Operational Experience with Long Duration Wildfire Mapping UAS Missions over the Western United States

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***Abstract*—The National Aeronautics and Space Administration, United States Forest Service, and National Interagency Fire Center have developed a partnership to develop and demonstrate technology to improve airborne wildfire imaging and data dissemination. In the summer of 2007, a multi-spectral infrared scanner was integrated into NASA's Ikhana Unmanned Aircraft System (UAS) (a General Atomics Predator-B) and launched on four long duration wildfire mapping demonstration missions covering eight western states. Extensive safety analysis, contingency planning, and mission coordination were key to securing an FAA certificate of authorization (COA) to operate in the national airspace. Infrared images were autonomously geo-rectified, transmitted to the ground station by satellite communications, and networked to fire incident commanders within 15 minutes of acquisition. Close coordination with air traffic control ensured a safe operation, and allowed real-time redirection around inclement weather and other minor changes to the flight plan. All objectives of the mission demonstrations were achieved. In late October, wind-driven wildfires erupted in five southern California counties. State and national emergency operations agencies requested Ikhana to help assess and manage the wildfires. Four additional missions were launched over a 5-day period, with near real-time images delivered to multiple emergency operations centers and fire incident commands managing 10 fires.**

***Keywords*—Unmanned aircraft system (UAS), Ikhana, wildfire, FAA, certificate of authorization (COA)**

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NOMENCLATURE

AIRMET	=	airmen's meteorological information
AMS	=	Autonomous Modular Sensor
ARTCC	=	Air Route Traffic Control Center
ATC	=	Air Traffic Control
COA	=	Certificate of Authorization
DFRC	=	Dryden Flight Research Center
DOD	=	Department of Defense
EAFB	=	Edwards Air Force Base
EFB	=	Electronic Flight Bag
ELS	=	Emergency Landing Site
FAA	=	Federal Aviation Administration
FOWSS	=	Fiber Optic Wing Shape Sensing
GA-ASI	=	General Atomics, Aeronautical Systems Inc.
GCS	=	Ground Control System
HALE	=	High Altitude Long Endurance
IFR	=	Instrument Flight Rules
Ku	=	Ku radio band
MQ-9	=	Predator B aircraft type designation
NAS	=	National Airspace System
NASA	=	National Aeronautics and Space Administration
nm	=	nautical miles
NOTAM	=	notices to airman
RSO	=	Range Safety Office
RVSM	=	Reduced Vertical Separation Minimum
SIGMET	=	significant meteorological information
UAPO	=	Unmanned Aircraft Program Office
UAS	=	Unmanned Aircraft System
UAV	=	Unmanned Aerial Vehicle
WRAP	=	Wildfire Research and Applications Partnership
WSFM	=	Western States Fire Mission

I. INTRODUCTION

CONDUCTING flights of unmanned aircraft systems (UAS) in the national airspace system (NAS) presents a set of unique challenges that are not common to operations with manned aircraft systems. Specifically:

1. UAS are generally designed for military applications in military theaters and not for civilian missions in civilian airspace.
2. The Federal Aviation Administration (FAA) requires the UAS operation to be approved on a case-by-case basis through a Certificate of Authorization (COA).
3. There is not an approved system that can be employed on a UAS to provide equivalent see-and-avoid capability to manned aircraft for collision avoidance.
4. Emergency procedures are complicated by not having a pilot on board the aircraft.

5. UAS flights in the NAS are uncommon and civilian Air Traffic Control (ATC) organizations are generally unfamiliar with UAS operations and procedures.
6. The potential loss of command and control radio link presents a unique emergency condition to UAS operators and ATC.

In the summer of 2007, the National Aeronautics and Space Administration (NASA) and its partners[5] conducted multiple high altitude, long endurance (HALE) UAS flights in the NAS to develop and demonstrate technology to improve airborne wildfire imaging and data dissemination.

Flights were conducted in close coordination with the FAA Unmanned Aircraft Program Office (UAPO), FAA Service Areas, and FAA Air Route Traffic Control Centers (ARTCC). This paper describes the operational challenges that were present in conducting UAS flights for the Western States Fire Mission Program and how they were overcome.

II. NASA IKHANA UNMANNED AIRCRAFT SYSTEM

Ikhana (ee-kah-nah) is a Native American Choctaw word meaning intelligence, conscious or aware. The name is descriptive of the research goals NASA has established for the aircraft and its related systems. The Ikhana UAS consists of the Ikhana aircraft, a Ground Control Station (GCS), ground support equipment, and ground communications systems.

The Ikhana aircraft is a Predator B (MQ-9) Unmanned Aerial Vehicle (UAV). It is remotely controlled by a pilot on the ground seated at a console located in the GCS. A payload operator seated at a control terminal in the GCS can remotely control science payloads carried aloft by Ikhana. The Ikhana UAS home base is Edwards Air Force Base, California (EAFB).

There are two kinds of ground communications to the aircraft: line-of-sight and satellite over-the-horizon systems. A portable ground data terminal provides command and control and payload uplink/downlink when the aircraft is within radio line of sight (approximately 70 nautical miles). The satellite communications system provides the over-the-horizon uplink and downlink to the GCS. Aircraft and telemetry data are downlinked to the GCS for display on the payload operator and user consoles.

Avionics equipment on board Ikhana is similar to that of manned aircraft with the exception that the control of avionics is via the uplink/downlink. The aircraft uses a Mode C transponder, where the squawk codes are sent from the pilot in the GCS. Voice communications are relayed from the GCS to Ikhana via the communications links. When communicating with ATC in the NAS there is no indication to the controller that the pilot is at a remote location. Primary aircraft navigation is via an integrated INS/GPS system and onboard flight computer that follows flight mission plans uploaded from the GCS. An emergency mission plan is also uploaded from the GCS to the flight computer in the event the aircraft loses communication link with the GCS.

[5] United States Forest Service and National Interagency Fire Center.

In order to fly in the NAS above 18,000 ft in Class A airspace, Ikhana must file an Instrument Flight Rules (IFR) flight plan. The standard navigation system on Ikhana does not fall under any of the typical aircraft suffixes for navigation equipment capabilities denoted on the flight plan. The Ikhana GCS features a moving map display that shows the aircraft position, terrain, and aviation features; however, it does not display current navigation information required for IFR flight such as airways and selectable aids to navigation.

A commercial, off-the-shelf Electronic Flight Bag (EFB) software product was installed in the GCS to display the aircraft position on current electronic charts (on the standard 28–day cycle). This enabled Ikhana to file IFR flight plans with an area navigation suffix (/I). Additionally, the EFB software was able to display weather imagery. Figure 1 shows Ikhana modified for the Western States Fire Mission. The under-wing pod was designed specifically for the mission, but is also reconfigurable for other payloads.

Figure 1. NASA Ikhana cruising over the Mojave Desert with sensor pod.[6]

III. WESTERN STATES FIRE MISSION

In 2003 the Wildfire Research and Applications Partnership (WRAP) project was funded by NASA. The objectives of the 5-year WRAP project were to foster collaborative partnerships between NASA and the US Forest Service to facilitate and demonstrate evolved and evolving technologies for increasing the information content and timeliness of earth resource data collected for wildfires.[7] These objectives were demonstrated in the Western States Fire Mission (WSFM).

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[6] NASA Photo: ED07-0186-04.
[7] Source: http://geo.arc.nasa.gov/sge/WRAP/ .

The goal of the WSFM is to demonstrate the use of long duration UAS flights to collect infrared imagery of wildfires in the western United States and to disseminate that data to users on the ground in near real time. The geographical region of interest is the western United States, west of the Rocky Mountains between the Mexican and Canadian boarders. Objectives for the WSFM include scientific and operational elements. The NASA Ames Research Center and the US Forest Service addressed the scientific goals and NASA Dryden Flight Research Center (DFRC) addressed the operational goals that are the focus of this paper.

Operational Objectives for WSFM:

1. Capability to conduct long duration missions greater than 20 hours over multiple fires (more than four fires per mission) throughout the Western United States.
2. Ability of NASA Ames Autonomous Modular Sensor to collect, process, and deliver fire imagery to fire personnel and incident commanders in near real time (within 10 minutes).
3. Demonstrate that a UAS can be safely operated in the NAS using the "file and fly" procedures of manned aircraft. "File and fly" abilities of manned aircraft are:
    a. Ability to fly anywhere in the NAS (outside of special use airspace).
    b. Ability to file an IFR flight plan less than two hours before a flight.

NASA Ames developed the primary sensor for the Western States Fire Mission, the Autonomous Modular Sensor (AMS). The sensor features the ability to scan using 12 spectral bands (infrared and visual) using an embedded precision navigation system that processes and geo-rectifies the image data for transmission to the GCS in real time. The sensor system is housed in a wing-mounted pod and the data telemetry link is through the aircraft Ku-band satellite communications link. The downlinked data is processed by scientific personnel in the GCS and distributed via a network server where the data can be called up by remote users using the freely available Google Earth® program.

In 2006 the General Atomics, Aeronautical Systems Inc. (GA-ASI) Altair® UAS was leased to NASA to conduct flight missions to support the Western States Fire Mission. GA-ASI operated the aircraft and NASA DFRC was responsible for mission planning and obtaining FAA approval of the flights in the NAS. NASA sought FAA approval through a case-by-case review process which resulted in NASA receiving a Certificate of Authorization (COA) that permitted the specific flight operation requested.

A COA was received in October of that year that enabled Altair® to fly for 21 hours over a fire in Yosemite National Park referred to as the Yosemite fire. Later that month the Altair® flew a 16-hour mission over the lethal Esperanza fire in Southern California. An emergency COA extension to the previously-approved COA was requested and received from the FAA in a short time period for this flight.

A follow-on series of Western States Fire Mission flights were conducted using the Ikhana aircraft in 2007 and are the subject of the remainder of this paper.

IV. MISSION PLANNING AND COORDINATION

The 2007 WFSM with Ikhana was built on the experiences of the 2006 Altair® missions. The Ikhana procurement by NASA DFRC was completed in November of 2006. A significant number of critical milestones were completed before Ikhana was mission-ready for the WSFM in August of 2007. These training, engineering, and operational milestones included:

- NASA DFRC personnel training (pilots, crewmembers, and technicians)
- GCS integration and testing
- Aircraft modifications to integrate the WSFM payload
- Pylon/pod integration and testing
- NASA DFRC flight readiness review
- FAA flight approval process (COA)

Approval for flight from an internal NASA DFRC safety review board and the FAA UAPO would be two significant operational hurdles. Both of these reviews required detailed descriptions of mission plans, procedures, and contingencies. The NASA DFRC safety review process also included all engineering and training issues.

The application for the WSFM COA was through the FAA UAPO COA Online website. The WSFM was considered by the FAA to be one of the most complex UAS missions in the NAS to date due to the large geographical area and flight schedule flexibility being requested. Planning flight tracks is difficult to do more than several days in advance due to the unpredictable nature of wildfires. Because of the complex nature of the missions and the aircraft, numerous informal meetings between FAA and NASA DFRC were conducted to determine what was reasonable to request in the COA application. The WSFM COA was submitted in February 2007, to give the FAA ample time to review all the details ahead of the proposed August flight missions.

A. *COA Application Components*

1) Geographical Region Requested

Conducting a mission of this magnitude and complexity required coordination with multiple Air Route Traffic Control Centers (ARTCCs). The area of interest was divided into three zones. Each zone contains no more than three ARTCCs. For a specific mission, only one zone would be considered, which would mean that no more than three ARTCCs would be impacted by a mission. This reduced the number of individual people needed in coordinating a single flight. Figure 2 shows zones that were requested in the COA application for the WSFM.

Ikhana is restricted from flight over densely populated areas by the both NASA safety policy and the FAA UAPO. NASA DFRC Range Safety Office (RSO) routinely conducts detailed safety risk analysis of all proposed missions from DFRC. The RSO determined that Ikhana would not fly over densely populated areas. The NASA safety keep-out zones are shown in red in Fig. 3. It is permissible for Ikhana to fly over the less densely populated

yellow areas when all aircraft systems are functioning nominally and the aircraft is in direct control of the pilot in GCS. If the aircraft loses its communication link with the GCS, it may not fly over red or yellow keep-out zones. This is discussed in greater detail in section B.1.

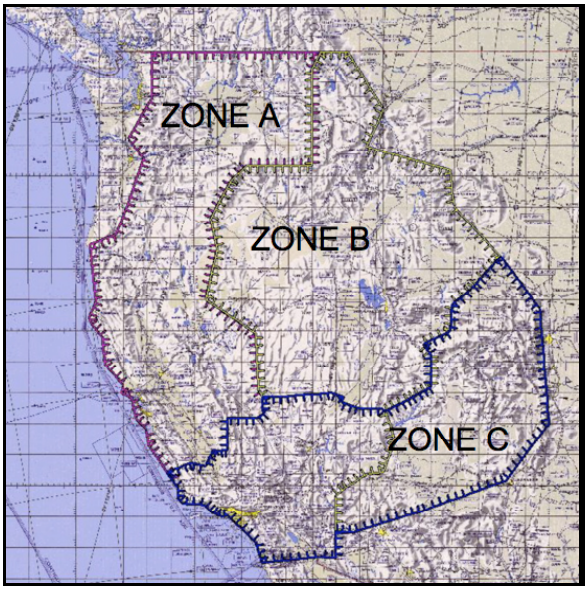

Figure 2. Geographical zones designated for the WSFM.

