NASA Dryden Flight Research Center
Unmanned Aircraft Operations

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Dryden Flight Research Center
Edwards AFB, CA

TOPICS

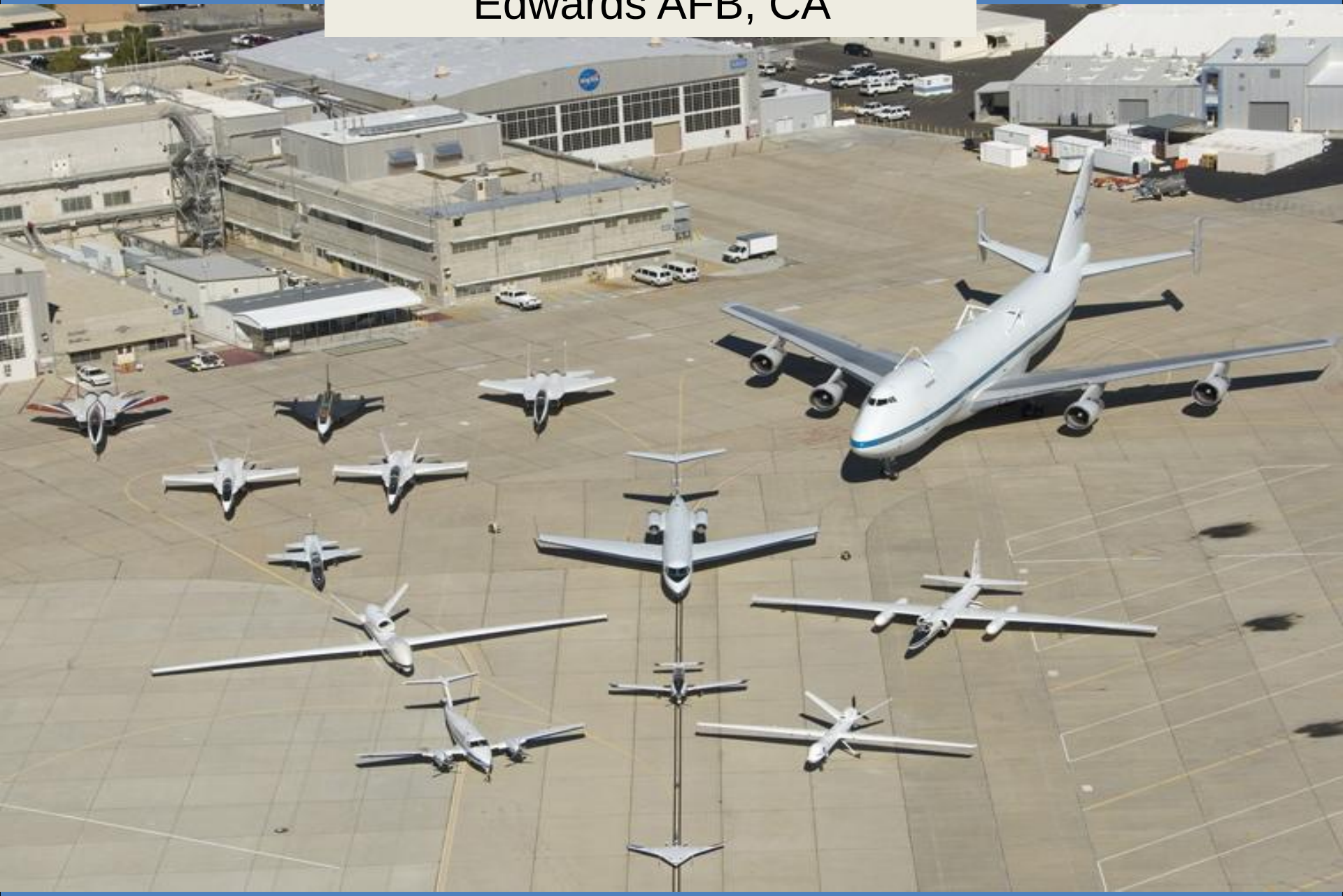
- **NASA Unmanned Aircraft Projects**

- **RQ-4 *Global Hawk***
  - **Earth Science Missions**
- **MQ-9 *Ikhana***
  - **Pilot – Vehicle Interface Design**

- **Concept of UAV Pilot / Operator**

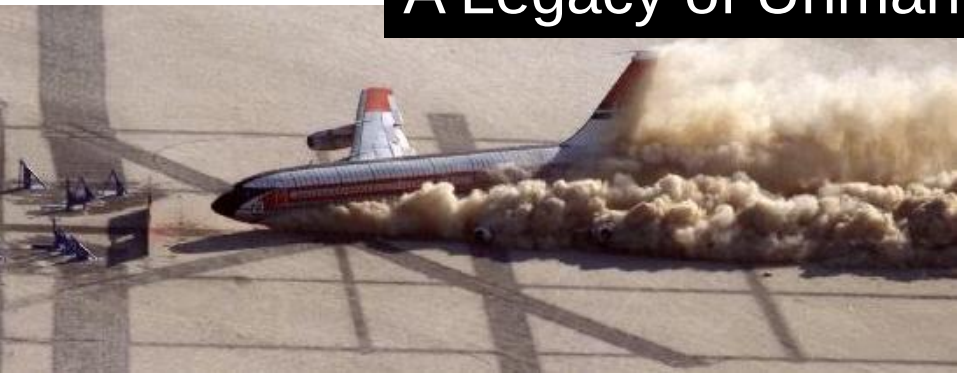
- ***Ikhana* Western States Fire Mission**

NASA Dryden Aircraft Fleet, Edwards AFB, CA

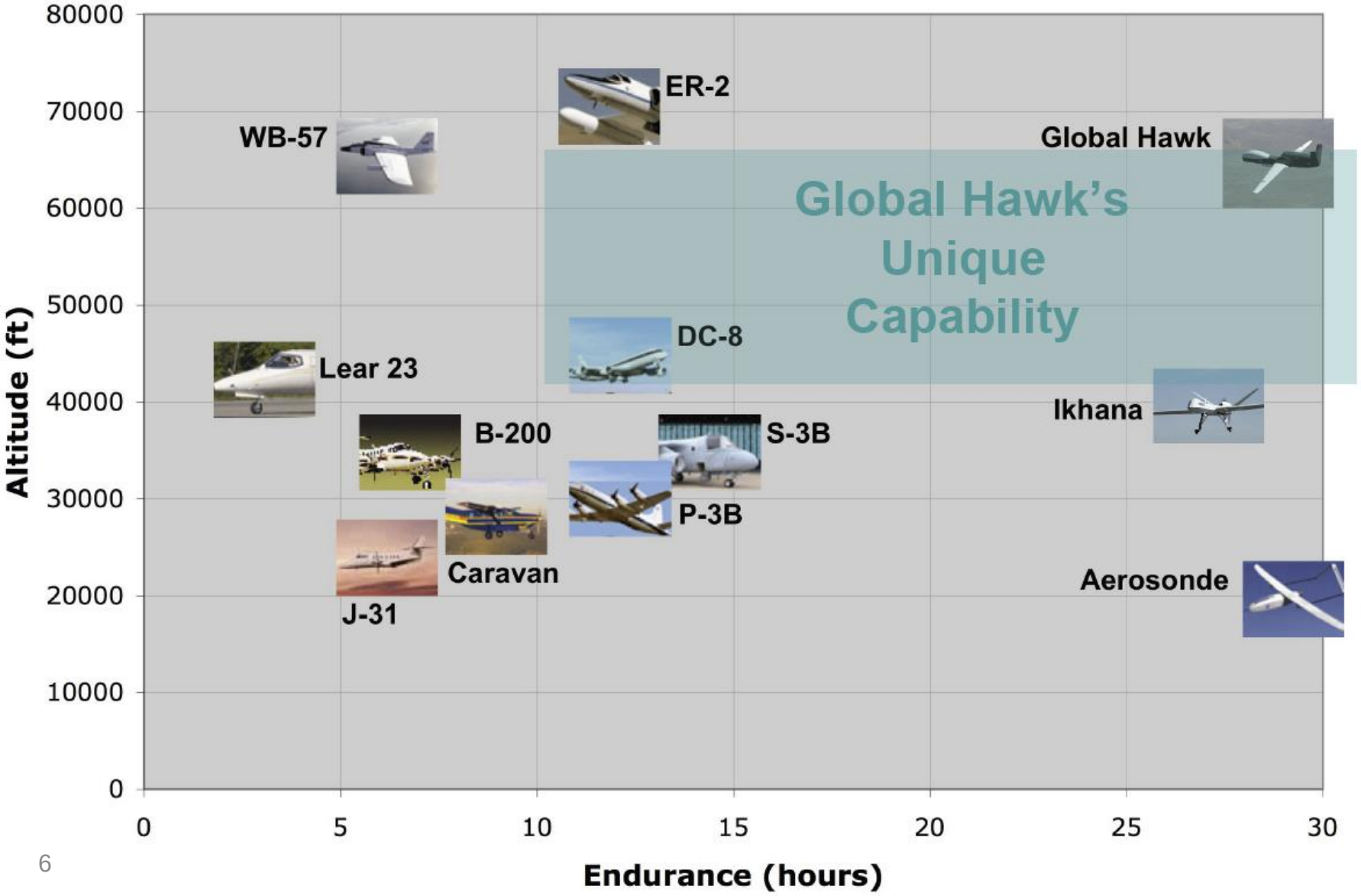



NASA Dryden Aircraft Fleet,
Palmdale Airport, CA

A Legacy of Unmanned Aircraft Research



NASA's Airborne Science Program Aircraft Capabilities



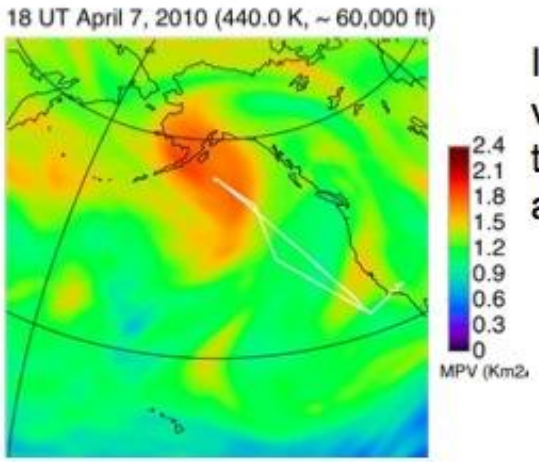
NASA Global Hawk Project Overview

CDR Philip Hall, NOAA
Global Hawk Deputy Project Manager
NASA Dryden Flight Research Center
Sept 30, 2010

