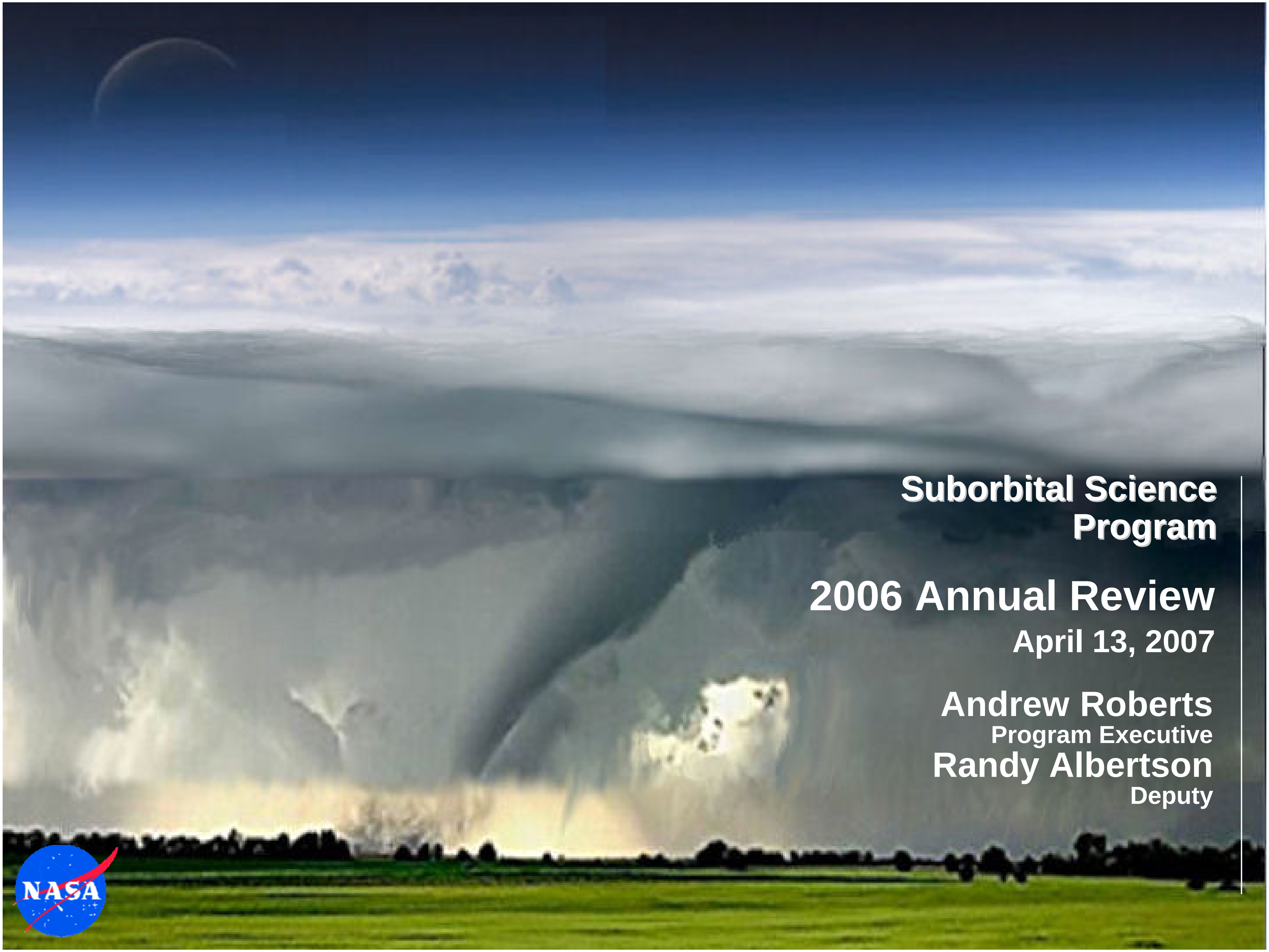


Suborbital Science Program

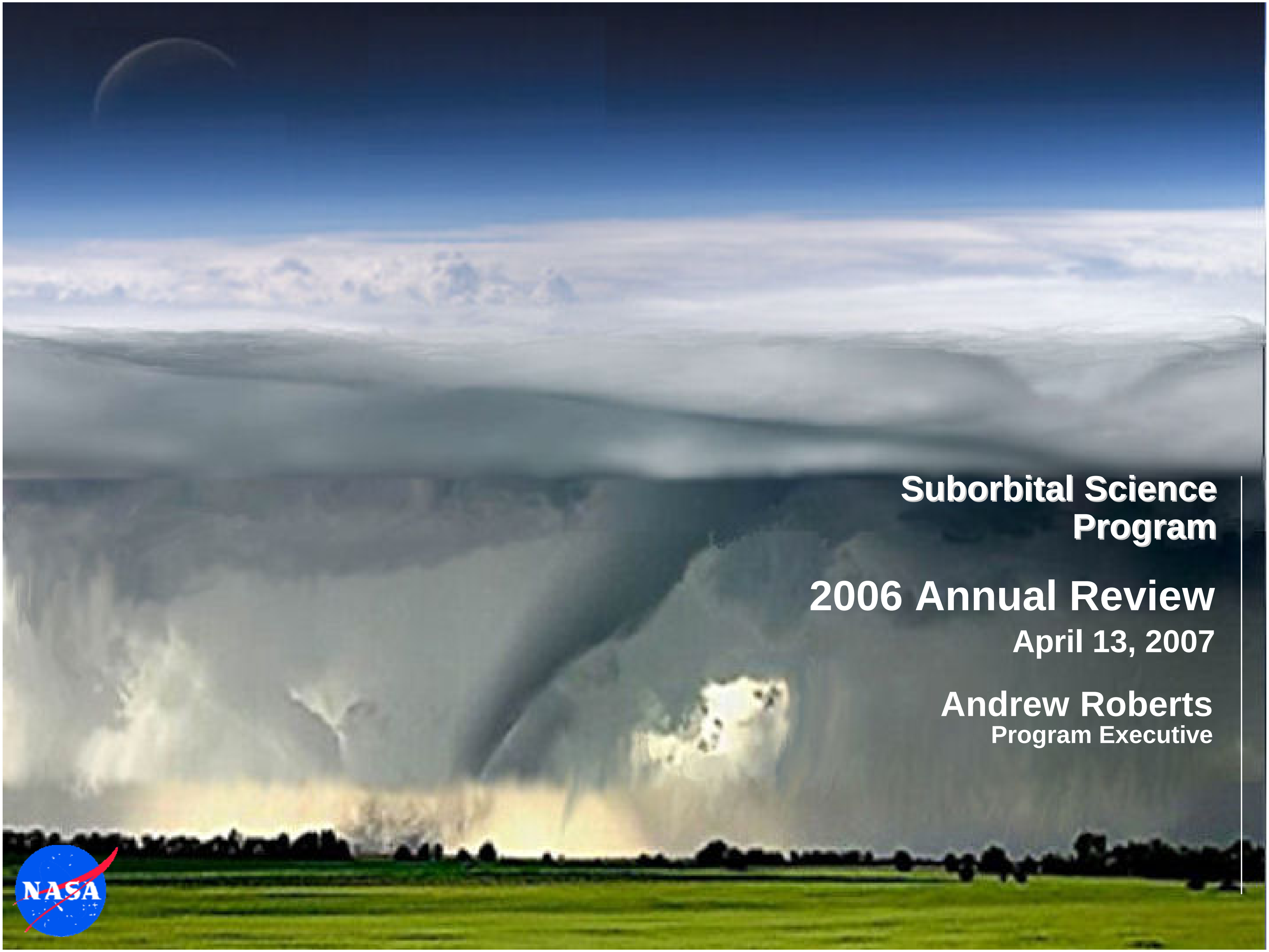
2006 Annual Review

April 13, 2007

Andrew Roberts
Program Executive
Randy Albertson
Deputy

Executive Summary Agenda

9:00	Opening/Introduction		
9:05	Program	Andy Roberts, Program Executive, Suborbital Science Program	
			Vision, goals & objectives
			Current structure
			Budget
			Collaborations
9:20	Ames RC	Steve Hipskind, Chief, Earth Science Division	
			Missions
			Flight requests
			Requirements
			Sensors
			Sierra
9:55	Goddard SFC	Anthony Guillory, Airborne Science Project Manager	
			DC-8 & CA
			P-3B
			Aerosonde
			Catalog (Comm, university, OGA)
10:10	Dryden FRC	Bob Curry, Director, Science Mission Directorate	
			ER-2
			UAVSAR/G-III
			UAS Demonstrations
			REVEAL
			Ikhana/Global Hawk
10:25	Johnson SC	Ken Cockrell, Program Manager, WB-57	
			WB-57
10:35	Program	Andy Roberts	
			Looking forward
10:45	Open Discussion		
10:55	Closing comments and action items		
11:00	Adjourn		



Suborbital Science Program

2006 Annual Review

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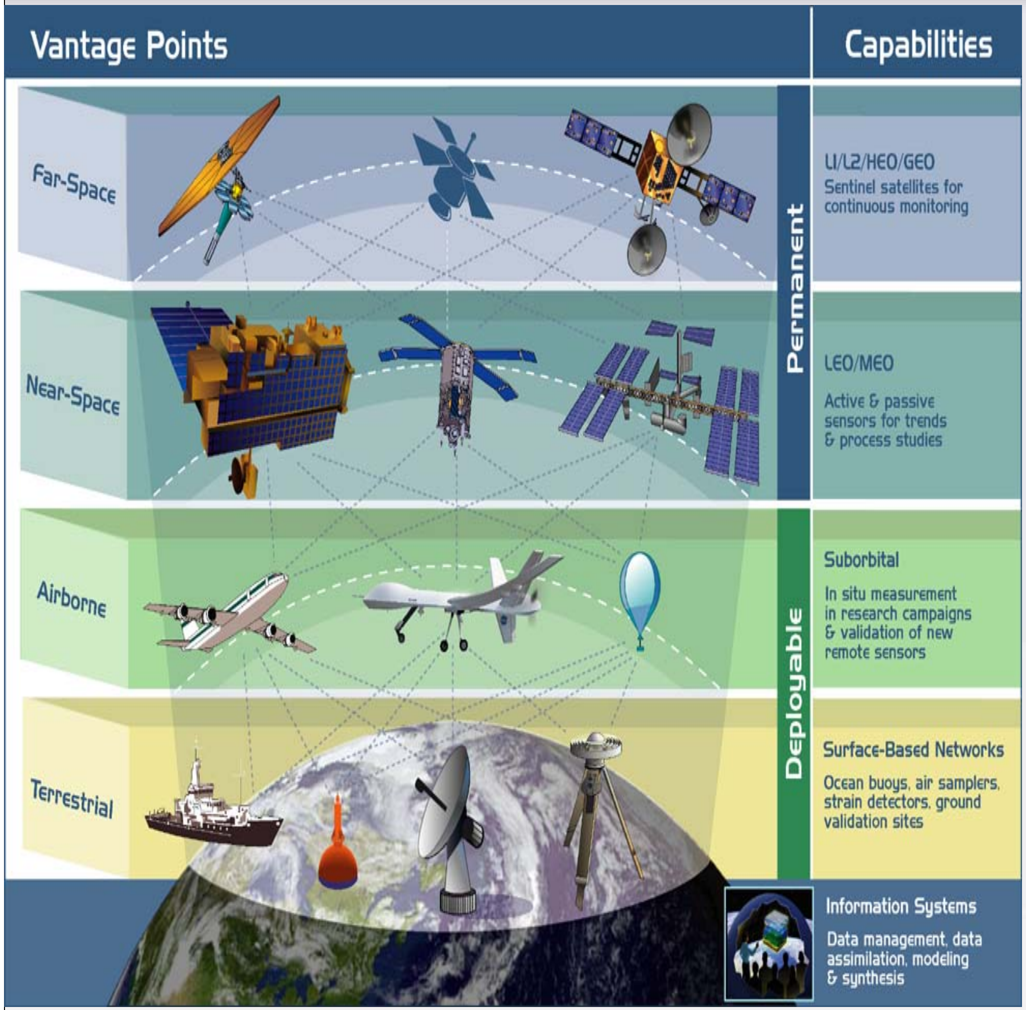
Andrew Roberts
Program Executive

NRC Decadal Survey for Earth Science:
(released 16 January 2007)

Space-based observations provide a global view of many Earth system processes; however, satellite observations have a number of limitations, including spatial and temporal resolution and the inability to observe certain parts of the Earth. Hence, they do not provide a picture of the Earth system that is sufficient for understanding key physical, chemical, and biological processes.

