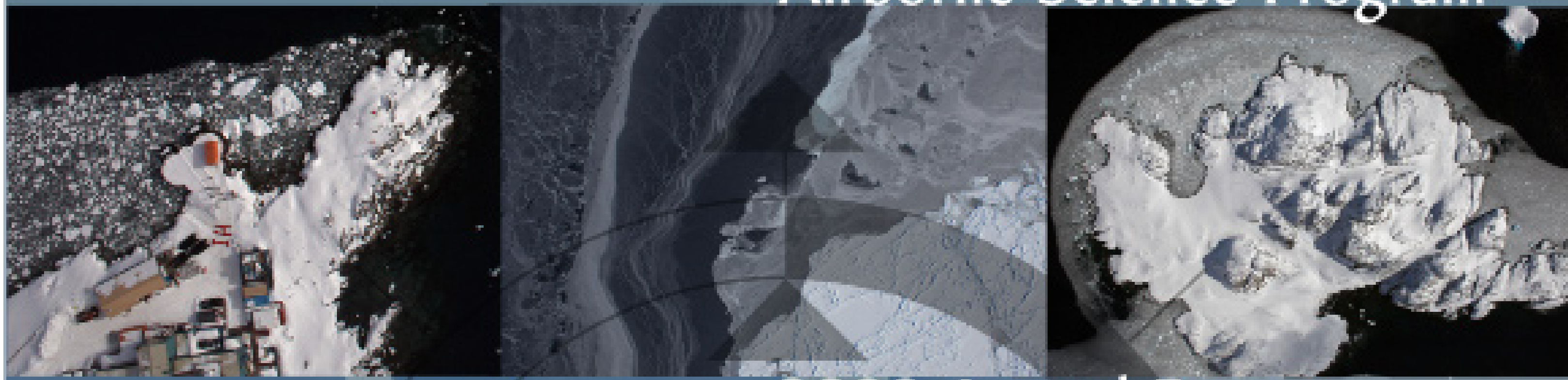
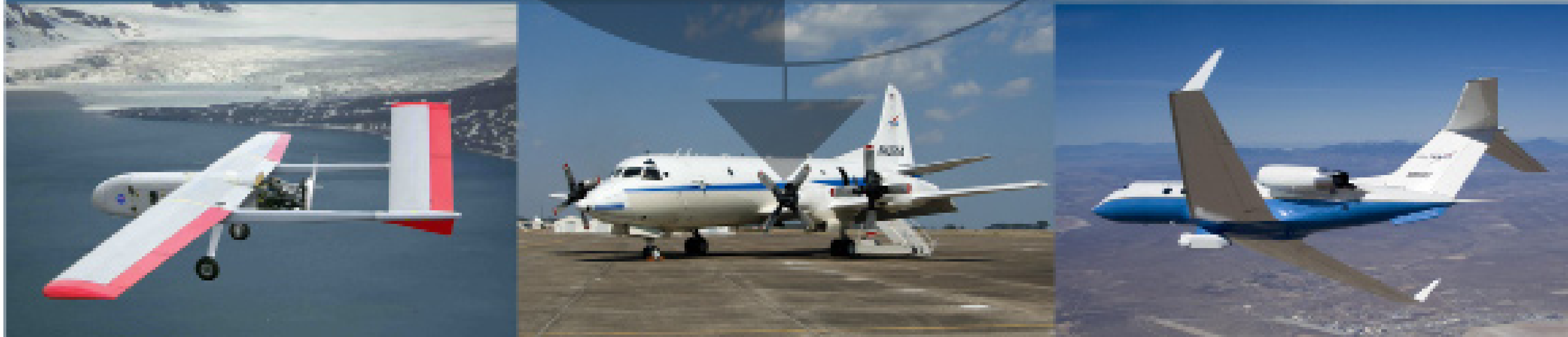
National Aeronautics
and Space Administration

Airborne Science Program



2009 Annual Report



NASA Science Mission Directorate
Earth Science Division

AIRBORNE SCIENCE PROGRAM

2009 Annual Report

FEBRUARY 2010

http://airbornescience.nasa.gov

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EXECUTIVE SUMMARY

NASA's Airborne Science Program had another busy year in FY09. The program flew missions and instrument tests on five core aircraft, eight catalog aircraft, and two new technology unmanned aircraft systems. The program completed a total of seventy flight requests for almost 1900 flight hours. More than a dozen different customer communities were served in all six focus areas of NASA Earth Science and related aerospace fields.

In 2009 we focused significant effort on the Cryosphere and completing IPY related missions. Greenland and Iceland ice monitoring missions were successful far-field missions for the G-III carrying the L-band UAVSAR and a new Ka-band SAR. The Characterization of Arctic Sea Ice Experiment (CASIE) mission proved our new SIERRA UAS, flying out of Svalbard, Norway. Operation Ice Bridge saw the P-3 in Greenland in the Spring while the DC-8 was outfitted for a major Fall mission over Antarctica, flying from Punta Arenas, Chile. The G-III with UAVSAR completed its first fully operational year with over 500 hours, including flights in Alaska.

In addition to launching the mid-size SIERRA UAS, our Global Hawk UAS was readied for its first science mission – GloPac – to take place in early 2010. Other missions, Pre-GRIP and GRIP, are in the pipeline for Global Hawk as well.

The DC-8 was the laboratory home during summer 2009 for the inaugural session of the Student Airborne Research Program (SARP), headed by the National Suborbital Education and Research Center (NRERC). With this success, we are planning another program for 2010.

Programmatically, the Airborne Science Program was impacted significantly in 2009 by the American Recovery and Reinvestment Act (ARRA), which has provided funds for needed upgrades and new capabilities. These efforts will provide payload portability and similar capability for near-real time data downlink on all platforms. Many of the outcomes from this program are expected during 2010.

Finally, the Airborne Science Program is looking forward to continued Operation Ice Bridge efforts, to participating in Earth Venture-1 missions, and to supporting upcoming satellite missions, including Decadal Survey missions.

FROM THE DIRECTOR

Welcome to NASA's Science Mission Directorate Airborne Science Program. In this 2009 version of our Annual Report, you will be presented with the breadth of our accomplishments and the work done to benefit the Earth science community on behalf of NASA and the Nation. FY2009 has been a truly memorable year for the Airborne Science Program with numerous firsts and some notable missions. I expect that after reading what we've done and plan, you will also recognize that NASA's Airborne Science Program is a remarkable national capability.

To start off though, I'd like to share an experience I had this year.

I was explaining some aspects of the Airborne Science Program to someone new to the program recently in the presence of one of our science focus area leads. In response to a question of how the program determines its portfolio, I conveyed that the program takes its guidance from our customer community; we focus on the priorities of our customers. Around this point, the science focus area lead, an individual I consider a strongly supportive customer, softly interjected: "partners". I was somewhat unprepared for being corrected at that moment, but continued on with the discussion with the new "customer " exchanging the term "customer" with "partner" as I thought appropriate.

Over the next few weeks the conversation kept creeping into my thoughts. Why would someone want me to change "customer," to "partner"? Based on a substantial amount of customer feedback, the program had worked hard to be seen as highly customer focused and responsive to our customers versus process driven. From subsequent feedback, it had appeared that the program had turned the corner and was being viewed as very customer conscious, resulting in a lot more favorable customer feedback. One of my internal explanations went to identifying the differences between "customer" and "partner". Without looking up the words in the dictionary I came up with customers are usually receivers of goods and services for which they pay. Partnership on the other hand infers a relationship based on some common goals and mutual interests. Partners are more likely to sacrifice for the greater good of achieving long term common goals. Partners are vested in each other. In the hierarchy of relationships, "Partners" appear to be on a higher level than "Customers". In a subsequent meeting with the same focus area lead, I brought up the matter again and he concurred that his intent was to convey, probably both to me and the new customer, that he saw the relationship between the Airborne Science Program and his focus area as a "Partnership" rather than a receiver-provider "Customer" relationship.

The Program is committed to staying on track: working collaboratively with our partners for mutually beneficial outcomes by providing quality, responsive and relevant airborne science services to the community. We're here to support and do it in a safe, efficient, cost effective, and value-added manner.

In keeping with those thoughts, I would like to cover some of the substantial achievements of the Airborne Science Program in 2009. FY2009 saw the G-III with the Unmanned Aircraft Vehicle Synthetic Aperture Radar (UAVSAR) become operational and demonstrate some of its potential in supporting International Polar Year (IPY), tectonic, terrestrial ecology and hydrology science. The P-3 and DC-8 inaugurated the first Operation Ice Bridge campaign season flying over 400 hours (far exceeding expectations) and collecting data on sea ice and glacier elevation, ice extent and bed characteristics. Operation Ice Bridge also included some coordinated flights with the G-III / UAVSAR's IPY mission, in addition to a collaborative effort with the National Science Foundation and British National Environmental Research Council's ICECAP mission in Antarctica. To round out Operation Ice Bridge, a catalog aircraft flew in southeast Alaska to measure glaciers.

In 2009, the WB-57 saw the superpod nacelle mated to the wings and completion of the gross weight increase certification of the landing gear, both critical capability enhancements for future missions. The Program also experienced a number of firsts. As part of IPY, the SIERRA Unmanned Aircraft System (UAS) flew its first science mission: Characterization of Arctic Sea Ice Experiment (CASIE). The multi-sensor payload successfully flew over 3000 km of sea ice out of Svalbard, Norway. The Global Hawk UAS flew its first NASA flights using a totally redesigned ground operations center. Finally, the Student Airborne Research Program (SARP) completed its first class with 29 students from all across the US.

Programmatically, 2009 was an eventful year. Airborne Science was provided $28,046,000 of American Recovery and Reinvestment Act funding to execute the first year of Operation Ice Bridge, in addition to investments to modify and sustain its fleet and science support infrastructure. The program was also assigned a Small Satellite, Unmanned Aircraft System project to develop enabling technologies for those emerging platforms. Airborne Science also made progress in the international and national arenas. Nationally the program members finished their work on a Federal Aviation Administration Aviation Rulemaking Committee on Small UAS, executed work under a UAS Memorandum of Understanding with the National Oceanic and Atmospheric Administration, and remained active in UAS in the National Air Space and Interagency Coordinating Committee on Airborne Geoscience Research and Applications (ICCAGRA) efforts. Internationally, the Program was active in developing collaborative relationships with the European Fleet for Airborne Research (EUFAR, the European Union counterpart to ICCAGRA) and the Chinese Center for Earth Observation and Digital Earth, as well as membership on a working group to address UAS-enabled Arctic science missions supporting the Arctic Council.

> The Program is committed to staying on track: working collaboratively with our partners for mutually beneficial outcomes by providing quality, responsive, and relevant airborne science services to the community.

The year also saw Andrew Roberts, our Program Director for the past 2 years, retire from NASA. Andy will be missed. During his tenure the Program grew healthier as he focused on bringing funding and mission stability to the centers, recognizing the program's professional performers, being increasingly responsive to the community and showing exceptional leadership. On behalf of the entire Airborne Science Team, I invite you to read through our 2009 Annual Report. We, as a program, are very proud of what we do and have accomplished and we would like to share that with you.

Randal Albertson
Airborne Science Program Director
(Acting)

PROGRAM ELEMENTS and EXECUTION

The Airborne Science Program consists of the following program elements:

1. Science Requirements and Management
2. Airborne Science Platforms
   - (a) Core Platforms (DC-8, WB-57, ER-2, G-III and P-3)
   - (b) Catalog Platforms (agency, interagency, commercial)
3. New Technology and Platform Development
   - (a) UAS (Global Hawk, SIERRA)
   - (b) Common Data and Communication Systems
4. Science Instrumentation and Support Systems

NASA Headquarters is responsible for determining program direction and content through the strategic planning and budget formulation processes. The program office is the interface to the Science Mission Directorate ensuring that program activities and investments support the broader agency. A major change in the program this past year was to remove core aircraft from the catalog and manage them individually.

Implementation of the major program elements takes place at the various research centers.

Ames Research Center has a lead role in program analysis, advanced planning, and science mission management. This includes management of Program flight requests and field campaign management through the Earth Science Project Office. Instrument and software support, flight planning, and development of interface standards are performed out of Ames Airborne Sensor Facility in partnership with the University of California. In addition, Ames personnel manage and operate the SIERRA UAS.

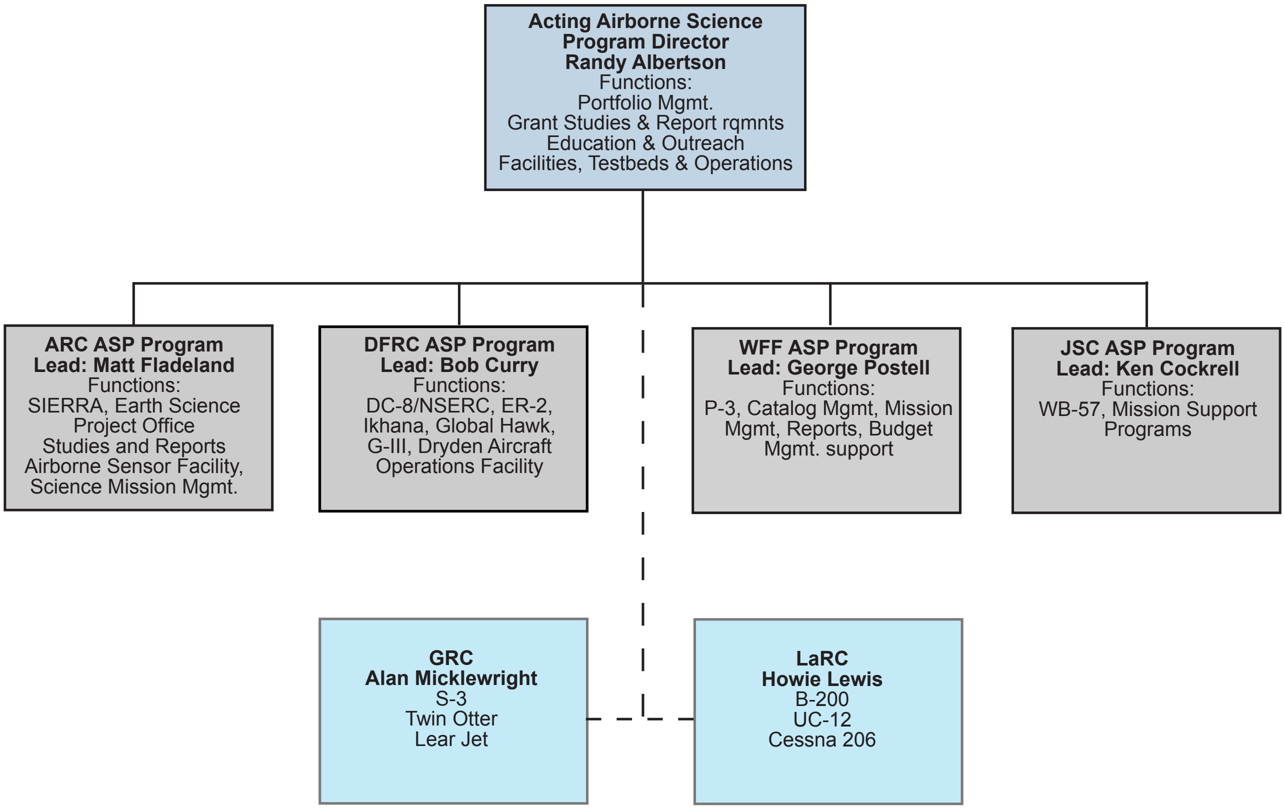


Figure 1:
NASA's Airborne Science Program organization.

Dryden Flight Research Center leads the operation and maintenance of the core DC-8, ER-2 and G-III aircraft. They also operate and maintain aircraft in the new technology and platform development area, including the Global Hawks. Another area Dryden is been actively engaged in is over-the-horizon network and communications research and development. Dryden oversees the cooperative agreement with the University of North Dakota's National Suborbital Education and Research Center. Dryden also manages the Dryden Aircraft Operations Center in Palmdale. For Program Year 2009, the Ikhana will be moved to catalog management and the G-III will become a core platform.

Goddard's Wallops Flight Facility is the lead for operating and maintaining the core low-altitude heavy-lift P-3B aircraft, and managing the catalog aircraft program through safety oversight of contracted aircraft. Wallops also continues the work in the field of small-class Uninhabited Aircraft Systems (UAS) research.

Johnson Space Center contributes to the program primarily by operating and maintaining the core WB-57 high-altitude research aircraft.

Langley and Glenn Research Centers support the program by providing access to their platforms through the catalog.

The FY09 budget for the Airborne Science Program was $31,271,000 with additional $28,046,000 in stimulus (aka American Recovery and Reinvestment Act funds) for a total of $59,317,000.

The breakdown into major components is shown in Figure 2. The history, including ARRA funds, is shown in Figure 3.

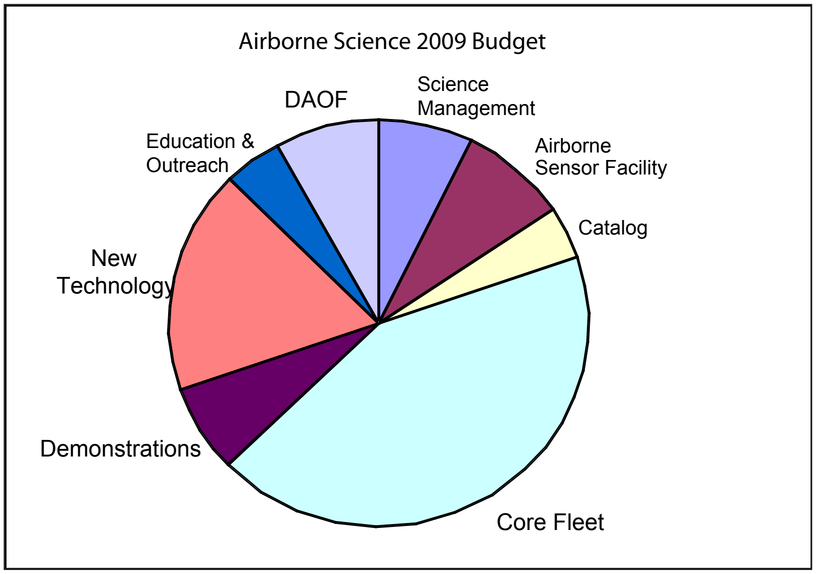


Figure 2:
Airborne Science Program budget breakdown.

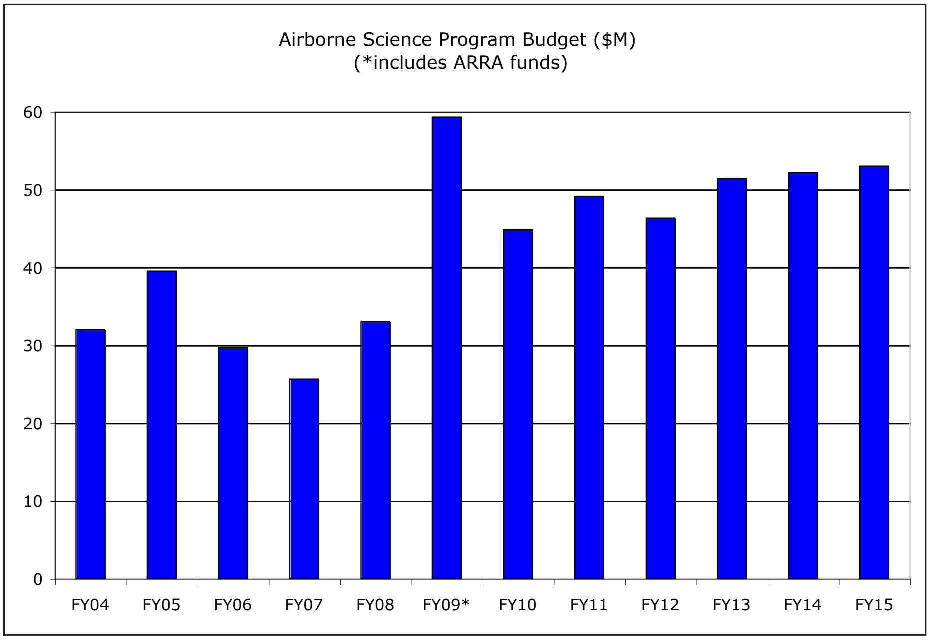


Figure 3:
Airborne Science Program recent and projected budgets.

SCIENCE MISSIONS and ACCOMPLISHMENTS

AVIRIS

Science Focus:	Carbon Cycle and Ecosystem Science
HQ Sponsor:	Wickland
PI:	Green

From February 27 through August 31, 2009, a total of 26 AVIRIS science flights were conducted on the ER-2 totaling 89.9 flight hours. It included a deployment to Wright-Patterson AFB, Dayton, OH, for the months of June and July. NASA sponsors included Diane Wickland and Andrew Roberts. Experiment sites included areas in central and southern California, New York, Vermont, New Hampshire, Massachusetts, Connecticut, Pennsylvania, West Virginia, Minnesota, Montana and South Dakota. AVIRIS data was also collected over experiment sites in Alberta and Ontario, Canada.

The series of AVIRIS flights were initiated with an in-flight spectral, radiometric, spatial, and uniformity calibration and characteristics of the AVIRIS imaging spectrometer. The science data gathered over experiment sites included the following: The characterization of forest functional types and their role in mediating ecosystem response to environmental change; Carbon cycling, vegetation nitrogen status and surface albedo.

Science data gathering was successfully completed by the ER-2 team over all requested experiment sites.

Scientists included Philip Dennison, Dar Roberts, Scott Ollinger and Phil Townsend. The AVIRIS instrument manager was Michael Eastwood.

For more information, visit: http//aviris.jpl.nasa.gov/

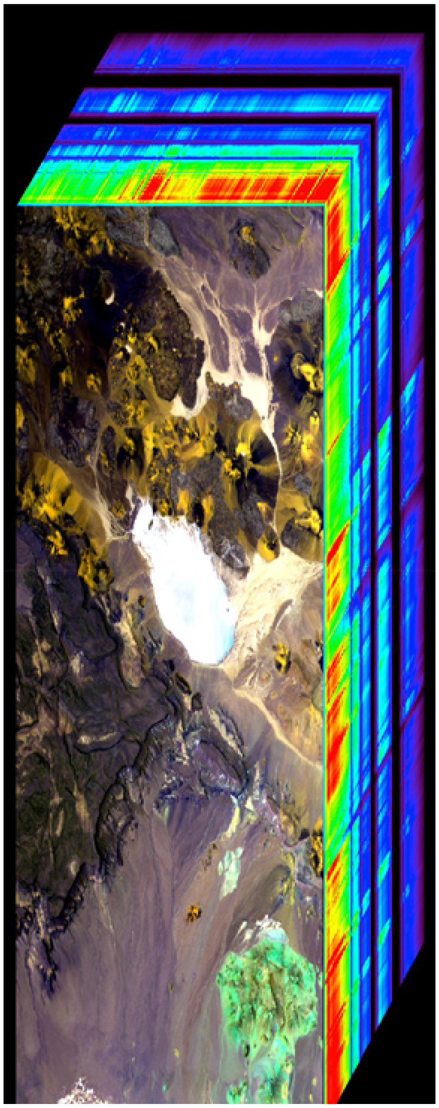


Figure 4:
Lunar Lake, NV Calibration site measured by AVIRIS from 65,000 feet on August 19, 2009.

CALIPSO Cal/Val

Science Focus: Atmospheric Composition and Chemistry
HQ Sponsor: Maring
PI: McGill

A series of flights on the LaRC B200 was flown to verify the calibration of the CALIOP lidar on the CALIPSO satellite before and after the switch from the primary to the backup CALIOP laser transmitter (http://earthobservatory.nasa.gov/Newsroom/view.php?id=38252) on March 12, 2009. The High Spectral Resolution Lidar (HSRL) was deployed on the B200 for eleven underflights of the CALIPSO satellite starting in January and ending in April. The data proved conclusively that the calibration of the satellite instrument was not affected by the change in lasers.

For more information, visit: http://science.larc.nasa.gov/hsrl/index.html

Figure 5:
HSRL Deployed in NASA Langley King Air B200.

CASIE

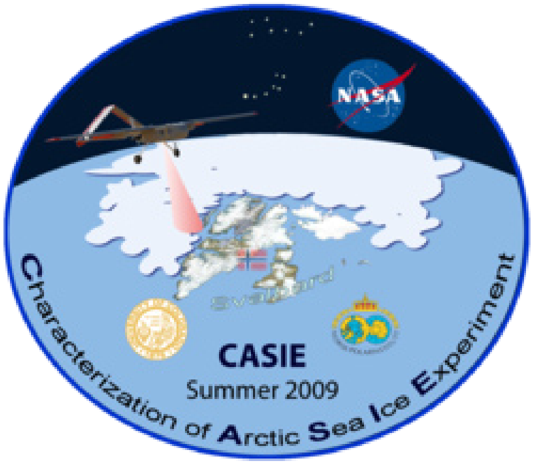
Science Focus:	Cryosphere
HQ Sponsors:	Kaye, Albertson
PI:	Maslanik

The Characterization of Arctic Sea Ice Experiment (CASIE), flown from Svalbard, Norway on the SIERRA UAS in July of 2009, was the aircraft campaign portion of the larger, NASA-funded IPY project titled “Sea Ice Roughness as an Indicator of Fundamental Changes in the Arctic Ice Cover: Observations, Monitoring, and Relationships to Environmental Factors.” This 3-year research effort, which combined satellite data analysis, modeling, and aircraft observations, includes scientists, engineers and students from the University of Colorado, Brigham Young University, Fort Hays State University and NASA’s Jet Propulsion Laboratory working together with research aviation specialists from NASA’s Ames Research Center.

The project is attempting to answer some of the most basic questions regarding the future of the Arctic’s sea ice cover. In particular, our work will help us better understand one of the most fundamental changes in sea ice cover in recent years – the loss of the oldest and thickest types of ice from within the Arctic Ocean. This change has been rapid and extreme. For example, our analysis of satellite data shows that the amount of older ice in 2009 is just 12% of what it was in 1988, a decline of 74%. The oldest ice types now cover only 2% of the Arctic Ocean as compared to 20% during the 1980’s. Not only does this change affect the total amount of ice in the Arctic, but it also affect the ability of the ice cover to resist increased warming. In turn, this loss of the old ice types will influence activities such as shipping and mineral exploration, and it is important for marine mammals and fish that use the ice cover as safe havens and platforms.

CASIE’s role in this project was to provide very detailed information on ice conditions by using a small unmanned aircraft (NASA’s SIERRA) that can fly long distances at low altitudes – a job that can be difficult and dangerous for large, manned aircraft, especially in the harsh Arctic environment. The primary payload consisted of 2 LIDARS and a C-Band SAR for providing information on ice surface roughness and topography, thickness, reflectance, and age. For this mission, the SIERRA team developed an icing warning system, in consultation with NASA GRC and NCAR, to provide the ground station with temperature and humidity data in real time.

For more information, visit: http://espo.nasa.gov/CASIE



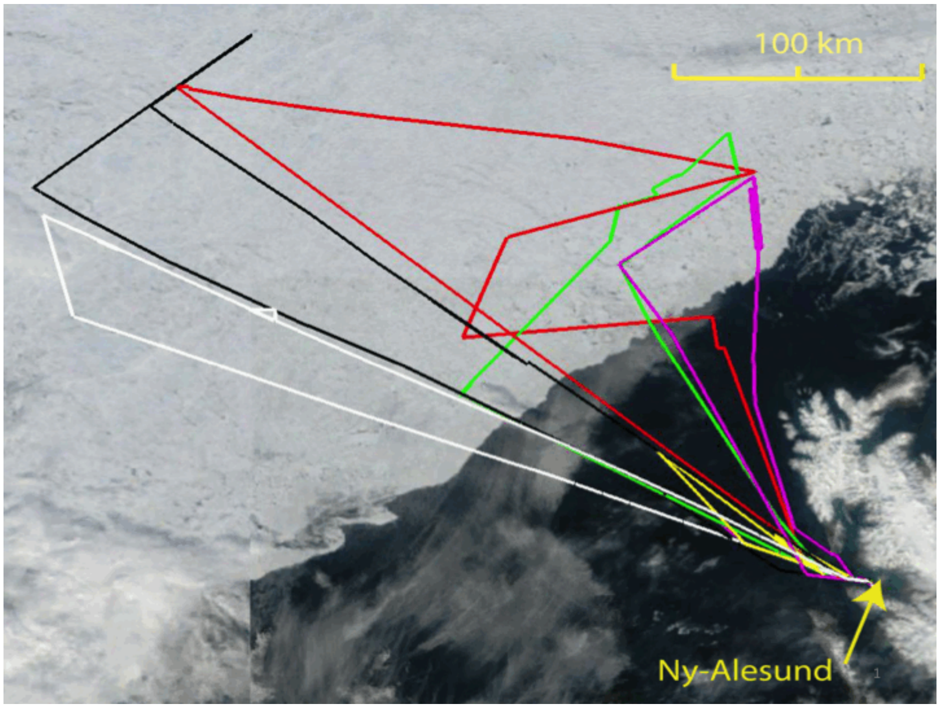


Figure 6:
This map shows the nearly 3000km of flight tracks over sea ice during 5 separate science flights of the CASIE payload on the SIERRA UAS.

