National Aeronautics and Space Administration

Airborne Science Program

2008 Annual Report

On the cover:

In the foreground are images of the NASA Airborne Science fleet. In the background is an image of sea ice break-up taken on April 12, 2008 during a low altitude pass over the Bering Sea during the ARCTAS Mission. Note the shadow of the DC-8 on the snow surface.

NASA Science Mission Directorate
Earth Science Division

AIRBORNE SCIENCE PROGRAM: FY08 ANNUAL REPORT

MARCH 2009

http://airbornescience.nasa.gov

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CONTRIBUTORS

The contribution of the following people to the development of this Annual Report is gratefully acknowledged: Randy Albertson, Vince Ambrosia, Gailynne Bouret, Larry Camacho, Ken Cockrell, Bruce Coffland, Michael Craig, Jim Crawford, Bob Curry, Frank Cutler, Steve Dinardo, Dave Easmunt, Michael Eastwood, Mike Gaunce, Michael Goodman, Anthony Guillory, Steve Hipskind, Chris Hostetler, Tom Mace, Brenda Mulac, Jeff Myers, Chris Naftel, Robert Navarro, Alexandra Novak, Steve Platnick, Tom Rigney, Andy Roberts, Susan Schoenung, Chris Scofield, Gary Shelton, Kent Shiffer, Rick Shetter, Ole Smistad, Bob Smith, Carl Sorenson, Geary Tiffany, Sue Tolley, John Valliant, Marilyn Vasques, Paul Windham, Rick Yasky, and Michael Zolensky.

EXECUTIVE SUMMARY

The Airborne Science Program had a good year in FY08. Our flight hours were up by over 60% from last year, yielding a far greater amount of data to the science community. Our program budget was leveled from its planned rapid decline. The international and interagency ARCTAS mission, NASA's major International Polar Year contribution, was accomplished in a highly successful manner, covering a major portion of the western Arctic region from Alaska to Europe. We brought the Dryden Airborne Operations Facility on line. We obtained two Global Hawk aircraft, and in FY09, we plan to fly their first missions. We successfully completed the G-III UAVSAR development program with approval to transition to science operations. The SIERRA aircraft completed its test flight series, and is now preparing for its first international science mission in FY09. We are providing leadership to the interagency ICCAGRA organization, which is producing real results, as we standardize our payload to aircraft interfaces with other agencies, as well as establishing a true real-time satcom capability throughout our aircraft fleet, which allows us to redirect our aircraft in flight, sharing data between the ground, air, and satellites simultaneously.

We have started a process for the standardization of payload interfaces between centers, which is a real paradigm shift, and which, when completed, will provide our science customer with real portability of sensors across centers and platforms. We have also extended our leadership on the global stage working with our international counterparts to coordinate our activities on climate change, allowing us to better support the science community. Next year, we will be chairing, with our European partners, the new ISPRS Airborne Science Standards Working Group. This is necessary as we operate in a global environment and fly coordinated missions with the international community. We have also jumped into a major leadership role for science uses of Unmanned Aerial Systems. Our education outreach programs are really making a difference, and we will add a student airborne campaign on the DC-8 in FY09 and will continue our WETMAAP programs to train teachers in remote sensing. We have identified over 1500 peer reviewed journal publications and another 15,000 bibliographic citations generated from data obtained by this airborne science program.

Our airborne program is in a unique and ready position to support the successful development of the decadal survey and venture class missions. Our global airborne support, combined with satellite and ground measurements, allows the science community to generate the information needed to advise our policymakers, who in turn lead our society. There is no question that the NASA Airborne Science Program in one of the jewels in NASA's crown. We are the only very high altitude science aircraft fleet, flying routinely above 95% of the atmosphere, with the largest rapidly-configurable flying laboratories.

This report presents a detailed summary of our accomplishments this past year, describing our field campaigns, the status of our fleet and technology development efforts, and our management, collaboration, and outreach to the science community and general public.

INTRODUCTION

It's hard to believe another year has already gone by and we are issuing another Annual Report. We have had a very good year, starting with the stabilization of our budget, which was given an increase of 22% over the next five years. This gives us a steady funding level, instead of the large reductions we were facing. At the same time, we are adjusting our program to add some significant capability in Unmanned Systems, aircraft science payload telecommunication/sensor webs, the UAVSAR project, and our development of standards across our platforms to improve sensor portability and effectiveness.

Much more of our funds were used this year on our core aircraft, the P-3, DC-8, WB-57s and ER-2s. We are improving the capability of the WB-57 to carry more without the loss of range and endurance. There have been significant strides in improving and standardizing the P-3 and DC-8 science station functionality and user interfaces. We are also adding the G-III to our core aircraft. As a part of its modifications to successfully operate the UAVSAR system, it now has the world's most precise autopilot for an aircraft of its class.

Other new technology vehicles, such as the Global Hawks, are now in the NASA inventory and are being prepared for their first science missions next year. This effort is made possible by our partnering with Northrop Grumman and NOAA. Our small SIERRA UAS is also on track for its first international mission next year supporting an International Polar Year research activity. These aircraft will really bring about a paradigm shift in airborne utilization for the science community, with their ability to fly over 11,000 miles and more than 30 hours, or fly down low, inexpensively, with small payloads in dangerous regions. In addition, we have assigned a liaison to the FAA Unmanned Aircraft Program Office to help work out UAS science flight issues. The FAA has also given us a seat in the small UAS aviation rulemaking committee so we are able to have input on the direction and process for getting these vehicles into the National Airspace.