Recommendation: NASA should support Earth science research via suborbital platforms: airborne programs, which have suffered substantial diminution, should be restored, and UAV technology should be increasingly factored into the nation's strategic plan for Earth sciences.

Suborbital Science Program



Program Objectives:

Satellite Calibration and Validation

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

New Sensor Development

Provide best value methods to reduce risk for new sensor concepts and algorithm development prior to committing sensors to spacecraft

Process Studies

Facilitate best value to acquire high spatial/temporal resolution focused measurements that are required to understand small atmospheric and surface structures which generate powerful Earth system effects.

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

Notional Mission Directorate Aircraft Contribution

- **Space Operations Mission Directorate (~$75M)**
- **Science Mission Directorate (~$25M)**
  - **(SOFIA ~ $40M)**
- **Aeronautics Research Mission Directorate (~$15M)**

******After 2010 SMD will require the bulk of the aviation funding for the agency**

Not Validated with MDs, these are ROM values

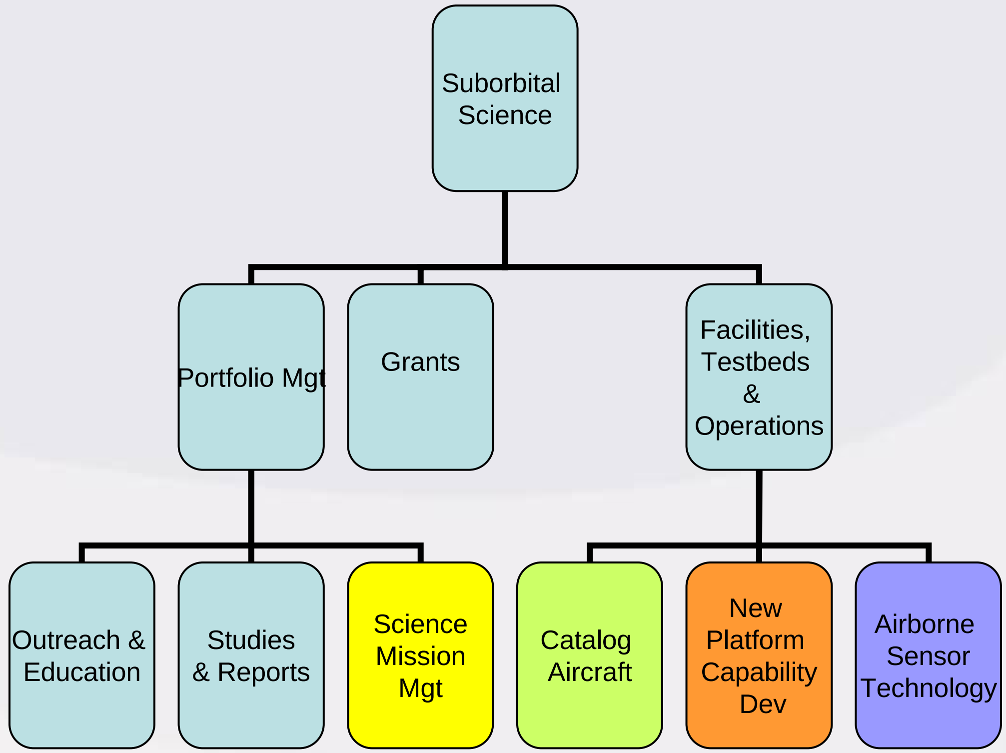
POP ($K)

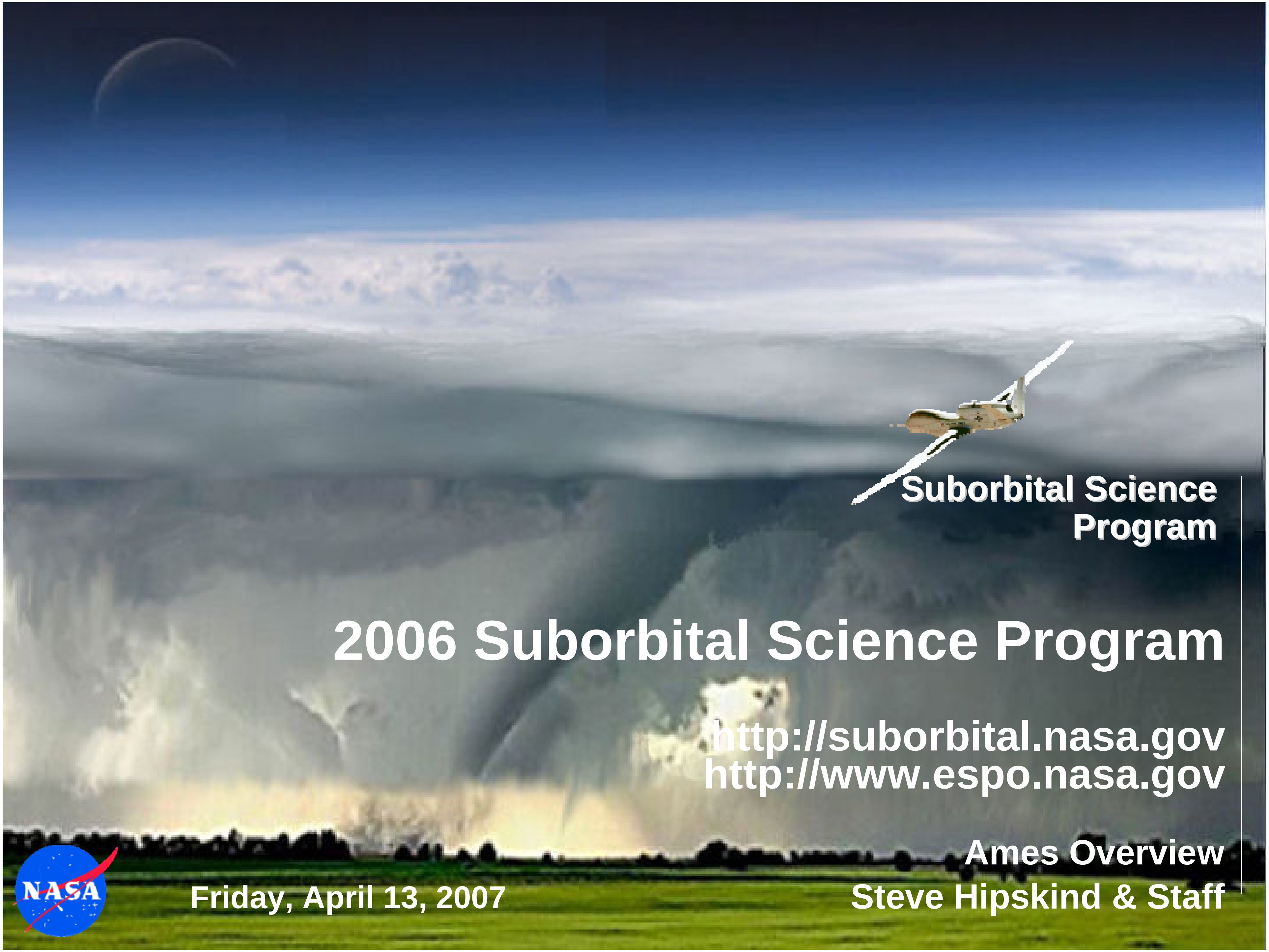
FY07	FY08	FY09	FY10	FY11	FY12
$30,939	$31,697	$31,480	$31,258	$29,164	$32,065

Program Management Structure

Program Elements & Center Responsibilities

Program Management – Hq & Center Leads
Science Requirements & Mission Support – ARC
Platform Catalog – GSFC/WFF
New Platform Technology - DFRC
Airborne Sensor Technology - ARC




Suborbital Science Program
2006 Suborbital Science Program
http://suborbital.nasa.gov
http://www.espo.nasa.gov
Ames Overview
Steve Hipskind & Staff
Friday, April 13, 2007
NASA

Outline - Ames Program Elements

- Program Requirements Definition
- Field Campaign Management
  - Flight Request Management
- Sensor & Instrumentation Element
- Sierra UAS

Requirements Definition Element

Matt Fladeland

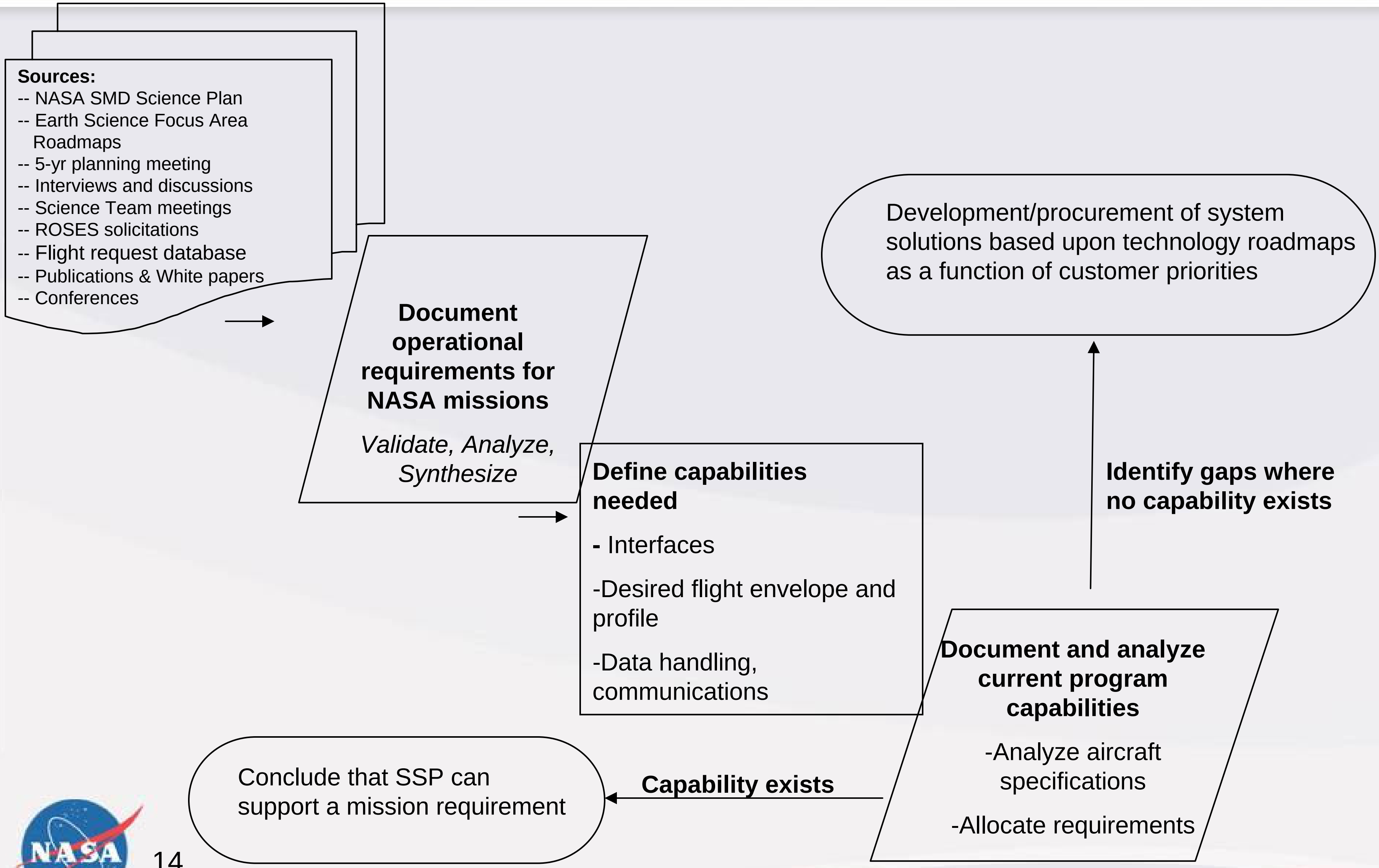
Requirements Definition Objectives

1. Elicit, catalog and analyze capabilities needed for suborbital observing platforms - a critical element of an integrated observing system for Earth science

