



# Flying Unmanned Aircraft: A Pilot's Perspective

*"It's not unpiloted..."*



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Note: The information in this presentation is the author's and may not reflect official NASA policy

# TOPICS

- **Pilot – Vehicle Interface Design**



- **Concept of Pilot / Operator**



- **Western States Fire Mission**

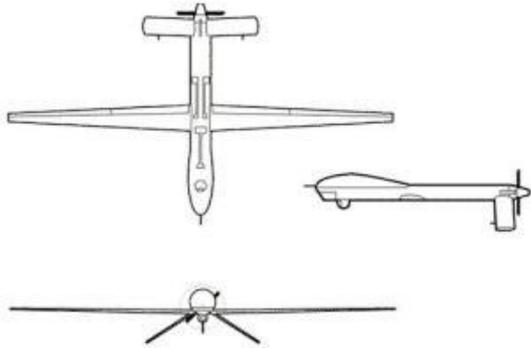


# A LEGACY OF UAV RESEARCH at NASA DRYDEN



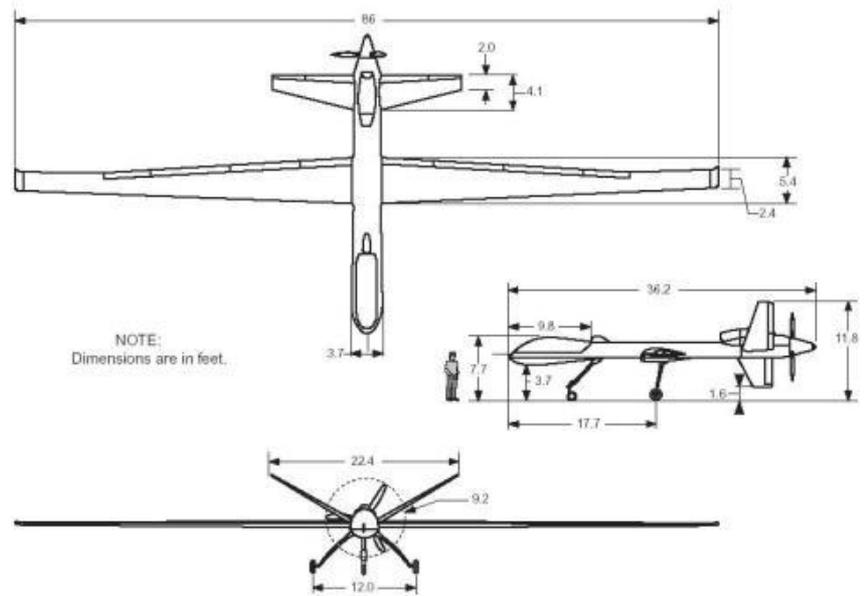
# More Uninhabited Vehicles





## MQ-1 Predator -A

48 ft wingspan  
2500 lb



## MQ-9 Reaper/ Predator-B

66 ft wingspan  
10,500 lb



Altitude: 45,000 ft.  
Endurance: 24 hours

# NASA MQ-9 *Ikhana*

*Ikhana* = Native American Choctaw word for...

“Intelligence”

“Learning”

“Awareness”



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

**C-Band  
Line-of-sight  
antennas**



# Ground Control Station



Over The Horizon  
Long Range Link  
Ku-band SatCom





Two Pilot Control Stations



The Control Room is in the cockpit!  
-Conversations  
-Phones Ring  
-People come and go

Two Cameras  
1. Daylight Color  
2. B&W IR



AOA

Pitch Angle

Air Speed

VSI

RPM/TORQ  
/SRL EG1

A1E  
MSL

101

81

H

89.3

27

586

NA

+1.6

-0.2

-46

24978



329 °

74.54

126.525

29.92

7241

AOA

Pitch  
Angle

Air  
Speed

82

H

VSI

RPM/TORQ  
/SRL EGT

100.1

Alt  
AGL

9

403

Playback (Up/Dn)

0.2 mm

62

-286

-5.4

-4.2

48

0.32

5203

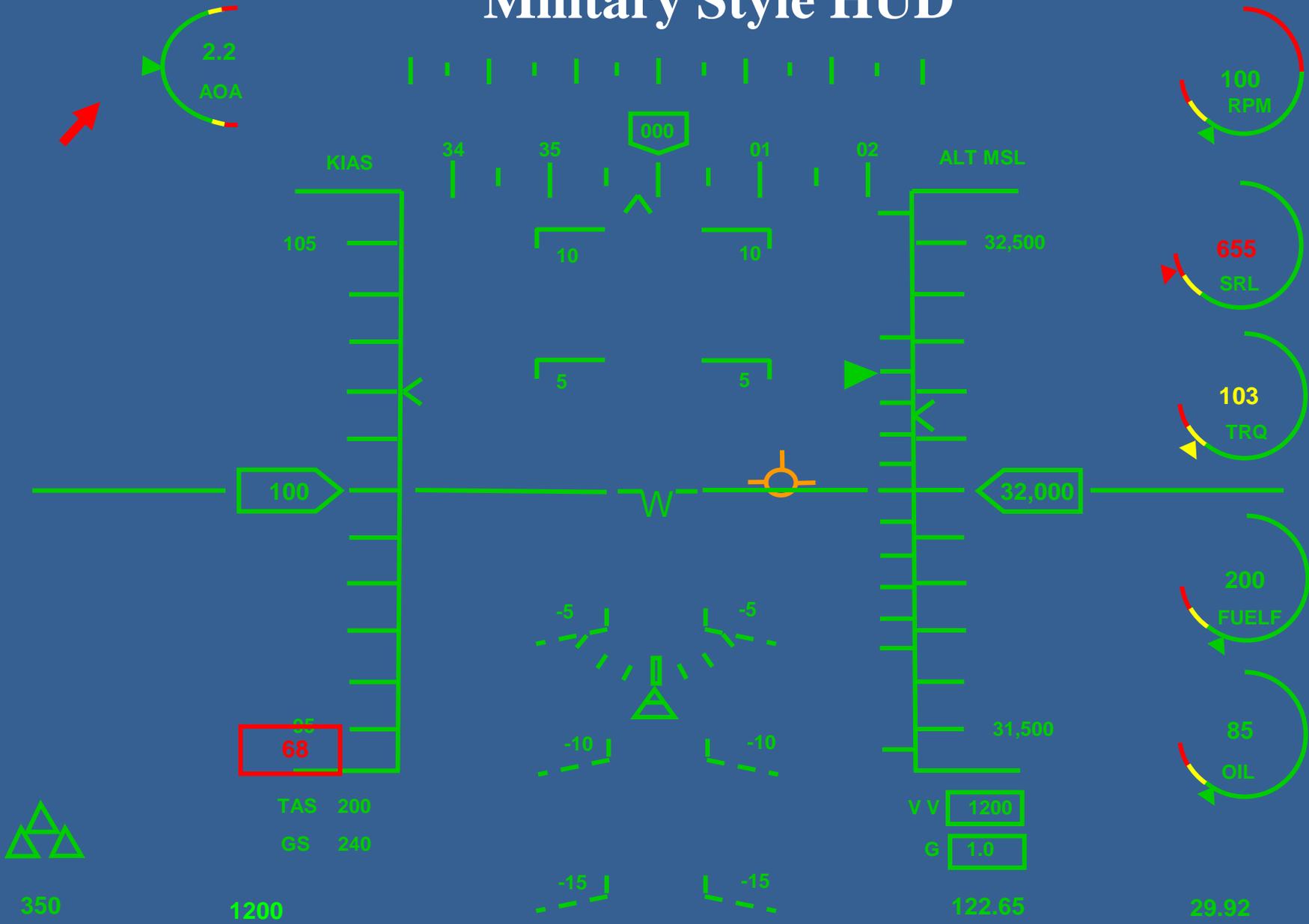
075°

30.00

CTock (GMT)

18 : 05 : 15

# Military Style HUD





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, 30° FOV!
- WELCOME to UAS flying!

# Pilot-Vehicle Interfaces

## Displays and controls

- WW II: Progression from Bi-Planes to Jets
- Post WW II: analyses of many accidents pointed to poor human-machine interfaces.
- Concerted effort over several decades has established standards and best practices for cockpit design.
- Multi-function, high task environment demands that error paths be minimized/simplified.
- Humans are tactile, visual, and analog...NOT digital.
- For the most part, the UAV development community has not utilized standardization of proven pilot-vehicle interface design.
- Some UAV mishaps are attributed to this (root cause).

