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

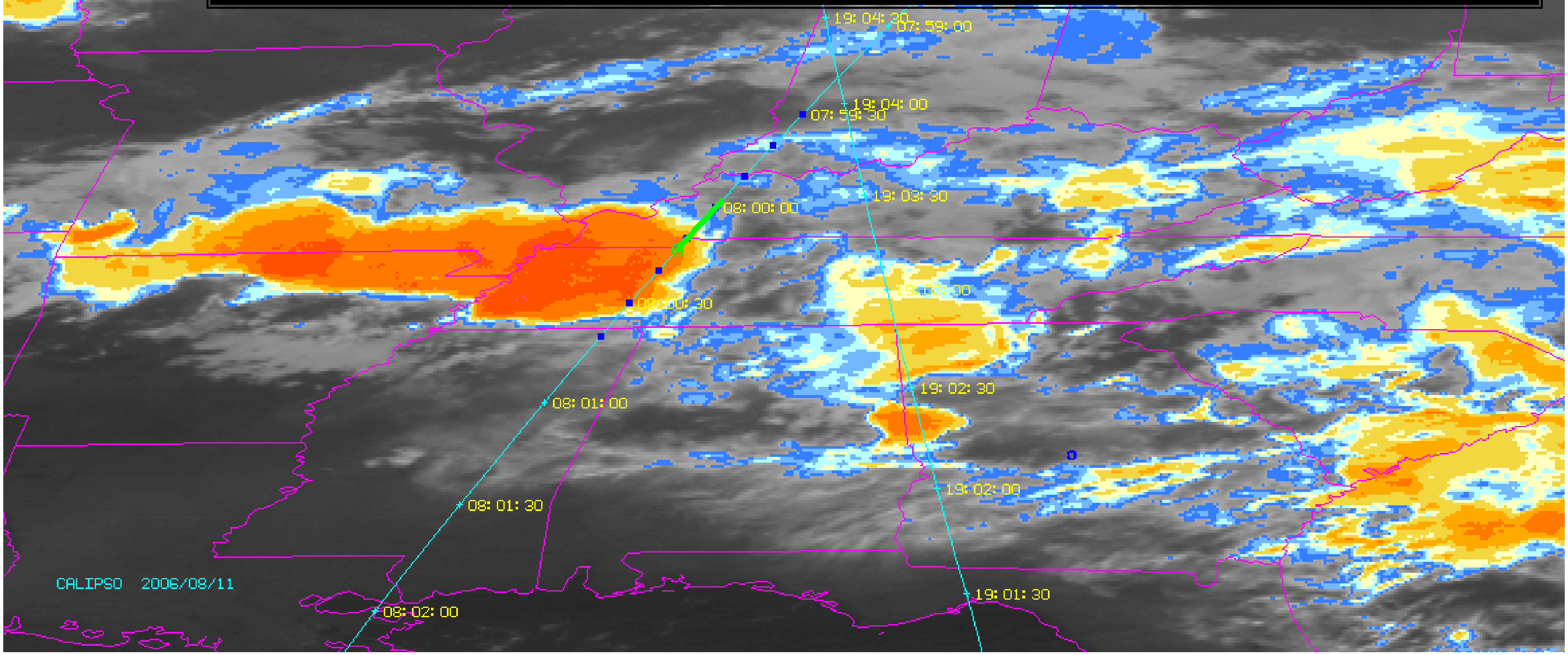
CALIPSO/Cloudsat Validation Experiment

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

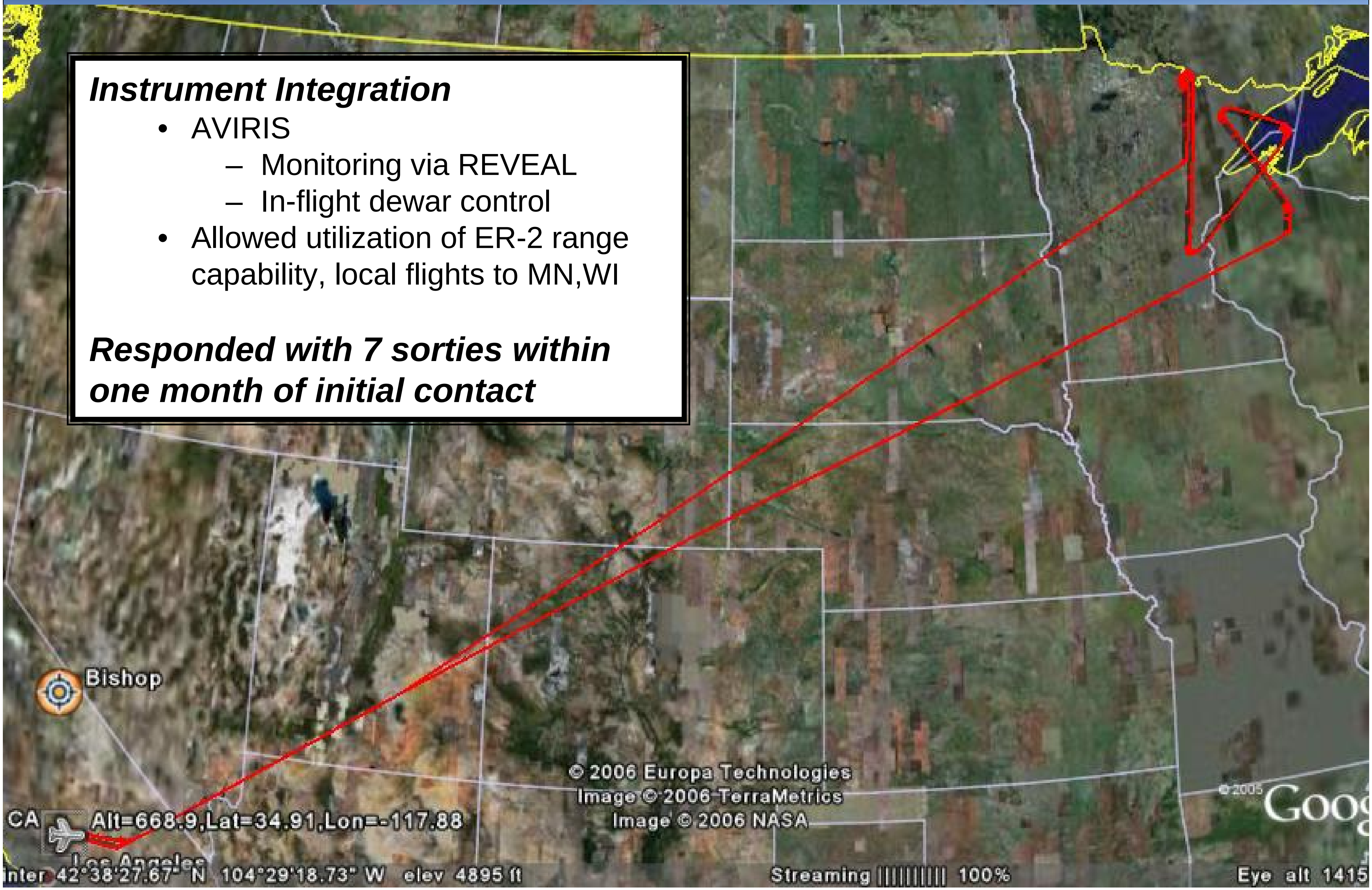


ER-2 AVIRIS

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



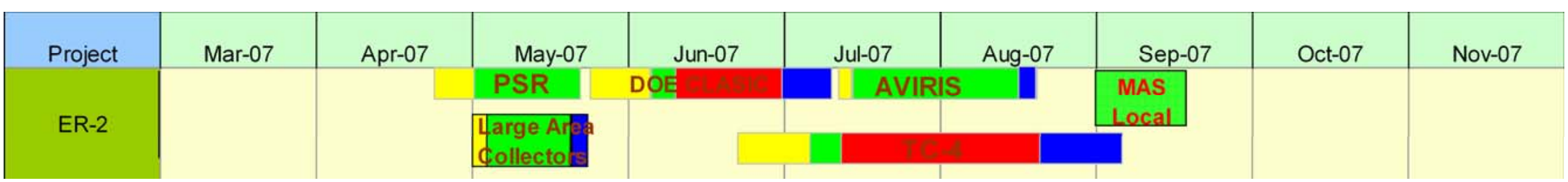
Outlook and Availability

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 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

