



# Airborne Science Program

## Observing Platforms for Earth System Science Investigations



WB-57



Global Hawk



ER-2



G III



Learjet



DC-8



Ikhana



P-3



S-3B



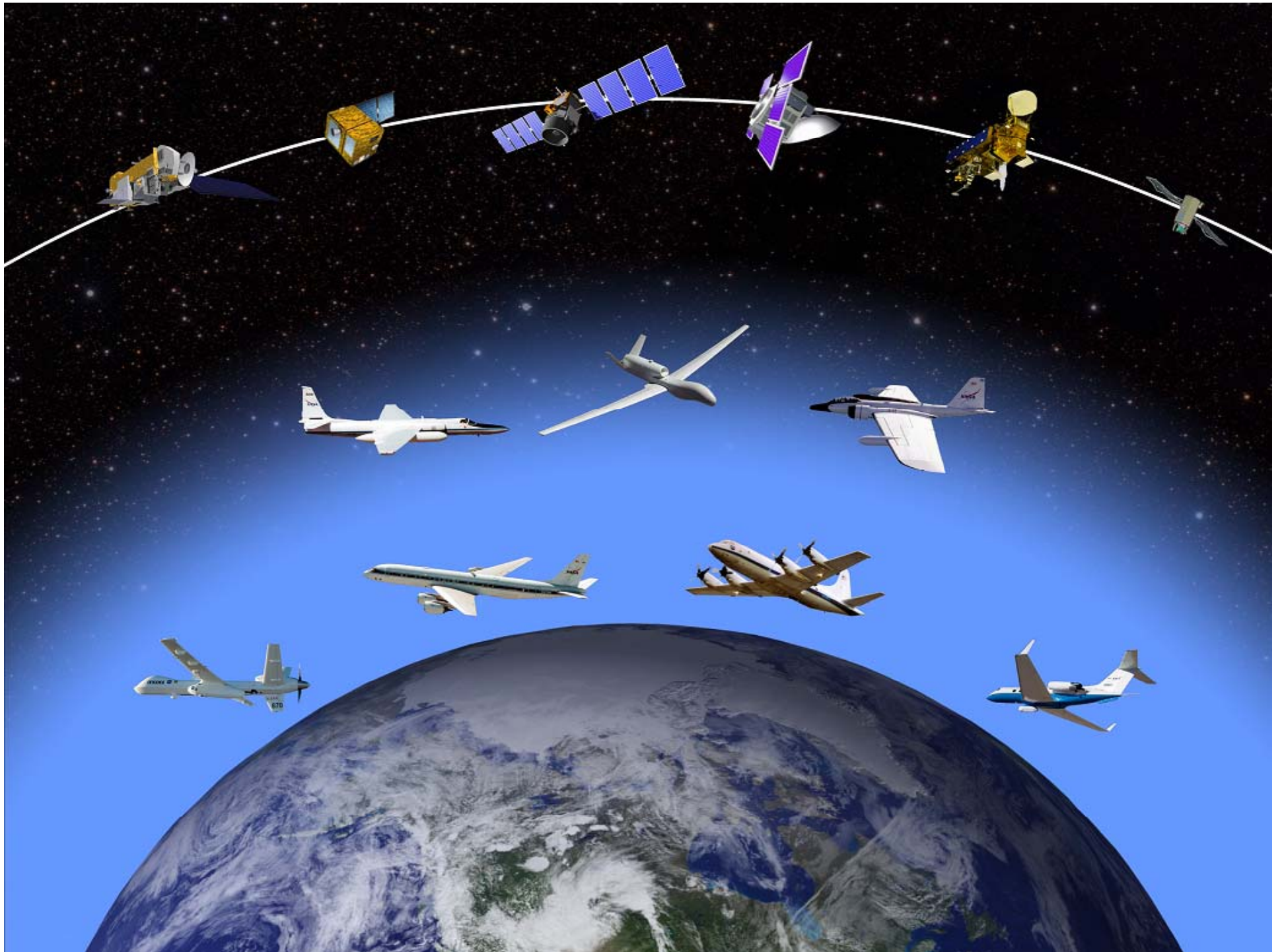
B-200



Twin Otter

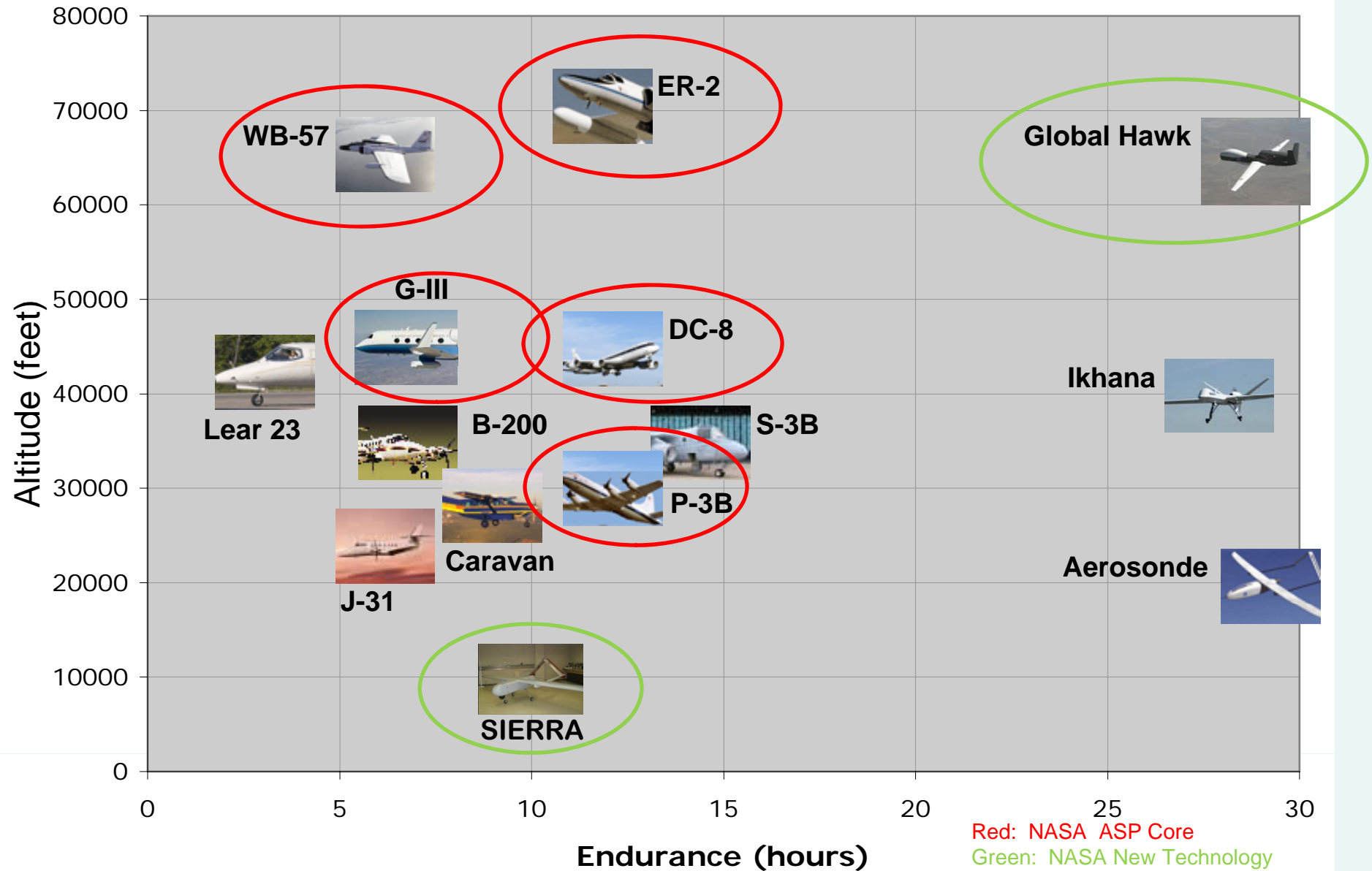


SIERRA





# NASA Unique Airborne Science Aircraft




Red: NASA ASP Core  
Green: NASA New Technology



# Dryden Aircraft Operations Facility

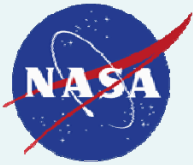
**Building 703:**  
SOFIA  
DC-8  
ER-2  
G-3