# The nightmare of poor interface design



# Humans are analog, tactile, visual.

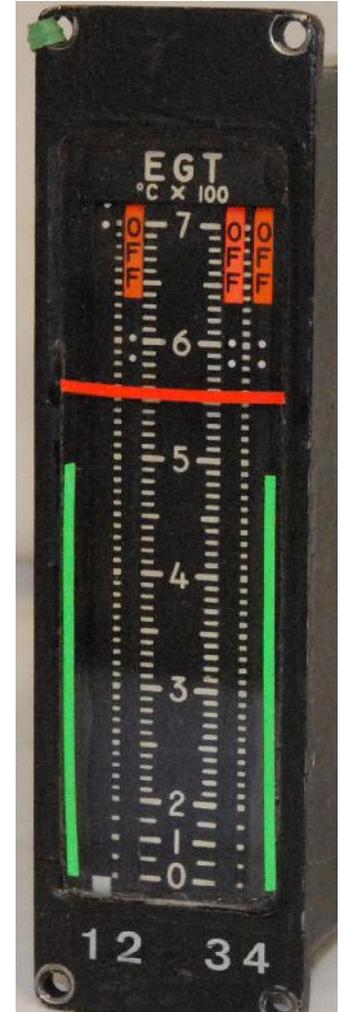
## What about the displays and controls?



