Suborbital Science Program Annual Review
Program Manager’s Session
NASA Headquarters, MIC 3
April 13, 2007

ER-2

Bob Curry
Director Science Missions Directorate
Dryden Flight Research Center
Capabilities & Background

Capabilities

- Ceiling > 70,000 ft
- Duration > 10 hours
- Range > 4,000 nautical miles
- Payload 2,600 lbs
  (700 lbs in each wing pod)
- GE F-118 Turbofan

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

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
FY06 Accomplishments

*Flew over 170 hours in support of Earth Science*

- CALIPSO/Cloudsat validation
- AVIRIS
- Large Area Collectors
ER-2 team deployed to Robins AFB
- Flew a total of 64.7 hours in 4 weeks (including 4 night flights over a 7 day period)

Targets
- Ranged from North Carolina coast to Kansas, south tip of Florida to Illinois
- Required heavy precipitation and water clouds as well convective cells to ensure proper measurements
**Instrument Integration**

- AVIRIS
  - Monitoring via REVEAL
  - In-flight dewar control
- Allowed utilization of ER-2 range capability, local flights to MN, WI

*Responded with 7 sorties within one month of initial contact*
Two aircraft mission ready for long-term Earth Science support

- ER-2’s are among the youngest aircraft in the NASA fleet
  - Tail #806 built in 1981
  - Tail #809 built in 1989
- Restructured project has brought most A/C support work in house reducing operational costs
- Planned retirement of the Air Force U-2 fleet will provide the ER-2’s with a large resource of parts and support equipment
  - Future availability of JPTS fuel will be a challenge
  - Potential upgrade – common fuel heater system to ER-2 and WB-57

Our current business model:

- Science supported rate of $3,700 /hour
- Reimbursable rate for non-science users of $10,000 /hour
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New Technology Element

Bob Curry
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Dryden Flight Research Center
New Technology - Overview

Objective:

*On-going development and demonstration of emerging technologies to enable more effective suborbital science capabilities of the future*

Primary Elements:

- G-3/UAVSAR
- Ikhana (Predator B) & Global Hawk
- Suborbital Telepresence
- Mission Demonstrations
- Studies
• **The Aircraft Science Platform**
  – Intercontinental capability (3500nm range, 0.85M, 45,000 ft)
  – Precision navigation capability (repeat pass interferometry)
  – Reconfigurable cabin & standardized equipment racks
  – Belly mounted standard MAU-12 science pod interface (1000 lbs)
  – Iridium, Inmarsat data links, on-board data system
  – AC & DC electrical power (up to 18 kW)
  – Self contained (no special ground support required)

• **The UAVSAR Instrument**
  – Robust repeat pass interferometry
  – Pod mounted instrument (transferable between platforms)
  – Synthetic Aperture Radar with 24 element array
    – Fully polarimetric at L-Band (1.2 GHz, 80 MHz band width)
    – Designed to be convertible to P-Band
• **Instrument Checkout Progressing @ JPL**
  – Electronic components integrated & in testing
  – Pod integration in progress
  – Expect delivery of instrument by end of April

• **System Flight Tests on G-3 Started @ DFRC**
  – Ground clearance tests for developmental flight series complete
  – Pylon/pod flight envelop cleared
  – Phase 1 flight thermal control tests complete
  – Precision autopilot flight tests started

10m flight path precision is expected, based on recent flight tests
• **Aircraft is configured for science support**
  – UAVSAR is current primary customer
  – Schedule available for additional users

• **Precision nav. system development**
  – Current system (Cycle 1) designed for limited conditions
    – 0.75M, 35,000 ft, 2 headings
  – Cycle 2 testing will begin in July
    – Multiple speeds, altitudes, and headings

• **Pod installation requires modification to support world wide operations**
  – Increased ground clearance with acceptable flow quality
  – Implementation planned in early 2008