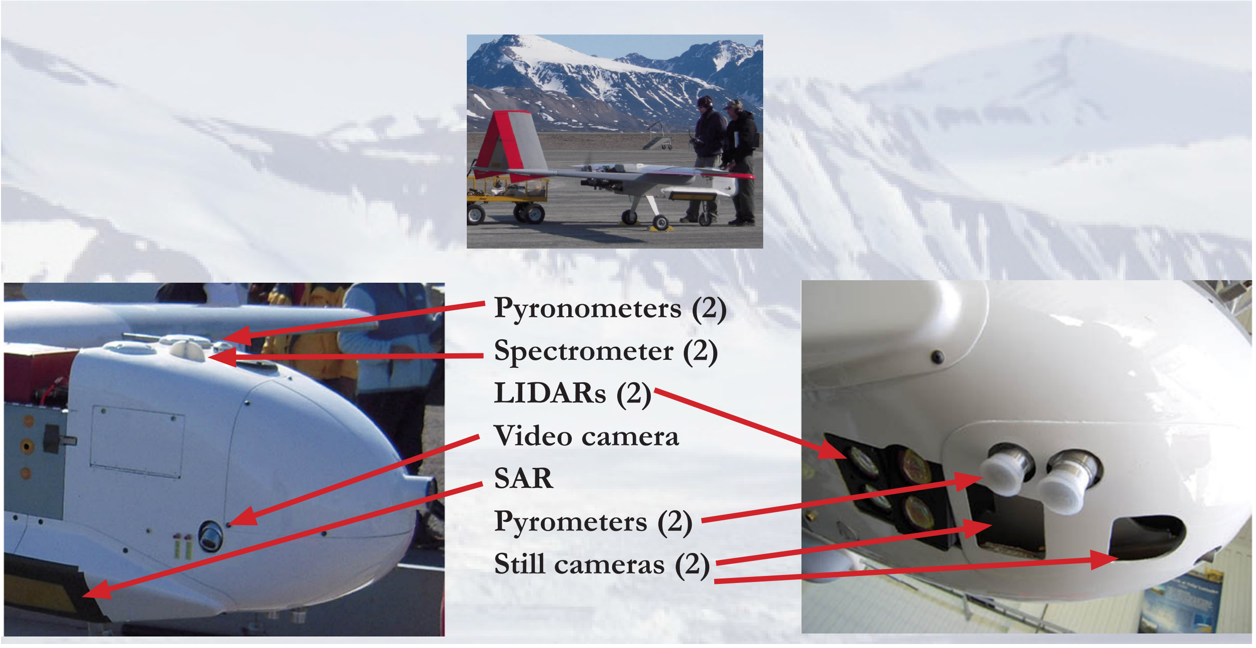
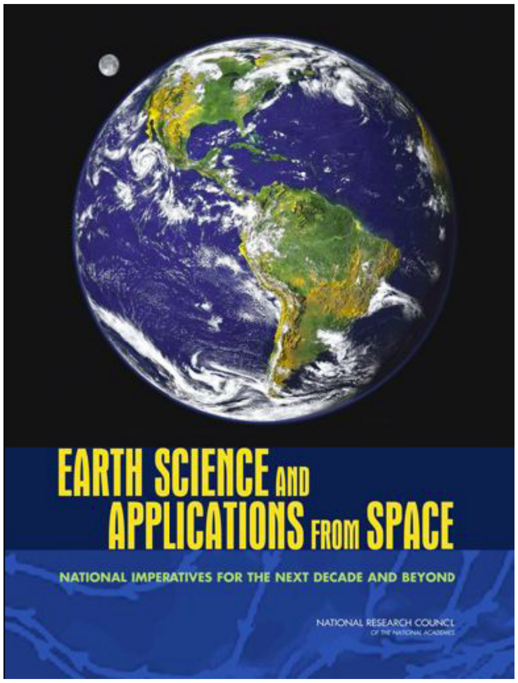


Figure 7:
This collection of images shows the SIERRA on the Svalbard tarmac and details the instruments integrated into the nose and forward fuselage.

Decadal Survey Support Missions

Since the National Research Council published its Decadal Survey report, "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond" in 2007, NASA's Science Mission Directorate has established science teams and is in the process of implementing these 15 new missions. The Airborne Science program has been working in parallel to support the Decadal Survey missions by flying instrument simulators and algorithm development experiments, and preparing to fly calibration and validation missions. The Program has also established relationships with the science teams to understand their upcoming needs and assist in planning through use of the flight request system and 5-year planning process.



In late FY08 and into early FY09, ASP flew PALS on the P-3 in support of Soil Moisture Active-Passive (SMAP). This will be the first of Decadal Survey missions to launch and additional fieldwork is anticipated. The Aerosol-Cloud-Ecosystems (ACE) mission will also make significant use of ASP assets beginning in 2010.

The ICESatII mission is being supported by Operation ICE Bridge.

Specific campaigns in FY09 in support of Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) and Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS) are discussed in detail below.

The IPY experiment flying an experimental Ka-band SAR on the G-III (described in the IPY section) also supported the Surface Water/Ocean Topography (SWOT) mission by flying a payload comparable to a simulator instrument that will be flying in the near future.

DESDYNI

Science Focus: Carbon Cycle & Ecosystem Science, Earth Surface and Interior

HQ Sponsors: Wickland, Dobson

PIs: Simard, Saatchi, Sequeira, Parrish, Aanstoos, Kearny, Jones, Rignot, Zebker, Moeller

The Deformation, Ecosystem Structure, and the Dynamics of Ice Mission (DESDynI) has been described as "a dedicated U.S. InSAR and LIDAR mission optimized for studying hazards and global environmental change." The recently-developed Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR) system represents the L-Band Interferometric Synthetic Aperture Radar component of that mission. Designed to fly on multiple aircraft, including Global Hawk, the UAVSAR flew 440.2 hrs during the period January 22 to October 2, 2009, on the NASA Gulfstream – III (G-III) aircraft. These sorties primarily were repeat-pass InSAR flights supporting early science objectives related to each of the focus areas for the DESDynI Mission.

Deformation studies included seismic activity and mudslide potential studies along the Hayward and San Andreas faults; California, Levee studies in the Sacramento Delta and along the Mississippi River; Subsidence along the Gulf Coast of Louisiana, and Volcanic activity in the Cascades, Yellowstone, and the Alaskan Aleutian Islands.

Ecosystem Structure studies included Kings Canyon in the Sierra Nevada, Boreal Forest sites in Canada, New Hampshire, and Maine, mixed forests in Pennsylvania and at the Harvard and Duke Forests, and coastal wetlands in North Carolina and Florida.

Finally, data to study the Dynamics of Ice were collected on a major deployment to Greenland and Iceland. (Described as part of IPY).

Deformation Studies in Southern California due to Seismic Activity

Deformation studies in Southern California were conducted as a series of missions originating and recovering at Dryden. Large contiguous areas were imaged along the San Andreas and Hayward faults from the San Francisco area to the Mexican border. Baseline imagery was collected from February 18 to April 4, 2009. Repeat pass imagery was collected from September 9 through September 21, 2009. The G-III flew 57.8 hours in support of three flight requests from Principal Investigators Paul Lundgren, Andrea Donnellan, and Eric Fielding to examine changes along the fault zones. Some of the same data are also being used by Eric Fielding and Catherine Jones to examine risk of mud slides in burned and defoliated landscapes. Additionally,

Figure 8:
UAVSAR mounted under the G-III at Dryden Flight Research Center.

repeat pass data were collected over the adjacent Sacramento delta region to examine potential stresses in the levee system (PI Jones).

Volcano –related Deformation in the Cascades, Aleutians, and Yellowstone

The G-III flew 51.4 hrs in support of Principal Investigator Paul Lundgren's study of deformation related to magma movement in the Cascades, the Alaskan Aleutian Islands, and Yellowstone.   The cascades were flown en route to and from two deployments to Anchorage, Alaska (June 21-23 and September 28- October 2, 2009). The Aleutians were flown on June 22 and September 29 using two sorties for each collection. (A refueling stop at Adak Is was necessary to complete each collection.) Baseline Imagery for Yellowstone was collected en route to New England on June 31, 2009.

For more information, visit: http://desdyni.jpl.nasa.gov/

Figure 9:
G-III/UAVSAR Flight Crew at Adak Is.

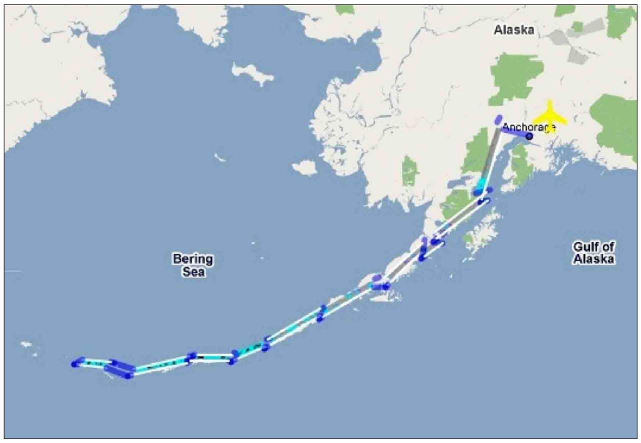


Figure 10:
Aleutian Islands Flight Lines.

ASCENDS

Science Focus: Atmospheric Composition and Chemistry
HQ Sponsor: Jucks
PIs: Abshire, Browell, Spiers

One major near-term requirement for the Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS) mission is to select a method and payload to measure CO_2. To that end, NASA had an outstandingly successful set of coordinated CO_2 laser flights over the DOE Atmospheric Radiation Measurement (ARM) Central Facility (CF) between 31 July and 7 August 2009. Four coordinated flights were made in Oklahoma with the NASA Langley UC-12, NASA Glenn Lear-25, Twin Otter International's Twin Otter, and the DOE Cessna covering altitudes from near the surface to 40-kft altitude. DOE in situ CO_2 point measurements were made on the tower at the ARM CF, and DOE radiosondes were launched to determine atmospheric state variables for each coordinated flight. The coordination between NASA, DOE, Vance AFB, and FAA for all operations was exceptional and enabled all flights to be conducted as planned. Two additional flights were conducted from NASA Langley with the Glenn Lear and Langley UC-12. All lasers and in situ sampling systems worked well during the field campaigns. All in situ data sets, including those from the UC-12, have been collected and distributed to all of the laser system teams for their comparison to the remotely derived CO_2 laser measurements. Results from these comparisons are expected to be available in early 2010.

Figure 11:
NASA Langley UC-12B aircraft awaits take off clearance as the Glenn Lear 25 takes off during joint operations in Ponca City, Oklahoma, in August 2009.

SWOT

Science Focus: Water and Energy Cycle
HQ Sponsor: ESTO
PI: Moller

The Surface Water and Ocean Topography mission (SWOT) is recommended by the NRC decadal survey to satisfy the elevation mapping requirements of two communities: surface water hydrology, and ocean surface topography. The primary instrument is a Ka-band Radar Interferometer (KaRIN) capable of simultaneously meeting coverage, accuracy and resolution requirements of both communities and enhances greatly the science achievable from a traditional profiling altimeter. The introduction of this new approach introduces additional algorithmic, characterization and calibration/validation needs that can be addressed through focused airborne campaigns in conjunction with traditional ocean altimeter calibration/validation measurements and existing and planned surface water gauge networks.

Figure 12:
Ka-Band antenna, funded by ESTO as part of GLISTIN project.

Surface water phenomenology presents some of the more immediate measurement and characterization questions due to the diversity of terrestrial water environments coupled with a paucity of relevant measurements. A recent (April 2009) opportunity arose to collect Ka-band data over terrestrial water bodies when the Glacier and Land Ice Surface Topography Interferometer (GLISTIN) (developed as a proof-of-concept sensor on the Gulfstream III under the NASA International Polar Year program – discussed elsewhere) transited to Greenland. En route to Greenland via North Dakota, data were collected in support of SWOT by rolling the G-III and collecting near-nadir backscatter profiles over local water bodies. Selected in collaboration with USGS and academic colleagues, these sites included Red River, Missouri River, Prairie Potholes, Devils Lake and the Big Bog. Flying into Thule, SWOT data was also collected over sea ice as a target of opportunity. These data will provide valuable backscatter statistics and for developing a land/water classification including over vegetated water.

For more information, visit http://decadal.gsfc.nasa.gov/swot.html

EPA Joint Sensors Mission

HQ Sponsor: Environmental Protection Agency
PI: Szykman

In 2009, NASA Langley integrated three instrument packages onto its Cessna 206 to provide support to the Ecosystem Services Research Program (ESRP) of the US Environmental Protection Agency's (EPA's) Office of Research and Development. The ESRP is a new, multi-year research initiative which will combine selected ecological indicator data and recent advances in resource economics to determine the value of services that terrestrial and aquatic ecosystems provide to humans. The instruments include a VISNIR Hyperspectral Imager called the Environmental Mapping Visible Imaging Spectrometer (EMVIS), a set of Hyperspectral ocean color radiometers (HyperOCR), and an infrared pyrometer.

The instruments will provide optical and thermal data for research in the ESRP-Nitrogen and ESRP-Coastal Carolinas program to determine how changes in reactive nitrogen loading from terrestrial landscapes relate to changes in nutrient cycling and the impact to the ecosystem services associated with nutrient retention provided by freshwater and marine systems, specifically in lakes and drinking water reservoirs in New England and in the Albemarle/Pamlico Sound region.

Results from Instrument Check Flights (ICF) on August 4, 2009 indicate strong correlations between remotely sensed sea surface temperatures and Chlorophyll-A concentrations, derived from a bio-optical model, and in situ data measured in the York River and Susquehanna River/lower Chesapeake Bay by the Virginia Institute of Marine Sciences (VIMS) Virginia Estuarine and Coastal Observing system and the NOAA Chesapeake Bay Interpretive Buoy system.

Following the ICFs, the Cessna 206 flew a series of science flights between August 25 and 30, 2009 spanning coastal to piedmont areas of North Carolina to collect EMVIS, HyperOCR, and thermal data for the ESRP Coastal Carolinas Program. A research goal is to integrate airborne hyperspectral remote sensor data and ENVISAT-1 Medium Resolution Imaging Spectrometer (MERIS) satellite data with in situ monitoring data and ferry-based water quality monitoring to provide a nearly continuous multi-resolution phytoplankton bloom monitoring capability for the entire Albemarle and Pamlico Sound region and the Neuse River estuary. During these flights, Langley served as the base of operations.

From September 13-18, 2009 the Cessna 206 deployed to New England to support data collection and algorithm development for water quality indicators over Long Island and Rhode Island Sounds, followed by a series of inland flights over selected New England lakes and ponds. During the deployment, the Cessna 206 surveyed 55 lakes in four states in a two-day period. Lakes were selected based on their trophic status. Aircraft data were supplemented by concurrently collected in situ data from several lakes by field crews provided by the states of Connecticut, Rhode Island, Massachusetts and New Hampshire, the University of New Hampshire, and coordinated by US EPA Region I.

The Cessna 206 flights in New England were conducted to support the Remote Sensing of Phytoplankton Program (ReSePP) at the EPA's Atlantic Ecology Division in Narragansett, Rhode Island.

Figure 13:
Installation of the three EPA hyperspectral ocean color radiometers on the NASA Cessna 206H aircraft.

High Winds

Science Focus: Water and Energy Cycle
HQ Sponsor: Entin
PI: Dinardo

L-band microwave radiometry is the key remote sensing technique for NASA's Aquarius satellite mission for ocean surface salinity research. The L-band radiometry acquires ocean surface brightness temperatures (TB), which respond to the change of sea surface salinity. To achieve accurate surface salinity measurements, the impact of ocean surface winds on L-band TB has to be corrected.

In February and March 2009, JPL's Passive and Active L-System (PALS) and Polarimetric Scatterometer (PolSCAT) were installed on the NASA P-3 research aircraft to acquire coincident L-band radiometer and radar data over a wide range of ocean surface wind speed.

The overall objective for the High-Winds'09 mission was to fly five instruments over predetermined flight lines over the North-Atlantic Ocean and Labrador Sea, based from Goose Bay, Newfoundland and Labrador, Canada. Engineering and program test flights were based from NASA WFF. All science team success criteria were determined by JPL PAL / PolSCAT science team.

Success criteria for High-Winds'09 were as follows:

- To acquire PALS and PolSCAT, passive and active microwave data to enable the development of algorithm during high wind conditions.
- L-band microwave RFI detection and GPS reflection systems will be tested.
- Dropping Airborne eXpendable Conductivity Temperature Depth (AXCTD) probes to study the near surface salinity signature

The GISMOS and GPSRS systems flew as piggyback instruments to collect data during High-Winds'09 allotted flights.

Figure 14:
P-3 performing PALS navigation calibration on Goose Bay taxi way.

Figure 15:
P-3 belly, PALS installed in the forward white radome, PolSCAT in the aft black radome.

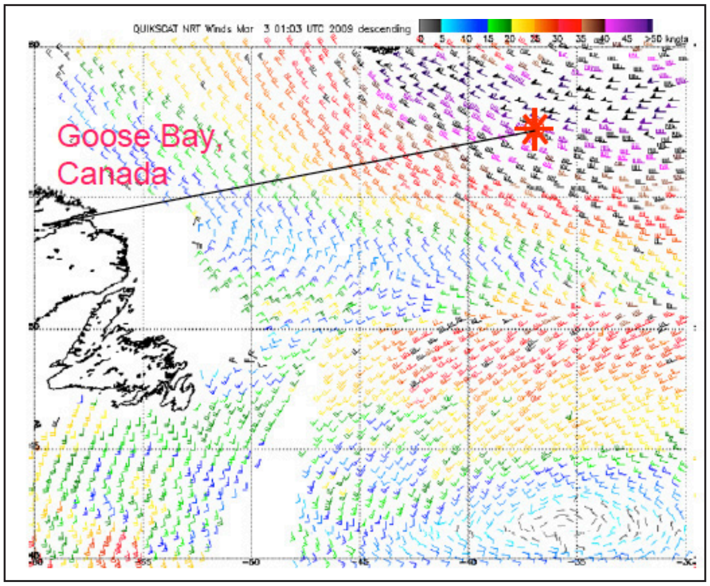


Figure 16:
March 3, NASA P-3 Flight track from Goose Bay, Canada to the selected way point in the Labrador Seas. At the waypoint, the P-3 performed High Winds '09 "Star" pattern, Circle flights and Wing wags.

The five instruments being flown aboard the NASA WFF P-3B were as follows:

- Passive Active L-band System (PALS) - Steven Dinardo, NASA JPL
- Airborne Polarimetric Scatterometer (PolSCAT) - Steven Dinardo, NASA JPL
- Airborne Expendable Conductivity Temperature Depth Probe (AXCTD), Dr. Daniel Jacob, NASA GSFC
- GNSS Instrument System for Multi-static Occultation (GISMOS) – Dr. James Garrison, Perdue University
- GPS Remote Sensing Instrument (GPSRS) – Dr. Michael Grant, NASA Langley Research Center

The High Winds '09 mission started with a flight on February 12, flying over the National Data Buoy Center Buoy 41002, off South Carolina to verify the calibration of POLSCAT. Next, a region identified for winter high winds is the Northern Atlantic and Labrador Sea area. This location shows the highest regional wind speeds as per current NASA QuickSCAT satellite data.

On February 16, the aircraft was deployed to Labrador seas to acquire data under high wind conditions. The High-Winds'09 missions were flown over a 3.5 week period (February 16- March 9, 2009), deployed out of Goose Bay airport. Goose Bay is a Canadian Forces Base (CFB) located in the town of Happy Valley-Goose Bay, Newfoundland and Labrador. CFB Goose Bay is presently operated as an air force base by Canadian Forces Air Command

Figure 17:
Local Goose bay film crew, interviewing Steve Dinardo, about the High-Winds'09 mission

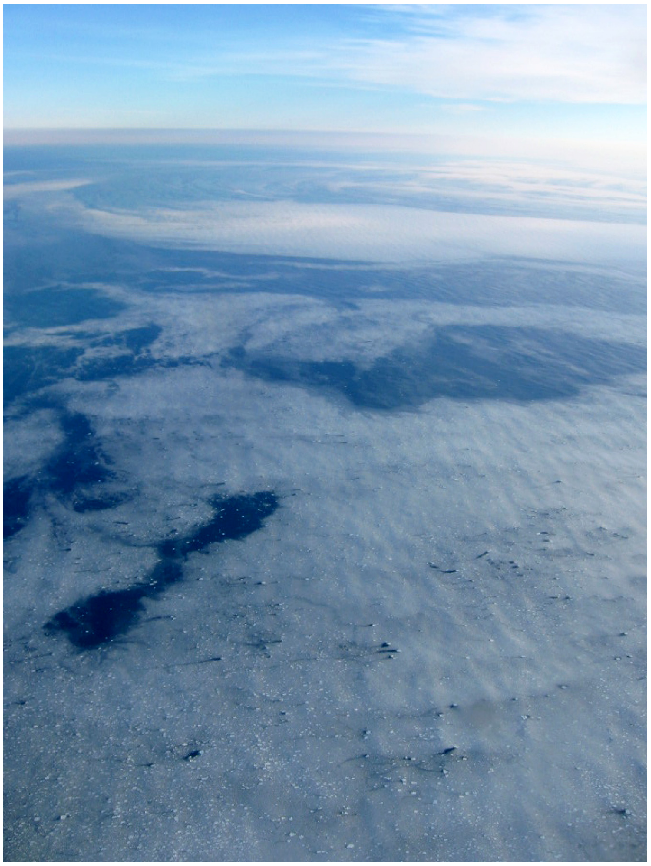


Figure 18:
En route from Goose Bay to high winds waypoint, picture captures the end of the ice sheet.

and is the site of NATO tactical flight training in Canada. It should be noted, The High Winds '09 mission received wonderful support from the CFB air operations and the Canadian weather services. Without there superb help, the High Wind Mission would not have been a success.

While in Goose Bay, P-3 flights were scheduled based on daily field meetings. Satellite data and data provide by the Canadian Weather services, was reviewed by the JPL science team and flights were made during periods of predicated ocean surface winds in excess of 50 Knots.

The P-3B High-Winds'09 campaign data is still being analyzed. Preliminary results are showing high correlation between PALS L-band radiometer and radar signals of ocean surfaces. The correlation of TB with radar backscatter is as high as the correlation with the surface wind speed (greater than 0.95). The results demonstrated the feasibility to use the radar backscatter to estimate the excess brightness temperature due to wind forcing.

Interferometric SAR Ice Mapping in Greenland

Science Focus: Cryosphere
HQ Sponsors: Kaye, Albertson
PIs: Zebker, Moller

On May 1, 2009, the NASA Gulfstream III (NASA502) departed Dryden Flight Research Center on its first deployment, a challenging mission to measure ice dynamics in Greenland and Iceland using first a Ka-Band and then an L-Band synthetic aperture radar. The aircraft and crew returned on June 17, having accomplished all primary and all secondary objectives. The two radar instruments successfully collected data over wetlands and flowing water in North Dakota, open ocean and ice packs, glaciers in Greenland and Iceland, wetland dynamics in the Florida everglades, coastal zone changes in the Louisiana gulf coast, and levees along the Mississippi River. In 31 sorties, encompassing over 170 flight hours, the DFRC/JPL crew collected approximately 6 Tb of radar data, providing the science community with unique views of the dynamics of snow and ice during the arctic melt, as well as a number of other dynamic environmental processes.

The deployment began with the Ka-Band radar, called GLISTIN (Glacier and Land Ice Surface Topography INterferometer). The GLISTIN instrument is a derivative of the L-Band system,

Figure 19:
The G-III and UAVSAR landing at Keflavik, Iceland. (Photo: M. Thomson)

Figure 20:
Flight route of G-III from Dryden Flight Research Facility to Greenland and Iceland during IPY, including stops in North Dakota and the Everglades.

designed and built as a proof-of-concept. Data were collected over prairie potholes, wetlands, and the Red and Missouri rivers in North Dakota and Minnesota in support of early design for the Decadal Study SWOT (Surface Water Ocean Topography) mission. NASA502 remained at Grand Forks, ND, overnight and proceeded to Thule, Greenland on May 2nd, collecting data over pack ice en route. For the next two weeks, Ka-Band data were collected over the Jacobshaven Glacier and along a transect to High Point (at 10,000 ft, the highest point in Greenland), allowing observations of a variety of snow and ice conditions. The flight on May 6 was a coordinated flight with the Airborne Topographic Mapper (ATM) sensor aboard the NASA P-3 as well as field measurements at Swiss Camp and High Point. Early results revealed that the Jacobshaven glacier calved approximately 1.5km over a 6-day interval.

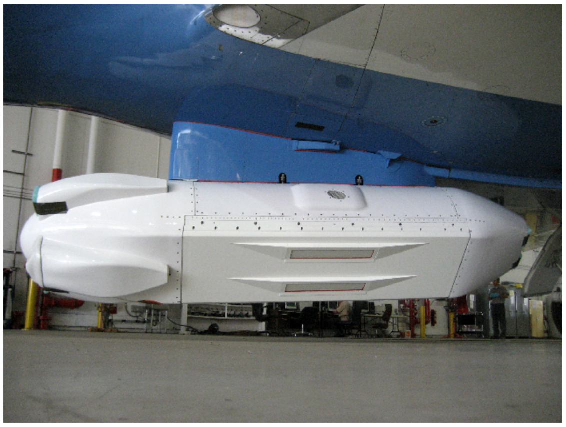


Figure 21:
Ka-Band antenna in pod mounted on G-III aircraft for flight to Greenland.

Flights with the second pod and L-Band UAVSAR (Unmanned Aerial Vehicle Synthetic Aperture Radar) began on May 15 and continued for the rest of the deployment. An inverter failure on that flight caused a re-deployment to Bangor, Maine for repairs, and the crew returned to Thule, with data en route, on May 20th. The crew changed out on May 26. Except for a brief overnight at Kangerlussuaq (Sondre Stromfjord) on June 4th to permit acquisitions in Eastern Greenland, flights continued from the "Top of the World" over the Greenland glaciers and ice sheet until June 8, accomplishing all objectives and options in Greenland.

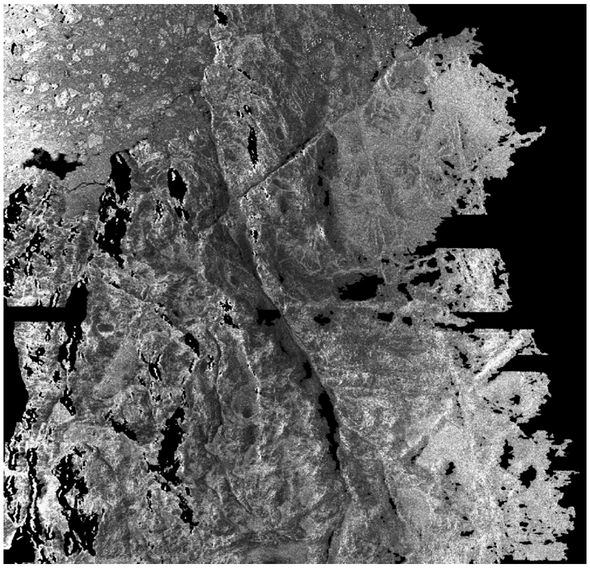


Figure 22:
Backscatter imagery for a short segment over Jakobshavn glacier. Data was collected at an altitude of 8km (MSL). The horizontal axis spans 7.5km and corresponds to the cross-track dimension of the radar. The map posting is 3m x 3m.

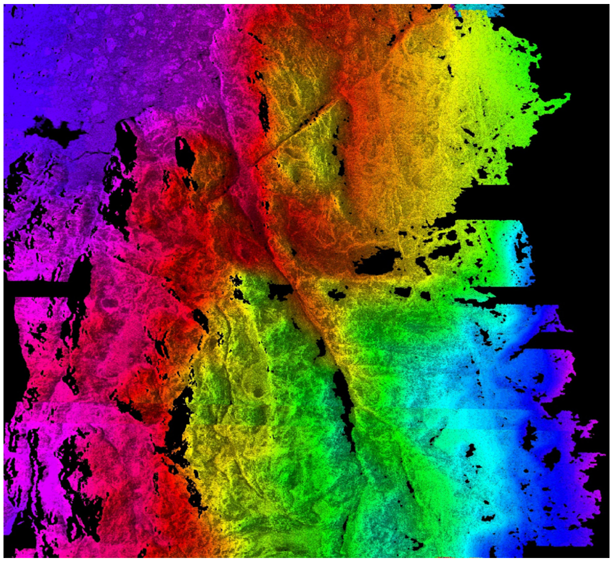


Figure 23:
Height elevation map corresponding to the same region as Figure 18. The color wrap is 800m.