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



**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**



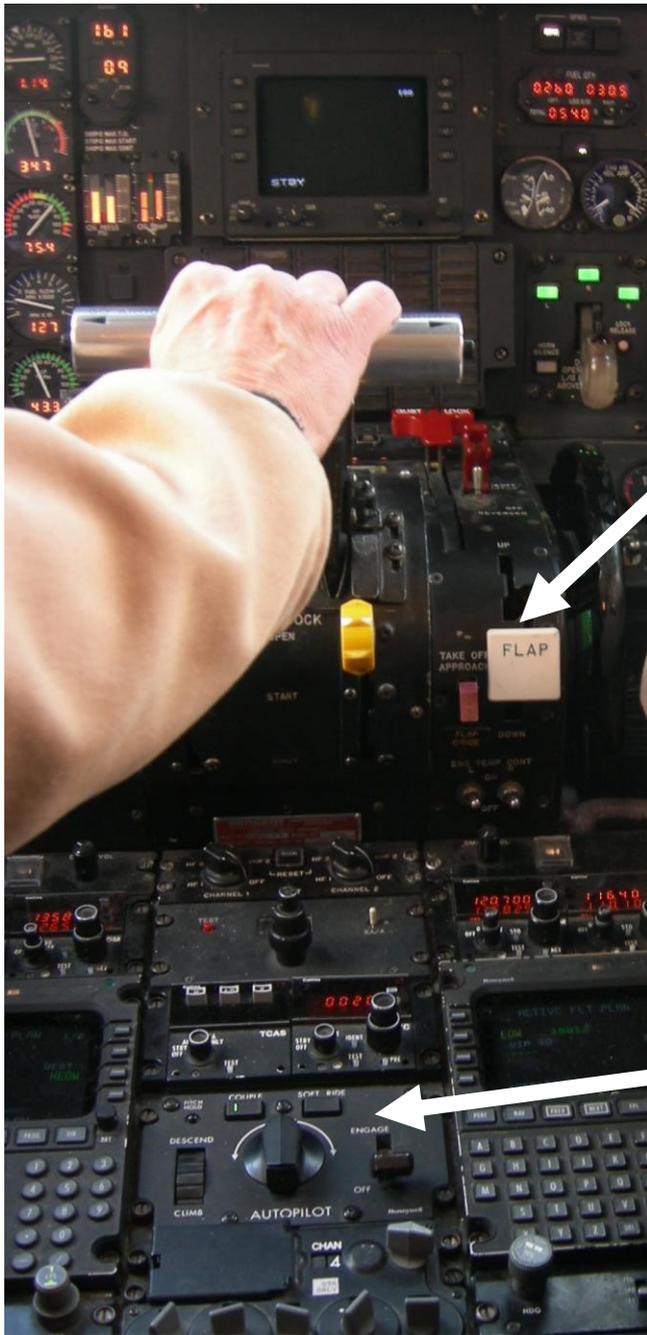
**Boeing 737**

# Digital Information ... in Analog Format



**UAS  
Tabular Display**

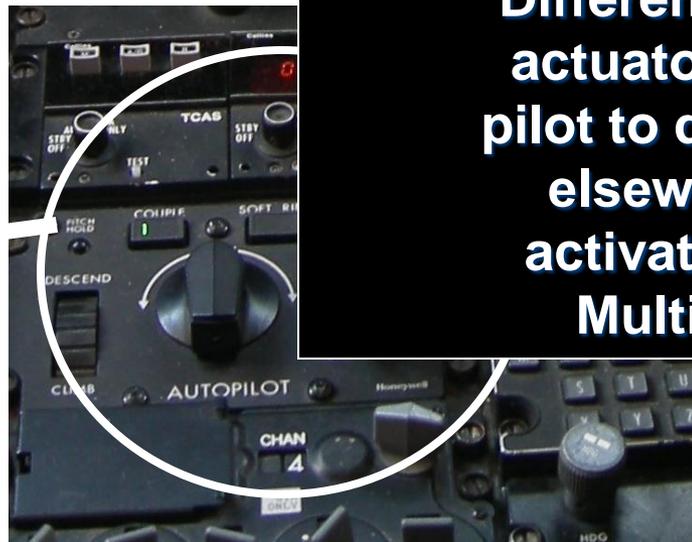




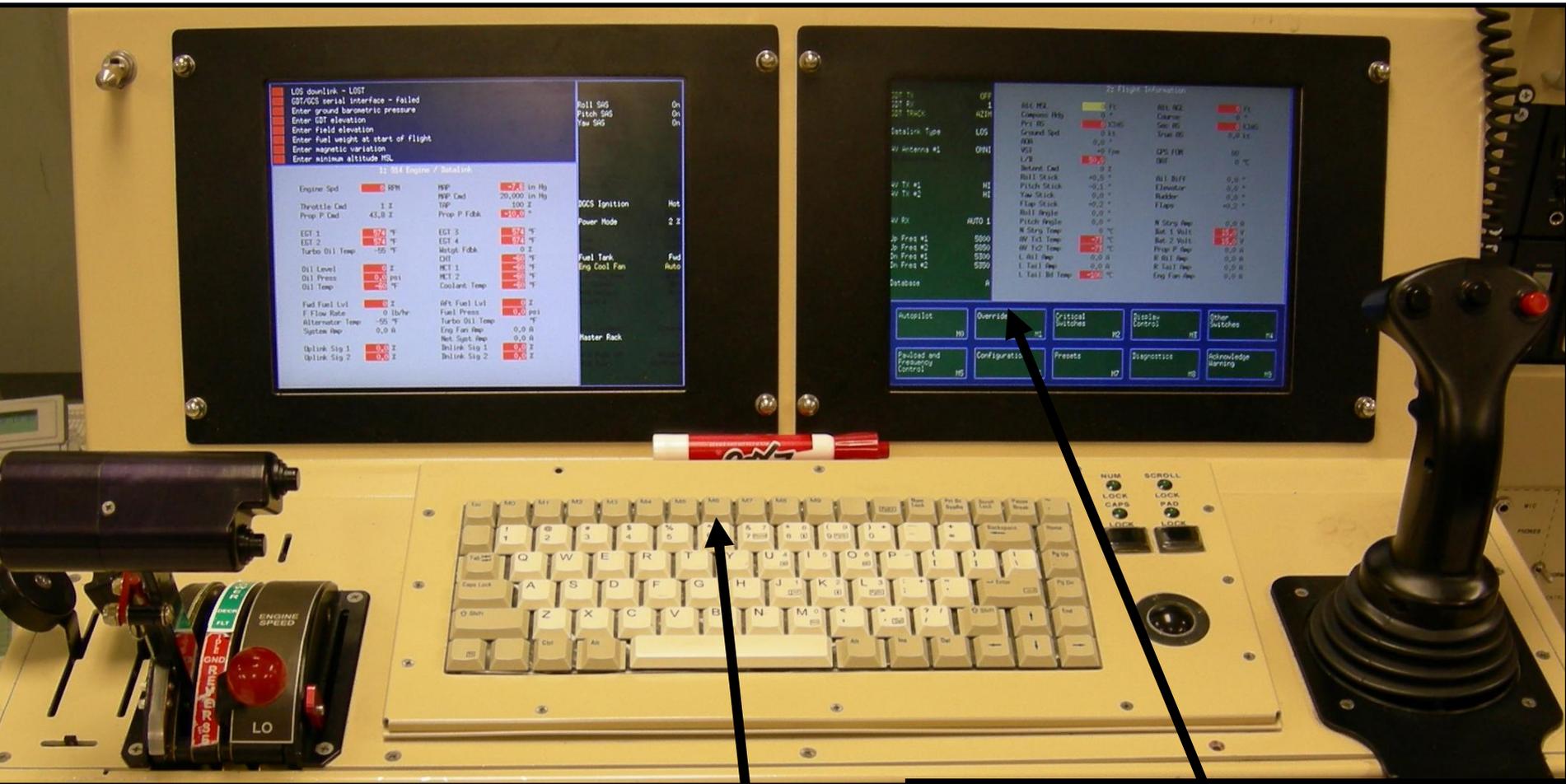
**Use of the Tactile sense**



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

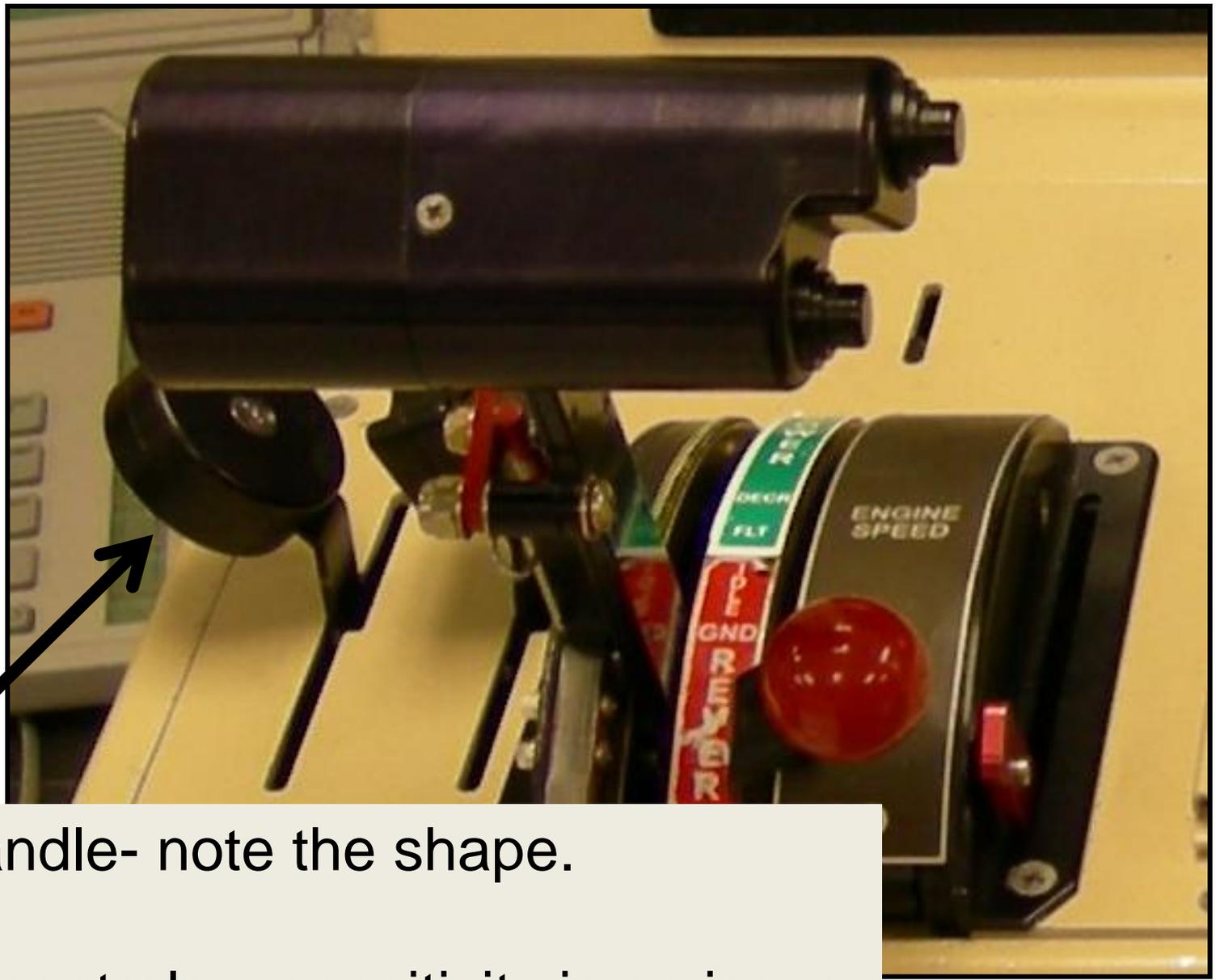


Systems Display Screens...all digital...no analog.  
Keyboard Controls...all switches are shaped identically.



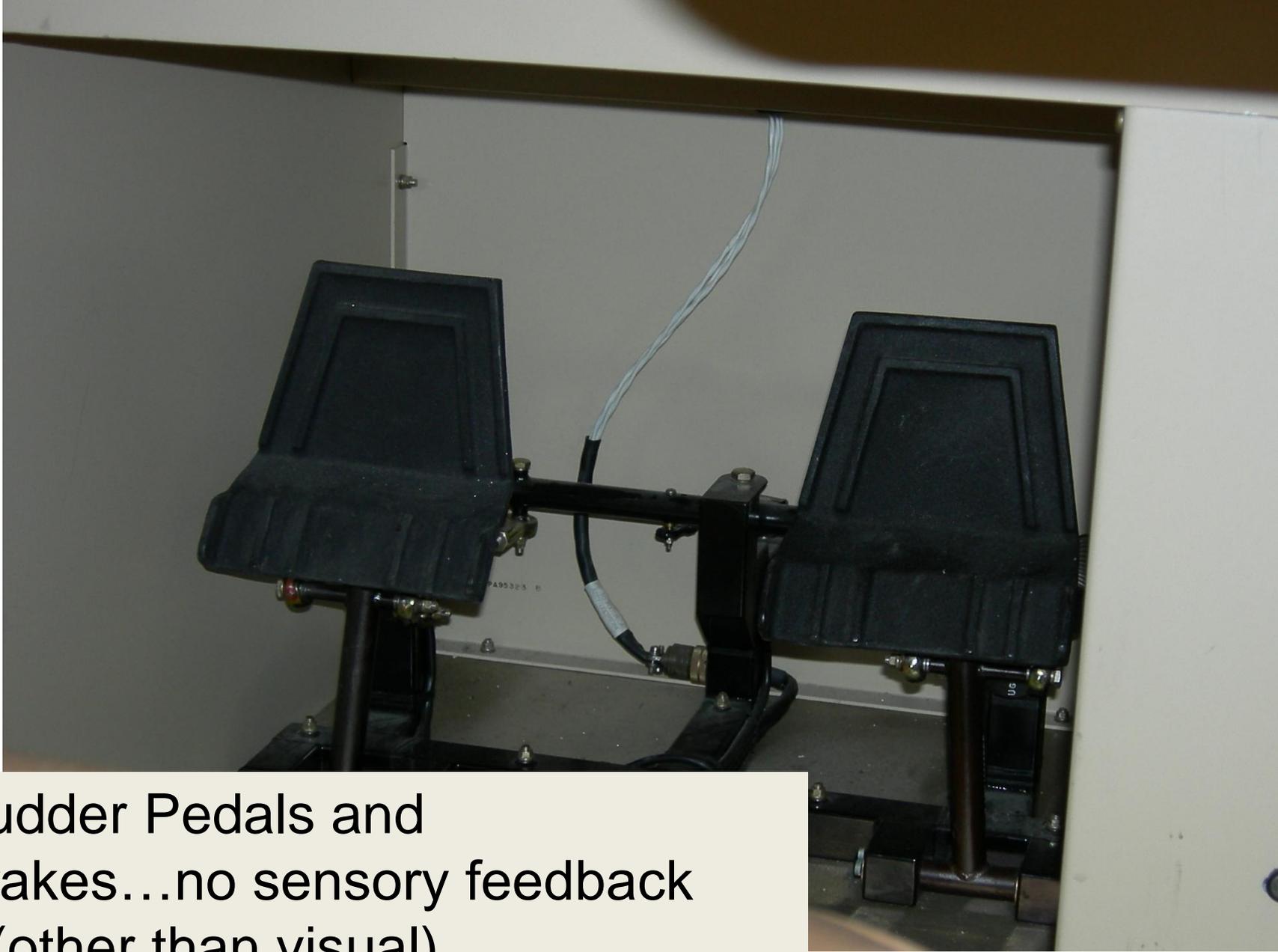
Cumbersome embedded menus

Visual Attention is diverted to the keyboard for systems actuation



Flap Handle- note the shape.

Engine controls – sensitivity is an issue.



