Suborbital Science Program

Dryden Flight Research Center

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**Program Objectives:**

**Satellite Calibration and Validation**

Provide methods to perform the cal/val requirements for Earth Observing System satellites

**New Sensor Development**

Provide methods to reduce risk for new sensor concepts and algorithm development prior to committing sensors to operations

**Process Studies**

Facilitate the acquisition of high spatial/temporal resolution focused measurements that are required to understand small atmospheric and surface structures which generate powerful Earth system effects

**Airborne Networking**

Develop disruption-tolerant networking to enable integrated multiple scale measurements of critical environmental features
Internal & External Program Drivers

- NASA Science Plan
- National Research Council Decadal Survey
- NASA Advisory Committee, Earth Science Subcommittee
- Global Earth Observation System of Systems
- Climate Change Science Initiative
- Ocean Action Plan

Alan Stern on Airborne Science:
“pennies on the dollar compared to satellite missions”

NOBEL Laureates with Airborne Science connections:
Sherry Rowland, Mario Molina, Paul Crutzen, George Smoot, John Mather
Dryden Flight Research Center - Overview

Dryden supports the NASA Airborne Science Program and the nation in the following elements:

**ER-2**
*Provide this unique, high altitude research platform to the science community*

**G-3**
*Provide a flexible, mid-range platform to the science community*

**DC-8**
*Flying laboratory, provide heavy lift platform and multiple instrument capability*

**Ikhana (Predator B) & Global Hawk**
*Provide access to developmental UAS capability*

**REVEAL**
*Disruption-tolerant airborne networking over-the-horizon*
ER-2

Capabilities
- Endurance > 10 hours
- Ceiling > 70,000 ft
- Payload 2,600 lbs
- Range > 4,000 nautical miles

Mission Support Features
- Multiple locations for payload instruments
- Pressurized and un-pressurized compartments
- Standardized cockpit control panel for activation and control of payload instruments.
- Iridium communications system
- World-wide deployment experience

FY06 Activity
- Over 170 science flight hours
- CALIPSO/Cloudsat Validation
- AVIRIS/REVEAL
- Large Area Collectors

Background and Status
- U-2 and ER-2 aircraft have been a mainstay of NASA airborne sciences since 1971
- Over 100 science instruments integrated
- Continuous capability improvements
- Two aircraft currently available for:
  - Remote sensing
  - Satellite calibration/validation
  - In-situ measurements and atmospheric sampling
  - Instrument demonstration, test and evaluation
Ikhana (Predator B)

Capabilities
Endurance: 30 hours
Ceiling altitude > 40,000 ft
Payload > 2,000 lbs (750 in pod)
Range: 3,500 nautical miles
Standard MQ-9 w/digital engine control

Mission Support Features
Airborne Research Test System
  • enables effective flight control research
Mobile ground control station
  • supports campaign deployment
External experimenter pod
  • rapid/flexible experiment integration

Status
‘Mission Ready’ date - June, 2007
  • A/C delivered in Nov. 2007
  • NASA pilots/crew in training
  • NASA unique systems in progress
First Science Campaign:
  • Western States Fire Mission
  • August, 2007
Cost-sharing with non-SMD projects
Global Hawk - Overview

**Capabilities**
- Endurance > 30 hours
- Range > 11,000 nmi
- Altitude 65,000 ft
- Payload > 1,500 lbs
- DC Power 2.0 KW
- AC Power 8.3 KVA

**Mission Support Features**
- Multiple payload locations.
  - Pressurized and un-pressurized.
  - Can accommodate wing pods (future).
- REVEAL system with ethernet network on the aircraft for payload C2/status.
- Fully autonomous control system, take-off to landing.
- Redundant LOS and BLOS aircraft command and control comm links.
- Redundant BLOS ATC comm links.
**Mission Objective**
- Provide new capability for solid earth science
  - Airborne repeat-pass radar imaging
  - Interferometric mapping of deforming surfaces

**Organization**
- Program Office: ESTO
- Instrument Dev. Lead: JPL
- Platform Dev. Lead: DFRC

**Description**
- Pod mounted instrument
- < 10 m tube flight path using JPL real-time DGPS and Dryden Platform Precision Autopilot
- Compatible with Gulfstream G-3 or UAS