The major airborne mission of the year was ARCTAS, which was a multi-aircraft, multi-agency, international program combining the efforts of three NASA aircraft, a

NOAA and a DOE aircraft, and aircraft from Canada, France, Germany and Russia. This mission was an example of where ASP investments in data transmission and sensor web technologies have really paid off by uplinking and downlinking data from multiple aircraft, while in flight, and then sharing the data between the aircraft, as well as with the ground operations center. This allows a shared flight experience across the distributed science team, maximizing the data return per flight hour.

We have also jumped in to help support the development of the Decadal Survey missions, including SMAP-VEX, PALs, LVIS, MASTER, Western States Fire Missions, Cold Land Process Experiment, AVIRIS, AMISA, UAVSAR and the Antarctica ATM/PARIS. These precursor support flights and missions were accomplished with the use of our core, new technology, and catalog aircraft suite. These earth science missions were augmented with support and funding from other NASA science divisions, Federal and State agencies, and with our international partners.

We flew over much of the globe this year – from Tahiti to the North Pole to Antarctica to Sweden - and based or flew our aircraft over most of the Earth's continents. This international activity would not have been possible without the very professional support we received from NASA's Office of External Affairs and the U.S. State Department.

This year we brought our Palmdale facility online and have already run some major missions from here. This has been a major stabilizing force to the entire Airborne Science Program. As of last year, both the DC-8 and SOFIA, our two biggest science aircraft in NASA, had no permanent housing. With the addition of the Global Hawks at DFRC, space had become an issue for the ER-2s as well. This new facility has contributed significantly to reducing our operational risk while stabilizing the program. By eliminating our aircraft basing uncertainty, the morale improved for those on the frontline, where the consequences of distraction can be lethal.

Our NOVICE project on the WB-57 was very successful in allowing sensors with little flight maturity a chance to demonstrate their capability and improve their operations under actual flight conditions. It is important to note this mission was squeezed between two hurricanes bearing down on Houston, which speaks to the dedication of our program personnel and the science teams. This small demonstration concept was so successful that additional projects are now being formulated to continue these types of flights for the instrument developers.

Our education and outreach programs are continuing, with the WETMAAP project for K-12, training teachers how to use remote sensing data in their classrooms. Education programs based at the University of North Dakota were also supporting undergraduate and graduate students, developing our future work force in remote sensing systems and applications. In fact, next year, UND participation will reach a new level with the development of a wholly student run airborne campaign on the DC-8.

We are continuing to improve our operations and have started an Airborne Science Recognition Program for our personnel, as the ASP is only as good as the people in it. I really believe we have the best of the best in conducting an airborne science program which is the envy of the international and interagency communities. Now we have a new recognition program to acknowledge those folks who manage to do the 'almost impossible' everyday and make it look easy.

We never forget that the scientists are our customers who fund us to help them collect their data using suborbital assets. The members of the ASP team know that the funds we get from the science world could be used in other ways. We all feel the scientists are our advocates and have determined these assets are making a difference for them. We look forward to providing them more, and unique, ways to get the data needed to meet their objectives in the most cost effective manner possible.

Andrew Roberts
Airborne Science Program Director

SCIENCE MISSIONS &

ACCOMPLISHMENTS

ARCTAS

The Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) field campaign represented NASA's largest commitment to atmospheric research in support of the International Polar Year (IPY). Sponsored by NASA's Tropospheric Chemistry and Radiation Science programs, ARCTAS consisted of major field campaigns in the spring and summer of 2008, involving the deployment of three NASA research aircraft to the Arctic to characterize atmospheric change in this climate-sensitive region. The NASA effort contributed to a larger interagency and international effort identified as POLARCAT (Polar Study using Aircraft, Remote Sensing, Surface Measurements and Models, of Climate, Chemistry, Aerosols, and Transport).

ARCTAS science objectives addressed four major themes:

1. Long-range transport of pollution to the Arctic including arctic haze, tropospheric ozone, and persistent pollutants, such as mercury.

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ARCTAS Science Teams

Figure 1
DC-8 ARCTAS Project Team in Fairbanks, AK.

Figure 2
(Above) NASA Langley team based from Barrow, Alaska, including HSRL science and B-200 flight operations personnel.

Figure 3
(Left) Group photo of P-3 instrument, forecasting, mission science, and ARCTAS management teams, Cold Lake, Alberta, July 2008.

Figure 4
DC-8 Arrival in Thule, Greenland, April 4, 2008. The DC-8 remained in Thule overnight and returned to Fairbanks the following day.

2. Boreal forest fires and their implications for atmospheric composition and climate.
3. Aerosol radiative forcing from arctic haze, boreal fires, surface deposited black carbon, and other perturbations.
4. Chemical processes with focus on ozone, aerosols, mercury, and halogens.

The ARCTAS experiment centered on three NASA aircraft, the DC-8, P-3B and B-200. The DC-8 flew 184 total flight hours in 22 sorties with a payload of 21 scientific instruments examining chemistry and aerosols. The P-3B logged 178 flight hours with 21 sorties consisting of a payload of nine instruments examining radiation and aerosols. The B-200 flew 176 flight hours over 48 sorties with the High Spectral Resolution Lidar (the primary validation instrument for CALIPSO) and the Research Scanning Polarimeter (the airborne simulator for the GLORY satellite instrument). These aircraft, along with ground sites and support staff, involved over 300 scientists and associates across eight NASA installations, 12 Universities, three government labs, and numerous support organizations. The extent of satellite, aircraft and ground coordination with observations, and use of real-time information transfer between and among the aircraft and ground to achieve the science and validation goals during ARCTAS was unprecedented.