**Palmdale Site 9 complex will provide for :**

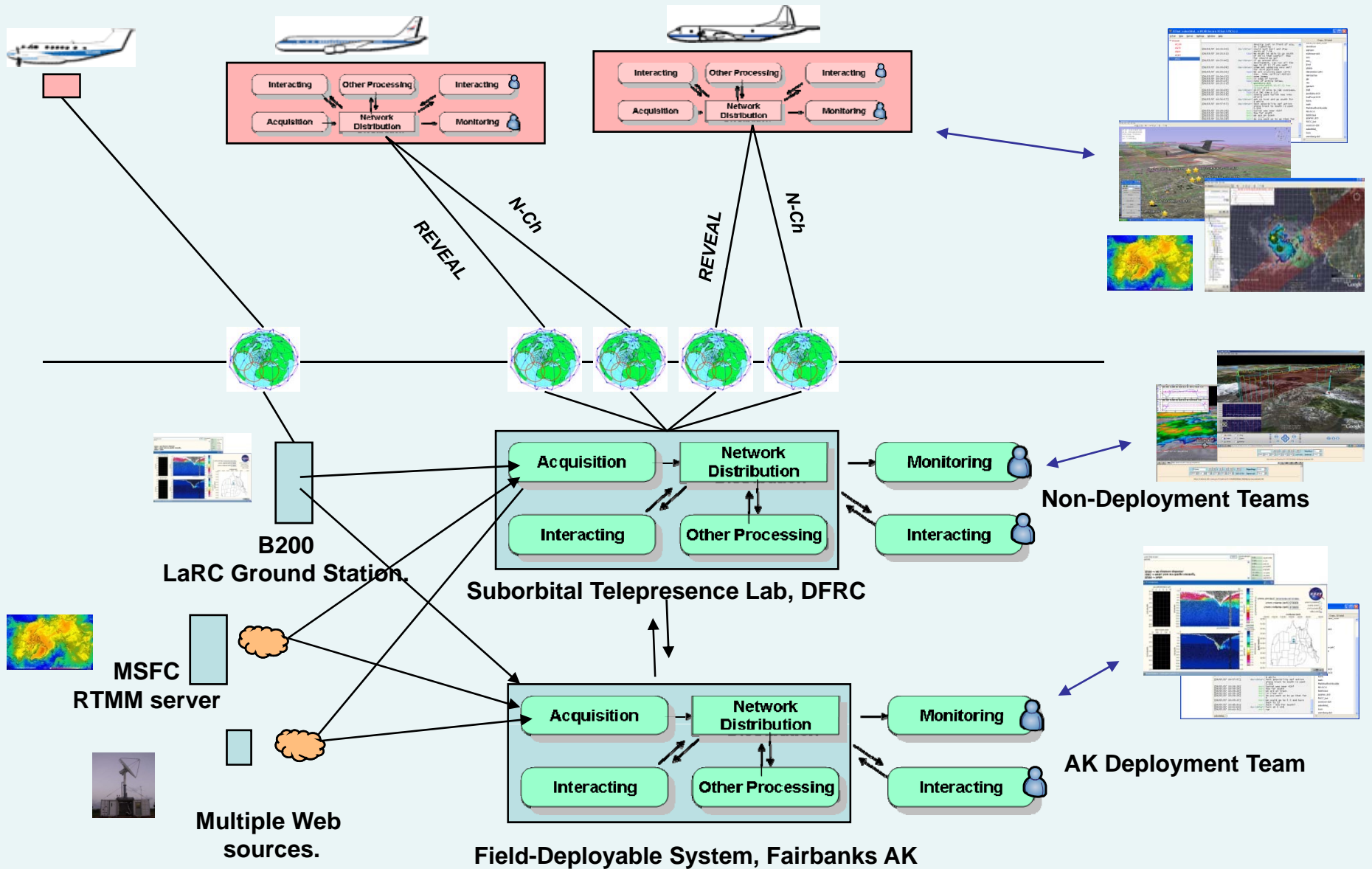
- **efficient consolidated operations of platform aircraft**
- **easy access for visiting science teams**

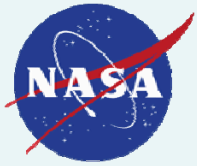




- New Technology -

# Sub-Orbital Tele-Communications





# DC-8 Flying Laboratory

## Large Capacity, Long Range and Endurance



### *Capabilities*

- Ceiling 42,000 ft.
- Duration 12 hours
- Range > 5,400 nautical miles
- Payload 30,000 lbs

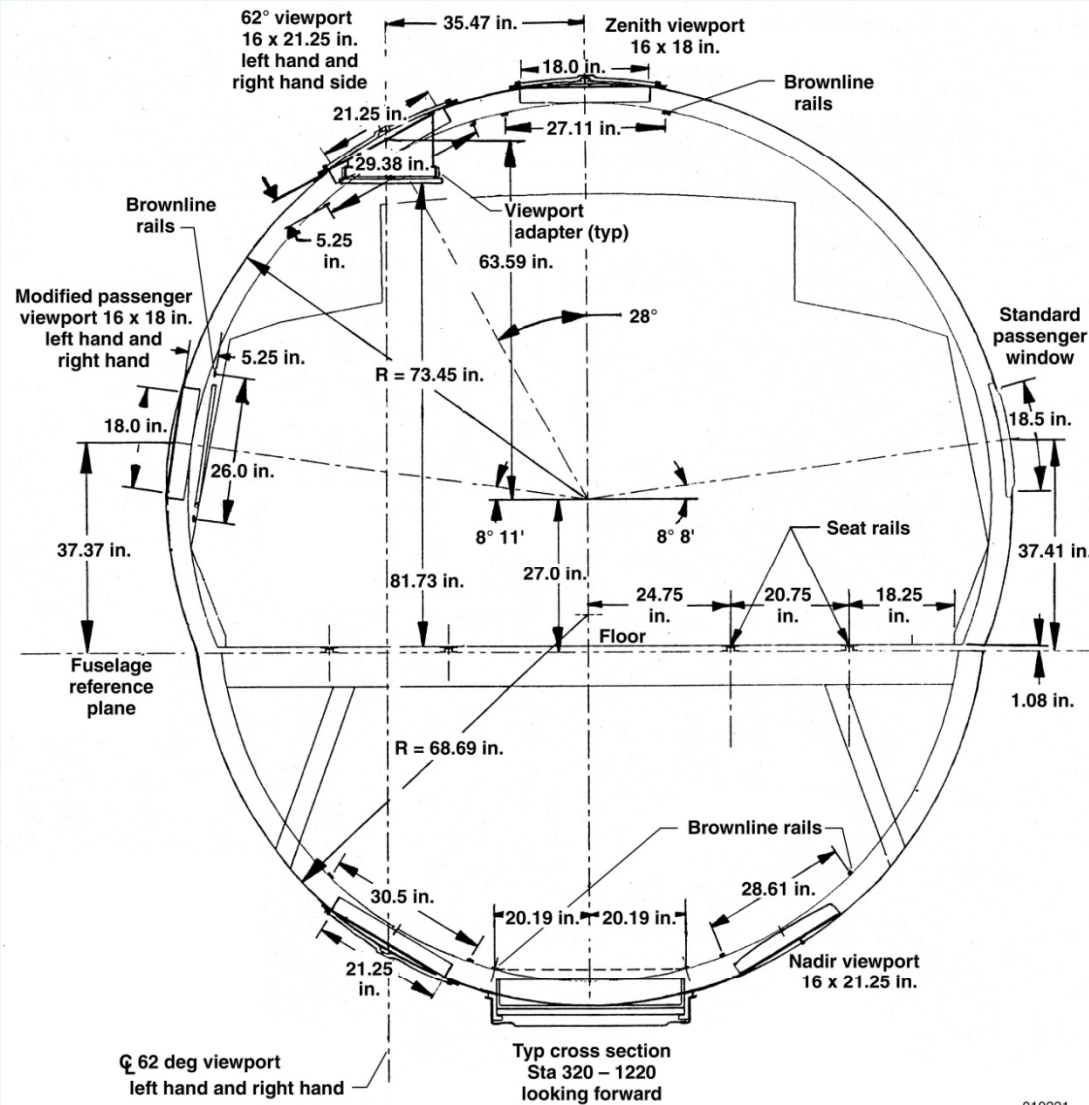
### *Mission Support Features*

- Shirtsleeve environment for up to 30 researchers
- Worldwide deployment experience
- Extensive modifications to support in-situ and remote sensing instruments
  - zenith and nadir viewports
  - wing pylons
  - modified power systems
  - 19 inch rack mounting