2. Provide reports on past, current, and future requirements for:
   a. spaceflight mission validation
   b. Research & Analysis (R&A) Program
   c. Technology development

3. Demonstrate traceability of Program investments to validated requirements & identify gaps.

Requirements Analysis Process



SSP 5-yr Plan

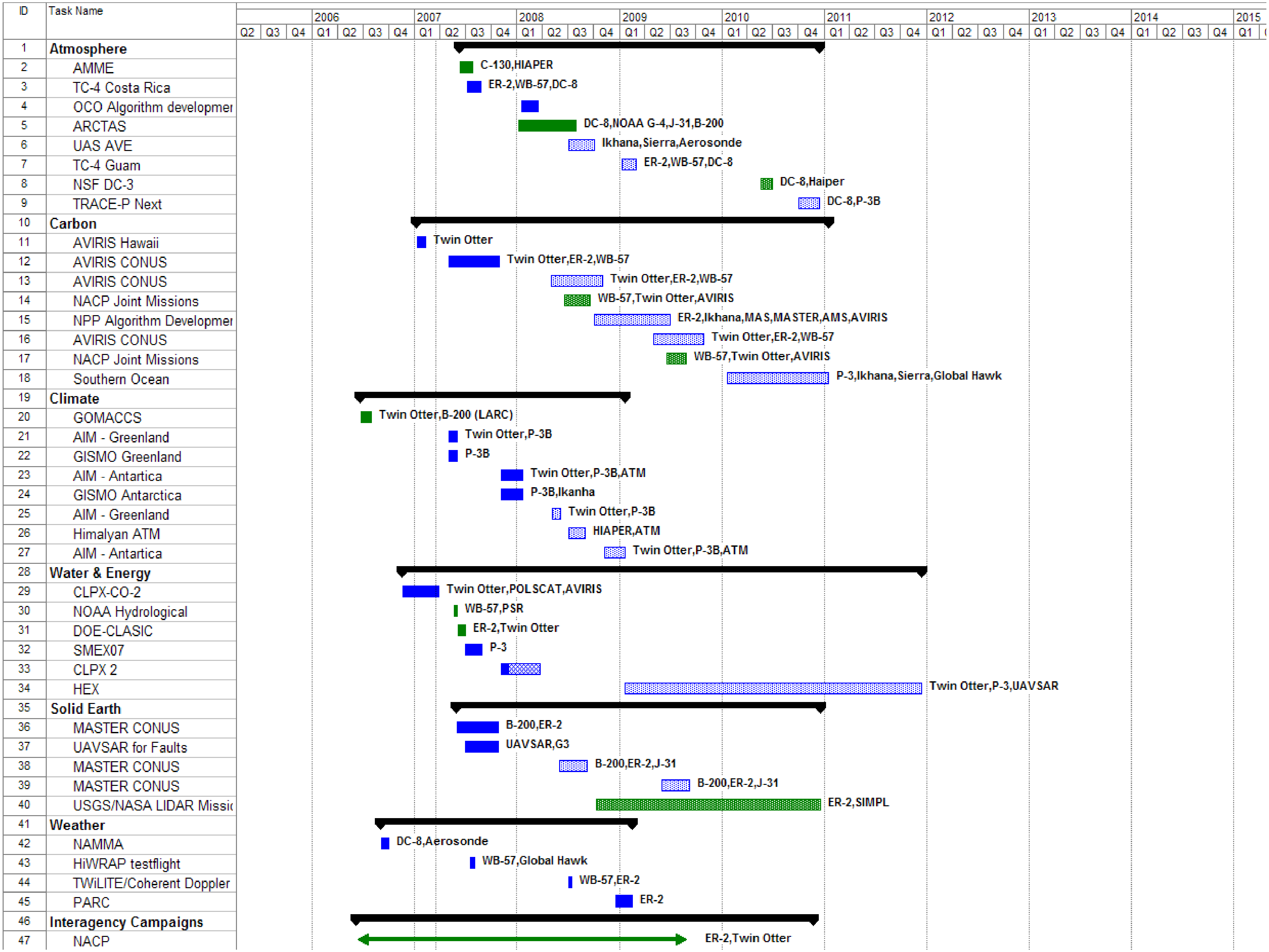
- Provides an annual update on the **near to mid-term requirements** for the program from the agencies science disciplines and flight projects.

- Developed through inputs from Science Focus Area Program Managers, scientists, and mission managers and consists of the following:

  - **major campaigns in each discipline,**
  - **sensor development and testing**
  - **future calibration and validation needs for upcoming space mission.**

- The 5-yr planning meeting is held annually or as needed; follow up by interviews to validate data

- This year the planning meeting will be held in late Aug-early Sept.



ID
Task Name
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1
1 Atmosphere
2 AMME C-130,HIAPER
3 TC-4 Costa Rica ER-2,WB-57,DC-8
4 OCO Algorithm developmer
5 ARCTAS DC-8,NOAA G-4,J-31,B-200
6 UAS AVE Ikhana,Sierra,Aerosonde
7 TC-4 Guam ER-2,WB-57,DC-8
8 NSF DC-3 DC-8,Haiper
9 TRACE-P Next DC-8,P-3B
10 Carbon
11 AVIRIS Hawaii Twin Otter
12 AVIRIS CONUS Twin Otter,ER-2,WB-57
13 AVIRIS CONUS Twin Otter,ER-2,WB-57
14 NACP Joint Missions WB-57,Twin Otter,AVIRIS
15 NPP Algorithm Developmer ER-2,Ikhana,MAS,MASTER,AMS,AVIRIS
16 AVIRIS CONUS Twin Otter,ER-2,WB-57
17 NACP Joint Missions WB-57,Twin Otter,AVIRIS
18 Southern Ocean P-3,Ikhana,Sierra,Global Hawk
19 Climate
20 GOMACCS Twin Otter,B-200 (LARC)
21 AIM - Greenland Twin Otter,P-3B
22 GISMO Greenland P-3B
23 AIM - Antartica Twin Otter,P-3B,ATM
24 GISMO Antarctica P-3B,Ikanha
25 AIM - Greenland Twin Otter,P-3B
26 Himalyan ATM HIAPER,ATM
27 AIM - Antartica Twin Otter,P-3B,ATM
28 Water & Energy
29 CLPX-CO-2 Twin Otter,POLSCAT,AVIRIS
30 NOAA Hydrological WB-57,PSR
31 DOE-CLASIC ER-2,Twin Otter
32 SMEX07 P-3
33 CLPX 2
34 HEX Twin Otter,P-3,UAVSAR
35 Solid Earth
36 MASTER CONUS B-200,ER-2
37 UAVSAR for Faults UAVSAR,G3
38 MASTER CONUS B-200,ER-2,J-31
39 MASTER CONUS B-200,ER-2,J-31
40 USGS/NASA LIDAR Missic ER-2,SIMPL
41 Weather
42 NAMMA DC-8,Aerosonde
43 HiWRAP testflight WB-57,Global Hawk
44 TWiLITE/Coherent Doppler WB-57,ER-2
45 PARC ER-2
46 Interagency Campaigns
47 NACP ER-2,Twin Otter

Platform Requirements

Platform Capabilities	Atm Comp StratChem/I d; TropChe 5 year	10 year	Carbon Cyc 5 year	10 year	Climate, Cryospher 5 year	10 year	Solid Eartl 5 year	10 year	Water Cycl 5 year	10 year	Weather 5 year	10 yea
Long Range (>5000nmi)	2; 2	1	3	2	1	0	1; 3	1; 1.5	3	2	2	1
Long Endurance (>12hrs)	2; 2	1	3	2	1	0	1; 3	1; 1.5	3	1	2	1
Base of operations in Re	1; 3	1	1	1	1	0	1; 2	1; 2	1	1	2	2
Very high altitude (>60 ft)	1; 3	1	3	2	2	0	2; 1	2; 1	3	2	1	1
Very low altitude (<1000ft)	1; 1	1	2	2	2	0	3; 3	3; 3	2	1.5	2	1
Vertical Profiling	1; 1	1	1	1	3	0	3; 3	3; 3	2	1.5	2	2
Heavy lift/Multiple payloads	2; 1	2	1	1	1	0	3; 3	3; 3	3	2.5	2	1
All Weather Conditions	2; 2	2	3	3	1	0	1; 2	1; 2	3	2.5	1	1
Monitoring/control Mult	3; 3	2	3	3	0	0	2; 3	1; 2	3	1.5	2	2
Terrain Avoidance / terr	3; 3	3	2	2	1	0	3; 3	3; 3	2	1	3	3
Formation Flight / stack	2; 2	2	1	1	2	0	1; 2	1; 1	3	2	2	1
Precision Trajectories &	3; 3	3	1	1	1	1	1; 1	1; 1	2	2	2	2
Payload-directed flight	3; 1	2	1	1	0	0	1; 1	1; 1	2	2	2	2
Quick deployment: even	3; 2	2	1	1	2	0	1; 1	1; 1	2	1.5	2	2
Expendable systems	3; 3	3	3	3	0	0	2; 3	2; 2	3	2	2	2
UAS access to airspace	1; 1	1	1	1	1	1	1; 2	1; 2	1	1	2	1

High   Medium   Low

Platform capabilities (DRAFT)

Future

Platform Capabilities	DC-8	WB-57	ER-2	P-3	G-III	Ikhana	Sierra
Long Endurance (>12hrs)						X	X
Long Range (>5000nmi)	X			X		X	
Base of operations in Remote Area	X	X	X	X			
Very high altitude (>60kft)		X	X				
Medium altitude (20-40kft)	X	X	X	X	X	X	
Very low altitude (<1000ft)	X			X			X
Very low airspeed (<60knots)							X
Vertical Profiling	X	X	X	X		X	X
Heavy lift (>5000lbs)	X	X		X			
All Weather Conditions	X			X			
Monitoring/control Multi-ship Operation; mother-daughter-ship							
Terrain Avoidance / terrain following							
Formation Flight / stacked, horizontal	X	X	X	X	X	X	X
Precision Trajectories & Position/Nav data					X		
Payload-directed flight	X	X					
Quick deployment; event driven		X	X		X		
Expendable systems / low cost systems							X

Suborbital Technology Roadmaps

Goal: To provide NASA ESD with unbiased analysis and review of technologies that meet the current and emerging needs by convening panels of subject matter experts in 6 different areas:

1. **Manned Aircraft systems**
2. **Unmanned aircraft systems**
3. **Payloads, data handling, and communications**
4. **Power & Propulsion**
5. **Technologies enabling UAS access to NAS**
6. **Mission planning and visualization tools**

Field Campaign Management

Mike Craig
Mike Gaunce
Kent Shiffer
Marilyn Vasques

Quincy Allison
Dan Chirica
Steve Gaines
Sue Tolley

2006 SSP Mission Accomplishments

- Stardust Re-Entry
- Costa Rica Aura Validation Experiment (CR-AVE)
- Arctic 2006
- Intercontinental Chemical Transport Experiment (INTEX-B) / MILAGRO
- CALIPSO-CloudSat Validation Experiment (CC-VEx)
- NASA African Monsoon Multidisciplinary Activities (NAMMA)
- Esperanza Fire UAS flight
- Looking Forward

Stardust Re-Entry

Dates & Location:	**14-15 Jan 2007; Utah desert**
Mission Objective:	**Spectral observations of high speed re-entry**
PI:	**Jenniskins, SETI Institute**
Sponsor:	**NESC**
Platform:	**DC-8**
Participating orgs:	**Univ. Stuttgart, Kobe Univ, U AK, Utah State, USAF Academy, Sandia**

Stardust Observation Campaign Team

- **Stardust Sample Return Capsule entered Earth's atmosphere at at 12.8km/s - fastest ever man-made re-entry**
- **Spectral measurements of spacecraft and ablation material**
- **Information obtained will improve understanding of natural meteors and life producing molecules**
- **Data on the heat shield will go into a forensic database and will provide a benchmark for Thermal Protection Systems (TPS) for future designs and computational model testing.**

Astronomy Magazine - Top Astronomy Story of the Year 2006

Costa Rica - Aura Validation Experiment (CR-AVE)

Dates & Location:	14 Jan - 11 Feb; San Jose, Costa Rica
Mission objective:	Aura Validation; Climatology Tropical Tropopause Region
PI:	Newman, GSFC; Jensen, ARC
Sponsor:	ESD, Atmospheric Composition; UARP, RSP
Platform:	WB-57

WB-57 w/ 29 instruments (in situ & rmt sensing) to observe:

- Ozone budget at high tropical altitudes
- Water vapor in the tropical tropopause region
- Sub-visible cirrus
- Cloud ice crystal sizes and shapes

Remote sensing instrument payload.