On June 8, the crew transited to Keflavik, Iceland, for an intensive series of flights over Lanjokull and Hofsjokull glaciers. The Principal Investigator, Marc Simons, was enthusiastic in his hope that these data would be the first 3-D vector measurements made over these rapidly changing glaciers. On June 14, the crew began its journey home, collecting repeat pass UAVSAR data in the Florida everglades to study vegetation structure, data along the Louisiana gulf coast to characterize subsidence, and data along the Mississippi River conduct levee condition assessments.

It took the science teams many months to analyze this large volume of data for scientific results. The response from the scientific community to the opportunity presented by this unique collection has been overwhelmingly positive. This was a highly ambitious undertaking, especially so for a first deployment. Despite the challenges of operating in an extreme environment with new systems, all the requested data were collected. This is a testimony to the excellence in design of the JPL radars and the DFRC Precision Autopilot, the robustness of the G-III as a platform aircraft, and the perseverance of the combined JPL/DFRC crew. This deployment, and the ones to come, will provide the science community new tools for environmental science, as well as providing pathfinders for the new instruments recommended by the NRC Decadal Study.

For more information, visit http://www.nasa.gov/centers/dryden/Features/G-III_uavsar_09.html

Operation ICE Bridge

Science Focus: Cryosphere
HQ Sponsor: Albertson
PI: Martin

Operation ICE Bridge 2009 was funded by the NASA Cryosphere Program Manager, Thomas Wagner and the NASA Airborne Science Program Manager, Randal Albertson. The Operation ICE Bridge Project Scientist was Seelye Martin of the University of Washington. The OIB Project Manager was Kent Shiffer from the NASA Ames Earth Science Project Office.

The Ice, Cloud, and land Elevation (ICE) Sat I satellite is nearing the end of its lifespan and is expected to be inoperable very soon. ICESat II is not expected to launch until 2014 at the earliest. With this in mind, the Airborne Science program established a campaign to bridge the data gap with NASA aircraft assets. This campaign was officially named “Operation ICE Bridge” or (OIB).

Operation Ice Bridge is now well underway. Incorporated into OIB are several NASA and commercial entities that will provide data for both the Arctic and Antarctic. In calendar year 2009 the primary scientific focus for OIB were the Arctic and Antarctic regions of sea and land ice.

From March 30 – May 6, 2009 the NASA P-3 from Wallops Flight Facility conducted the spring portion of OIB out of Thule and Kangerlussuaq, Greenland with great success. The P-3 aircraft and crew flew a total of 20 science flights over 172 flight hours, the most of any previous P-3 deployment.

Instrumentation on the P-3 included the Laser Vegetation Imaging Sensor (LVIS), Airborne Topographic Mapper (ATM), Pathfinder Airborne Radar Ice Sounder (PARIS), and the University of Kansas Snow Radar. NASA P-3 flight lines included sea and land ice with ICESat I under-flights. These instruments provided observations of land ice, sea ice and extended Arctic sea ice along coastal Greenland and a long leg transit to/from Fairbanks, Alaska, while underflying ICESat I.

In two separate measurement campaigns in May-June and in August-September, the University of Alaska Geophysical Institute’s Chris Larsen flew a single engine Otter aircraft with a laser altimeter to acquire elevation profiles and compute mass balances of the remote Stikine Glacier and glaciers surrounding Glacier Bay on the Alaskan peninsula near Juneau. Weather was favorable and the mission was completed on time. Dr. Larsen was able to complete 52.4 of the 60 flight hours allocated for these combined Alaska missions.

In Austral Spring, October 15 –November 23, 2009, the NASA DC-8 completed an unprecedented 227.4 flight hours including 21 science flights in the

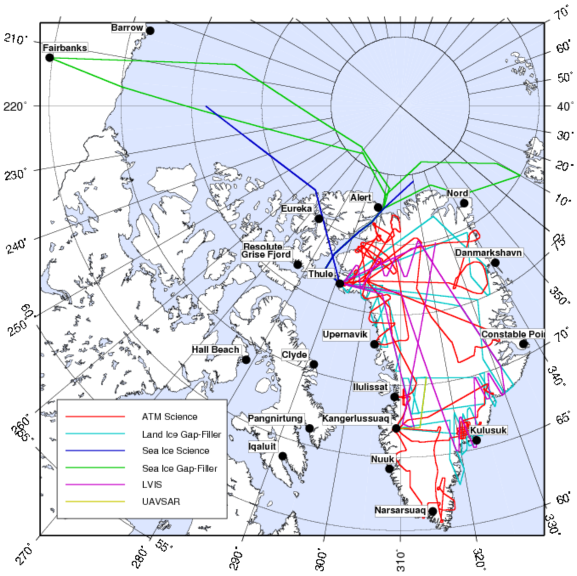


Figure 24:
Operation Ice Bridge Science flight lines over Greenland and the Arctic, Mar. 30 through May 6, 2009. (Image courtesy John Sonntag)

southern hemisphere over Antarctica from Punta Arenas, Chile. Unusually clear weather over the glacial and sea ice targets provided measurements of some locations that have never been measured before.

Cryospheric instruments onboard the NASA DC-8 included the ATM and LVIS instruments previously flown on the NASA P-3, the Multichannel Coherent Radar Depth Sounder/Imager (MCoRDS/I) ice sounder and KU band snow depth sounder from the University of Kansas, as well as an airborne gravimeter supplied by Lamont-Doherty Earth Observatory of Columbia University. Also included in the instrument mix was the Digital Mapping System (DMS) provided by John Arvesen of Cirrus Systems. This combination of instruments will provide extremely valuable data set to the earth science community. The NASA DC-8 platform has an extended range envelope that provides a substantial increase in time over the glacial and sea ice target areas when deployed for remote locations such as Punta Arenas, Chile.

Figure 25:
Western Greenland glacier, south of Thule Air Base. (Photo: James Yungel)

Figure 26:
NASA P-3 outside hangar 8, April 2009, Thule Greenland. (Photo: Kent Shiffer)

Figure 27:
University of Alaska, Fairbanks, contracted single engine Otter on Alaskan glacier, May 2009 (Photo: Chris Larsen, UAF)

Figure 28:
A greeting from team members at Palmer Station, Antarctic Peninsula, during overpass flight of the NASA DC-8. Photo taken by the Digital Mapping System (John Arvesen, Principle Investigator, Cirrus Systems).

Atmospheric Chemistry instruments were added to the DC-8 payload as piggyback flyers to try to gain some experience over the rarely measured Antarctic atmosphere. These insitu measurement instruments included AVOCET measuring CO_2, Diode Laser Hygrometer (DLH), Differential Absorption CO Measurement (DACOM), measuring the trace gases CO, CH_4, N_2O, CO_2, and H2O(v) and the University of California, Irvine Whole Air Sampler (WAS).

In Austral Spring (November – December), Don Blankenship, Principle Investigator for the University of Texas, was contracted to provide science data for Antarctic glaciers that the DC-8 cannot reach from Punta Arenas with the Ken Borak, Basler BT-67 aircraft. [This was done in conjunction with an NSF/NERC science mission.] The focus work for the BT-67 is the Cook and Totten glaciers surface elevation and observation of East Antarctica. The instrumentation suite on board the BT-67 includes an Ice Penetrating Radar, Magnetometer, Laser Altimeter, and a Gravity Meter. Basic data from the instrumentation suite consists of profiles of (a) ice thickness, (b) ice-surface elevation, (c) free-air gravity and (d) magnetic field intensity. This work was done in conjunction with an NSF/NSERC science mission.

More information can be found on the OIB web site at: http://www.espo.nasa.gov/oib/

Antarctica 2009 Mission Blog sites
http://www.nserc.und.edu/blogs/
http://blogs.nasa.gov/cm/blog/icebridge

Western States Fire

Science Focus: Applied Science: Disaster Management
HQ Sponsor: Ambrose, Dorne
PI: Ambrosia

The Western States UAS Fire Imaging effort project, received ARRA funding to continue support of wildfire imaging efforts through 2011. The efforts focus on the use of the NASA Ikhana UAS and the NASA DFRC B200 King Air (currently under airframe modifications). The Ikhana is currently allowed to fly fire missions within 50 nm of Special Use Airspace (SUA). This limitation has steered the WRAP team to look to additional manned platforms (NASA DFRC B200 King Air) for less restrictive flight operation capabilities. The NASA DFRC B200 King Air is being modified to allow various sensor packages and satellite data telemetry to be outfitted on the platform, and is planned for platform / sensor check-flights in Summer 2010, prior to the major western US fire season. The WRAP team anticipates use of that platform to support wildfire imaging efforts.

Due to a minimal fire season in fall 2008 (early FY2009), the AMS-Wildfire sensor and the Ikhana did not support any fire data collection missions. During the second and third FY quarter of FY2009, the Autonomous Modular Scanner (AMS)-Wildfire sensor spectral characteristics were modified to prepare it for use in supporting atmospheric science on the NASA Global Hawk UAS, as part of the GloPac mission series. Due to weight and balance issues with the Global Hawk platform, the AMS-Wildfire was removed from the GloPac payload. The sensor was de-integrated and made available to support wildfire observation missions on the Ikhana in late summer 2009. After sensor spectral channel modifications in September 2009 (to change the mid-IR channels to their fire imaging characteristics used previously), the AMS-Wildfire was further modified by expanding the sensor from 12-channels to 16-channels, allowing for both high- and low-gain sensor spectral sensitivities in the mid-infrared (Mid-IR) and thermal-infrared (TIR) wavelength channels (channels 9-12). This allowed for improved discrimination of wildfire properties.

After the sensor modifications were completed, the AMS was installed in the Ikhana and a test flight was flown to ensure system operations prior to supporting national / state fire emergencies. A four-hour test flight was flown September 11, 2009 within the confines of the Edwards Air Force Base (EAFB) Restricted Area, and system shakeout occurred. Following the test mission, various issues involving the aircraft / satcom data telemetry system were discovered (nationwide fleet issues) and the aircraft / sensor issues were worked on extensively.

The western US fire season was considered “light” by previous fire year averages and nationwide, the season was closed by mid-October 2009. No fire support missions were therefore flown in late FY 2009. The southern California fire season remained an area of concern, due to the frequent occurrence of Santa Ana wind conditions, spawning large fire complexes. Due to these potential fire issues, both the NASA-ARC and NASA-DFRC Ikhana mission team remained at-the-ready to support any necessary wildfire emergency request flights in October / November 2009 (early FY2010).

For more information, visit: http://geo.arc.nasa.gov/sge/WRAP/

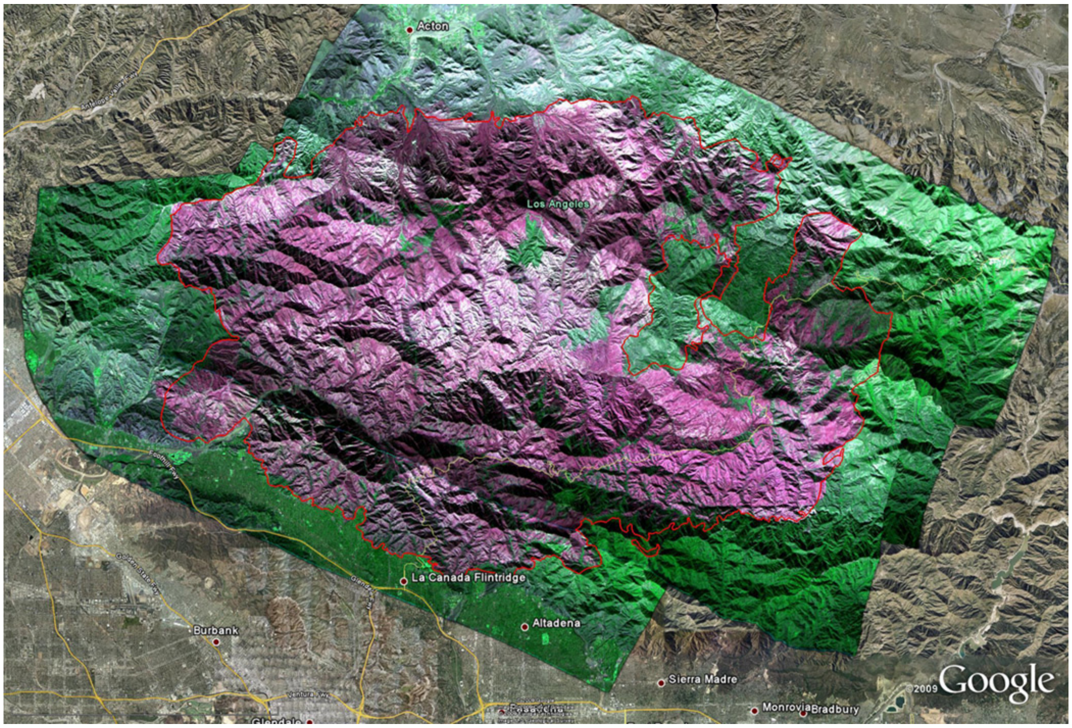


Figure 29:
Image of Station Fire that burned 160,000 acres in the Angeles National Forest obtained with AMS sensor.

AAFEx

HQ sponsor: Aeronautics Research Mission Directorate

During January and February 2009 the DC-8 was employed in a ground test series to support the Alternative Aviation Fuel Experiment (AAFEX) at the NASA Dryden Aircraft Operations Facility (DAOF) in Palmdale, California. The rising cost of oil coupled with the need to reduce pollution and dependence on foreign suppliers has spurred great interest and activity in developing alternative aviation fuels. Detailed studies are required to ascertain the exact impacts of the fuels on engine operation and exhaust composition. In response to this need, NASA acquired candidate alternative fuels from a variety of sources and burned the fuels in the NASA DC-8 to assess changes in the aircraft's CFM-56 engine performance and emission parameters relative to operation with standard JP-8. The AAFEX Aeronautics Research Mission Directorate project managed by Dan Bulzan of NASA Glen Research Center and under the direction of the Project Lead Scientist Bruce Anderson of NASA Langley Research Center, the AAFEX tests sought to establish fuel matrix effects on: 1) engine and exhaust gas temperatures and compressor speeds and pressures; 2) engine and auxiliary power unit (APU) gas phase and particle emissions and characteristics; and 3) volatile aerosol formation in aging exhaust plumes. A secondary goal of the study was to evaluate the role of ambient conditions in regulating volatile aerosol emissions. Gas phase measurements included the standard certification species (CO_2, CO, NO_x, and THC) along with hydrocarbons, hazardous air pollutants (HAPS), and oxygenated compounds. Measured particle parameters included smoke number; number density, size distribution and total

Figure 30:
Arial view of the AAFEX test setup showing DC-8 in the open-air engine run-up facility at the Dryden Aircraft Operations Facility in Palmdale, CA.

mass; black carbon morphology, composition and total mass; volatile aerosol speciation and mass; and particle mixing state. In addition to NASA, test participants included DOD, FAA, EPA, Boeing, General Electric, Pratt & Whitney, Carnegie Mellon University, Harvard, MSU, UCSD, and UTRC.

During AAFEX, the aircraft was parked outdoors in the DAOF open-air engine run-up facility and complete sets of gas and particle emission measurements were made as a function of thrust as the engine alternately burned JP-8 or one of the alternative fuels. Two fuels were procured for the tests: a Fischer/Tropsch (FT) fuel prepared from natural gas and an FT fuel made from coal. The test series consisted of five fuel configurations: (1) Standard JP-8, (2) Shell Fischer-Tropsch fuel from natural gas (FT1), (3) 50/50 JP-8/FT1 blend, (4) Sasol Fischer-Tropsch fuel from coal (FT2) and, (5) 50/50 JP-8/FT2 blend.

To delineate fuel-matrix related changes in emissions from those caused by changes in ambient conditions, samples were alternately drawn from the exhaust of an engine on the opposite wing, which was simultaneously burning JP-8. To examine plume chemistry and particle evolution in time, samples were drawn from inlet probes positioned 1, and 30 m downstream of the aircraft's inboard engines; instruments were also placed in a trailer parked ~200 meters behind the aircraft to measure aerosol and gaseous properties in the more aged plume. In addition, the 1 m rake included multiple gas and aerosol inlet tips so that during initial tests, emissions could be mapped across the breadth of the engine exhaust plane to establish the extent of the core-flow region within the near-field plume. Taking advantage of the broad diurnal variation in air temperature in the Mojave Desert, tests were conducted in the early morning and at mid-day to examine the effect of ambient conditions on gas phase and volatile aerosol emissions.

Preliminary results have shown that: (1) Alternative fuels do not affect engine performance but may cause fuel system seal leaks. (2) Engine black carbon emissions are substantially reduced when burning Fischer-Tropsch fuels. (3) The aircraft engine consumes ambient methane at most power settings. (4) A great deal was learned regarding the temperature dependence of engine emissions which will be used to influence local air quality modeling.

For more information, visit:
http://www.nasa.gov/topics/aeronautics/features/aafex.html

RACORO

Sponsor: Ambrose, Dorne
PI: Hostetler

RACORO was a deployment to Oklahoma for the Routine ARM Aerial Facility (AAF) Clouds with Low Optical Water Depths Optical Radiative Observations (RACORO) sponsored by the Department of Energy (http://acrf-campaign.arm.gov/racoro/). The B200 deployed the HSRL and the Research Scanning Polarimeter, which is the prototype for the Aerosol Polarimetry Sensor that will launch on the Glory satellite in 2010. On RACORO, the B200 flew coordinated patterns with the CIRPAS Twin Otter, which was outfitted with a variety of in situ cloud and aerosol sensors. In addition to significantly augmenting the science output from the DOE's RACORO effort, this campaign also provided a data set that will be used to assess future satellite aerosol and cloud retrievals, including Air Particulate Sampler (APS) retrievals, combined APS-CALIPSO retrievals, and retrievals relevant to the next generation polarimeter and lidar combination on the ACE Decadal Survey mission.

For more information, visit: http://acrf-campaign.arm.gov/racoro/

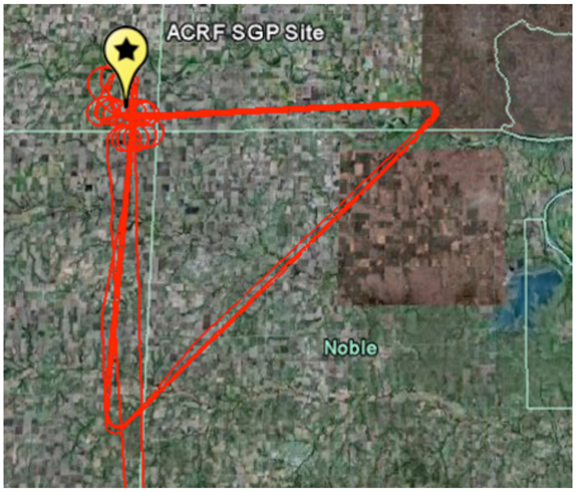


Figure 31:
DOE Radiation monitoring site in Oklahoma. Flight tracks for Twin Otter flying below and the King Air flying above.

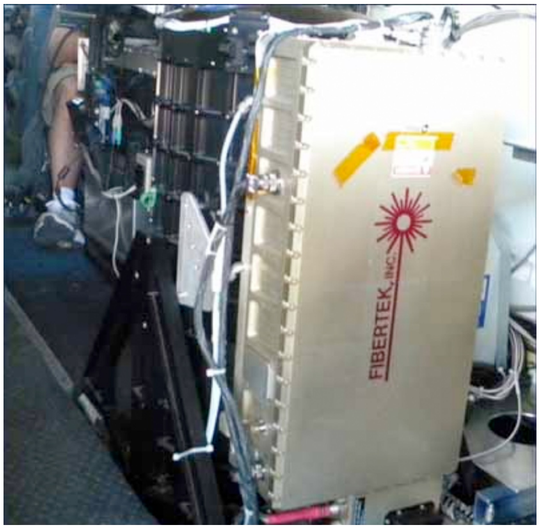


Figure 32:
A High Spectral Resolution Lidar and Research Scanning Polarimeter are located within the King Air.

TM Relay

HQ sponsor: NASA Launch Services Program

Figure 33:
Launching of Delta II rocket from Vandenberg AFB.

NASA Airborne Science added yet another new role to its résumé in May when the DC-8, teamed with Ktech, successfully relayed and recorded telemetry transmitted by a Delta II rocket boosting a satellite into orbit. NASA Launch Services Program (LSP) asked the Airborne Science Program to show that the DC-8 could rendezvous over 1100 miles off the tip of Baja with a rocket launched from Vandenberg AFB and provide real-time data to the launch team back at Kennedy Space Center. The Delta II rocket provided by LSP contractor United Launch Alliance carried an experimental satellite for the Missile Defense Agency. Ktech provided the telemetry tracking and receiving equipment and technical support team on the DC-8.

Instrument Test Flights

In FY 2009, the Airborne Science Program continued to support technology development, including projects funded by the Earth Science Technology Office (ESTO) Instrument Incubator Program (IIP) and Airborne Instrument Technology Transfer (AITT) program.

These flights include a variety of science instruments including RADARs, LIDARs, optical instruments and passive microwave experiments. By demonstrating these instruments can operate in an aircraft environment, increased technology readiness levels can be demonstrated, bringing the development one step closer to being mission ready. Since some airborne experiments must be compact, rugged and semi-autonomous, this forces the instrument teams to develop technologies also needed for the rigors of space operation. Airborne instruments also supply data that can be used to design the operating parameters of space instruments. They are a vital link in the development of space-based instruments by providing actual measurements of real-world phenomena. This understanding enables space instruments to be properly designed and to optimize data collection parameters.

Some of the more significant demonstration flights conducted this past year include SIMPL, TWiLiTE, and CO_2 Laser Sounder.

SIMPL

The first science flights of the Slope Imaging Multi-polarization Photon-Counting Lidar (SIMPL) were conducted in February, 2009. SIMPL's development was sponsored by NASA's Earth Science Technology Office (ESTO) Instrument Incubator Program (IIP). The SIMPL project was selected by the IIP in response to a call for instrumentation that enabled improved elevation mapping of ice sheets, glaciers and sea ice. David Harding (Goddard Space Flight Center, Code 698) is the SIMPL Principal Investigator.

SIMPL is an advanced technology airborne laser altimeter. It incorporates beam splitting, micropulse single-photon ranging and polarimetry technologies at visible (green, 532 nm) and near-infrared (NIR, 1064 nm) wavelengths in order to achieve simultaneous sampling of surface elevation and the physical state of the surface along four parallel profiles. The deployment goals were to demonstrate the instruments measurement capabilities and document the system performance by collecting data over snow and ice targets. SIMPL was deployed on Glenn Research Center's Lear 25 flown out of Cleveland, OH. During three flights totaling about 8 hours, data was collected over ice cover on Lake Erie and snow-covered landscapes in Ohio and Pennsylvania. Additional instrumentation included an Applanix POS-AV system provided by the NASA Airborne Science Office at Ames Research Center, collecting position and attitude data used to geolocate SIMPL's profiles. Also deployed was nadir video to document the flight lines.

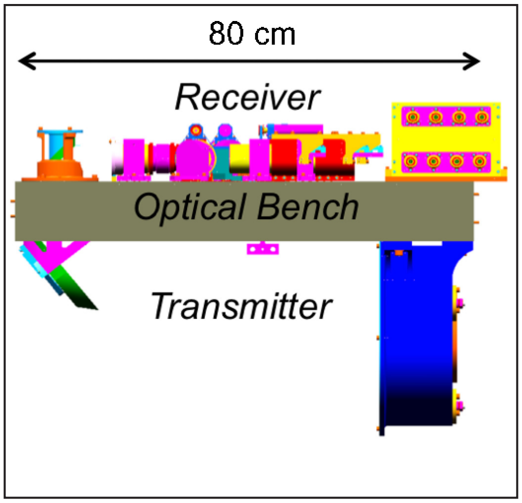


Figure 34:
SIMPL's shared optical bench (grey) and off-axis parabola telescope (blue) maintains alignment between the transmit beams and the receiver.

The ice cover results, providing an analog for sea ice, demonstrated the unique capabilities achieved by SIMPL. Depolarization data at both near-infrared and visible wavelengths differentiated open water leads, young translucent ice, older more granular ice and snow-covered ice, important differentiators for measuring sea ice free-board (height above water), which is an indicator of ice thickness. The high-precision single photon ranging differentiated smooth ice, roughened ice and compression ridges related to sea ice formation processes. The SIMPL demonstration of these capabilities is particularly important to the ICESat-2 mission now in formulation. ICESat-2, scheduled for a 2015 launch, will use multi-beam, micropulse single photon ranging, either at visible or near-infrared wavelengths. ICESat-2, follow-on to the ICESat mission, has a focus on monitoring changes in ice sheet elevation and sea ice freeboard. SIMPL is serving as a pathfinder for ICESat-2 technology development.

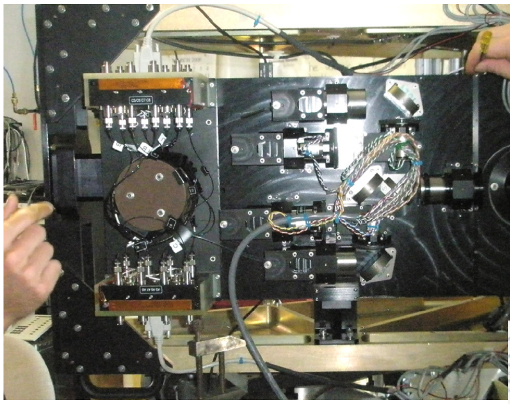


Figure 35:
SIMPL's receiver side.

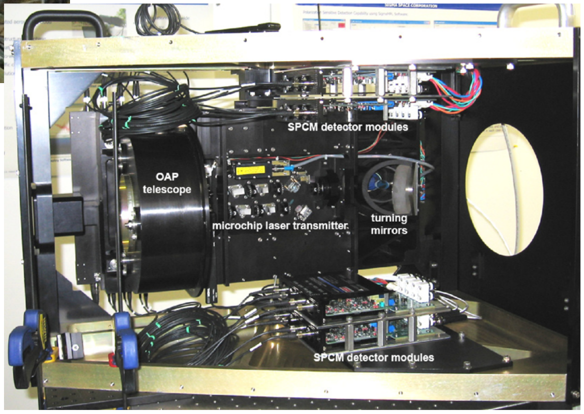


Figure 36:
SIMPL's transmitter side.

TWiLiTE

In September, 2009 Bruce Gentry (PI) and his team from NASA's Goddard Space Flight Center completed successful integration and engineering flight testing of the Tropospheric Wind Lidar Technology Experiment (TWiLiTE) on the NASA ER-2. The TWiLiTE Doppler lidar measures vertical profiles of wind by transmitting a short laser pulse into the atmosphere, collecting the laser light scattered back to the lidar by air molecules and measuring the Doppler shifted frequency of that light. The magnitude of the Doppler shift is proportional to the wind speed of the air in the parcel scattering the laser light. TWiLiTE was developed with funding from the Earth Science Technology Office's Instrument Incubator Program (IIP). The primary objectives of the TWiLiTE program are twofold: 1) to advance the development of key technologies and subsystems critical for a future space based Global Wind Sounding Mission, as recommended by the National Research Council in the recent Decadal Survey for Earth Science and 2) to develop, for the first time, a fully autonomous airborne Doppler wind lidar instrument to demonstrate tropospheric wind profile measurements from a high altitude downward looking, moving platform to simulate spaceborne measurements.

In February the team shipped the TWiLiTE instrument to Edwards AFB, integrated it into the NASA ER2, and conducted initial engineering test flights that demonstrated autonomous operation and key engineering functions of TWiLiTE and generated a wealth of engineering data. Detailed analysis of the data enabled the team to make the modifications necessary to correct any remaining issues. The instrument and team returned to Edwards in September for an extended round of engineering flights to further test the instrument operation. In this deployment, 25 hours of flight

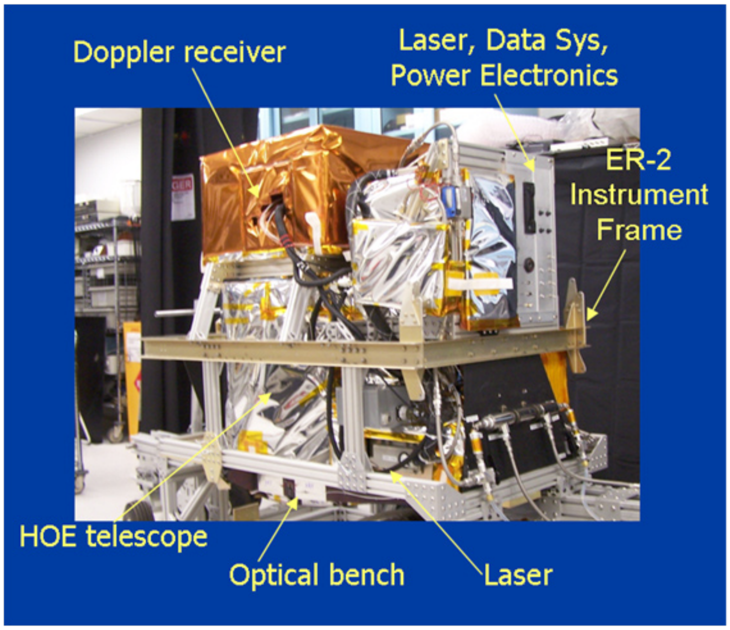


Figure 37:
Illustration of TWiLiTE assembled for ER-2.

data were obtained and, with support from the ER-2 pilots and ground crew, a number of challenging problems were identified and addressed culminating in successful operation of the instrument. These flights validated the nadir viewing wind profiling measurement concept and provided system level validation of the key technologies. TWiLiTE is the first fully autonomous airborne Doppler wind lidar and represents an important step on the path to space.