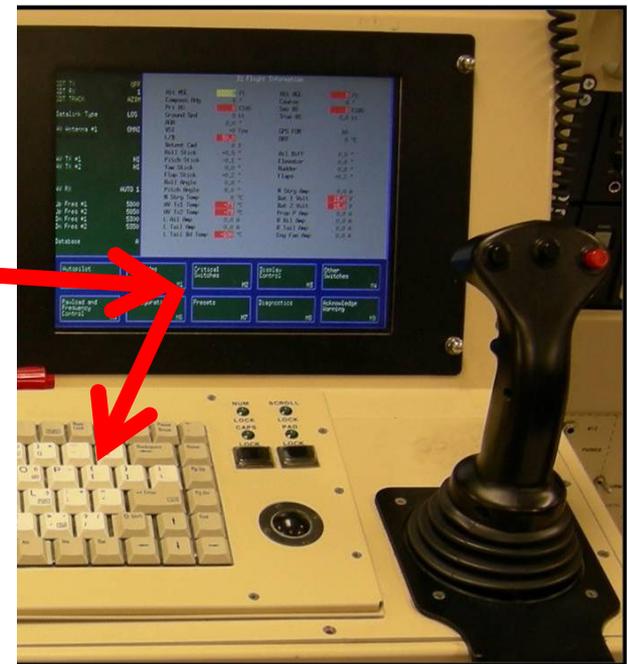
Rudder Pedals and  
Brakes...no sensory feedback  
(other than visual)

# Example of control / display issues

Q: How do I TURN **ON**  
the Fuel Heaters?

**Fuel Heat Inhibit**

**Disable / Enable**



# Example of Display and Control Issues

## IFF Transponder “IDENT” Task

1. Remove right hand from control stick
2. Move cursor to tracker display
3. Click on TOOLS menu
4. Scroll to IFF
5. Click to open IFF window
6. Click “IDENT” button
7. Click “APPLY”

**Accessed by trackball  
and Left/Right buttons**



Prototype Advance GCS are in Development  
But...by which standards? Company proprietary...



# RQ-4 Global Hawk



**Length: 44 ft**  
**Wing: 116 ft.**  
**GWT: 30,000 lb**

**Altitude: 65,000 ft.**  
**Endurance: 30 hours**

# Global Hawk Operations Center



Q: What's a "pilot"?

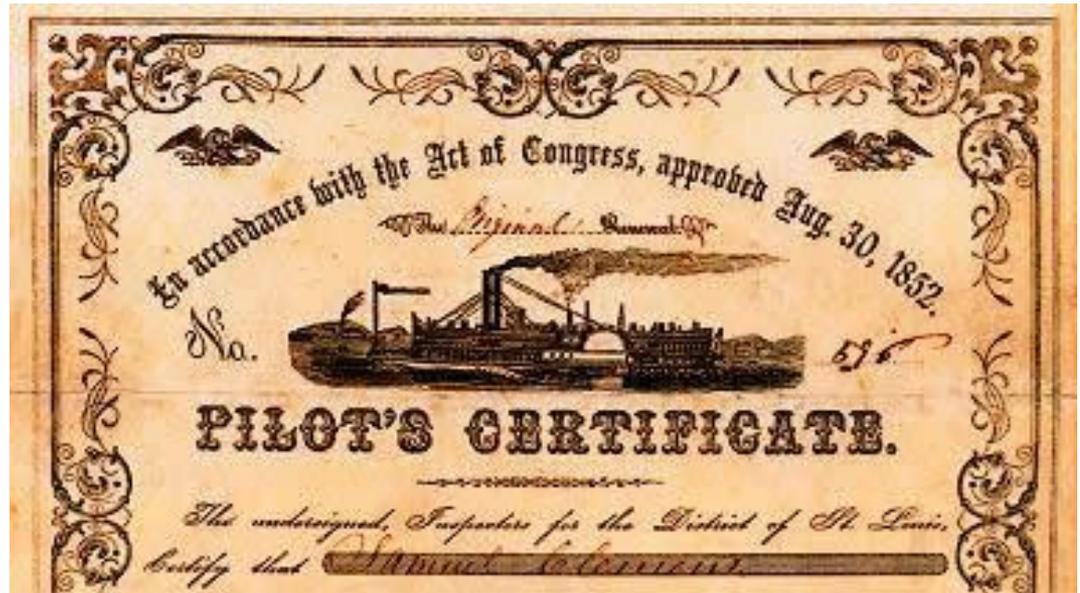
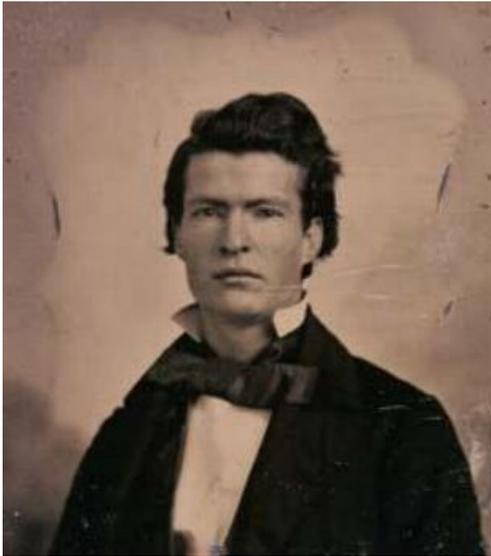
Q: What's a UAS pilot?



# Defining "Pilot" :

## Recognizing a changing paradigm

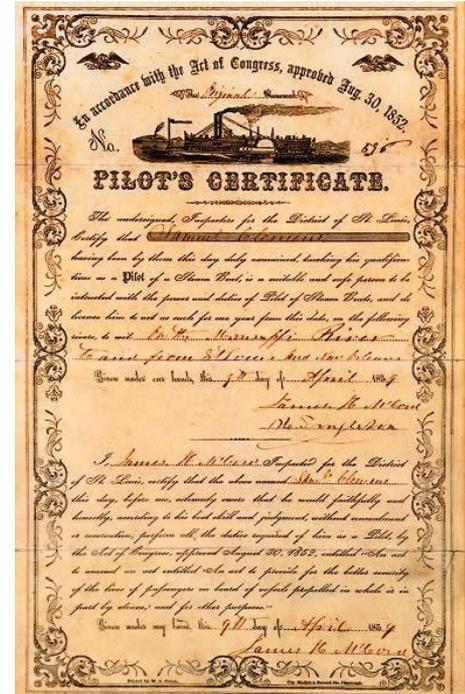


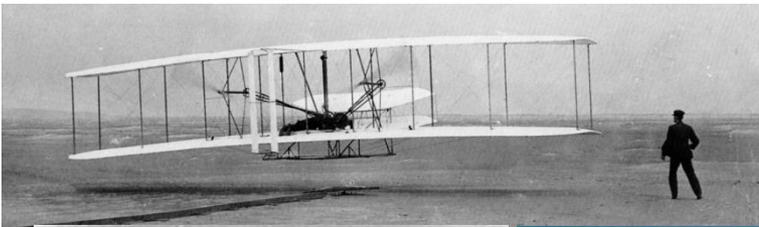


**Samuel Clemens and his Pilot's Certificate**

19<sup>th</sup> Century Pilot.

- Riverboat Captain
- Skills: River navigation, rudder control, soundings, shovel coal, supervisor...

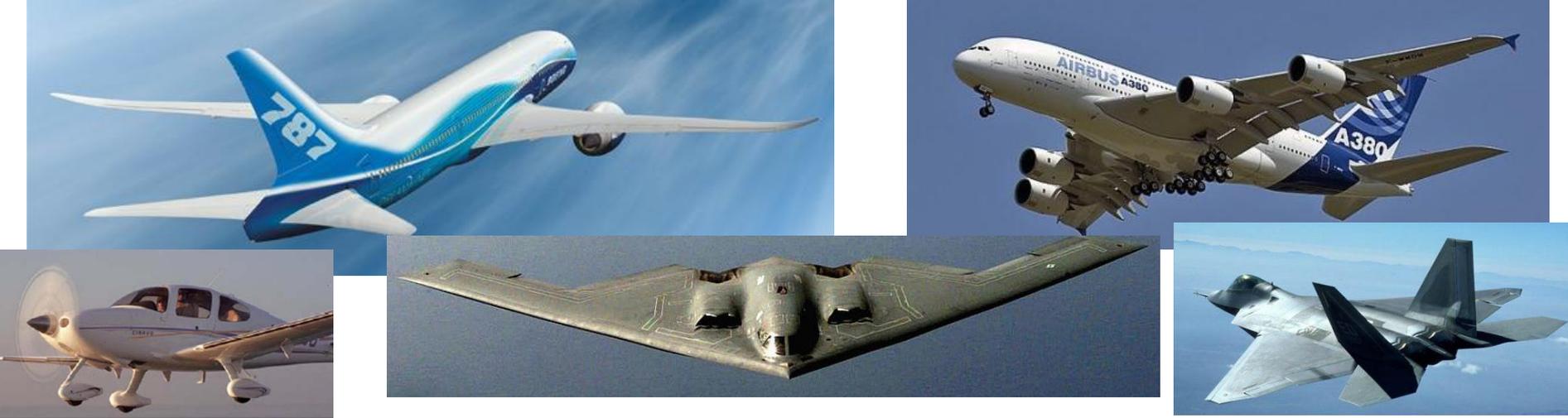




## 20<sup>th</sup> Century Pilot

- Strapped to an airplane, direct interface to controls.
- Motor skills are primary metric of performance
- Increasing use of automation, systems management.