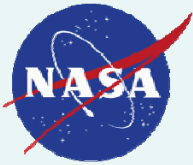




# DC-8 Viewports



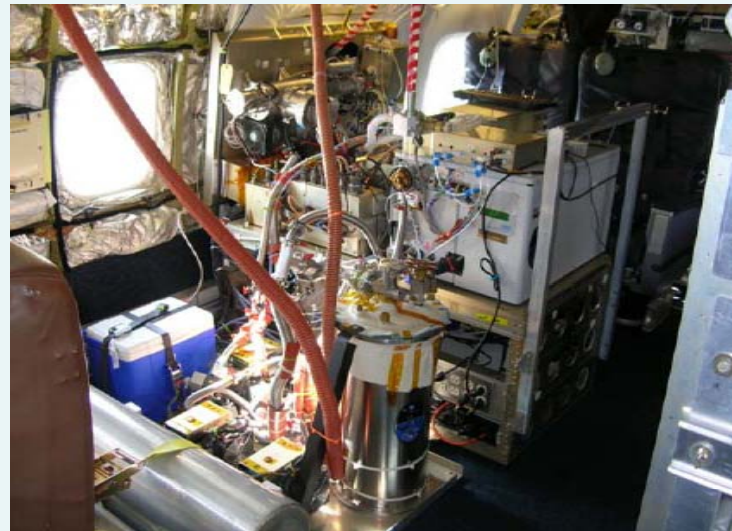




# ARCTAS

– Recent Campaigns –

## Examples of External Instrumentation





# ER-2

## Very High Altitude, Long Range and Endurance



### ***Capabilities***

- Ceiling > 70,000 ft
- Duration > 10 hours
- Range > 4,000 nautical miles
- Payload 2,600 lbs  
(700 lbs in each wing pod)

### ***Mission Support Features***

- Multiple locations for payload instruments
- Pressurized and un-pressurized compartments
- Standardized cockpit control panel for activation and control of payload instruments
- World-wide deployment experience



### ***Background and Status***

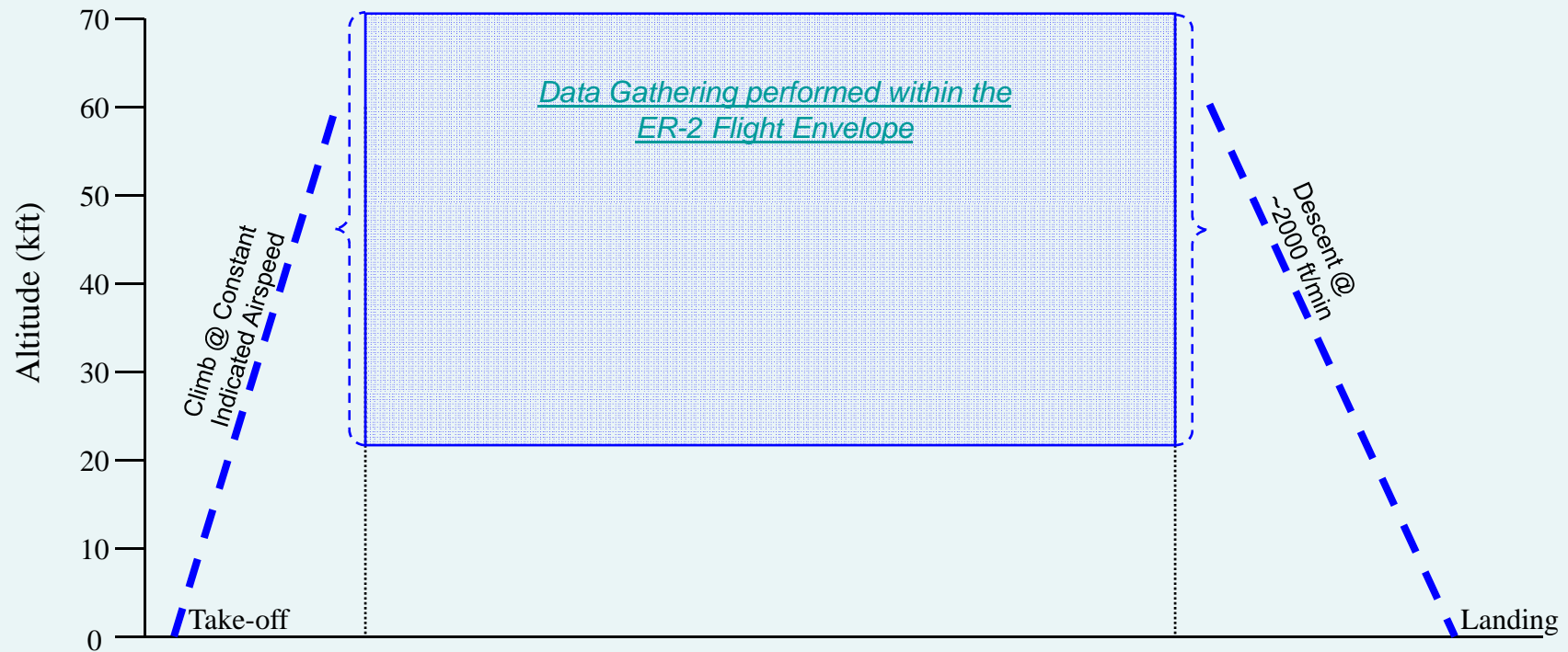
- U-2 and ER-2 aircraft have been a mainstay of NASA airborne sciences since 1971
- Over 100 science instruments integrated
- Two aircraft

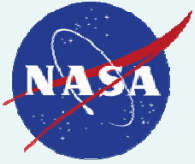


# ER-2



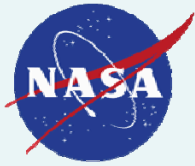
## Typical Data gathering Profile





## ER-2 Instrument Integration Locations





# TC-4

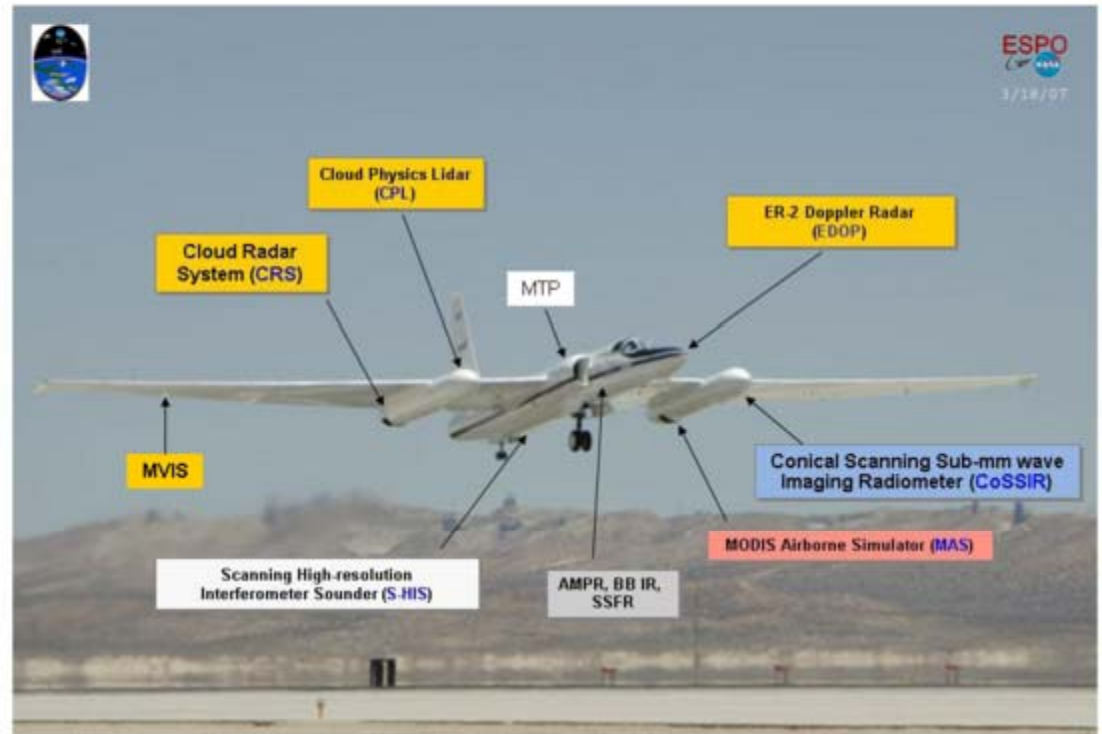
## – Recent Campaigns – Tropical Composition, Climate and Cloud Coupling



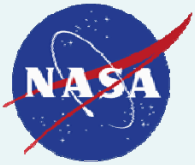
**Goal:** Investigate the structure, properties and processes in the tropopause transitional layer of the tropical Western Pacific.