• **G-3/UAVSAR capability expected to be fully operational and ready to support science missions by late 2008**

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<thead>
<tr>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
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- **IIP**: Task Start
- **Phase B**: Instrument CDR
- **Phase C/D**: G-3 Aircraft Mods CDR
- **Science**: Instrument 1st Flt
- **ORR**:
Ikhana (Predator B)

**Capabilities**
- Endurance > 24 hours
- Altitude > 40,000 ft
- Payload > 2,000 lbs (750 in pod)
- Range 3,500 nautical miles
- Highly reliable UAS
  - Standard MQ-9 w/digital engine control
  - Triple redundant flight control systems, dual redundant power & networks
  - Predator family has logged over 200,000 hours

**Mission Support Features**
- Internal payload compartments
- External experiment pod
  - wing pylon in development
  - ethernet & power connectivity
- Experimenter network and data system
- Mobile ground control station
  - Ku Satcom for over the horizon missions
  - 6 experiment monitoring stations
- Airborne Research Test System
  - 3 processor research flight control and/or mission computer
  - allows autonomous control of the aircraft and some systems
  - able to host research control laws
Ikhana (Predator B) – Status

‘Mission Ready’ date - June, 2007
- A/C delivered in Nov. 2006
- NASA pilots/crew in training
- Experimenter’s Handbook in development

Current commitments
- Western States Fire Mission August 2007
- ARMD Fiber Optic Wing Shape Sensor
- UAV-AVE Summer, 2008
Global Hawk

**Capabilities**
- Endurance > 30 hours
- Altitude 65,000 ft
- Payload > 1,500 lbs
- Highly reliable, mature UAS
  - Triplex system redundancy
  - Candidate airframes have flown 740 hrs hours (combined)

**Mission Support Features**
- Multiple payload locations
  - 40 ft³ pressurized
  - 62 ft³ un-pressurized
  - Can accommodate wing pods (future)
- Flies above conventional air traffic altitudes
- Fully autonomous control system, take-off to landing
- Inmarsat for over the horizon missions

**Status**
- Aircraft transfer to Dryden expected by Summer
  - 2 ACTD aircraft
  - NASA HQ and Pentagon approval in place
  - NASA/USAF MOA will be final step
- Technical requirements defined
  - Startup phase (training, GSE, logistics, spares . .)
  - On-going flight program (2 flts per month)
- Business plan depends on external partner(s); negotiations with DoD, industry, and other civilian agencies are on-going
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
Objective:
Conduct representative science missions with UAS’s to demonstrate capabilities and expose issues and limitations

<table>
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<tr>
<th>Mission</th>
<th>Successes</th>
<th>Issues / Resolution</th>
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<tbody>
<tr>
<td><strong>Alaska</strong></td>
<td>• 15 hour operations&lt;br&gt;• UAS in the NAS&lt;br&gt;• Self Deployment</td>
<td>• High Latitude Sat. Coverage =&gt; Pending&lt;br&gt;• FAA Coordination =&gt; NASA Responsibility on Future Missions</td>
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<td>• NASA/USCG partnership&lt;br&gt;• General Atomics Altair</td>
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<td><strong>Maldives AUAV Campaign</strong></td>
<td>• Autonomous precision coordinated flight with mini-UAV’s&lt;br&gt;• Foreign deployment</td>
<td>• UAS export control =&gt; NASA involvement&lt;br&gt;• Risk management =&gt; Implement/develop appropriate science/flt rigor and procedures</td>
</tr>
<tr>
<td>• UCSI/NSF/NASA&lt;br&gt;• PI led, NASA consultation&lt;br&gt;• ACR Manta</td>
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<td><strong>Channel Islands</strong></td>
<td>• 20 hour operations&lt;br&gt;• UAS in the NAS with FAA exp. cert.</td>
<td>• A/C systems unreliable at altitude =&gt; resolved by re-design&lt;br&gt;• Internal payload integration =&gt; external pod&lt;br&gt;• Contractor dependence =&gt; NASA operations</td>
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<tr>
<td>• NASA/NOAA partnership&lt;br&gt;• General Atomics Altair</td>
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<td><strong>Western States Fire - 2006</strong></td>
<td>• 23 hour flights&lt;br&gt;• On-board data processing and real time transfer to field&lt;br&gt;• Quick response into the NAS to support real-life emergency</td>
<td>• Access to NAS greatly de-scoped =&gt; Initiated in-depth FAA/NASA collaboration for UAS mission support&lt;br&gt;• Risk management processes =&gt; established req'ts and processes for alternative landing sites</td>
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<td>• NASA/USFS/NOAA&lt;br&gt;• General Atomics Altair&lt;br&gt;• FIRE sensor</td>
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<tr>
<td>– Developed at Ames&lt;br&gt;– Tailored to UAS</td>
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<tr>
<td>Mission</td>
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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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<tr>
<td>• Ikhana / NASA operations</td>
<td>• More effective interaction with USFS users</td>
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<td><strong>UAV AVE - Summer 2008</strong></td>
<td>• May involve international airspace operations</td>
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<tr>
<td>• NASA Atmos. Chem. program</td>
<td></td>
<td></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
**Background**

