Airborne Science Program
Observing Platforms for Earth System Science Investigations

WB-57
Global Hawk
ER-2
G II
DC-8
Ikhana
Learjet
P-3
B-200
Twin Otter
S-3B
SIERRA
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
Science Integration Labs

660 ft

ER-2’s

DC-8

G-III

SOFIA
Sub-Orbital Tele-Communications

- New Technology -

Suborbital Telepresence Lab, DFRC

B200
LaRC Ground Station

MSFC
RTMM server

Multiple Web sources.

Field-Deployable System, Fairbanks AK

Non-Deployment Teams

AK Deployment Team
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 Examples of External Instrumentation
**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

Data Gathering performed within the ER-2 Flight Envelope
ER-2 Instrument Integration Locations
Recent Campaigns

TC-4
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

ER-2 flight track on 19 July 2007

On-board Hardware provides continuous aircraft data and limited monitoring and control of science instruments.

Interactive Visualization enables informed decision making during flight:
- Integrates satellite, airborne and surface data sets
- Displays model and forecast parameter fields
- Tracks airborne vehicle state information
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’.

[Images of NASA Global Hawks and Edwards Air Force Base]
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.

<table>
<thead>
<tr>
<th>Block 10 Specifications</th>
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<tbody>
<tr>
<td>Endurance</td>
<td>&gt; 30 hours</td>
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<tr>
<td>Service Ceiling</td>
<td>&gt; 60,000 ft</td>
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<tr>
<td>Range</td>
<td>&gt; 11,000 nmi</td>
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<tr>
<td>Payload</td>
<td>~ 1,500 lb</td>
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<tr>
<td>Length</td>
<td>44 ft</td>
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<tr>
<td>Wingspan</td>
<td>116 ft</td>
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</table>

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

<table>
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<tr>
<th>Power Type</th>
<th>Power (KW)</th>
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<tr>
<td>DC</td>
<td>2.0</td>
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<tr>
<td>AC</td>
<td>8.2</td>
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</table>

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 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

Aircraft On-Board Systems

Each Payload Compartment

Payload

Experiment Interface Panel

Experiment Interface Panel

Aircraft Power

28V DC, 110V (400Hz) AC

Power On/Off, Uninhibit Status/Fault Feedback

Ethernet Based

Custom Converter

Internet

Distributed Science Team (worldwide)

Pilot / Payload Control Redundant TM (Iridium)

Experimenter / Payload Control Dedicated Data TM

REVEAL

Master C2

Distributed Science Team (worldwide)
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.
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.
UAV-SAR (JPL)
Two Pods to be used (only one shown)

Effort may lead to the development of Generic GH Pods for future Payloads
Proposed Future Payloads (cont)

**HIWRAP (GSFC)**
Ku and Ka band radar for the measurement of wind and rain profiles.

**Gold (LaRC)**
Backscatter LIDAR for accurate measurements of ozone and aerosols in the troposphere.

Both instruments will require a NGC developed “Deep Radome”
“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
Flight operations with the Ikhana have demonstrated unprecedented UAS capability for data collection in the civil air space.

Long Range, Duration Flights Over the Western States

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

<table>
<thead>
<tr>
<th>Mission</th>
<th>Goals</th>
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<tr>
<td><strong>Western States Fire - 2007</strong></td>
<td>- More extensive use of NAS</td>
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<tr>
<td></td>
<td>- First Ikhana science mission</td>
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<tr>
<td></td>
<td>- More effective interaction with USFS users</td>
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<tr>
<td></td>
<td>- Ikhana / NASA operations</td>
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<tr>
<td></td>
<td>- NASA/USFS/NOAA</td>
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<td><strong>UAV AVE - Summer 2008</strong></td>
<td>- May involve international airspace operations</td>
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<td></td>
<td>- Ikhana / NASA operations</td>
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<td></td>
<td>- NASA Atmos. Comp. program</td>
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#### Flight Planning Challenges
- FAA control boundaries
- Special use airspace
- $E_C$ calcs (avoid pop. centers)
- Contingency routing
- Alternate and emerg. landing sites
<table>
<thead>
<tr>
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<th>Center</th>
<th>Duration (Hours)</th>
<th>Payload (lbs.)</th>
<th>Subsidized Cost (SMD)</th>
<th>Max Altitude (ft.)</th>
<th>Airspeed (knots)</th>
<th>Range (Nmi)</th>
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Suborbital Commercial Vehicles
(Several Companies in Development – X-Prize Winner shown for illustrative purposes)

Space Ship One & White Knight One