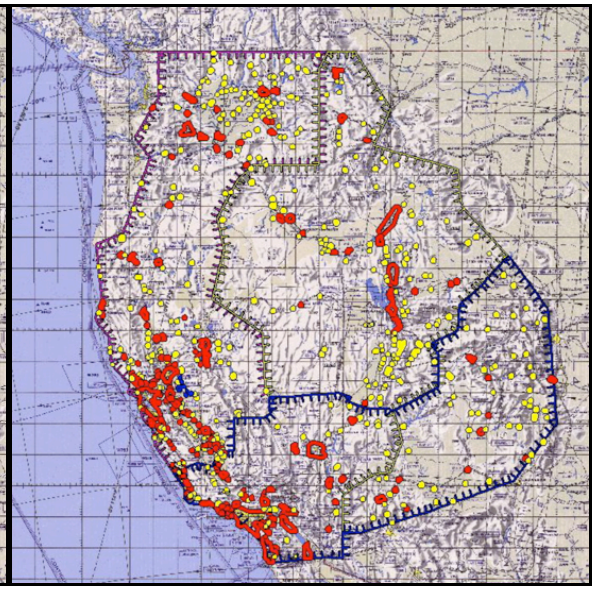

Figure 3. NASA safety keep-out zones.

Flight tracks were originally developed for each zone (A-B-C) that would allow the aircraft to avoid all red and yellow keep-out zones. Initial discussions with the FAA indicated that the best way to plan a flight track was to determine a "backbone" flight track. The "backbone" would have small "spoke" segments added later to enable the aircraft to fly to the fire area for interest. In April, a two-day meeting between NASA and FAA representatives (including air traffic control) was conducted to coordinate the WSFM flights. During that meeting, it was determined that the best way to plan a flight track was to determine the fires of interest three days before flight and plan to fly from fire to fire (or point to point navigation). The "backbone" routes were an artifact of the old thought process for mission planning but were used as a frame of reference for the COA, as will be discussed in the "Mission Results" section below.

2) Altitude

The flight plan altitude was determined by aircraft performance and airspace constraints. The desired altitude based on aircraft performance would have been in the 35,000- to 40,000-foot range. This would also be an attractive altitude for avoiding bad weather during the summer months. At that time, Ikhana was not certificated to fly in a band of altitudes from 29,000 ft to 41,000 ft known as Reduced Vertical Separation Minimum (RVSM). Because of this, it was determined that Ikhana would file for flight at 23,000 ft.

A requirement for flight in the NAS is an equivalent "see-and-avoid" capability to manned aircraft. This was achieved with the WSFM by conducting all flights in positive controlled airspace (Class "A") under IFR. Ikhana does have a limited capability to look for other air traffic through optical means, however, the air traffic controller would provide the primary separation between Ikhana and other aircraft. To transition to class "A" airspace, which begins at flight level 180 (18,000 ft MSL pressure altitude), Ikhana conducted initial climb and final descent in Edwards Air Force Base (AFB) restricted airspace.

3) Flight Plans

The FAA required 72 hours notice before a flight to allow time for dissemination to all concerned ARTCCs and to brief Air Traffic Control (ATC) employees scheduled for duty during Ikhana's flight. This required the scientific and operational staff to put together a specific flight plan three days before flight. The flight plan contained waypoints for each fire of interest and the track-lines were designed to avoid the previously mentioned populated area 'keep-out' zones. The flight mission planning process began on Sunday afternoon so that the flight mission plan could be submitted to the FAA on Monday to allow for a Thursday takeoff. This also allowed for the flight to slip a day to Friday if unforeseen events occurred. Thus a practical limitation of no more than one flight per week was created.

B. *Aircraft Emergency Procedures*

Emergency procedures for UAS are particularly more complex when operating in the NAS. There exists the potential to cause harm to persons and property in the air and on the ground. A great deal of effort was made by the Ikhana team to reduce those hazards to an acceptable level. Characteristics of Ikhana, such as the remote aircraft control and systems monitoring, create situations that are not common to manned aircraft.

Alternatives and contingencies must be planned for each location along the flight track. The pilot's visual awareness of the terrain below the aircraft is very limited by the camera system provided on the aircraft. Due to this lack of real-time situational awareness, emergency landing sites were identified prior to conducting the mission.

1) Lost Link

Mission plans with altitude and waypoint information were sent to the aircraft from the GCS. Pilots would transmit both a normal mission plan and a lost-link mission plan. In the event that Ikhana loses its command-and-control link with the GCS, the lost-link mission plan that has already been loaded into the flight computer's memory is executed. The lost link mission plan was programmed to avoid over-flying both the red and yellow (less-densely populated) areas to reduce risk to the public.

It was very important that ATC know in advance what the aircraft would do in this situation to avoid conflicts with other aircraft. The lost-link mission plan was continually updated by the pilot during the flight. In the event of lost link, the aircraft would have continued on its current flight path or (if over a wildfire) loitered for 15 minutes. Next the

aircraft would return to Edwards AFB along the flight path via the shortest distance (make a right 180° turn if flying outbound or continue if on the return leg).

2) Electrical Failure Emergency

In the event of failure of the aircraft's electrical system to generate power from the engine, the aircraft draws power from batteries. The Ikhana battery configuration for these missions had enough capacity to last for approximately three hours, which translates to roughly 400 nautical miles (nm), assuming a reasonable amount of time for descent and maneuvering at the landing site. If Ikhana is greater than 400 nm from Edwards AFB when this emergency occurs, an alternate emergency landing site (ELS) is required. Agreements were made with Mountain Home AFB and Michael Army Airfield to enable Ikhana to land under these conditions. Figure 4 shows that the entire COA region is within 400 nm of an ELS (designated as *Primary Emergency Landing Sites*). In the agreements, the specific risks and hazards in landing Ikhana under satellite control were addressed and ground procedures to be followed in the event of an emergency landing were provided.

3) Engine Failure

In the event of a loss of thrust due to an engine or propeller malfunction, an emergency landing site is required within glide distance of the aircraft. At a cruise altitude of 23,000 ft, the aircraft can conservatively glide for 50 nm. Predefined ELSs, spaced no greater than 100 nm from each other throughout the entire COA area, were required. These emergency landing sites were designated *Secondary Emergency Landing Sites.* Direction from the FAA was that these secondary ELSs could not be active civil or joint-use airports, and NASA DFRC stipulated that no military airports could be considered unless prior coordination had been completed.

A team was assembled to search the western United States for dry lake beds, abandoned runways, and farm fields that would be suitable landing sites away from populated areas. Suitability was rated by the pilots and the RSO on a scale of 1 to 4, with 1 being an ideal location for an emergency landing and 4 being a location that was only suitable for a crash landing that would not endanger the public.

The result of this analysis was a database of over 280 emergency landing sites that contained valuable data on the site condition and satellite imagery collected from Google Earth® showing what an actual approach might look like. During each mission, this data was reduced to a subset of appropriate ELSs to the route and kept in a binder that was opened to the active secondary ELS. Situational awareness of the active ELS was maintained in real time by the Mission Director in the GCS. Figure 5 shows the secondary ELS range rings depicted on the COA region. During actual flight, zooming in on this map shows more detail than what is shown here.

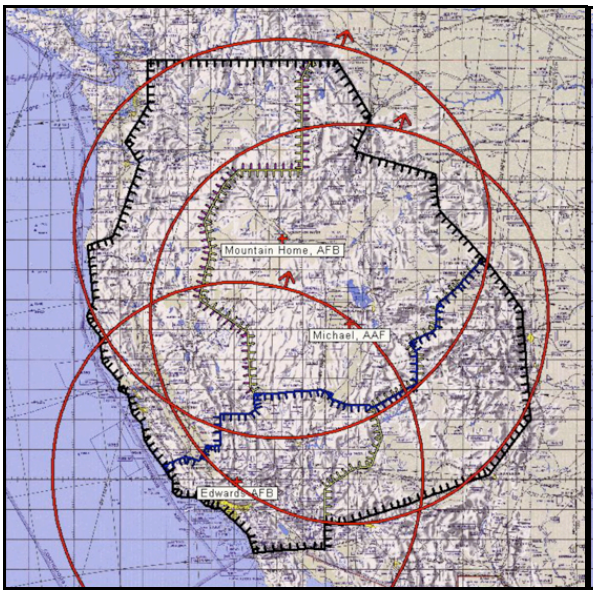

Figure 4. Primary ELSs.

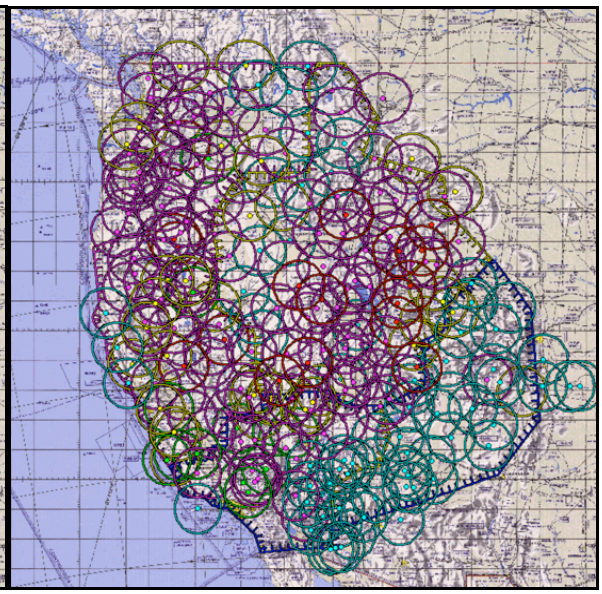

Figure 5. Secondary ELSs.

V. MISSION RESULTS

In late July, NASA DFRC received an approved COA for the WSFM flights. Restrictions in the COA included a reduced geographical range for Ikhana. Flights would be limited to within 75 nm of the "backbone" route. Additional restrictions that turned out to be significant during flights included:

- No flight in areas affected by planned GPS testing, solar storms, or predicted RAIM outages. RAIM is the abbreviation for Receiver Autonomous Integrity Monitoring, which indicates the integrity of GPS signals.
- No flight plan into forecast moderate or severe turbulence… or areas where convective SIGMETs have been issued or into known or forecasted icing conditions. SIGMET stands for Significant Meteorological Information and is a weather advisory regarding adverse weather that is of concern to all aircraft.

On August 16, the first WSFM flight was flown. The flight was limited to 9.5 hours to verify that all the planning and coordination in fact could be executed smoothly for a real flight. Over the next 6 weeks a total of four planned missions were executed and culminated in a 20-hour flight that extended from Southern California to within 50 nm of the Canadian border. Table 1 provides a summary of these flights.

To most ATC controllers and surrounding air traffic, handling Ikhana was no different than handling a manned aircraft. Ikhana responded to altitude and course deviations as a manned aircraft would. Air Traffic Control was able to provide real-time flight plan adjustment to allow for increased delay times at fires and flight track and altitude deviation requests around weather. At times, Ikhana was asked to "look for traffic" by ATC and on

some occasions was able to spot the traffic through the onboard camera system. Ikhana demonstrated the ability to intermix with manned aircraft in the airspace.

A. *Significant Operational Issues During the WSFM*

1) COA Limitation to Remain Within 75 nm of Backbone Route

This limitation resulted in the scientific team only investigating fires that were within the reduced area. On the August 30th flight, significant wildfires were located in Northern Idaho, which were beyond the approved area. NASA's request to extend flights to this region was denied and other lower priority fires were studied during that mission. This geographical restriction remained in force for all the planned flights for the WSFM. The FAA wanted to assess several Ikhana fire missions before extending the COA into new areas. During the Southern California Emergency Response Missions, the 75 nm restriction was lifted and Ikhana was permitted to fly beyond the boundaries specified in the COA.

2) Restriction to Remain Clear of Regions of Scheduled GPS Testing

Initially, this restriction did not appear that it would be significant. Ikhana flights had to be scheduled around, and on one occasion, delayed 24 hours due to GPS testing/jamming exercises at military bases in the vicinity of WSFM routes. These regions were identified by FAA Notices to Airman (NOTAMs) and typically consisted of an inverted cone centered at the test site with increasing radius with increasing altitude. When flying at 25,000 ft, Ikhana could be affected at a range of up to 300 nm. It is unknown at this time specifically how GPS testing/jamming would effect Ikhana's navigation capabilities and at what range .

3) Access to Line-of-Sight Communications Frequencies

For flight within approximately 70 nm of Edwards AFB, Ikhana is controlled via a direct-line-of-sight radio link. Significant military UAS operations in the same general area required NASA DFRC to work around the Dept. of Defence (DOD) flight schedules to have access to these frequencies. In many cases this meant that Ikhana flight operations in the local area were conducted outside of normal business hours. This required that some of the Ikhana crew begin work as early as 3:00 AM , further complicating scheduling issues for personnel that perform multiple duties on long duration flights.

4) Unexpected Weather Along Flight Route

The COA restricted flight from areas of adverse turbulence, convection and icing. During the flight planning process it was difficult to take weather into account. Flight tracks were designed and transmitted to FAA more than 72 hours in advance, meaning weather forecasts for the day of flight were not meaningful. Weather forecasts, especially Airmen's Meteorological Information (AIRMETs) and Significant Meteorological Information (SIGMETs), were closely watched as the flight day approached.

The 16.1-hour flight on August 30th was launched with several convective SIGMETs issued for areas of the Western United States that were not under the planned flight track. Ikhana was approximately two hours into the flight over Utah when the EFB software XM weather service depicted the boundaries of a convective SIGMET along the flight track. A significant heading deviation was requested that took Ikhana several hundred miles from its original track to avoid the weather. The capability of the EFB to display weather and flexibility provided to Ikhana by ATC allowed the flight to continue safety.