- HQ requested study of Arctic and Antarctic scenarios
  - Feasibility
  - Preliminary risk assessment
  - Cost estimates
- Results provided in white paper (includes SBU)

**Key Findings**

- Long duration polar missions are feasible, but will incur increased risks
- Recommendations
  - Vehicle upgrades
    - Ikhana => redundant generator, Iridium A/C C2 link
    - Global Hawk => Iridium A/C C2 link
  - Use conventional airfields and accept cost of transit flight time

**Best opportunities**

- During IPY
  - Arctic missions with Ikhana
- Beyond IPY
  - Global Hawk missions to either hemisphere
  - Ikhana missions to Arctic or Antarctic coastal and peninsular regions
Background

- Outgrowth from ACCESS 5 and recent UAS mission experiences (this year: 4 face-to-face meetings and weekly multi-agency phone conference)
- FAA views DFRC as expert in civil UAS operations and safety processes
- NASA participation in FAA UAS activities are crucial to insure:
  - Suborbital science mission needs are addressed
  - Transfer of knowledge
  - Push the regulatory envelop
- Activities are being integrated into Suborbital Science Technology Working Group

Near-term approach (five years or so)

- Establish reliable and effective methods to work with the COA process
- Progressively expand science mission capability (profiling, re-direct, etc)

Long Term approach

- Participate in FAA UAS policy development efforts
  - SC203: civil national airspace system UAS policy development
  - International interactions with ICAO, EASA and EUROCAE
- Make available NASA aircraft and expertise to develop supporting technologies
**Background**

- NOAA concept for 5-year Arctic dropsonde survey
  - Global Hawk ops from Fairbanks, AK
  - 3 flights per week, 4 months per year
- Dryden feasibility study has generated interest in the economics of sustained flight operations
- ROM for dedicated Global Hawk usage: $22M/yr (120 flights, 2640 flight hours, including deployment expenses)

**Concept**

- Emulate satellite coverage of a region(s) of interest
- Capitalize on UAS range/endurance
- Blend dedicated use of surrogate satellites with cyclic suborbital science requirements to maximize cost sharing

- *Near-term operations can begin immediately with ER-2 and transition to Global Hawk when appropriate*

**Aircraft as ‘Surrogate Satellites’**

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<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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<tr>
<td>• Focus coverage on regions/times of interest</td>
<td>• Limited spatial coverage</td>
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<tr>
<td>• On-going sensor upgrade and maint.</td>
<td>• Limited altitude (20 km)</td>
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<td>• Continuous trajectory re-planning</td>
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<td>• Adjustable program lifetime</td>
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**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