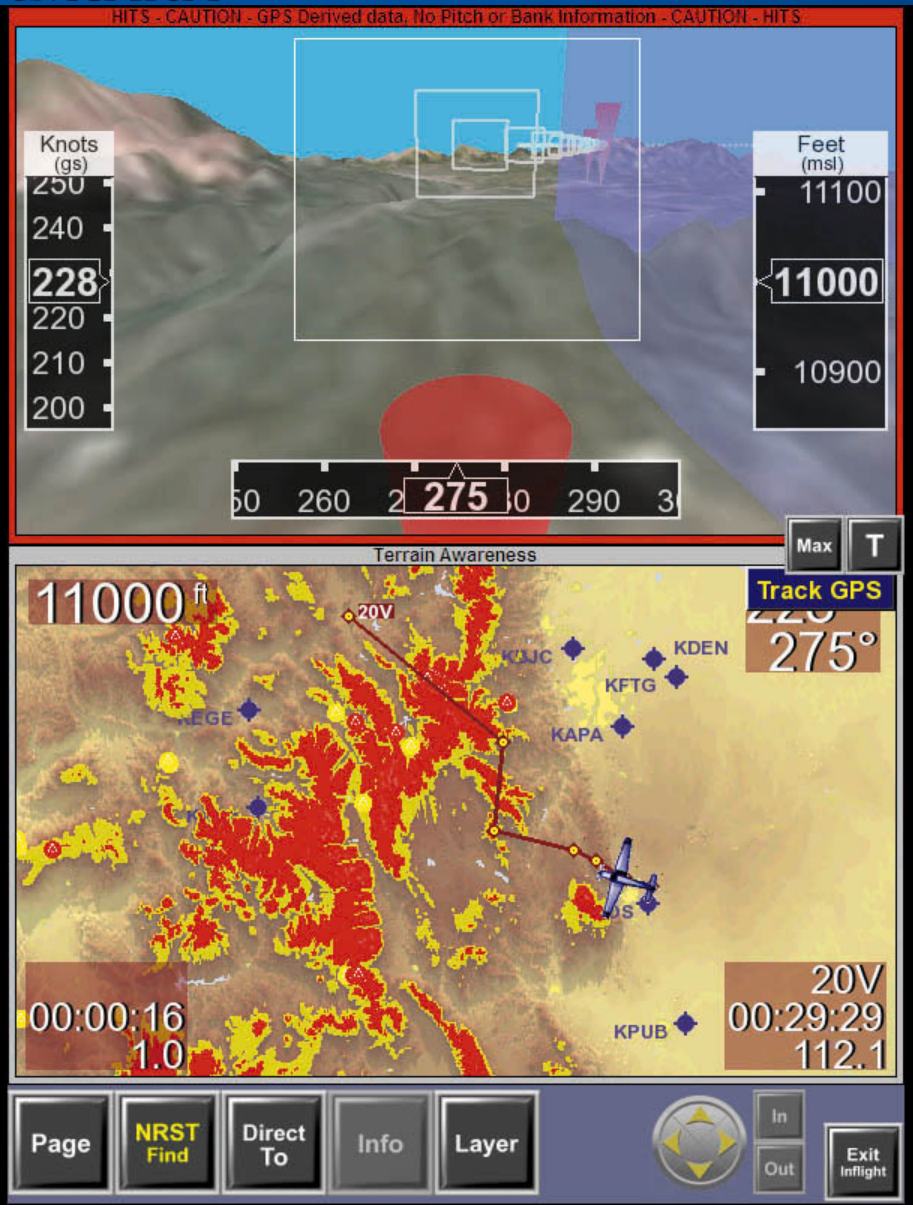
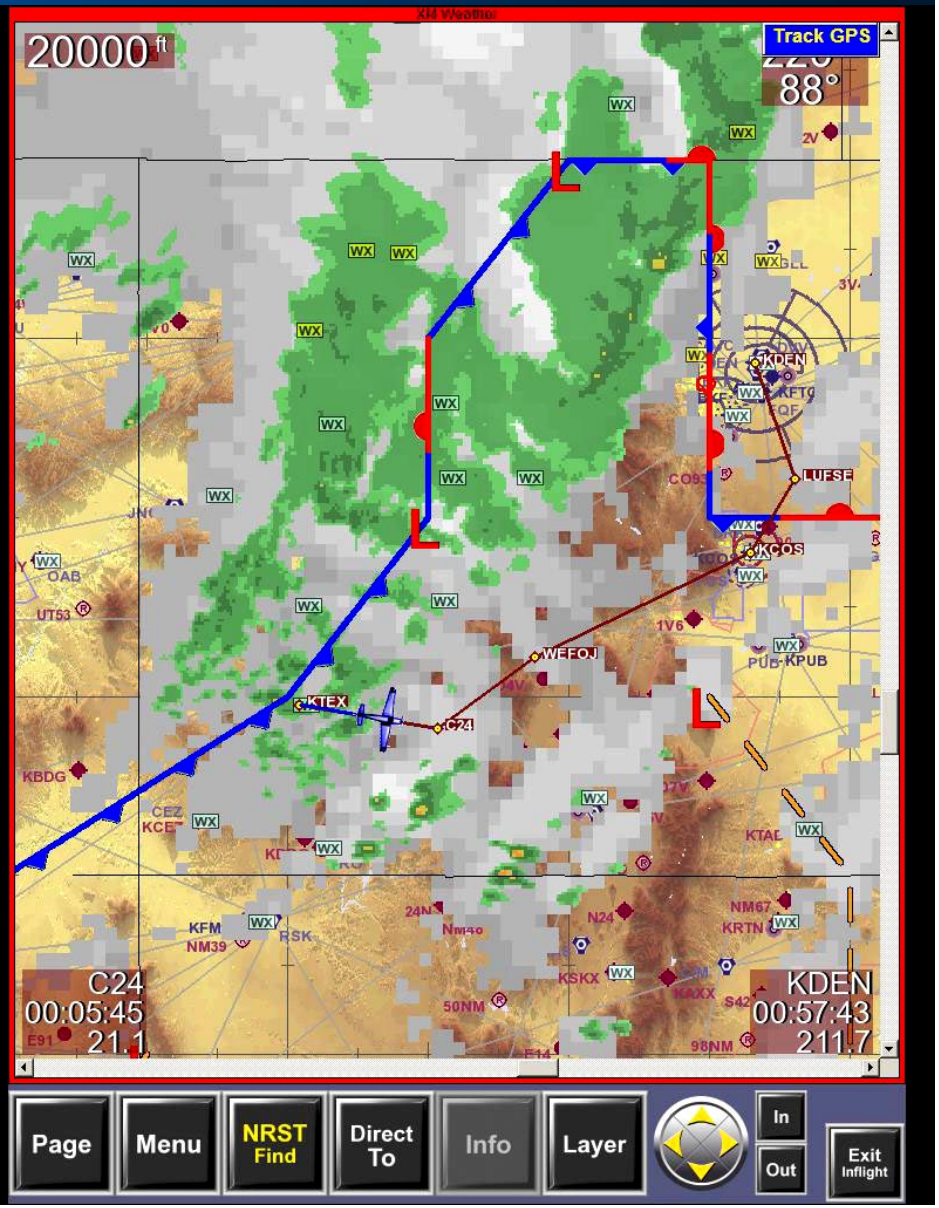