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New Technology - Overview

Objective:

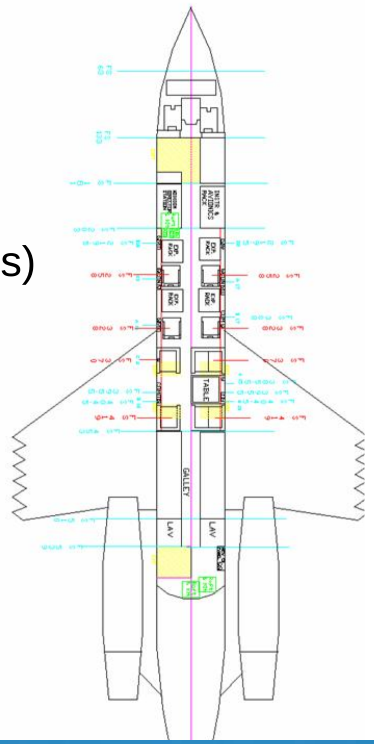
On-going development and demonstration of emerging technologies to enable more effective suborbital science capabilities of the future

Primary Elements:

- **G-3/UAVSAR**
- **Ikhana (Predator B) & Global Hawk**
- **Suborbital Telepresence**
- **Mission Demonstrations**
- **Studies**

G-3 UAVSAR Mission Capabilities