The Project Scientists for the ARCTAS mission were Dr. Daniel Jacob of Harvard University and Dr. Hanwant Singh of NASA Ames. The Platform Scientist for the DC-8 was Dr. Jack Dibb of the University of New Hampshire. The Platform Scientist for the P-3 was Dr. Phil Russell of NASA Ames. For the B-200, the Platform Scientists were Dr. Chris Hostetler and Dr. Richard Ferrare of NASA Langley. The Chief Meteorologist was Dr. Henry Fuelberg of Florida State University.

Spring Phase

During the spring, aircraft deployed to Fairbanks and Barrow, AK to examine arctic haze associated with long-range transport of pollution from mid-latitudes. During this phase of the mission, NASA aircraft, along with partner aircraft from NOAA and DOE, documented polluted arctic airmasses of North American, Asian, and European origin. Flights were guided by forecasts from chemical transport models, were integrated with satellite overpasses by NASA's Aura, Aqua, CALIPSO, and Terra satellites, and were supplemented by ground observations at numerous Arctic research sites (e.g., Canadian and U.S. ozonesonde stations, Aeronet sites, Summit Greenland station, etc.). The data collected will improve future satellite monitoring of Arctic change and will aid the development of models that are better equipped to predict future changes in the arctic associated with atmospheric composition and climate. A notable early scientific result from the spring mission is the apparent discrepancy in satellite observations of BrO by Aura's OMI instrument. Aircraft observations of BrO and ozone exhibit concentrations and distribution patterns that indicate the need to reexamine satellite assumptions governing the retrieval of this important indicator of springtime halogen chemistry, which is a major driver of near-surface ozone variability.

Summer Phase

During the summer phase, the three aircraft and a portable ground station called NATIVE deployed to Cold Lake, Alberta and to Yellowknife, in the Northwest Territories. The summer flights documented the impact of boreal fires at high northern latitudes by sampling near-field and downwind emissions from Canadian wildfires, as well as long-range transport of smoke and trace gases from fires in Siberia and Northern California. Observations were coordinated with partner aircraft from Germany and France, which were based in Greenland, to

Figure 5
Dr. Henry Fuelberg of Florida State University presents the daily weather brief from the University of Alaska in Fairbanks.

sample downwind evolution of Canadian fire emissions. Observations examined smoke aerosols, chemistry, radiative impacts, and the height of fire plumes. These data are already improving the capability of satellites such as CALIPSO to distinguish between clouds and thick smoke from fires. Data collected on the height of fire plumes is of particular significance for improving models, as this is the single-most important variable for determining downwind transport patterns.

California Air Resources Board (CARB) Flights

The DC-8 and P-3B also performed a short series of flights sponsored by, and in collaboration with, the California Air Resources Board to examine greenhouse gas emissions and air quality across the state of California. These flights were unique in several respects. Flights were able to examine areas typically inaccessible to research aircraft with extensive low-level flight in polluted areas in the Los Angeles basin and Central Valley areas, as well as several missed approaches at Los Angeles International Airport. The unexpected and intense wildfires in California provided an important contrast with the boreal fires observed later in Canada. Ultimately, the data collected during these flights will help California better understand local sources and the relative importance of upwind influences on air quality (e.g., transport from Asia and emissions from offshore shipping).

URL: http://www.espo.nasa.gov/arctas

Figure 6
NOAA P-3, NASA P-3, and NASA DC-8 in a panoramic image at the Fairbanks International Airport.

Decadal Survey Support Missions

In 2007, the National Research Council published its Decadal Survey report entitled, "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond," in which fifteen new NASA satellite missions were recommended. As the Science Mission Directorate has worked during 2008 to address these missions, establishing science teams and planning and designing the missions, the Airborne Science program has worked in parallel to prepare to support the new missions.

The Airborne Science Program flew a number of science missions and instrument test flights in FY08 comprising approximately 190 flight hours that support development of systems for upcoming Decadal Survey science missions. These include:

- PALS instrument on the Twin Otter as part of SMAPVEX 08, in support of the Surface Moisture Active Passive (SMAP) mission. MAPIR and other instruments were also flown on the P-3, also as part of SMAPVEX 08.

- AVIRIS instrument on the ER-2 over the Sierra Nevada, Monterey Bay, and other locations, as a precursor to HYSPIRI flights planned for 2009.

- LVIS instrument on the B-200 as a demonstration of capabilities suitable for DESDYNI.

- ACCLAIM instrument on the Langley UC-12 and Learjet 25 in test and preparation for ASCENDS instrument selection. (See Fig. 7)

- SIMPL instrument on the Learjet 25 and ER-2 (future) for Lidar mapping, as a forerunner to LIST, and a demonstration for potential ICESAT gap-filler missions.