The TWiLiTE team is funded separately by NASA HQ under the Airborne Instrument Technology Transition (AITT) program (Program Scientist: Dr. Ramesh Kakar) to reconfigure the TWiLiTE instrument to fly on the NASA DC-8. One objective of the AITT program will be to co-fly TWiLiTE with the Doppler Aerosol Wind (DAWN) lidar system currently in development by NASA Langley under the IIP program. The DAWN lidar uses a different technology to measure winds using the backscattered laser light from atmospheric aerosols. The combination of a molecular Doppler lidar (TWiLiTE) and an aerosol Doppler lidar (DAWN) represents the 'hybrid' approach recommended by the National Research Council in the recent Earth Science Decadal Survey as the best solution to provide space based tropospheric wind measurements. Flights of TWiLiTE and DAWN will provide the first opportunity to examine the 'hybrid' Doppler lidar approach experimentally.
For additional information contact Bruce Gentry (Bruce.M.Gentry@nasa.gov).

Figure 38:
TWiLiTE roll-out with Space Shuttle in background at Dryden Flight Research Center.

CO_2 Laser Sounder

During October 2008 Goddard's CO_2 Laser Sounder Team successfully demonstrated its new-pulsed airborne lidar to measure CO_2 absorption. The instrument was configured to fly on the NASA Glenn Research Center's Lear 25 aircraft. The lidar measures the optical absorption due to atmospheric CO_2 in the nadir column from the aircraft to the surface. The lidar uses a pulsed fiber laser whose wavelength is scanned across the CO_2 line, a 20 cm diameter receiver telescope, and time and height resolved photon counting detector and signal processing.

Initial measurements were demonstrated with the lidar scanning a CO_2 line absorption near 1571 nm while flying in the vicinity of Cleveland OH. Laser backscatter and absorption measurements were over a variety of land surface types, including water surfaces and through thin clouds, broken clouds and to cloud tops. Strong laser signals were observed at altitudes from 2.5 to 11 km on two flights.

The team completed three additional airborne flight tests during December 2008. During these the team flew its CO_2 Sounder lidar on the NASA-Glenn Lear-25 and gathered over 6 hours of atmospheric CO_2 column line shape and depth measurements. Airborne CO_2 line shape measurements were made over Ohio on several flights while flying from 3-11 km altitudes. Subsequently the team deployed to Ponca City, OK, just east of the DOE ARM site. There it made 2 flights with 4 hours of airborne

Figure 39:
Aircraft at ARM site.

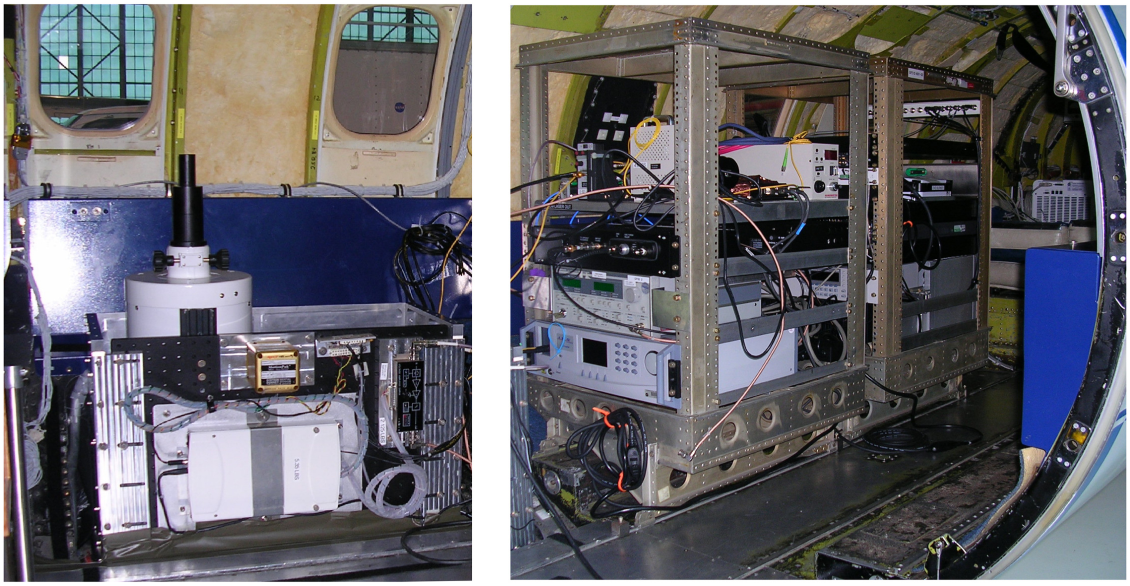
measurements. The flight patterns were at altitudes from 3-8 km centered above the ARM site. The increased CO_2 absorptions at higher altitudes were evident in all flights.

The flights were also coordinated with investigators at LBNL, who flew an in-situ CO_2 sensor on a Cessna aircraft inside the CO_2 sounder's flight pattern. These yielded 2 profiles of CO_2 from 5 km to the surface for comparisons. Data analyses showed agreement to better than 2% (6 ppm).

Goddard's CO_2 Laser Sounder Team successfully completed an extensive set of airborne measurements with its lidar instrument in summer 2009. The lidar measures the optical absorption of atmospheric CO_2 in the nadir column from the aircraft to the surface by stepping a pulsed laser transmitter in wavelength across the 1572.33 nm CO_2 absorption line. The time resolved laser backscatter and CO_2 absorption and line shape are measured by a photon counting receiver. Several instrument improvements were made since the lidar was flown in December 2008.

The instrument was installed on the NASA Glenn Research Center's Lear-25 aircraft in July 2009. Nine science flights were flown over Nebraska, eastern Illinois, the DOE ARM site near Lamont OK, eastern North Carolina and over the Chesapeake Bay and the Eastern Shore of Virginia. Each flight was just over 2 hours long and was flown with altitudes stepped from 3-13 km. The instrument worked well and CO_2 line shapes and absorptions vs. altitude were measured on all flights. Data analysis is underway.

The Goddard airborne CO_2 Sounder team is led by Jim Abshire (PI). The CO_2 Sounder activity is a precursor for the NASA ASCENDS mission, and is supported by ASCENDS funding, and the ESTO IIP and the Goddard IRAD programs.



Figures 40 and 41:
Pulsed airborne version of CO_2 Sounder Instrument on the NASA Glenn Lear-25.

AESMIR

The AESMIR 2009 test flights took place in January 2009. Installed on the P3 flying out of WFF, the instrument operated successfully at 25,000 ft. This experiment was internally funded by Goddard Space Flight Center. The PI was Edward Kim.

AESMIR is a new passive microwave instrument. The goal of this project was to complete the first test flights of this instrument on the P-3. This was a new installation and general instrument performance checkout over ocean and land was desired. The flights took place offshore of WFF and up and down the coast. The instrument achieved successful operation at 25kft for 7hrs,. Airspeeds were up to 300KIAS and the instrument experienced temperatures as low as -30C ambient. The tests also included low-level runs at 200ft.

General plans include additional demonstration flights leading to deployment for satellite calibration/validation in the future.

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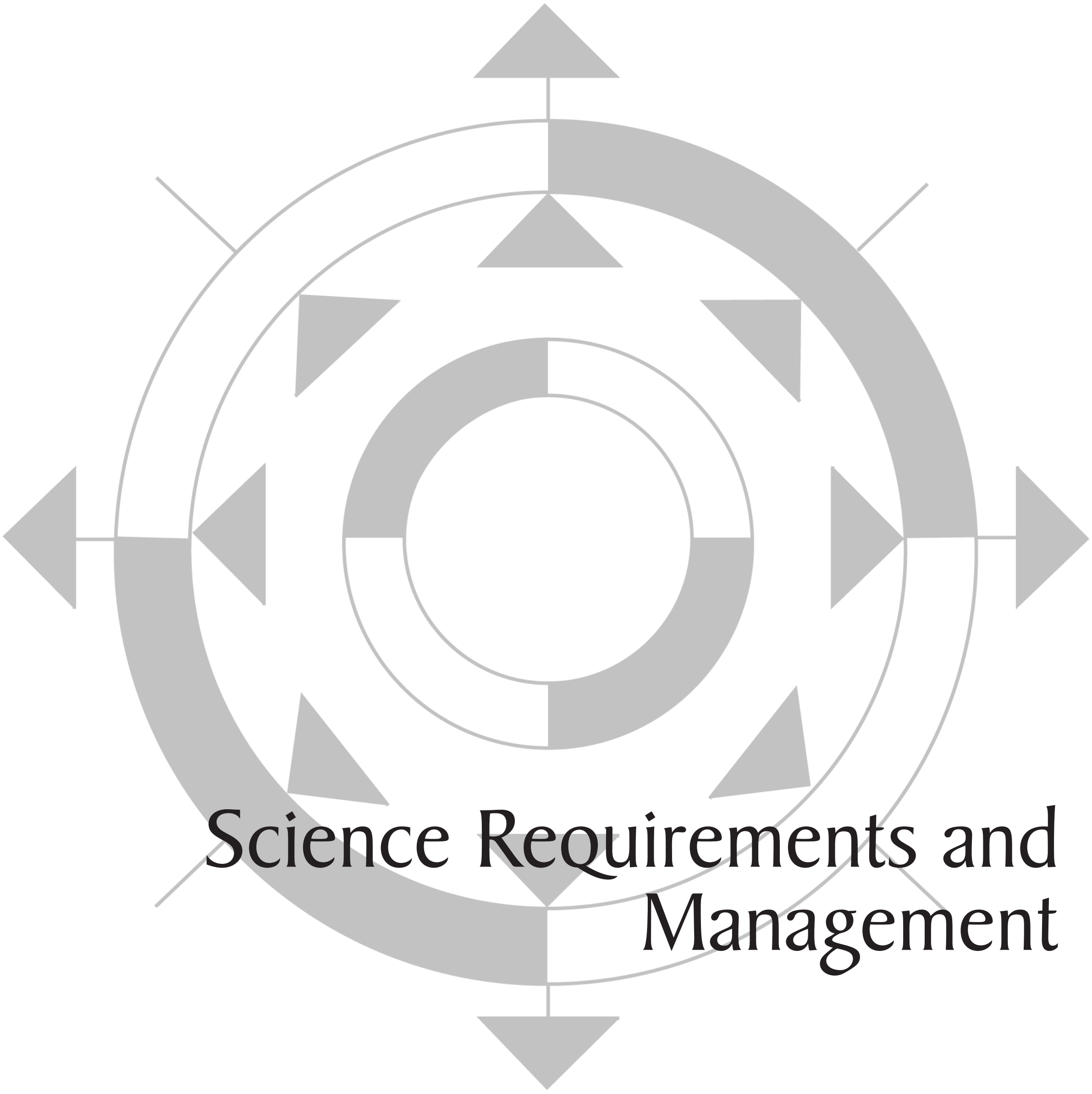
Figure 42:
Picture of AESMIR installed on the P-3.

AIRBORNE SCIENCE PROGRAM ELEMENTS



Science Requirements and Management

Science and Requirements

The Science Requirements and Management program element, implemented from the Airborne Science Office at NASA Ames, provides the information and analyses to ensure that the composition of the aircraft catalog, aircraft schedules, and investments in new technologies are directly and clearly traceable to current and planned science mission requirements. In addition, the Earth Science Project Office (ESPO) provides support through requirements analysis, flight request tracking and management, and mission concept and science instrument integration development and support.

Requirements are collected and validated in partnership with the three key stakeholder groups within the earth science community:

1. Mission scientists and managers of space flight missions in need of data for satellite calibration and algorithm validation.
2. Engineers and developers of new instruments in need of test flight or operations.
3. Scientists in need of airborne observations for answering science questions.

Near term requirements are gathered primarily through the online flight request system as well as inputs from mission science teams, conferences and scientific literature. The need for airborne observations related to priority SMD missions is tracked using a 5-year plan, updated annually, and by frequent communications with the NASA Earth Science Program Managers. For longer-term requirements, the program engages in a systematic process of collecting requirements from conferences, workshops, publications and interviews. Requirements gathered include platform altitude, endurance, range, and payload capacity, as well as telemetry, navigation data recorders, multidisciplinary sensors, and science-support systems.

A major effort in FY2009 concerned the formulation of the Operation Ice Bridge. The Ames team worked with Seelye Martin, then Program Manager for the Cryosphere Science Program, and the Cryosphere Science community to define areas that should be included in an airborne gap-filler campaign. The final report, "An Analysis and Summary of options for collecting ICESat-like data from aircraft through 2014", was the basis for Operation Ice Bridge.

In support of the National Research Council Decadal Survey entitled, "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond," in which fifteen new satellite missions were recommended for NASA to pursue, the Airborne Science Office at Ames began the process of documenting airborne requirements for supporting all aspects of the Decadal Survey missions in development including instrument development, future calibration/validation plans, and algorithm development. This report will include an overview of the missions, airborne instruments, plans for calibration and validation, and a schedule of expected activities and assets. A first draft has been completed and the final report will be completed in mid-FY2010.

Flight Request System

The year 2009 was very productive for the Airborne Science Program Science Operations Flight Request System (SOFRS). Improvements have been made to the SOFR system to reflect additional requested changes in notifications and access. SOFRS can be accessed through the website (http://airbornescience.nasa.gov).

There were 167 flight requests submitted in 2009. Seventy flight requests were completed, 42 were rolled over to 2010 and the rest were withdrawn or canceled depending upon the availability of resources at the time of the request. The details are listed below.

Flight requests were submitted for 15 aircraft platforms and flew more than 1800 flight hours in all. Several large campaigns were successfully conducted this year (CASIE, ASCENDS, Operation ICE Bridge etc).

Aircraft	Submitted	Total Approved	Total Completed	Total Science Flight Hours Flown
DC-8	8	3	3	20.3
ER-2	31	17	13	150.7
P-3	15	9	7	216.1
WB-57	10	1	1	44.5
Twin Otter	26	4	2	103.8
B-200	13	8	8	331.8
G-III	33	25	24	526.0
Lear 25	5	NA*	3	66.7
T-34	1	1	1	26.4
Cessna 206	1	1	1	41.0
Aerosonde	3	0	0	0
Global Hawk	3	1	0	0
Ikhana	3	0	0	0
Blank	14	4	..	10
SIERRA	8	5	5	76
Other	7	2	2	273.4
TOTAL:	167	80	70	1876.7
KEY				
Submitted:	Flight Request entered into the system.			
Total Approved:	All flight requests that have been approved.			
Total Completed:	Flight requests completed in 2009.			

Table 1: *Flight requests for FY2009.*

*Some internally approved Langley B-200 and GRC Learjet 25 and T-34 flight requests were separate from the ASP FR system but the completed science hours are reflected in this summary.

Aircraft hours flown for maintenance, check flights and pilot proficiencies are not included in these totals.

The annual Airborne Science Call Letter was distributed in June of 2009. Airborne Science aircraft science flight hours are continuing to increase.

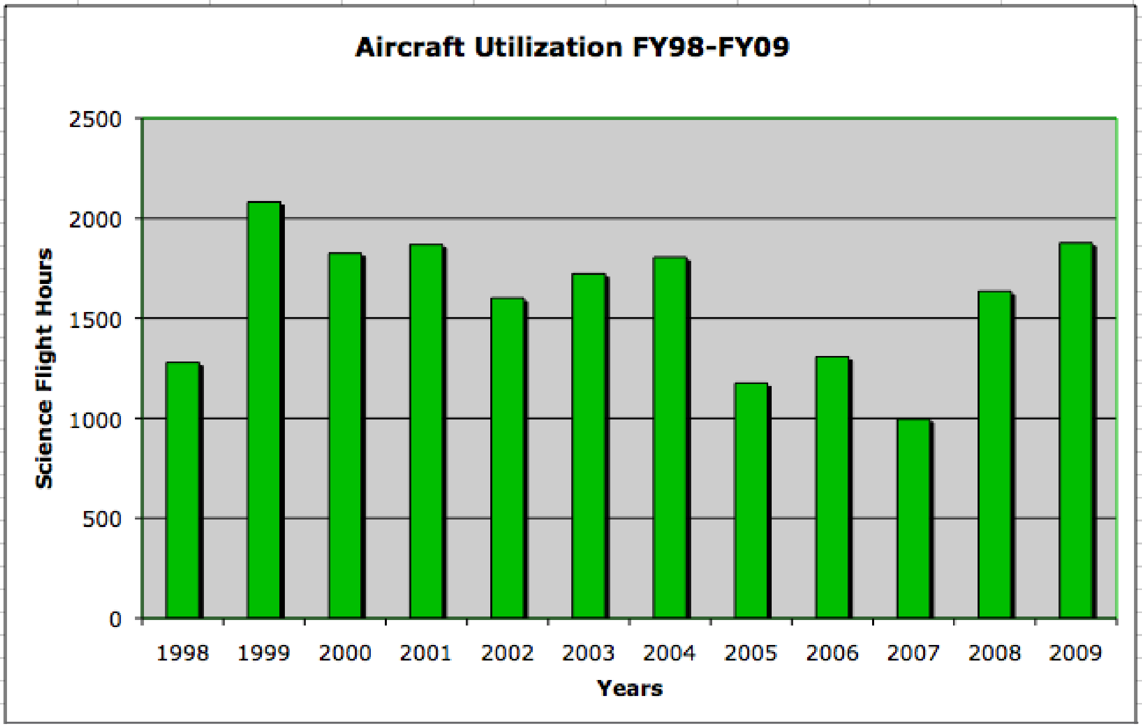


Figure 43:
Aircraft Utilization FY 98-FY09.

JASSIWG

Joint Airborne Science Sensor Integration Working Group

The Airborne Science Program has initiated a multi-center working group to examine the differences in engineering requirements and processes across the airborne science fleet, and to assess the potential benefits for common information and design requirements among the aircraft. The Joint Airborne Science Sensor Integration Working Group (or JASSIWG) was made up from representatives from six NASA centers, as well as the Aerospace Corporation and NSERC.

The goal of the working group is to improve access to NASA airborne platforms from the science community by coordinating and streamlining NASA aircraft instrument integration requirements and technical information across the platforms. This streamlining will allow a more consistent access experience by the science community, and will encourage migration of science instruments across the NASA fleet. It has the added advantage of reducing redundant activities and fostering communication across the NASA centers, as well as improving science management operations. A key element of the success of the JASSIWG effort is the consensus and acceptance by both the science and aircraft engineering communities to a more common requirements set.

Current JASSIWG activities are focused on the development of updated aircraft platform Experimenter Handbooks, using a common structure and format, and analysis of aircraft integration requirements to assess potential for commonality.

During FY09, the working group conducted two meetings to discuss general approach, planned work, and consensus documents. The working group developed a Payload Information Form (PIF), which will be used by the PI-community to define needs and requirements for integrating and flying scientific payloads on NASA Airborne Science platforms. In addition, a standard outline, format, and requirements syntax for the Experiment Handbooks was agreed to. Each of the centers has agreed to update their respective handbooks by March 2010. These include the DC-8, ER-2, WB-57, P-3, G-III, Global Hawk, Langley B-200/UC-12B, S-3, Twin Otter, Learjet 25, and SIERRA aircraft.

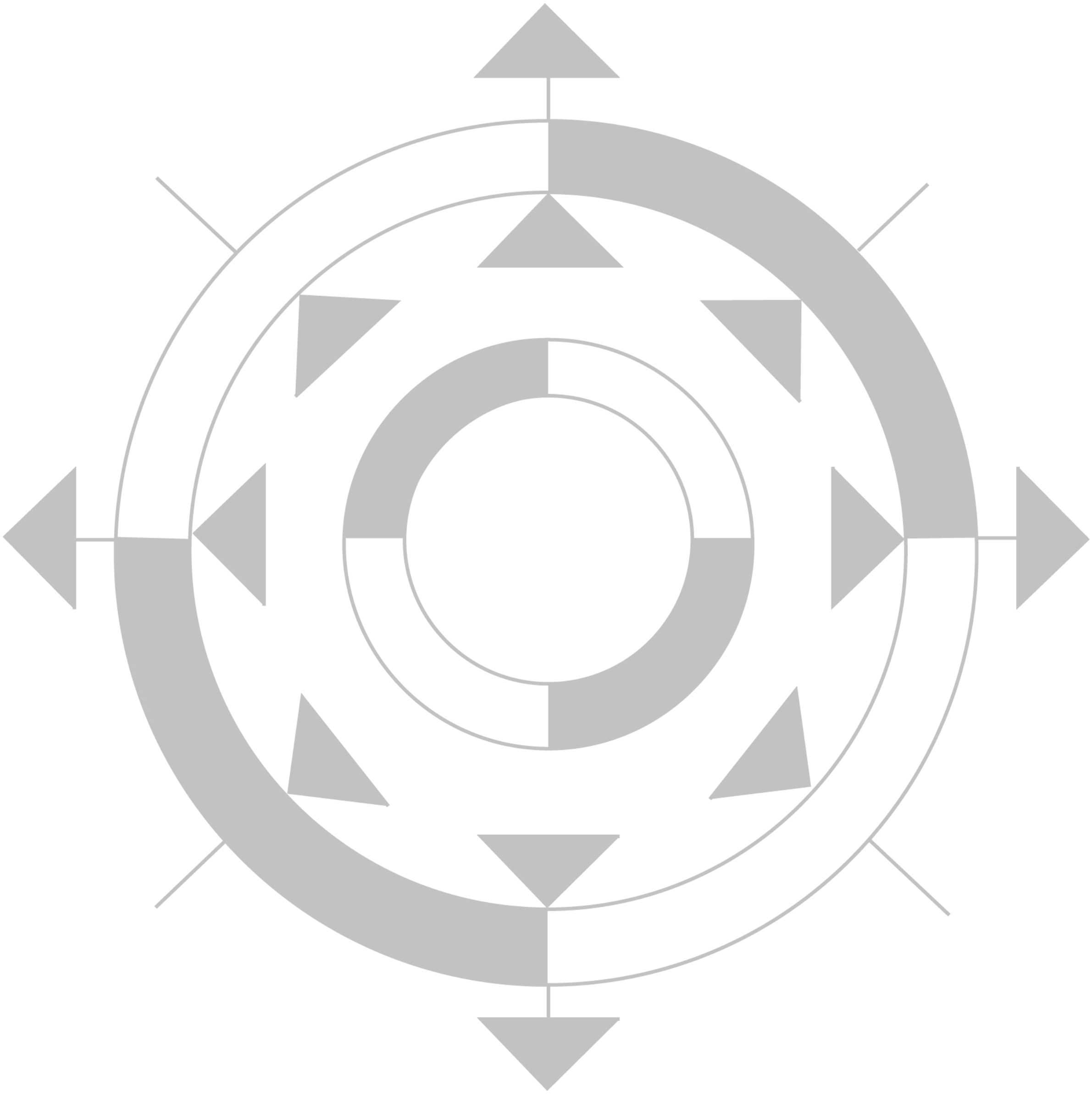
Extensive effort was devoted to extracting, reviewing, and assessing aircraft requirements for four of the ASP platforms, the DC-8, ER-2, WB-57, and P-3. Approximately 850 design, operational, and safety requirements were identified for the four platforms, which were put into spreadsheet form for additional analysis. These requirements were binned by subsystem (electrical, mechanical, etc.) and were assessed for: (1) conditions under which they must be met by the PI, (2) clarity of description and syntax, potential redundancy with other similar requirements, and (3) the degree to which similar requirements might be made common (standard practice) across the aircraft.

A web page has been developed as a part of the Airborne Science Program web site to describe the function of the working group and to be the source for the documents generated by the

JASSIWG effort (http://airbornescience.nasa.gov/instrument/JASSIWG). In addition, an internal web archive was set up by NSERC to host working documents, draft analyses, past presentations, etc.

Results of the JASSIWG efforts were presented at the 2009 ASP Annual Review and the Interagency Coordinating Committee for Airborne Geosciences Research and Applications (ICCAGRA) working group meeting. Also, a technical paper and poster of the JASSIWG approach and results were given at the 33rd International Symposium on Remote Sensing of Environment (ISRSE), in Stresa, Italy in May 2009.

AIRCRAFT PLATFORMS



Core Fleet and Catalog Aircraft

Aircraft Platforms

Introduction

The task of providing sustained access to highly modified aircraft for research observations requires a diverse portfolio of NASA investments in core aircraft coupled with strategic partnerships with NASA centers, other agencies and industry. The core platforms sustained by NASA ASP, which include the WB-57, ER-2, DC-8, G-III, and P-3B. All are unique, highly modified aircraft with significant investments in ports, hard points, pods and other infrastructure. These national assets provide assured access to capabilities that cannot be found anywhere else, including very high altitudes, extreme duration flight, large payload, all for a reasonable hourly cost to the project. When the core aircraft capabilities exceed partner requirements, the catalog aircraft, consisting of NASA, other government agency, and commercial aircraft are often a more appropriate choice. Commercial aircraft that respond to the yearly Broad Agency Announcement and clear interviews and inspections are then available under a Blanket Purchase Agreement to immediately respond to project need. NASA also invests in a few new technology platforms to determine and demonstrate their potential utility to airborne Earth system science investigations. Currently the Global Hawk is funded as a new technology platform, while the SIERRA and Ikhana are recent graduates.

Airborne Science Program Resources	Platform Name	Center	Duration (Hours)	Useful Payload (lbs.)	GTOW (lbs.)	Max Altitude (ft.)	Airspeed (knots)	Range (Nmi)	Internet and Document References
Core Aircraft	ER-2	NASA-DFRC	12	2,900	40,000	>70,000	410	>5,000	http://www.nasa.gov/centers/dryden/research/AirSci/ER-2/
	WB-57	NASA-JSC	6	6,000	63,000	65,000	410	2,172	http://jsc-aircraft-ops.jsc.nasa.gov/wb57/
	DC-8	NASA-DFRC	12	30,000	340,000	41,000	450	5,400	http:///.nasa.gov/centers/dryden/research/AirSci/DC-8/
	P-3B	NASA-WFF	12	16,000	135,000	30,000	330	3,800	http://wacop/wff.nasa.gov
	Gulfstream III (G-III) (mil: C-20A)	NASA-DFRC	7	2,610	45,000	45,000	459	3,400	http://airbornescience.nasa.gov/platforms/aircraft/g3.html
NASA Catalog Aircraft	King Air B-200 AND UC-12B	NASA-LARC	6.2	4,100	12,500	35,000	260	1250	http://airbornescience.nasa.gov/platforms/aircraft/b-200.html
	DHC-6 Twin Otter	NASA-GRC	3.5	3,600	11,000	25,000	140	450	http://www.grc.nasa.gov/WWW/AircraftOps/
	Learjet 25	NASA-GRC	3	3,200	15,000	45,000	350/.81 Mach	1,200	http://www.grc.nasa.gov/WWW/AircraftOps/
	S-3B Viking	NASA/GRC	>6	12,000	52,500	40,000	450	2,300	http://www.grc.nasa.gov/WWW/AircraftOps/
	Ikhana (Predator-B)	NASA-DFRC	30	3,000	10,000	52,000	171	3,500	http://airbornescience.nasa.gov/platforms/aircraft/predator-b.html
New Technology	Global Hawk	NASA-DFRC	31	1500	25,600	65,000	335	11,000	http://airbornescience.nasa.gov/platforms/aircraft/globalhawk.html
	SIERRA	NASA-ARC	11	100	445	12,000	60	550	http://airbornescience.nasa.gov/platforms/aircraft/sierra.html

Table 2:
Platform capabilities and specifications of available aircraft.

NASA's DC-8

The NASA DC-8 completed its second year of operations flying from its new home at the Dryden Aircraft Operations Facility (DAOF) located in Palmdale, California. The University of North Dakota, National Suborbital Education and Research Center (NSERC) under cooperative agreement with NASA, continues to promote and support science operations using the DC-8 Airborne Science Laboratory.

The NASA DC-8 aircraft flew 47 flight hours during FY09 in its support of the following major missions: TM (Telemetry) Relay, SARP (Student Airborne Research Program), and Operation ICE Bridge instrument integration missions. Operation Ice Bridge flights continued into FY10. The aircraft remained reliable throughout the year accomplishing all planned missions.

Technology improvements to the DC-8 aircraft also continued throughout FY09. Aircraft facilities and hardware upgrades on the DC-8 included:

- Installation of new high reliability data system servers and UPS systems.

- Upgraded Iridium communications system that was increased from 4 channels to 8 channels increasing the bandwidth to19.2 KB/second.

- New high speed dual channel Broadband Global Area Network (BGAN) Inmarsat communications systems providing 864 KB/second possible bandwidth.

- Yoke-mounted tablet computers linked to the aircraft data network that enable flight situational awareness and communications for the pilots.

- New distribution system for pulse-per-second (PPS) timing data and National Maritime Electronics Association (NMEA) GPS data.