Chart Case Professional

IKHANA





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
    - Application was submitted as a “hub and spoke”
  - 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

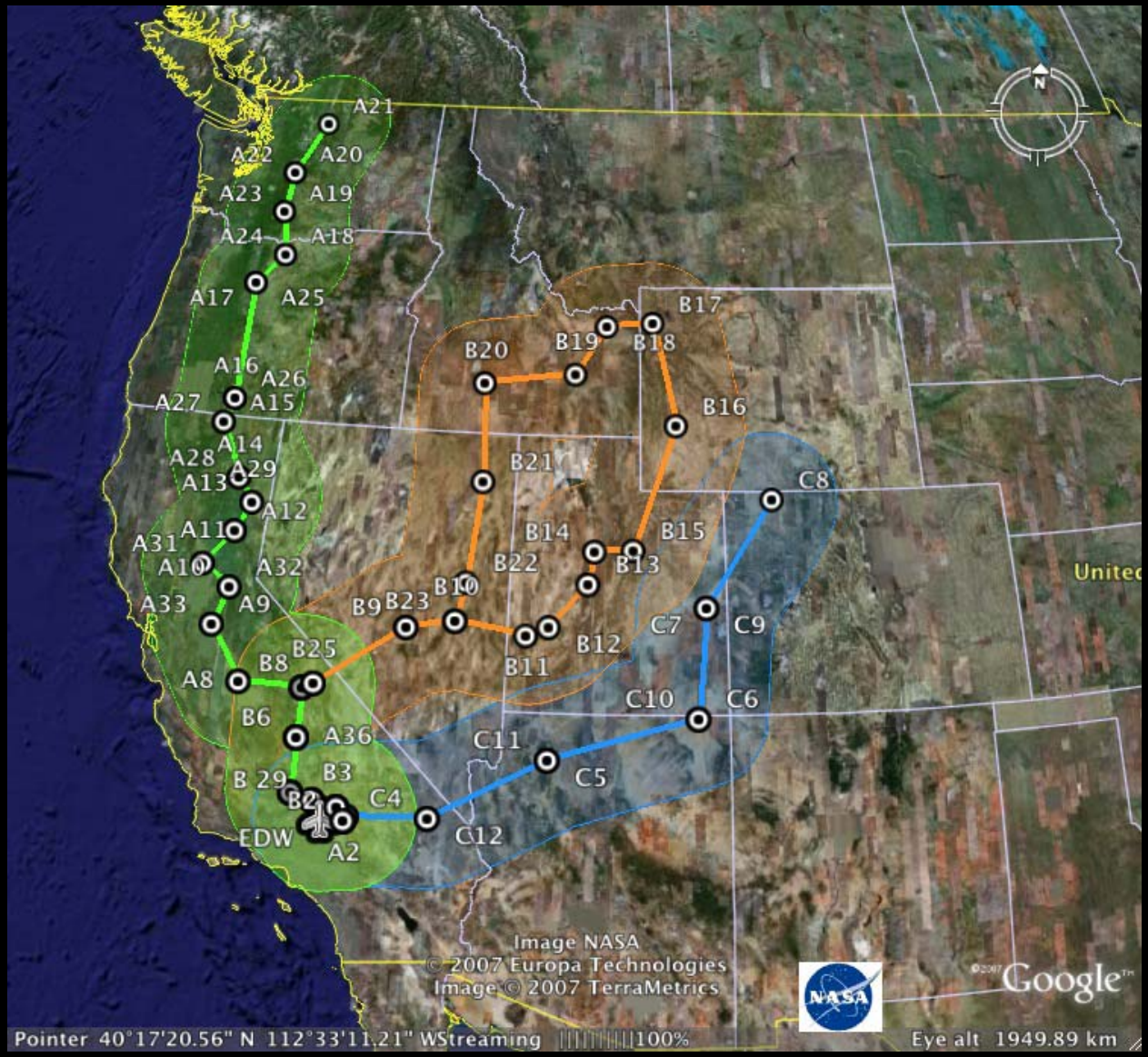
COA: Special Provisions (con't)

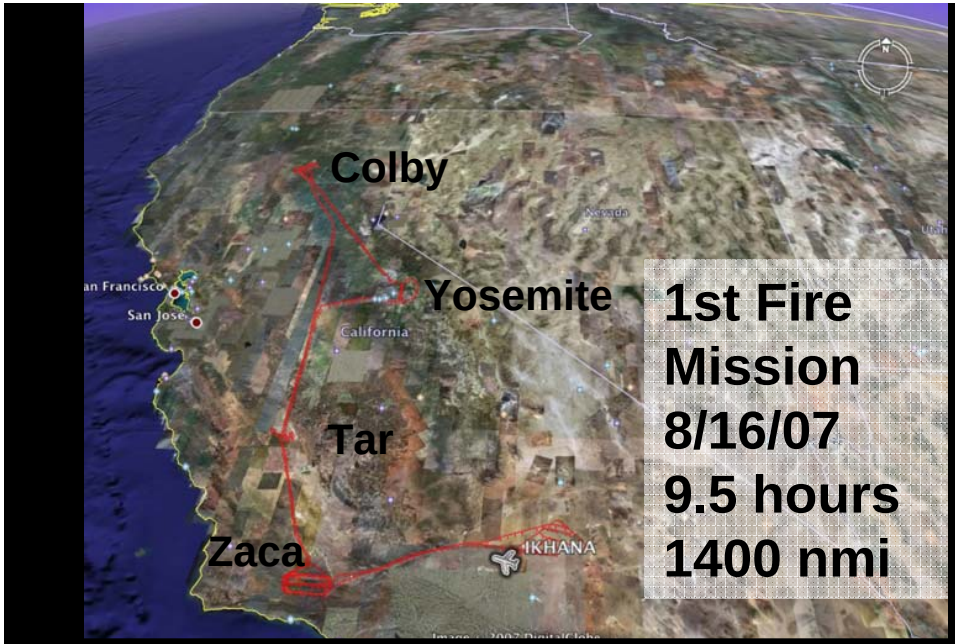
IKHANA

- 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




Colby
Yosemite
Tar
Zaca
IKHANA
San Jose
California
Nevada
Utah
1st Fire
Mission
8/16/07
9.5 hours
1400 nmi