21<sup>st</sup> century pilot... "fly-by-wire" ....

- Pilot is "Remotely" connected to the controls, systems management, monitor autonomous operations.
- **In some cases, motor skills have little/no relevance.**



Global Hawk cockpit:  
Autonomous operations.  
Mouse and keyboard controls.



# What is a “pilot” ?

## Knowledge, Ability, and Skill Sets

(relative relationships are not necessarily to scale)



Video Gamer



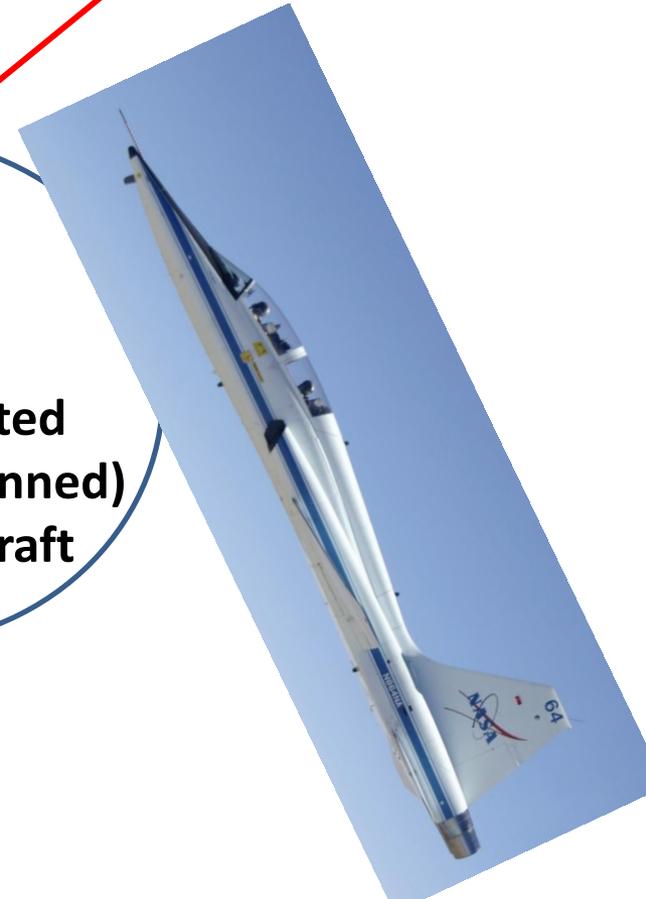
Radio Controlled  
Visual Line-of-sight

Remotely  
Piloted  
Unmanned  
Aircraft  
System

Piloted  
(manned)  
Aircraft



**What SHOULD  
these people  
have in common?**



# What is a “pilot” ?

## Knowledge, Ability, and Skill Sets

(relative relationships are not necessarily to scale)

**Video Gamer**

**Reset Button**

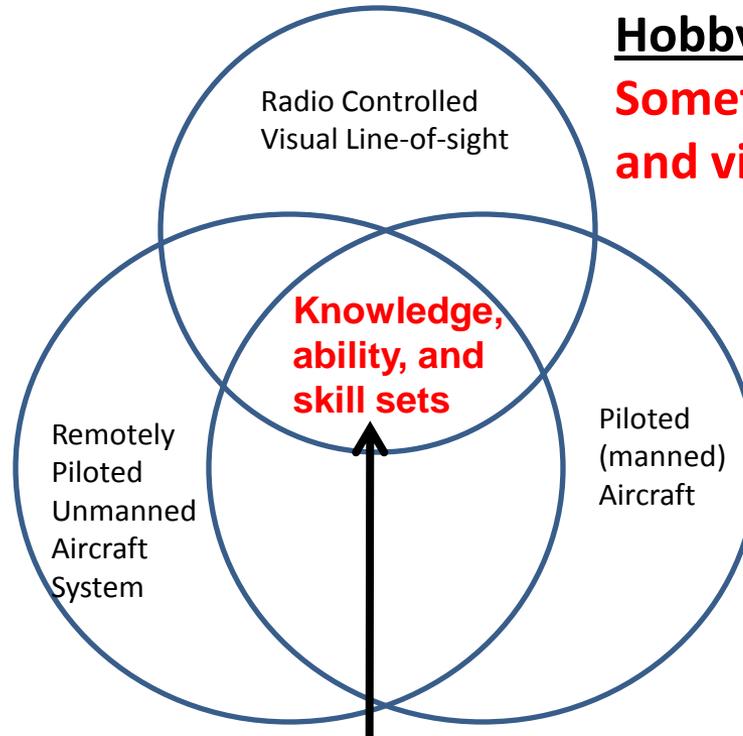
**Model airplane**

**Hobbyist**

**Sometimes...left is right,  
and vice versa.**

**UAV Pilot**

**Skill sets depend on  
control method**



**Jet Jock**

**Self-preservation instincts.**

**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.**

NASA Proposal:  
A Collaborative R&D Effort  
with DOD, DHS, and FAA

Objective is integration and routine access to  
NextGen ATM System  
and National Airspace System

- **Separation Assurance/Sense & Avoid**
  - **Systems Verification/Validation**
- **Frequency Spectrum Management**
  - **Human-Machine Integration**

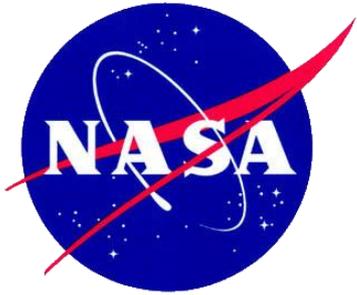
# Pilot Vehicle Interface Issues

- UAS Pilot/Operator
  - Loss of senses
    - Audition
    - Vestibular Cues
    - Olfactory
    - Monocular vision & reduced FOV (e.g., 30 degrees)
- Long duration missions ...complacency, boredom
- Crew handovers
- No standard requirements/training
  - USAF - rated pilots
  - Army - specially trained soldiers
  - Raven operators - one week of training

# Pilot Vehicle Interface Issues

- Ground Stations
  - Lack of standardization
  - Lack of application of 70+ years manned cockpit experience
  - Huge disparity in level of automation & proposed use of NAS
    - Raven, Predator, Shadow, Global Hawk
  - Rush to service
    - Advanced Concepts Technology Demonstrations
    - Engineering displays became operational
      - Improved GCS efforts are underway
  - Proprietary
  - Generally not built with eye toward NAS
  - UAS specific issues
    - Delays
    - Loss of link
    - Contingency operations
    - Link strength/Type
    - Data-link Frequency Use
    - Vehicle Speed/maneuverability (pilots and ATC)