New facility instruments are:

- Three stage EdgeTech Hygrometers for relative humidity measurements
- Heitronics Infrared Radiation Pyrometers for IR surface temperature measurements
- Rosemount temperature probes for Total and Static Air temperature
- High resolution cabin pressure transducers

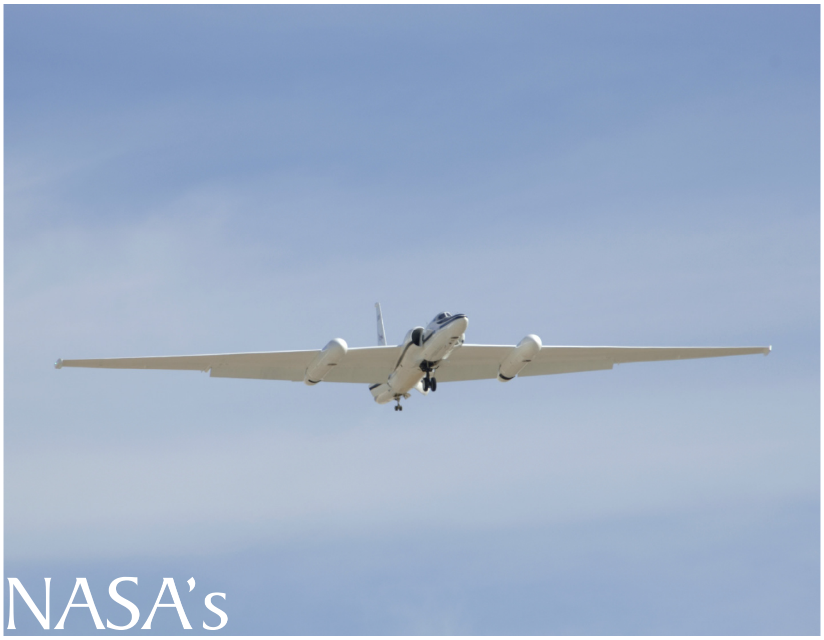
Figure 44:
Ktech TM data receiving antenna mounted in nose of DC-8 supporting NASA/USAF Vandenberg, CA rocket launch TM Relay Mission. The SOFIA aircraft is in the background.

Looking forward into FY10, the aircraft has recently completed its B-Check airworthiness inspection and is preparing to complete Service Bulletin inspections on all four engines and the wing fuel tanks in preparation for missions planned to start in March 2010. The maintenance work is ARRA funded. The aircraft will also enter a low utilization maintenance program (LUMP) beginning in 2010, which will minimize the amount of time out of service for maintenance in the future.

Details on the DC-8, its capabilities, and points of contact can be found at: http://www.nasa.gov/centers/dryden/aircraft/DC-8/index.html

Figure 45:
Students return from another successful DC-8 SARP mission to Palmdale, CA

Figure 46:
University of Kansas MCoRDS antenna system is integrated to the DC-8 in preparation for Antarctic Operation ICE Bridge mission.



NASA's ER-2

NASA operates two ER-2 (806 and 809) aircraft as readily deployable high altitude sensor platforms to collect remote sensing and in situ data on earth resources, atmospheric chemistry and dynamics, and oceanic processes. The aircraft also are used for electronic sensor research, development and demonstrations, satellite calibration and satellite data validation. Operating at 70,000 feet (21.3 km), the ER-2 acquires data above ninety-five percent of the earth's atmosphere. The aircraft also yields an effective horizon of 300 miles (480 km) or greater at altitudes of 70,000 feet.

In November 2008, ER-2 806 was taken out of service temporarily to conduct a required 200 hour phase inspection.

In February, the ER-2 team integrated the Tropospheric Wind Lidar Experiment, TWiLiTE, sensor and flew its first flight on February 19, 2009. Unfortunately, the sensor encountered some in-flight failures and had to be returned to home base for trouble shooting and repair. The sensor flew again in September.

In March, the ER-2 team conducted four Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) flights over the Santa Monica Mountains and two Autonomous Modular Systems (AMS) sensor flights utilizing both aircraft 806 and 809, showing team flexibility on accomplishing flight requirements.

In April, the ER-2 team continued to fly the AVIRIS sensor on A/C 809 over required experiment sites. Team also uploaded the Large Area Collectors (LAC) and began flying sensor towards end of April and into May. A new Sandia National Laboratories High Altitude Telemetry Sensor (HATS) sensor was successfully integrated into A/C 809 and flown over Albuquerque, New Mexico.

In May, ER-2 team completed flying the LAC and the HATS sensor and began to prepare for the upcoming deployment campaign at Dayton Ohio. In mid June, the ER-2 809 deployed to Wright-Patterson AFB (WPAFB), in Dayton, OH, in support of the WPAFB-AVIRIS campaign.

Science flights were also conducted over sites in Canada (Alberta, Ontario and North of Hudson bay), New York, Vermont, New Hampshire, Massachusetts, Connecticut, Pennsylvania, W. Virginia, Minnesota, Montana and South Dakota. The AVIRIS flights were conducted to gather data and characterize forest functional types by canopy-based measurement of three key functional traits: cell structure, shade tolerance, and recalcitrance. Data will also be used to investigate forest growth, carbon cycling and the interaction between ecosystems and climate. During the WPAFB-AVIRIS campaign the ER2 806 flew a total of 55.2 hours (including 12 hrs of transit time) of the estimated 69.8 hrs (79%) during the WPAFB AVIRIS/CPL campaign. A total of 35 defined experimental sites were flown and some sites were repeated. The WPAFB-AVIRIS campaign was completed on July 29, 2009.

In August, the team continued to fly the AVIRIS sensor over required experiment sites in Southern and Northern California. In September, the TWiLiTE sensor returned to DFRC and was uploaded into A/C 806 and completed it required flights.

In summary, the ER-2's flew a total of 204 flight hours combined totaling 72 sorties.

In addition, In 2009, the ER-2 project supported several education and outreach events by providing a presentation and demonstration of the pressure suit. Presentations were made at several local schools in the Antelope Valley, at an Edwards AFB air show, at the TATTOO air show at WPAFB, Dayton Ohio, and at the special Air Force Junior ROTC "honors camps" at the University of Oklahoma and University of New Mexico. The ER-2 team also supported the NASA Headquarters aeronautics theme at the Albuquerque balloon festival in Albuquerque, New Mexico.

In fiscal year 2010 the ER-2 operations will be re-located from DFRC hangar 4840, to the Dryden's Aircraft Operations Facility (DAOF) in Palmdale. This move, along with efforts to share infrastructure with other projects, will allow the ER-2 to continue to maintain its reduced hourly flight cost.

Details on the ER-2s, their capabilities, and points of contact can be found at: http://www.nasa.gov/centers/dryden/research/AirSci/ER-2/

Figure 47:
TWiLiTE in Q-Bay of ER-2.

NASA's WB-57

FY09 was a busy year for NASA's WB-57s. In FY09, the two WB-57s flew a total of 849.6 hours, split almost equally between the two aircraft.

The WB-57 did not fly any Airborne Science missions this year, but time was devoted to mission planning for upcoming Airborne Science flights. The MACPEX mission is currently planned for May-June of 2010 and will carry a suite of approximately 21 instruments. Instrument selection began in December of 2009.

The gross weight increase project, which began near the beginning of FY08, made great progress this year and will be completed in the first quarter of FY10. The goal is to increase the allowable take-off weight to 72,000 lbs, an increase of 9,000 lbs, or 14% over the existing weight.

In parallel to the gross weight increase project, the superpods project was worked to allow the WB-57 to fly ER-2 superpods on the mounts that were previously used for J-60 engines, just outboard of the main WB-57 TF-33 engines. Each superpod assembly on the will be able to accommodate 400 pounds of payload in the forebody and an additional 175 pounds in the midbody.

The addition of the superpod capability will enable the Airborne Science Program to fly selected payloads on either the ER-2 or WB-57 aircraft with no modification. The increased gross weight provides increased payload carrying capability, and increased fuel capacity in a variety of aircraft configurations. Aircraft range and endurance penalties due to payload weight will be reduced or eliminated for all configurations.

In February 2009, the President signed the American Recovery and Reinvestment Act of 2009 into law, $1.6 million of which will go towards the remanufacture of ailerons for the WB-57. This is timely because currently there is no source of spare or replacement ailerons for the WB-57 aircraft. The aileron is a control surface located on the trailing edge of the wing that controls the aircraft in the roll axis. If the ailerons on either of NASA's WB-57 aircraft fail or are damaged, the aircraft down time required for repair would be unacceptable from an operations and schedule perspective. A similar delay to phased maintenance would result if an unacceptable condition (crack, corrosion, etc.) were to be found on the aileron during inspection.

A three-phase approach was taken, with phase zero being paid for with non-ARRA funds to get the project started as soon as possible. Phase zero includes the engineering evaluation of spare ailerons, and the engineering for both the honeycomb panels and the trim tabs. Phase one includes the engineering for the leading edge assemblies and the procurement and manufacturing of the honeycomb panels and trim tabs. Phase two will include the leading edge procurement and manufacturing and the final assembly of the ailerons. The program is scheduled to be completed by the end of 2010.

Planned for early 2010 is a series of test flights for a new Instrument Incubator Program (IIP) instrument, the High-Altitude Imaging Wind and Rain Profiler (HIWRAP). The principle investigator is Gerald Heymsfield from NASA-GSFC. HIWRAP will be installed on a 6-foot pallet on the WB-57. Since the HIWRAP instrument will only take up a small fraction of the carrying capability of the WB-57, two payloads will piggyback on the HIWRAP flights. The Hurricane Imaging Radiometer (HIRAD) from NASA-MSFC will measure ocean surface wind speeds. The Diode Laser Hygrometer (DLH), built by Glenn Diskin at NASA-LaRC is also scheduled to fly with HIWRAP. DLH testing began during the NOVICE mission in 2008, but was not completed at that time.

Details on the WB-57's, their capabilities, and points of contact can be found at: http://jsc-aircraft-ops.jsc.nasa.gov/wb57/.

NASA's P-3

The P-3 is based at Goddard Space Flight Center's (GSFC's) Wallops Flight Facility (WFF). The P-3 participated in an instrument development experiment and two major missions during FY09.

The instrument test experiment involved a series of local instrument development flights from Wallops for the GSFC Airborne Earth Science Microwave Imaging Radiometer (AESMIR) in January of 2009. A total of 15.8 hours were flown in support of these test flights.

The first major mission of the year was High Winds based out of Goose Bay, Canada in February and March 2009 for the purpose of Aquarius algorithm development. The principal objective was to develop algorithms capable of deriving ocean salinity in a high wind regime, for example, in the North Atlantic winter. The detailed objectives are described elsewhere in this report. All mission objectives were met with a total of 48.2 science flight hours in support of the High Winds mission.

Figure 48:
P-3 at Thule AFB for Operation Ice Bridge flights.

The second major mission of the year was Operation Ice Bridge (Greenland) that was conducted in late March through early May. The mission was an expansion of the annual P-3 deployment to Greenland in order to "bridge" between ICESat-I and ICESat-II. The objectives were focused on ice sheet extent and thickness along with sea ice measurements and underflights of ICESat-I. This mission resulted in the most flight hours on the P-3 for any mission. Operation Ice Bridge will be an annual mission until ICESat-II is launched. There were 171.2 science hours flown supporting Operation Ice Bridge..

The P-3 spent the rest of FY09 after Ice Bridge in heavy maintenance at the AeroUnion Corporation in Chico, CA. A thorough wing inspection was conducted as part of the Special Structural Inspection as a result of the aircraft reaching 19,000 total flight hours. Some repairs were required as a result of the inspection. All of the required repairs were made.

The P-3 flew a total of 291.5 flight hours in support of the Airborne Science Program.

Details on the P-3, its capabilities, and points of contact can be found at: http://wacop.wff.nasa.gov/LAAPBDesc.cfm

NASA's G-III

NASA DFRC operates the Gulfstream III (G-III), which became part of the ASP core fleet during 2009. The primary work of the G-III is to carry the L-band UAV-SAR instrument, a NASA JPL-developed payload for repeat-pass interferometry. To accomplish repeat pass successfully, the aircraft is flown with a custom-designed precision avionics package, designed by NASA DFRC.

The UAVSAR project began at JPL in 2004, and produced its first image in 2007 over Rosemond Dry Lake. Engineering flights continued into FY 2009, with the first science flight on February 18, 2009. The UAVSAR program was highly successful in 2009, flying 440.2 hrs during the period January 22 to October 2, 2009, on the G-III aircraft.

The G-III performed UAV-SAR missions in FY09 carrying both the original L-band SAR, and an alternative Ka-band SAR. Each instrument was integrated into a separate pod. The Ka-Band SAR operations and L-Band SAR operations over Greenland were part of an IPY program described elsewhere.

Deployments/Missions in FY09 included:

- Greenland & Iceland (May/June)
- Cascades & Alaska (July)
- Bangor Maine (August)
- Cascades & Alaska (Sept.)

The G-III flew a total flight hours of 431.1 in FY09.

G-III UAVSAR plans for FY10 include 34 flight requests with approximately 550 flight hours. These include local flights and deployments to Hawaii, Central America, Canada, and Alaska. Local science flights from Palmdale, California include imaging of the San Andreas and Hayward Faults, Monitoring the Sacramento Delta Levees, and obtaining Soil Moisture in the San Joaquin Valley. The Hawaiian deployment will primarily involve repeat pass imaging of the Volcanoes on the Big Island and also baseline imaging for ground deformation/ground movement studies of the islands of Maui, Molokai and Oahu. The Central American deployment will cover mapping of 3D vegetation structure, Volcanoes, and Mayan Archeology in Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, and Panama. Imaging of the Gulf Coast near New Orleans for subsidence studies and imaging of the Mississippi River Levees are also planned this deployment. Upcoming deployments include a Soil Moisture Active Passive (SMAP) mission based in Saskatchewan, Canada and imaging US volcanoes in the Cascades and Alaska.

JPL continues to make system upgrades to the UAVSAR. Aircraft maintenance will include completing the right engine overhaul. American Reinvestment and Recovery Act (ARRA) funds were approved to fabricate a 3rd UAVSAR pod to enable supporting both development of the Global Hawk UAVSAR capability and continuing G-III missions. The fabrication of the 3rd pod is expected to be completed by July 2010

Details on the UAVSAR instrument and the G-III, its capabilities, and points of contact can be found at: http://uavsar.jpl.nasa.gov/ and at http://www.nasa.gov/centers/dryden/aircraft/G-III_UAVSAR/index.html

Catalog Aircraft

The Airborne Science Program provides NASA scientists with access to a virtual catalog of NASA-owned aircraft, interagency aircraft, university operated aircraft, and commercial aircraft. In this, ASP leverages the ability to support our science customers with the right platform to get the required airborne measurements to produce effective, lowest cost science results. Since non-core aircraft are only used when needed, they are not funded except on a fully reimbursable basis, thus saving the agency significant funds while making available to the science community a wide variety of platforms in a cost efficient manner. Since FY2007, many of our commercial aircraft have been incorporated into a Blanket Purchase Agreement (BPA) that establishes rates and a contract mechanism to quickly use the companies' services. At the same time there is no minimum purchase requirement.

NASA LaRC Aircraft

B-200 and UC-12B

The Research Services Directorate (RSD) at the NASA Langley Research Center (LaRC) operates a Hawker Beechcraft King Air B200 and a similar aircraft, a former military UC-12B. The aircraft are based at LaRC in Hampton, Virginia. RSD has experience working with science customers to optimize missions to meet their research requirements within the operational characteristics of the aircraft. The King Air aircraft are ideally suited for small to mid-sized instruments flying dedicated profiles or operating in conjunction with other instruments in these or other aircraft flying coordinated patterns.

The two aircraft incorporate the following features and systems: GPS navigation systems, weather radar, up linked weather information and TCAS in the cockpit; 29 x 29-in. and 22 x 26-in. nadir-viewing portals with an available pressure dome fitted for the smaller aft portal; electrical power distribution and AC conversions systems; GPS antenna outputs; and Iridium satellite phone accessibility. An Applanix 510 and associated PosTrak navigation and display system are available at LaRC to enhance the overall navigation system capabilities of either aircraft. Starting in FY09, the Applanix 510 has flown regularly on the B200 aircraft. An in situ sampling head, outside air temperature probe, and hygrometer probe are installed on the exterior of the UC-12B aircraft to support LaRC's In situ Atmospheric Sampling System. Also, the UC-12B aircraft has a cargo door for oversized components, in addition to the passenger entry door.

These twin-engine turboprop airplanes are certified to 35,000 ft for the B200 and 31,000 ft for the UC-12B aircraft, but are non-Reduced Vertical Separation Minima (RVSM) certified and, therefore, limited to 28,000 ft in the National Airspace System (NAS) without prior FAA coordination and approval. At maximum takeoff gross weights, the aircraft can carry a crew of three (pilot, co-pilot and research system operator), a 1200-lbs research payload, and enough fuel for a 4-5 hour high-altitude mission covering 800-1000 nautical miles.

Over the past year these two aircraft have successfully re-integrated and flown four research payloads:

- High Spectral Resolution Lidar (HSRL) - LaRC (B200)
- Research Scanning Polarimeter (RSP) - NASA Goddard Institute for Space Studies (B200)
- In situ Atmospheric Sampling System - LaRC (UC-12B)
- Advanced Carbon and Climate Laser International Mission (ACCLAIM) instrument – ITT (UC-12B)

FY09 mission accomplishments included 155 and 73.2 research flight hours on the B200 and UC-12B aircraft, respectively. The following missions were flown:

- Local CALIPSO validation flights on the B200 aircraft with HSRL
- B200 deployment to Birmingham, Alabama for the Environmental Protection Agency (EPA) with HSRL and RSP
- B200 over flights of South Carolina wild fires with HSRL and RSP for the EPA
- B200 deployment to Ponca City, Oklahoma for the Department of Energy's (DOE's) Routine AAF Clouds with Low Optical Water Depths Optical Radiative Observations (RACORO) campaign with HSRL and RSP
- Local research flights on the UC-12B aircraft for Advance CO2 Sensing of Emissions over Nights, Days and Seasons (ASCENDS) with the LaRC In situ Atmospheric Sampling System and the ITT ACCLAIM instrument
- UC-12B deployment to Ponca City, Oklahoma for ASCENDS with the LaRC In situ Atmospheric Sampling System and the ITT ACCLAIM instrument

During FY09, the two LaRC aircraft flew coordinated patterns with several other atmospheric science platform aircraft. Specifically, the B200

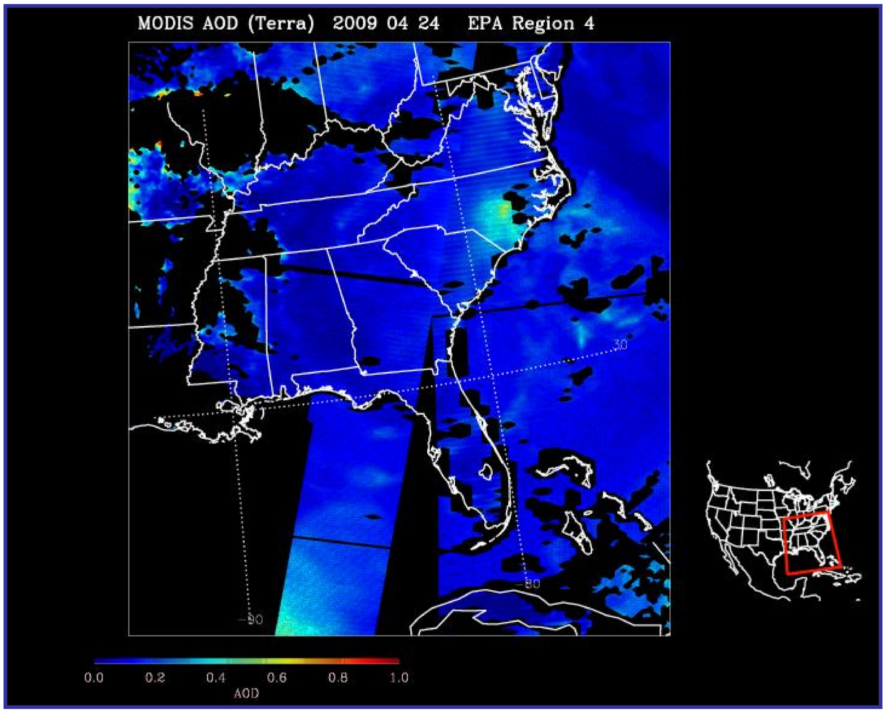


Figure 49:
MODIS images of South Carolina wildfires, requested by EPA.

aircraft flew coordinated patterns with the CIRPAS Twin Otter during the RACORO mission. In addition, during the UC-12B's deployment to Ponca City, the aircraft flew in conjunction with the DOE Cessna, NASA Glenn (GRC) Lear 25, and Twin Otter International's Twin Otter. At the conclusion of the deployment, the LaRC UC-12B aircraft conducted two flights with the GRC Lear 25 from LaRC.

The over flights of the South Carolina wild fires were made one day after receipt of the EPA's request for HSRL measurements of the smoke plumes. The over flights were made from LaRC, with no deployments required.

Projected missions for FY10 include: CALIPSO validation flights across a wide range of latitudes; ASCENDS development flights; EPA-sponsored biomass-burning research flights; the DOE's Carbonaceous Aerosol and Radiative Effects Study campaign; and the National Oceanic and Atmospheric Administration's (NOAA's) CalNex campaign.

The B200 and UC-12B aircraft have been included in four Earth Venture proposals.

Cessna

The Research Services Directorate (RSD) at LaRC also operates a Cessna 206H Stationair general aviation aircraft for aeronautics and atmospheric sciences research, in addition to the two King Air aircraft described elsewhere in this report. The aircraft is based at NASA LaRC in Hampton, Virginia.

The Cessna 206H incorporates the following features and systems: GPS navigation systems; up-linked weather information in the cockpit; researcher work station in the rear seat; Universal Access Transceiver; ADS-B; NASA LaRC General Aviation Baseline Research System (GABRS); electrical power distribution and AC conversion systems; and GPS antenna outputs.

The aircraft is certified to 15,700 ft (supplemental oxygen is required above 12,500 ft). With maximum fuel at 55% power, the aircraft can carry a crew of three (pilot, co-pilot, and researcher), a 575-lb payload (in excess of the GABRS), and enough fuel for a 5.7-hour flight covering 700 nautical miles.

NASA GRC Aircraft

The NASA Glenn Research Center continued their outstanding support of the Airborne Science Program in 2009 flying over 220 total hours in four different aircraft.

The Learjet 25 completed ESTO missions with the GSFC CO2 Sounder led by PI Jim Abshire and the SIMPL (lidar) led by Dave Harding. The aircraft also participated in the ACCLAIM coordinated operations mission flying the CO2 Sounder along with aircraft from LaRC, JPL, and DOE in Ponca City, OK. Additional missions for the Learjet included Solar Cell Calibration and Advanced Aircraft Systems sensor development .

Figure 50:
S-3B

The Twin-Otter continued its airborne sensor development work for the Air Force Research Lab. Sensors first flown, developed and demonstrated on the GRC Twin-Otter are now being flown in both Iraq and Afghanistan in support of national objectives.

The T-34C partnered with NOAA for the third consecutive year in providing hyperspectral imagery in support of Great Lakes research. The HSI was developed by GRC PI John Lekki. The T-34C underwent modification this year to incorporate a nadir port for the HSI and other sensors.

The S-3B completed a successful ground test of the Argon ST/AFRL developed the Multi-mission Advanced Sensor Testbed (MAST) pod. This fully self-contained pod features the Argon ST Daedelus Airborne Multispectral Scanner (AMS) in addition to a Near-vis/Near-IR (NVIS/NIR) HSI sensor. It also features an integrated inertial and GPS navigation system and an L-band antenna and video transmitter which is compatible with ROVER. Coupled with the S-3 Inmarsat, the MAST pod should make the S-3 an extremely capable and versatile platform for a multitude of ASP missions. Flight test of the MAST pod is proposed during FY10.

Figure 51:
Learjet

Figure 52:
T-34C

Figure 53:
Twin Otter

Ikhana

NASA Dryden Flight Research Center's remotely piloted Predator B aircraft equipped with an infrared imaging sensor recently conducted post-burn assessments of two Southern California large wildfire sites, the Piute Fire in Kern County and the Station Fire in the Angeles National Forest. Named Ikhana, the unmanned aircraft completed a seven-hour imaging flight in November of 2009 from NASA's Dryden Flight Research Center on Edwards Air Force Base, Calif. NASA and the U.S. Army partnered to obtain the post-burn imagery.

More than 160,000 acres of burn area in the Angeles National Forest northeast of Los Angeles were scanned. The scanner collected images that will indicate any remaining hot spots in the fire area. Another use of the images is for the U.S. Forest Service's Burned Area Emergency Rehabilitation, or BAER. The Station Fire imaging flight tracks were flown in the national airspace system though close coordination with the Federal Aviation Administration.

The Autonomous Modular Scanner, developed by NASA's Ames Research Center at Moffett Field, Calif., was carried in a pod under the aircraft's wing. The scanner operates like a digital camera with specialized filters to detect light energy at visible, infrared and thermal wavelengths. The scanner operated with a new photo mosaic capability at the request of the U.S. Forest Service. A photo mosaic provides ease of interpretation for the end user, which in the case of an active wildfire is the fire incident commander.

The BAER data is derived from autonomous processes operating on the multi-spectral data available on the Autonomous Modular Scanner. The processes can be changed mid-mission to optimize collection of critical information, either in mapping active fires or assessing post-burn severity.

The post-burn images collected by the scanner were transmitted through a communications satellite to NASA Ames, where the images were superimposed over Google Earth and Microsoft Virtual Earth maps to better visualize the locations. The images then were made available to the Forest Service for initial assessment of the damage caused by the fires and rehabilitation required.

Ikhana carried the Autonomous Modular Scanner for Western States Fire Mission flights in 2007 and 2008, imaging wildfires from south of the U.S. border with Canada to near the Mexican border. Critical information about the location, size and terrain around the fires was sent to commanders in the field in as little as 10 minutes.

The Ikhana team obtains data by using instrumentation developed at the Ames Research Center, Moffett Field, Calif. They combined the sensor imagery with Internet-based mapping tools to provide fire commanders on the ground with information enabling them to develop strategies for fighting the blazes. In support of the Fire Missions, the Ikhana flew approximately 20 flight hours and helped to save both lives and property.

The Ikhana is a civil variant of the Predator B aircraft built by the San Diego-based General Atomics Aeronautical Systems Inc. NASA dubbed the aircraft Ikhana (ee-KAH-nah), a Native American word from the Choctaw Nation meaning intelligent, conscious or aware.

Ikhana supports Earth science missions and advanced aeronautical technology development. The aircraft also is a testbed to develop capabilities and technologies to improve the utility of unmanned aerial systems. Designed for long-endurance, high-altitude flight, Ikhana was modified and instrumented for use in multiple civil research roles.

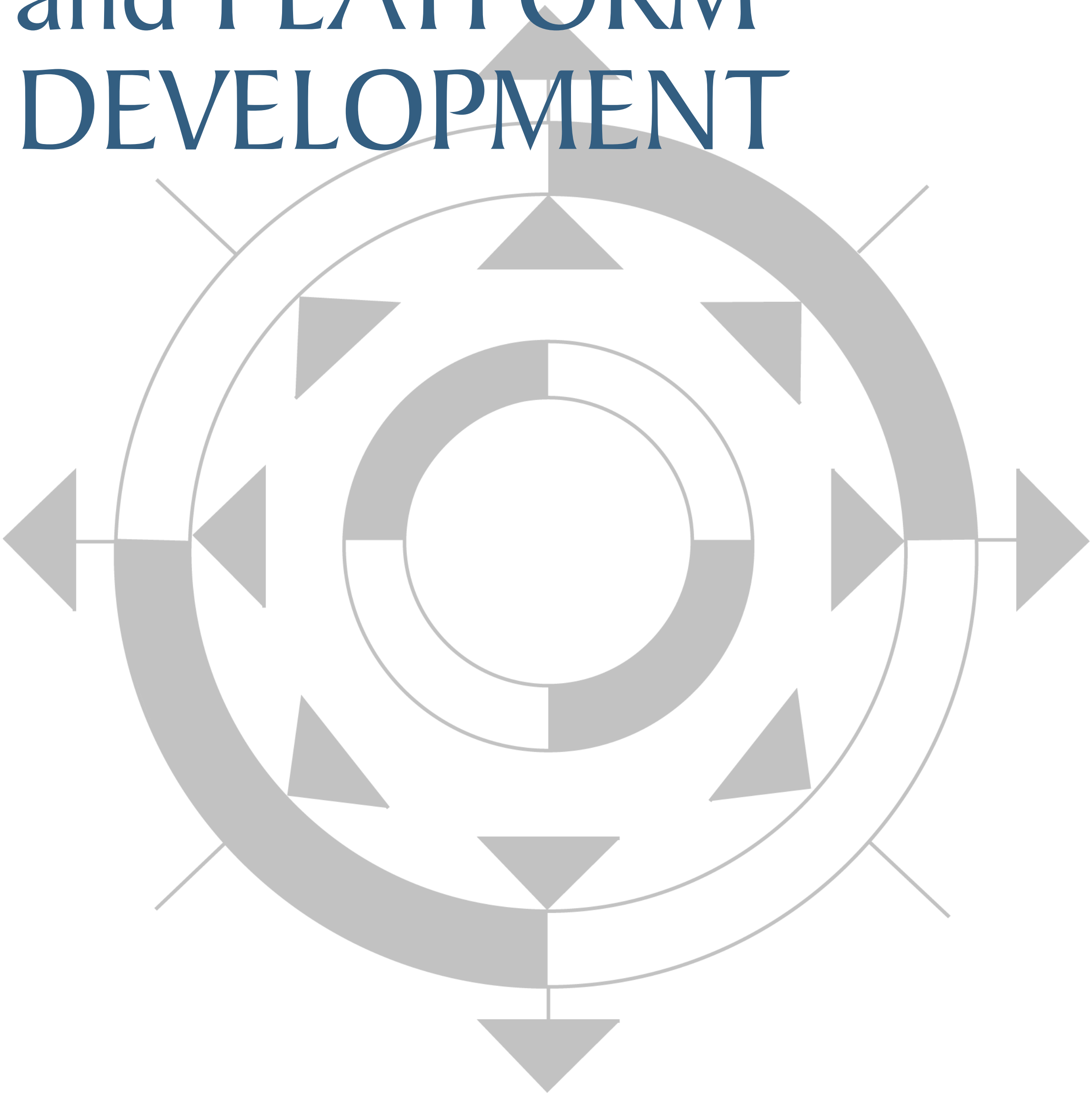
In 2009, the Intelligence, Information Warfare Directorate (I2WD), a laboratory within the U.S. Army's Communications-Electronics Research, Development, and Engineering Center (CERDEC) was Ikhana's primary customer. I2WD is utilizing the Ikhana and Dryden's UAS expertise to develop sensor technologies that will eventually be used on Predator B aircraft.