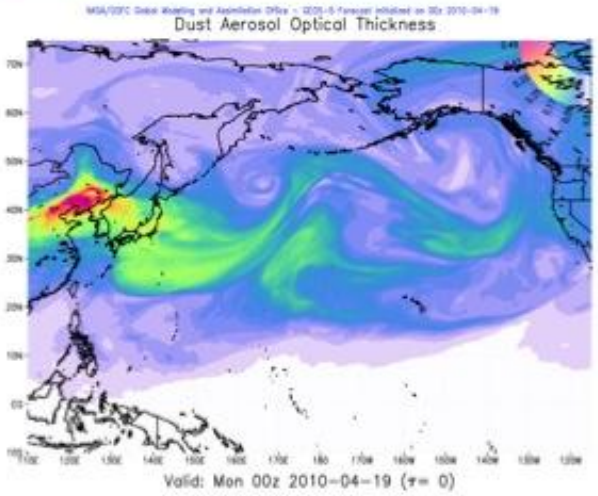
Global Hawk Operations Center (GHOC)

First Global Hawk Science Mission

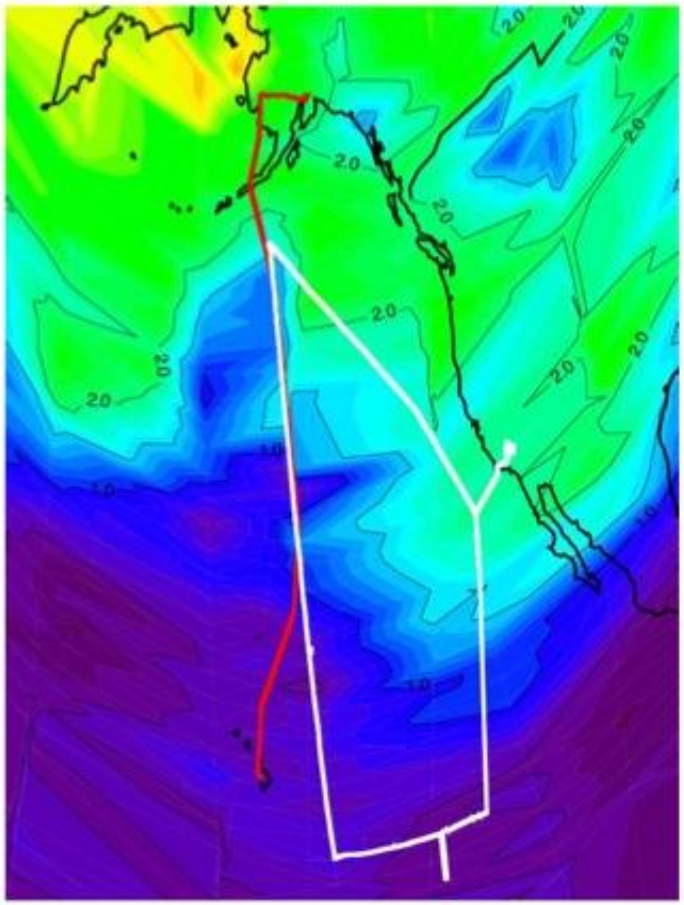
GloPac Science Highlights



Intercept an Arctic vortex fragment that broke off on about March 28

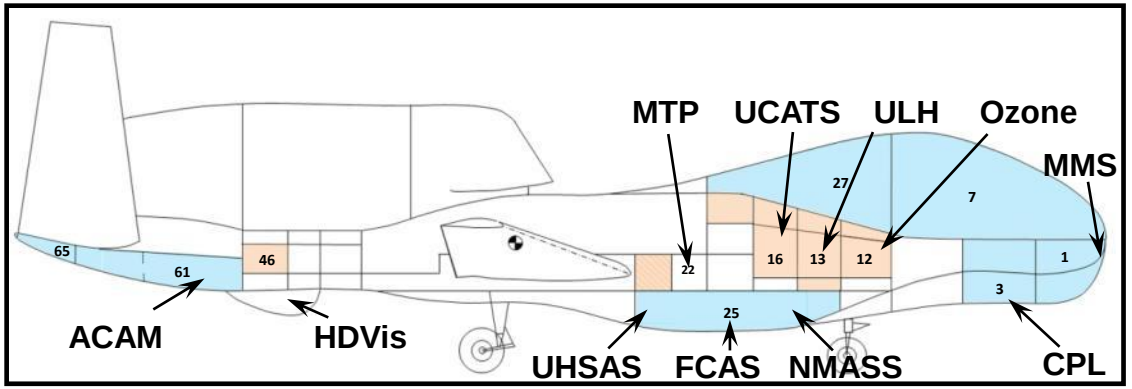


Sample Asian dust from the Gobi Desert



Rendezvous with the NSF GV aircraft and underfly the Aura satellite.

GloPac Instrument Overview



ACAM	Airborne Compact Atmospheric Mapper (GSFC)	Cross-track scanning spectrographs of NO2, O3, & aerosols.
CPL	Cloud Physics LIDAR (GSFC)	Backscatter LIDAR for hi-res profiling of clouds & aerosols.
FCAS	Focused Cavity Aerosol Spectrometer (U. of Denver)	Aerosol size and concentration measurements.
MMS	Meteorological Measurement System (ARC)	Science quality aircraft state variable measurements.
MTP	Microwave Temperature Profiler (JPL)	Passive microwave radiometer meas. of O2 thermal emissions.
HDVis	HiDef Video System (ARC)	Time-lapse nadir color digital imagery with georeferencing.
NMASS	Nuclei-mode Aerosol Size Spectrometer (U. of Denver)	Aerosol size and concentration measurements.
Ozone	UAS Ozone (NOAA)	Dual-beam UV photometer for accurate O3 measurements.
UCATS	UAS Chromatograph for Atmospheric Trace Species (NOAA)	Dual gas chromatographs for N2O, SF6, H2, CO, & CH4 meas.
UHSAS	Ultra-High Sensitivity Aerosol Spectrometer (Droplet Measurement Technologies)	Ultra-high sensitivity aerosol spectrometer.
ULH	UAS Laser Hygrometer (JPL)	In-situ hi-accuracy atmospheric water vapor measurements.

GloPac Flight Tracks

April 7th
14.1 hrs, 4600nm, 61200 ft

April 13th
24.3 hrs, 8000nm, 62300 ft

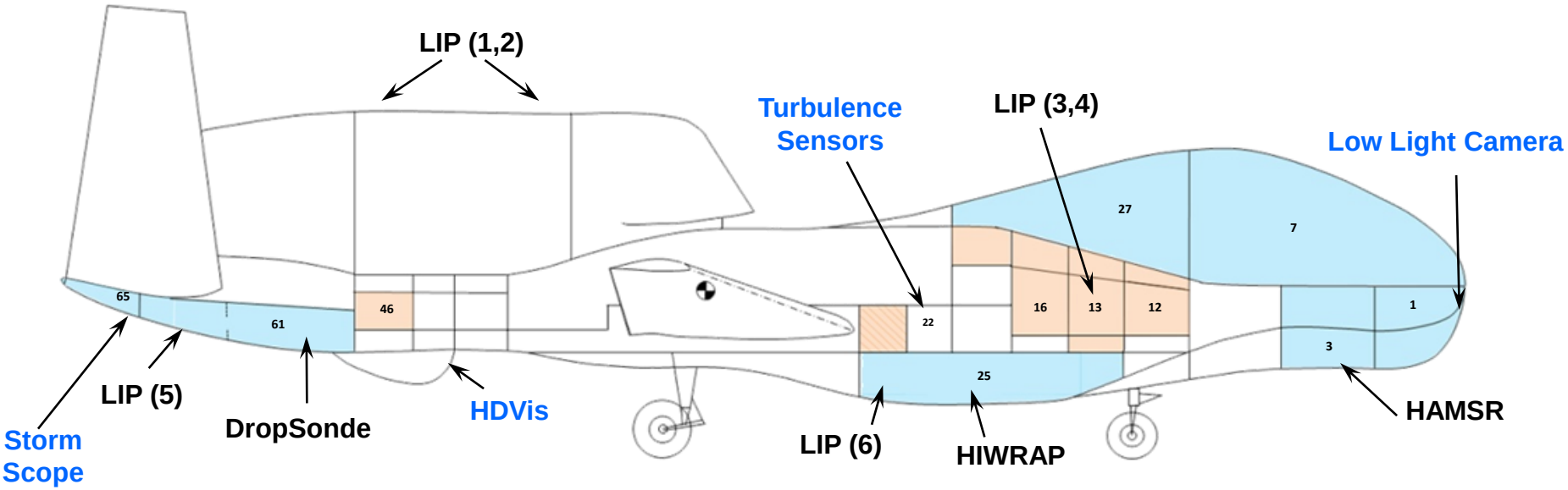
April 23rd
28.6 hrs, 9700nm, 65200 ft

(April 2: Range flight, 6.3 hrs)
(April 30: Equatorial flight attempt, 9.3 hrs)