Highlights:

- Correlative obs w/ Aura instr's: TES, MLS, HIRDLS
- UTLS temperatures much colder than average - extensive sub-visible cirrus
- First observations of black carbon - constrain GHG radiative forcing
- TTL dominated by neutral organic aerosols, stratosphere dominated by acidic sulfate aerosols
- TTL cirrus - quasi-spherical, surprisingly large ice xtal

In-situ instrument payload.

Science Team meeting held Mar 2007

Arctic 2006

Dates & Location:	18-29 Mar 2006; Greenland, Northern Canada, Alaska
Mission Objective:	ICESat, GLAS validation; ice sheet mapping
PI:	Cavalieri, Markus, GSFC, Krabill, WFF/GSFC
Sponsor:	ESD, Climate, Cryosphere Program+Sat Validation
Platform:	P-3

Sensors:

- Snow Radar (first flight), Univ. Kansas
- Polarimetric Scanning Radiometer, NOAA
- Delay Doppler Monopulse Radiometer, APL
- Airborne Topographic Mapper, ATM 4, WFF

Transit pattern from NASA Wallops to Washington, Alaska, Greenland and then back to Wallops.

Highlights

- Validation measurments for:
  ICESat, GLAS, ESA Envisat
- Survey Greenland Ice Sheet - west coast region

2nd Intercontinental Chemical Transport Experiment (INTEX-B)

Dates & Location:	**1 Mar-12 May 2006; Mexico, Texas, Hawaii, Washington, Alaska**
Mission Objective:	**Pollution transport & transformation**
PI:	**Singh, ARC (lead), Brune, Penn State, Crawford, LaRC, Jacob, Harvard**
Sponsor:	**ESD, Atmospheric Composition; Tropospheric Chemistry; NSF MILAGRO**
Partners:	**Mexico, Canada, Germany**
Platforms:	**DC-8, Sky J-31, B-200, NCAR C-130, DLR Falcon**

Deployment sites and flight tracks flown during the INTEX-B Mission.

- Largest, most complex campaign of 2006; collaboration w/ NSF **MILAGRO**
- INTEX-B focused on pollution entering N.America from the west
- INTEX-A (2004) on pollution leaving E. coast into Atlantic basin
- 41 instruments, > 300 scientists, engineers & support
- DC-8 - 17 science flights with a total of 143 flight hours
- 1st Phase - Air pollution from Mexico City and biomass burning
- 2nd Phase - Tracking pollution from Asia across Pacific basin

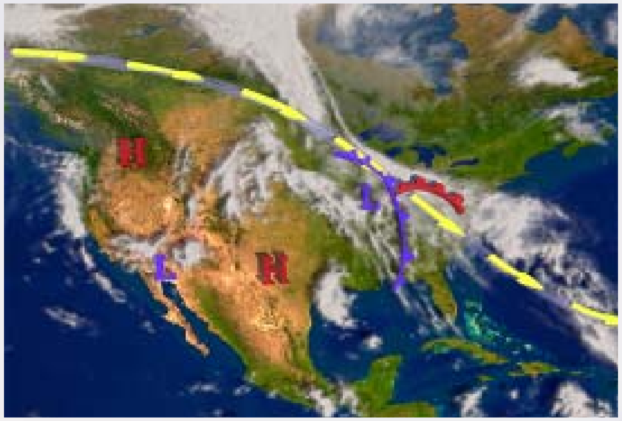
Science team meeting Mar 2007

CloudSat CALIPSO Validation Experiment (CC-Vex)

Dates & Location:	**24 Jul - 14 Aug 2006: Atlanta, GA**
Mission Objective:	**Cloudsat CALIPSO validation**
PI:	**Trepte, LaRC (CALIPSO)**
	Mace, Univ.Utah (CloudSat)
Sponsor:	**ESD, Satellite Validation**
Platforms:	**ER-2, LaRC B-200, WMI Lear**

- 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.

CloudSat and CALIPSO pairing set a new standard in terms of precision placement of Earth-orbiting satellites. Both satellites look at the same clouds in the atmosphere.



Understanding clouds and their influence on weather and climate presents significant challenges; Yellow curve shows satellite overpass

NASA African Monsoon Multidisc. Activities (NAMMA)

Dates & Location:	**Aug 2006; Cape Verde, Dakkar, Senegal**
Mission Objective:	**Hurricane genesis, Easterly waves, Saharan dust**
PI:	**Zipser, Univ. Utah**
Sponsor:	**ESD, Weather**
Platforms:	**DC-8, NPOT&TOGA Radars, SMART-COMMIT, balloon**

- **Major campaign with >100 scientists, engineers & support**
- **Collaboration with NOAA Hurricane Research Division**
- **Coordinated intercomparison flight with UK BAE-146**
- **Cape Verde National Institute of Meteorology and Geophysics (INMG) participation**
- **Coordination with AMMA - major European campaign studying West African Monsoon - impact on water & climate**
- **13 DC-8 flights sampling 7 Easterly Waves**
- **Genesis of tropical systems Debby, Ernesto, Gordon, and Helene**
- **Data fed to NOAA for tracking storms across the Atlantic as they approach the Carribean and Eastern US**

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)

Upcoming Campaigns

- Tropical Composition, Cloud & Climate Coupling (TC-4)
  - July-Aug 2007
  - San Jose, Costa Rica & Panama
  - DC-8, ER-2, WB-57, NPOL Radar, NATIVE
- Arctic Research Composition of Troposphere w/ A/C & Satellites (ARCTAS)
  - Arctic Air Quality mission supporting IPY
  - Two phases Mar - Jul 2008
- UAS AVE (Aura Validation) summer 2008

Flight Request Management

Marilyn Vasques
Sue Tolley

Flight Request System

http://suborbital.nasa.gov/flight/request.html

Web based system for community access to NASA suborbital assets & reporting to program management.

NASA process allows for flexibility in planning missions with long (multi-year) lead times

Flight Request Summary

FY06 Flight Request Summary

Aircraft	Submitted	Total Approved	Total Completed	Total Flight Hours Flown
DC-8	13	4	4	264
ER-2	19	12	11	168
WB-57	18	6	5	122
P-3	7	3	3	123
Twin Otter	23	11	10	199
B-200	7	6	6	157
Caravan	3	2	2	29
J-31	3	2	2	79
Aerosonde	9	4	2	74
Altair	8	7	1	73
TOTAL	110	57	46	1288

KEY

Submitted: Flight entered into the system

Total Approved: All flight requests that have been approved.

Total Completed: Flight requests completed or partially completed.

Sensors & Instrumentation Element

Jeff Myers
Bruce Coffland
Rose Dominguez
Pat Grant
Ted Hildum
Mike Fitzgerald
Paul Windham

Sensor & Instrumentation Element:

Roles:

<u>Engineering Support:</u>

Assists with payload integrations and promotes the portability of systems by developing common platform interfaces and infrastructures

<u>Sensor Operations:</u>

Maintains a small suite of facility sensors and support equipment for multi-disciplinary ESD use

<u>Sensor Development:</u>

Fosters R&D in airborne instrument technology, as risk reduction for future satellite missions, for on-orbit cal/val, and process studies (via solicitations and directed funding)

Engineering Services

Payload Integration Support for:

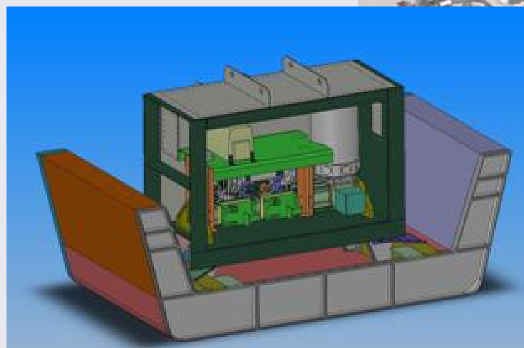
Ikhana UAS:
AMS, DCS, MicroMaps

WB-57:
NOBALT, DCS, Nav Recorders

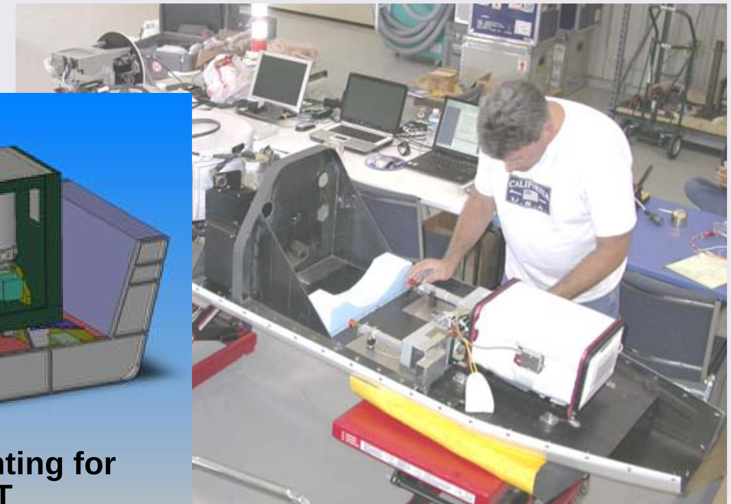
ER-2:
DCS & video

B-200s
LVIS Lidar, DCS

J-31:
CAR, POS-AV



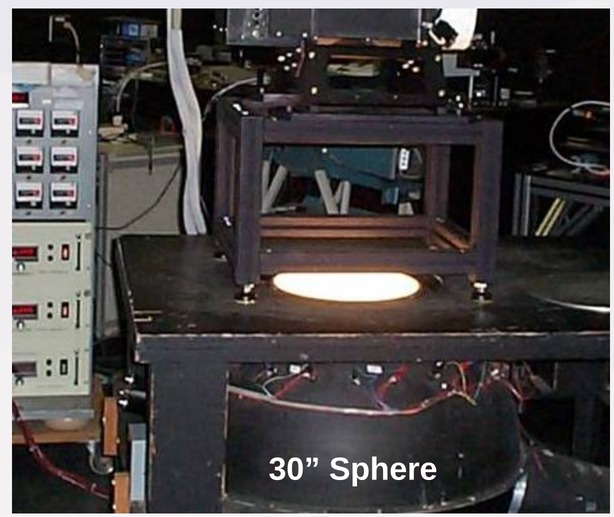
WB-57 Pallet Mounting for NOBALT



AMS in Ikhana Sensor Pod

IR Instrument Calibration Lab

Provides NIST-traceable spectral and radiometric measurements for multiple radiometers and imaging devices