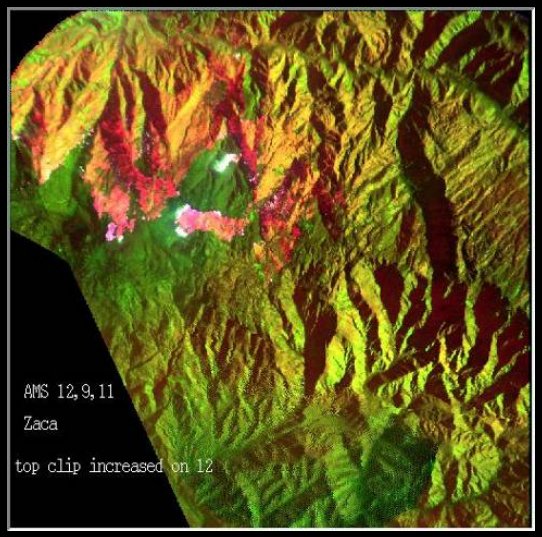

Domke Lake
GW
Big Bend
Oregon
Wyoming
Moonlight
Nevada
Lick
Middle T
San Jose
California
Grouse
Zaca
IKHANA
North
Fairmont
Arizona
Los Angeles
3rd Fire
Mission
9/7/07
20 hours
3200 nmi

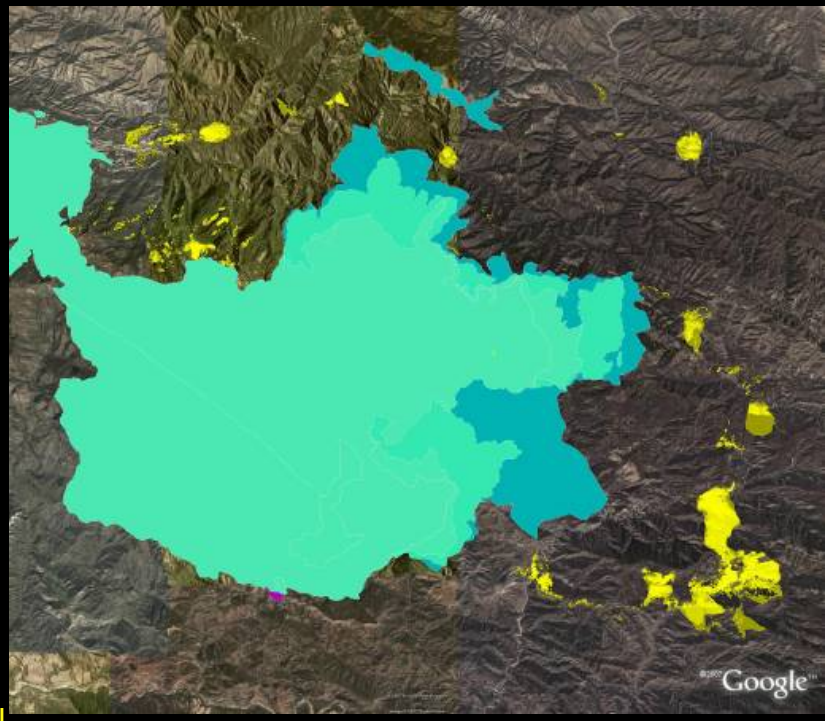

Castle Rock
WH Complex
Idaho
Oregon
Trapper Ridge
Columbine
Nevada
Utah
California
IKHANA
2nd Fire
Mission
8/29/07
16.1 hours
2500 nmi


Moonlight
Lick
California
Grouse
IKHANA
Butler
4th Fire
Mission
9/27/07
10 hours
1800 nmi

WSFM #1 - Zaca Fire

IKHANA



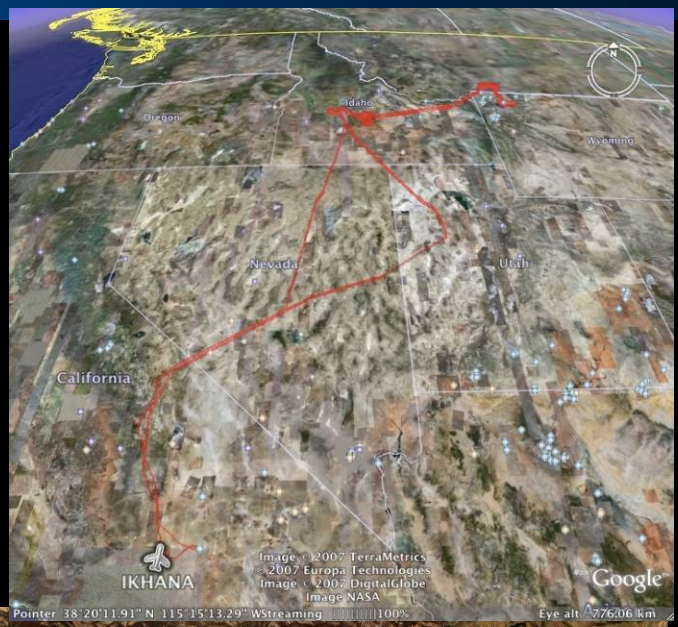


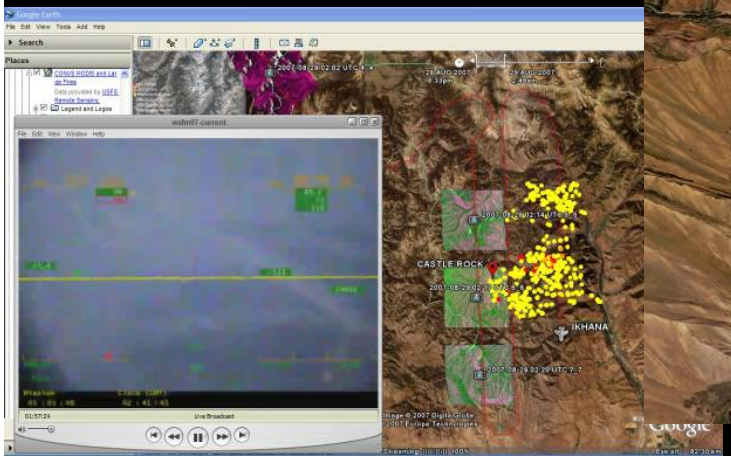
- Delivered real-time data to Incident Command on Zaca; well received, clamored for more data
- Director, Fire and Aviation Management, USFS, R5: "I was standing in Area Command for the Zaca incident on the morning of the first flight. Our conversation surrounded the "fog of war" existing due to an inversion 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. I look forward to the eventual inclusion of this technology and platform as a standard component of our arsenal. The reduction in cost, exposure to air crews currently flying infrared sorties, and the real time and extended nature of the intel provided are all advantageous to our mission. Thank you and all those with the foresight before who saw the potential and reached out in cooperation to make it a reality."