A variety of atmospheric and remote sensing instruments, including duplicates of those sensors on orbiting satellites, can be installed to collect data during flights lasting up to 30 hours.

NASA's Ikhana has a wingspan of 66 feet and is 36 feet long. More than 400 pounds of sensors can be carried internally and over 2,000 pounds in external under-wing pods. Ikhana is powered by a Honeywell TPE 331-10T turbine engine and is capable of reaching altitudes above 40,000 feet.

There are no funded Earth Science related support projects planned for FY2010.

NEW TECHNOLOGY and PLATFORM DEVELOPMENT



Global Hawk

NASA Dryden and Northrop Grumman Corporation (NGC) are working under a five year partnership for the stand-up and operation of the NASA Global Hawk system. NGC is providing technical, engineering, maintenance, operations support and the command and control portion of the ground control station. NASA Dryden is providing the facilities for aircraft maintenance and ground control station, and is responsible for ensuring airworthiness of the vehicles, quality assurance, configuration management, and system safety. NASA and NGC are each providing approximately half of the project staffing and will share equal access to the NASA Global Hawk system.

The Global Hawk system is the only available UAS with performance specifications suitable to meet certain high altitude, long endurance science payload objectives. During USAF Global Hawk operations, it has already demonstrated an endurance of more than 31 hours with the capability to take more than 1500 lb (680 kg) of payload to an altitude of 65,000 ft (20 km) while cruising at 350 knots. As such, it represents a major step forward in platform capabilities available for scientific research. The Global Hawk aircraft has numerous existing payload compartments and the potential for adding wing pods. The aircraft has the capacity to provide science payloads with substantial margins for payload mass, volume, and power in these payload spaces.

At the beginning of 2009, NASA and Northrop Grumman held a debut ceremony at NASA Dryden to publicly announce the development of this new capability. Distinguished representatives from Northrop Grumman, the USAF, and NASA, including Andrew Roberts (Figure 48), gave speeches highlighting the NASA/NGC partnership and the use of the Global Hawk system for gathering Earth science data. Displays for each of the Global Hawk Pacific science campaign instruments were positioned around one of the Global Hawk aircraft.

During the stand-up of the program, the two aircraft have undergone extensive inspections and maintenance prior to their return to flight. Also, modifications have been made to the aircraft command and control communications system and the payload support system. In addition, a building-based Global Hawk Operations Center (GHOC) has been developed that is configured to independently support aircraft and payload operations. The Flight Operations Room (FOR) of the GHOC consists of the workstations occupied by the personnel responsible for the flight control and management of the aircraft operations. The Payload Operations Room (POR) of the GHOC consists of the workstations occupied by the personnel responsible for the various aircraft payloads. The POR personnel can monitor payload status, receive payload data, and control the individual payloads.

The first flight of a NASA Global Hawk occurred on October 23, 2009. The purpose of this initial flight of TN 872 was to check out the aircraft systems and verify the functionality of the ground control station. The duration of the first flight was four hours and the aircraft reached an altitude of 61,400 ft. Four additional flights were conducted to further check out systems and gain experience with flight operations. During these flights, NOAA Commander Phil Hall became fully qualified as a Global Hawk Pilot. After the fifth flight was completed, modifications began on the aircraft to support the first science campaign, which is Global Hawk Pacific. TN 871 is being prepared for it's first flight as a NASA aircraft, which will occur in early 2010.

Figure 54:
Then Airborne Science Program Manager Andrew Roberts at Global Hawk debut ceremony at DFRC.

SIERRA

The Sensor Integrated Environmental Remote Research Aircraft (SIERRA) is an unmanned, fixed-wing aircraft, operated by NASA Ames, which is able to carry up to 100 lbs of science payload, with endurance from 8-12 hours, up to 12,000 ft. The project is a partnership between NASA ASP and the Naval Research Laboratory to demonstrate a multi-mission, medium payload platform for sensor development and science missions suited to unmanned aerial applications.

In FY2009 the SIERRA team completed the New Technology Demonstration phase of the project by successfully flying the CASIE mission from Svalbard, Norway in July 2009. To prepare for this mission, the team conducted cold weather ground tests in Truckee, CA, and cold weather flight test in Dugway, Utah, in partnership with the US Army. An icing mitigation payload was also developed and implemented to provide realtime temperature and humidity data during the flight. The complex instrument integration, which included 2 LIDARS, a SAR, 3 digital cameras, 2 microspectrometers, a pyronometer, and pyrometer demonstrated the utility of SIERRAs relatively large payload accommodations for this class of UAS.

In FY2010 the SIERRA UAS will enter into the ASP aircraft catalog and be available for NASA science missions. The SIERRA team anticipates supporting both EV-1 as well as AITT projects. In addition, partnerships with the USFS, USGS, and NOAA will provide additional resources for increasing the number of payloads available for future science missions.

Figure 55:
Preparation and precheck before first science flight of SIERRA.

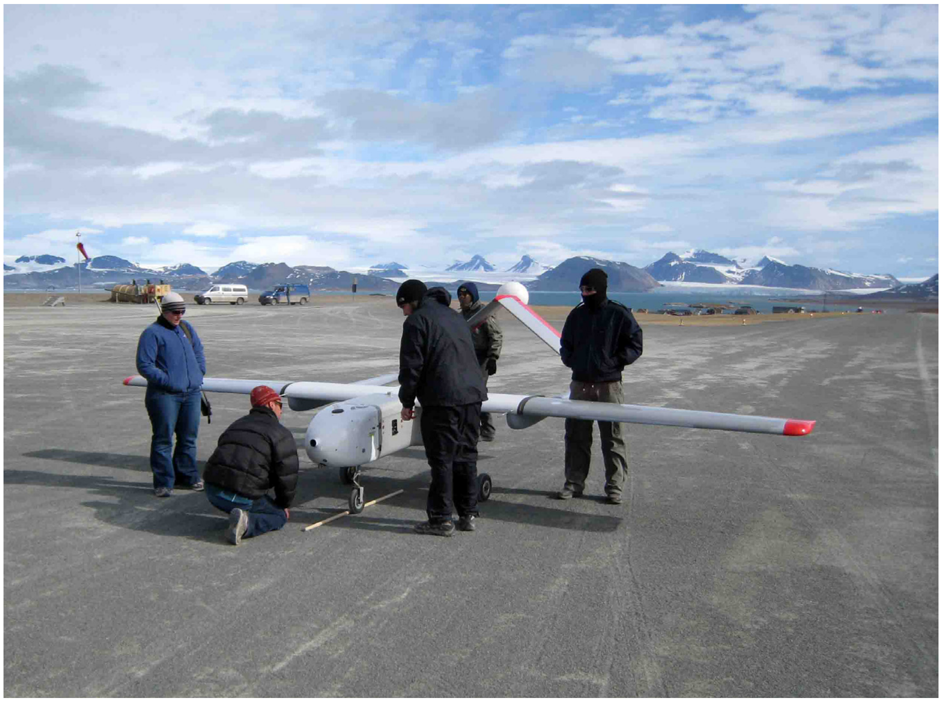


Figure 56:
Post flight check out.

Common Data and Communications Systems

Full-scale development is underway on a new generation of airborne data systems that will be deployed on the core NASA science aircraft over the next several years. With the increasing availability of satellite communications systems for aircraft, the potential for greatly increasing the science utility of these platforms is becoming evident. Data from the payload instruments, together with aircraft position, but can be broadcast to science teams on the ground, who can then actively adjust their experiment plans, and coordinate multiple platforms, in near real-time. For unattended instruments on platforms such as the ER-2 or Global Hawk, these bidirectional links will also be used to monitor instrument performance, conduct real-time diagnostics, and command changes to system parameters over the course of a mission. Some of these techniques have been demonstrated on the Ikhana UAS with a Ku-band telemetry system, and on the DC-8 and ER-2 using Iridium satellite phone modems. A new Inmarsat BGAN sat-com system was also installed for this purpose on the DC-8 this year.

Key elements of this new communication architecture include an onboard Ethernet network linking the payload instruments to a common server, and a user-transparent sat-com system that extends the network to a ground operations center. It will also utilize standard communications protocols and data formats, including the IWG-1 format developed by the Interagency Working Group for Airborne Data and Telecommunications Systems (IWGADTS.)

Figure 57:
Ethernet switch.

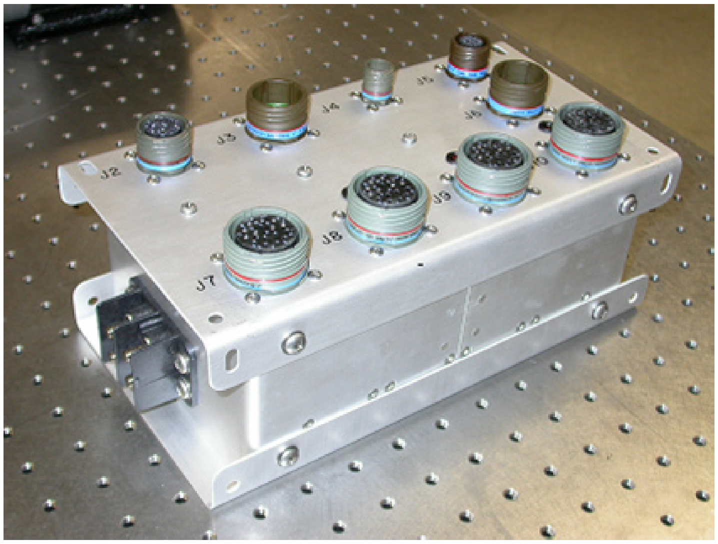


Figure 58:
The Experimenter Interface Panel (EIP) unit.

Data visualization tools, customized to the different instrument types, are also essential to present the information to the science teams in a usable form for decision making. Software development for this purpose is being led by the University of North Dakota's National Suborbital Education and Research Center (NSERC) and the Real Time Mission Monitor team at Marshall Space Flight Center. Based on initial implementations by NSERC on the DC-8, these tools will be further implemented in the Global Hawk Operations Center (GHOC) at NASA Dryden in early 2010. Elements of the NASA Ames Collaborative Decision Environment (CDE) and its related web applications, will also be incorporated to facilitate communication and data-sharing with extended science teams across the Internet. Derived from software used to manage the Mars planetary rovers and adapted to airborne platforms for the Western States Fire UAS Missions, the CDE enables real-time interchange between science investigators and mission participants from virtually any location.

Along with the complex software required to support the real-time data environment, specialized flight hardware is also required. One essential element is an enhanced version of the navigation data recorders currently in use on the ER-2 and WB-57 aircraft. These units capture platform and other state data from the aircraft avionics systems and re-broadcast them to the payload instruments. Incorporating the Ethernet network functionality developed at Dryden Flight Research Center on the REVEAL project, the next-generation of these systems will be called the NASA Airborne Science Data and Telemetry (NASDAT) system and is scheduled to deploy 2010. Modified versions of REVEAL were deployed on the P-3 and DC-8 this year, as NASDAT prototypes. Accompanying this will be a new standard Experimenter Interface Panel (EIP) that will provide electrical power, network communications, and the state data feeds to the various aircraft payload areas. The first of the new EIP units were completed in 2009, and will be installed on the Global Hawk, together with a modified REVEAL unit, pending the availability of the new NASDATs. The EIP/NASDAT combination will eventually be installed on all the core NASA science platforms. In addition, the Global Hawk UAS has unique hardware requirements to transform it into a science platform. A Master Payload Control System/

Power Distribution Unit (MPCS/PDU) system, also completed this year, will allow the mission pilot to monitor and control the power and basic functionality of each instrument individually. A separate telemetry Link Module was developed to interface with the high-speed Ku-band satcom system slated for the Global Hawk. The Link Module will include database software and mass storage for buffering science data, and a dedicated computer for onboard processing with mission-specific algorithms. This flight hardware development is being conducted at the Airborne Sensor Facility (ASF) at NASA Ames Research Center.

This integrated communications and data-sharing concept will be initially demonstrated on the Global Hawk UAS during its inaugural science missions in early 2010, with the associated visualization and web-based tools being hosted in the Global Hawk Operations Center. It will then be gradually implemented across the NASA airborne science fleet as platforms are upgraded and satellite communications systems become more widely available. A universal web-portal for outside access to the real-time mission data is also slated for implementation.

SCIENCE INSTRUMENTATION, FACILITIES and SUPPORT SYSTEMS

Airborne Sensor Facility

Formerly known as the Airborne Science and Technology Laboratory, and located at Ames Research Center, the ASF jointly supports the Airborne Science Program and the EOS Project Science Office. It encompasses the development and operation of facility instrumentation and ancillary systems for community use by NASA investigators. It also provides payload integration engineering support for the science platforms. The facility sensors at the ASF include the MODIS and ASTER Airborne Simulators (MAS and MASTER,) the Autonomous Modular Sensor (AMS) for UAS platforms, and various tracking cameras and precision navigation systems for mission documentation. Working in conjunction with UND/NSERC and several NASA engineers, this group is also leading the implementation of real-time airborne data networks and internet-based "sensor web" technologies for the program. In addition, the lab operates a calibration facility for remote sensing instruments, which functions as a community asset and supports a variety of NASA airborne sensors and radiometers. Additional functions of the ASF include flight data processing, distribution and archive, and flight planning support for remote sensing flight requests. The facility is staffed by the Univ. of California, Santa Cruz, under the NASA Ames UARC (University Affiliated Research Center.) Highlights of 2009 activities follow.

Global Hawk Payload Systems Project

The design and implementation of the payload communications infrastructure for this major new science platform was completed in 2009. A number of custom flight hardware modules were developed and tested, including a Master Payload Control System/Power Distribution Unit (MPCS/PDU) that allows the mission pilot to remotely monitor and control the power and basic function of each payload instrument. A new standard Experimenter Interface Panel was developed for fleet-wide use, which provides electrical power and data communications; and a prototype of the new NASDAT system (NASA Airborne Science Data and Telemetry module) was fielded on the DC-8 and P-3. Based on a modified REVEAL system, this will be the standard airborne network host for the larger science platforms. A Telemetry Link Module was also developed as a peripheral on the Global Hawk airborne network, which will host a database of the mission science data, and respond to download queries across the high-speed Ku-band sat-com system (See the New Technology section for related information.)

MASTER (MODIS/ASTER Airborne Simulator)

MASTER was a key instrument on the DC-8 Student Airborne Research Program (SARP) missions. Students participated in data collections over a variety of study sites that included agricultural areas, and an algal bloom incubator zone in the waters of Monterey Bay. Several of the subsequent SARP teaching modules were based on these data sets. A ten-year time series was also continued, with MASTER data being collected over several long-term study sites in Arizona and New Mexico. These data are being used to monitor changes in desert hydrology, and to develop remote sensing methodologies for understanding surface energy balance. MASTER will be in extended maintenance through the spring of 2010.

MAS (MODIS Airborne Simulator)

After more than 650 high-altitude missions on the ER-2, the MAS system is undergoing partial refurbishment. The digitizer system is being upgraded, and the scanning optics section is being replaced. It is anticipated to return to service in mid-2010.

AMS (Autonomous Modular Sensor)

Designed for automated operations on a large UAS, the AMS has been used mainly to develop methods for real-time fire mapping, flying on the Ikhana Predator-B. This year it was temporarily converted for use on the upcoming Global Hawk GLOPAC missions, with an added spectral band for water

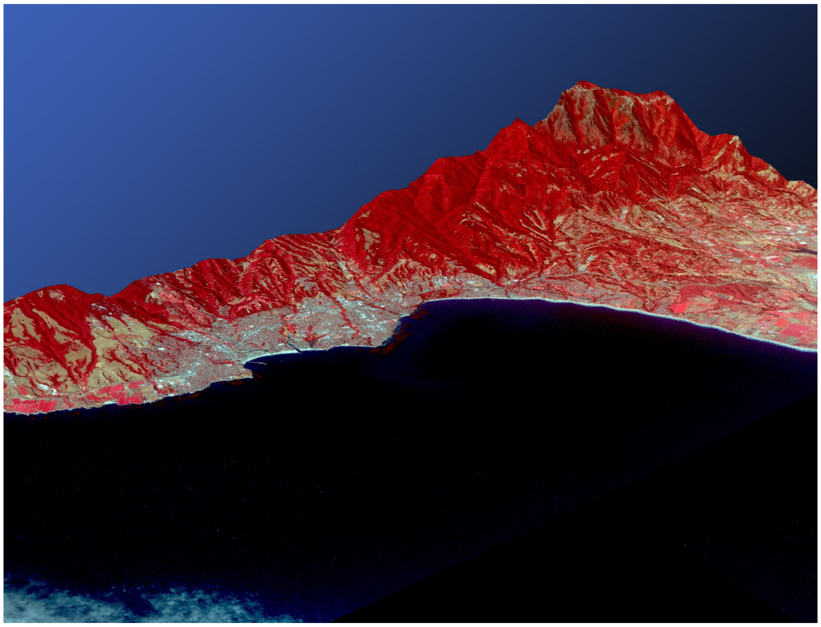


Figure 59:
3-D rendering of MASTER imagery over Santa Cruz, CA, from a DC-8 Student Airborne Research Program (SARP) mission, July 22, 2009.

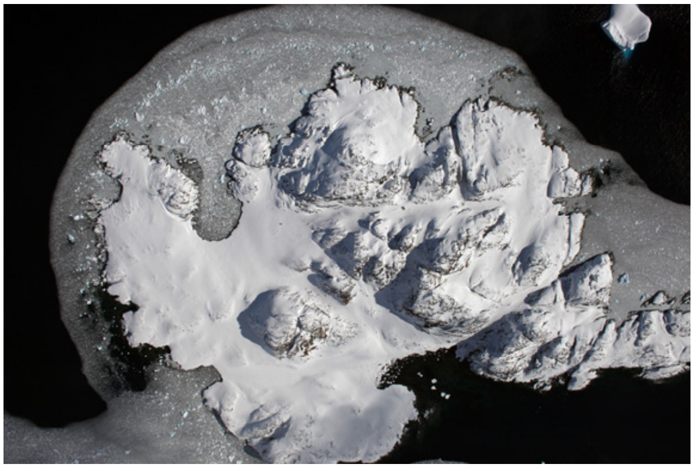


Figure 60:
Lichfield Ice Bridge as captured by the DMS tracking camera during Operation Ice Bridge.

vapor mapping, and was flight-tested on the ER-2. After being de-manifested from GLOPAC for weight reasons, it was re-configured for fire work, and flown on Ikhana for burned area assessment following the large Station Fire event in southern California.

Digital Tracking Cameras

These include 16- or 21-megapixel Cirrus digital cameras, synchronized to a precision navigation system on board the aircraft. They are used as secondary tracking devices to provide scene context and mission documentation for the science payload. Over 200,000 frames of imagery were collected this year during the IceBridge missions in Antarctica, where they will be used to study the surface texture and topology within coincident lidar and radar data sets. Time-lapse digital video cameras are also employed as needed, and a new Ethernet-hosted video system is being developed for the Global Hawk UAS, which will enable investigators on the ground to download imagery of selected areas during a mission, without monopolizing limited satellite communications resources.

Applanix POS/AV (Aircraft Position/Orientation System)

These stand-alone systems provide high-fidelity platform navigation and attitude data to science payload systems that require precision geo-location. They are interfaced directly to various facility instruments, and other sensors (e.g. Lidars) as required. This year POS/AV systems were deployed on the P-3, DC-8, ER-2, and several B200 aircraft.

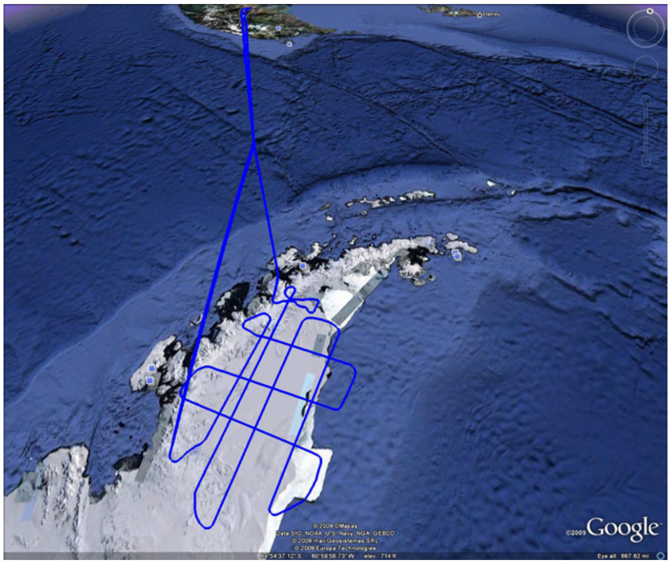


Figure 61:
A typical DC-8 mission profile from Operation IceBridge, derived from the POS/AV system data. The operating base at Punta Arenas, Chile can be seen at top, together with multiple flight tracks over the Antarctic Peninsula (11/16/09.)

The ASF manages a sub-contract with Twin Otter International, Inc., which conducts flights with a variety of NASA remote sensing systems. The activities this year primarily involved the JPL Passive/Active L-/S-band microwave instrument (PALS) and the POLSCAT polarimetric Ku-band scatterometer.

Data mining and distribution of precursor HyspIRI data sets, consisting of coincident MASTER, AVIRIS, and HyMap archival data sets, is ongoing together with JPL. AVIRIS and MASTER are slated to be flown together on the ER-2 over selected sites for HyspIRI algorithm development over the next several years.

The facility is also responsible for maintaining the websites for the Airborne Science Program, and the MAS, MASTER, and AMS sensors. It also provides graphical support to the program for conference materials and education and outreach activities.

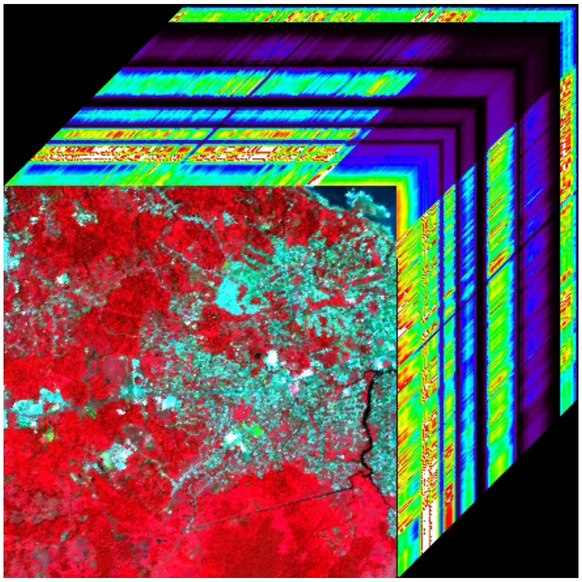


Figure 62:
A merged data set of HyMap and MASTER over Limon, Costa Rica. Acquired on 3/27/05, it covers a spectral region from 460nm to 13.0μm, and is being used as a precursor data set for the new HyspIRI satellite program.

Dryden Aircraft Operations Facility

The Dryden Aircraft Operations Facility (DAOF) in Palmdale, California now serves as the home base for the NASA DC-8, ER-2's and G-III aircraft. Co-location of these airborne science platforms into a single hangar results in substantial cost savings through the sharing of infrastructure and aircraft support crews. The DAOF provides common services such as machine shops, ground equipment maintenance, over-head cranes, warehousing, and mission planning. The Stratospheric Observatory For Infrared Astronomy (SOFIA), a heavily modified Boeing 747-SP for astrophysics research is also based at the DAOF and will provide further cost savings to the airborne science program as it too shares infrastructure costs of the DAOF.

Scientists from around the world are also benefitting from the new facility. An integration laboratory was included to allow instrument teams to assemble, check out and calibrate sensors prior to installation on the aircraft. The lab provides for safe handling of chemicals and cryogens, ground operations of lasers and simulation of aircraft power sources. Located about 65 miles north of Los Angeles, the City of Palmdale has convenient travel and logistics services for visiting experimenters as well as access to the U.S. Air Force Production Flight Test Complex (Plant 42) facilities.

In 2009 deployments to sites ranging from Tahiti to Antarctica were staged from the DAOF. The versatile facility was also used to conduct ground-based experiments into engine exhaust properties and also provided lecture and laboratory space for the Student Airborne Research Program.

Figure 63:
Welcome sign for the Dryden Aircraft Operations Facility.

Figure 64:
The DAOF hangar allows co-location of numerous large and small aircraft.

After over a year of modification and development, the DAOF was formally dedicated on April 9, 2009. The ceremonies drew local, regional, state and federal officials along with several hundred guests to the cavernous hangar and office complex. Steve Volz, associate director for Flight Programs for NASA's Earth Science division participated as the senior NASA official and spoke to the assembly on the importance of the airborne science program to the nation's orbital assets for Earth observation.

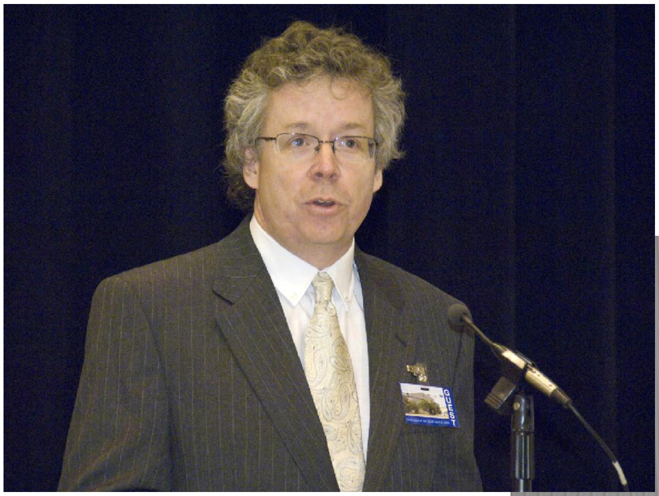


Figure 65:
Steve Volz speaks at the DAOF dedication ceremony.

Figure 66:
Installation of the NASA meat-ball on the new facility.

COLLABORATIONS and PARTNERSHIPS

Collaborations and Partnerships

FAA Liaison Efforts

In a continuing effort to address access for Unmanned Aircraft Systems (UAS) to the National Airspace system (NAS) in support of our science missions, the Airborne Science Program has maintained a liaison within the Federal Aviation Administration (FAA) Unmanned Aircraft Program Office (UAPO). The relationship between the FAA and NASA has grown stronger as a result of the liaison, with a greater understanding within the FAA of NASA's mission needs and its robust safety processes. By actively working with the FAA, the Airborne Science Program has been successful in obtaining key permissions for important and high profile operations. Two noteworthy successes occurred this year, with the granting of the Certificate of Authorization (COA) for Aerosonde Hurricane Operations in the Atlantic Ocean north of Barbados airspace, and for the Global Hawk Pacific Mission (GloPAC) that is to occur in early 2010 over the Pacific and Arctic Oceans. A significant amount of coordination by the FAA went into both of these COAs and reflects the relationship that has been established between the FAA and NASA.

Certificate of Authorizations (COA)

The Certificate of Authorization (COA) continues to be the only method for federal public UAS to access the NAS. This year a total of 12 COAs were issued to NASA and 16 applications for both new and renewals of continuing operations are waiting to be approved. The COAs are broken out by center in the table below.