# Western States Fire Mission





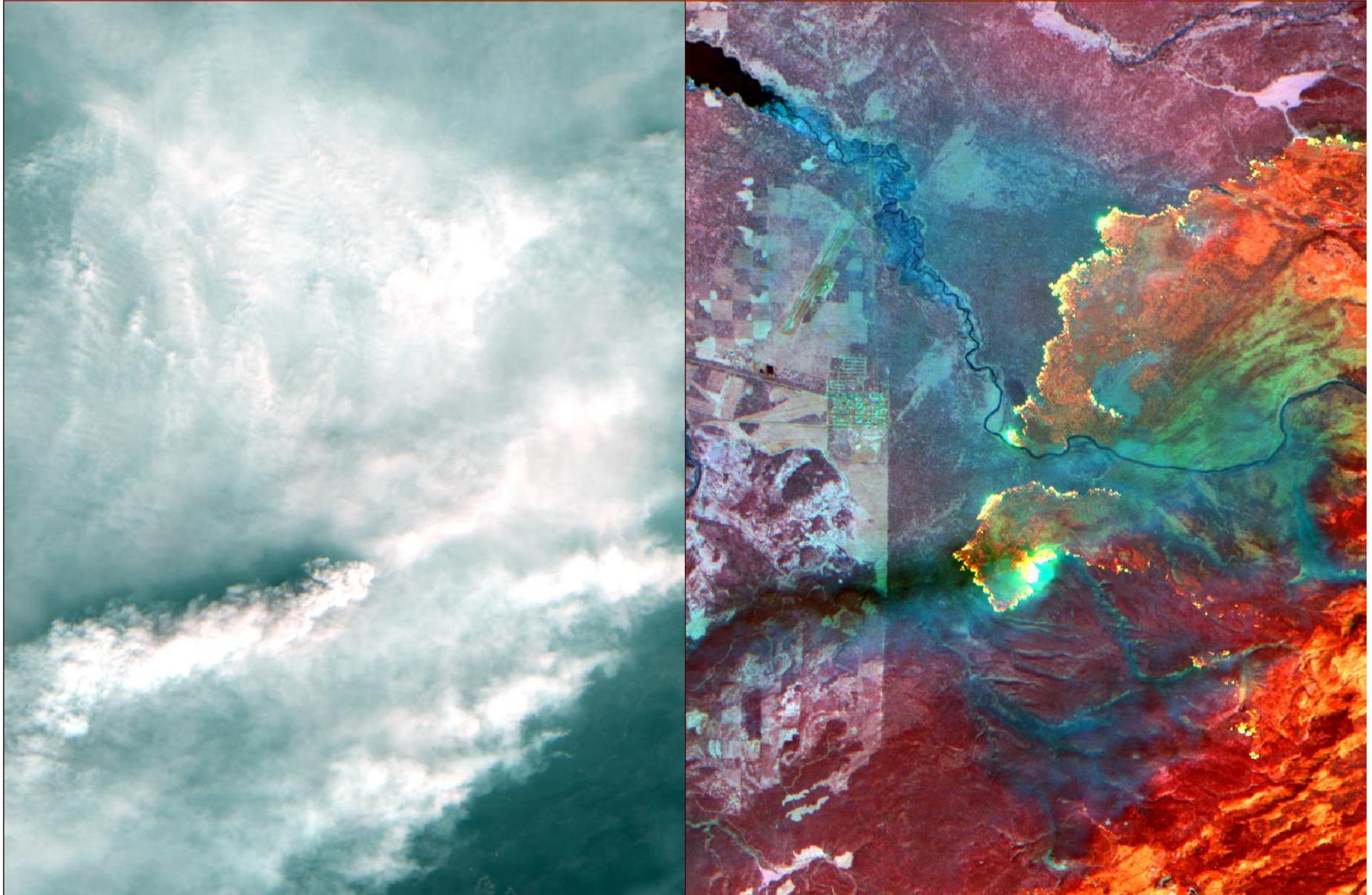
Where do you put  
Limited Resources?



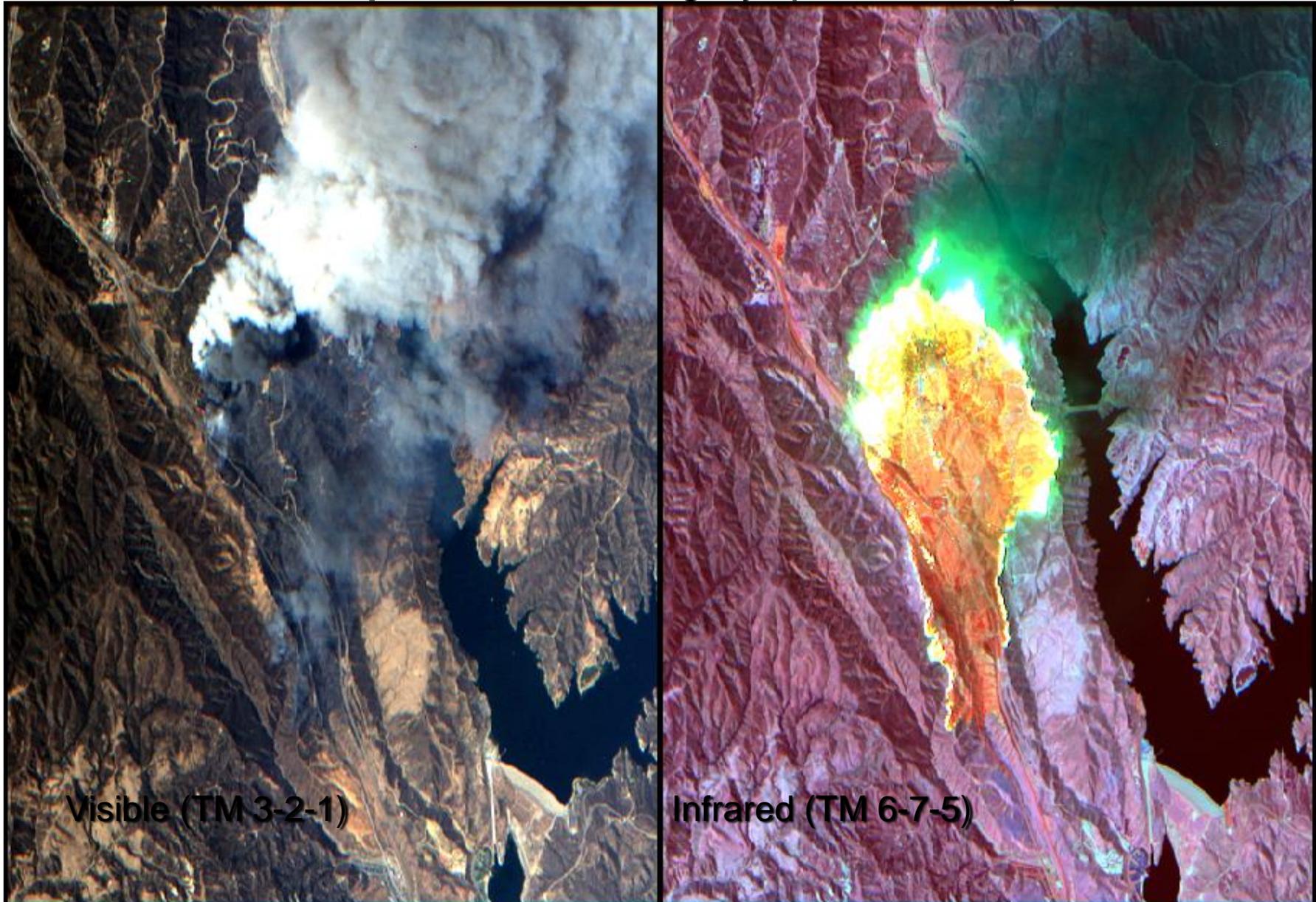
...and keep them  
Safe!



