NASA Experience with UAS Science Applications

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• Background

• Science demonstration missions
  – USCG Alaska
  – NOAA Channel Islands
  – Western States Fire
  – Esperanza Fire

• Current Status of NASA Dryden UAS Science Platforms

• Summary
Background

• NASA Sub-Orbital Science Program
  – Objectives
    ♦ Development of space-based sensors
    ♦ Satellite calibration/validation
    ♦ Ephemeral phenomena
    ♦ Atmosphere/near-space in-situ observations
    ♦ Improve Earth process models
  – Aircraft Platforms
    ♦ Traditional: ER-2’s, DC-8, WB-57’s, others
    ♦ New Technology: UAS’s

• Why Unmanned Aerial Systems (UAS’s) for Science Missions?
  – Unique capabilities
    ♦ duration
    ♦ range
  – Operations in hazardous locations
    ♦ extended polar missions
    ♦ volcanic plumes, hurricane
  – Implications for the future of environmental monitoring & response missions
Science UAS Development Challenges

- Science missions impose unique requirements on UAS vehicles and operations
  - Access to national/international airspace
  - Unusual flight profiles
  - Reconfigurable sensor installations
  - Cost control
  - Global tele-presence for instrument command and control

- Conducting representative, scientific missions is the best way to push the technology
  - Confirm performance and capabilities
  - Expose limitations and unexpected issues
  - Progressive build-up of mission complexity
  - Engage the science community

“Flight research separates the ‘real from the imagined’ and makes known the ‘overlooked and unexpected’”

Hugh L. Dryden
USCG Alaskan Maritime Surveillance

- Objective: Evaluate use of a UAS for intelligence, surveillance, and reconnaissance (ISR) operations

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- Overview
  - United States Coast Guard (USCG), NASA, GA, and others
  - General Atomics Altair (high-altitude Predator B derivative)
  - Payload
    - surface surveillance radar, . . .
    - internal integration
  - Flight Operations: Summer, 2004
    - Self deployment from California to Alaska
    - Launch and recovery team operating remote from mission operations center in Juneau
    - Over the horizon shore to ship communications relay
Major Accomplishments
- Long-range, remote deployment of aircraft, crews, and project team
- Multiple aircraft control and communication hand-offs
- Established Northern latitude limit for geostationary satellite data link
- Provided streaming video to support Alaska wildfire management

Issues: Reduced Mission Scope
- Sensor integration complications
- High latitude satellite coverage less than anticipated
- Flight limitations due to low satellite elevation angle
Objective: Evaluate the use of a UAV for future science and operational requirements
- Atmospheric research
  - sample low-level Eastern Pacific jets
- Atmospheric research
  - coastal mapping, wildlife monitoring, marine enforcement

Overview
- NOAA, NASA joint project
- General Atomics Altair
- Internal payload integration
- Flight operations
  - Spring, 2005 and Fall, 2005
    - Flights in National Air Space (NAS) under Certificate of Authorization (COA)
      - primarily at FL430
      - descents below 18,000 ft escorted by chase plane
NOAA/NASA UAV Demonstration Project

- Major Accomplishments
  - 20 hour missions
  - over 2500 miles of ocean coverage
  - UAS in the National Airspace with FAA experimental type certificate

- Issues
  - Airspace coordination complications
  - UAS systems reliability under extended high altitude operation
  - Complexity of internal payload integration
Western States Fire Mission

- Objective: Identify and monitor wildfire events throughout the Western United States and provide near real-time products to field units

- Overview
  - NASA, USFS, NOAA, GA partnership
  - General Atomics Altair with centerline pod
  - Payload
    - Wildfire sensor – Developed at NASA Ames
      - 13 spectral bands optimized for fire characterization
      - Fully autonomous
    - near real-time data transfer
      - on-board processing (geo-rectification)
      - overlayed with Google-Earth imagery
      - internet access by end users
    - in-situ atmospheric sampling
    - experiment command and control from ground
  - Flight operations: Fall, 2006
    - XX flights from base at Grey Butte, CA; primarily in military airspace
    - Only 1 flight into National Air Space (NAS), always at FL430
Western States Fire Mission

• Major Accomplishments
  – grid patterns over Yosemite National Park
  – re-direction based on satellite data
  – 23 hour flights
  – coordination with satellite overpasses
  – outstanding data quality
  – demonstrated the importance of virtual presence for experimenters

• Issues: Reduced Mission Scope
  – FAA processes in transition
  – complex risk management issues

Flight Planning Challenges
  • FAA control boundaries
  • Special use airspace
  • $E_C$ calcs (avoid pop. centers)
  • Contingency routing
  • Alternate and emerg. landing sites
Esperanza Fire Emergency Response

- California Office of Emergency Services requested NASA assistance
  - 40,000 acres (62 sq mi)
  - 5 firefighters killed
  - 34 homes destroyed

- First use of FAA Emergency COA for civilian disaster response
Esperanza Fire Emergency Response

- Friday, Oct. 27 10:00 AM - Received request

- Saturday at 3:45 PM – Aircraft launched
  - FIRE sensor returned to Grey Butte and installed on A/C
  - Ground safety analyses
  - Requested and received FAA approval
  - Aircraft prepared for flight

- Sunday 7:30 AM - Landing

16 flight hours
94 images, 44 shapefiles
Ikhana (Predator B)

A NASA Unmanned Aerial System
Supporting Long-Duration Earth Science Missions

‘Mission ready’ in July, 2007

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
Ikhana (Predator B)

Payload Areas
- Wing-mounted pods
- Avionics Bay
  - Payload Tray
  - Chin compartment

Experimenter Network
- Ethernet network connecting avionics bay and remote pods
- Communications, recording, downlink, time code, aircraft state data
Other Mission Support Features

- 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
• **Objective**: Advanced airborne SAR capability
  – autonomous operation
  – interferometry products

• Radar development - NASA JPL

• Aircraft modifications and flight testing – NASA Dryden
  – Development activity on G-3
  – Instrument housed in external pod
  – A/C precision navigation for
    ♠ repeat pass interferometry
    ♣ flight path control to within +/- 5 m

• Portable to Predator B class UAS
  – long duration for continuous event monitoring
  – high altitude for long uninterrupted flight lines
**Global Hawk**

**Capabilities**
- Endurance > 30 hours
- Altitude 65,000 ft
- Payload > 1,500 lbs
- Highly reliable, mature UAS

**Mission Support Features**
- Multiple payload locations
  - 40 ft³ pressurized
  - 62 ft³ un-pressurized
  - Can accommodate wing pods (future)
- Flies above conventional air traffic
- Fully autonomous control system, take-off to landing
Related Technologies

• Sub-orbital Tele-presence (Airborne Sensor Web)
  – 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

• Access to airspace
  – Near-term expectations (next five years or so)
    ♣ Certificate of Authorization processes
  – Long-term
    ♣ Rules and procedures for UAS certification and routine operation in the national air space
    ♣ Technology development
• Unmanned Aerial Systems offer great potential for Earth science missions of the future

• Performing representative science missions has been critical to understanding and guiding UAS technology implementation

• New platform and sensor capabilities are under development

• A follow-on to the Western States Fire Mission will be conducted in Summer, 2007 with the NASA Ikhana aircraft