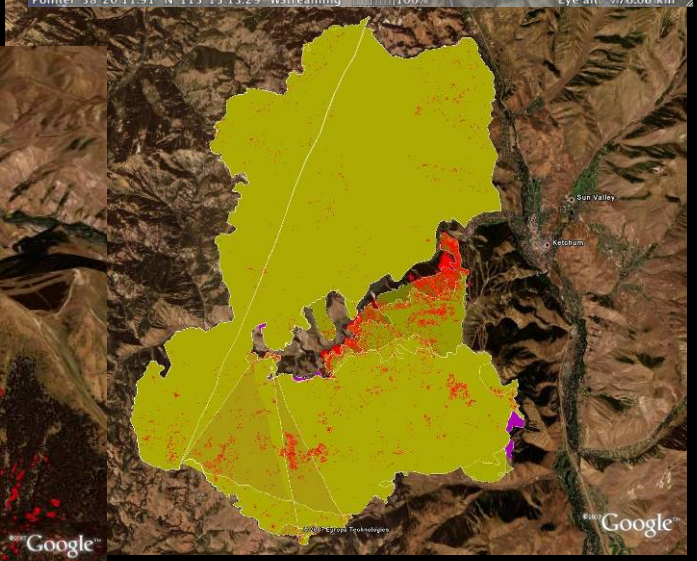
WSFM #2 - Aug 29-30, 2007

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 real-time data to Incident Command on Castle Rock; used for operations and redeployment of resources on the fire based on our 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 FAA.



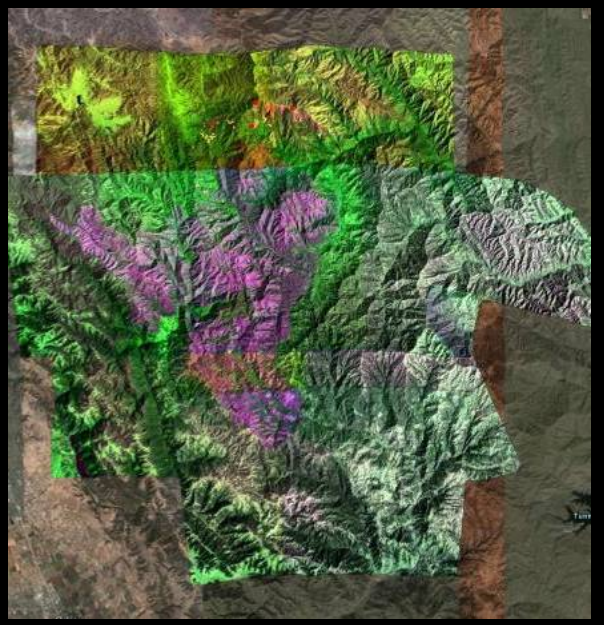


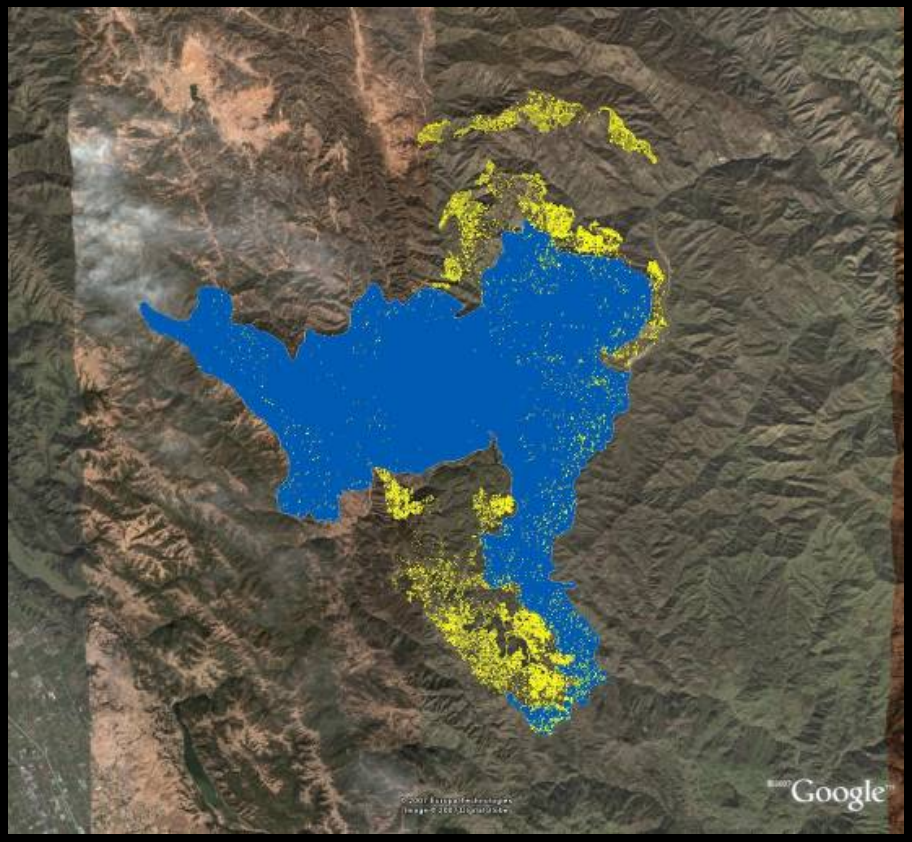


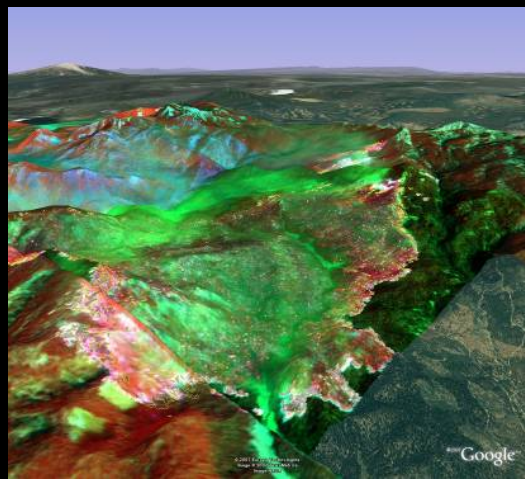
WSFM #3 - September 7-8, 2007

IKHANA

- Collected and transmitted 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)