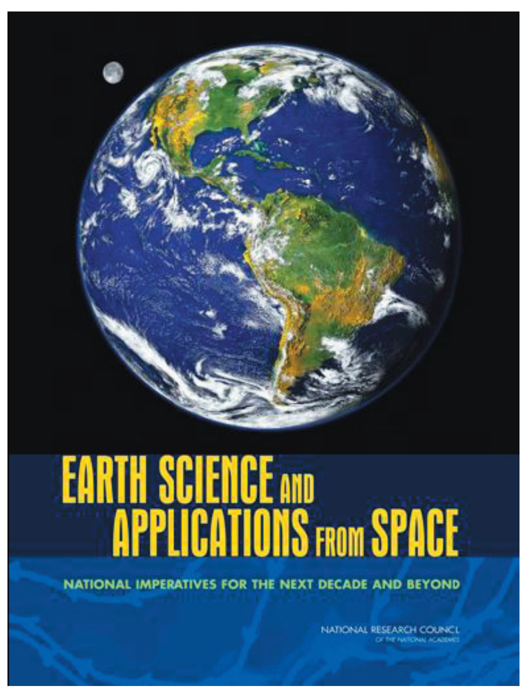


Figure 7
ACCLAIM instrument on the Lear-25 (left), as it flew in October 2007.

Passive Active L-band System (PALS)

SMAPVEX08 included the JPL/NASA Passive Active L-band System (PALS), a time shared radiometer and radar instrument. For SMAPVEX08, PALS was installed on a NASA contracted aircraft (Twin Otter- deHavilland DHC-6 aircraft) along with three additional radiometer back ends, a University of Michigan Agile Digital Detector, a University of Iowa L-Band Interference Suppressing Radiometer, and the NASA GSFC Analog Double Detector.

PALS successfully completed 12 data flight hours over Ames, Iowa and 37 data flight hours over Maryland's Choptank soil moisture project site area. In addition, PALS and the three radiometer back ends collected 15 dedicated RFI flights data hours around the Washington area, and 24 transit hours of RFI data.

Airborne Visible Infrared Imaging Spectrometer (AVIRIS)

The Airborne Visible Infrared Imaging Spectrometer (AVIRIS) flew on the Twin Otter for low altitude/high spatial resolution flights in Hawaii in January. From June through August, it flew on the NASA ER-2 for high altitude/high spatial resolution to cover sites in the Western U.S. and Canada, and out of Westover AFB, MA, to cover the central and eastern U.S. and Canada (see p. 63). It then went back on the Twin Otter in September to cover sites in Southern and Central California.

Finally, an opportunity arose in late October to image an algal bloom in Monterey Bay, California. The NASA ER-2 team, without any prior notice or planning, was able to mount the AVIRIS and MASTER on board the aircraft, and within a week, able to successfully collect data. This special opportunity in the fall has helped prepare for HYSPIRI algorithm-development flights, to be teamed again with MASTER flights planned for 2009.

Laser Vegetation Imaging Sensor (LVIS)

The Laser Vegetation Imaging Sensor (LVIS) payload package flew approximately 36 hours on a B-200 in New Mexico, Nevada, and California in 2008 in preparation for support of the upcoming DESDynI mission. The LVIS team also used this flight opportunity to demonstrate a new 10-bit, high-speed waveform digitizer that is being investigated for use on the DESDynI Lidar, perform an atmospheric delay experiment, and to collect data along GLAS tracks and Long Valley Caldera.

Full-waveform, 25 m footprint lidar data was collected over a variety of vegetation cover types and topographic slopes to determine the impact of off-nadir pointing on measuring vegetation canopy heights and vertical structure with a lidar. Under the currently planned design, the DESDynI mission consists of a multi-beam, 25 m footprint lidar and an Interferometric Synthetic Aperture Radar (InSAR). If both instruments are flown on the same spacecraft platform and in a short repeat orbit, the lidar will need to point off-nadir by up to 16 degrees to achieve global coverage at the required spatial resolution. The data from this flight series is still being analyzed. If this experiment, data, and the associated modeling efforts determine that the scientific impact of off-nadir pointing is too large, then DESDynI will have to be implemented as two separate spacecraft, one for the InSAR and one for the lidar.

Advanced Carbon dioxide and Climate LAser International Mission (ACCLAIM).

The ACCLAIM instrument flew locally on the LaRC UC-12 (similar to the LaRC B-200) on 11 flights between September 23 and October 30, 2008. The flight tracks were over southeastern Virginia and northeastern North Carolina, and each flight lasted about three hours (33.8 hours total). ACCLAIM had also previously flown on the Learjet 25 in 2007.

The purpose of the campaign was to conduct airborne validation of the remote measurements of carbon dioxide (CO_2) with the ACCLAIM system. In situ measurements of CO_2 were also made on this aircraft, and spiral maneuvers were done at the center of the flight track for comparison with the remote ACCLAIM CO_2 column measurements. This is a critical step in the development and demonstration of the laser/lidar system that is going to be used for global measurements of CO_2 as part of the ASCENDS (Active Sensing of CO_2 Emissions over Nights, Days, and Seasons) mission.

The results from this flight campaign demonstrated that the ACCLAIM instrument can make CO_2 column measurements with high precision and high accuracy (better than 0.75% or 3 ppm of CO_2). These were the first high quality, remote, laser measurements of CO_2 made from an airborne platform.