A record number of COA applications were received by the FAA this year, which has resulted in a severe backlog. A corresponding lag in application approvals has occurred, with many applications taking several months more than the standard 3 months to be processed. However, the FAA has recognized that there is an issue, and is taking multiple steps to remedy the problem. As a starting point, all the COAs that have applications awaiting approval that are renewals for previous operations have been given extensions that expire August 31, 2010. While this is not a solution in itself, it does demonstrate that the FAA is cognizant of the effect of the problem on

NASA Center	COAs Issued 2009	COAs Pending
Ames Research Center	9	5
Dryden Flight Research Center	2	0
Langley Research Center	0	10
Wallops Flight Facility	1	1

Table 3: Certificates of Authorizations issued in 2009.

on the UAS community and that it is willing to take steps to assure that operations can continue uninterrupted until the backlog is relieved. Staffing levels are being increase and a full review of the COA process is underway to help identify ways to streamline the process, particularly for renewals that are unchanged from the previous year.

UAS ExCom

This year, NASA was invited to join the newly formed UAS Executive Committee (UAS ExCom). The UAS ExCom is a multi-agency Federal executive-level committee comprised of the FAA, Department of Defense (DoD), Department of Homeland Security (DHS), and NASA. The committee was formed in recognition of the need for the UAS operated by each of these agencies to access to the National Airspace System (NAS) to support operational, training, and research and development requirements, and that technical, procedural, regulatory, and policy solutions are needed to deliver incremental capabilities leading to routine access. The primary goals of the UAS ExCom are to

1) Coordinate and align efforts between key federal government agencies to achieve routine safe federal public UAS operations in the national airspace system (NAS).
2) Coordinate and prioritize technical, procedural, regulatory, and policy solutions needed to deliver incremental capabilities.
3) Develop a plan to accommodate the larger stakeholder community, at the appropriate time.
4) Resolve conflicts between Federal Government agencies (FAA, DoD, DHS, and NASA), related to the above goals.

The Associate Administrator of the Aeronautics Research Mission Directorate (ARMD) is representing NASA on the UAS ExCom. To ensure participation from the Science Mission Directorate (SMD), and thus the Airborne Science Program, NASA has two representatives on the UAS ExCom Senior Steering Group (SSG), one from the Airborne Science Program and one from ARMD. These individuals work closely with the Associate Administrator to ensure all of NASA's UAS interests are represented appropriately to the ExCom. The formation of the UAS ExCom is significant in that it represents a tangible commitment by FAA senior leadership to address the UAS airspace access challenge.

Other FAA Activities

The liaison continued to support the FAA UAPO with important technical studies and rulemaking activities. The recommendations produced by the Small UAS Aviation Rule Making Committee (sUAS ARC), an activity heavily supported by NASA last year and this, were finalized earlier in the year. The recommendations are now going through a Safety Risk Management Panel (SRMP) to be assessed for safety and NASA is participating in this activity. Other work includes an ongoing study about using TCAS on UAS and developing criteria for UAS contingency planning. NASA also participated in HUREX, a collaborative decision environment experiment conducted by MITRE to assess disaster response (specifically hurricane landfall) by multiple agencies using UAS.

International Activities and Collaborations

ICCAGRA/EUFAR

In FY2009, Interagency Coordinating Committee for Airborne Geoscience Research and Applications (ICCAGRA) representatives voted to create a working group for coordinating agency activities related to the use of Unmanned Aircraft Systems (UAS). The working group was formed with representatives from NASA, NOAA, NSF, USGS, and NRL and was co-chaired by Matt Fladeland and Brenda Mulac from NASA. The purpose of the working group is to encourage open communication and information exchange between the agencies about plans to use UAS and to describe roadblocks to implementation. The working group provides a forum in which each of the member agencies can share lessons learned from UAS operations and other UAS experiences. The first priority of the working group is to summarize the various requirements and use cases for each agency, and then provide a concise summary to the FAA to further their understanding of our needs for accessing the National Airspace System.

As a part of the Airborne Science Program (ASP) initiative to increase dialog and cooperation with the airborne activities of other nations, as well as with international governmental and non-governmental multilateral organizations, we have increased our participation in the International Society of Photogrammetry and Remote Sensing (ISPRS). First, we have identified the International Symposium on Remote Sensing of Environment (ISRSE), an ISPRS symposium, as the major forum for increasing ASP dialog with the international airborne community as well as with the international community of researchers whose focus is space acquired data. In addition ASP initiated and currently participates in Working Group 1, Standardization of Airborne Platform Interface, of ISPRS Commission I, Image Data Acquisition-Sensors and Platforms.

In May of 2009, ASP participated in the 33rd International Symposium on Remote Sensing of Environment in Stresa, Italy. ASP participants exhibited NASA technology, attended workshops and exchanged technical papers with approximately 1,000 delegates from more than 50 countries. The 34th ISRSE will be convened in Sydney, Australia in April of 2011.

The first meeting of ISPRS Working Group I-1 was convened as an adjunct to the 33rd ISRSE in Stresa. NASA and other members of the U.S. ICCAGRA Committee were joined in the working group meetings by the European Facility for Airborne Research (EUFAR) from Toulouse, France and by the Center for Earth Observations and Digital Earth (CEODE) of the Chinese Academy of Sciences from Beijing, China.

The second meeting of the working group will be held in Calgary, Canada in June of 2010 as a part of the ISPRS Commission I Symposium.

IWGADTS

Since 2005 the Interagency Working Group for Airborne Data and Telecommunications Systems (IWGADTS) has been a subgroup to ICCAGRA for the purpose of developing recommendations leading to increased productivity and interoperability among airborne platforms and instrument payloads. The IWGADTS group produces increased synergy among research programs with similar goals and enables the suborbital layer of the Global Earth Observing System of Systems.

This past year IWGADTS held its regular spring meeting in Boulder and conducted outreach via overview paper number PS-C3-13 at the 33rd International Symposium for Remote Sensing of Environment (ISRSE). The efforts of IWGADTS dominated EUFAR report DN6.4.1 (draft) on US standards and protocols for data exchange and data links. Works in progress this year include recommendations for sensor alert services and for command/query of remote instruments during real-time operations. For post flight data archives, file formats, metadata management, and data discovery recommendations are being discussed.

MEDIA, EDUCATION and OUTREACH

Media, Education and Outreach

NSERC

The National Suborbital Education and Research Center – a cooperative agreement between NASA and the University of North Dakota – provides education and public outreach support to the Airborne Science Program. Educational support includes student research opportunities and public outreach support includes mission-related outreach, exhibits at conferences, engaging the public through social networking outlets and connecting with national media outlets.

The 2009 Student Airborne Research Program

A major contribution to the ASP education activities was the implementation of the first Student Airborne Research Program (SARP). This program took place during July-August 2009 and included 29 competitively selected undergraduate and graduate Earth system science and engineering students representing 26 schools from across the U.S. The objective of the program was to give these students access to Earth science research using the NASA DC-8 research platform. The students engaged in three experiments: 1) in-situ atmospheric gas sampling using the Whole Air Sampler, 2) remote sensing of evapo-transpiration processes using the MASTER instrument, and 3) remote sensing of physical ocean processes using the MASTER instrument. The flights took place over California's Central Valley for the gas sampling and evapo-transpiration experiments, and over Monterey Bay for the oceanography experiment.

The program was six weeks and started off with a week of teleconferences to discuss science topics with the students, introduce them to faculty and provide logistical information. The following week the students and faculty arrived in Irvine, CA where they participated in a series of introductory lectures by project advisors and NASA program managers at the UC Irvine campus. The third week was spent in Palmdale, CA where students were given more lectures on mission planning. While in Palmdale, students also participated in two science flights on the DC-8 where they collected all their data. Field campaigns were also organized to coincide with over flights and students were able to participate in these as well. The fourth and fifth weeks were spent back at UC Irvine where students analyzed

Figures 67:
NSERC 2009 students.

gas samples in a chemistry lab and multi-spectral imagery in a computer lab. The sixth week – also at UC Irvine – focused on data interpretation and the program ended with each student presenting their research results. These presentations, as well as introductory faculty and NASA program manager presentations, can be viewed on the NSERC-SARP website (http://www.nserc.und.edu/learning/SARP.html) under the SARP Multimedia button. Three SARP students were selected based on their outstanding projects and presentations to share their results at the NASA exhibit December 2009 during the American *Geophysical Union Fall Meeting*.

Several media outlets covered the SARP mission including numerous local newspapers and a feature story on National Public Radio (See NPR.com "Earth Science From the Sky: The Next Generation"). A video of the mission was produced by NSERC and will be available for viewing through the NSERC website and NSERCTV on YouTube.

Operation ICEBridge Education and Outreach

Another ASP contribution to education activities was conducted during the most recent DC-8 mission Operation ICEBridge. For previous flights, data systems onboard the DC-8 have been configured so that people on the ground could chat with those on board the DC-8 during a flight as well as track the science flights in Google Earth. These applications were used as a classroom activity so that Earth science educators around the country could watch the science flights and interact with mission scientists. An announcement of this activity was emailed to the National Science Teachers Association Earth science educator list. Upon announcement of the activity, approximately 100 5th-12th grade teachers expressed interest in participating. A Google Earth KML file was created that included a DC-8 flight track feature as well as various landmarks throughout Antarctica. This file was emailed to all the participating educators so that they could track the DC-8 in real-time during OIB. Educators also had access to an internet-based chat application that allowed them to ask questions directly to scientists on board the DC-8. Plans are to include this classroom activity in all future airborne science missions when possible.

In addition to the education activity, NSERC promoted OIB to the general public through a blog, video and photography. Video clips from science flights were posted to YouTube through the NSERCTV channel and photos were added to blog postings to give updates about flight schedules, objectives and outcomes. NSERC is currently producing an OIB mission video to highlight the mission science topics and the airborne instruments used for collecting data.

Informational Booths at International Conferences

NSERC maintained a booth at the 2008 AGU Fall Meeting showcasing a video of the ARCTAS mission and recruiting students for the first Student Airborne Research Program as well as promoting airborne science activities to the Earth science community. NSERC also supported ASP presence at the 2009 International Symposium of Remote Sensing of the Environment in Stresa, Italy. This was done in collaboration with the ASP group at UC Santa Cruz/NASA Ames. An exhibit displaying past and future ASP missions as well as airborne instruments was promoted to the international community of scientists present. Information on education and public outreach efforts were also shared with conference attendees. NSERC will also be supporting this same exhibit at the 2009 AGU Fall Meeting in conjunction with the NASA exhibit.

Social Networking

NSERC maintains a presence on YouTube (NSERCTV) and Facebook with an NSERC Facebook page. Mission news and updates are shared with Facebook fans and mission video clips are uploaded to NSERCTV and advertised through the Facebook page. The Facebook page has been very convenient for staying in touch with the airborne science community, especially the student demographic. Facebook users can connect to this page by doing a Facebook (www.facebook.com) search for "National Suborbital Education and Research Center" and becoming a fan. Recent updates sent to fans of the NSERC Facebook page include links to NPR audio stories covering Operation ICEBridge as well as links to the NSERC OIB blog.

ISRSE

NASA's Airborne Science Program was well represented at the May 2009 International Symposium on Remote Sensing of the Environment (ISRSE) conference in Stresa, Italy, May 4-8. ASP staff presented papers and posters for sessions on airborne platforms, airborne science, UAS platforms and science, as well as a session on airborne science programs. In addition to the conference, side meetings included a joint meeting between the European Fleet for Airborne Research (EUFAR) and the U.S. Interagency Coordinating Committee for Airborne Geosciences Research and Applications (ICCAGRA) to explore partnering opportunities between U.S. agencies and our European colleagues. The Program also organized a kick-off meeting of the ISPRS WG1/I that will focus on airborne observations.

In general, the meeting was very successful in creating interest in the next generation of capabilities and did well to communicate the leadership role that NASA maintains in airborne science.

UAS Workshop

A pre-conference workshop on UASs for remote sensing was a big success. More than 30 people from 6 continents attended. The workshop highlighted features of both large and small UASs, a variety of sensor systems, and a range of applications with a focus on wildfire monitoring. The speakers included NASA and U.S. Forest Service personnel, as well as users/ developers from Hungary, Spain, and Italy. The local Italian UAS company, Aermatica, brought a small vertical take-off-and-landing UAS to the exhibit hall.

WETMAPP Seminar

WETMAAP, developed by Chadron State College, the USGS National Wetlands Research Center, and the USGS Mid-Continent Geographic Science Center, is partially supported by the NASA Airborne Science Program.   A primary goal of the Program is to improve science, math, and geography in the classroom through the appropriate use of NASA

Figures 68:
August 2009 WETMAAP workshop field trip to Wallops Island study site.

imagery, integrated with maps, aerial photography, and airborne and satellite imagery using wetland as the focal element.

The WETMAAP Program develops and offers wetland training sessions and maintains a website for educators and professionals that provide basic instruction in ecological concepts, technological skills, and methods of interpretation necessary for understanding and assessing wetland and upland habitat change. Training sessions explore wetlands using multiple data sets and introduces traditional mapping technology to formal and informal educators.

The WETMAAP materials are designed for use by secondary education teachers, undergraduate and graduates students, university and college professors, informal educators, and local and regional government officials. The Airborne Science Program has supported the WETMAAP program and selected workshops since 1995. Support has consisted of funding, ASP photography and digital imagery, and NASA satellite imagery. Also members of the Airborne Science Program staff have participated in WETMAAP workshops as trainers and guest lecturers.

Of the 163 WETMAAP workshops facilitated between 1995 and 2009, NASA supported 36 workshops throughout the United States, Costa Rica, and Panama. For 2009, WETMAAP completed the Wallops Island site and presented a two-day wetland education workshop held in August with 8 participants. Day 1 was the in class hands-on training and Day 2 was a field experience visiting wetland locations associated with the site. The response by informal educators from Marine Science Consortium (MSC) who attended the session was positive. As a result of networking a collaborative effort was established between the MSC Undergraduate Education Coordinator and Education Coordinator at NASA Wallops Flight Facility to sustain the Wallops Island wetland training with additional sessions scheduled for 2010. For the International Symposium of Remote Sensing and the Environment (ISRSE) held in May at Stress, Italy, a pre-conference seminar on WETMAAP was also presented by ASP personnel. Briefing documents on "Developing Multiple Components for an Education Model for the NASA Airborne Science program" were distributed. WETMAAP also completed the initial site visit and site identification for developing a workshop on coral reefs along the coast of Puerto Rico.

CeNAT Workshops

NASA aircraft have acquired data with various sensors for a variety of research objectives involving both NASA and Costa Rican investigators since the early 1980's. This collaborative relationship lead to an agreement signed in 2002 which was the basis for the Costa Rican Aircraft Research and Technology Applications (CARTA I) project in 2003 and the CARTA II project in 2005. These agreements were implemented through the Costa Rican National Center for Advanced Technology (Centro Nacional de Alta Tecnologia - CeNAT) as part of its National Program for Airborne Research and Remote Sensing (PRIAS).

Remotely-sensed data acquired through the CARTA I and II projects with sensors on the NASA WB-57 aircraft provided both multispectral and hyper spectral scanner data as well as digital camera imagery. In addition, Synthetic Aperture Radar (SAR) data was acquired with the AIRSAR sensor on the NASA DC-8 aircraft in 2004, and Lidar data was acquired with the NASA LVIS sensor on a DOE aircraft in 2005. These data have been used for a variety of research and applications purposes by various Costa Rican agencies and Universities, and has been made available to the NASA Decadal Survey and the NASA-SERVIR project for coverage of the Costa Rican portion of the Central American Biological Corridor.

During early FY2009, it was decided that even more information could be derived from these data and future airborne science data acquisitions after more advanced training of Costa Rica scientists, natural resource managers, and graduate students. Subsequently, through a collaborative effort between the NASA Airborne Science program and CeNAT, a series of workshops was arranged for additional training in the analysis of data acquired with sensors on airborne platforms. A series of two-day workshops were scheduled. Several were conducted in 2009 and several will take place in 2010. Each focuses on SAR (AIRSAR & UAVSAR), and Lidar (LVIS). Arrangements were made with U.S. experts in the analysis of each type of data to conduct each two-day workshop. The workshops take place in the CeNAT-PRIAS remote sensing lab with support of the PRIAS technical staff. The workshops involve a hands-on-the-computer approach using commonly available image analysis software. Emphasis is being given to the use of the data that exists in the CeNAT-PRIAS database that covers the entire country of Costa Rica, but the characteristics of data from other airborne science sensors are also covered. Workshop participants include personnel from Costa Rican government agencies, public universities (faculty and graduate students), and private organizations, each of which will focus SAR (AIRSAR & UAVSAR), and Lidar (LVIS). Arrangements were made with U.S. experts in the analysis of each type of data to conduct each two-day workshop. Workshop participants include personnel from Costa Rican government agencies, public universities (faculty and graduate students), and private organizations.

Figures 69:
A CeNAT workshop conducted in Costa Rica.

Newsletter

The Airborne Science Program (ASP), in an effort to reach out to program staff and the larger airborne science community, published our first newsletter in July 2008. These four-page quarterly editions strive to feature significant recent airborne deployment activities and program accomplishments, as well as brief highlights of other ongoing and planned activities. We also include a perspective from the ASP management, schedules of upcoming program activities, events of interest to our extended community, and capabilities of our core aircraft fleet. The ASP Newsletter is distributed broadly, via email to the ASP staff, and the larger airborne science community (Airborne Science Call Letter list server), and is available on the ASP web site (http://airbornescience.nasa.gov/)

Recognition and Awards

Spring 2009 Awards

Team Achievement
Wallops P-3 ARCTAS Upload Team

Engineer
Michael Cropper
P-3 Configuration Manager

Project/Mission Management
Chris Naftel
Global Hawk Project Manager

Outstanding Achievement
John McKee
Airborne Science Range &
Telemetry Liaison

Special Award:
Andrew C. Roberts
Director, NASA Airborne Science
Program.
For distinguished leadership of the
Airborne Science Program.

Fall 2009 Awards

Team Achievement
Global Test Range & Over-the-Horizon Networks (REVEAL), DFRC

Exceptional Performance
Peter Peyton
Technician/Mechanic

Sustained Achievement
Bill Brockett
Research Pilot

Administrative Achievement
Rosalie Toberman
Contracting Officer

In Appreciation for Extraordinary Support of Operation IceBridge:
Eric Schmidt

Looking Ahead to FY10 and Beyond

The Airborne Science Program has benefitted substantially from the support provided from our NASA leadership, our partners and our science community. Our focus for the future is to deliver on our commitments to missions and field capabilities that cost effectively enhance the science return coming from airborne experiments.

In 2010 and beyond, the Airborne Science Program plans to further implement its vision of maximum sensor portability. NSERC will provide the P-3B with a data distribution and communication system like that on the DC-8 so that instruments integrated on one will require minimum change to be integrated on the other. Leveraging investments made possible through the American Recovery and Reinvestment Act (ARRA), the ASF will build and start fielding common equipment interface panels between the WB-57, ER-2, and Global Hawk.

The year 2010 will also see some substantial platform sustainability activities undertaken. The P-3B will complete its depot level maintenance and special structural inspection and the DC-8 and ER-2 will initiate low utilization maintenance programs appropriate for their operational tempo and projected to produce significant life-cycle cost savings. The WB-57 is scheduled to complete its Gross Weight Increase project with flight demonstration and certification. ARRA is enabling the upgrade of the P-3B's avionics and autopilot systems as well as the design and fabrication of replacement ailerons for the WB-57. The B-200 aircraft operated from DFRC will be modified to be a remote sensing capable aircraft. Other examples of Airborne Science funded ARRA efforts include:

- DAOF modifications and upgrades
- Construction of a third UAVSAR Pod for use on Global Hawk and the G-III
- Operation Ice Bridge Science Team funding
- Development of a Global Hawk Mobile Operation Facility for Aircraft command and control

Several ASP-related ARRA projects are a partnership with the Earth Science Technology Office and the Research and Analysis Program. These include:

- Laser Vegetation Imaging Sensor (LVIS) -2
- Enhanced MODIS Airborne Simulator (eMAS)
- Portable Remote Imaging SpectroMeter (PRISM)
- Global Ozone Lidar Demonstrator (GOLD)
- Global Hawk wing pylons

Most ARRA projects awards are expected to be completed in 2010, with a few planned to continue into 2011.

Mission-wise, the Global Hawk (GH) will perform its inaugural science mission: GLOPAC (Global Hawk Pacific), which is a combination Aura calibration-validation / IPY mission. Following GLOPAC, Global Hawk will prepare for the

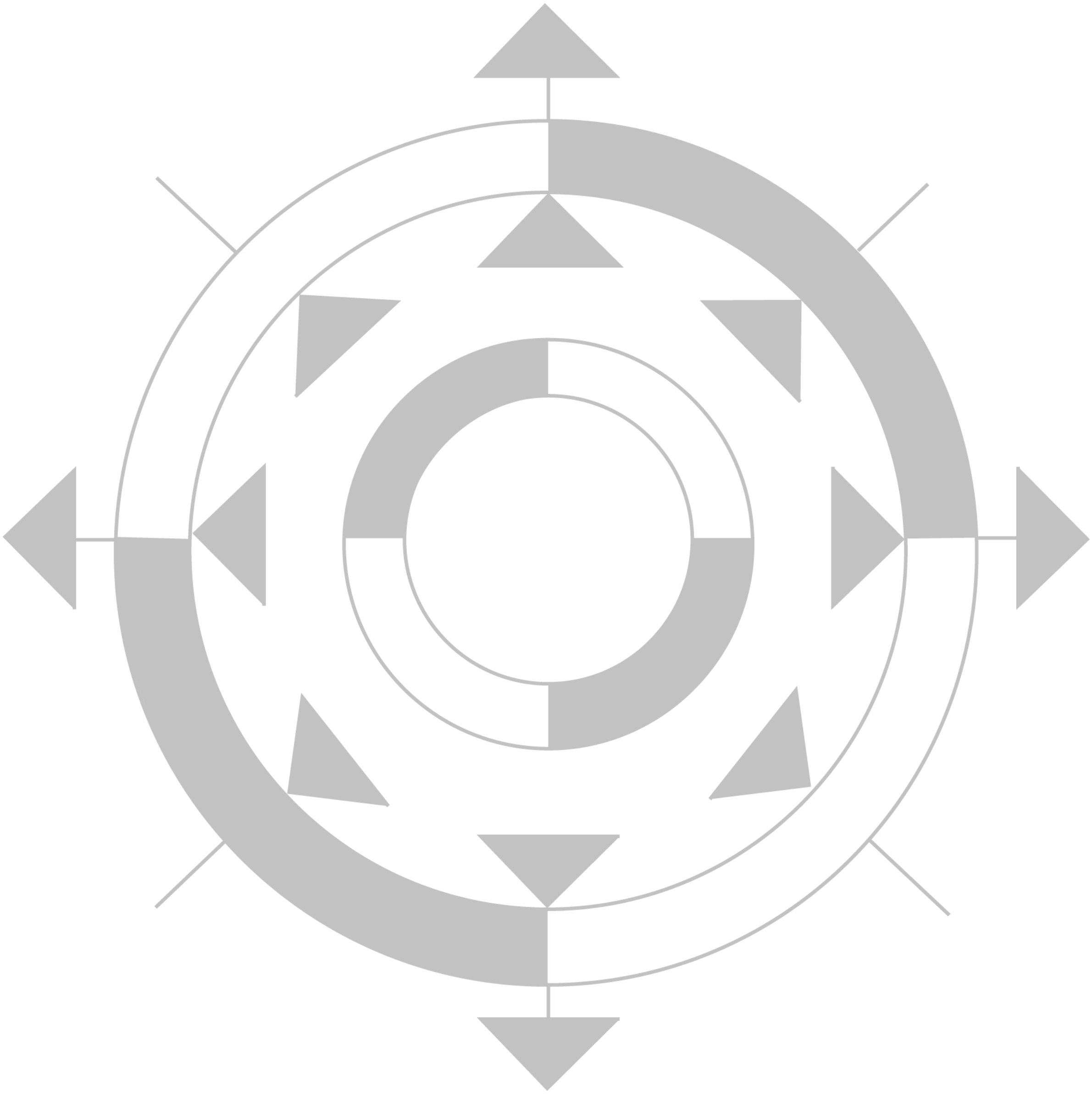
Genesis and Rapid Intensification Processes (GRIP) mission, an atmospheric dynamics mission to study hurricane processes, which will include both the DC-8 and Global Hawk. The "Pre-GRIP" mission will flight-demonstrate new sensor technologies and GRIP flight profiles. All the GH activities are in partnership with the NOAA Unmanned Aircraft System (UAS) Program Office. Operation Ice Bridge will start its second of six seasons, concentrating on Greenland with the DC-8 and P-3B. The G-III is projected to have a very full second operational year with many more years planned.

The first ESSP Earth Venture Initiative (EV-1) projects will be awarded and start up to five years of systemic measurements. Decadal Survey missions are also expected to increase substantially in the upcoming years. The year 2010 will also be the first year in the development of PRISM a JPL ocean color hyperspectral imager as well as be the close-out year for IPY activities. The 2nd Student Airborne Research Program mission will be accomplished, building on the 2009's success and lessons learned.

Activities will continue to develop a permanent ISPRS committee on Airborne Sciences in addition to our collaborations with EUFAR and CEODE. Airborne Science will continue to contribute to the efforts of ICCAGRA, UAS in the NAS and our UAS science partnerships with NOAA and DOE.

Programmatically, a permanent program director will be announced. The program will continue its efforts to continually improve its processes and products. We will prepare for the future by furthering payload portability and standardization efforts and understanding of the needs of our science community. Airborne Science remains committed and prepared to meet the challenges of the future and ready to contribute its part in NASA's mission to understand the Earth system.

APPENDICES



APPENDIX A

In Memoriam

Frank Caldeiro

Figure 70:
Frank Caldeiro

On October 3rd, the WB-57 team lost a valuable team member and friend, Fernando "Frank" Caldeiro. He had battled brain cancer for two and a half years.

Prior to his career at NASA, Frank worked for Rockwell International. From 1985 through 1988, he served as a test director during the production and flight test of the Rockwell/USAF B-1B Bomber. In 1988, he transferred to Kennedy Space Center to work for Rockwell International as a propulsion specialist.

Frank was hired by NASA at Kennedy Space Center in 1991 as a cryogenics and propulsion systems expert for the safety and mission assurance office. He participated in 52 space shuttle launches while at KSC. He enjoyed living in Florida and met his wife, Donna there.

Frank was selected as an Astronaut in 1996, NASA's 16th class of astronaut candidates, or "ascans". His class was dubbed "The Sardines" because at 44 members, they were the largest group of astronaut candidates ever chosen by NASA.

Born in Buenos Aires, Argentina on June 12, 1958, Frank was the first person of Argentinean descent to train for a spaceflight. He was proud of his Argentinean and Spanish heritage, enjoying visits to both of those countries to visit relatives and friends.

Frank started working with the WB-57 High Altitude Research Program in the Aircraft Operations Division in early 2006. He was a private pilot as well, flying a Rutan Long Ez experimental aircraft out of Ellington Field, so he loved the atmosphere of work in Aircraft Operations. Along with his work managing the integration of scientific instruments onto the WB-57, he also had the opportunity to fly as a test director with the C-9 Reduced Gravity Program.

Frank is survived by his wife, Donna, and his two daughters, Annie and Michelle. He will be dearly missed by all who knew him.

Bob Danielson

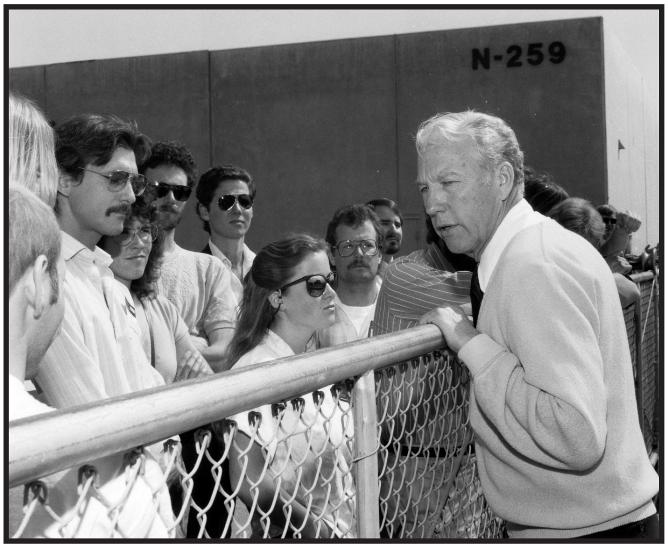


Figure 71:
Bob Danielson (right) talking with visitors to NASA Ames watching an ER-2 launch.