**Validate Aura and CALIPSO/CloudSat satellite data.**

**Participating Aircraft:**  
ER-2, DC-8 and WB-57

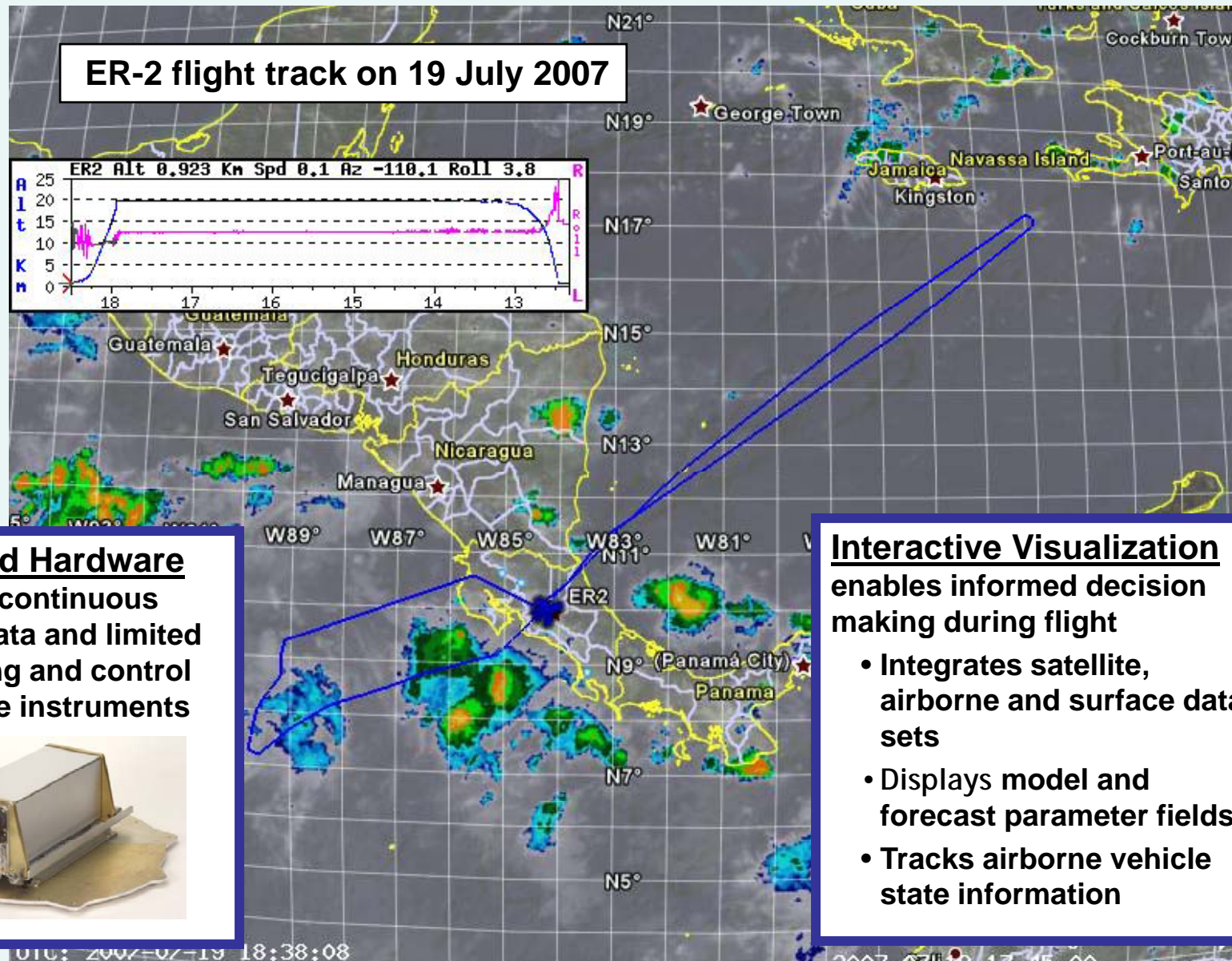


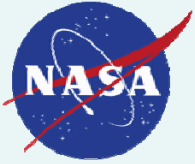
**NASA ER-2 deployed to San Jose, Costa Rica with 9 remote sensing instruments, August 2007**



– Recent Campaigns –

# TC-4 Real-Time Mission Management



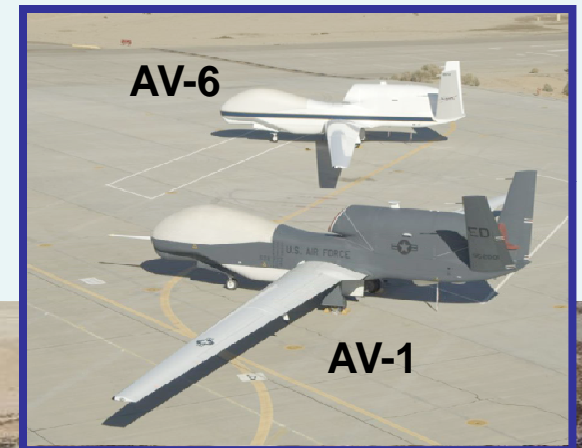


- Global Hawk Overview -

# NASA Global Hawks



- Two Advanced Concept Technology Demonstration (ACTD) aircraft transferred to NASA in September, 2007 (AV-1 and AV-6).
- Aircraft are based at the Dryden Flight Research Center on Edwards Air Force Base.
- Configuration and performance similar to standard 'Block 10'.



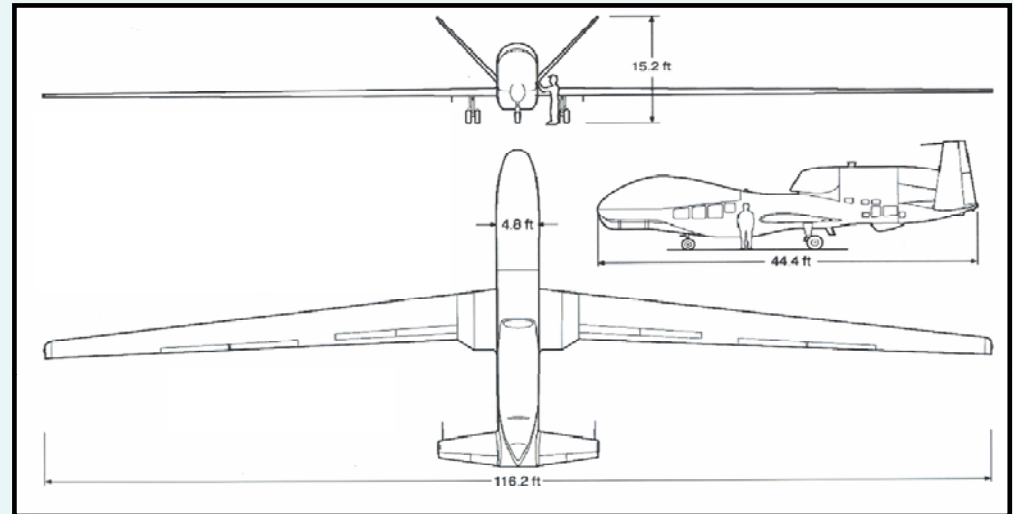


# Global Hawk Overview



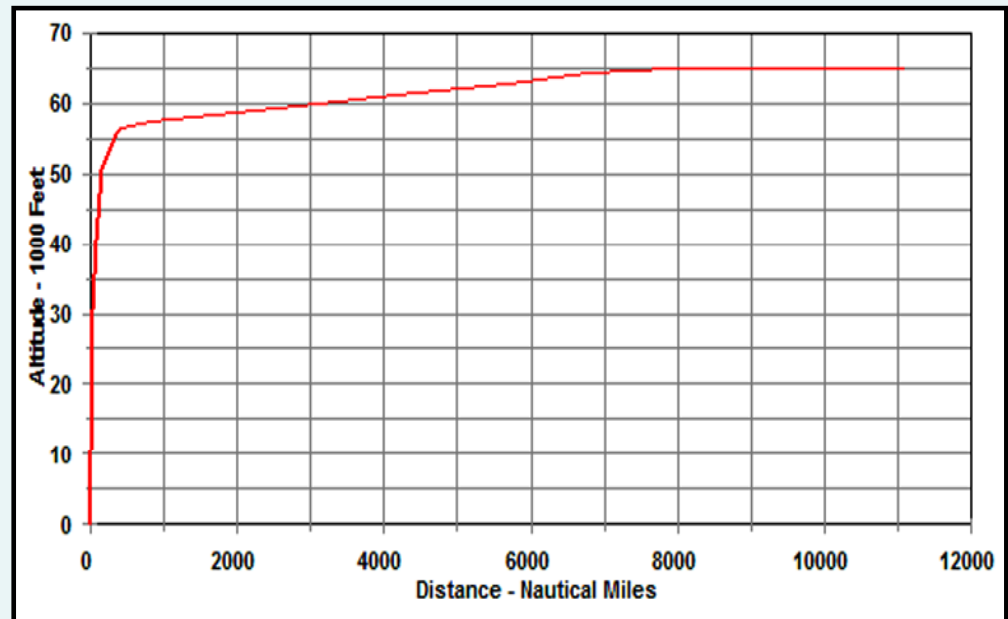
## Northrop Grumman RQ-4

- Long range, unmanned, autonomous, reconnaissance vehicle.
- Operational vehicles are in service with US Air Force (Block 10 and 20) and Navy (Block 10).
- Other variants under development.