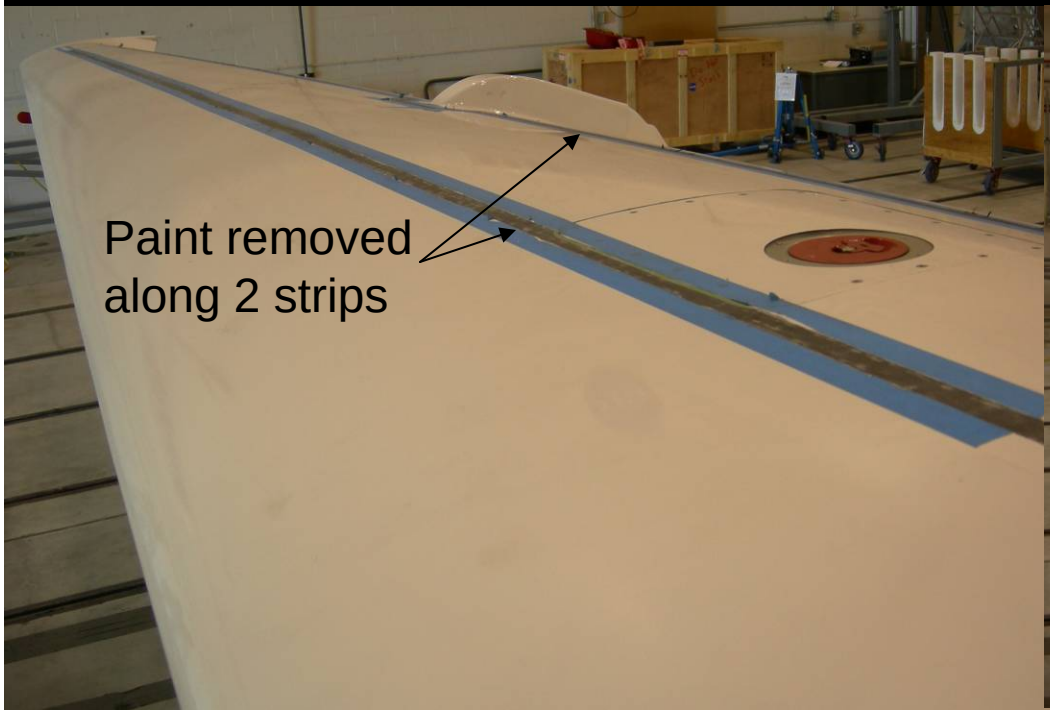


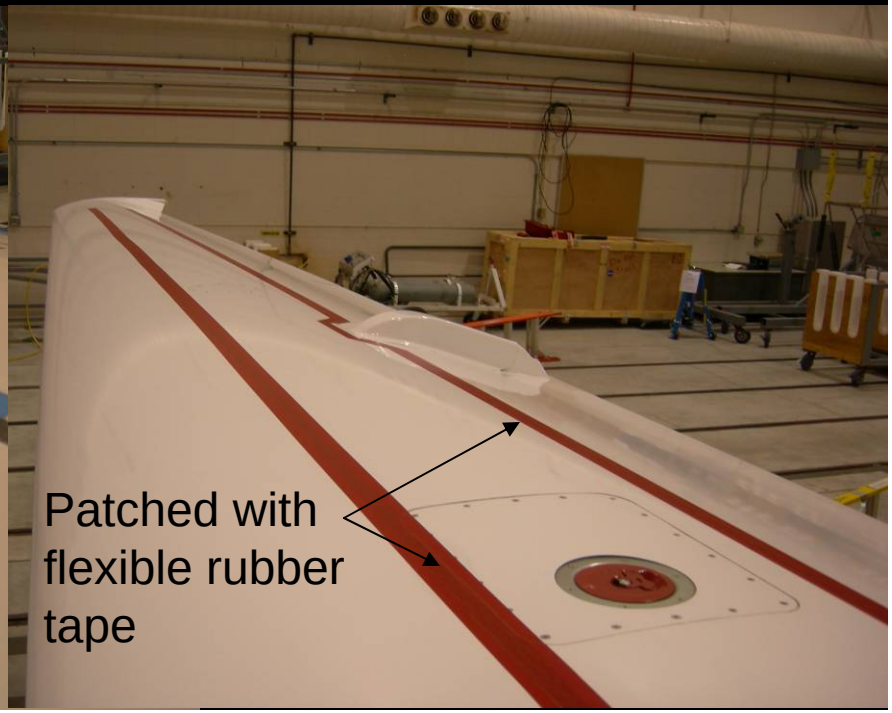


California Emergency Wildfire Response

IKHANA

- Oct 20-21: High winds (>50 MPH) drive wildfires in 4 southern California counties
- Oct 22nd: Ikhana team began preparation for a possible fire mission
- Two impediments to launching a mission
  - Failed hard drive in the wildfire sensor
  - Ikhana wings being modified for fiber-optic wing sensor demonstration
    - Tiger team assembled to assess airworthiness





California Emergency Wildfire Response

IKHANA

Oct 22nd - Monday

- Ikhana Project team contacted by California Office of Emergency Services requesting imagery of Southern California wildfires
  - Kim Zagaris, Chief Fire and Rescue Branch
  - 500,000 people evacuated
  - More than 11 fires burning
- Planning telecons held with NASA teams and USFS
- FAA notified
- Range safety office began reviewing population centers around fire areas
- NASA Ames and USFS teams deploy to Southern California
- Wing repair completed

Oct 23rd - Tuesday

- Sensor hard drive repaired and verified
- FAA extended 75 nm COA limit to the south
  - Could not extend COA to within 10 nm of Mexican border (Harris fire)
- Mission plan submitted to FAA
- Tech Brief of mission plan delivered to NASA Dryden Management