Bob was a Lockheed engineer, who was a critical player in the initial acquisition of the ER-2 aircraft (circa 1971) for the High Altitude Earth Science program at Ames Research Center. Under Marty Knutson and in conjunction with a strong ARC management team, he formed the initial airborne science group, which elevated remote sensing into a state-of-the-art science contributor. Under his engineering oversight, the High Altitude Branch flourished and provided grist for the mill for the medium altitude aircraft, which included the C-130, Convair 990, Lear 23/24, DC-8, BE-200 and the C-141 Kuiper Space Science aircraft (circa 1974). During this time, Bob was an indispensable cog in the safety and oversight for the engineering development of such programs.

Bob was the first front seater that came down from the USAF 58th Weather Reconnaissance Squadron at Kirtland AFB in September of 1968. The fleet of WB-57s they flew were used for the usual looking at other people from up high as well as atomic testing sampling. They called themselves "F Troop" after the TV show that was popular at the time. A major at the time, Bob acted as the contingent commander. NASA/JSC contracted with the USAF in 1968 to operate a WB-57F: this was the initiation of high altitude remote sensing in the agency. The 58th personnel, like Bob, flew front seat and NASA and USAF personnel flew back seat as sensor operators/navigators. JSC modified the WB-57F at General Dynamics, Fort Worth, to accept a removable NASA earth observation pallet in the space that had served as the rotating bomb bay. In 1972, the USAF left the program due to budget constraints and the aircraft was transferred to NASA and JSC. It was renumbered NASA 925 and was the first NASA high altitude aircraft with remote sensing capabilities in the inventory. Bob was a pilot during these first years and in 1972 returned to his USAF duties. Marty hired Bob when he retired from the USAF and the rest is history.

I would be remiss, if I didn't mention a personal experience with Bob. He was detailed to the DC-8 program to provide engineering oversight during a major D check in Tucson, Arizona. There were six of us going to dinner at a steak house, where suit ties were not welcome and if you tried to enter with one, you were immediately grabbed and your tie was scissored off. Bob was the only one who didn't get the message and the inevitable happened. He took it in stride and everyone had a good laugh.

He will be missed.

Contributed by Geary Tiffany and Ole Smistad

APPENDIX B

Airborne Program History

Origins of an Airborne Earth Science Program at NASA

Marty Knutson, godfather of U-2s at NASA, revealed some of his highlights of the Program during a recent interview.

Today's Airborne Science Program (ASP) continues a proud tradition supporting the study of Earth from space, begun in the Gemini years, continuing through MTPE, EOS, and forward now with the Decadal Survey Recommendations. In 1964 Olav (Ole) Smistad was head of the JSC Aircraft Office at the Johnson Space Center where Ole Leo Childs and Harold Toy acquired a Convair 240, which flew its first Earth remote sensing mission that same year. From these simple beginnings, the management structure sprouted, that would evolve into our Airborne Science Program.

In an effort to capture some of the heritage and evolution of the program, ASP is collecting and archiving program related history snippets when ever possible. In this short article I have tried to share some insight into the early years of the U-2 program at NASA, highlighting the contributions of a stubborn, blunt speaking, professional aviator, who had a huge impact on Airborne Science at NASA. In 2008, Jim Weber and Andy Roberts talked to Marty Knutson in a taped interview. The thirty nine page interview transcript was rich with stories, often rambled and appeared stream of consciousness, with little direction from the interviewers. These stories spoke to the origins of the U-2 program at NASA and twists of fate that brought them to Ames, the evolution of the reimbursable projects,, and Marty's as facility director at Dryden. Unfortunately the interview ran out of steam before we got to the meaty topics of Aircraft consolidation at DFRC, or the establishment of Dryden as an independent Center. I have tried to take these war stories and place many of them in the context of NASA themes of the late ‘60s, early ‘70s.

In this short story, I have captured several of Marty's stories in limited detail and without his colorful language.

Contributed by Jim Weber

……

Marty Knutson attended the University of Minnesota majoring in electrical engineering. He began his aviation career as an aviation cadet in the U.S. Air Force in 1950. Following service in the Korea conflict and participation in developmental test and operation missions in F-84s, he joined the CIA's Air Division flying U-2s. He retired from the Air Force in 1970, having logged over 6,500 hours of flight time.

Marty was flying U-2s out of Cyprus in mid 1970, when he retired from the Air Force. As Marty was retiring, the CIA was considering getting out of the air business, as the big eyes in space were becoming very capable. The agency was planning to give a couple of U-2s to NASA. Marty was asked to help NASA develop a U-2 Program Plan, Marty reluctantly agreed after loosing a drinking contest with Carl Duckett, the Deputy Director of the CIA.

These were heady times for NASA, we were in the thick of the Apollo missions, and trying to come up with a new, post Apollo plan for the Agency. Thomas O. Paine was the NASA administrator. John Naugle was NASA's Associate Administrator for Space, The Earth Resources Technology Satellite (ERTS) program was just starting. In 1970 NASA selected GE as prime contractor for ERTS.

John Naugle was reluctant to embrace Marty, as he was concerned about Marty's connection with the CIA, concerned about any connection with a spy agency. Naugle left an introductory meeting when he learned Marty was flying CIA missions as recently as the week before.

Naugle came to want Marty to come to NASA with the aircraft, currently slated to go to Rome NY. Marty, who grew up in Minnesota, knew he doesn't like the cold, balked at the idea. After some wrangling, Marty agreed to start the U-2 program at Ames, an offer he couldn't pass up. It seems JSC wasn't interested in the U-2s, as they were convinced hey would crash.

Hans Mark was the Director of Ames at the time. He had heard from the NASA Administrator and the Director of the CIA that Marty was coming. In 1971 Marty Joined NASA at the Ames Research Center as manager of the Airborne Instrumentation Research Project. Shortly after arriving at Ames, Marty was prohibited from flying the U-2s, reflecting John Naugle's fear of agency guys.

Marty combined his knowledge of the U-2 ops, and the insight into the AF/CIA U-2 supply chain to ensure NASA got low hour airframes, Marty got three airplanes from the Agency, just out of overhaul, all the updates and everything. Marty repainted the U-2s in the NASA colors. The first airplane came to Ames Research Center in June of ’71.

Figure 72:
1981 photo of Ames Aircraft on the ramp.

The U-2s filled an important niche in the early ‘70s. ERTS was late and there were science investigators already funded. They let Marty design the sensors that would simulate what the satellite was supposed to produce, and then fly over three major test sites: the East Coast, the center of the U.S., and a bunch of other test areas.

That’s when Marty started flying again. Headquarters had them on a flight schedule that they couldn’t meet. The airplane had more legs than the pilots did. So I started flying. So Marty went to Hans Mark and said, “Here’s the program and your plan you signed when it went to headquarters. And here’s the one we can use, because we don’t have enough pilots.”

In 1984, on deployment to Alaska, while sitting in his BOQ room, Marty was putting new fishing line on his rod when Ames Center Director, Bill Ballhouse calls. Marty is summoned back to Ames. Marty returns quickly and when meeting with Ballhouse is requested to run the Dryden Flight Research Facility. Marty, not wanting to go to the desert again, was able to negotiate a number of changes, including that he maintain his position at Ames, in addition to managing the Dryden facility, keep his residence in Los Altos, be on TDY at Dryden, and have access to an airplane. Marty also made a point that should Dryden a full-fledged NASA Center and he would advocate for that In May, 1984, Martin A. Knutson was appointed Director of Flight Operations for

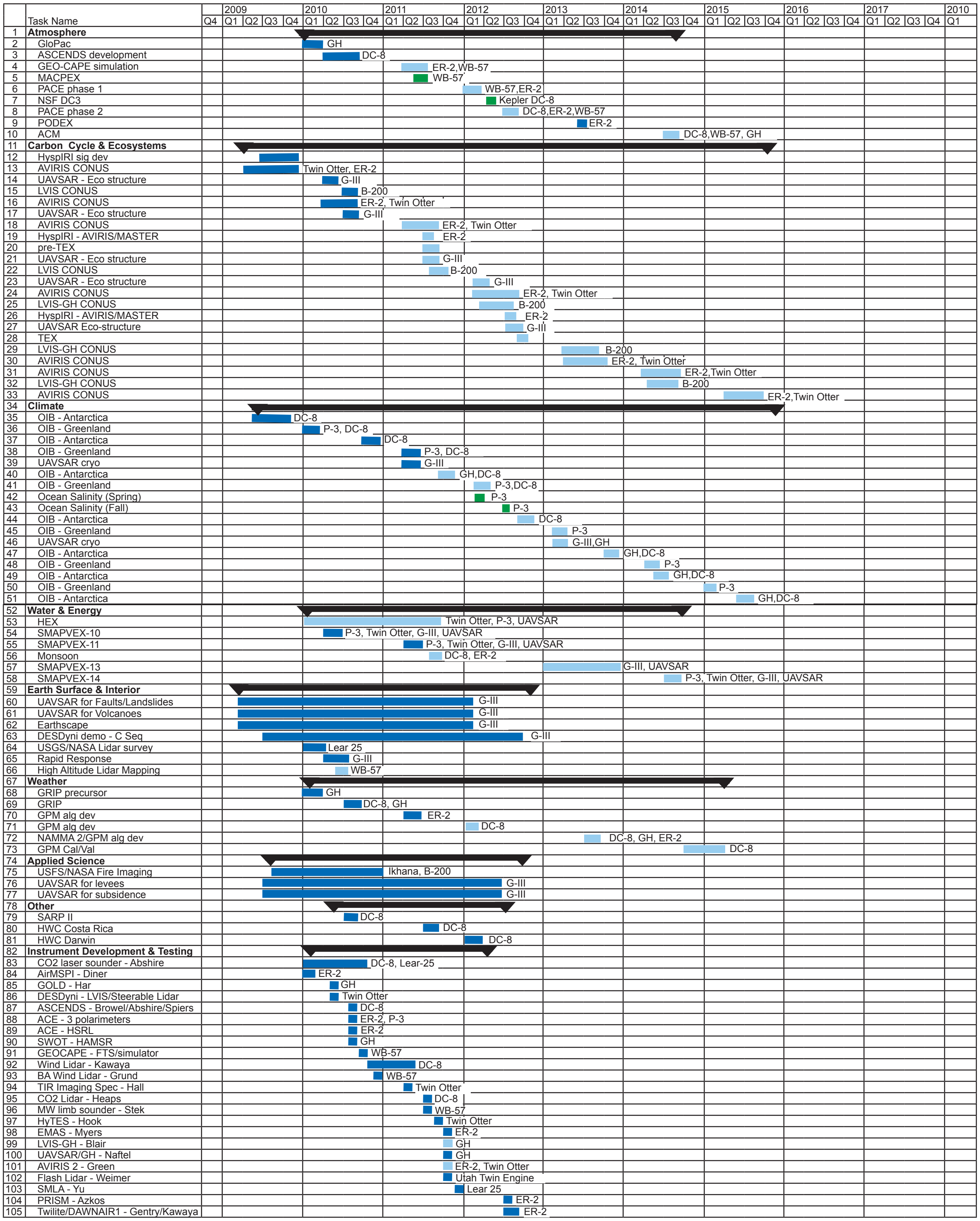
NASA's Ames Research Center at Moffett Field, California, and also was assigned the additional position as Site Manager of the Ames-Dryden Flight Research Facility at Edwards, California, a position he held until 1990. (Here the interview ends)

Marty returned to Ames in 1990 as Chief of Flight Operations for Ames Research Center until his retirement from NASA in 1997.

Marty has several awards including the Meritorious Service Medal and the Distinguished Flying Cross, both from the Air Force. He has also received the Intelligence Star twice, NASA's Outstanding Leadership Award and the Presidential Rank of Meritorious Executive. He is an Associate Fellow of the Society of Experimental Test Pilots and a charter member of the federal government's Senior Executive Service.

APPENDIX C

Five-Year Plan



	Task Name	
1	**Atmosphere**	
2	GloPac	GH
3	ASCENDS development	DC-8
4	GEO-CAPE simulation	ER-2,WB-57
5	MACPEX	WB-57
6	PACE phase 1	WB-57,ER-2
7	NSF DC3	Kepler DC-8
8	PACE phase 2	DC-8,ER-2,WB-57
9	PODEX	ER-2
10	ACM	DC-8,WB-57, GH
11	**Carbon Cycle & Ecosystems**	
12	HyspIRI sig dev	
13	AVIRIS CONUS	Twin Otter, ER-2
14	UAVSAR - Eco structure	G-III
15	LVIS CONUS	B-200
16	AVIRIS CONUS	ER-2, Twin Otter
17	UAVSAR - Eco structure	G-III
18	AVIRIS CONUS	ER-2, Twin Otter
19	HyspIRI - AVIRIS/MASTER	ER-2
20	pre-TEX	
21	UAVSAR - Eco structure	G-III
22	LVIS CONUS	B-200
23	UAVSAR - Eco structure	G-III
24	AVIRIS CONUS	ER-2, Twin Otter
25	LVIS-GH CONUS	B-200
26	HyspIRI - AVIRIS/MASTER	ER-2
27	UAVSAR Eco-structure	G-III
28	TEX	
29	LVIS-GH CONUS	B-200
30	AVIRIS CONUS	ER-2, Twin Otter
31	AVIRIS CONUS	ER-2,Twin Otter
32	LVIS-GH CONUS	B-200
33	AVIRIS CONUS	ER-2,Twin Otter
34	**Climate**	
35	OIB - Antarctica	DC-8
36	OIB - Greenland	P-3, DC-8
37	OIB - Antarctica	DC-8
38	OIB - Greenland	P-3, DC-8
39	UAVSAR cryo	G-III
40	OIB - Antarctica	GH,DC-8
41	OIB - Greenland	P-3,DC-8
42	Ocean Salinity (Spring)	P-3
43	Ocean Salinity (Fall)	P-3
44	OIB - Antarctica	DC-8
45	OIB - Greenland	P-3
46	UAVSAR cryo	G-III,GH
47	OIB - Antarctica	GH,DC-8
48	OIB - Greenland	P-3
49	OIB - Antarctica	GH,DC-8
50	OIB - Greenland	P-3
51	OIB - Antarctica	GH,DC-8
52	**Water & Energy**	
53	HEX	Twin Otter, P-3, UAVSAR
54	SMAPVEX-10	P-3, Twin Otter, G-III, UAVSAR
55	SMAPVEX-11	P-3, Twin Otter, G-III, UAVSAR
56	Monsoon	DC-8, ER-2
57	SMAPVEX-13	G-III, UAVSAR
58	SMAPVEX-14	P-3, Twin Otter, G-III, UAVSAR
59	**Earth Surface & Interior**	
60	UAVSAR for Faults/Landslides	G-III
61	UAVSAR for Volcanoes	G-III
62	Earthscape	G-III
63	DESDyni demo - C Seq	G-III
64	USGS/NASA Lidar survey	Lear 25
65	Rapid Response	G-III
66	High Altitude Lidar Mapping	WB-57
67	**Weather**	
68	GRIP precursor	GH
69	GRIP	DC-8, GH
70	GPM alg dev	ER-2
71	GPM alg dev	DC-8
72	NAMMA 2/GPM alg dev	DC-8, GH, ER-2
73	GPM Cal/Val	DC-8
74	**Applied Science**	
75	USFS/NASA Fire Imaging	Ikhana, B-200
76	UAVSAR for levees	G-III
77	UAVSAR for subsidence	G-III
78	**Other**	
79	SARP II	DC-8
80	HWC Costa Rica	DC-8
81	HWC Darwin	DC-8
82	**Instrument Development & Testing**	
83	CO2 laser sounder - Abshire	DC-8, Lear-25
84	AirMSPI - Diner	ER-2
85	GOLD - Har	GH
86	DESDyni - LVIS/Steerable Lidar	Twin Otter
87	ASCENDS - Browel/Abshire/Spiers	DC-8
88	ACE - 3 polarimeters	ER-2, P-3
89	ACE - HSRL	ER-2
90	SWOT - HAMSR	GH
91	GEOCAPE - FTS/simulator	WB-57
92	Wind Lidar - Kawaya	DC-8
93	BA Wind Lidar - Grund	WB-57
94	TIR Imaging Spec - Hall	Twin Otter
95	CO2 Lidar - Heaps	DC-8
96	MW limb sounder - Stek	WB-57
97	HyTES - Hook	Twin Otter
98	EMAS - Myers	ER-2
99	LVIS-GH - Blair	GH
100	UAVSAR/GH - Naftel	GH
101	AVIRIS 2 - Green	ER-2, Twin Otter
102	Flash Lidar - Weimer	Utah Twin Engine
103	SMLA - Yu	Lear 25
104	PRISM - Azkos	ER-2
105	Twilite/DAWNAIR1 - Gentry/Kawaya	ER-2

APPENDIX D

ASP Bibliography Project

NSERC began working on a NASA Airborne Science bibliography in September 2007. Scopus (www.scopus.com), an on-line database product of Elsevier Publishing Co., was used to conduct the search. Scopus currently contains 33 million references and is continuously updated. References date back to 1869. Scopus contains references from 15,000 peer-reviewed journals representing all the sciences, in addition to conference proceedings, book series, trade publications, and other sources.

Keywords were provided by NASA's Airborne Science Program, and were searched in both acronym and expanded form. A list of keywords used is given below. From the keyword searches, 1,357 journal articles, 244 conference papers, and 53 review papers were found. Each journal article abstract was read to confirm its relevance to NASA Airborne Science. As of November 2009, the tally for the number of citations related to journal articles is 15,437. The content of journal articles and conference proceedings published during 2009 included the CAMEX, INTEX, NAMMA, CRYSTAL-FACE, AVE, STRAT, TC4, ARCTAS and ATV-1 Jules Verne missions.

The bibliography is constructed as an Excel file that can be sorted on many different parameters including year published, author and research aircraft. This file can be accessed at www.nserc.und.edu/missions/ASbiblio.html. References dating from 1979 to November 2009 are represented.

The information compiled to date is likely incomplete. Scopus is not able to conduct full-text search of references. Thus, if a keyword is not present in the abstract or title of a reference, the reference will be absent from bibliography as-is. Work will continue to locate additional NASA Airborne Science references. Plans for improving the bibliography include searching on more variations of the keywords; searching for key authors; and searching in alternate databases.

Key words used for SCOPUS and Scirus search:

1. African Monsoon Multidisciplinary Analyses (AMMA/NAMMA)
2. Airborne Antarctic Ozone Experiment (AAOE)
3. Airborne Arctic Stratospheric Expedition (NASA AASE)
4. Airborne Southern Hemisphere Ozone Experiment (ASHOE)
5. Arctic Mechanisms for Interaction Between Surface and Atmosphere (AMISA)
6. Arctic Research of the Composition of the Troposphere (ARCTAS)
7. ATV-1 Jules Verne
8. Aura Validation Experiment (AVE/NASA AVE/CR-AVE)
9. Cirrus Regional Study of Tropical Anvils and Cirrus Layers (CRYSTAL-FACE)
10. DC 8 mission
11. DC-8
12. ERAST
13. Intercontinental Chemical Transport Experiment (INTEX/INTEX-A/INTEX-B)
14. KWAJEX
15. Measurement for Assessing the Effects of Stratospheric Aircraft (MAESA)
16. NASA Convection And Moisture Experiment (NASA CAMEX)
17. NASA DC 8
18. NASA DC-8
19. NASA ER-2
20. NASA ERAST
21. NASA Ozone and Nitrogen Experiment
22. NASA P-3B
23. NASA POLAR AVE

24. NASA POLARIS
25. NASA SAGE III
26. NASA SASS Ozone and Nitrogen Experiment
27. NASA SPADE
28. NASA TC4
29. NASA Tropical Cloud Systems and Processes
30. NASA WB-57
31. Ozone Loss and Validation Experiment
32. Photochemistry of Ozone Loss in the Arctic Region in summer
33. Polar Aura Validation Experiment
34. SASS Ozone and Nitrogen Experiment
35. Southern African Regional Science Initiative
36. Stratospheric Photochemistry Aerosol and Dynamics Experiment (SPADE)
37. Stratospheric Tracers of Atmospheric Transport (STRAT)
38. Stratospheric Troposphere Exchange Project
39. Tropical Cloud Systems and Processes
40. Tropical Ozone Transport Experiment
41. Twin Otter
42. Vortex Ozone Transport Experiment

APPENDIX E

Acronyms & Abbreviations

A

AAFEx	Alternative Aviation Fuel Experiment
AAPS	Air Particulate Sampler
ACE	Aerosol Cloud Ecosystems
ACCLAIM	Advanced Carbon and Climate Laser International Mission
AESMIR	Airborne Earth Science Microwave Radiometer
AFB	Air Force Base
AGU	American Geophysical Union
AIAA	American Institute of Aeronautics and Astronautics
AIRSAR	Airborne Synthetic Aperture Radar
AITT	Airborne Instrument Technology Transfer
AMISA	Arctic Mechanisms of Interaction between Surface and Atmosphere
AMMA	African Monsoon Multidisciplinary Analyses
AMS	American Meteorological Society
AMS	Autonomous Modular Sensor
AOD	Aerosol Optical Depth
ARC	Ames Research Center
ARM AAF	Atmospheric Radiation Measurement Aerial Facility
ARM CF	Atmospheric Radiation Measurement Central Facility
ARMD	Associate Administrator of Aeronautics Research Mission Directorate
ARRA	American Recovery & Reinvestment Act
ASCENDS	Active Sensing of CO_2, Emissions over Nights, Days and Seasons
ASF	Airborne Sensor Facility
ASTER	Advanced Spaceborne Thermal Emission & Reflection Radiometer
ASP	Airborne Science Program

ATM	Airborne Topographic Mapper
AVIRIS	Airborne Visible & Infrared Imaging Spectrometer
AVOCET	Atmospheric Vertical Observations of CO2 in the Earth's Troposphere
AXCTD	Airborne eXpendable Conductivity Temperature Depth

B

BGAN	Broadband Global Area Network
BPA	Blanket Purchase Agreement

C

CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarization
CALIPSO	Cloud Aerosol Lidar & Infrared Pathfinder Satellite Observation
CASIE	Characterization of Arctic Sea Ice Experiment
CDE	Collaborative Decision Environment
CDF	California Department of Forestry
CeNAT	Costa Rican National Center for Advanced Technology
CEODE	Center for Earth Observation & Digital Earth
CH_4	Methane
CHAPS	Cumulus-Humilus Aerosol Processing Study
CIMH	Caribbean Institute for Meteorology
CIRES	Cooperative Institute for Research in Environmental Sciences
CIRPAS	Center for Interdisciplinary Remotely-Piloted Aircraft Studies
CLASIC	Cloud & Land Surface Interaction Campaign
CMU	Carnegie Mellon University
CO	Carbon monoxide
CO_2	Carbon dioxide
COA	Certificate of Authorization
CPL	Cloud Physics Lidar

D

DACOM	Differential Absorption CO Measurement
DAOF	Dryden Aircraft Operations Facility
DAWN	Doppler Aerosol Wind [lidar]

DCS	Digital Camera System
DESDynI	Deformation, Ecosystem Structure and Dynamics of Ice
DFRC	Dryden Flight Research Center
DHS	Department of Homeland Security
DLH	Diode Laser Hygrometer
DMS	Digital Mapping System
DOD	Department of Defense
DOE	Department of Energy
DOE LBNL	Department of Energy Lawrence Berkeley National Laboratory
DSS	Decision Support System

E

EIP	Experimenter Interface Panel
ENVISAT	Environment Satellite
eMAS	Enhanced MODIS Airborne Simulator
EMVIS	Environmental Mapping Visible Imaging Spectrometer
EOS	Earth Observing System
EPA	Environmental Protection Agency
ESA	European Space Agency
ESPO	Earth Science Project Office
ESTO	Earth Science Technology Office
EUFAR	European Fleet for Airborne Research
ESRP	Ecosystem Services Research Program

F

FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FOR	Flight Operations Room
FT	Fisher/Tropsch

G

GABRS	General Aviation Baseline Research System
GE	General Electrics
GHOC	Global Hawk Operations Center
GISMOS	Global Integrated Sustainability MOdel

GLISTIN	Glacier and Land Ice surface Topography Interferometer
GloPac	Global Hawk Pacific
GOLD	Global Ozone Lidar Demonstrator
GPS	Global Positioning System
GRIP	Genesis & Rapid Intensification Processes
GSFC	Goddard Space Flight Center
GSPRS	GPS Remote Sensor

H

$H_2O(v)$	Water vapor
HAPS	Hazardous air pollutants
HATS	High Altitude Telemetry Sensor
HI-WRAP	High Altitude Imaging Wind & Rain Profiler
HSRL	High Spectral Resolution LIDAR
HSRL	Histo-Scientific Research Laboratories
HyperOCR	Hyperspectral Ocean Color Radiometers
HUREX	Hurricane Exercise

I

ICCAGRA	Interagency Coordinating Committee for Airborne Geosciences Research and Applications
ICECAP	International Climate & Environmental change Assessment Project
ICESat	Ice, Cloud and Land Elevation Satellite
ICF	Instrument Check Flights
IIP	Instrument Incubator Project
INTEX	Intercontinental Chemical Transport Experiment
IRAD	Internal Research & Development
IPY	International Polar Year
ISPRS	International Society for Photogrammetry and Remote Sensing
ISRSE	International Symposium on Remote Sensing of Environment
IWGADTS	Interagency Working Group for Airborne Data and Telecommunication System

J

JASSIWG	Joint Airborne Science Sensor Integration Working Group

JP-8	Jet fuel
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center

K

KaSPAR	Ka-band SWOT Phenomenology Airborne Radar

L

LAC	Large Area Collectors
LaRC	Langley Research Center
LIDAR	Laser Imaging Detection & Ranging
LSP	Launch Services Program
LVIS	Laser Vegetation Imaging System

M

MACC	Multi-Agency Coordination Center
MACPEX	Mid-latitude Airborne Cirrus Properties Experiment
MANPADS	Man-Portable Air Defense Systems
MAS	Modis Airborne Simulator
MAST	Multi-mission Advanced Sensor Testbed
MASTER	Modis/Aster Airborne Simulator
MCoRDS/I	Multichannel Coherent Radar Depth Sounder
MERIS	Medium Resolution Imaging Spectrometer
MODIS	Moderate Resolution Imaging Spectrometer
MOU	Memorandum of Understanding
MPCS/PDU	Master Payload Control System/Power Distribution Unit
MSU	Missouri University of Science and Technology

N

N_2O	Nitrogen oxide
NAS	National Academy of Science

NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASDAT	NASA Airborne Science Data & Telemetry
NCAR	National Center for Atmospheric Research
NGC	Northrup Grumman Corporation
NIR	Near IR
NMEA	National Maritime Electronics Association GPS
NOAA	National Oceanic and Atmospheric Administration
NOVICE	Newly-Operating and Validated Instruments Comparison Experiment
NOx	Nitrogen oxides
NRL	Naval Research Laboratory
NSF	National Science Foundation
NSERC	National Suborbital Education and Research Center

O

OIB	Operation ICE Bridge

P

PALS	Passive active L- and S-band (microwave instrument)
PolSCAT	Polarimetric Scatterometer
POR	Payload Operations Room
POS	Position & Orientation Systems
PPA	Platform Precision Autopilot
PPS	Precise Positioning Service
PPS	Pulse per second
PRIAS	National Program for Airborne Research and Remote Sensing
PSR	Polarimetric Scanning Radiometer

Q

QuickSCAT	Quick Scatterometer

R

RACORO	Routine ARM Clouds with Low Optical Radiative Observations
ReSePP	Remote Sensing of Phytoplankton Program
ROTC	Reserve Officers' Training Corps
RSD	Research Services Directorate
RSP	Research Scanning Polarimeter
RTMM	Real Time Mission Monitor
RTVSM	Reduced Vertical Separation Minima

S

SAR	Synthetic Aperture Radar
SARP	Student Airborne Research Program
SIERRA	Sensor Integrated Environmental Remote Research Aircraft
SIMPL	Slope Imaging Multi-polarization Photon-Counting Lidar
SMAP	Soil Moisture Active-Passive
SMD	Science Mission Directorate
SOFIA	Stratospheric Observatory for Infrared Astronomy
SOFRS	Airborne Science Flight Request System
SPS	Standard Positioning Service
SSG	Senior Steering Group
sUAS ARC	small UAS Aviation Rule Making Committee
SUA	Special Use Airspace
SWOT	Surface Water and Ocean Topography

T

TC4	Tropical Composition, Cloud & Climate Coupling Experiment
TCAS	Traffic Collision Avoidance System
THC	Total hydrocarbons
TM	Telemetry
TTL	Tropical Tropopause Layer
TWiLiTE	Tropospheric Wind Lidar Technology Experiment

U

UAPO	Unmanned Aircraft Program Office
UAS	Unpiloted Aircraft Systems
UAV	Unmanned Aerial Vehicles
UAVSAR	Unmanned Air Vehicle Synthetic Aperture RADAR
UCSD	University of California San Diego
UND	University of North Dakota
URS	Uninterruptible power supply
UTRC	United Tech Research Center

V

VIMS	Virginia Institute of Marine Sciences

W

WAS	Whole Air Sampler
WETMAAP	Wetland Education Through Maps and Aerial Photography
WFF	Wallops Flight Facility
WPAFB	Wright-Patterson Air Force Base
WRAP	Wildfire Research and Applications Partnership
WSFM	Western States Fire Mission