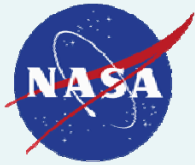


## Block 10 Specifications

Endurance	> 30 hours
Service Ceiling	> 60,000 ft
Range	> 11,000 nmi
Payload	~ 1,500 lb
Length	44 ft
Wingspan	116 ft







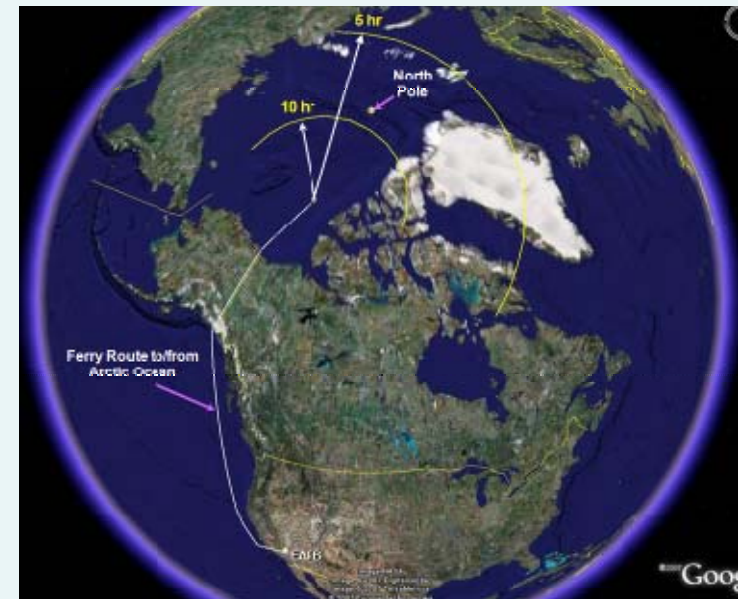
- Global Hawk Overview -

# NASA - Initial Science Operations



## Flight Operations

- Based at NASA Dryden, Edwards Air Force Base.
  - Long-duration data collection over the Arctic, Pacific and Western Atlantic oceans.
  - Flight over land will follow the same corridors already in use by GH, when practical.





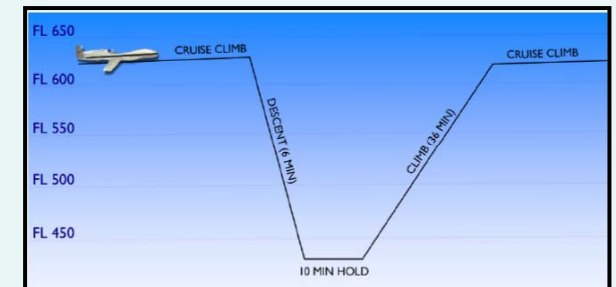
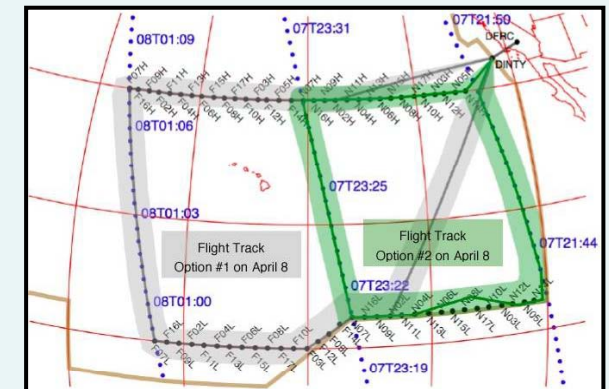
- Global Hawk Overview -

# NASA - Initial Science Operations



## Flight Operations, cont.

- Aircraft flies below FL 420 only in the EAFB restricted range.
- Flight routing
  - A nominal flight path (multiple way-points) is programmed prior to flight.
  - Alterations from the nominal path are executed with additional way-points during flight.
- Vertical profiling for science objectives
  - Must remain above conventional air traffic.
  - Depends on knowledge of the hazard environment (icing, convective systems, etc).
  - Has small impact on range/duration capability.





# NASA - Initial Science Operations



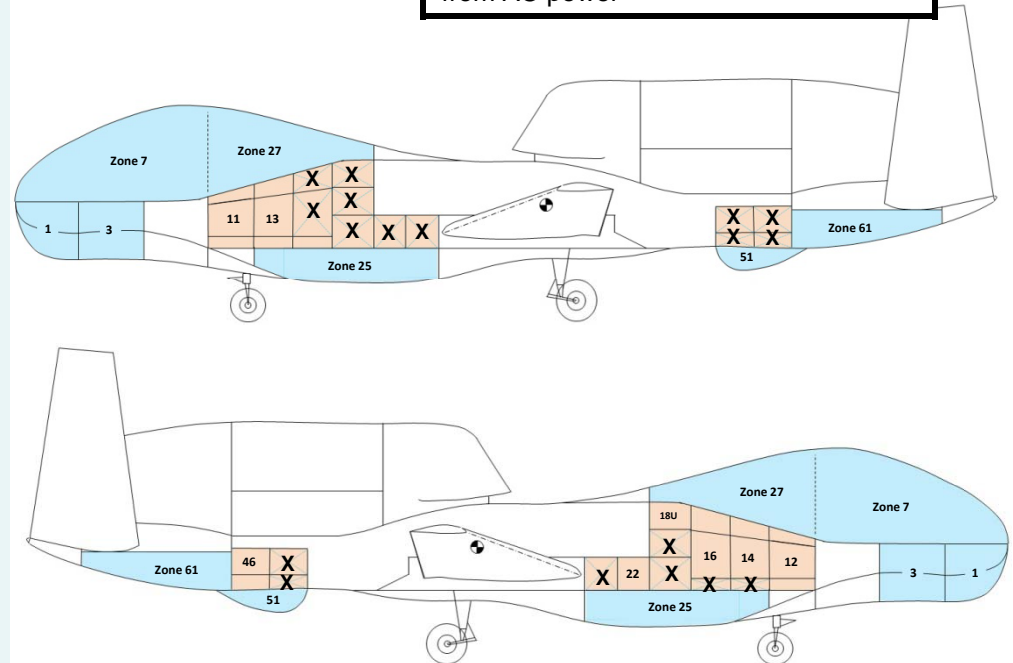
## Instrument Accommodations

- Total payload weight ~ 680 kg (1,500 lbs)
- Multiple compartments
  - Standardized power and command/control interface (EIP's)
  - Some ECS controlled
    - Pressure alt < 8.2 km
    - 0 < Temp < 55° C
    - No condensation
  - Some w/19" rack mounting
- Integration
  - Conducted by NASA / Northrop Grumman team
  - Pre-flight simulations
    - Full mission duration
    - Extreme environments
    - Full functional check-out

### Power for Experiments

DC	2.0 KW
AC	8.2 KVA

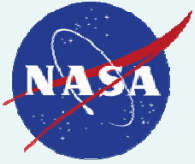
Additional 7.8 KW DC can be derived from AC power



### Legend:

- ECS controlled, pressurized compartments:
- Non-ECS controlled, unpressurized compartments:
- Compartment space unavailable to payloads:





- Global Hawk Overview -

# NASA - Initial Science Operations



## Global Hawk Operations Center (GHOC)

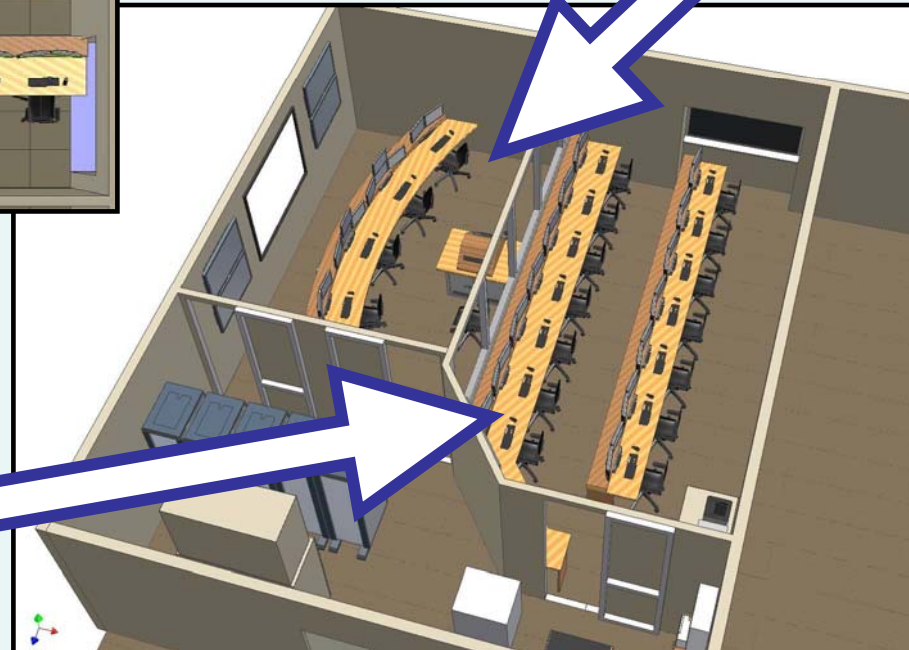


### Flight Operations

- Pilot, science mission specialist + others
- Vehicle control, navigation, air traffic coordination
- Control of science payload power and inhibits

