## Performance Summary

<table>
<thead>
<tr>
<th></th>
<th>ER-2</th>
<th>WB-57</th>
<th>Global Hawk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Altitude</strong></td>
<td>&gt;70,000 ft</td>
<td>65,000 ft</td>
<td>65,000 ft</td>
</tr>
<tr>
<td></td>
<td>&gt;21 km</td>
<td>20 km</td>
<td>20 km</td>
</tr>
<tr>
<td><strong>Payload</strong></td>
<td>2,900 lb</td>
<td>8,800 lb</td>
<td>1,500 lb</td>
</tr>
<tr>
<td></td>
<td>1,300 kg</td>
<td>4,000 kg</td>
<td>700 kg</td>
</tr>
<tr>
<td><strong>Duration</strong></td>
<td>&gt;10 hours</td>
<td>6.5 hours</td>
<td>30 hours</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>&gt;4,000 nm</td>
<td>2,500 nm</td>
<td>&gt;10,000 nm</td>
</tr>
<tr>
<td></td>
<td>&gt;7,400 km</td>
<td>4,600 km</td>
<td>&gt;18,500 km</td>
</tr>
<tr>
<td><strong>Airspeed</strong></td>
<td>410 kts</td>
<td>410 kts</td>
<td>335 kts</td>
</tr>
</tbody>
</table>

*Note: performance parameters are sensitive to payload distribution and atmospheric conditions*
Manned Platforms

**WB-57**

Based at Ellington Field, Texas / NASA JSC
2 aircraft available for science missions
Dual crew

Variant of the Canberra, B-57 airframe developed for Air Force weather reconnaissance
Recent upgrades have increased gross weight and added new payload accommodations

- Science mission operations since the 1970’s
- World-wide deployment experience

- Multiple pressurized and unpressurized compartments
- 115 VAC and 28 VDC experimenter power
- Common payload infrastructure

**ER-2**

Based at Palmdale California / NASA DFRC
2 aircraft available for science missions
Single crew

Air Force U-2 derivative
Over 100 science instruments integrated
WB-57 Payload Accommodations

Payload Locations

Wing Pods

Nose

Pallet Bay

Wing Hatches

Tail Cone

Aft Fuselage
Global Hawk

- Highly reliable Unmanned Aircraft System (UAS)
  - Multiply redundant system design
  - Military experience with Global Hawk now exceeds 40,000 flight hours and 12 years of operation

- NASA owns three, Advanced Concept Technology Demonstrator (ACTD) aircraft

- Aircraft are based at the Dryden Flight Research Center on Edwards Air Force Base

- Configuration and performance similar to standard ‘Block 10’

- First NASA flight – Oct. 23, 2009
Global Hawk Payload 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></th>
<th>DC</th>
<th>AC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.0</td>
<td>8.8</td>
</tr>
</tbody>
</table>

Additional 7.5 KVA 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)

- Unique to NASA Global Hawk operations
- Located at Dryden Flight Research Center, Edwards AFB, CA

- Designed to enhance scientist’s participation during flight
  - Situational awareness
  - Controlled access to flight crews
  - Science collaboration

- Researchers have limited command and control access to their instruments
GloPac – Global Hawk Pacific

April 7th
14.1 hrs, 4600nm, 61200 ft

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

April 13th
24.3 hrs, 8000nm, 62300 ft

GloPac Total: 82.6 hrs

April 23rd
28.6 hrs, 9700nm, 65200 ft
GRIP
Genesis and Rapid Intensification Processes
Opportunities for International Missions

- Collaborative science opportunities announced through NASA ROSES
- Availability
  - Commitments generally developed 12 to 18 months before deployment
  - ER-2 and WB-57 have schedule opportunities, contact project managers for discussion of interests
  - Global Hawk is heavily committed over next three years
- Reimbursable missions for ER-2 or WB-57
  - Rate structure
    - User fee (fuel included), per hour, per week
    - Mission peculiar costs
    - Travel, logistics, instrument integration, satellite communications
for more information