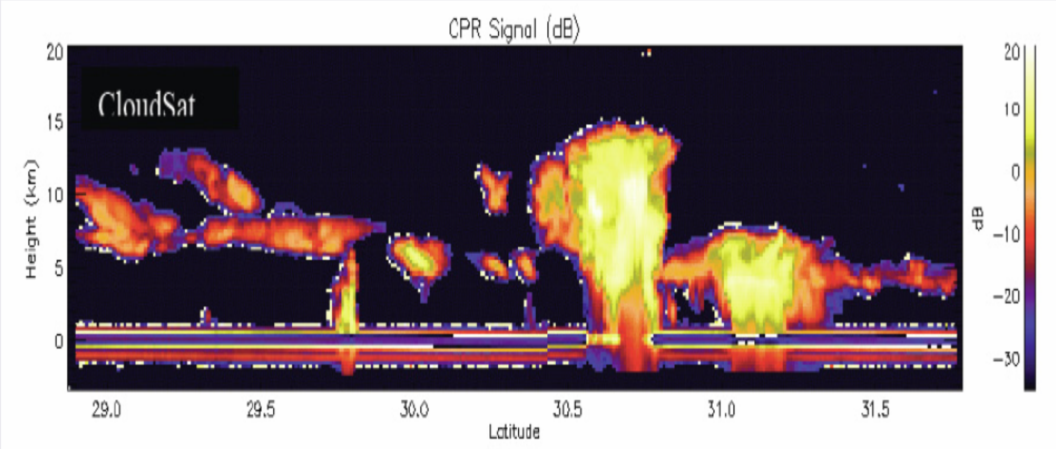


30” Sphere

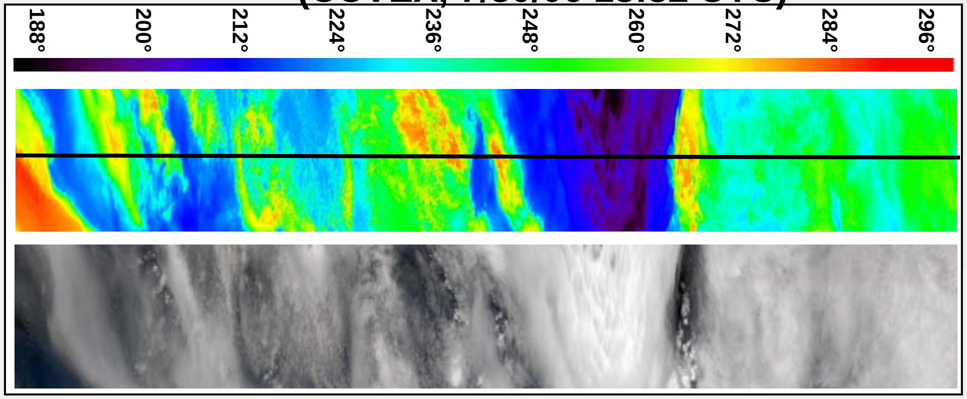
Operational Systems

<u>Sensor Systems:</u>

- **UAS-Modular Sensor System (AMS)**
- **DCS & Video Cameras**
- **MODIS & ASTER Airborne Simulators (joint w/ EOS)**



MAS data (below) with coincident CloudSat data (CCVEX, 7/30/06 18:32 UTC)

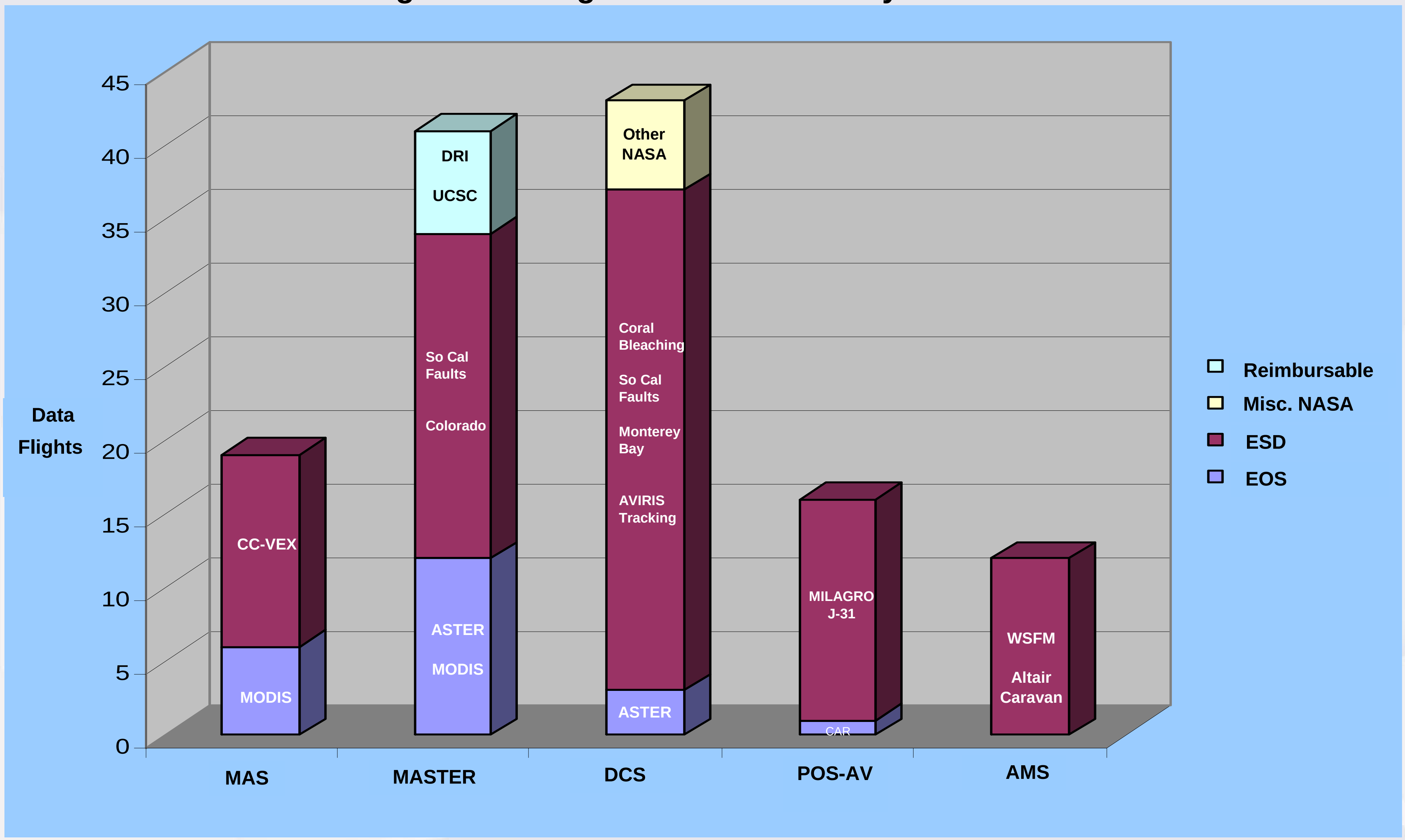


<u>Support Equipment:</u>

- **POS-AV stand-alone precision navigation systems**
- **Navigation Data Recorders and Experimenter Interface Panels**
- **Misc. pressure housings, power supplies, high-altitude heaters, etc.**

FY06 Sensor Utilization

R&A Program the largest user of these systems



Sensor Technology Development

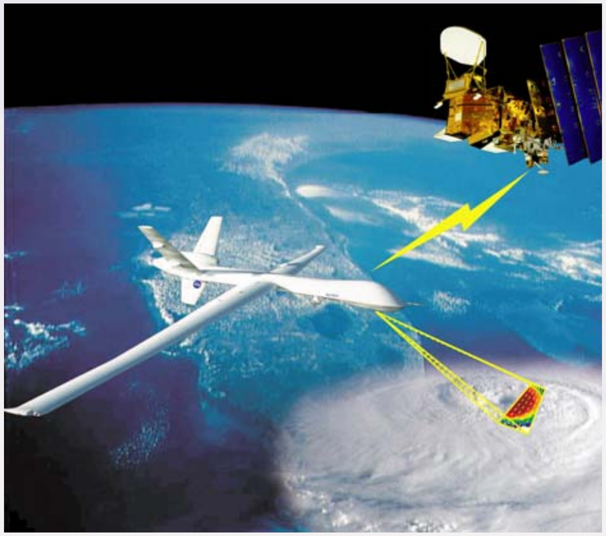
Ongoing Projects:

- UAS Autonomous Modular Sensor System
- PCATS General-purpose payload computer and high-speed telemetry interface system
- Next-generation universal Navigation Data Recorder
- Upgraded tracking cameras (DCS, Video)
- Expanded Suborbital Web Portal
  - Real-Time Display of Mission data
  - Sensor Web implementation tools

HQ Solicitations Supported:

- ROSES: AURA validation UAS payload
- ROSES: IPY UAS payload development
- ESTO-IIP: Ongoing evaluation of suborbital support requirements

AMS and PCATS Data Systems



SIERRA UAS

Objective: To provide a low cost, reconfigurable, light class UAS for the Suborbital Science Platform catalogue

Strategy: Leverage partnership with NRL to provide existing UAS for science

Impact: Fills a UAS capabilities gap in the platform catalogue between Aerosonde and the Altair

- Progress to date: design and testing of flight control avionics, actuators, radios, power system, wiring harness, lighting, fuel system, brakes, electrical subsystems, installation and testing of the engine.
- Procedures for ground testing, flight testing, operations and maintenance drafted
- Remaining tasks: cooling system, operation & checkout of electrical systems, complete ground test program, finalize flight test plan, conduct AFSRB and FRR, and execution of flight plan

Summary

- Ames has a small, but dedicated team providing key support to the Suborbital Science Program through:
  - Requirements Definition
  - Field Campaign Management
  - Flight Request System
  - Sensor & Instrumentation Support
  - Suborbital Portal
- Many of the Ames staff in both ESPO & ASTL have 20+ years experience with the Airborne Science program
- Field Campaigns have been cost effectively managed with a flawless record of safety and success