Oct 24th - Wednesday

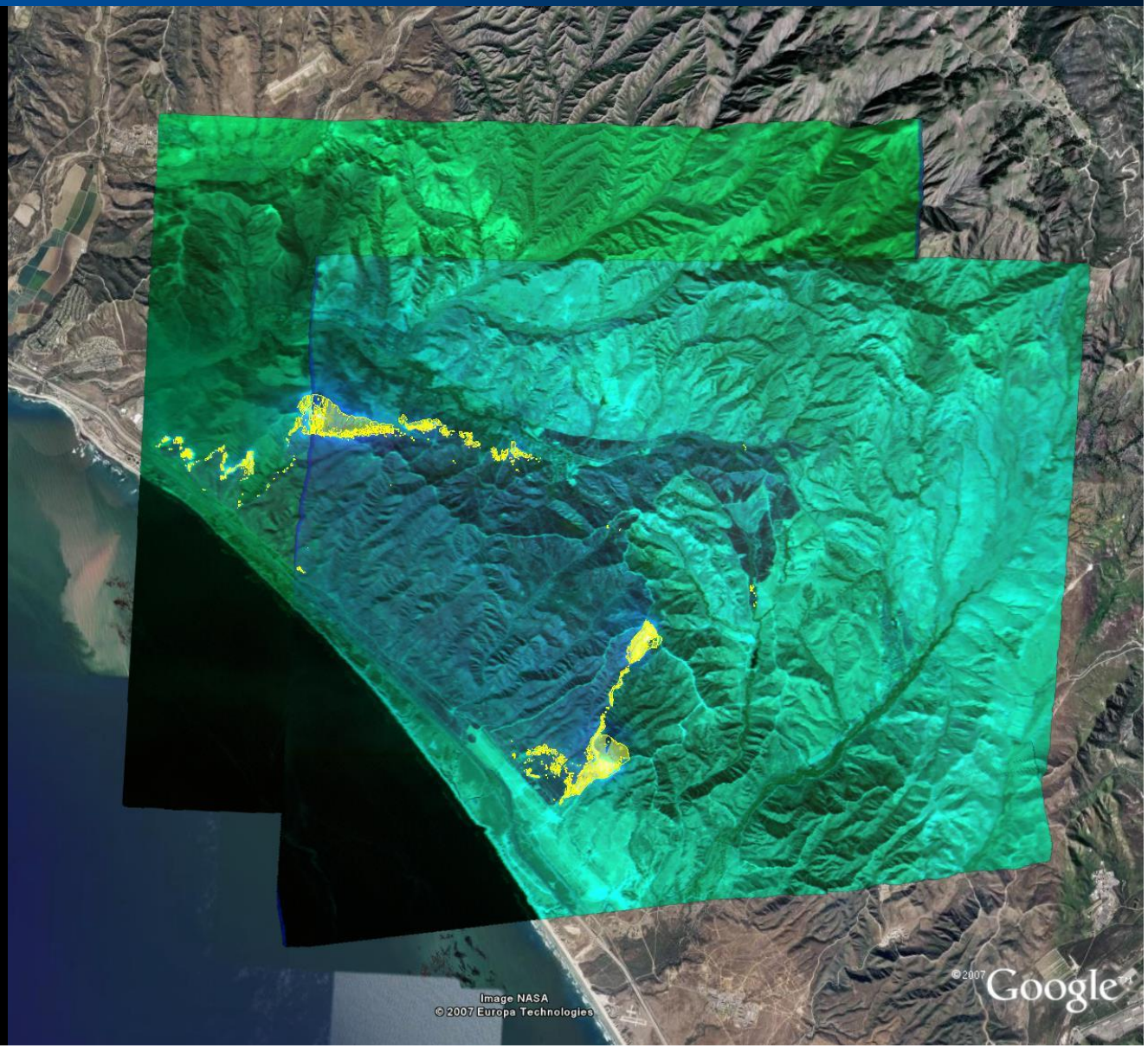
- Launched 1st emergency response mission @ 9am


Edwards AFB
IKHANA
~1350 nmi route
~9 hours
Ranch, Buckweed
Grass Valley, Slide
Los Angeles
Anacapa Island
Riverside
Anaheim
Santa Ana
Long Beach
Santiago
Santa Catalina Island
Nicolas Island
Rice
Ammo
Poomacha
Witch
San Clemente Island
Harris
Image NASA San Diego
© 2007 Europa Technologies
Image © 2007 DigitalGlobe
Pointer 33°51'09.31" N 117°19'07.50" Welev 664 m
Streaming 100%
Eye alt 374.54