5) ATC Coordination

Considering the ground-breaking nature of the WSFM objectives, the successful coordination of airspace access for Ikhana's flights with FAA UAPO and ARTCC personnel was a great success for these missions. Clearly both NASA and FAA worked together as partners in demonstrating what was possible with the WSFM. ARTCC personnel were open minded and receptive to the prospect of Ikhana's flights through their airspace. They communicated their concerns and suggested resolutions. Conference phone calls with ARTCC representatives were conducted before and after missions. The fact that no significant misunderstandings or miscommunications occurred spoke to the professionalism of both the FAA and NASA staff members.

6) Staffing Requirements

Long duration flights (> 10 hours) for the WSFM required multiple crewmembers for all operational positions due to crew duty day limitations. This included the pilots, system monitors, mission directors, and electronics and maintenance technicians. When flights longer that 12 hours were conducted, multiple shifts were implemented and crew duty hour rules complied with. Pilots and technicians from the aircraft's manufacturer, General Atomics Aeronautical Systems Inc., were contracted to provide additional staff.

Non-standard flight schedules, intermittent sleep schedules, and extended on-call status have the potential to fatigue crewmembers. At crew briefings, crew rest and readiness issues were made top priority by project pilots to try to ensure that everyone was sufficiently rested. These concerns will continue to be significant issues for long duration, non-scheduled flights that involve natural phenomenon.

B. *Emergency Response Missions in Southern California*

At the completion of the last planned WSFM, the instrument pod was removed from Ikhana and preparations for the next Ikhana flight research experiment, the Fiber Optic Wing Shape Sensing (FOWSS). Part of this preparation included a substantial modification to the wing surfaces for an experimental sensor integration. On October 22nd the Ikhana Project received a request from the California Office of Emergency Services for imagery of the Southern California wildfires. There were over 11 fires burning which had caused the evacuation of 500,000 people (later increasing to over 1,000,000 people).

A wing repair was completed to return the aircraft to service. The team was reassembled and the sensor pod reinstalled on Ikhana's wing. The FAA was notified and mission plans

were submitted. The population areas in Southern California were reevaluated (due to the evacuation) and keep-out zones updated. NASA DFRC requested an emergency COA from the FAA based on the already-established WSFM COA. The emergency COA relieved some previous restrictions. As an example, only 24 hours notice of the flight plan was required before flight (versus 72 hours). The southern COA boundary was also extended past the 75-nm limit to a line that was 10 nm from the Mexican border.

Flight Date	Flight Duration	Fires Flown	Mileage
16 Aug	9.5 hrs	4	1400
29 Aug	16.1	5	2500
7 Sept	20	11	3200
27 Sept	9.9	4	1800
24 Oct	9	9	~1350
25 Oct	8.7	8	~1350
26 Oct	7.8	8	~1350
28 Oct	7.1	11[8]	~1350

Table 1. WSFM Flight Summary

Two days later on October 24th, the first emergency response mission in Southern California was initiated. Over the next five days, a total of four flights were flown (see Table 1). The cooperation and coordination with FAA to make these flights occur was outstanding. Because of a declared State of Emergency, Ikhana's flights were given priority over GPS testing/jamming exercises, but no conflicts arose. Ikhana flights received great flexibility and priority from ATC in responding to this national emergency situation in the congested Southern California airspace.

VI. CONCLUSION

The objectives for the WSFM were met in 2007. Long duration missions over multiple fires were conducted where near real-time dissemination of wildfire data was achieved. NASA and the FAA demonstrated that a UAS could operate in the NAS similarly to a manned aircraft. Significant steps toward being able to "file and fly" in the NAS were accomplished. Progress will continue with future missions.

The experience gained in the 2006 and 2007 planned missions enabled the program to rapidly respond to Southern California wildfires. The COA application by NASA required much effort, but the system worked in keeping the process moving and organized.

[8] This included Burned Area Emergency Response (BAER) assessment imagery of the Esperanza fire.

Developing contingencies for emergency landing sites in the entire area of interest was a significant work load for NASA DFRC. This planning provided successful risk management to protect public safety. Good communication, hard work, and the professionalism of all persons involved in this project were key to its success.

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Operational Experience with Long Duration Wildfire Mapping

UAS Missions over the Western United States

June 12, 2008 AUVSI
LCDR Philip Hall, NOAA

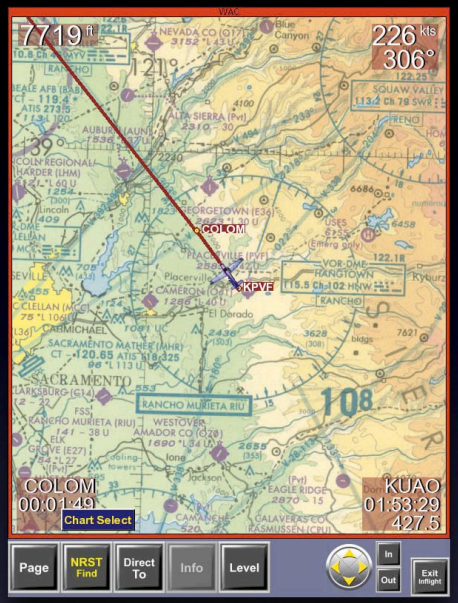
Unmanned Aircraft System Operational Challenges

- UAS Designed for Military Applications
- COA Requirements
- No FAA Approved "See-and-Avoid" System
- Contingency Planning with Remote Pilot
- UAS Operations are novel in the NAS
- "Lost-link" Scenerio is Unique to UAS

2007 Western States Fire Mission on Ikhana

- Background
- Mission Planning
- Mission Execution
- Lessons Learned

IKHANA UAS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KPVF
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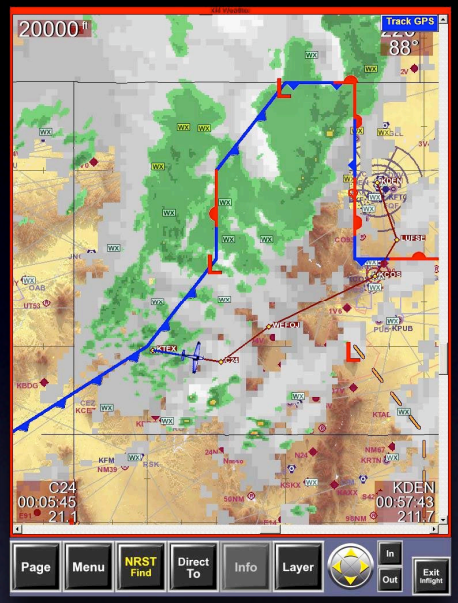
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Layer
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Out
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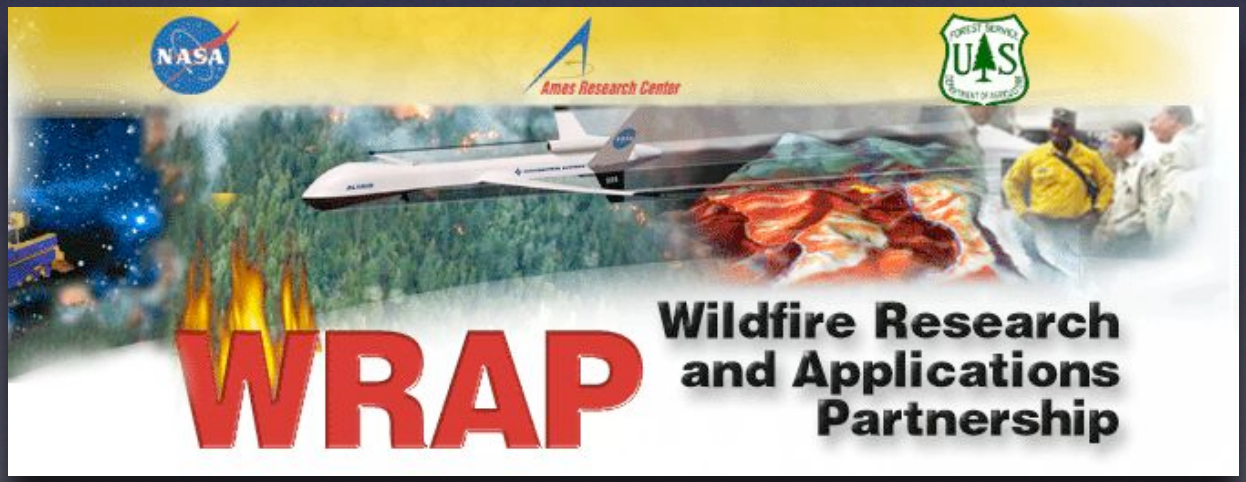
IKHANA

3002

Western States Fire Mission

- 20-Hour UAS Missions in the Western US
- Deliver Fire Imagery to Firefighters < 10 Min
- File and Fly Similar to Manned Aircraft