GloPac Total: 82.6 hrs

Second Global Hawk Science Mission

GRIP Instrumentation



HIWRAP - **High Altitude Imaging Wind and Rain Profiler**

DropSonde - **NOAA DropSonde System**

HAMSR - **High Altitude MMIC Sounding Radiometer**

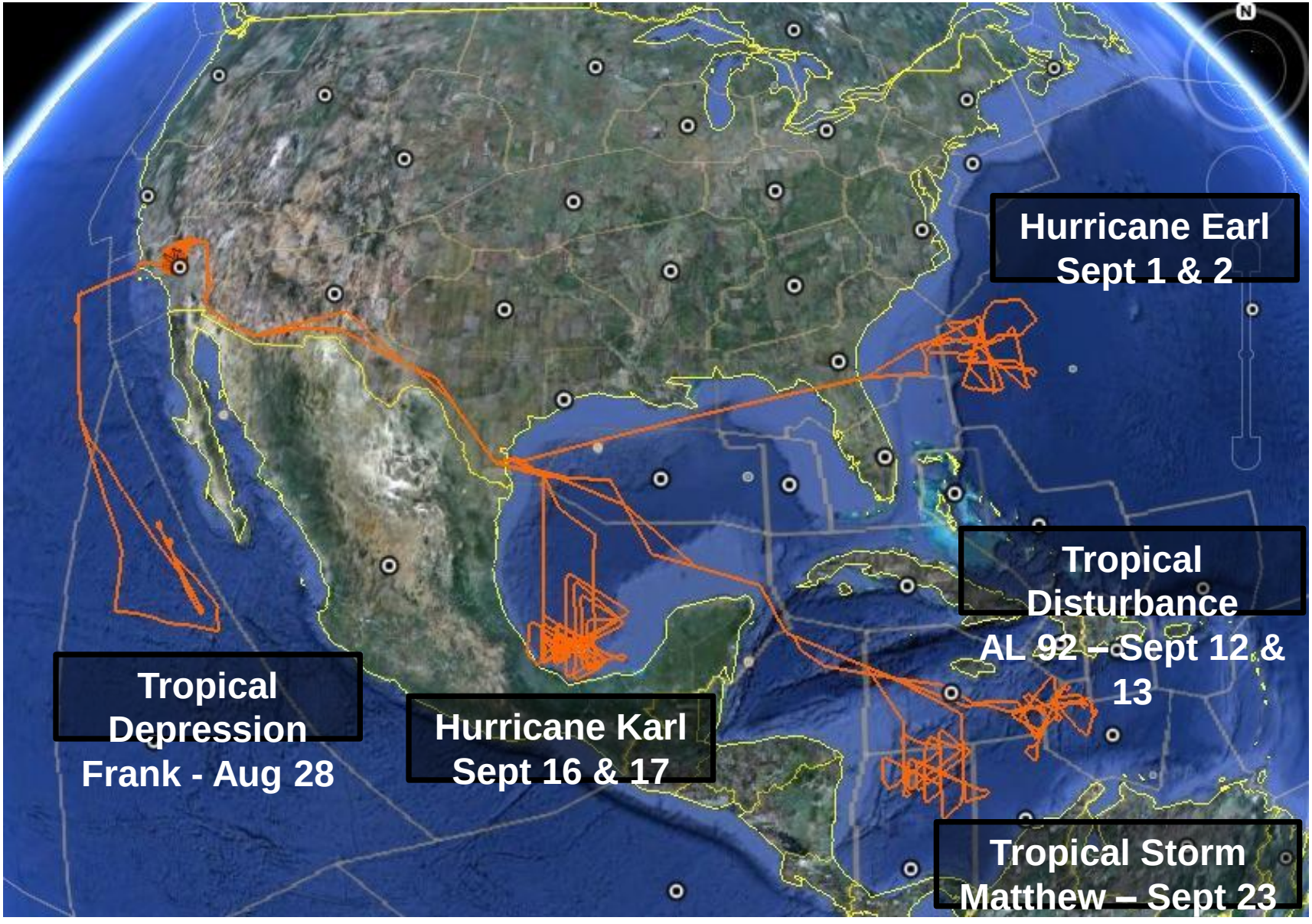
LIP - **Lightning Instrument Package**

2 Cameras - **HDVis and Low Light for Pilot Situational Awareness**

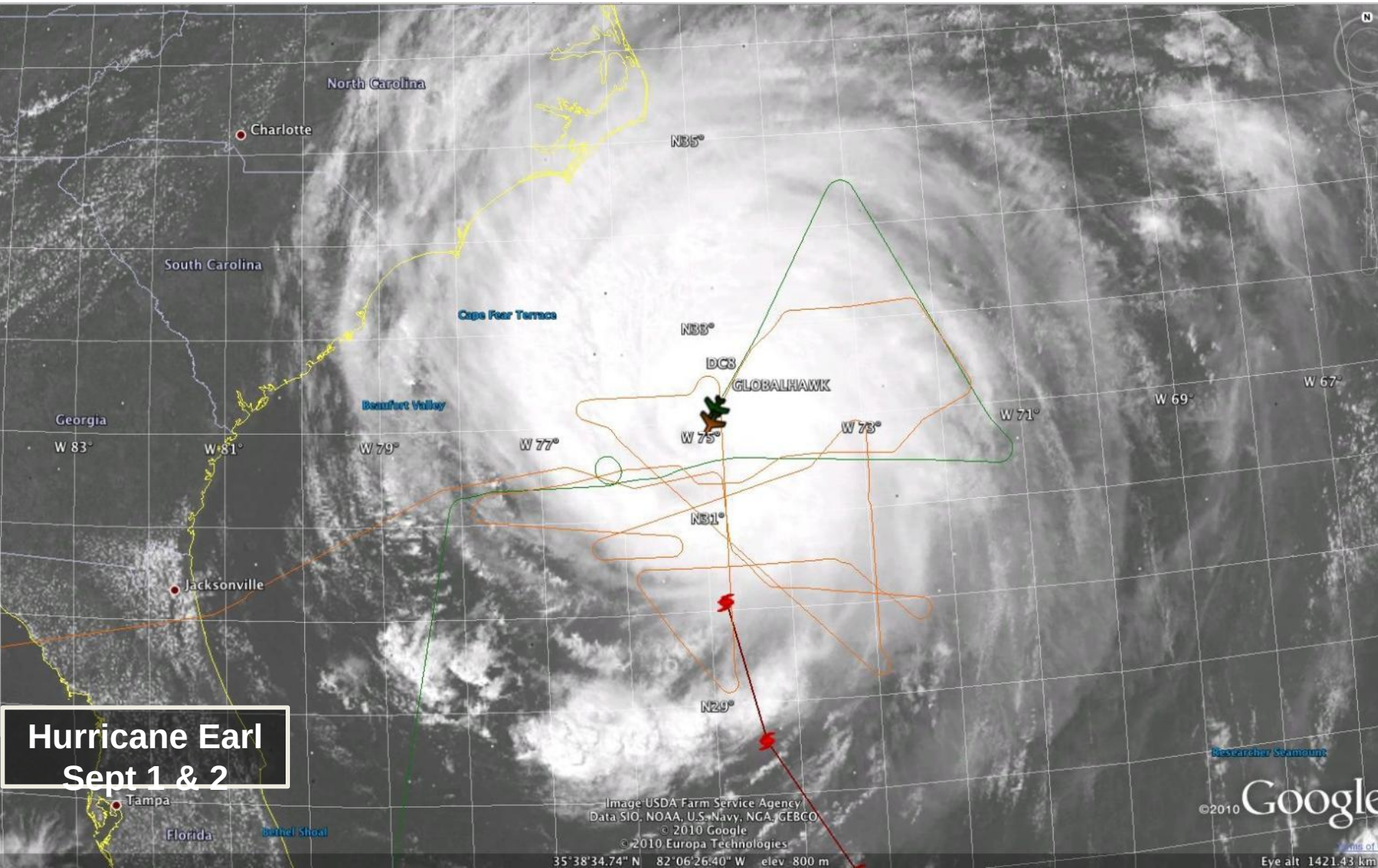
Storm Scope - **Lightning Detection Display in the GHOC**