### Payload Operations

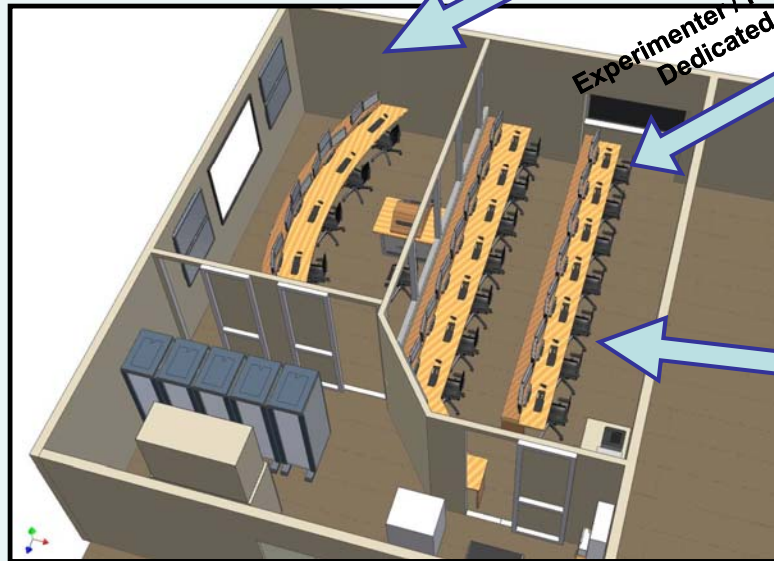
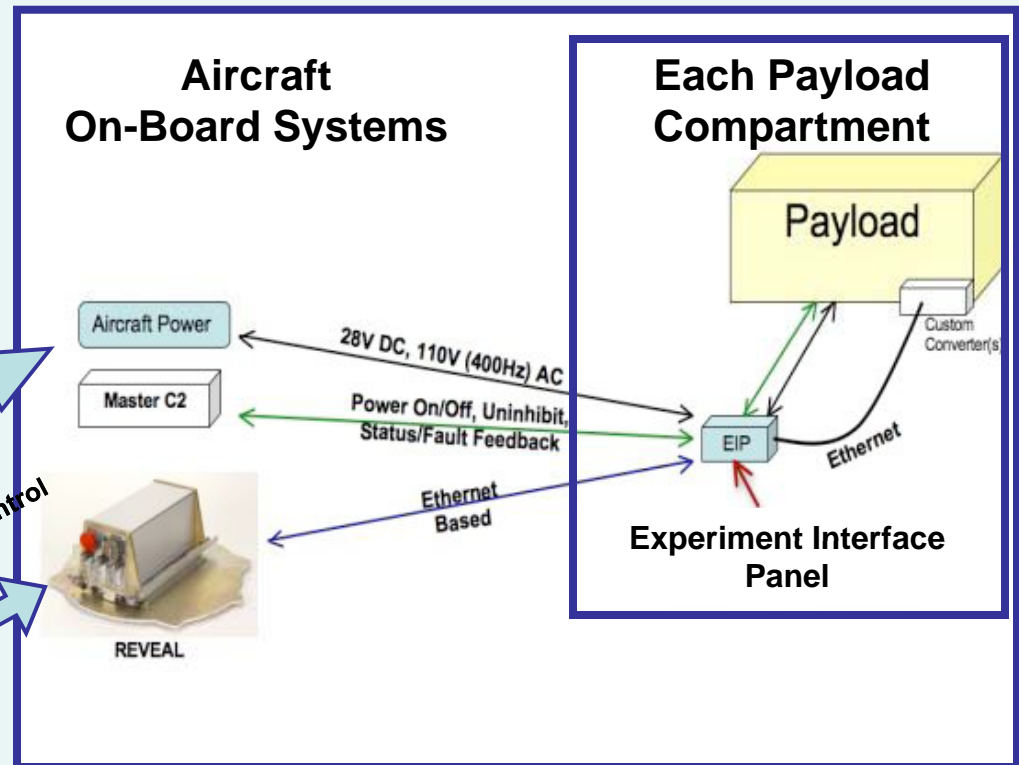
- Experiment team collaboration
- Data monitoring and control of science instruments
- Access to external science community through internet





- Global Hawk Overview -

# NASA - Initial Science Operations



Pilot / Payload Control  
Redundant TM (Iridium)

Experimenter / Payload Control  
Dedicated Data TM

Internet

Distributed Science Team  
(worldwide)



- Global Hawk Overview -

# NASA – Future Capabilities

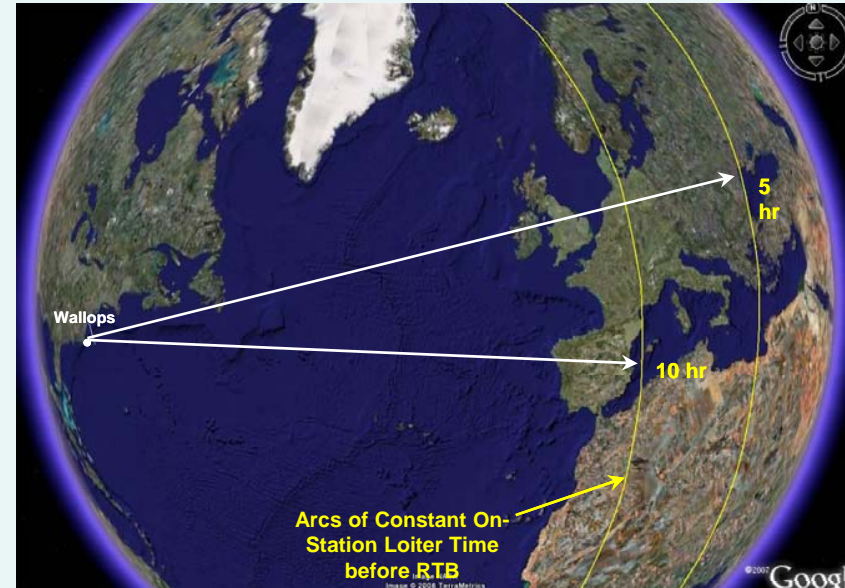


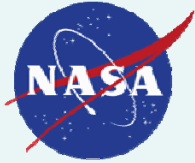
## Deployment to U.S. east coast

- Extended operations over eastern Atlantic.
- Extended operations over Greenland.

### Key requirements

- Portable ground control station development (take-off and landing only).
- Extensive logistics (potentially site improvements) to support ground infrastructure.
- Frequency and airspace coordination at remote facility.





- Global Hawk Overview -



# NASA – Future Capability

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## **Removable payload enclosures.**

- Would allow science teams to integrate their equipment in parallel with other aircraft activities and at their own facilities.
- Requires design and development.

## **Wing stores for additional payload housing.**

- Structural hard-points included in wing design.
- Various concepts have been developed.
- Data review and feasibility studies in progress.

## **High bandwidth telemetry of experimenter data.**

- Aircraft is configured for high-gain Ku band antenna.
- Required hardware is available but implementation is not funded.

## **More aggressive flight operations for science objectives.**

- Vertical profiling to lower altitudes, operations in the vicinity of hazardous weather.
- Dependent on:
  - Airspace policy development for UAS.
  - Operational confidence to be gained from experience.