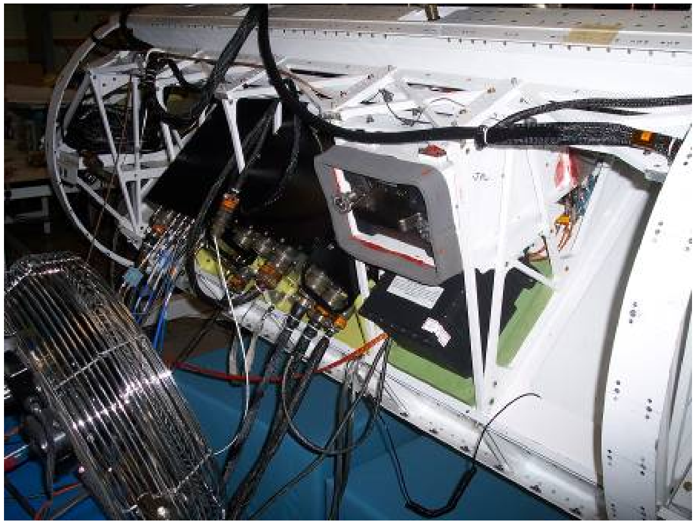
- ***The Aircraft Science Platform***
  - Intercontinental capability (3500nm range, 0.85M, 45,000 ft)
  - Precision navigation capability (repeat pass interferometry)
  - Reconfigurable cabin & standardized equipment racks
  - Belly mounted standard MAU-12 science pod interface (1000 lbs)
  - Iridium, Inmarsat data links, on-board data system
  - AC & DC electrical power (up to 18 kW)
  - Self contained (no special ground support required)