Mission Preparation

Aircraft Ordered

Delivered

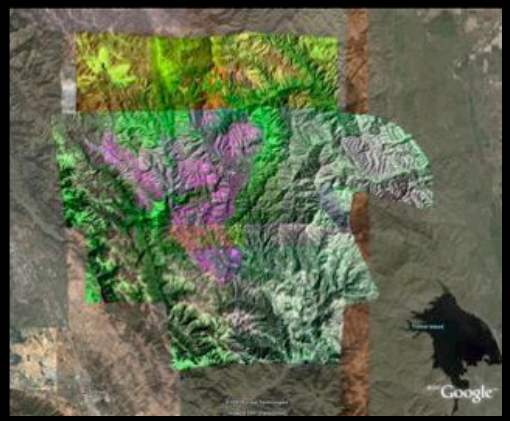
GCS Delivered

Fire Pod Integration

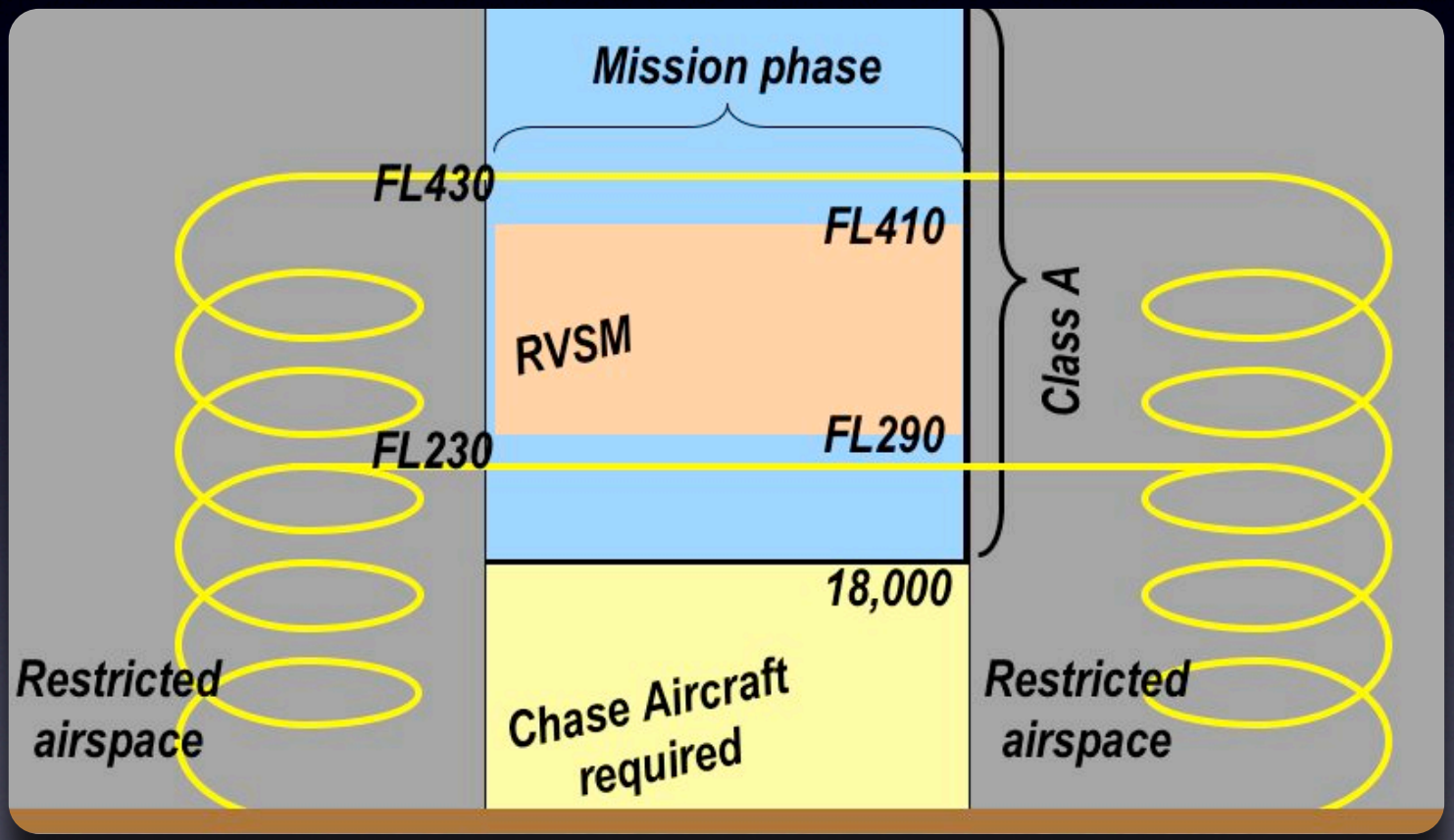
Crew Training

GCS Modifications

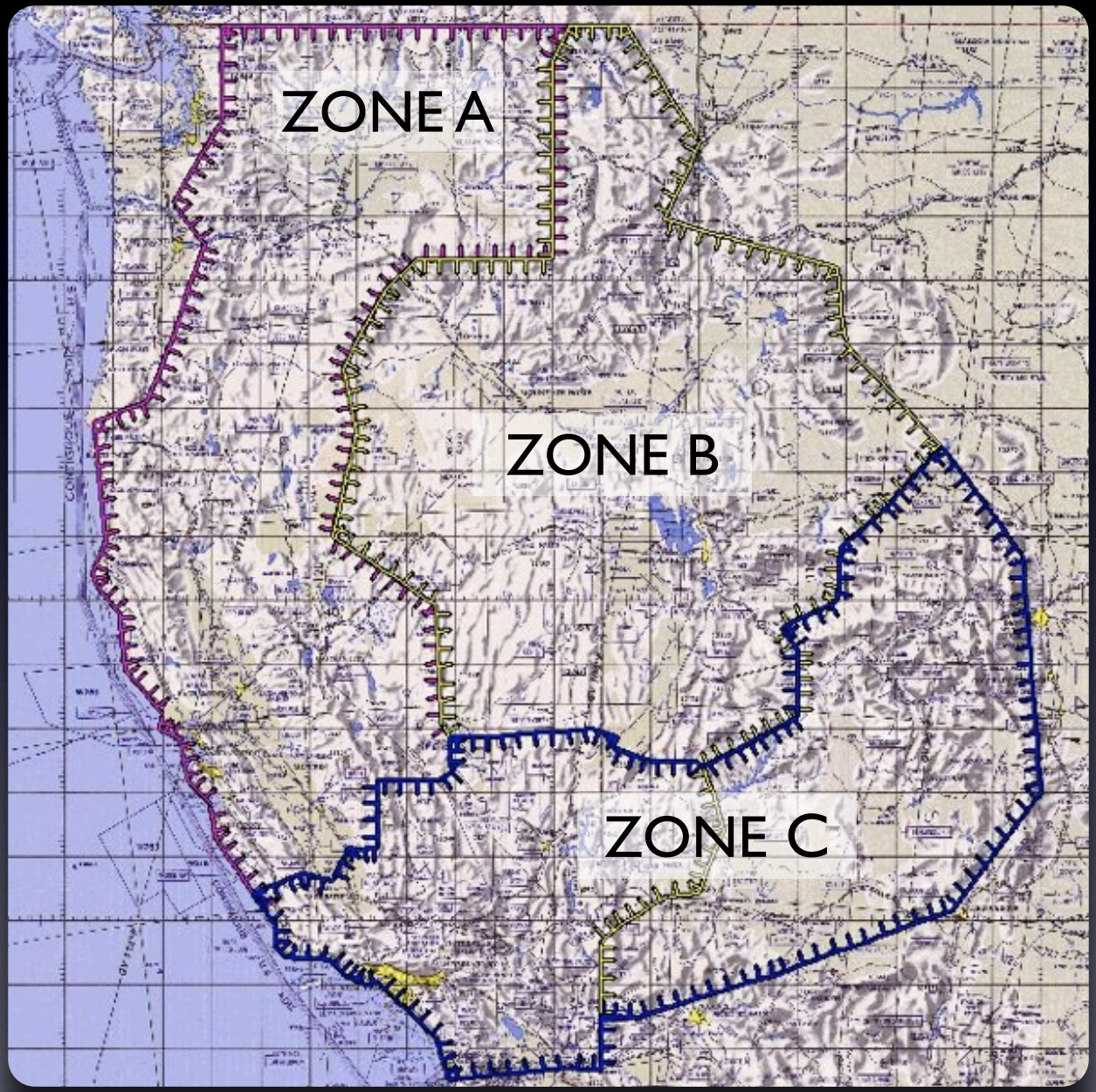
Western States Fire Mission



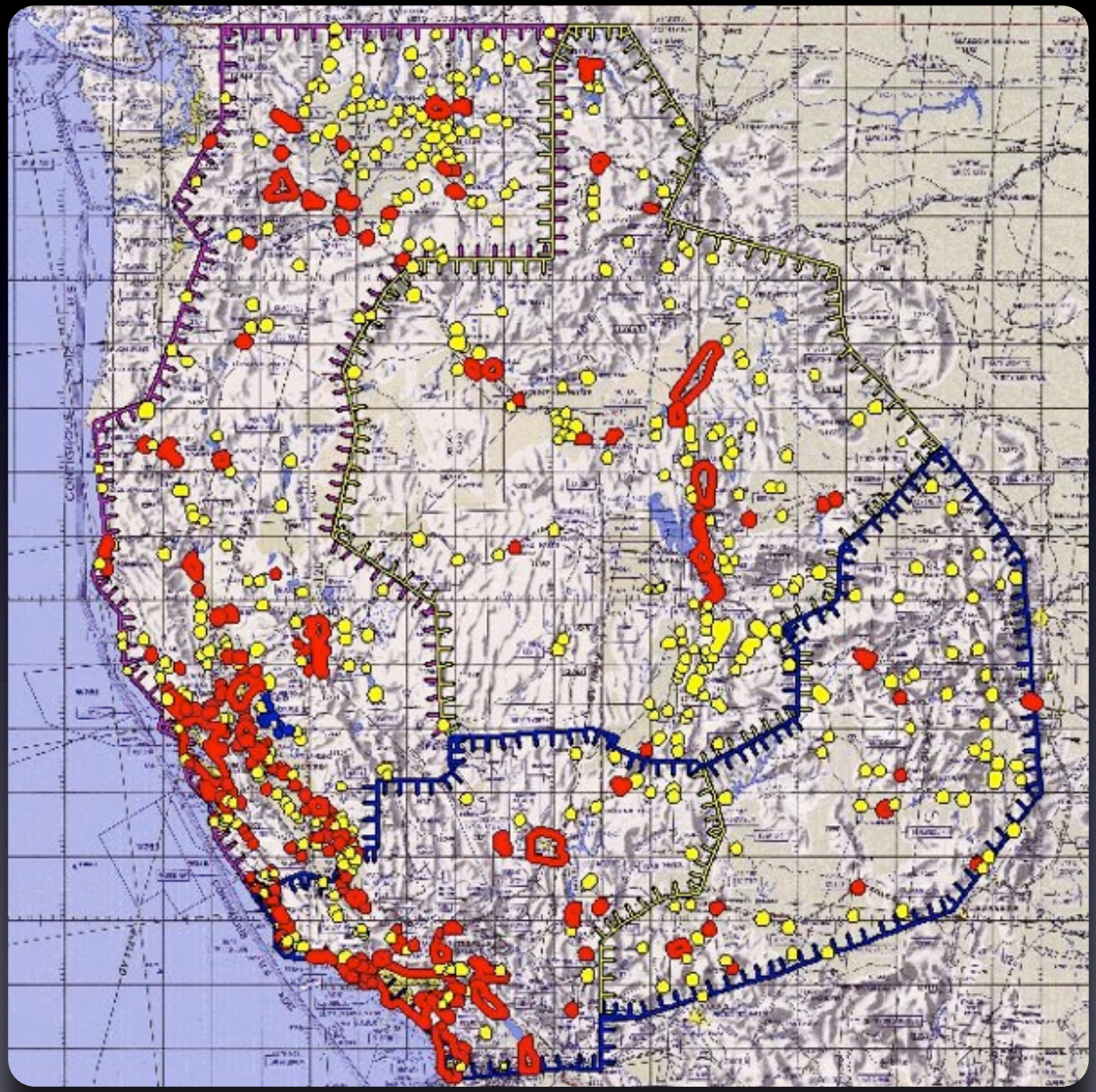
Mission Planning
Airspace



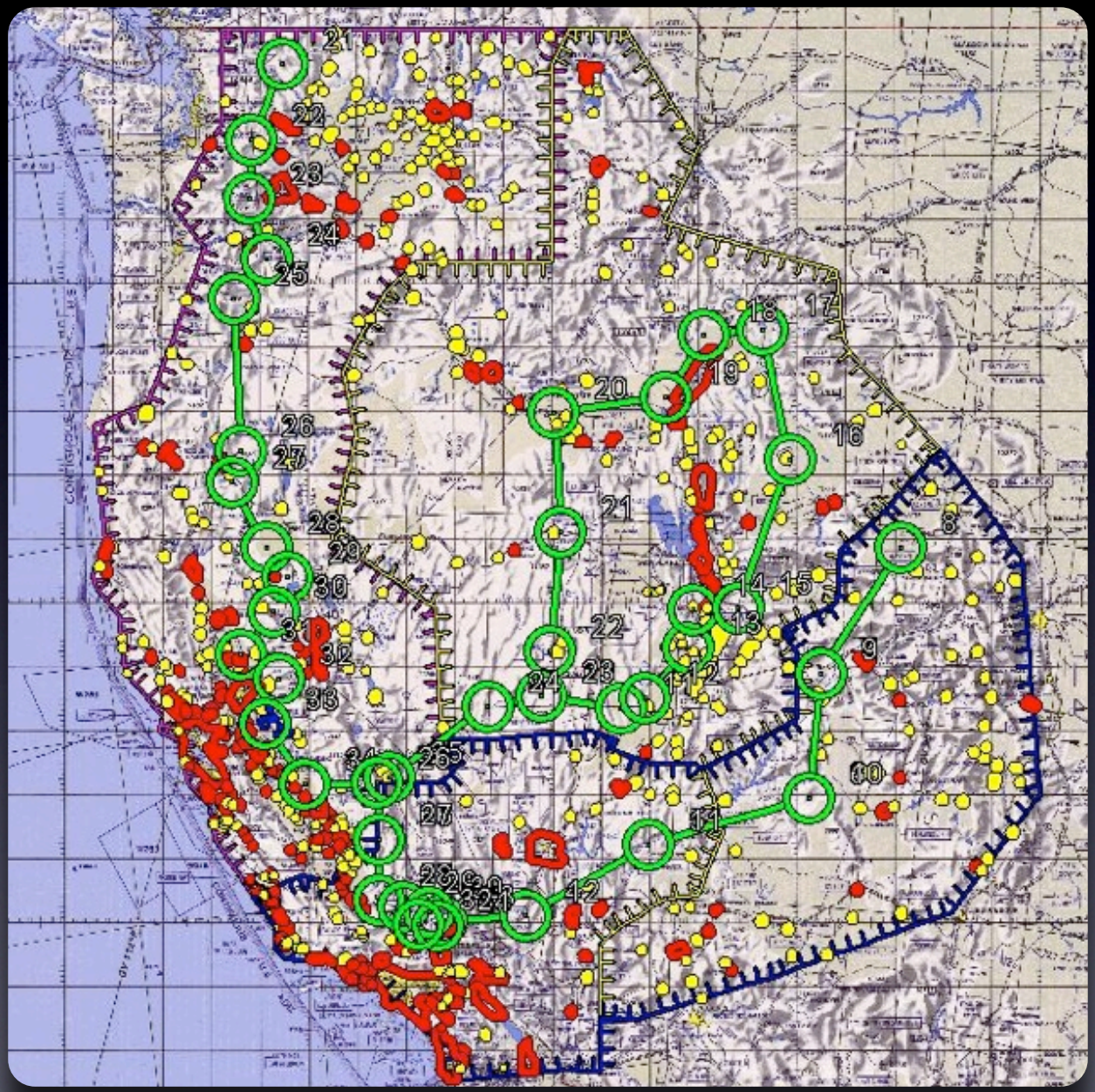
COA Application Zones

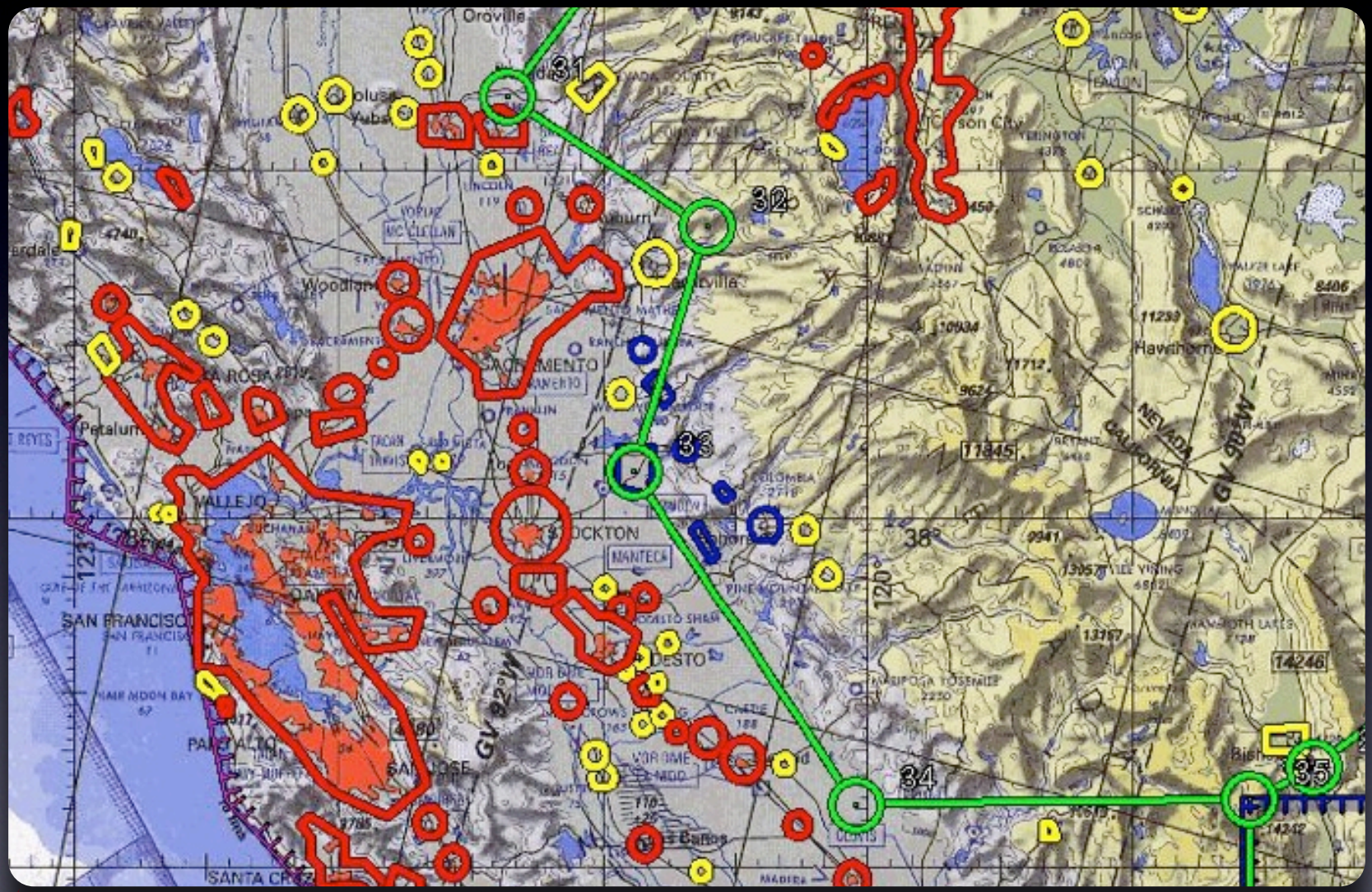