# Yellowstone Fires from ER-2



# Representative Imagery (From ER-2)

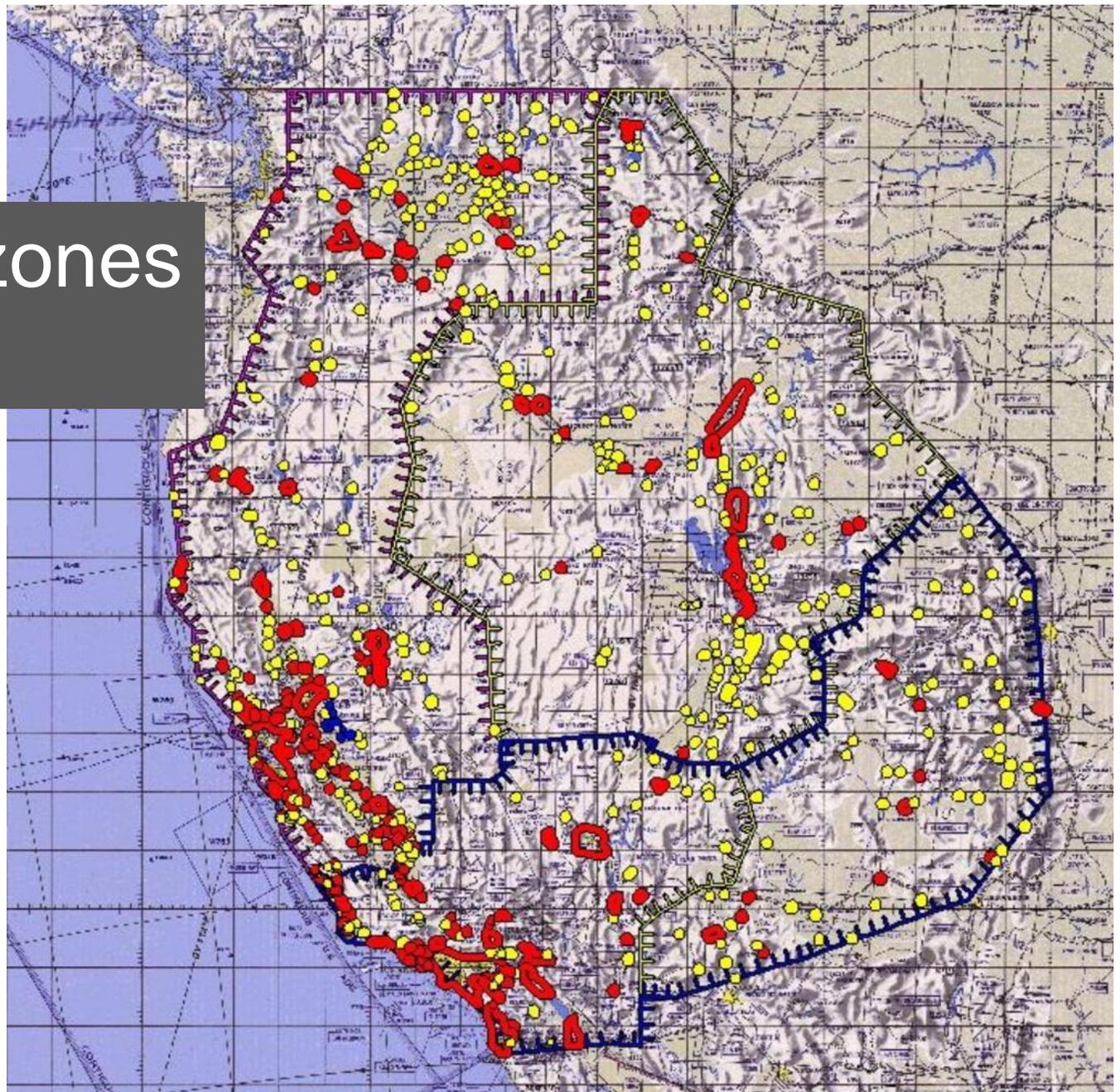


**Castaic Fire, CA (8/26/96)**  
(25 Meter Resolution; 65,000 ft AGL)

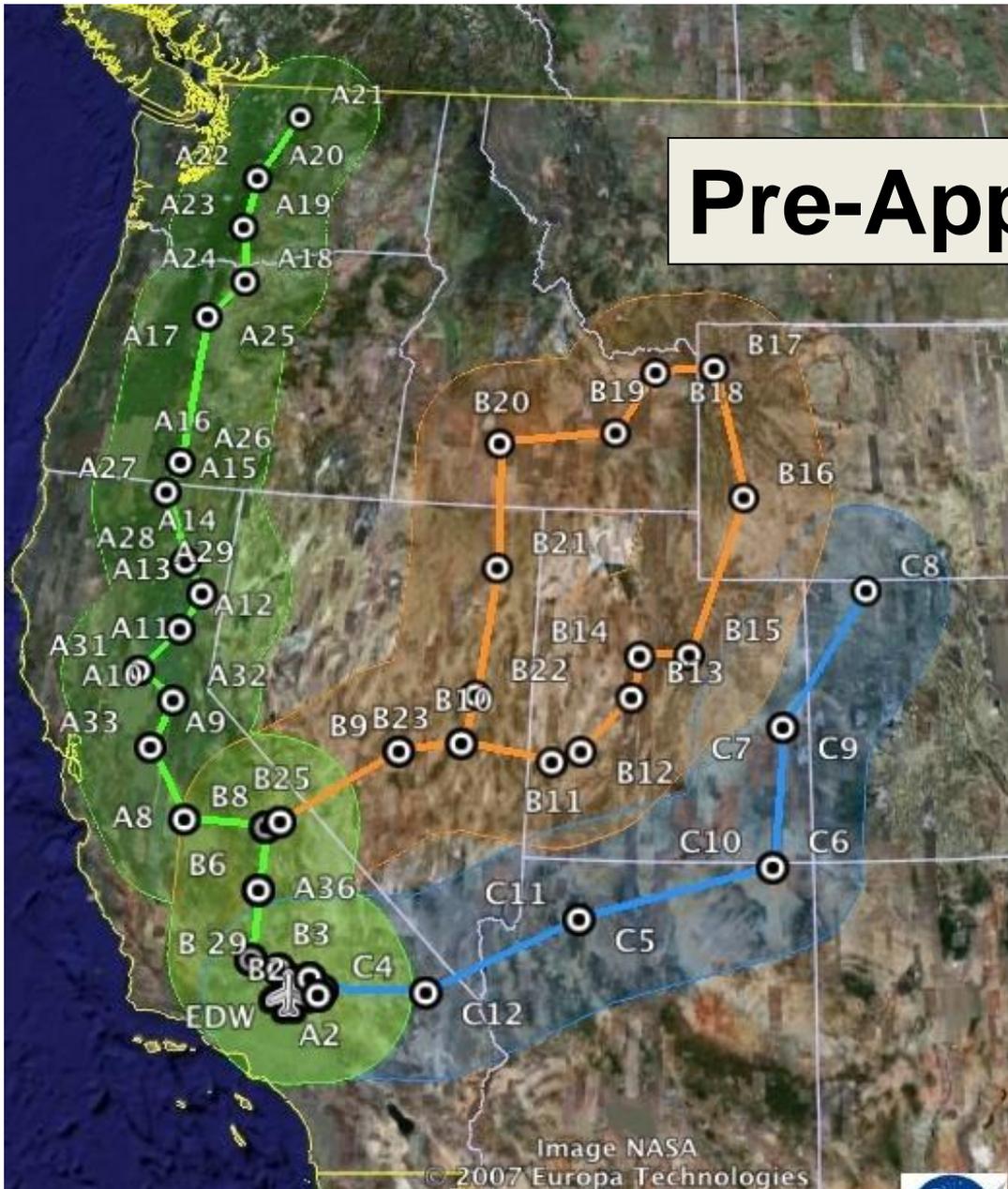
# FAA Provisions

- **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

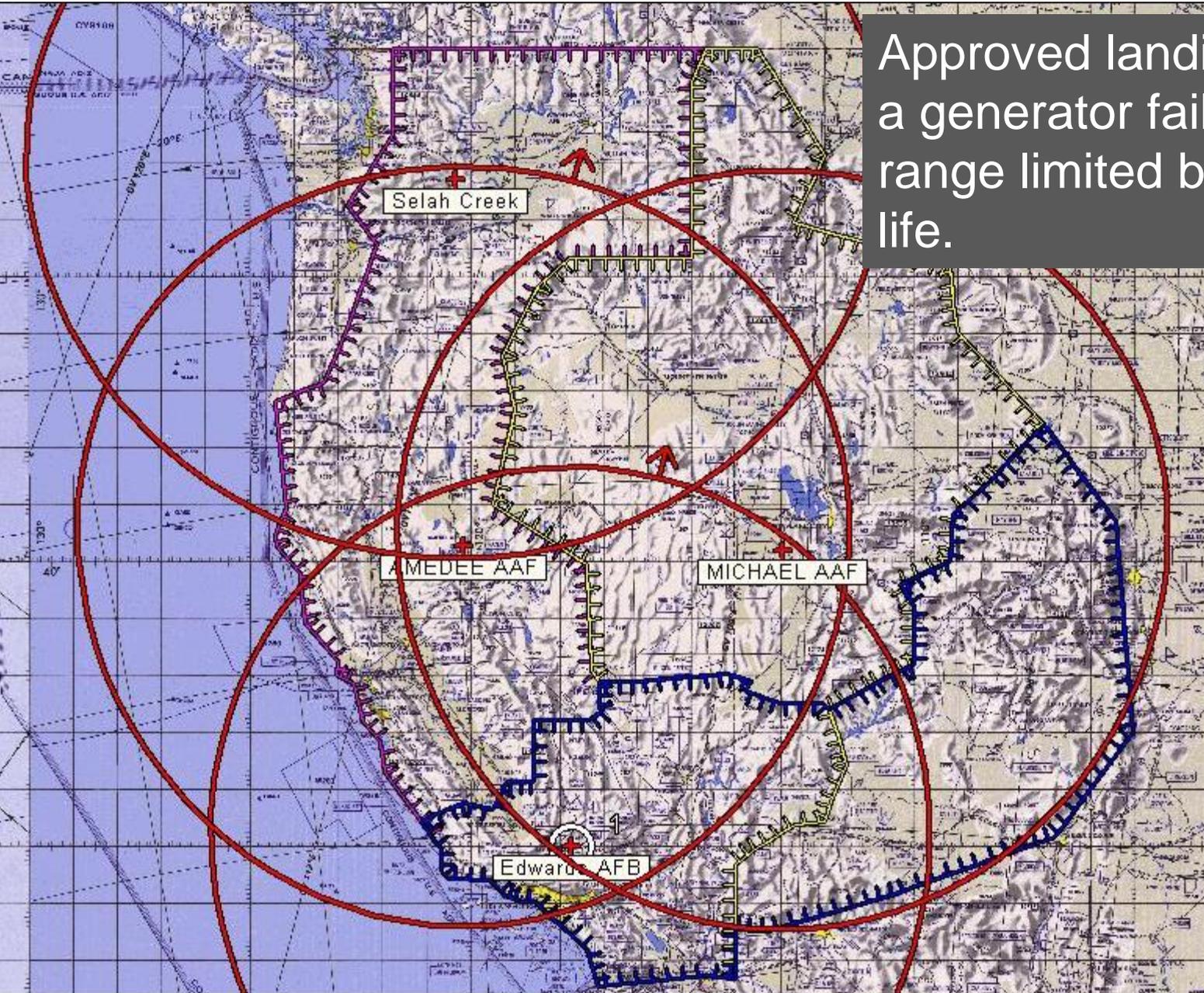


# Pre-Approved Routes



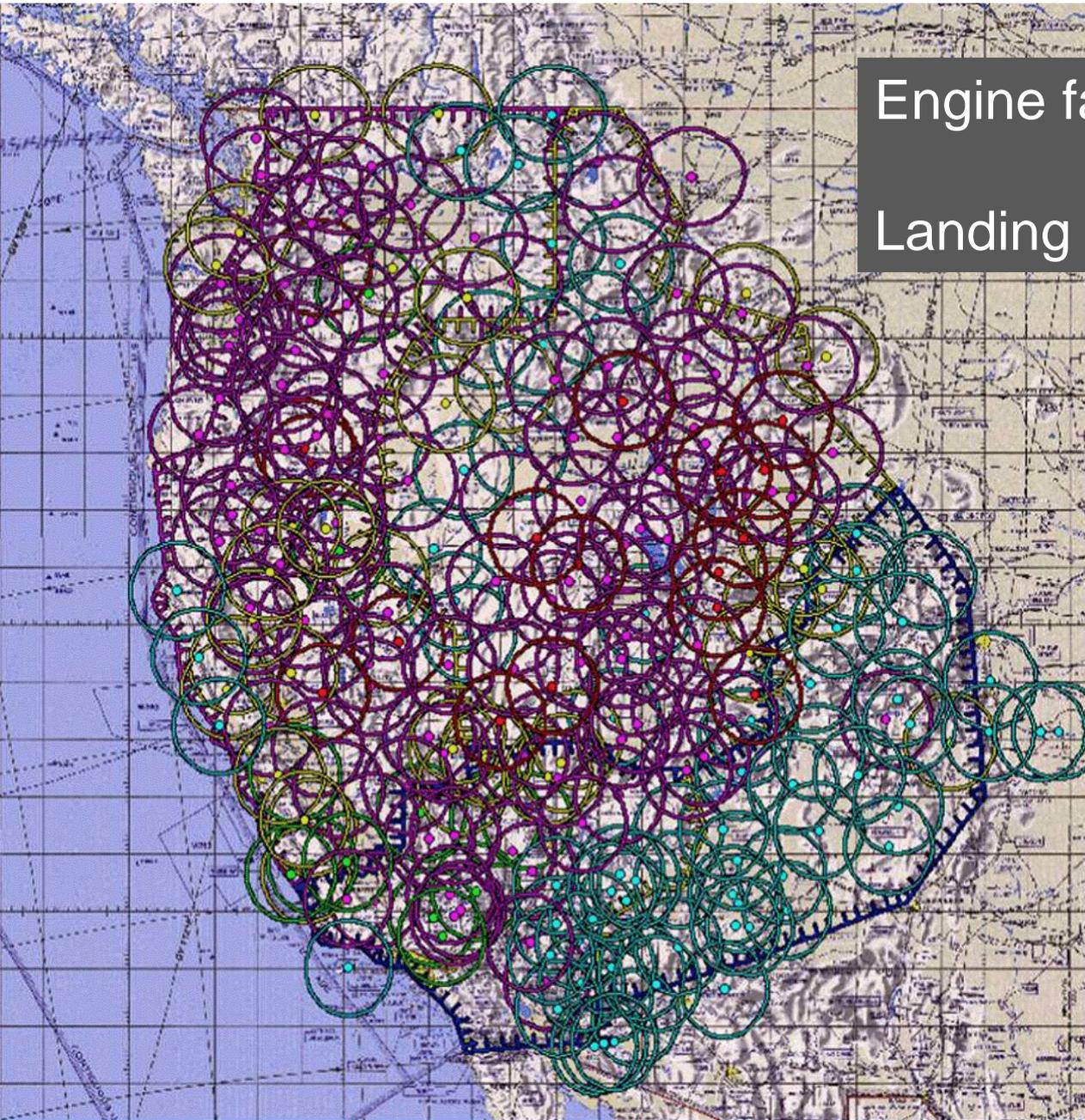
Actual flight route negotiated in real-time to acquire data over fires.