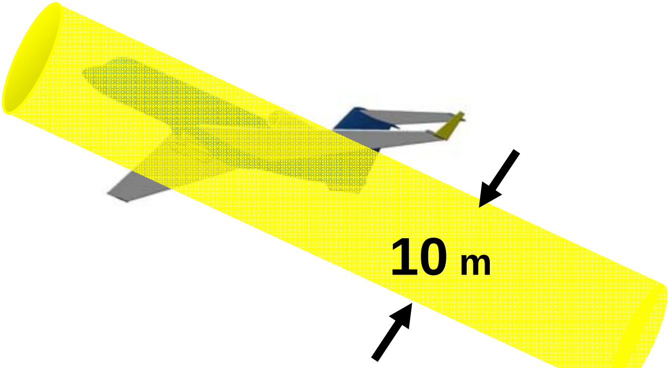
- ***The UAVSAR Instrument***
  - Robust repeat pass interferometry
  - Pod mounted instrument (transferable between platforms)
  - Synthetic Aperture Radar with 24 element array
    - Fully polarimetric at L-Band (1.2 GHz, 80 MHz band width)
    - Designed to be convertible to P-Band

G-3/UAVSAR Technical Progress

- ***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

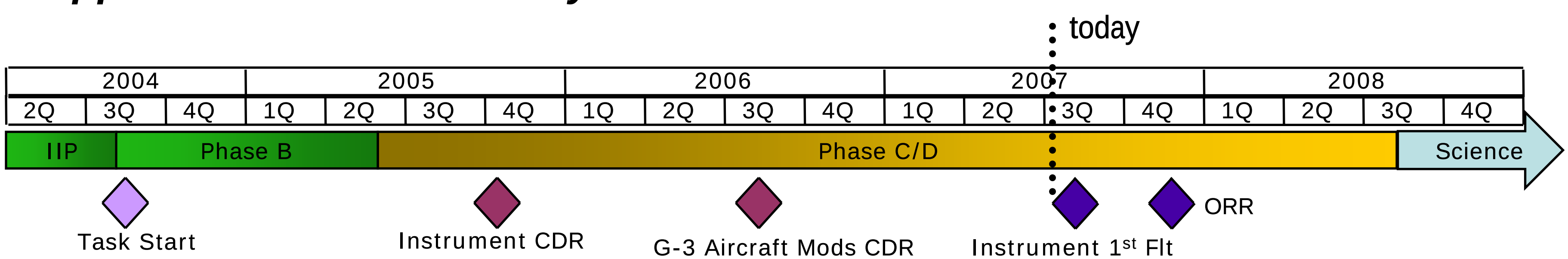


10m flight path precision is expected, based on recent flight tests

G-3/UAVSAR Outlook & Availability

- ***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***



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