<table>
<thead>
<tr>
<th>Task Start</th>
<th>Instrument CDR</th>
<th>G-3 Aircraft Mods CDR</th>
<th>Instrument 1st Flt</th>
<th>ORR</th>
</tr>
</thead>
<tbody>
<tr>
<td>2Q 2004</td>
<td>3Q 2004</td>
<td>4Q 2004</td>
<td>1Q 2005</td>
<td>2Q 2005</td>
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<td>1Q 2008</td>
<td>2Q 2008</td>
<td>3Q 2008</td>
<td>4Q 2008</td>
<td>1Q 2009</td>
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**G-3 UAVSAR Overview**
**Instrument Checkout Progressing @ JPL**
- Electronic components integrated
- Pod integration complete
- L-Band testing in progress
- Expect delivery of Ka Band instrument by end of October

**System Flight Tests on G-3 progress @ DFRC**
- Ground clearance tests for developmental flight series complete
- Pylon/Pod flight envelope cleared
- Phase 1 flight thermal control tests complete
- Precision Autopilot flight tests complete

10m flight path precision is demonstrated, based on recent flight tests
Suborbital Telepresence

**Objectives**

- Develop/demonstrate low-cost services for science payloads
  - Situational awareness
  - Decision support; productivity
  - Sensor web: *i.e.* Instrument interaction/C4I
- Applicable to all suborbital platforms, but special significance for UAS applications
CloudSat CALIPSO Validation Experiment (CC-Vex)

<table>
<thead>
<tr>
<th>Dates &amp; Location:</th>
<th>24 Jul - 14 Aug 2006: Atlanta, GA</th>
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<tbody>
<tr>
<td>Mission Objective:</td>
<td>Cloudsat CALIPSO validation</td>
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<tr>
<td>PI:</td>
<td>Trepte, LaRC (CALIPSO)</td>
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<tr>
<td></td>
<td>Mace, Univ.Utah (CloudSat)</td>
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<td>Sponsor:</td>
<td>ESD, Satellite Validation</td>
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<td>Platforms:</td>
<td>ER-2, LaRC B-200, WMI Lear</td>
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- CloudSat / CALIPSO launched 28 Apr 2006
- 12 comparison flights by ER-2, 4 at night
- B-200 King Air - 3 flights
- Lear - 7 flights
- Measurements of: thick and thin cirrus, mid-layer clouds, precipitating clouds, clouds with ice, water, and mixed phases, and aerosols.
- Results lead to improvements in satellite data products released in Dec 2006.
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>
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<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>• NASA/USFS/NOAA</td>
<td>First Ikhana science mission</td>
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<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 airspace operations</td>
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<tr>
<td>• NASA Atmos. Comp. program</td>
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<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


**Special Studies**

**UAS for Polar Science Missions**
- Concept study for UAS Arctic and Antarctic science mission scenarios
  - Feasibility, preliminary risk assessment, cost estimates
  - Predator B and Global Hawk
  - IPY time frame and beyond
  - Results provided in white paper (includes SBU)

**FAA Collaborations**
- Outgrowth from ACCESS 5 and recent UAS mission experiences
- Near-term expectations (5 years or so)
  - More effective use of the COA process, expand mission complexity
- Long-term approach
  - Support FAA UAS policy development efforts (domestic and international)
  - Make NASA aircraft and expertise available to develop supporting technologies

**Surrogate Satellites**
- Sustained aircraft ops to provide near-continuous coverage of a region
- Capitalize on UAS range/endurance and cost benefits
- Blend dedicated use of surrogate satellites with cyclic suborbital science requirements to maximize cost sharing

**Beyond current scope of the Suborbital Science Program, but potentially a cost-effective augmentation to space-based Earth observatories**
**New Technology - Summary**

**G-3 UAVSAR**
- A promising new capability for the science community

**Ikhana**
- NASA operations as a Suborbital science platform to begin this Summer

**Global Hawk**
- NASA operations could begin as early as 2008 pending partnership development

**Suborbital Telepresence**
- Phased development of airborne sensor web components with critical campaign support to TC-4

**Mission Demonstrations**
- Develop ‘real-world’ UAS experience through progressively sophisticated science missions

**Studies**
- Advanced planning for new mission opportunities