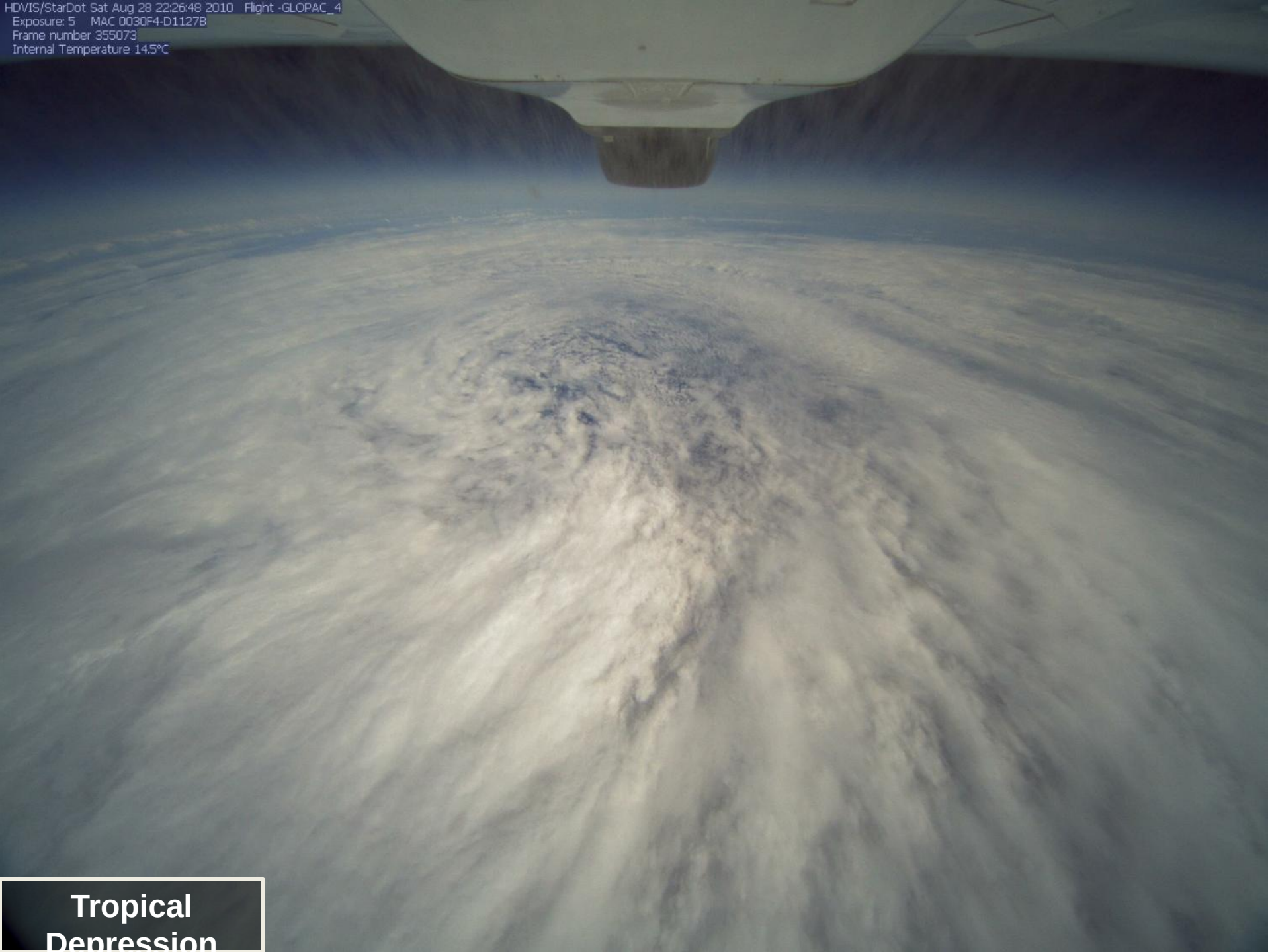
Accelerometers - **Real-time Turbulence Time-history Display in the GHOC**

GRIP Storm Flights



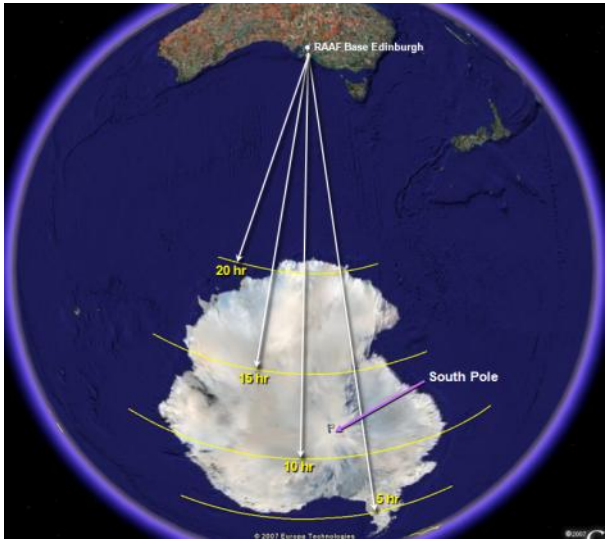
Real Time Mission Manager

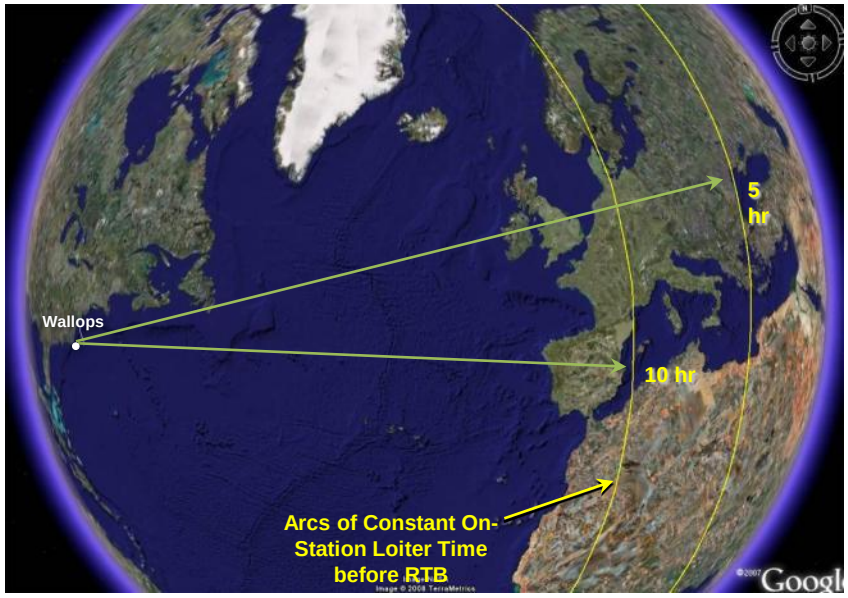


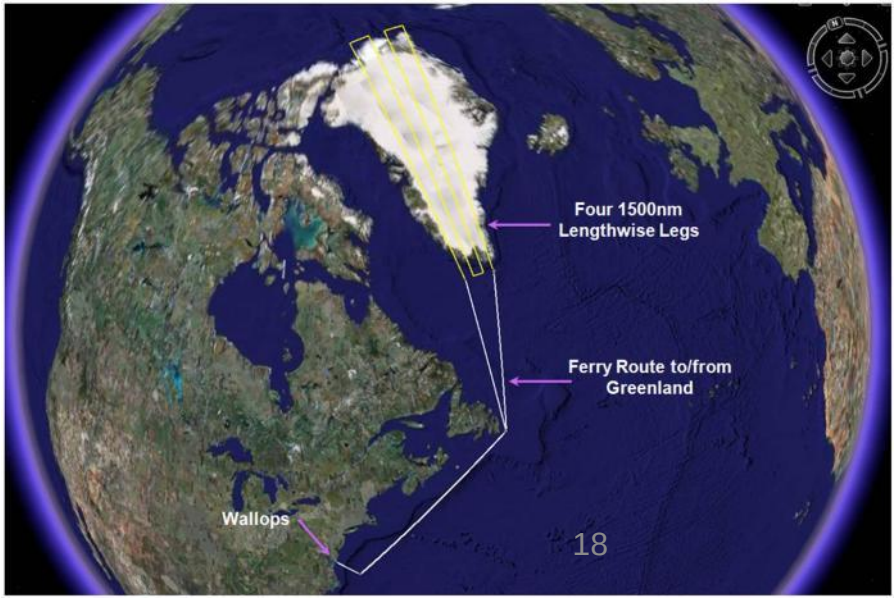

HDVIS/StarDot Sat Aug 28 22:26:48 2010 Flight -GLOPAC_4
Exposure: 5 MAC 0030F4-D1127B
Frame number 355073
Internal Temperature 14.5°C
Tropical Depression