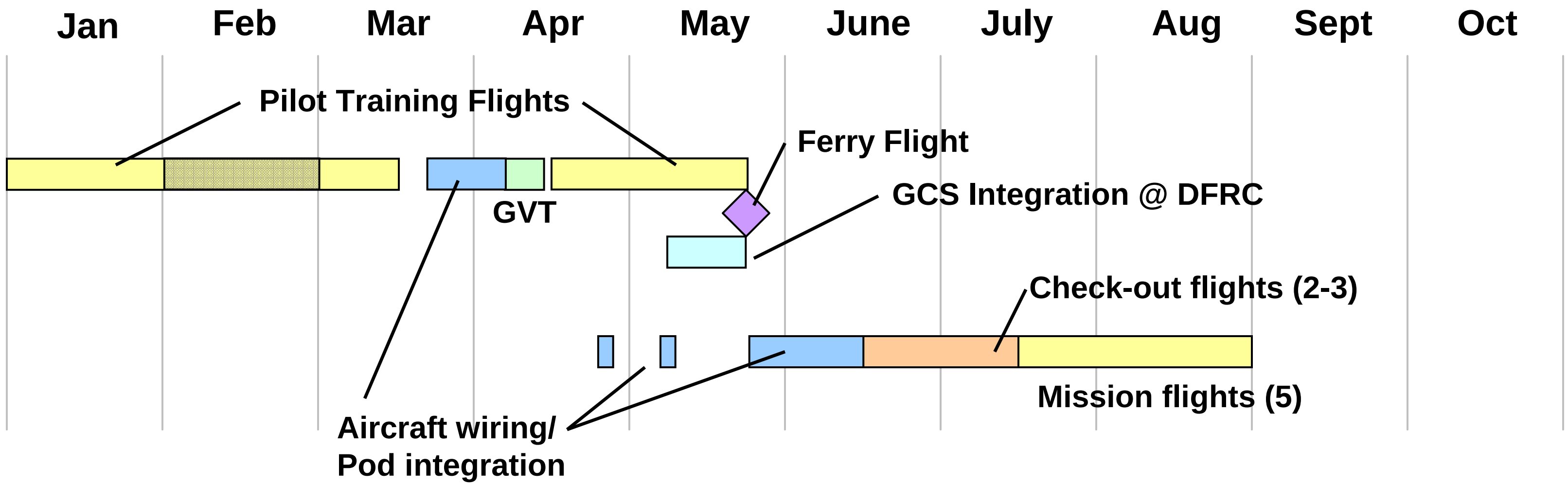
Ikhana (Predator B) – Status

'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



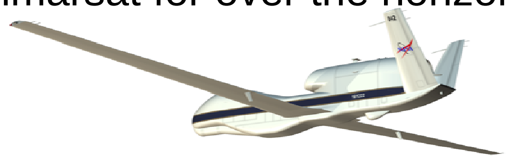
Global Hawk

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 ft^3 pressurized
  - 62 ft^3 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

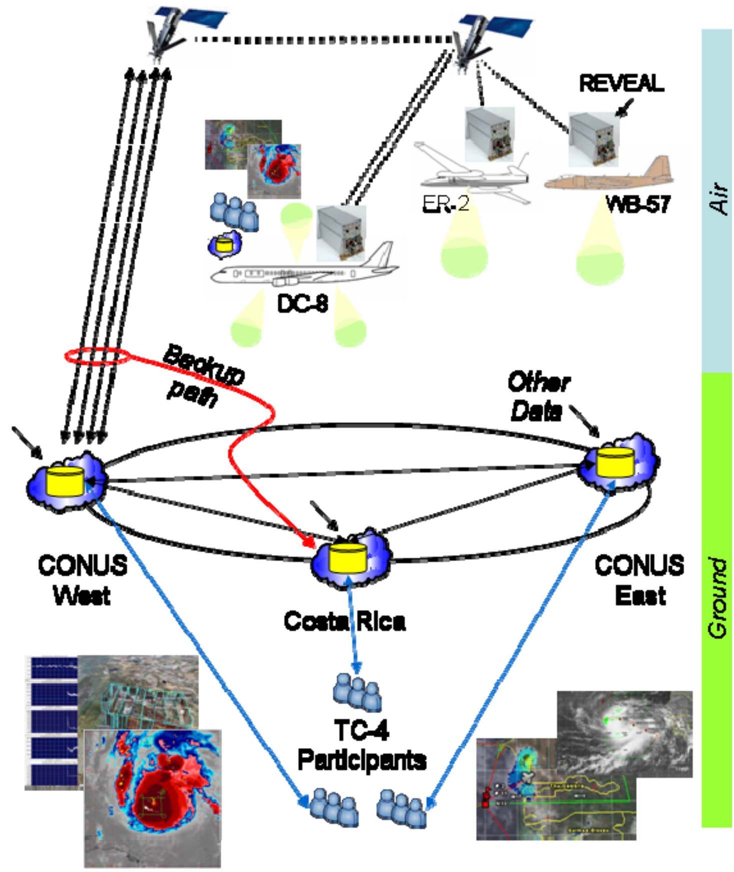
- Aircraft transfer to Dryden expected by Summer
  - 2 ACTD aircraft
  - NASA HQ and Pentagon approval in place
  - NASA/USAF MOA will be final step
- Technical requirements defined
  - Startup phase (training, GSE, logistics, spares . .)
  - On-going flight program (2 flts per month)
- Business plan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