Suborbital Science Program

Goddard Space Flight Center

Wallops Flight Facility

Anthony Guillory
Airborne Science Project Manager

Catalog Aircraft

FY06

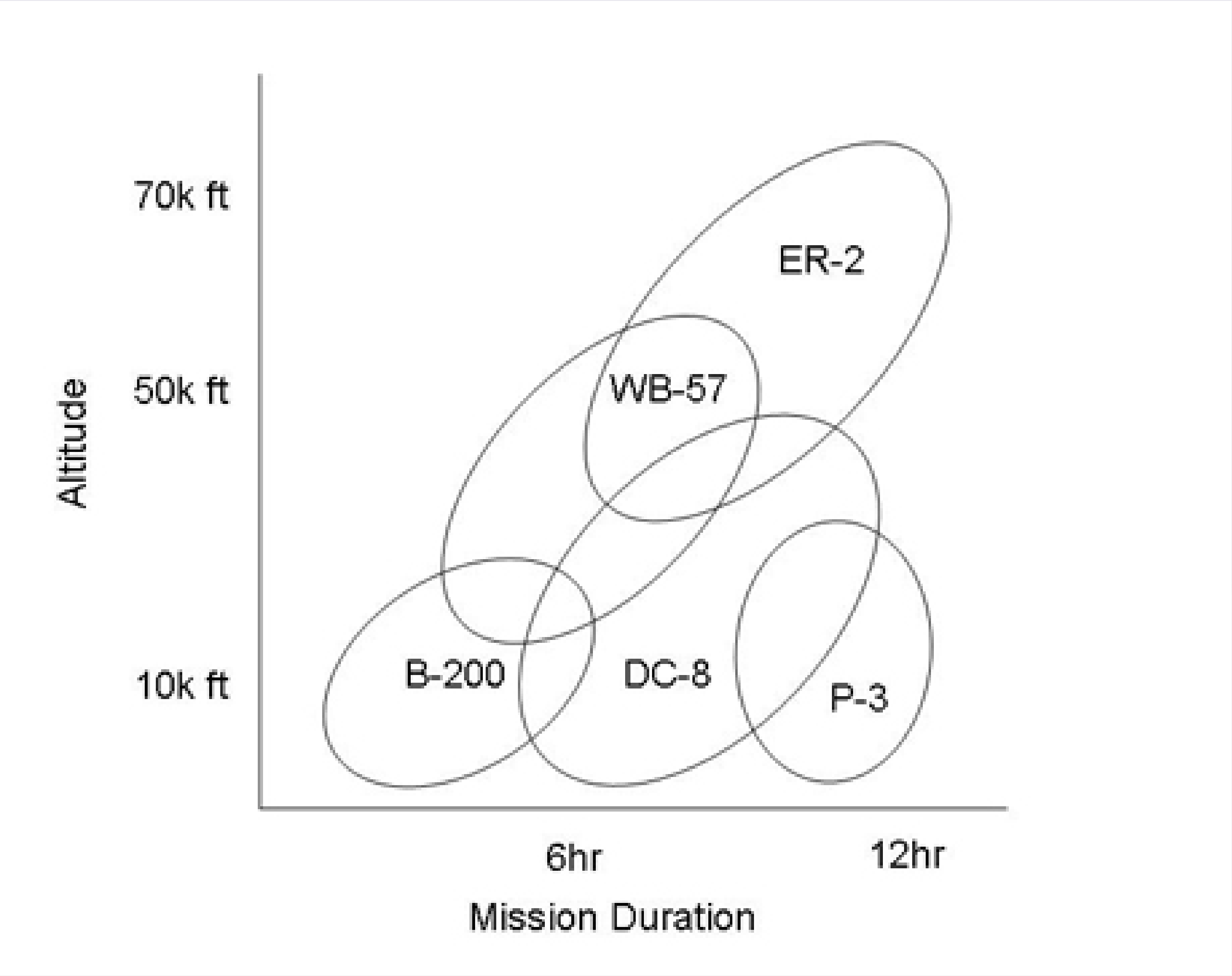
- NASA
  - DC-8
  - WB-57
  - ER-2
  - P-3
- Commercial
  - Twin Otter
  - J-31
  - Caravan
  - A-200
- Other Government
  - DOE B-200
  - NRL P-3

FY07

- NASA
  - DC-8
  - WB-57
  - ER-2
  - P-3
  - B-200
- Commercial
  - Twin Otter
  - J-31*
  - Caravan
  - A-200
  - + BPA Vendors
- Other Government
  - DOE B-200
  - NRL P-3 & C-12

 * J-31 may not be available in FY07

Notional Flight Envelopes



Non NASA Aircraft
Procurement Mechanisms

- ❑ In Place
  - Subcontracting
    - GSA Airtec (limited to twin turbo props)
    - Ames UARC contract
  - Sole Source (e.g., Dynamic Aviation A-200)
  - DOE/Ames Inter-Agency Agreement
  - LOA with NRL

- ❑ Pending Award
  - Blanket Purchase Agreement

Blanket Purchase Agreement

- ❑ RFQ for BPA was released in February
- ❑ No contract minimum
- ❑ Solicited Platform Categories:
  - Manned: Light
  - Manned: Medium
  - Manned: Heavy
  - UASs
  - Lighter-than-Air
- ❑ 13 vendors responded
  - Responses in all categories, except Lighter-than-Air
- ❑ Targeted for Award in June
- ❑ Tasked on a Mission by Mission Basis

P-3 Accomplishments FY06

Mission	Dates	Flt Hrs	Sorties
Arctic 2006	March 2006	84.0	14
RadSTAR-A	May-June 2006	5.1	4

P-3 Plans

<u>Major Missions</u>

Arctic Ice Mapping	**Greenland**	**April-May 2007**

Twin Otter in FY06

Mission	Dates	Flt Hrs	Sorties
AVIRIS Fall 2005	October 24 – November 30	63.6	20
AVIRIS Coral Reef	December 7 – December 22	52.3	19
AVIRIS Spring 2006	April-May 2006	83.2	21

Total Flight Hours: 199.1
Total Sorties: 60

Twin Otter in FY07

Mission	Dates
AVIRIS Hawaii	Jan-Feb 2007
CLPX-II	Dec 2006, Jan, Feb 2007, Summer 2007

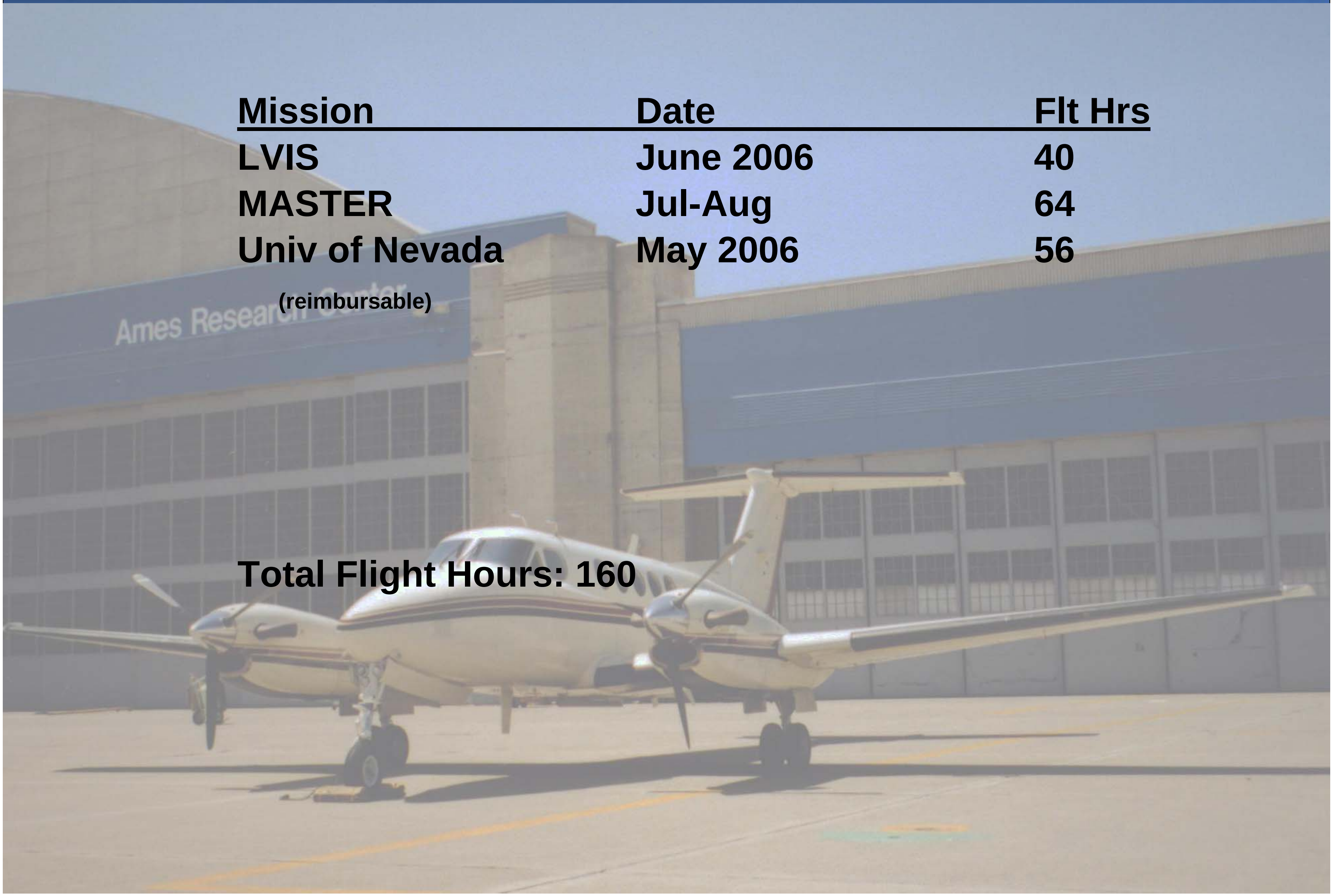
Sky Research Caravan

Mission	Flt Hrs
Western States Fire	28.9

DOE B-200

Mission	Date	Flt Hrs
LVIS	June 2006	40
MASTER	Jul-Aug	64
Univ of Nevada (reimbursable)	May 2006	56

Total Flight Hours: 160



J-31

Mission	Dates	Flt Hrs	Sorties
MILAGRO	Spring 2006	79	15

Aerosonde in FY06

- NASA/NOAA Hurricane Demonstration 2006
  - Based out of Key West, FL
  - Media Day held in September
  - FAA did not grant COA in time to conduct science missions in FY06
  - Hurricanes did not cooperate either

DC-8 University of North Dakota Cooperative Agreement

All missions have been highly successful

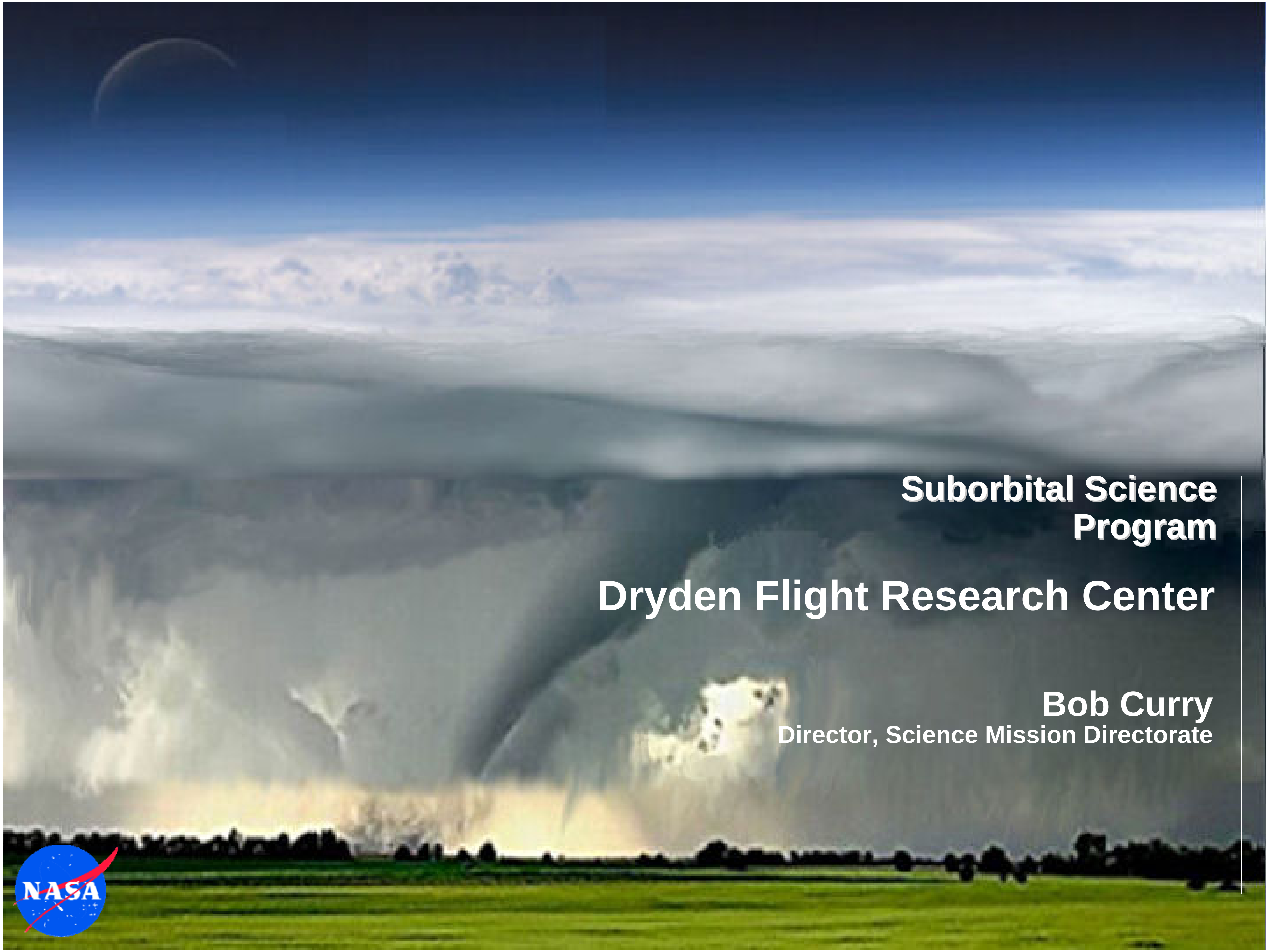
- Year 3 starts in June 2nd
- Plotting a course for year 4 and 5 and beyond.
- Negotiate new milestones as we move forward.