Population Keep-out Zones



Backbone Flight Routes

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MANTECA
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PALO ALTO
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CALIFORNIA
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GV 98°W
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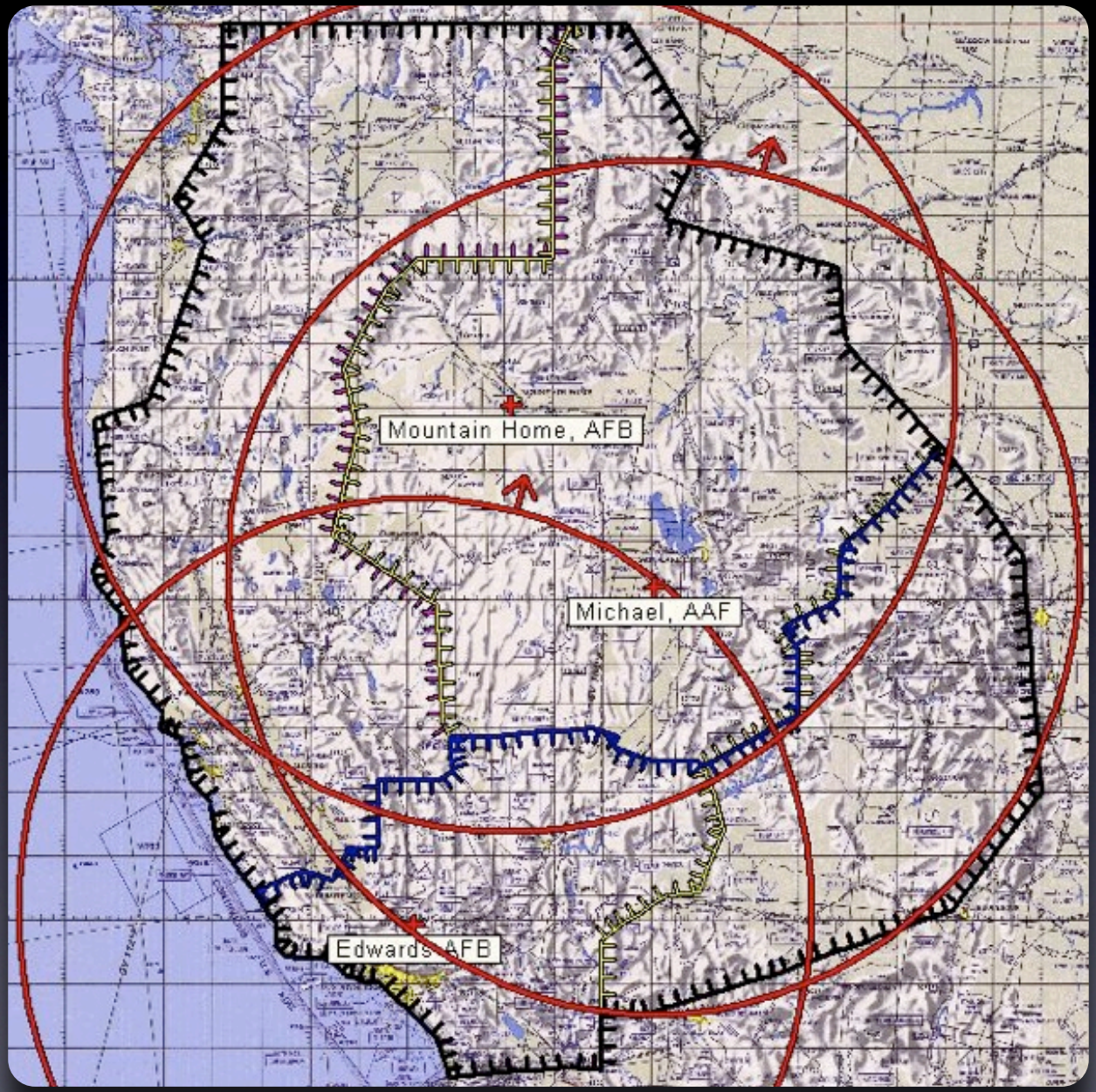
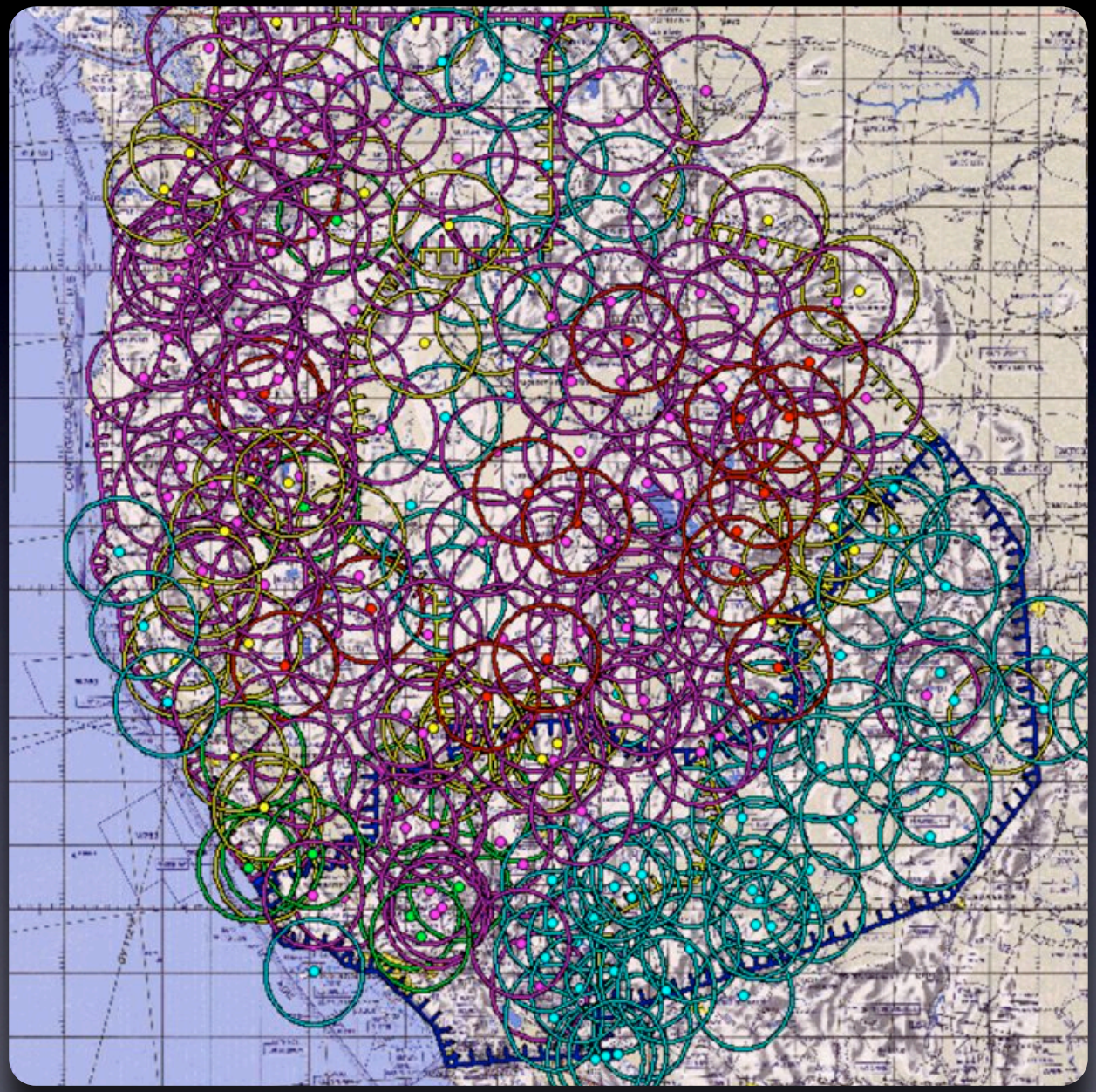
14246