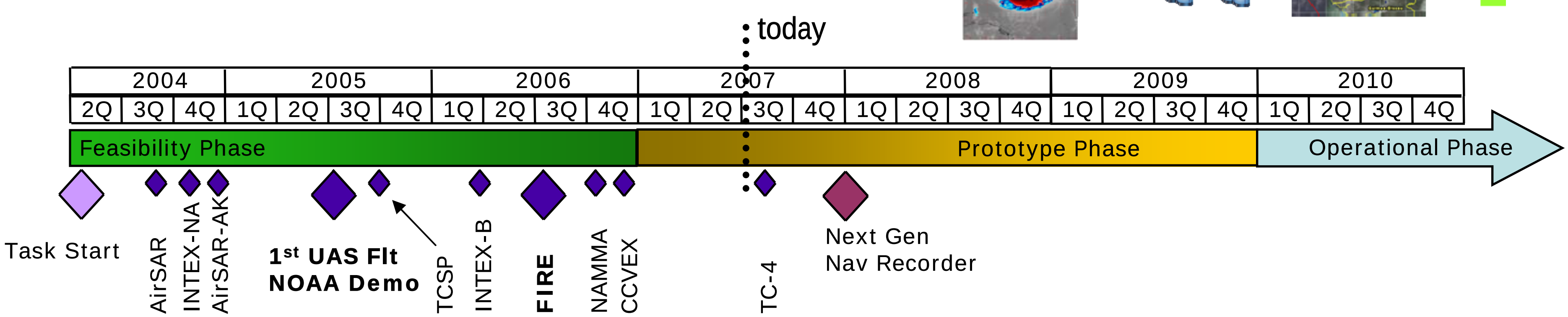
Suborbital Telepresence

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





UAS Mission Demonstrations

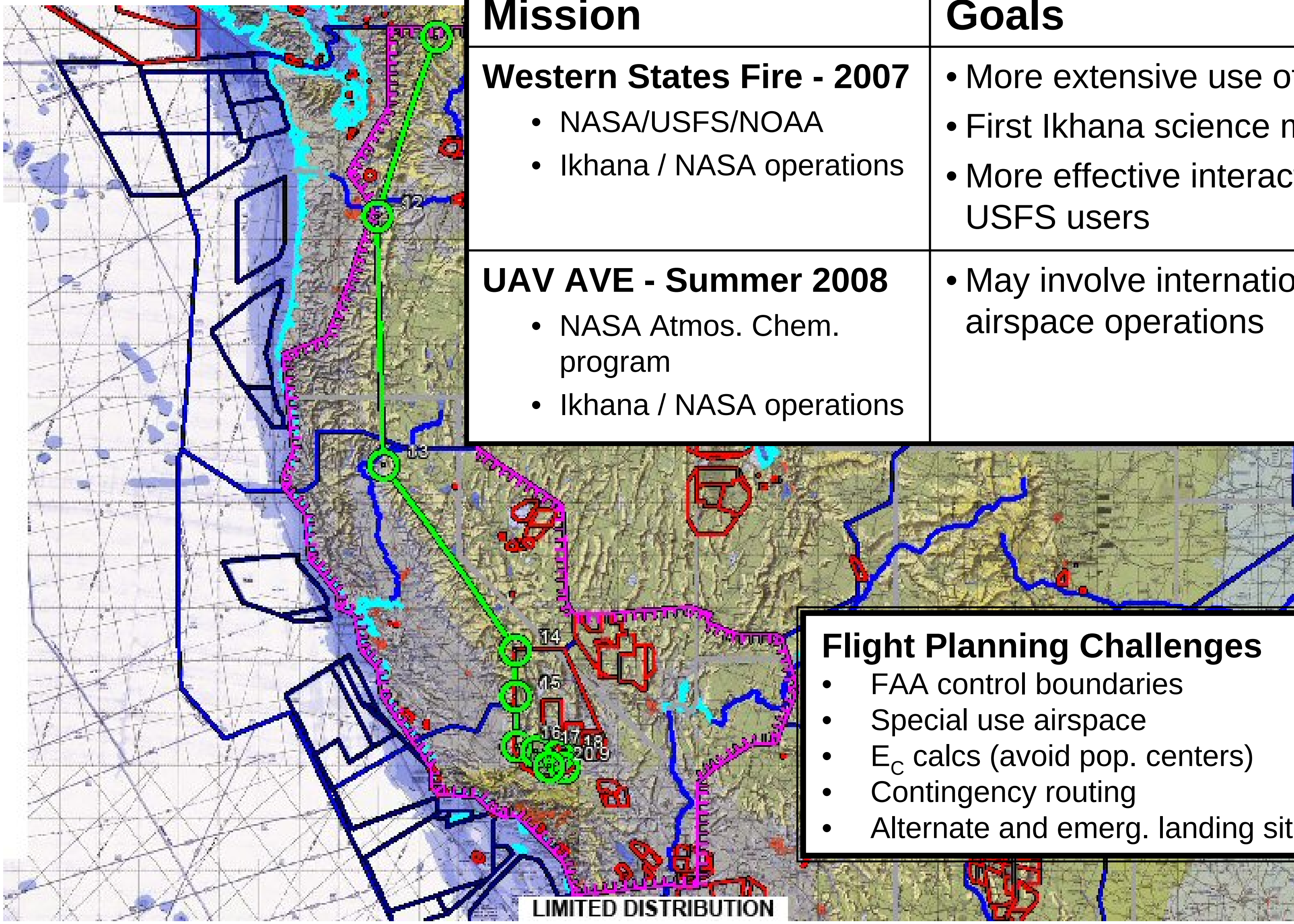
Objective:

Conduct representative science missions with UAS's to demonstrate capabilities and expose issues and limitations

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

Mission Demonstrations - Planned

Mission	Goals
Western States Fire - 2007 • NASA/USFS/NOAA • Ikhana / NASA operations	• More extensive use of NAS • First Ikhana science mission • More effective interaction with USFS users
UAV AVE - Summer 2008 • NASA Atmos. Chem. program • Ikhana / NASA operations	• May involve international airspace operations



Flight Planning Challenges

- FAA control boundaries
- Special use airspace
- E_C calcs (avoid pop. centers)
- Contingency routing
- Alternate and emerg. landing sites

Studies – UAS for Polar Science Missions


Uninhabited Aerial System Capabilities for Earth Science in the Polar Regions

Current Version Includes Proprietary Information – for government use only

A White Paper
Prepared by:

NASA Dryden Flight Research Center
Earth Sciences Capability Demonstration Team

February, 2007

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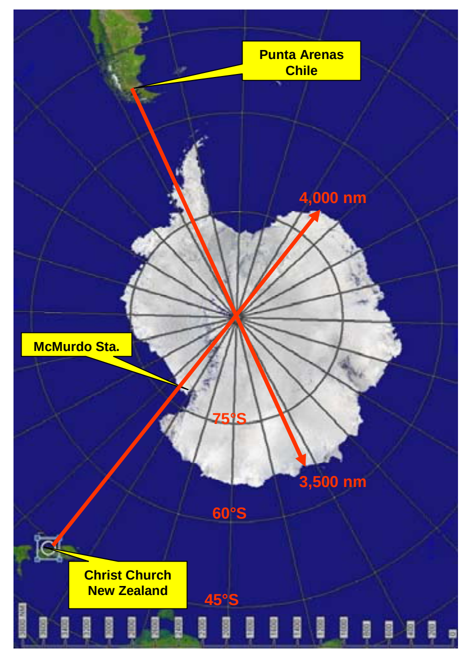
Background

- 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

Studies –FAA Collaboration

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

Studies – Surrogate Satellites

Background

- NOAA concept for 5-year Arctic drop-sonde 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'

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

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