Swath Imaging Multi-polarization Photon-counting Lidar (SIMPL)

SIMPL was flown on the Glenn Research Center Learjet 25 in 2008 on an engineering test flight to test electrical and mechanical configurations and interfaces. SIMPL is a multi-beam, push-broom, photon-counting laser altimeter that operates at 532 nm and 1064 nm wavelengths. An augmentation being considered for the ICESat-II Decadal Survey Mission is a multi-beam, photon counting laser altimeter operating at 532 nm. The SIMPL data will provide valuable insights into the benefits of this measurement approach for the ICESat-II mission. In the longer term, the efficiencies of photon counting provide a potential pathway to achieving the demanding goal of the Lidar Surface Topography (LIST) mission. LIST is a third tier Decadal Survey mission for global, high-resolution laser altimeter mapping of the Earth.

Beginning in 2009, the various Decadal Survey science mission teams will initiate calibration/validation plans, instrument flight test schedules, and in some cases, algorithm development flight programs. The ASP is preparing a requirements document based on a survey of these missions to collect the needs of the science teams and assess and allocate airborne support for these missions in the coming years.

Aerosonde Tropical Storm Observations

Science Focus: Weather
Sponsor: NOAA, A. Roberts, NASA HQ
Location: Atlantic Ocean, Barbados

The Aerosonde Unmanned Aerial System (UAS) was chosen to be part of the NOAA/NASA UAS Hurricane Demonstration Project with evaluation flights beginning in 2005. On September 16, 2005, an historic ten-hour Aerosonde mission marked the first time detailed observations were provided by a UAS in boundary layer conditions during a tropical storm.

In 2008, the project goals were to fully test and document the capabilities and limitations of the Aerosonde platform, provide critical low-altitude wind and thermodynamic data directly to NOAA's National Hurricane Center in real time, and through research and analysis of all the data collected, improve our basic understanding of the hurricane environment to improve future forecasts of hurricane intensity change.

With the demonstrated capacity to operate in hurricane conditions and provide low altitude, in situ observations in a critical region where manned aircraft cannot safely operate, the NOAA, NASA and DOE partners agreed in February 2006 to focus on low-level hurricane winds. The Low Altitude, Long Endurance (LALE) portion of the demonstration project made additional landmark events on November 2, 2007, with a 17.5 hour mission into Hurricane Noel, which directly impacted the National Hurricane Center operational forecast by providing near real-time data. UAS hurricane endurance (17.5 hours) and minimum altitude (82 m) records were also achieved.

The 2008 UAS Hurricane (LALE) demonstration project is a NOAA/NASA partnership which is focused on using small

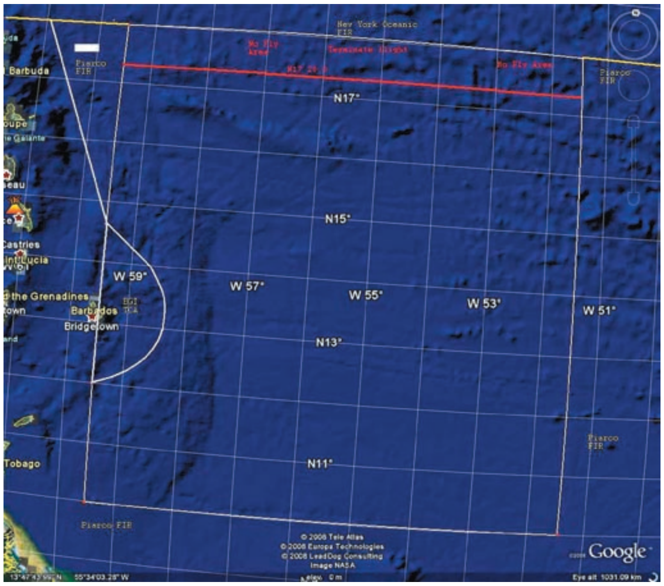


Figure 8
2008 UAS proposed operations area (Atlantic Ocean east of Barbados).

UAS platforms to obtain in-situ measurements in areas that are inaccessible to manned or larger UAS platforms. Dr. Joseph Cione of NOAA is the principal investigator, with support from the NASA Airborne Science Program.

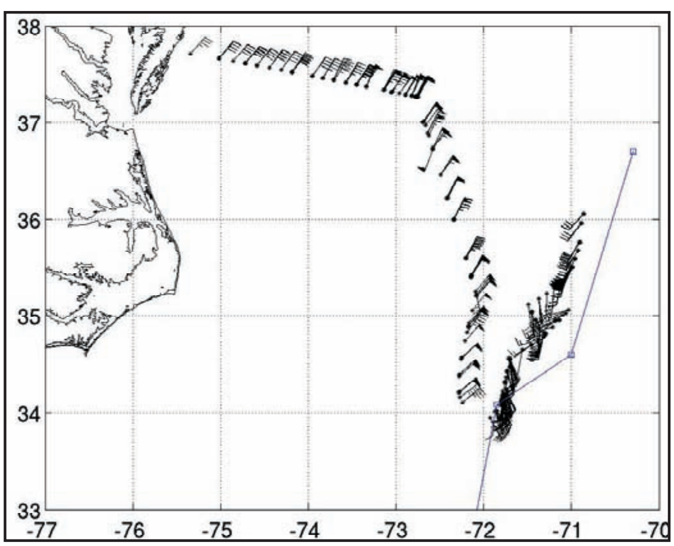


Figure 9
UAS flight path (black/wind barbs) and storm track (blue) into Hurricane Noel on November 2, 2007. Storm intensity at UAS take-off was 65 knots.