<table>
<thead>
<tr>
<th>Program web-Site</th>
<th>ER-2</th>
<th>WB-57</th>
<th>Global Hawk</th>
</tr>
</thead>
</table>
Back-Up Charts
Global Hawk Pacific (GLOPAC)

Objectives

- First demonstration of the Global Hawk unmanned aircraft system (UAS) for NASA and NOAA Earth science research and applications.
- Validation of instruments on-board the Aura satellite.
- Exploration of trace gases, aerosols, and dynamics of remote upper Troposphere / lower Stratosphere regions.
- Sample polar vortex fragments (IPY) and atmospheric rivers.
- Risk reduction for future missions that will study hurricanes and atmospheric rivers.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACAM</td>
<td>Airborne Compact Atmospheric Mapper (GSFC)</td>
</tr>
<tr>
<td>CPL</td>
<td>Cloud Physics LIDAR (GSFC)</td>
</tr>
<tr>
<td>FCAS</td>
<td>Focused Cavity Aerosol Spectrometer (U. of Denver)</td>
</tr>
<tr>
<td>MMS</td>
<td>Meteorological Measurement System (ARC)</td>
</tr>
<tr>
<td>MTP</td>
<td>Microwave Temperature Profiler (JPL)</td>
</tr>
<tr>
<td>HDVis</td>
<td>HiDef Video System (ARC)</td>
</tr>
<tr>
<td>NMASS</td>
<td>Nuclei-mode Aerosol Size Spectrometer (U. of Denver)</td>
</tr>
<tr>
<td>Ozone</td>
<td>UAS Ozone (NOAA)</td>
</tr>
<tr>
<td>UCATS</td>
<td>UAS Chromatograph for Atmospheric Trace Species (NOAA)</td>
</tr>
<tr>
<td>UHSAS</td>
<td>Ultra-High Sensitivity Aerosol Spectrometer (Droplet Measurement Technologies)</td>
</tr>
<tr>
<td>ULH</td>
<td>UAS Laser Hygrometer (JPL)</td>
</tr>
</tbody>
</table>

Notes:
- Cross-track scanning spectrographs of NO2, O3, & aerosols.
- Backscatter LIDAR for hi-res profiling of clouds & aerosols.
- Aerosol size and concentration measurements.
- Science quality aircraft state variable measurements.
- Passive microwave radiometer meas. of O2 thermal emissions.
- Time-lapse nadir color digital imagery with georeferencing.
- Aerosol size and concentration measurements.
- Dual-beam UV photometer for accurate O3 measurements.
- Dual gas chromatographs for N2O, SF6, H2, CO, & CH4 meas.
- Ultra-high sensitivity aerosol spectrometer.
- In-situ hi-accuracy atmospheric water vapor measurements.
Global Hawk - PreGRIP

Risk reduction for Global Hawk participation in Genesis and Rapid Intensification Process (GRIP)

• 2 Flights operated from GHOC
  – Edwards range
  – Gulf, demonstrate COA

• July

• Partial payload integration
  – Drop sondes
  – HiWRAP
  – HAMSR
  – LIP

• Demonstrate:
  – Access to Gulf of Mexico and Caribbean
  – Methodology and sensors for operation near hazardous weather
    • stormscope
    • forward video both daylight and IR
**Global Hawk – Future Capabilities**

- **Mobile Operations Facility**
  - Allows deployed operations
    - Antarctic missions based in Chile or Australia
    - Eastern U.S. basing for greater coverage of Atlantic and Greenland
  - Supports terminal operations only, science team will support missions from the Dryden GHOC

- **Instrument integrations in progress**
  - UAVSAR (synthetic aperture radar)
    - Dual wing pylons for aero symmetry and mass balance
    - Bi-static interferometry option
  - Lidars for atmospheric profiling and topographic mapping
# ER-2 Payload Accommodations