Future Mission Capability

Portable Ground Station



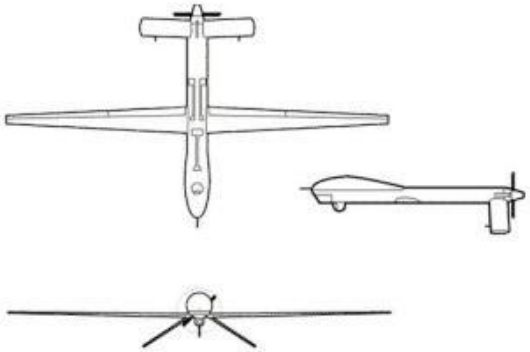




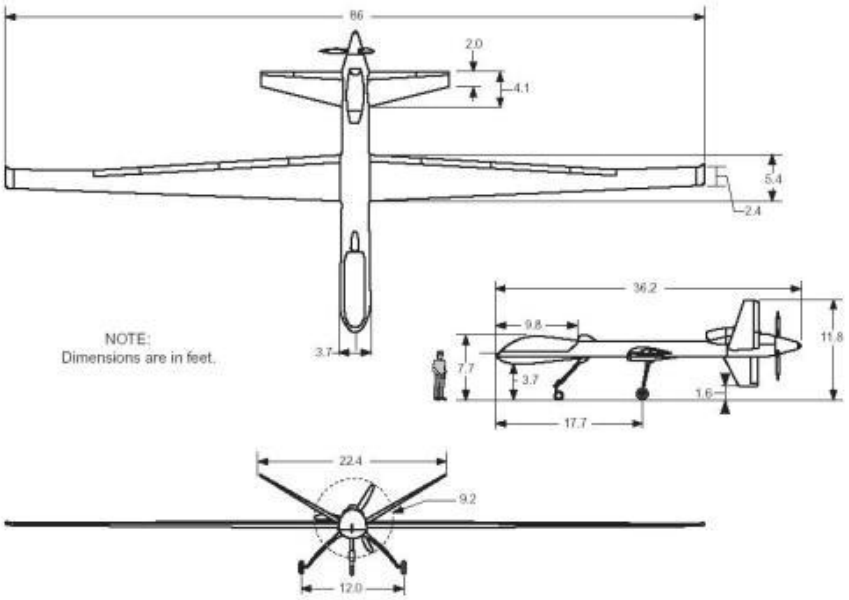
Global Hawk Project Team

Project Management, Pilots, Aircraft Mechanics, Avionics Technicians, Operations Engineers, Software Developers, Quality Assurance, Logistics, Public Affairs, Flight Test Engineers, Crew Chiefs, Configuration Management, Systems Engineers, System Safety, Range Safety, Ground Control Station Developers, Communications Engineers

MQ-9 Predator-B/Reaper (*Ikhana)*



MQ-1 Predator -A



MQ-9 Reaper/ Predator-B

NASA MQ-9 *Ikhana*

Ikhana **= Native American Choctaw word for**

“Intelligence”

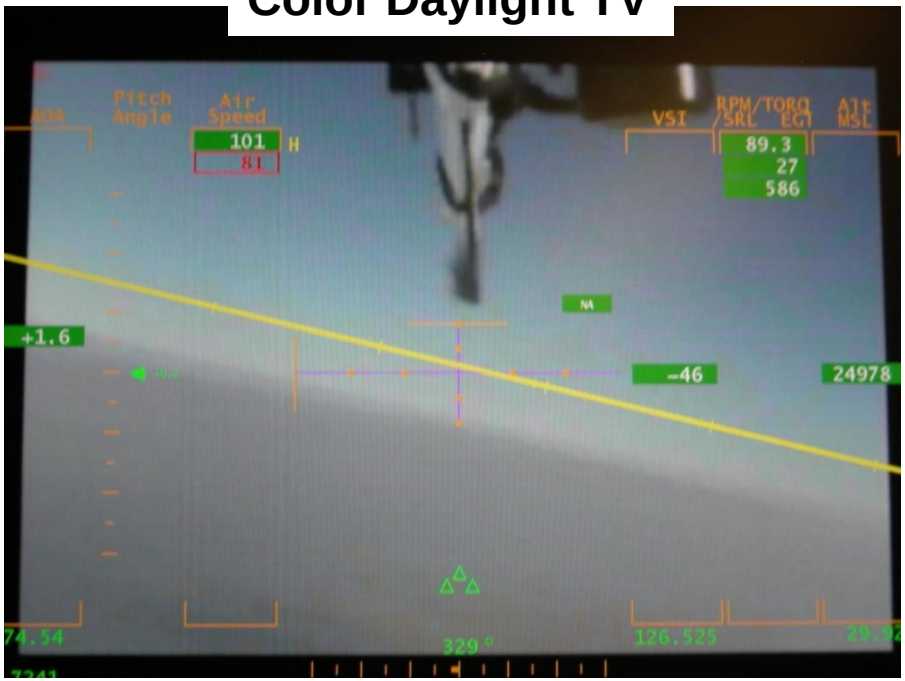
“Learning”

“Awareness”

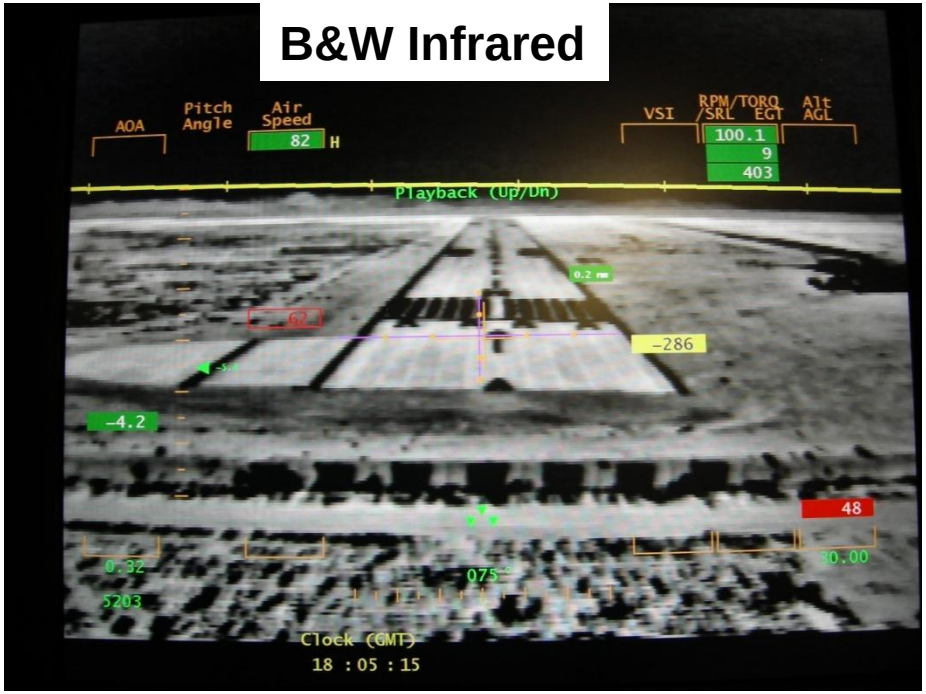
GENERAL ATOMICS
AERONAUTICAL SYSTEMS

Two Cameras in the Nose

Color Daylight TV



B&W Infrared



Initial power-up, fueling, engine start, and local area flying

Ground Control Station

Over The Horizon
Long Range Link
Ku-bandSatCom

MQ-9 Ground Control Station (GCS)

Two Pilot Stations


Brawny

So, what's it like to fly a UAS?

Well….What if you stepped into your cockpit…

…and you lost 4 of your 5 senses?

You **only** have *vision!*

Only 1 sense?

- You ***can't hear*** the engine rpm fluctuating
- You ***can't feel*** vibrations, accelerations or motion
- You ***can't smell*** the fuel leak
- You ***can't taste*** the electrical fire smoke
- AND, you ***lose vision*** in one eye, 30º FOV!
- WELCOME to UAS flying!

The nightmare of poor interface design

With decades of evolving cockpit design, today's aircraft exhibit common standard control and display formats and arrangements.

Example: The "T" arrangement
It works in many types, small and large.

Cessna 182

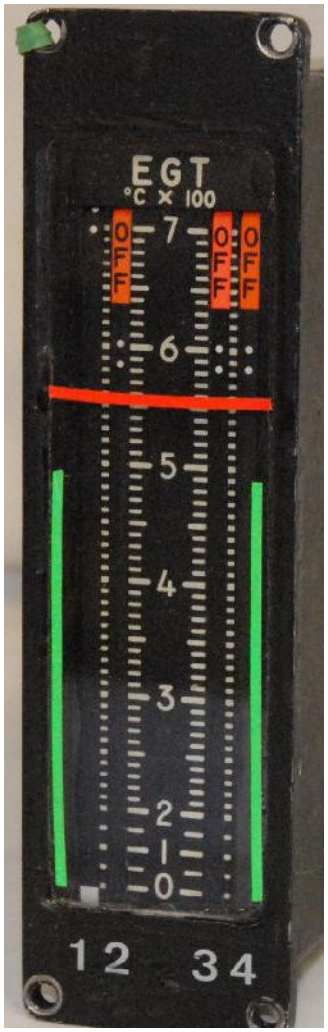
Boeing 737

Humans are analog, tactile, visual.

What about the displays and controls?

No need to memorize numbers if the normal range and limits are displayed (red lines, green arc).