The 2008 campaign was based out of Barbados, after a statistical analysis of past storm tracks and matching of available international airspace allowed us to maximize our chances to successfully sample a hurricane. Unfortunately, no storms developed or passed through the operations area during the study timeframe, always a risk for weather-based studies, thus no flights were flown. However, the successful planning and logistics of the 2008 campaign provided a "head start" on next year's mission. Required planning activities now in place include:

- Diplomatic clearances obtained for UAS operations.
- Airspace access with approved operation plans for Barbados, Trinidad & Tobago, and the Piarco Flight Information Region (FIR).
- In-country support from the Barbados Military, Caribbean Institute for Meteorology (CIMH), and the University of West Indies (UWI).

Preparations are now in work for the 2009 mission, which will also be based from Barbados, building on the accomplishments of this year's activities.

AMISA

Science Focus: Climate Variability & Change, Atmospheric Composition
Sponsor: H. Maring, NASA HQ
Location: Arctic, Sweden

DC-8 overflies Swedish icebreaker Oden near North Pole during AMISA mission.

The NASA DC-8 conducted a successful mission in August focusing on the relationship between the atmosphere and Arctic sea-ice. At the conclusion of the summer 2008 ARCTAS mission, the DC-8 was deployed to Kiruna, Sweden to participate in the Arctic Mechanisms of Interaction between Surface and Atmosphere (AMISA) mission.

This mission was a collaborative effort involving scientists from the University of Colorado, NOAA, the University of Leeds, University of Stockholm, NASA Goddard Space Flight Center and the University of North Dakota. The Principal Investigator of the project was Dr. Al Gasiewski, who worked with his team of engineers and students from the Center for Environmental Technology at the University of Colorado, along with mission scientist Dr. Ola Persson of NOAA and the University of Colorado/CIRES, and Co-Investigator Dr. Donald Cavalieri of NASA Goddard Space Flight Center. The investigators were able to use the robust performance and available space on the DC-8 as a platform for integrating a variety of instruments used in detecting both atmospheric processes and sea-ice surface characteristics.

The mission involved five science flights throughout the month of August. Measurements taken during these flights included atmospheric temperature and humidity profiles, sea-ice surface imagery and measurements of atmospheric aerosol

Figure 10
The Oden Research Vessel taken from the NASA DC-8 during an AMISA mission flight. Photo credit: Rick Shetter.

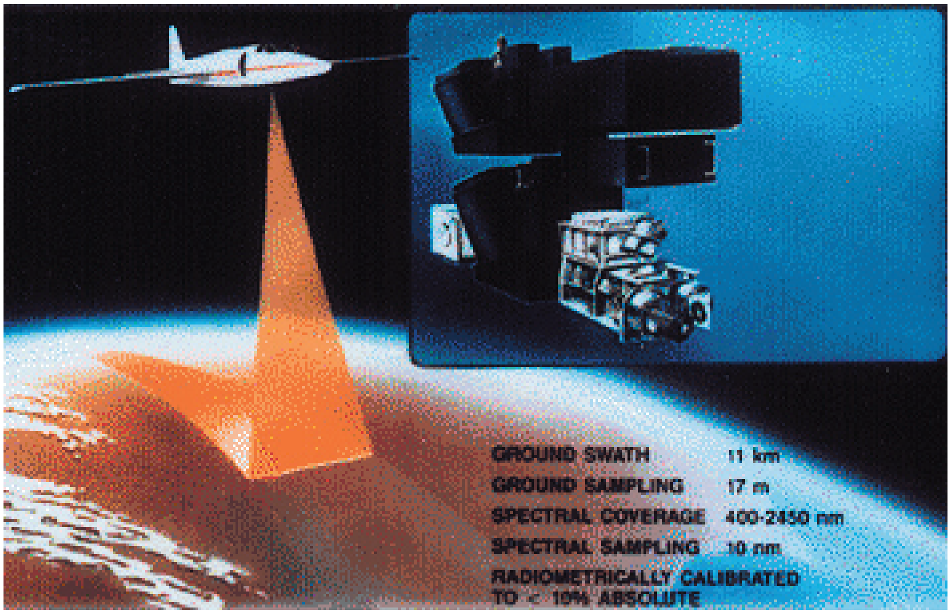
particle properties and their size distribution. These data will be used directly to further the understanding of the relationship between cloud processes, atmospheric radiation and the Arctic climate. They will also be used to test and validate similar measurements taken by NASA satellites.

While on the ground in Kiruna, the DC-8 and its team of scientists and flight crew were housed in the Arena Arctica at the Kiruna Airport, located at 67 degrees North latitude, above the Arctic Circle. The large hangar and environmental science facility served as the deployment site for two previous NASA science field campaigns involving the DC-8, the SOLVE campaign in 2000 and the SOLVE-II campaign in 2003.

The AMISA mission was an International Polar Year (IPY) project organized in conjunction with a related European IPY project, the Arctic Summer Cloud Ocean Study (ASCOS).

URL: http://www.nserc.und.edu/missions/AMISA.html

AVIRIS: Cal/Val



Science Focus: Carbon Cycle & Ecosystems
Sponsor: D. Wickland, NASA HQ
Location: U.S. and Canada

From June 5 through August 14, 2008, a total of 20 AVIRIS science flights were flown on the ER-2, totaling 92.7 flight hours. It included a deployment to Westover ARB, MA, for the month of July. Other data sites included areas in central and southern California, Michigan, Wisconsin, Maryland and Minnesota. AVIRIS data was also collected over experiment sites in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, and Québec, Canada.