WSFM #5 - Ammo Fire, Oct 24th

IKHANA

Hot spots in yellow

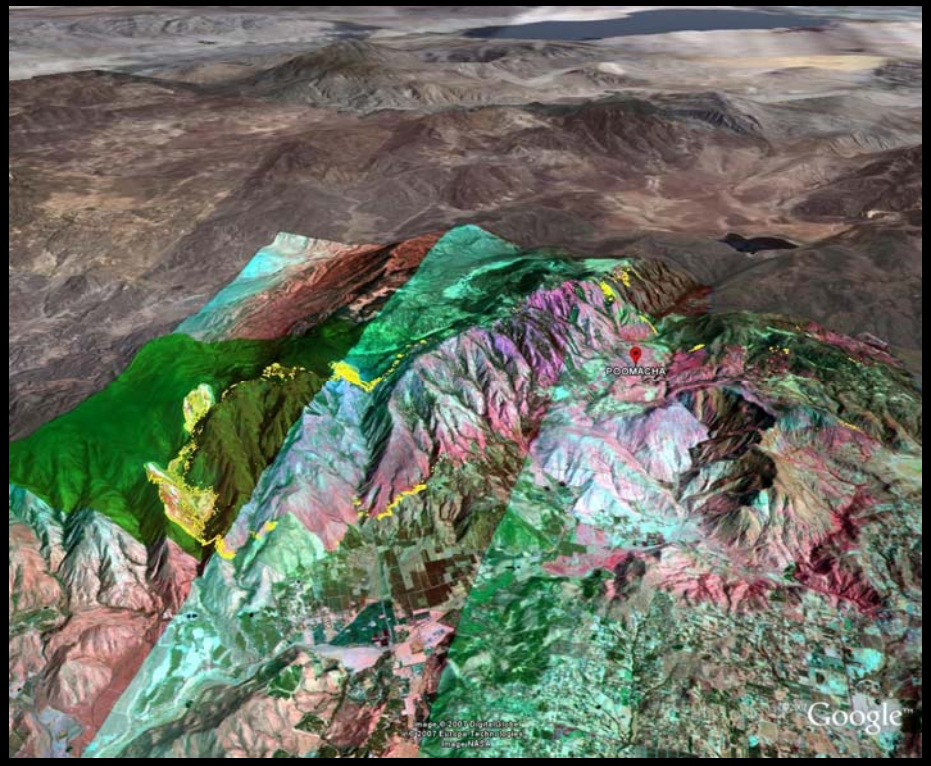


WSFM #6 - Oct. 25th

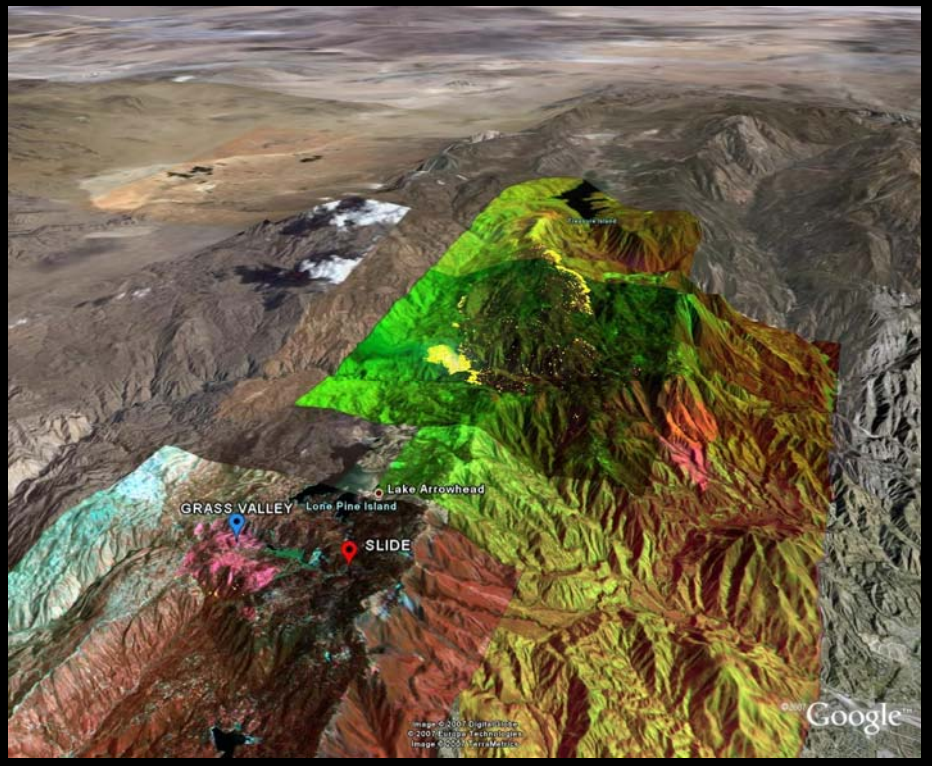
IKHANA

Hot spots in yellow

Poomacha / Rice Fires – 3D with Hot Detects



Grass Valley / Slide Fires - 3D with Hot Detects



WSFM #7 - Oct. 26th

IKHANA

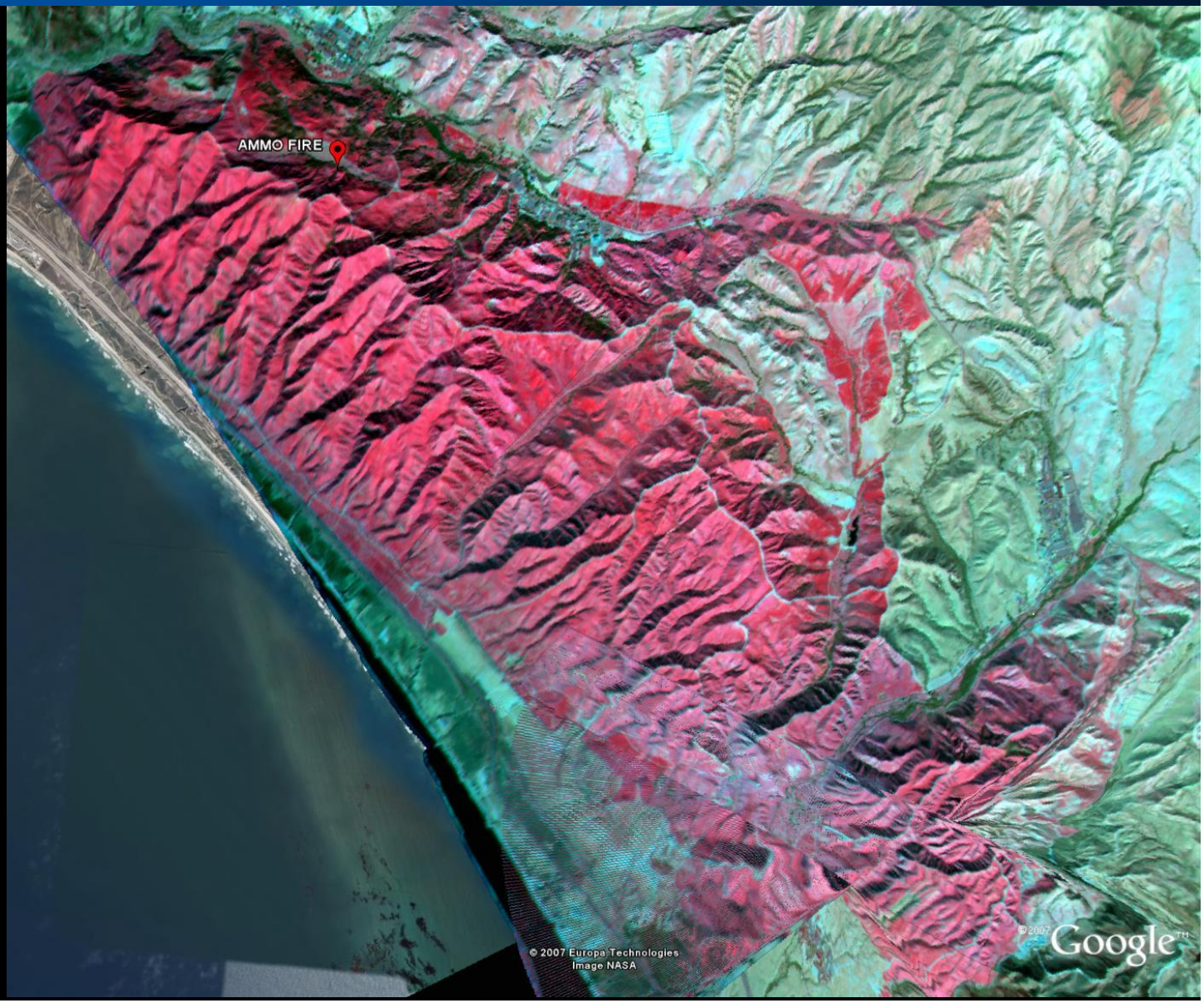
Hot spots in yellow

Santiago Fire –
3D with Hot Detects

WSFM #8 - Ammo Burn Area, Oct. 28th

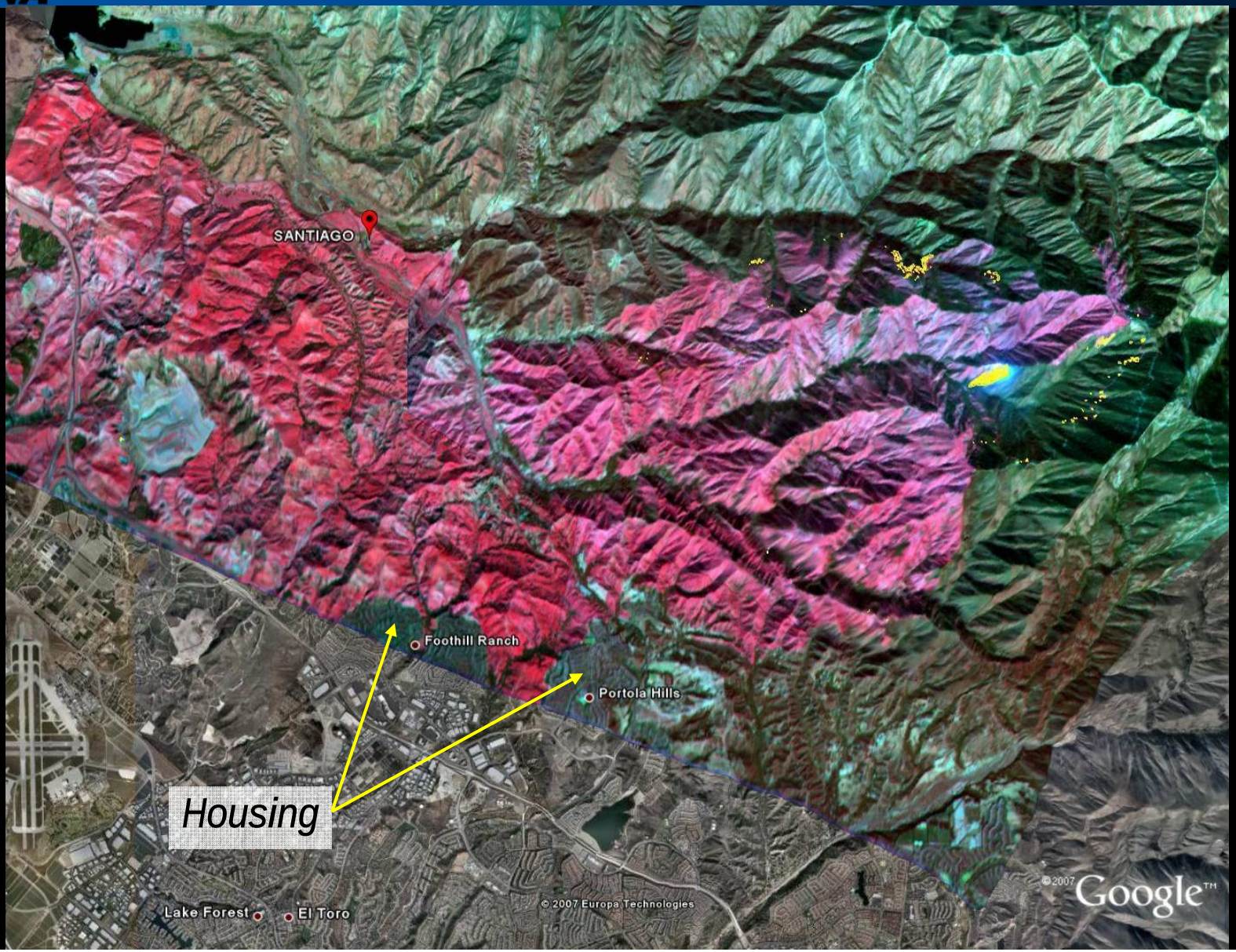
IKHANA

Sensor optimized for Burn Area Emergency Response (BAER) imagery



WSFM #8 - Santiago Fire, Oct. 28th

IKHANA



WSFM #4-#8 Southern California Results

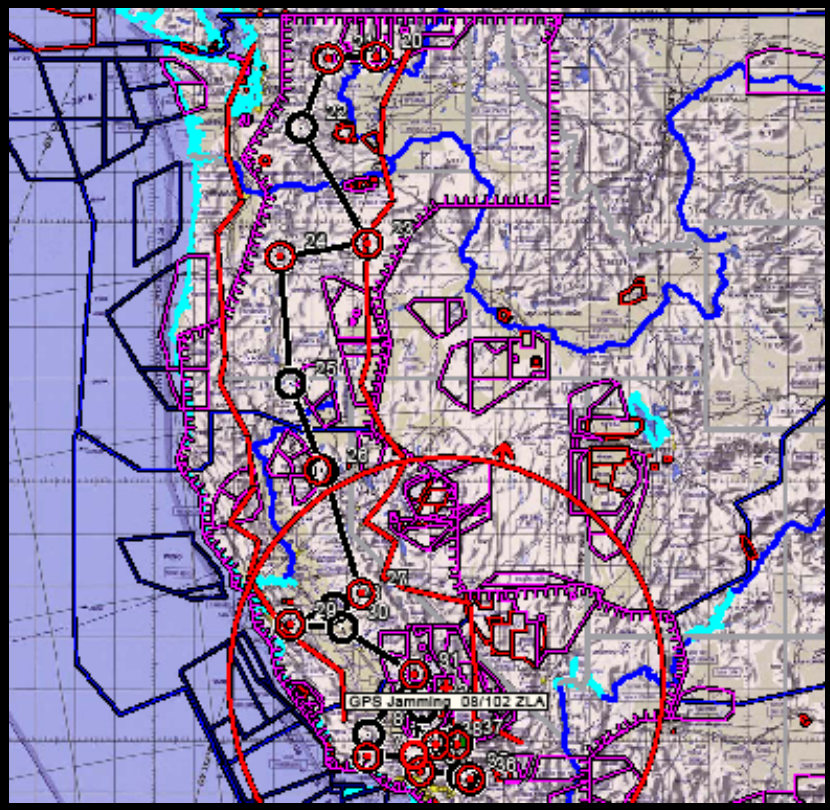
IKHANA

- 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) to:
  - Emergency ops: FEMA, NIFC, NorthCom, California EOC
  - Individual Fire Incident Commands
- 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
  - Nellis Range
  - China Lake
- C-band frequency access
  - Competing with Gray Butte Operations
- Emergency landing site permission
- Weather
  - Wind
  - Clouds
  - Icing
  - Thunderstorms
- Airfield use outside of normal operating hours
- 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
  - Gray Butte for Command/Control frequency flexibility
  - Nellis Range for GPS Testing flexibility
- DFRC Range Safety Office (RSO) - Population Keep-out Zones
- Secondary Emergency Landing Site Selection Team
  - Project mgmt, RSO, Pilots, Operations
  - Identified, analyzed, categorized, prioritized, and cataloged over 280 sites
- General Atomics


Questions?
IKHANA
NASA
870