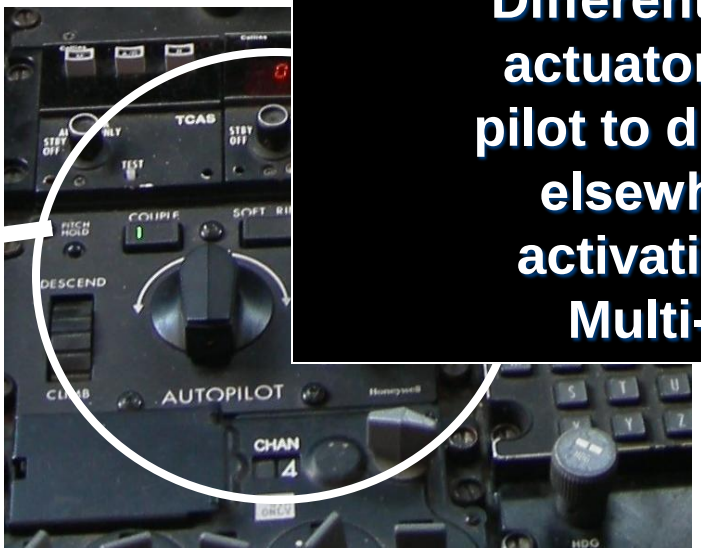
Digital display might not readily show trends and relationship to limits



Digital Information
Can be displayed in Analog Format

Unmanned Aircraft System
Digital /Tabular Display Format

Use of the Tactile sense



Different shapes of actuators enable the pilot to direct attention elsewhere…while activating systems. Multi-tasking

Q: What's a "pilot"?

Defining “Pilot” :
Recognizing a changing paradigm

What is a “pilot” ?
Knowledge, Ability, and Skill Sets

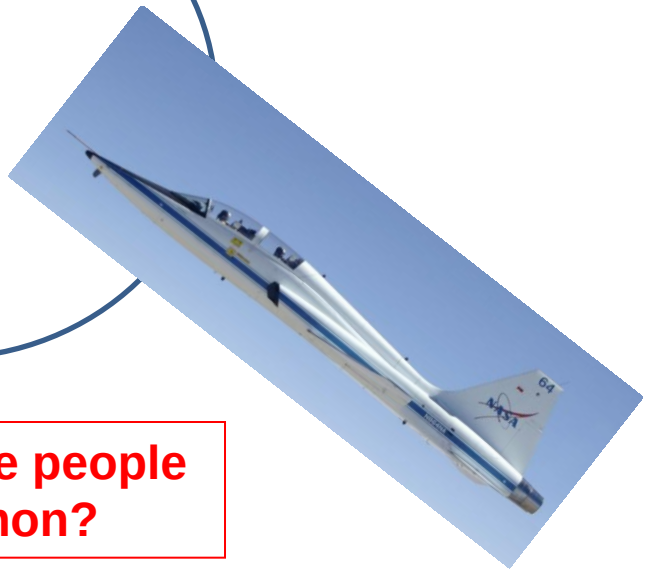
(relative relationships are not necessarily to scale)

Video Gamer
Reset Button

Radio Controlled
Visual Line-of-sight
Sometimes…left is right, and vice versa.

Piloted (manned) Aircraft
Self-preservation instincts.

Remotely Piloted Unmanned Aircraft
Skill sets depend on control method



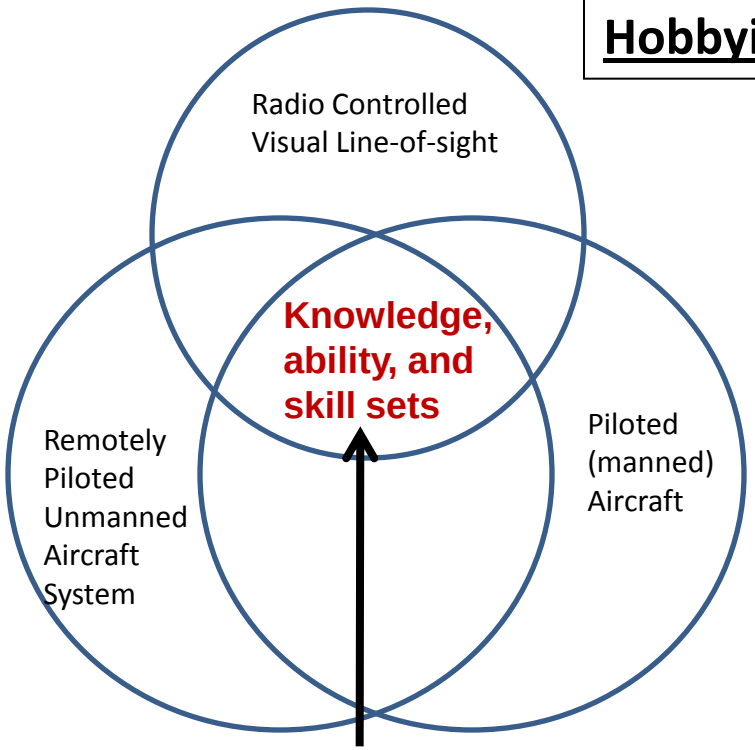
What do these people have in common?

What is a “pilot” ?
Knowledge, Ability, and Skill Sets

(relative relationships are not necessarily to scale)

Video Gamer

Model airplane Hobbyist



UAV Pilot

Jet Jock

Airmanship / Air Sense / Knowledge: **Navigation; Communication protocols; FAA Airspace Rules, Requirements, and Regulations; Terminal area procedures, Weather forecasting and alternate airfield assessment, Mission planning, Emergency procedures, aircraft systems, principles of flight, etc.**

Western States Fire Mission

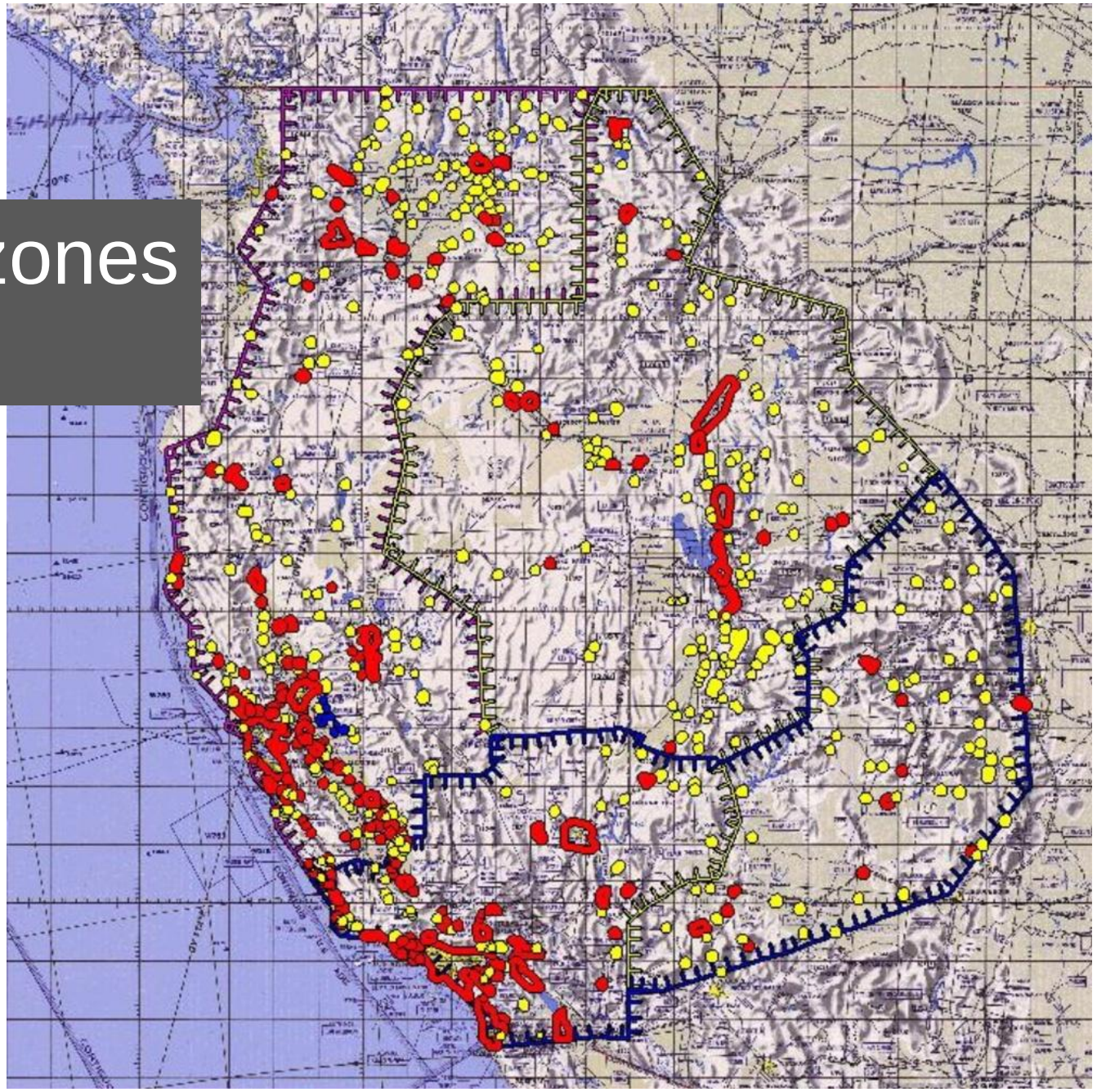
Where do you put Limited Resources?