The series of AVIRIS flights were initiated with an in-flight spectral, radiometric, spatial, and uniformity calibration and characterization of the AVIRIS imaging spectrometer. The science data gathered over experiment sites included characterization of forest functional types and their role in mediating ecosystem response to environmental change, carbon cycling, vegetation nitrogen status and surface albedo, field validation with seepage from marine, urban and submerged city sources, and live fuel moisture retrieval for Southern California fire danger assessments.

Science data was successfully gathered over all requested experiment sites by the ER-2 team. AVIRIS scientists included Philip Dennison, Dar Roberts, Scott Ollinger, and Phil Townsend. The AVIRIS instrument is managed by JPL (Instrument Manager: Michael Eastwood, Chief Scientist: Robert Green).

URL: http//aviris.jpl.nasa.gov

California Fire Emergency Response

Science Focus: *Applied Science, Disaster Management and Airborne Science*

Sponsor: *S. Ambrose & A. Roberts, NASA HQ*

Location: *California*

The 2008 Northern California Fire Emergency Response Missions were a major component of the Western States UAV Fire Mission – 2008. The mission efforts were supported by the Applied Sciences and the Airborne Science Programs at NASA Headquarters. The focus of the NASA effort was to support technology demonstration missions and infusion with fire management agencies, such as U.S. Forest Service and CalFire.

At the request of the NASA Applied Sciences program, the Wildfire Research and Applications Partnership (WRAP) project team developed a 2008 plan for providing emergency wildfire information to fire agencies during the wildfire season (summer and fall). NASA and FEMA committed to funding approximately 60 flight hours on the Ikhana UAS to support emergency data collection operations with the AMS-Wildfire instrument. The AMS-Wildfire instrument was developed to demonstrate autonomous operations of remote sensing data collection and processing of real-time (Level 2) products from the on-board processors accompanying the instrument. The AMS-Wildfire sensor was configured with critical spectral regions to define hot temperature

Figure 12
The NASA Ikhana UAV is shown with the AMS-Wildfire sensor pod located under the wing during mission operations in early FY2008. The pod can be configured for other instrumentation and mission configurations.

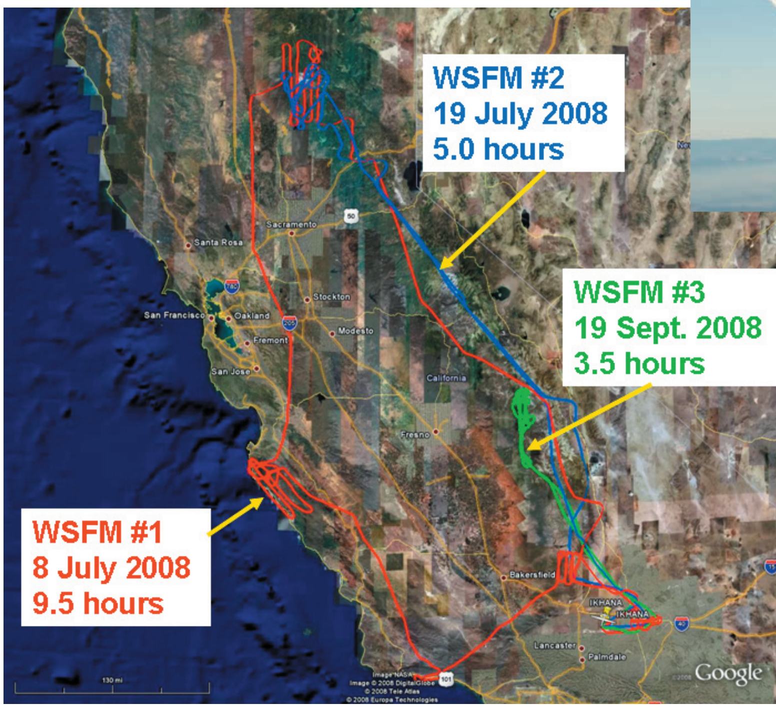


Figure 11
The NASA Ikhana UAS, containing the AMS-Wildfire sensor system flew three primary emergency support missions over the 2008 Northern California firestorm areas. This map displays the location and flight tracks of those missions.

targets, such as those found in wildfire events. The AMS instrument demonstrated real-time delivery of fire imagery and on-board, algorithm-processed, hot-target detection data, as well as burn area assessment data to fire management teams.

NASA was called into service in late June 2008 through requests originating from the California Governor's Office of Emergency Services, CalFire, and FEMA, to support the large number of wildfires burning in Northern California. The Northern California wildfires started in late June, spawned by several hundred lightning strikes in the dry timber forested lands primarily surrounding the northern end of the California Central Valley. Several thousand fires grew together into larger complexes, necessitating the need for airborne reconnaissance over large tracts of land. The NASA missions were planned and flown over those fire complexes with real-time data derived from the sensor, distributed to the Multi-Agency Coordination