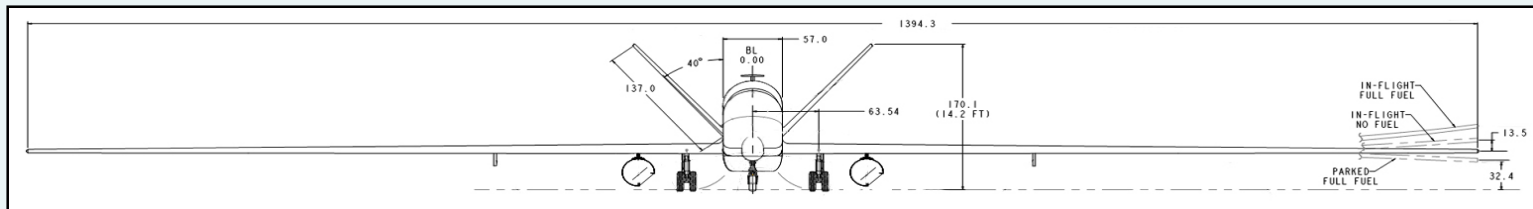
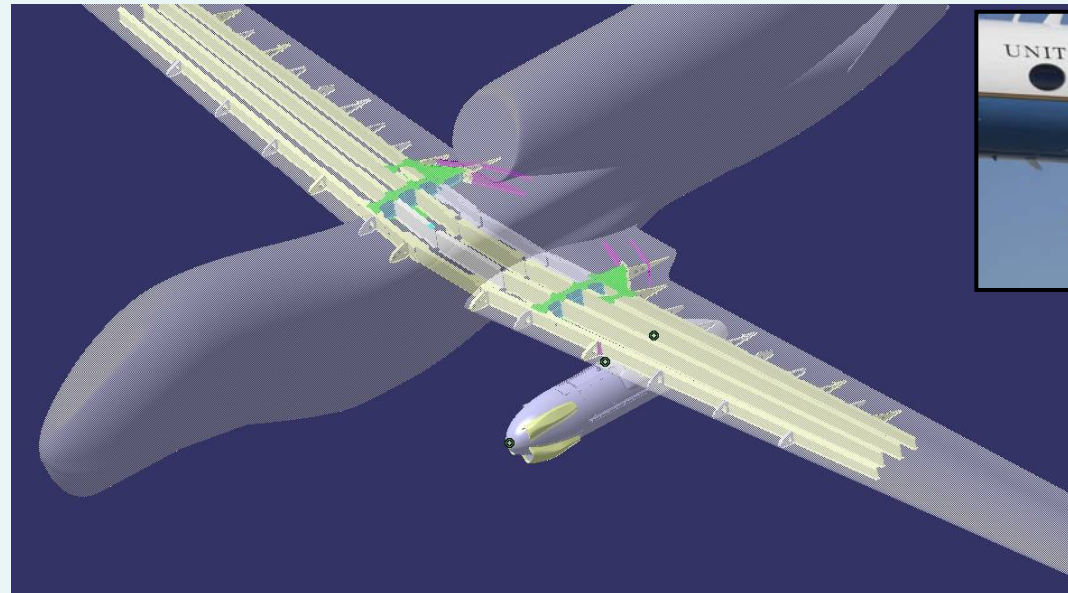
- Global Hawk Overview -



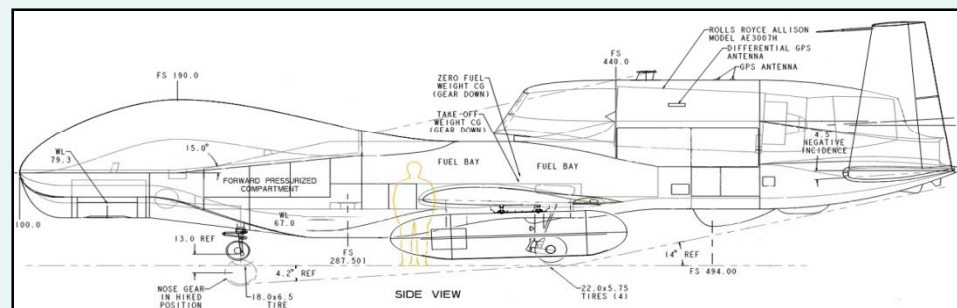
# Proposed Future Payloads

## UAV-SAR (JPL)

Two Pods to be used  
(only one shown)



Effort may lead to the  
development of  
Generic GH Pods  
for future Payloads

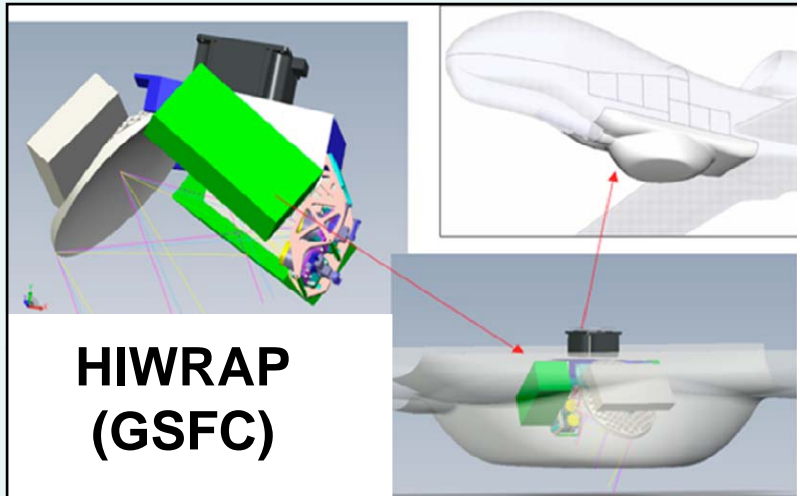




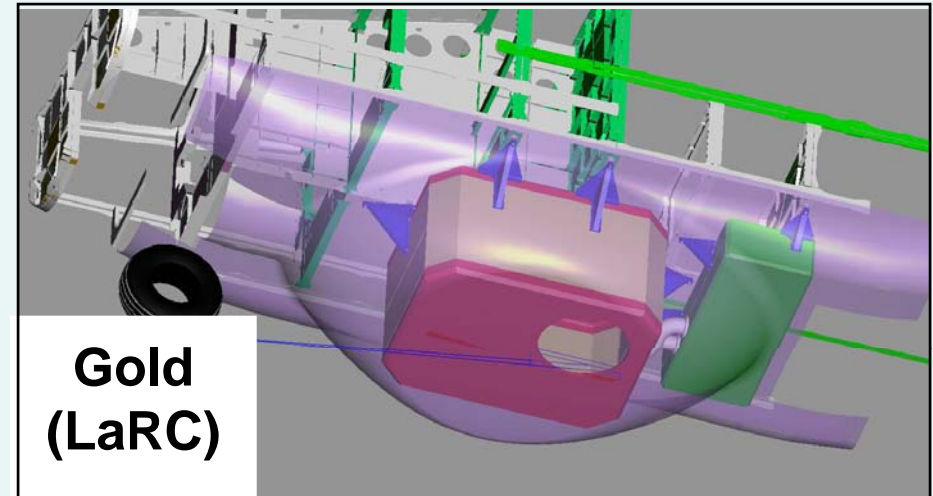


- Global Hawk Overview -

# Proposed Future Payloads (cont)



**Ku and Ka band radar for the measurement of wind and rain profiles.**



**Backscatter LIDAR for accurate measurements of ozone and aerosols in the troposphere.**



**Both instruments will require a NGC developed "Deep Radome"**



## P-3B Scientific Accommodations

Goddard Space Flight Center - Wallops Flight Facility - Airborne Science

- “Glass” cockpit & flight management system
  - IRS & GPS-coupled
  - Accommodates in-flight changes to experiment profiles
  - Outputs standard ARINC-429 bus
  - Next upgrade: Dryden Data System



- 4-engine turbo-prop
  - Economically suited to long duration low altitude work

- Global range
  - 8-10 hours
  - 3000-3500 NM (altitude dependent)