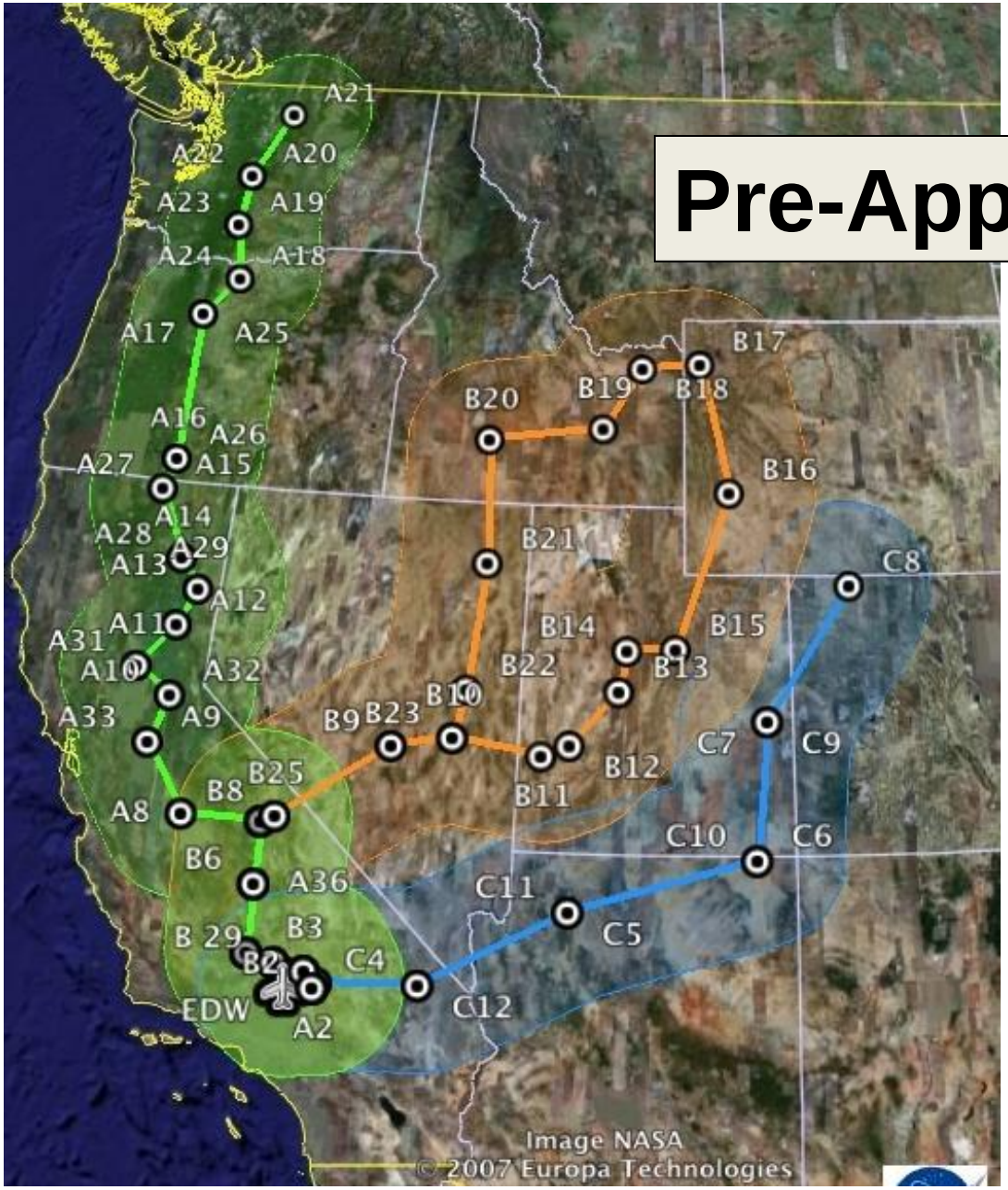
…and keep them Safe!

FAA Provisions

- **One assigned Flight Level (FL 230), in Class A airspace.**
- **-Two-way radio communication and transponder.**
- **- Climbs/descents while in Edwards AFB airspace.**
- **File flight plan 72 hrs prior, fly 1 of 3 “standardized” routes.**
- **Demonstrated “Lost Link” ability: Return via same route.**
- **Emergency landing sites: Military only.**
- **Designate “set-down sites” (fields, lakebeds) if engine failed.**
- **MQ-9 demonstrated reliability/capability/systems redundancy**