Primary Emergency Landing Sites



Secondary Emergency Landing Sites



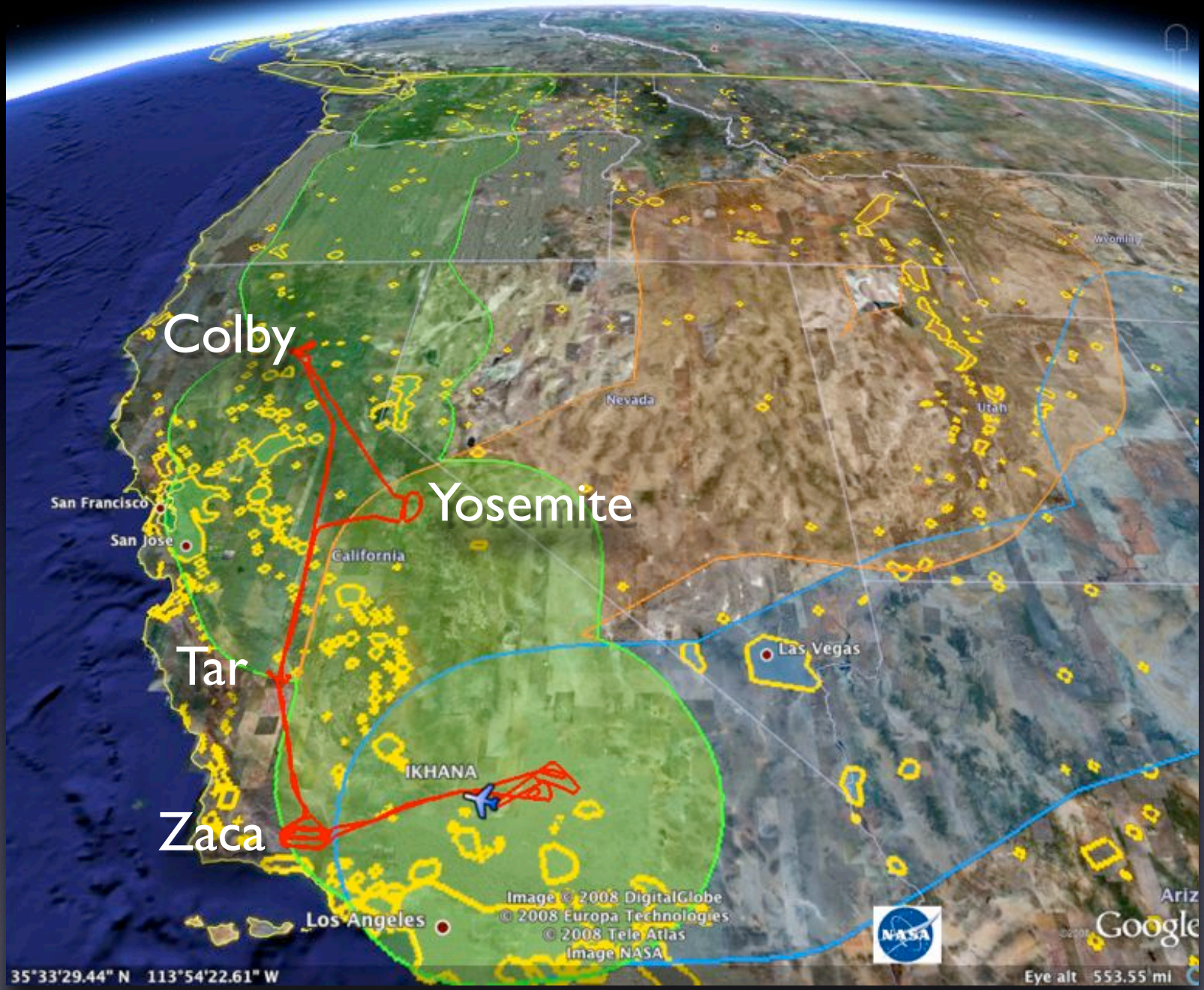
COA Restrictions

Weather

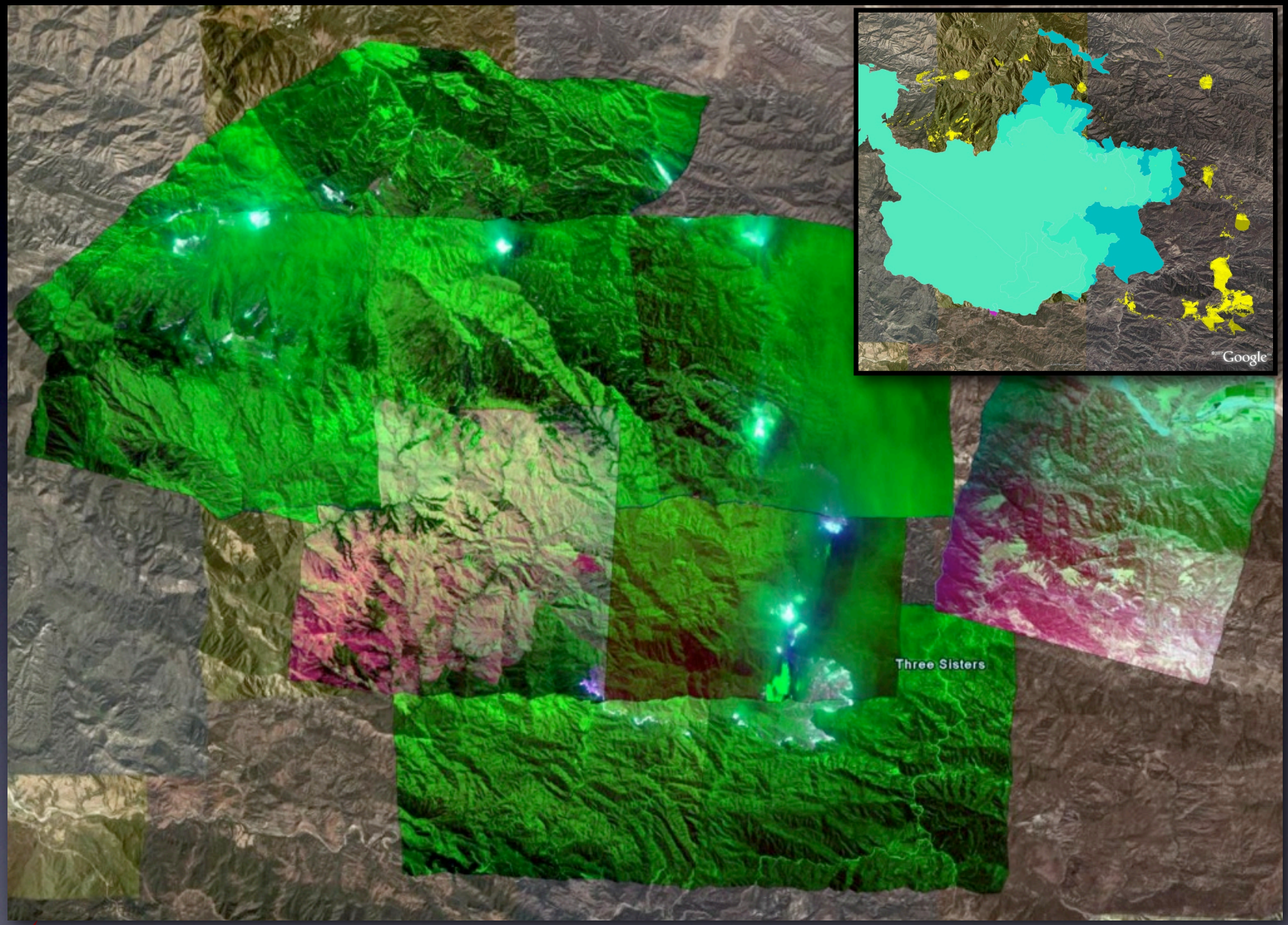
GPS Testing

Boundaries

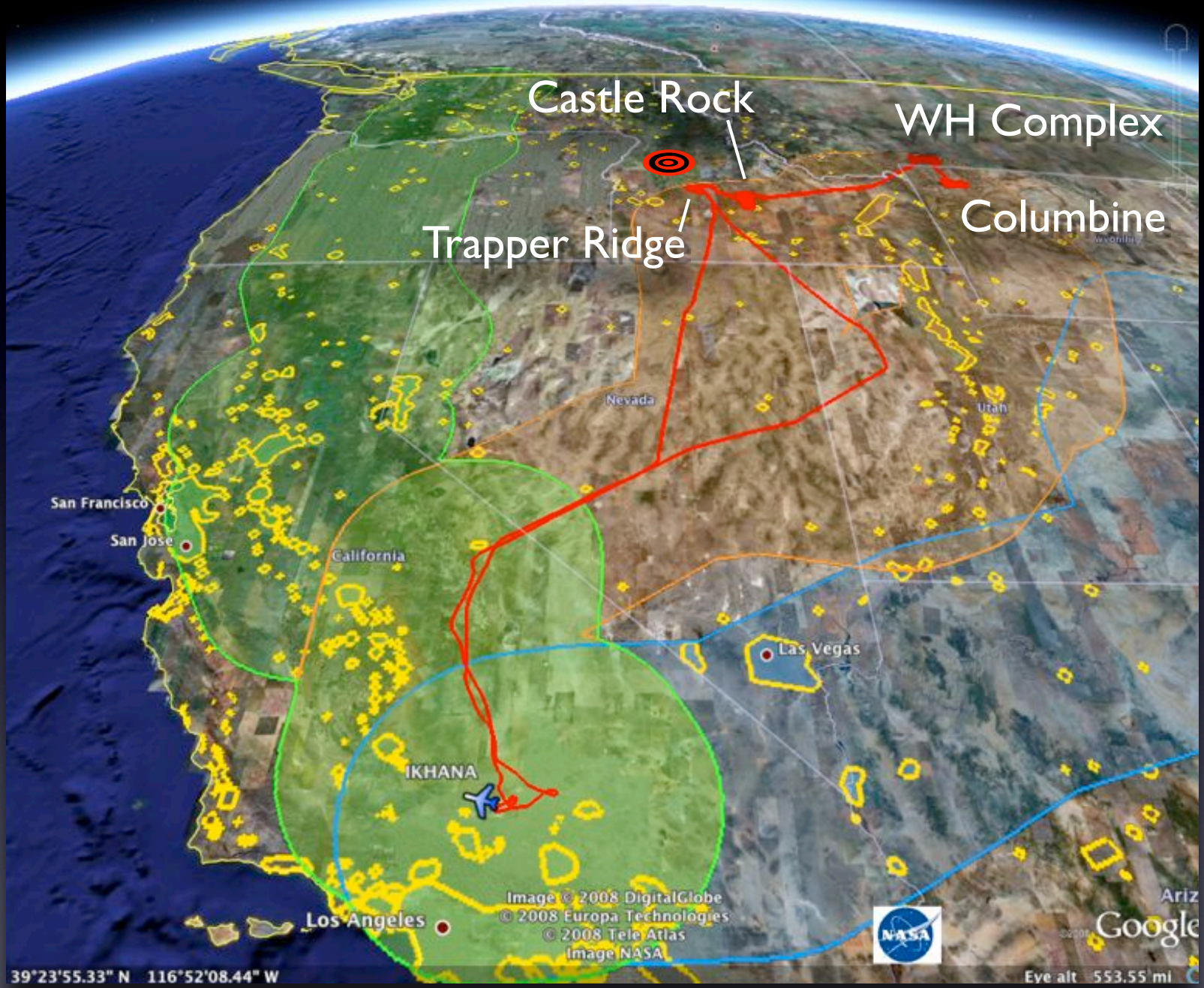
Aug. 16 9.5 hrs 1400 mi



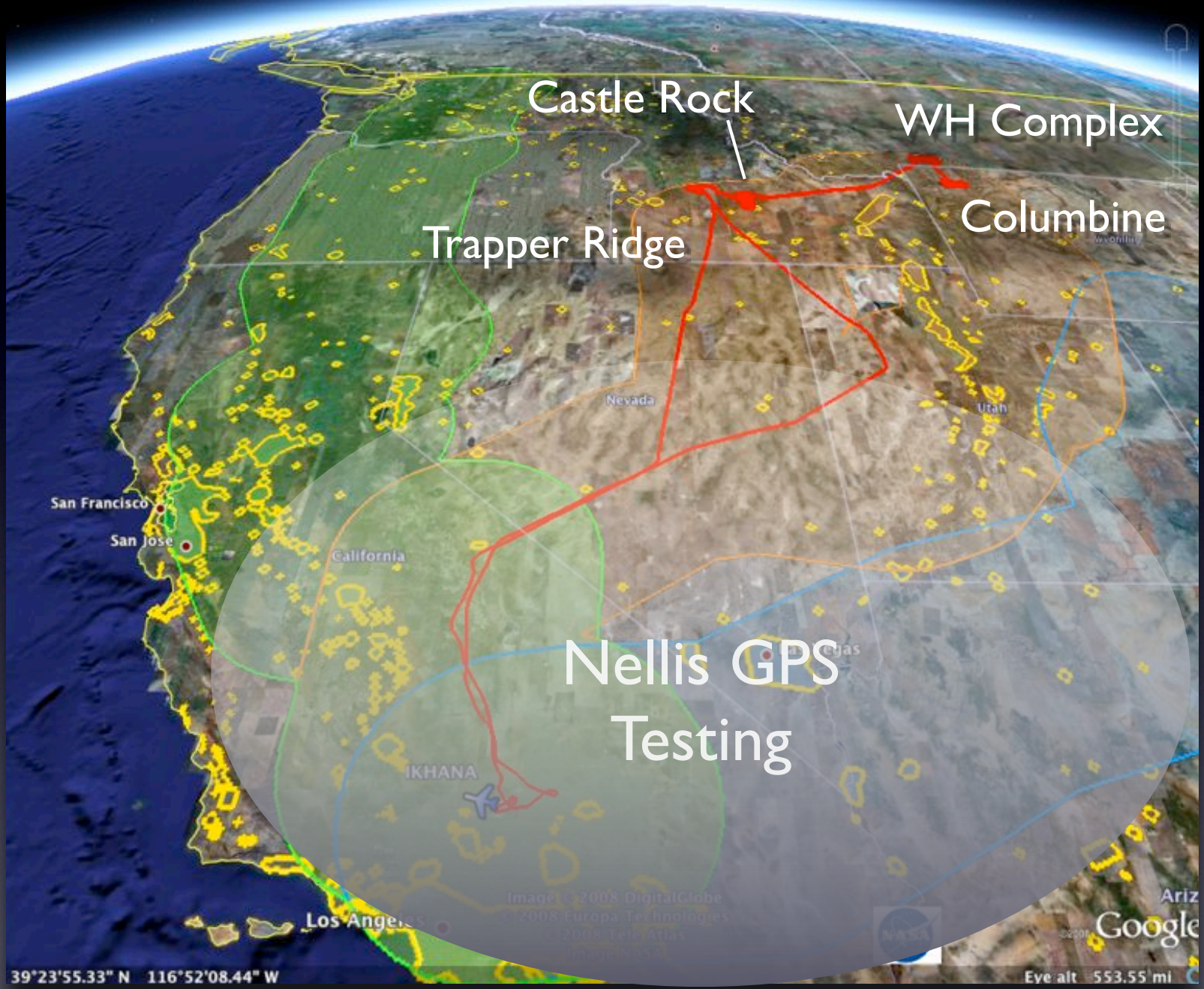
Zaca Fire



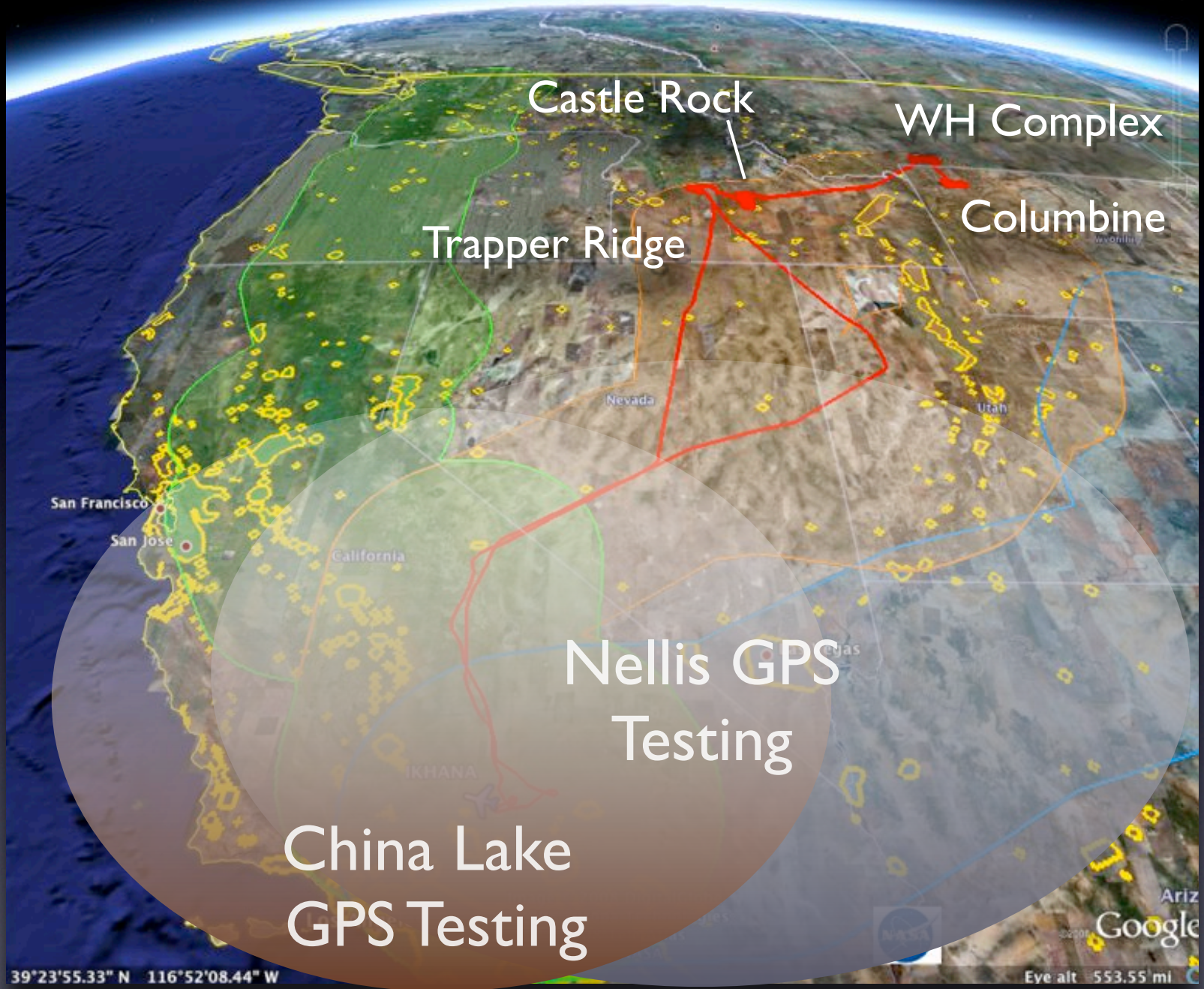
Aug. 29 16.1 hrs 2500 mi



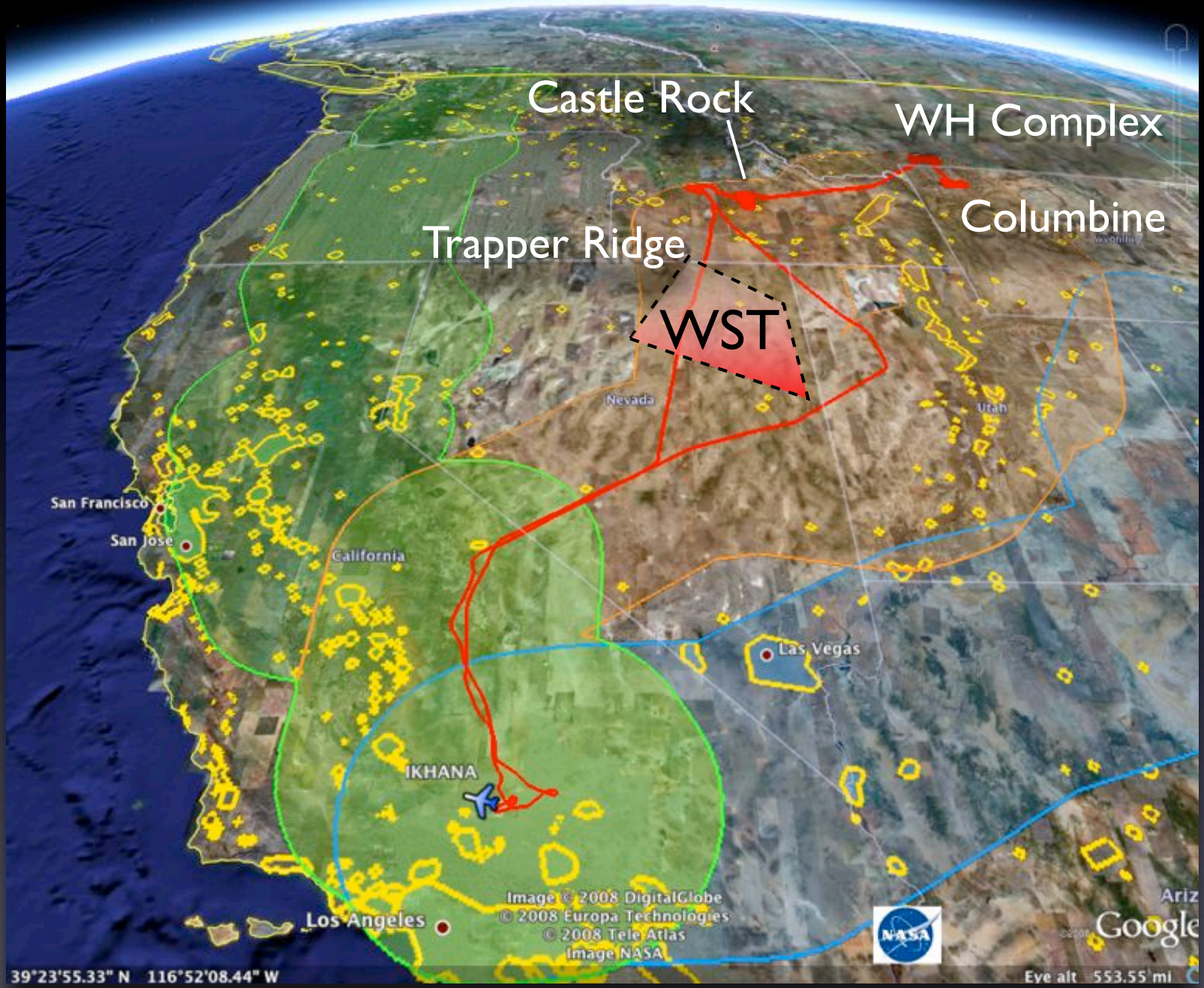
Aug. 29 16.1 hrs 2500 mi



Aug. 29 16.1 hrs 2500 mi



Aug. 29 16.1 hrs 2500 mi



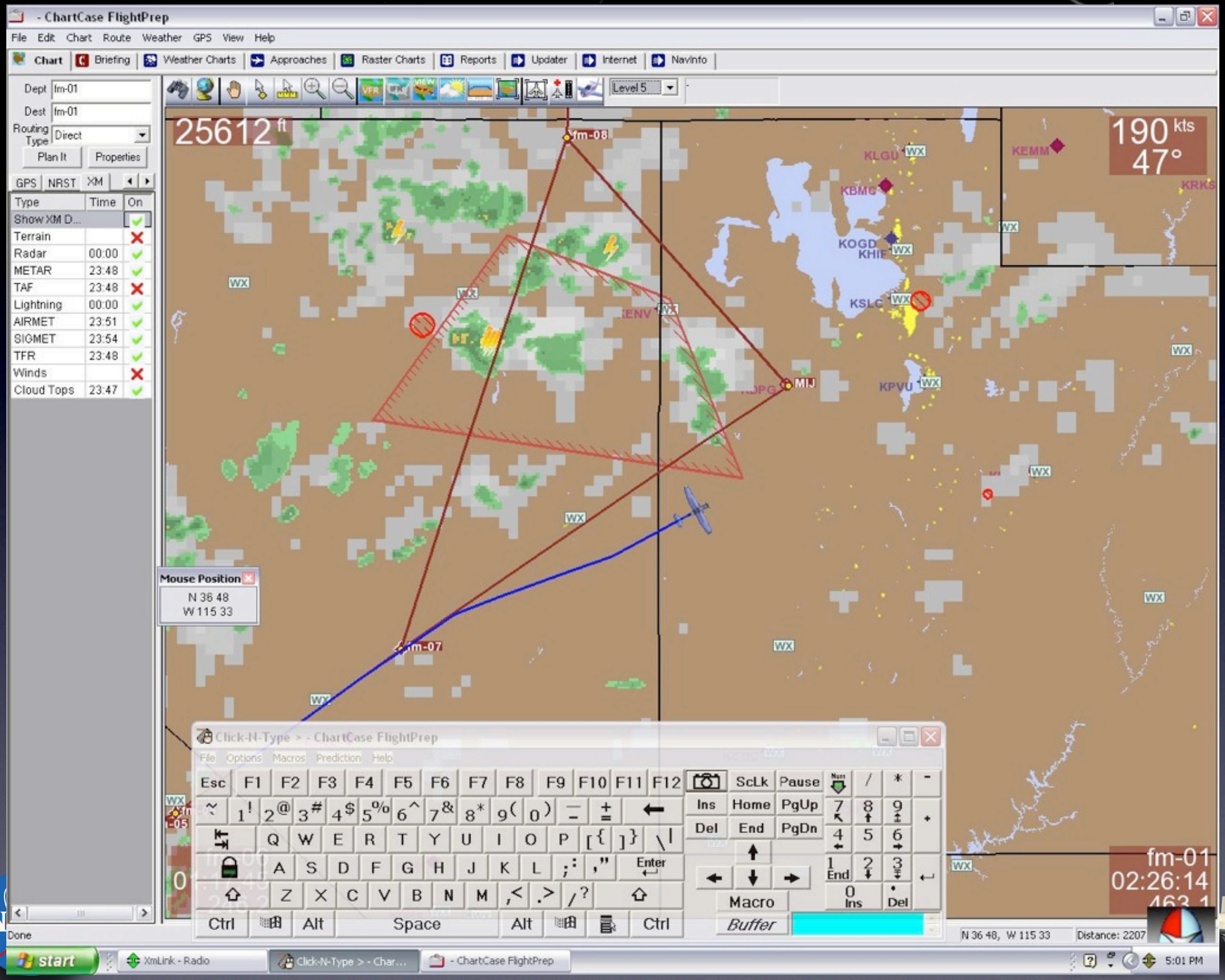

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Chart Briefing Weather Charts Approaches Raster Charts Reports Updater Internet Navinfo
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Dest fm-01