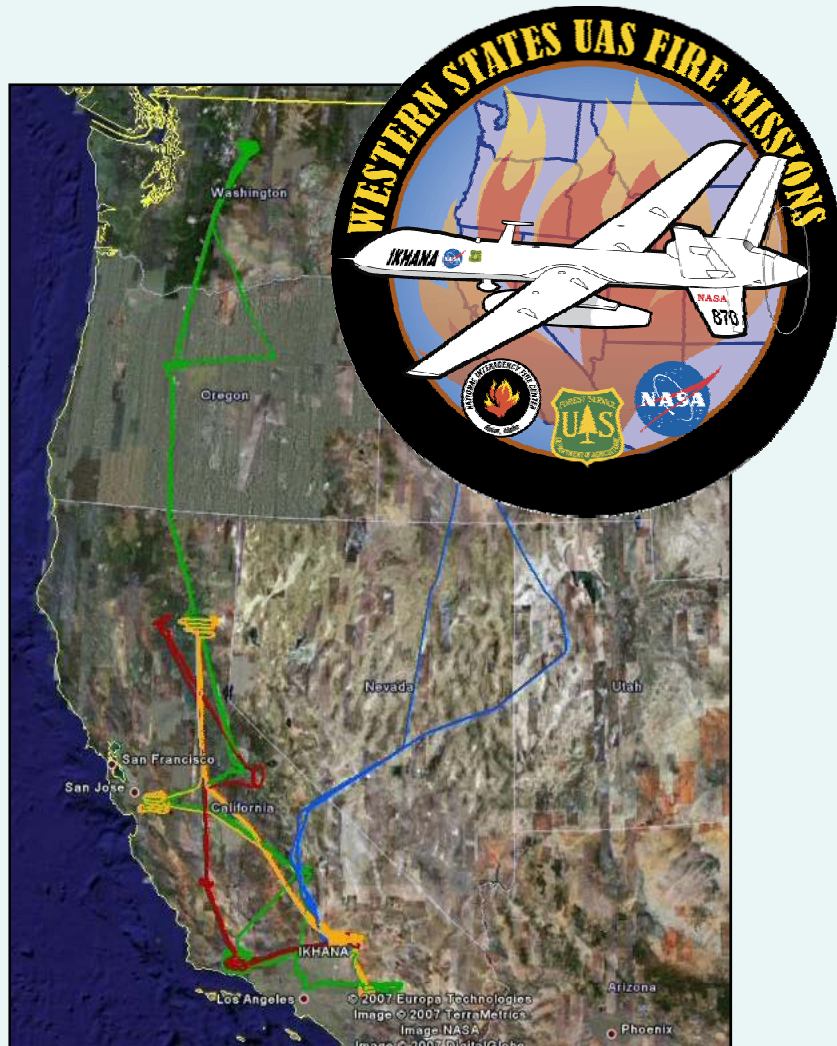
## NASA WB-57 Johnson Space Center





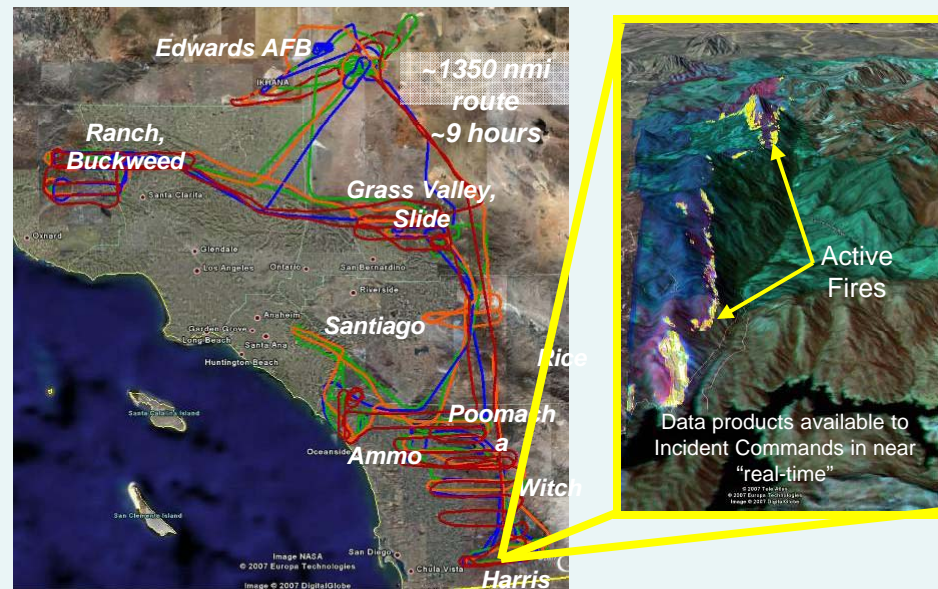
-UAS Technology -

# Ikhana - Western States Fire Mission



**Long Range, Duration Flights Over the Western States**

Flight operations with the Ikhana have demonstrated unprecedented UAS capability for data collection in the civil air space



**Emergency Response Missions into Congested Airspace**

# Esperanza Fire

Oct 27, 2006: CA OES requests NASA assistance

- 40,000 acres (62 sq mi)
- 5 firefighters killed
- 34 homes destroyed

Oct 28, 2006: Altair UAV deployed

- 16:27 flight hours
- 94 images, 44 shapefiles
- Incident Command

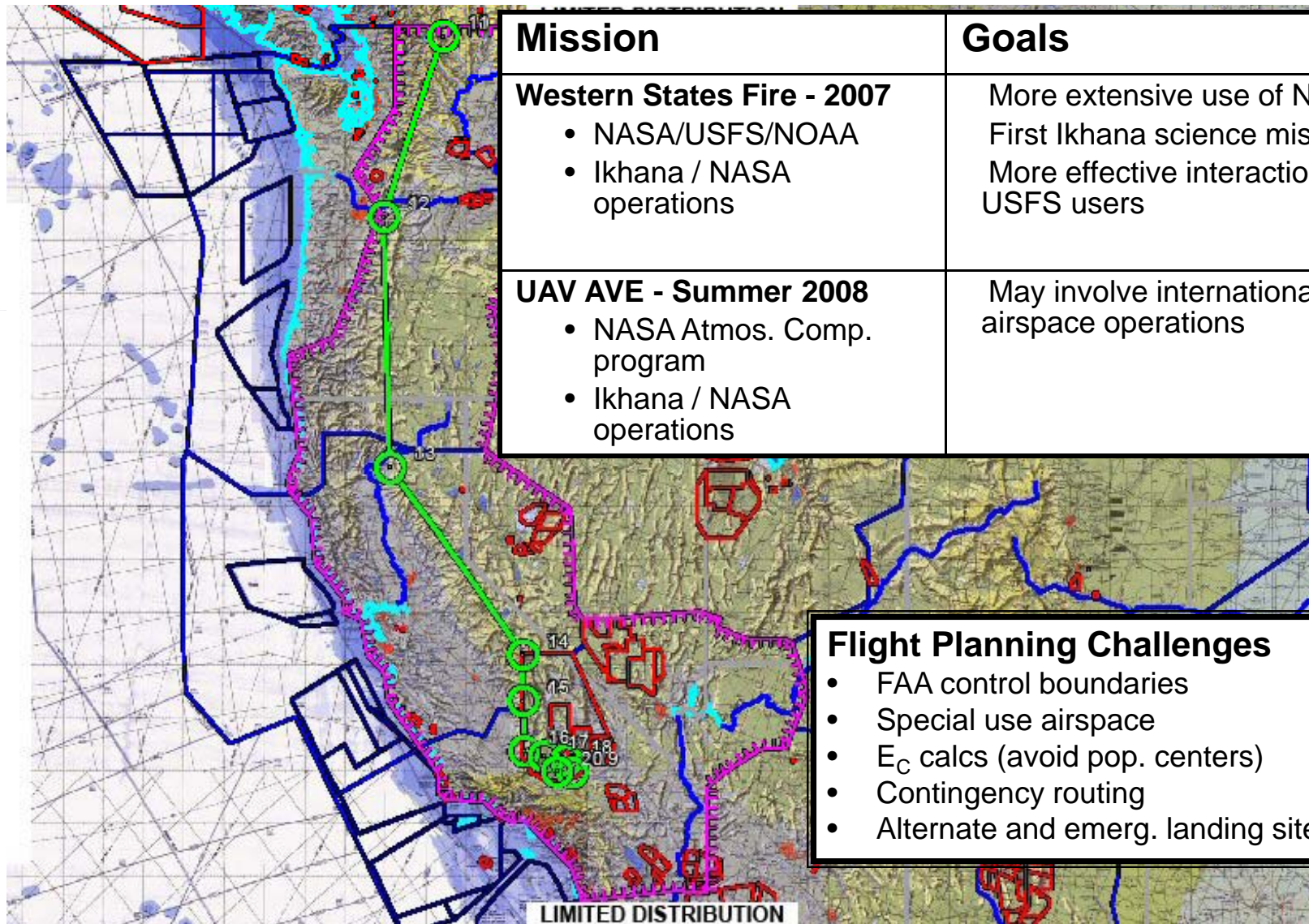


*“Getting real time UAS data to Incident Command Center was one of two major accomplishments this past year” (Director, CA Dept. Forestry)*

*“If we had NASA’s technology earlier, we could have gotten fires under control sooner.” (Director, CA Office of Emergency Service)*



# Mission Demonstrations - Planned



# Platform Comparison Summary

Platform Name	Center	Duration (Hours)	Payload (lbs.)	Subsidized Cost (SMD)	Max Altitude (ft.)	Airspeed (knots)	Range (Nmi)
<b>Core Aircraft</b>							
<a href="#">ER-2</a>	DFRC	12	2900	\$3500	>70000	410	>5000
<a href="#">WB-57</a>	JSC	6	6000	\$3500	65000	410	2172
<a href="#">DC-8</a>	DFRC	12	30000	\$6500	41000	450	5400
<a href="#">P-3B</a>	WFF	12	16000	\$3500	30000	330	3800
<a href="#">Gulfstream III</a>	DFRC	7	2610	\$2500	45000	459	3400
<b>UAS</b>							
<a href="#">Ikhana</a>	DFRC	24	>2000	\$3500	40000	171	3500
<a href="#">Global Hawk</a>	DFRC	31	1500	\$3500	60000	335	11004



# Suborbital Commercial Vehicles

(Several Companies in Development – X-Prize Winner shown for illustrative purposes)

Space Ship One  
& White Knight One