DC-8 Accomplishments & Plans

Mission	Dates	Flt Hrs	Sorties
Stardust	January 2006	12.3	4
INTEX-B	Feb-May 2006	146.1	22
NAMMA	Aug-Sept 2006	118.2	18
Planned			
TC4	July 13-Aug 10, 2007	126.0	~16-18

Total FY06 Flight Hours: 276.6
Total FY06 Sorties: 44

NASA African Monsoon Multidisciplinary Activities Mission


Suborbital Science Program
Dryden Flight Research Center
Bob Curry
Director, Science Mission Directorate
NASA

Dryden Flight Research Center - Overview

Dryden supports the NASA Suborbital Science Program in the following elements:

ER-2 (part of the SSP Catalogue)
Provide this unique, high altitude research platform to the science community

New Technology (Dryden lead)
On-going development and demonstration of emerging technologies to enable more effective suborbital science capabilities

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

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

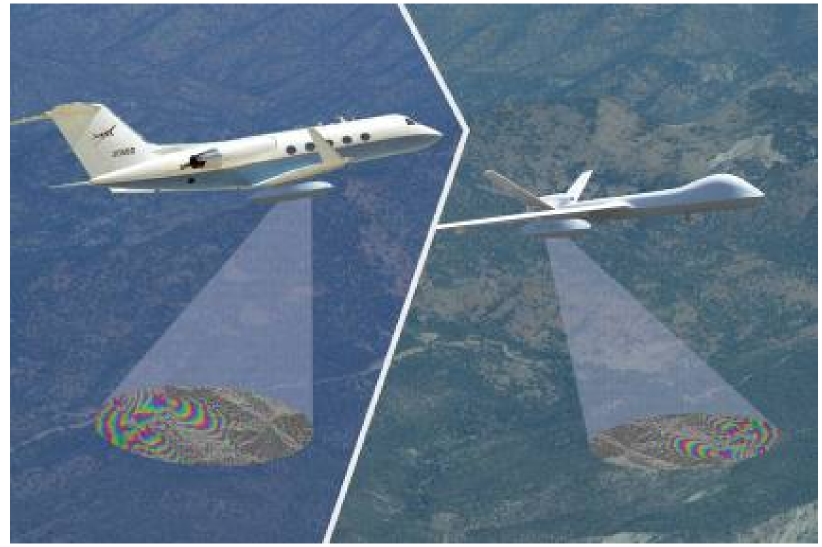
- Over 170 science flight hours
- CALIPSO/Cloudsat Validation
- AVIRIS/REVEAL
- Large Area Collectors

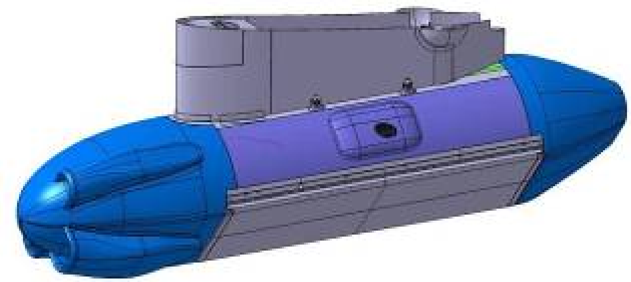
Background and Status

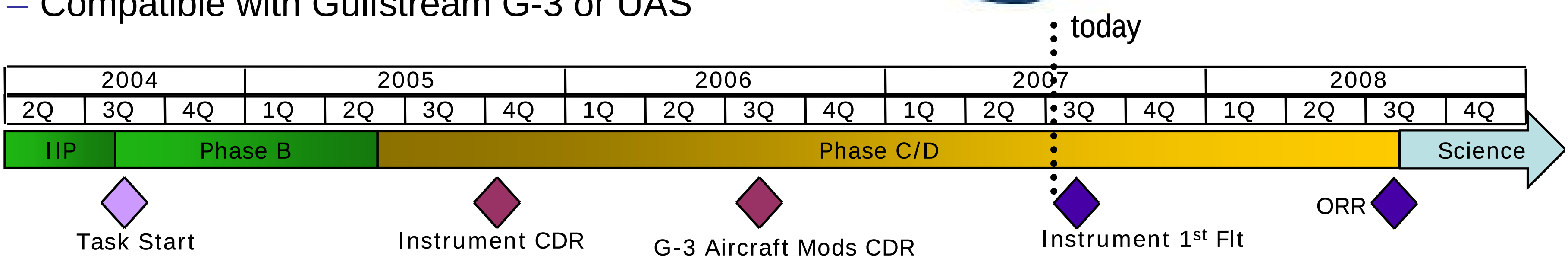
- U-2 and ER-2 aircraft have been a mainstay of NASA airborne sciences since 1971
- Over 100 science instruments integrated
- Continuous capability improvements
- Two aircraft currently available for:
  - –Remote sensing
  - –Satellite calibration/validation
  - –In-situ measurements and atmospheric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

G-3 UAVSAR Overview

- ***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



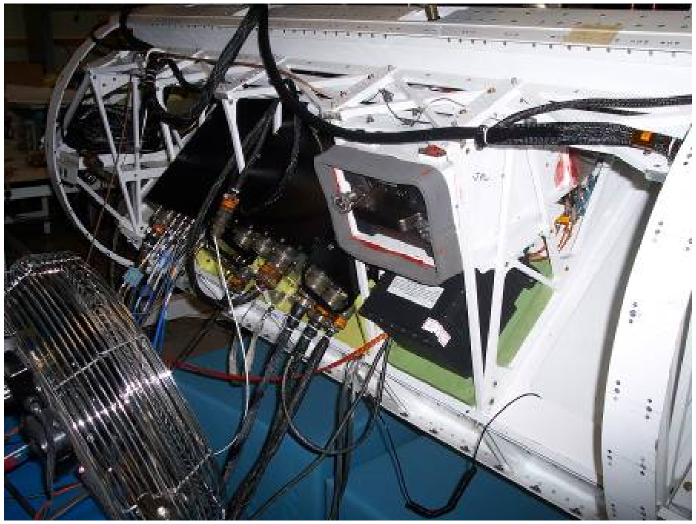




G-3/UAVSAR Technical Progress

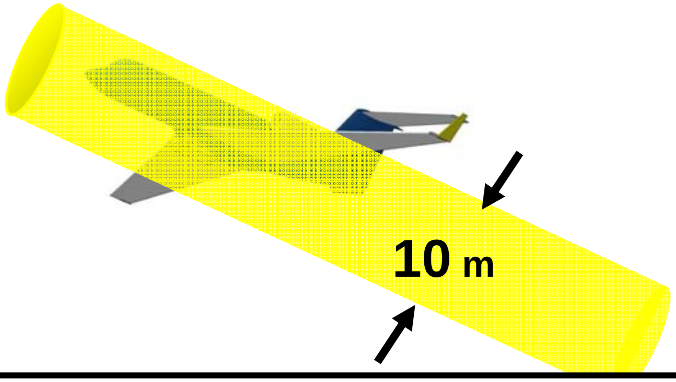
Instrument Checkout Progressing @ JPL

- 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

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

Capabilities

Endurance > 30 hours

Altitude 65,000 ft

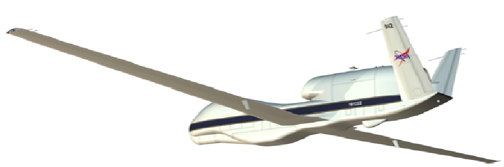
Payload > 1,500 lbs

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

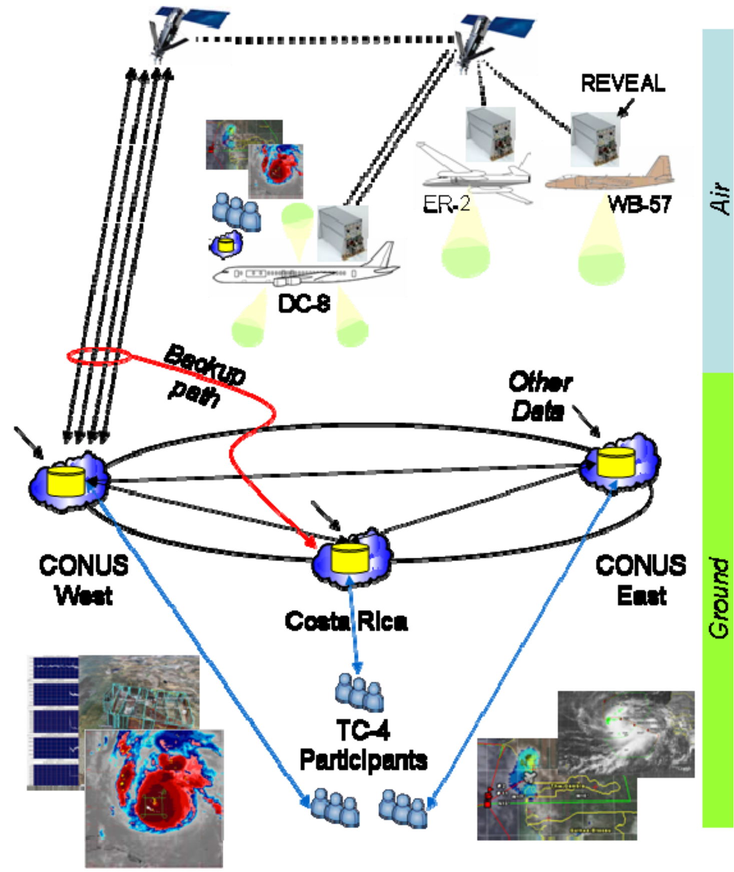
- Startup phase (training, GSE, logistics, spares . .)
- On-going flight program (2 flts per month)

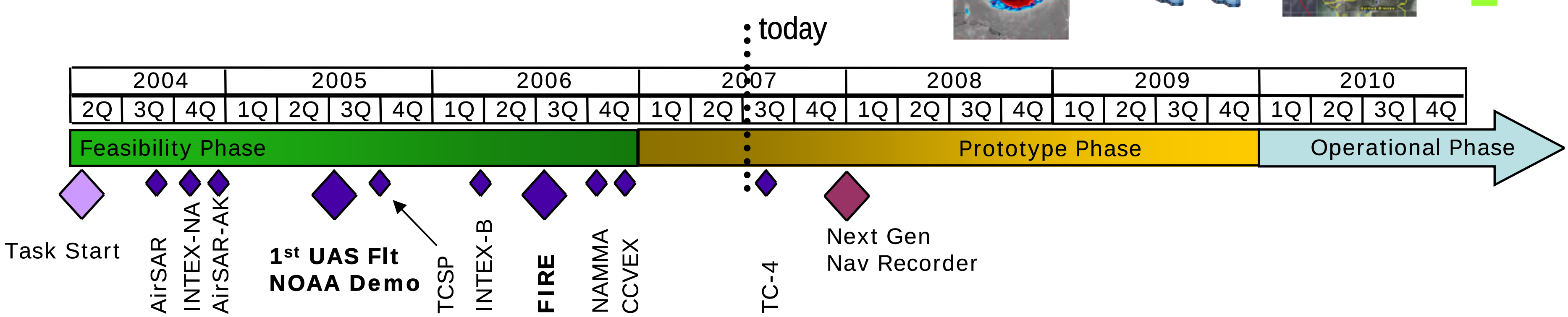
Business plan depends on external partner(s); negotiations with DoD, industry, and other civilian agencies are on-going