<table>
<thead>
<tr>
<th>Area</th>
<th>ft³</th>
<th>m³</th>
<th>lb</th>
<th>kg</th>
<th>VAC (3φ)</th>
<th>VDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Nose</td>
<td>47.8</td>
<td>1.35</td>
<td>605</td>
<td>294</td>
<td>50A at 115/208</td>
<td>2kW at 28</td>
</tr>
<tr>
<td>2. Equipment Bay (Q-Bay)</td>
<td>64.6</td>
<td>1.83</td>
<td>1,300</td>
<td>590</td>
<td>100A at 115/208</td>
<td>4kW at 28</td>
</tr>
<tr>
<td>3. Left wing pod</td>
<td>86.0</td>
<td>2.43</td>
<td>650</td>
<td>294</td>
<td>50A at 115/208</td>
<td>2.2kW at 28</td>
</tr>
<tr>
<td>4. Right wing pod</td>
<td>86.0</td>
<td>2.43</td>
<td>650</td>
<td>294</td>
<td>50A at 115/208</td>
<td>2.2kW at 28</td>
</tr>
<tr>
<td>5. System 20 pod</td>
<td>.74</td>
<td>.02</td>
<td>45</td>
<td>20.4</td>
<td>30A at 115/208</td>
<td>840W at 28</td>
</tr>
<tr>
<td>6. Centerline pod</td>
<td>14.0</td>
<td>.40</td>
<td>350</td>
<td>159</td>
<td>30A at 115/208</td>
<td>840W at 28</td>
</tr>
</tbody>
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Mission Support

ER-2 and WB-57 both have long history with world-wide deployment capabilities.

**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.

ER-2 flight track on 19 July 2007
DC-8 Flying Laboratory
Large Capacity, 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
Gulfstream III
UAV Synthetic Aperture Radar (UAVSAR)

Capabilities
- Ceiling 45,000 ft.
- Duration 6 hours
- Range > 3,400 nautical miles
- Payload 2,610 lbs

Mission Support Features
- Center-line pod/pylon supports UAVSAR instrument
- Precision flight path capability
- Shirtsleeve environment instrument support
- World-wide deployment capability

UAVSAR
- Repeat-pass interferometry
- Ka- and L-band capability (separate pods)
- Designed for UAV operation – possible integration to Global Hawk
Ikhana (Predator B)
Medium Altitude, Very Long Endurance

Capabilities
• Duration > 24 hours
• Ceiling > 40,000 ft
• Payload 2,000 lbs, 750 lbs in wing pod
• Range 3,500 nautical miles

Mission Support Features
• Highly reliable UAS
• Deployment ready
  – Mobile ground station
  – High bandwidth science data link
  – Transport by land/sea/air
  – Ku Satcom for over the horizon missions
• External experiment pod with payload tray for parallel mission processing
• Internal payload compartments
• Experimenter network and data system
• Airborne Research Test System
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
Communications

- Separate links for aircraft and payload communications
- Iridium provide primary ‘beyond line of sight’ command and control for aircraft and experimenters
- High bandwidth links for experimenters can be accommodated as required
GloPac – Global Hawk Pacific

- First Global Hawk science flight
  - Apr 7
  - 14.1 hrs
  - Sampled polar vortex
  - Fulfilled last IPY goal
  - Satellite underpass

- Second Global Hawk science flight
  - Apr 13-14
  - 24.3 hrs
  - A-train satellite underpass
  - 2 vertical profiles to 43K'
  - Dipped to 12 degrees N
GloPac – Global Hawk Pacific

- First Global Hawk Arctic flight
  - Apr 23-24
  - 28.6 hrs
  - Reached 85 deg North (new Global Hawk record)
  - Reached 65k ft altitude
  - Sampled Arctic air
  - Investigated Asian dust plume
  - Satellite underpass