Airborne Science Program
Observing Platforms for Earth System Science Investigations
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
Sub-Orbital Tele-Communications

- New Technology -

Suborbital Telepresence Lab, DFRC

B200
LaRC Ground Station

MSFC
RTMM server

Field-Deployable System, Fairbanks AK

Multiple Web sources.

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
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

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

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

On-board Hardware provides continuous aircraft data and limited monitoring and control of science instruments
NASA Global Hawks

- Global Hawk Overview -

- 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

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Endurance</td>
<td>&gt; 30 hours</td>
</tr>
<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>
</tr>
<tr>
<td>Length</td>
<td>44 ft</td>
</tr>
<tr>
<td>Wingspan</td>
<td>116 ft</td>
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</table>
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>
<thead>
<tr>
<th>Power Source</th>
<th>Power Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC</td>
<td>2.0 KW</td>
</tr>
<tr>
<td>AC</td>
<td>8.2 KVA</td>
</tr>
</tbody>
</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

Pilot / Payload Control
Redundant TM (Iridium)

Experimenter / Payload Control
Dedicated Data TM

Aircraft Power

28V DC, 110V (400Hz) AC

Power On/Off, Uninhibit
Status/Fault Feedback

28V DC, 110V (400Hz) AC

Experiment Interface Panel

Payload

Custom Converters

Ethernet

Experiment Interface Panel

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.
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
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”
P-3B Scientific Accommodations

- "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.
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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<tbody>
<tr>
<td><strong>Western States Fire - 2007</strong></td>
<td>More extensive use of NAS</td>
</tr>
<tr>
<td>• NASA/USFS/NOAA</td>
<td>First Ikhana science mission</td>
</tr>
<tr>
<td>• Ikhana / NASA operations</td>
<td>More effective interaction with USFS users</td>
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<tr>
<td><strong>UAV AVE - Summer 2008</strong></td>
<td>May involve international</td>
</tr>
<tr>
<td>• NASA Atmos. Comp. program</td>
<td>airspace operations</td>
</tr>
<tr>
<td>• Ikhana / NASA operations</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
## Platform Comparison Summary

<table>
<thead>
<tr>
<th>Platform Name 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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<tbody>
<tr>
<td><strong>Core Aircraft</strong></td>
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<tr>
<td>ER-2</td>
<td>DFRC</td>
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<td>WB-57</td>
<td>JSC</td>
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<tr>
<td>Ikhana</td>
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<tr>
<td>Global Hawk</td>
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<td>1500</td>
<td>$3500</td>
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<td>335</td>
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Suborbital Commercial Vehicles
(Several Companies in Development – X-Prize Winner shown for illustrative purposes)