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





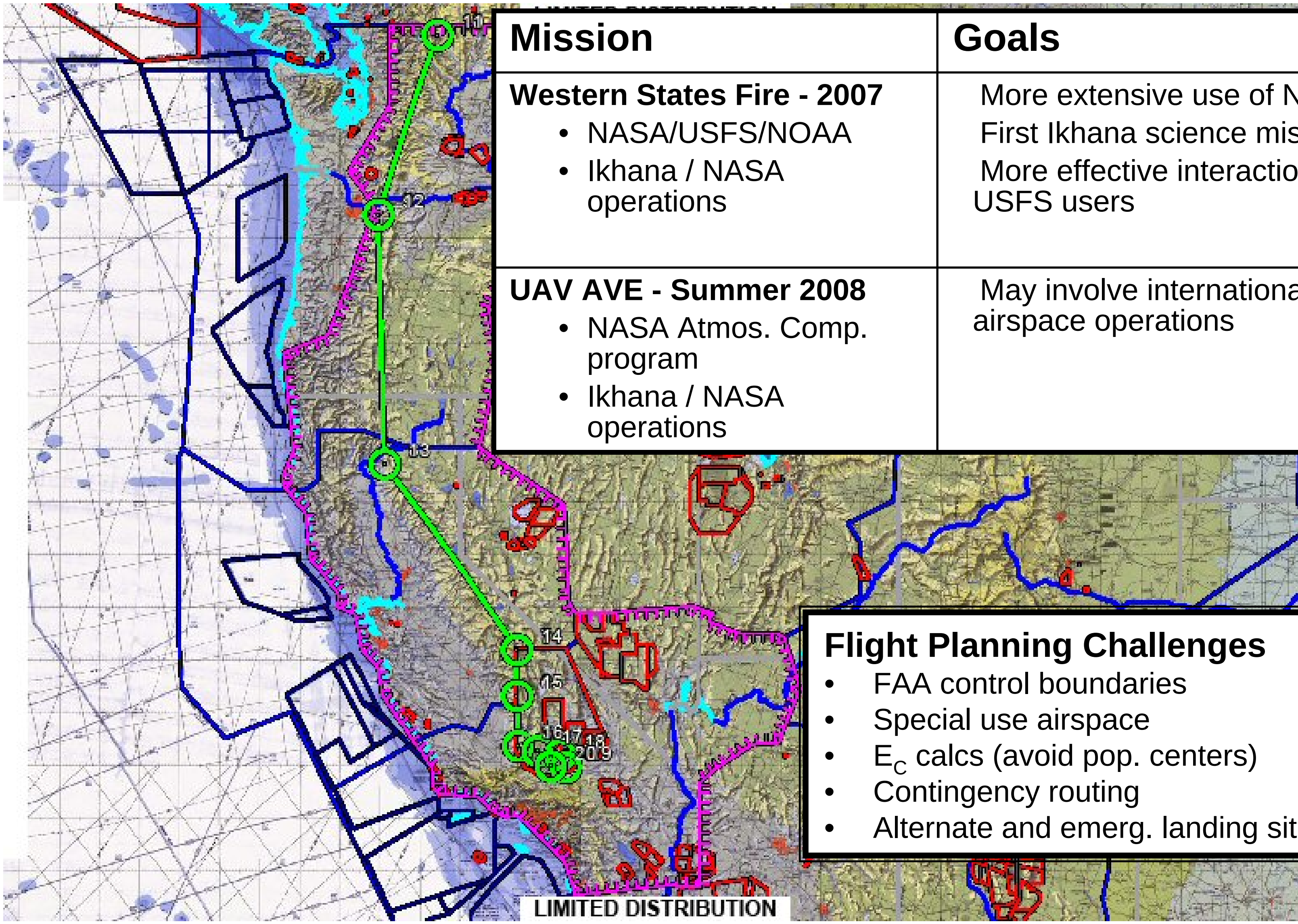
UAS Mission Demonstrations

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 => ext.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. Comp. 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

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)


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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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

Suborbital Science Program

Johnson Space Center

Ken Cockrell
WB-57 Program Manager

WB-57

WB-57 Capabilities

Two Aircraft
- Built in the 1960's from B-57 Medium Bomber Airplanes

Performance
- 6,000 lb payload; Simplified Integration
- 63,000 ft maximum altitude
- Maximum duration 6 hours +
- Maximum range 2,500 nm
  - Reduced by payload weight
- Cost per flight hour: $3,400 for SMD-sponsored missions

Upgrades

Increased maximum take-off weight

- New landing gear (F-15E) is key to achieving
  - Will be ready for TC4 Costa Rica
- Increased weight preserves range and endurance capability without regard to payload weight
- Plan is to have complete prior to TC4 Guam in January 2009

Superpods

- Allows simpler interchange of experiments between ER-2 and WB-57
- Requires weight increase to realize required range and endurance with Superpods aboard
- Plan is to field Superpods during TC4 Guam, January 2009

Fuel System

WB-57 Uses standard jet fuel

- Jet A+ Civil
- JP-8 Military

Need fuel heat for certain mission conditions

Studying increased capacity and CG control to increase duration to 8 hrs and range to 3,000 nm

Engines

Long-term project

- New model engines are in-hand (TF33-PW-7)
- Significant engineering required

Provide large efficiency gains

- Up to 10 hrs endurance (along with fuel system improvements)
- Up to 4,000 nm range (along with fuel system improvements)

Altitude performance improved

Synergy

Program has a well-developed user base that leverages support from DoD and several other users

- FY06 Operations: 757.2 flight hours
  - Missions: 93.2% (6.8% training and maintenance)
    - – NASA: 27.9%
      - » SMD: 16.1%
    - – DoD and Other: 65.3%

Possibility of a 3rd airplane, sponsored by DoD

Future Viability

Ongoing upgrades

- New landing gear
- Increased weight
- Superpods

Future upgrades

- Fuel system (heat and capacity)
- Engines
- New autopilot
- New Ejection Seats

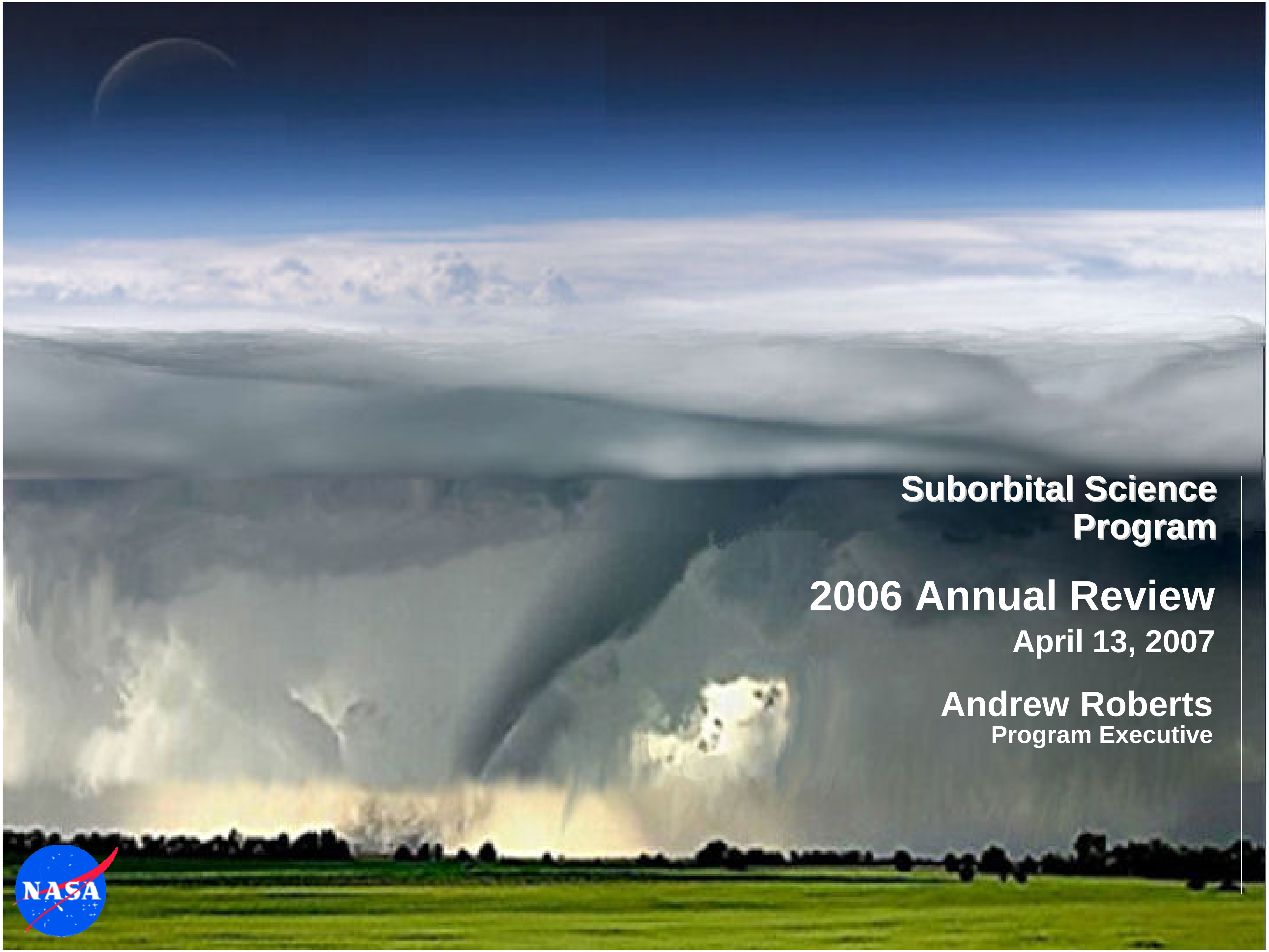
Summary

WB-57 is a workhorse

- Excellent payload capability
- Reasonable altitude capability
- Reasonable range and endurance
- Series of upgrades in-work and identified to greatly enhance performance

Broad user base helps to sustain the platform

Reasonable operating costs



Suborbital Science Program

2006 Annual Review

April 13, 2007

Andrew Roberts
Program Executive

Program Direction

- Improve support for customers with national science objectives requiring airborne assets
  - Increased emphasis on supporting vetted national science requirements
    - Requirements documentation
    - Science to capability to assets
  - Standard instruction for integration
    - Increase payload portability, reduce integration cost
  - Upgrade planning in out years
    - Gross weight increase, super pods, fuel heating, avionics,…
  - Utilization of NASA SSP assets first to maximize return on investment

Looking Forward

- Missions
  - FY07
    - Arctic Ice Mission
    - TC-4
    - CLASIC
    - Western States Fire Mission
    - Hurricane Boundary Layer Mission
    - UAVSAR
  - Beyond
    - ARCTAS
    - TC-4 Guam
    - TCSP II
    - UAVSAR missions

Looking Forward

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    - TC-4 Guam
    - TCSP II
    - UAVSAR missions

Next 3 months

TC-4 campaign starts in Costa Rica – WB-57, DC-8 & ER-2

Ikhana begins operations, Western States Fire mission

WB-57 accomplishes NAST mission

ER-2 accomplishes CLASIC mission with DOE

P-3 accomplishes Arctic Ice mission

DC-8 completes C-Check and Avionics Upgrade

WB-57 completes Main Landing Gear Upgrade

UAVSAR first flight on G-III