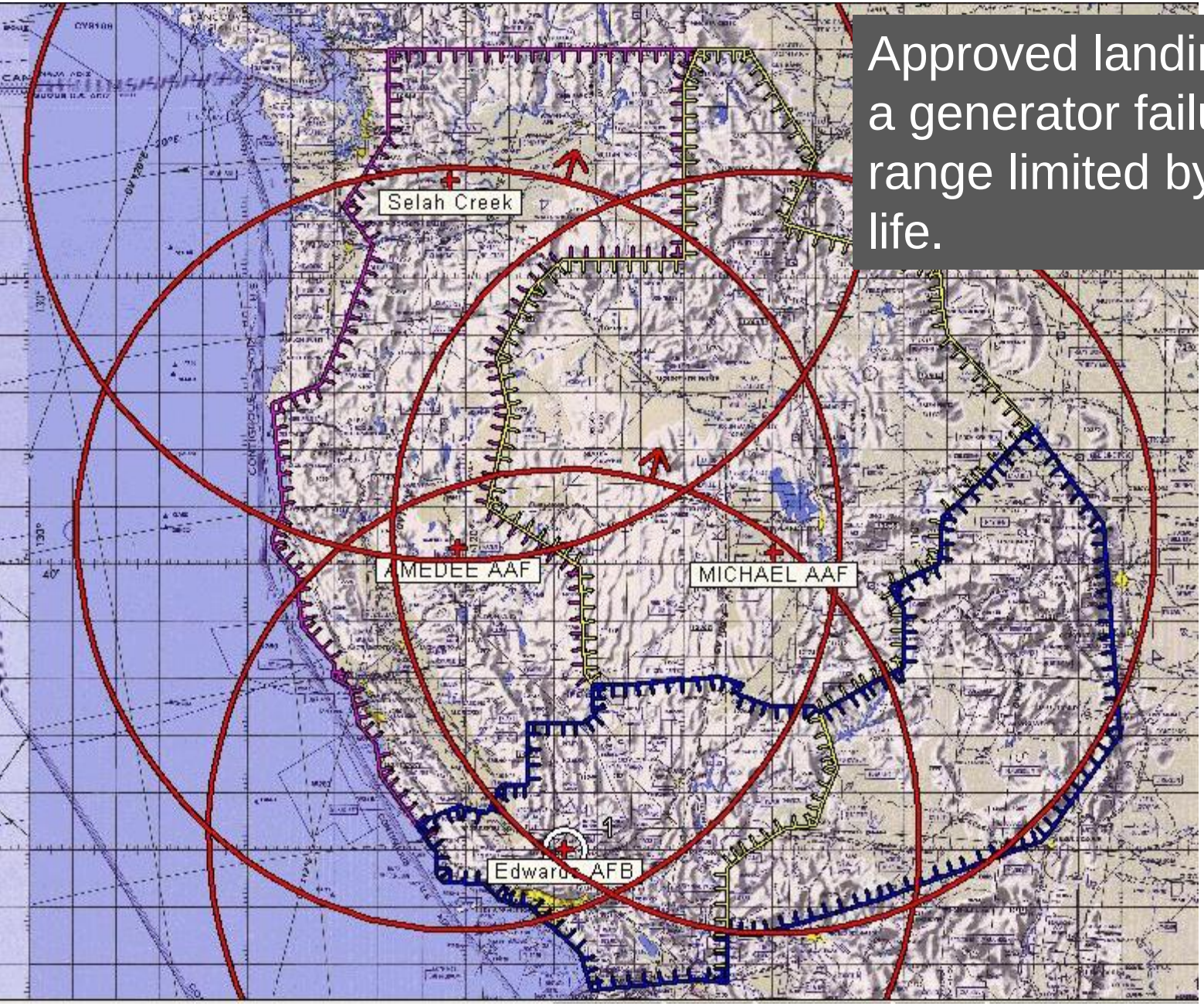
Keep-out zones



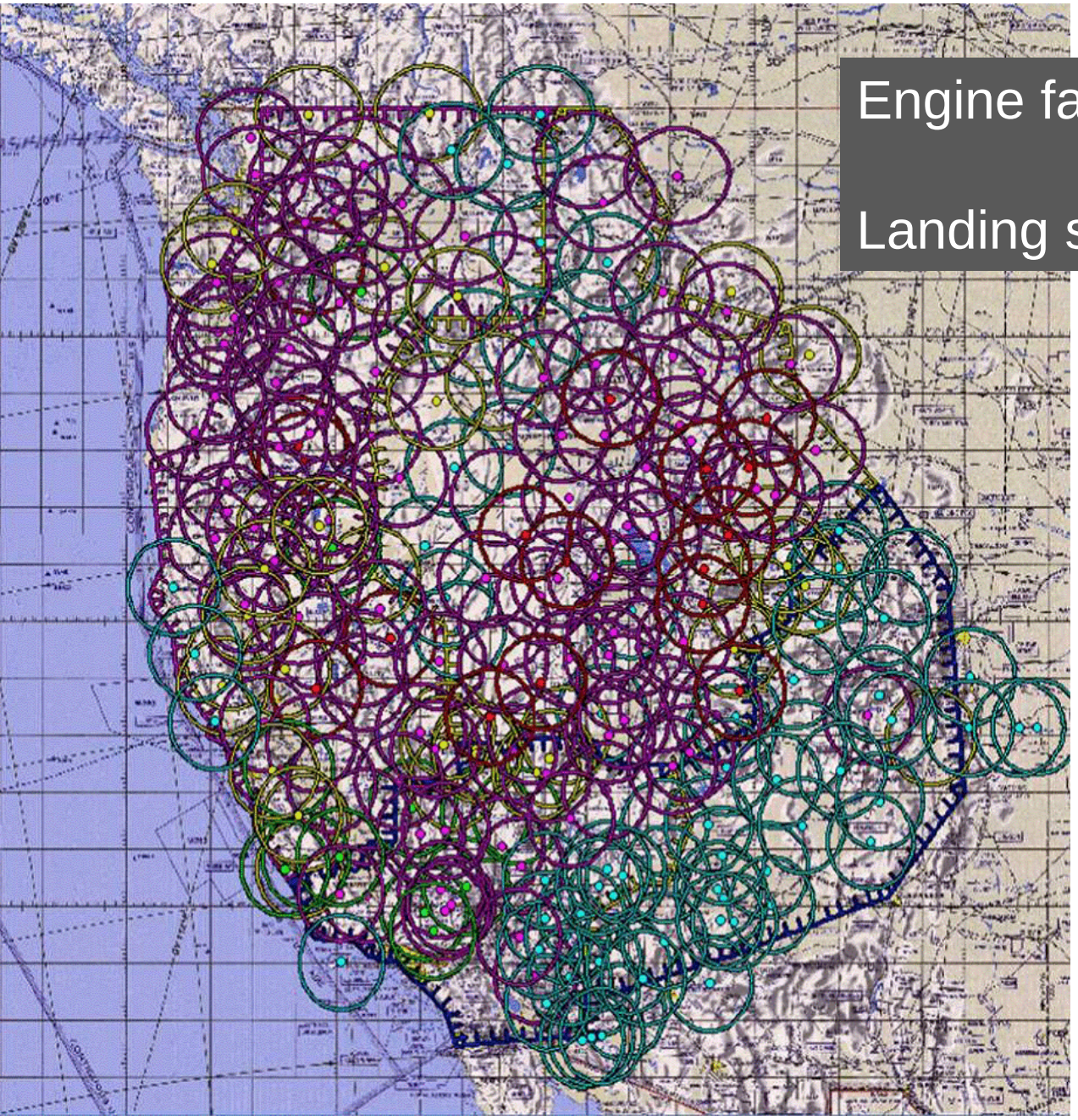


Pre-Approved Routes

Actual flight route negotiated in real-time to acquire data over fires.



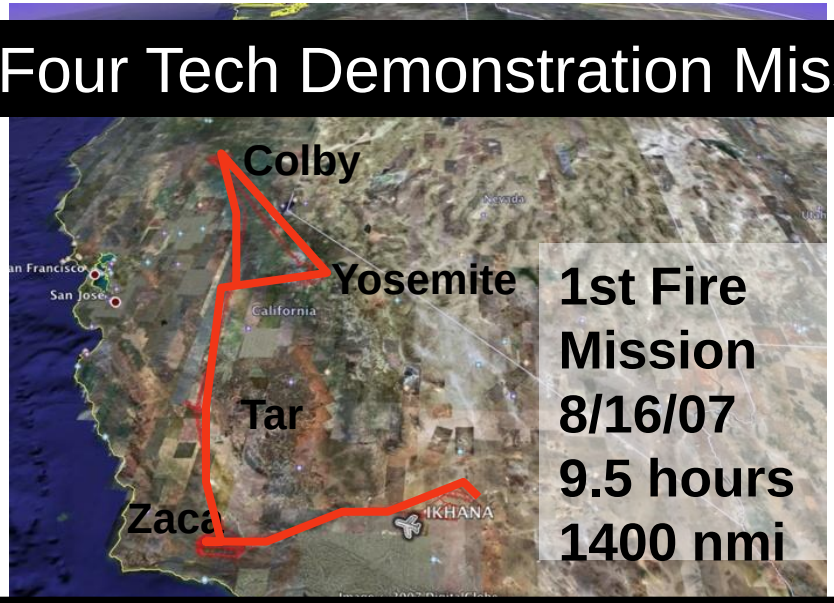
Approved landing sites for a generator failure and range limited by battery life.



Engine failure glide range

Landing sites

Four Tech Demonstration Missions



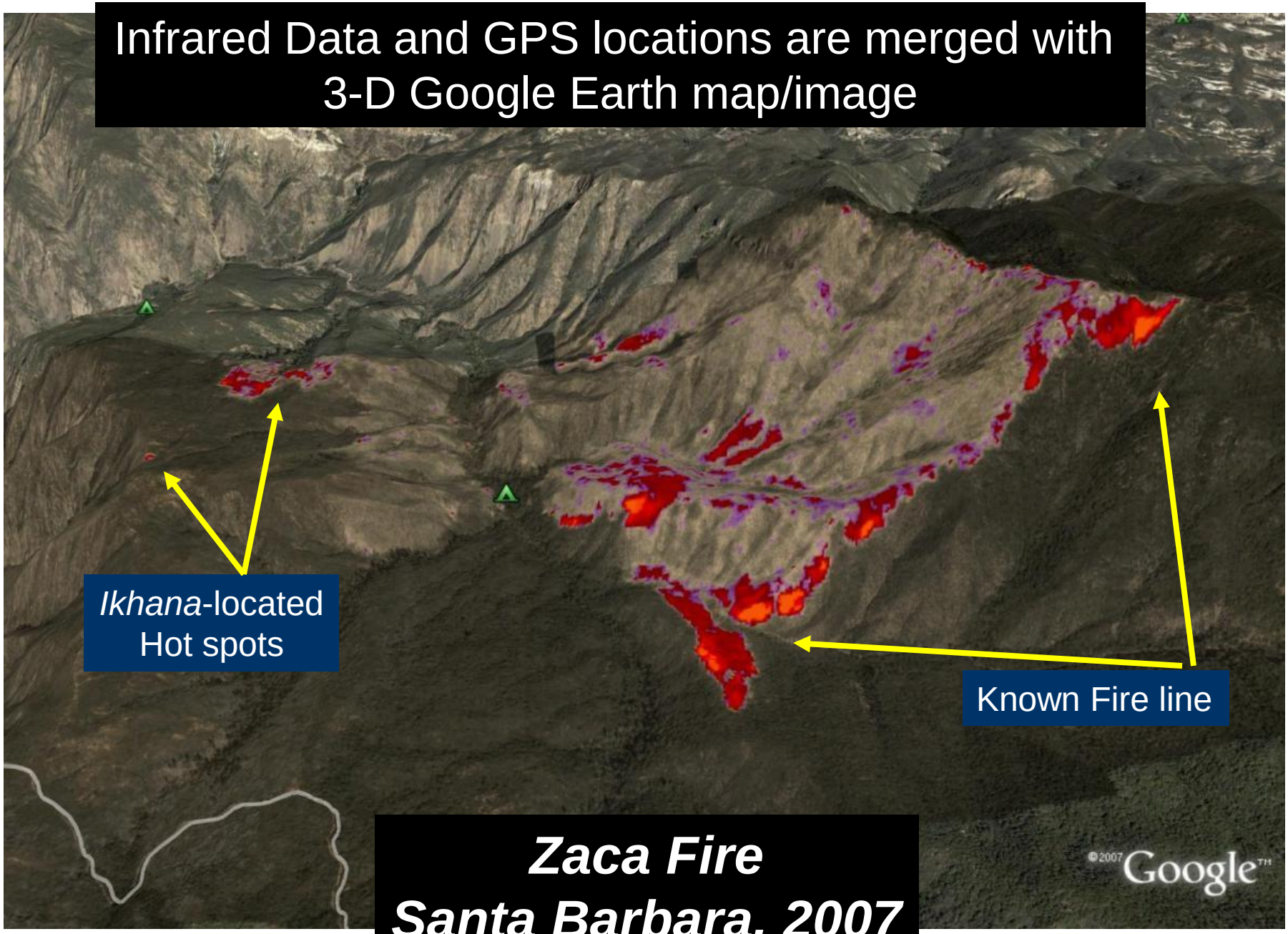

Edwards AFB
IKHANA
~1350 nmi route
~9 hours
Ranch, Buckweed
Grass Valley, Slide
Los Angeles
Anacapa Island
Riverside
Anaheim
Santa Ana
Santiago
Long Beach
Rice
Santa Catalina Island
Ammo
Poomacha
Nicolas Island
Witch
San Clemente Island
Harris
Image NASA San Diego
© 2007 Europa Technologies
Image © 2007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

The end product:

Infrared data “draped” on Google Earth 3-D terrain maps.

Delivered to the Fire Incident Commander in less that 10 minutes.


Treasure Island
Lake Arrowhead
Lone Pine Island
SLIDE
NASA Ikhana Fire Imagery


Infrared Data and GPS locations are merged with 3-D Google Earth map/image
Ikhana-located Hot spots
Known Fire line
Zaca Fire Santa Barbara, 2007
©2007 Google™

Successful Results
Quotes from the Fire Incident Commanders:

- "…fire-fighting resources effectively applied…"
- "I've seen the future, and it's here."
- "10,000 residences saved today, thanks to NASA…"

Thanks for listening.