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

Riverside

Anaheim

Santiago

Santa Ana

Long Beach

Rice

Ammo

Poomacha

Witch

Harris

Image NASA San Diego

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©2007 Mexico  
Google



## 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

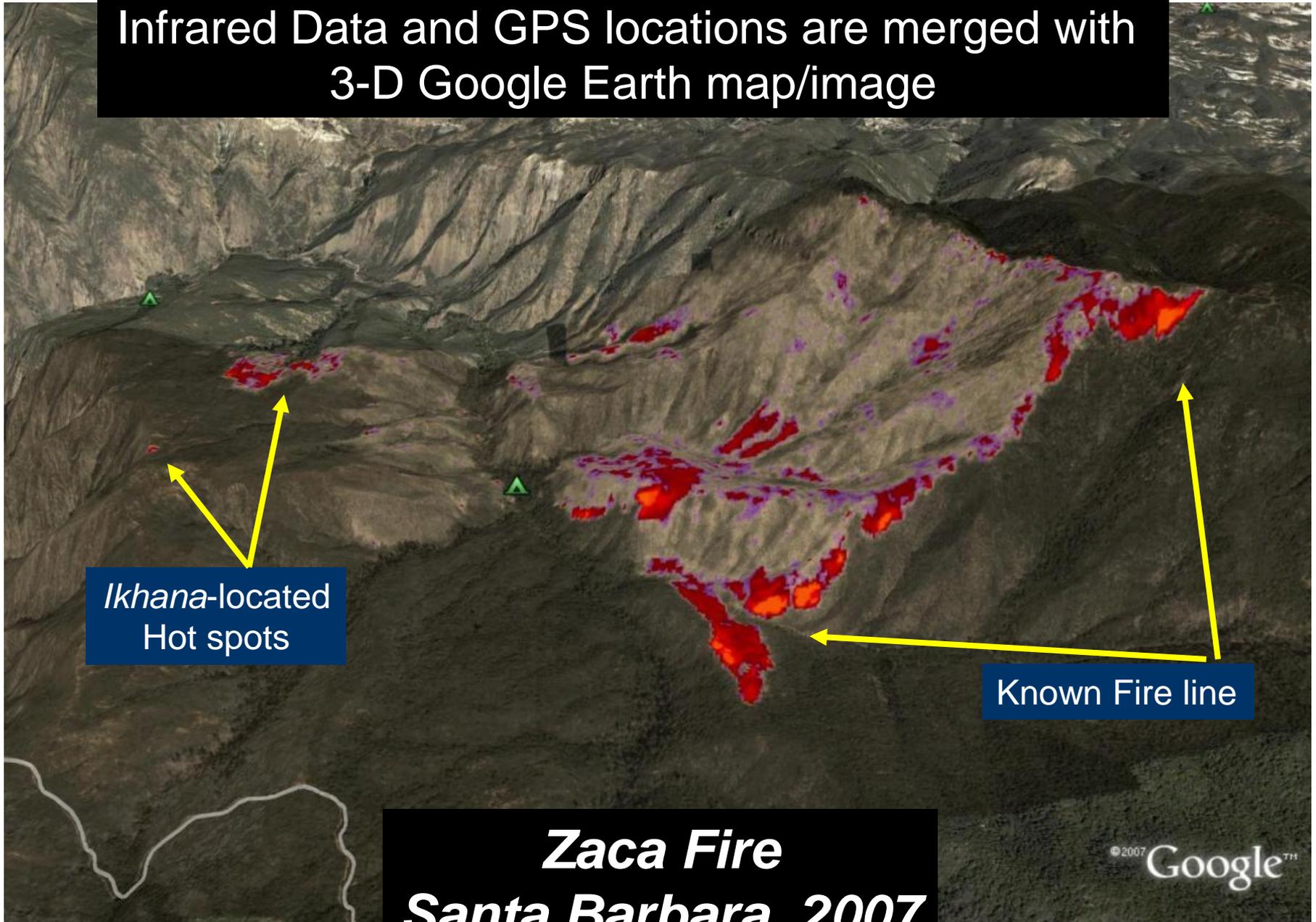
Lake Arrowhead

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**

# 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.....Questions?**