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GPS NRST XM
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Show XM D...
Terrain
Radar 00:00
METAR 23:48
TAF 23:48
Lightning 00:00
AIRMET 23:51
SIGMET 23:54
TFR 23:48
Winds
Cloud Tops 23:47
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47°
fm-08
fm-07
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KBMG
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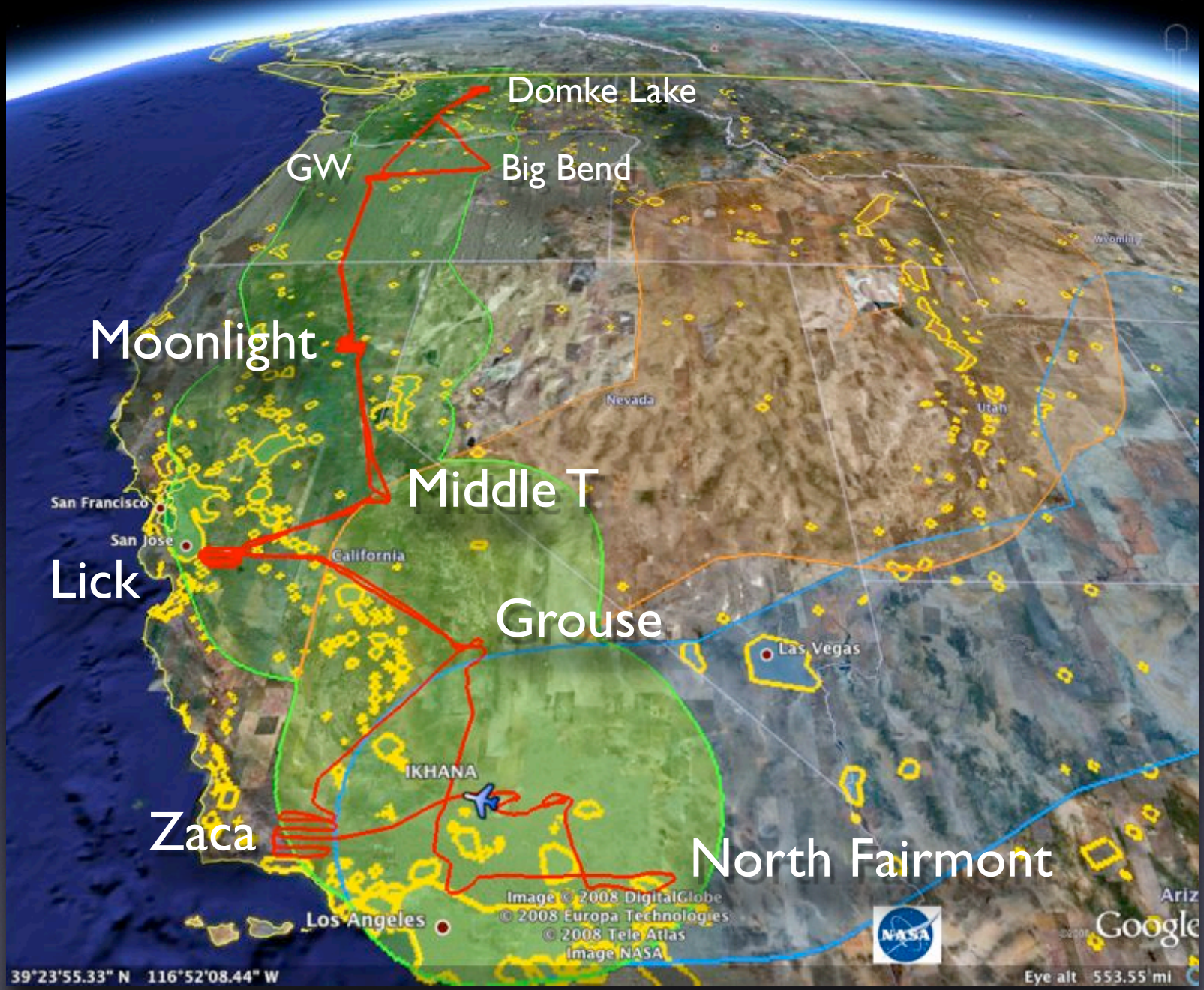
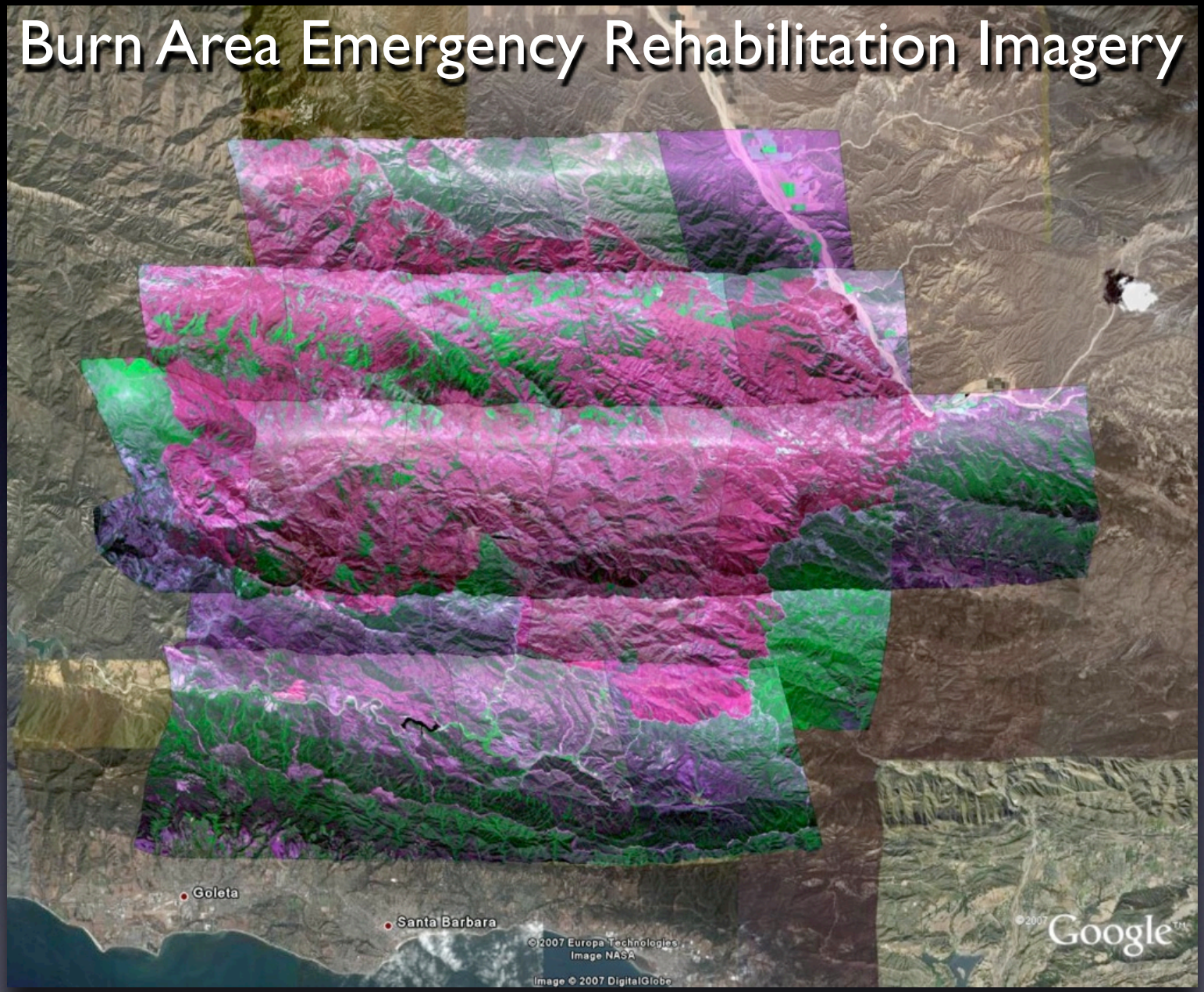
Sept. 7 20 hrs 3200 mi

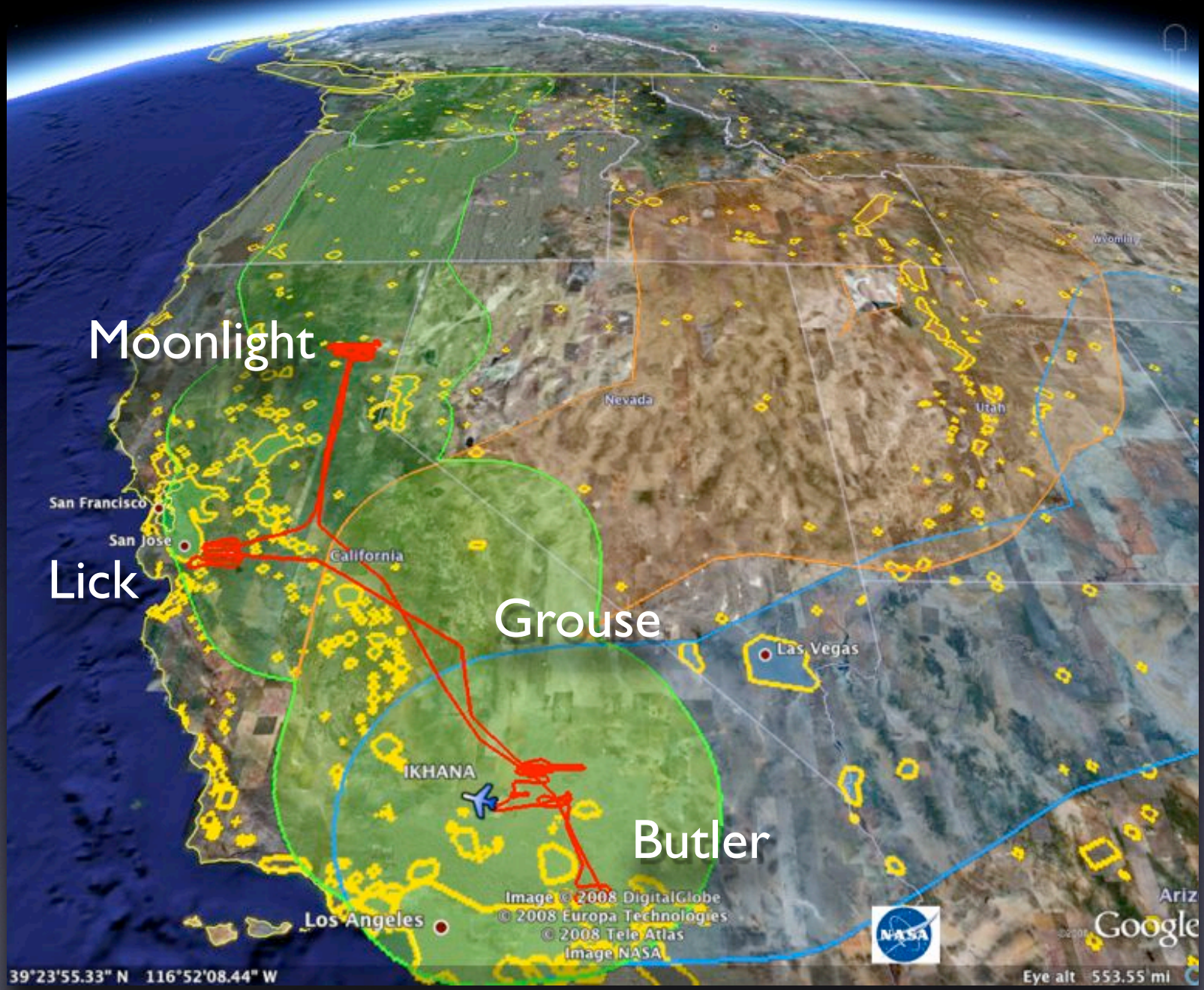


Zaca Fire

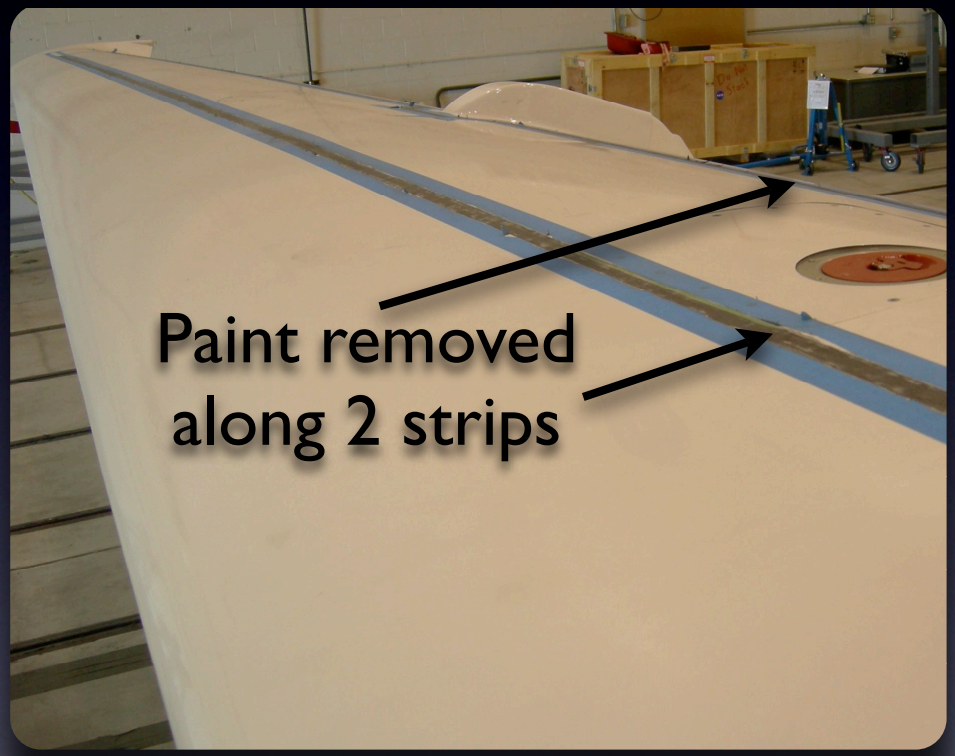
Burn Area Emergency Rehabilitation Imagery

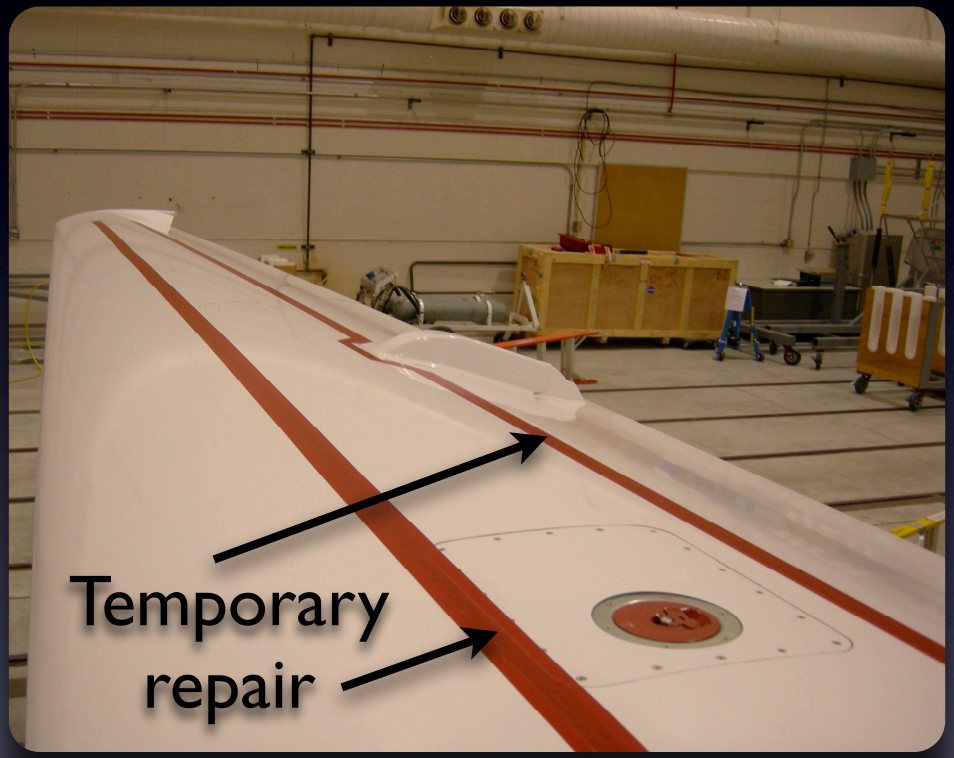


Sept. 27 10 hrs 1800 mi



Fiber Optic Wing Shape Sensing Project





Southern California Fires
Emergency Response

Southern California Wildfires Emergency Response Oct. 26 - 9 hrs

Santiago Fire

Mission Accomplished!

Flight Date	Duration (hrs)	Fires	Mileage (nm)
16 Aug	9.5	4	1400
29 Aug	16.1	5	2500
7 Sept	20.0	11	3200
27 Sept	9.9	4	1800
24 Oct*	9.0	9	~1350
25 Oct*	8.7	8	~1350
26 Oct*	7.8	8	~1350
28 Oct*	7.1	11**	~1350

* Southern California Wildfire Emergency Response
** Including Burn Area Emergency Rehabilitation Imagery

Lessons Learned

- Mission Planning is Complex and Demanding
- Personnel Resources Required are Substantial
- Excellent Communication with FAA is Key to Success

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