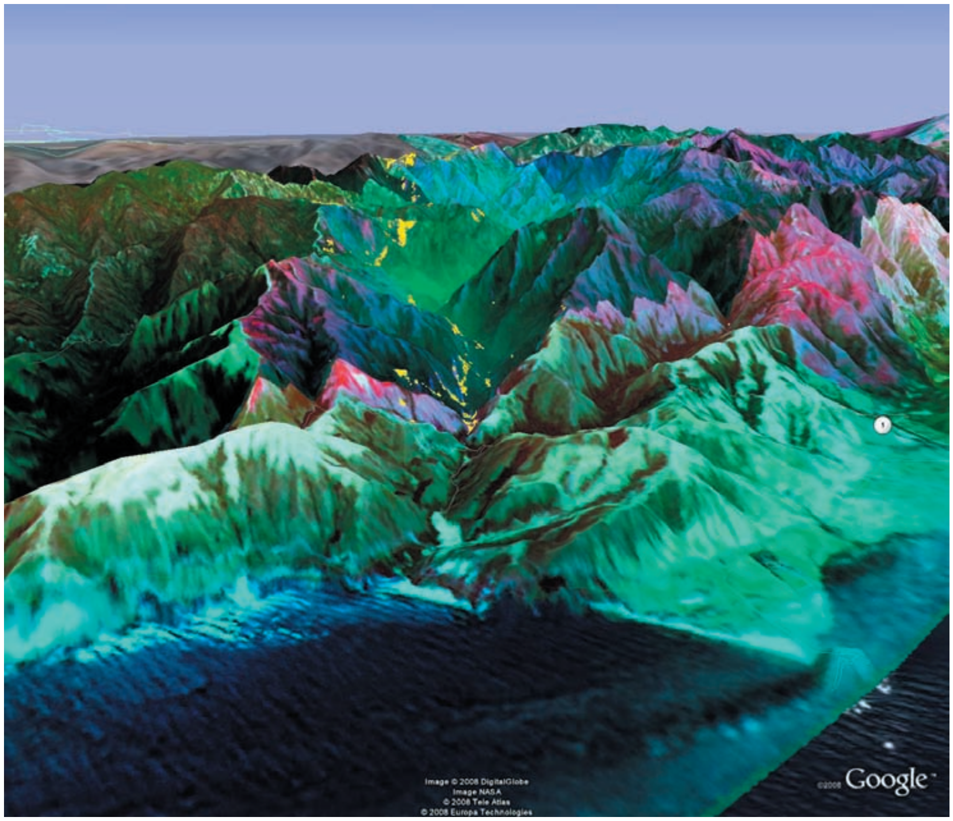


Figure 13
AMS-Wildfire sensor data, collected from the NASA Ikhana UAS over the Basin Fire near Big Sur California on July 8, 2008. This 3D rendering shows the AMS sensor-derived hot spot fire fronts generated from an autonomous, real-time processing algorithm running on processors on the aircraft. The fire front can be seen distinctly burning in the imagery as yellow pixels. This information was delivered in near-real-time to the on-site Incident Command Team.

Center (MACC) in Redding, California and to the Sacramento Area Coordination Center (SACC).

The Ikhana flew four missions over the Northern California fire complexes on July 8 and 19, and September 17 and 19. The July 8 mission flew 9.5 hours, covering the Piute, Clover, Silver, North Mountain, American River, Cub Complex, Canyon Complex, Basin, and Gap fires. The July 19 mission lasted 5.0 hours, covering the American River, Camp, Cub Complex, Canyon, and Piute fire. The September 17 mission (a sensor checkout flight) extended 3.0 hours, supporting the collection of post-fire burn assessment data on the Piute fire. Finally, the September 19 mission flew 3.5 hours, covering the Cascadel and Hidden fires in the central Sierra Nevada.

The wildfire imaging missions again demonstrated the value of real-time, critical sensor–derived information to support federal and state disaster management agencies. Both the NASA-Dryden Ikhana team and the NASA-Ames science sensor team were successful in rapidly integrating, supporting and flying emergency sorties at least six-weeks prior to the original team mission schedule. The missions highlighted the agency's ability to support the disaster management community with readily-adaptable data and information. These missions are helping to foster new collaborations between the State of California and NASA, and to advance NASA-derived airborne technologies for operational use within those agencies. The missions also showcased the capabilities of autonomous on-board sensor processing (development of real-time Level 2 information products), satellite data telemetry, and a Collaborative Decision Environment (CDE) data visualization tool. Each of these capabilities is currently being used and integrated in various stages with the major wildfire management agency.

Vincent G. Ambrosia of NASA Ames is the WRAP project Principal Investigator. Further information on the WRAP project, specifically the 2008 Northern California Ikhana fire missions, can be found at: http://geo.arc.nasa.gov/sge/WRAP.

Southern California Post Fire Evaluation

Science Focus: *Disaster Management*

Sponsors: *S. Ambrose, NASA HQ*
D. Wickland, NASA HQ

Location: *California*

Following the 2007 fire mapping flights in Southern California with the Ikhana UAS, the Airborne Science Program was tasked with collecting a time series of science-grade imagery to document the post-fire conditions at the various sites, and their subsequent recovery over the course of a year.

The MASTER sensor (MODIS/ASTER Airborne Simulator) was flown on a U.S. Dept. of Energy B-200 aircraft over the 14 major fire sites beginning immediately after the fires were extinguished in November, 2007. Repeat collections were performed in April of 2008 following the spring rains, and again during the August dry period, to capture the maximum and minimum soil moisture conditions over the course of one season. Funded by the Earth Science Division R&A Program (Simon Hook, Project Scientist) this effort encompassed a total of 238 flight lines and over 3,000 miles of MASTER data. Researchers at JPL have performed some initial analysis on this unique and extensive data set (over 130 Gbytes,) which is intended to support a variety of studies related to

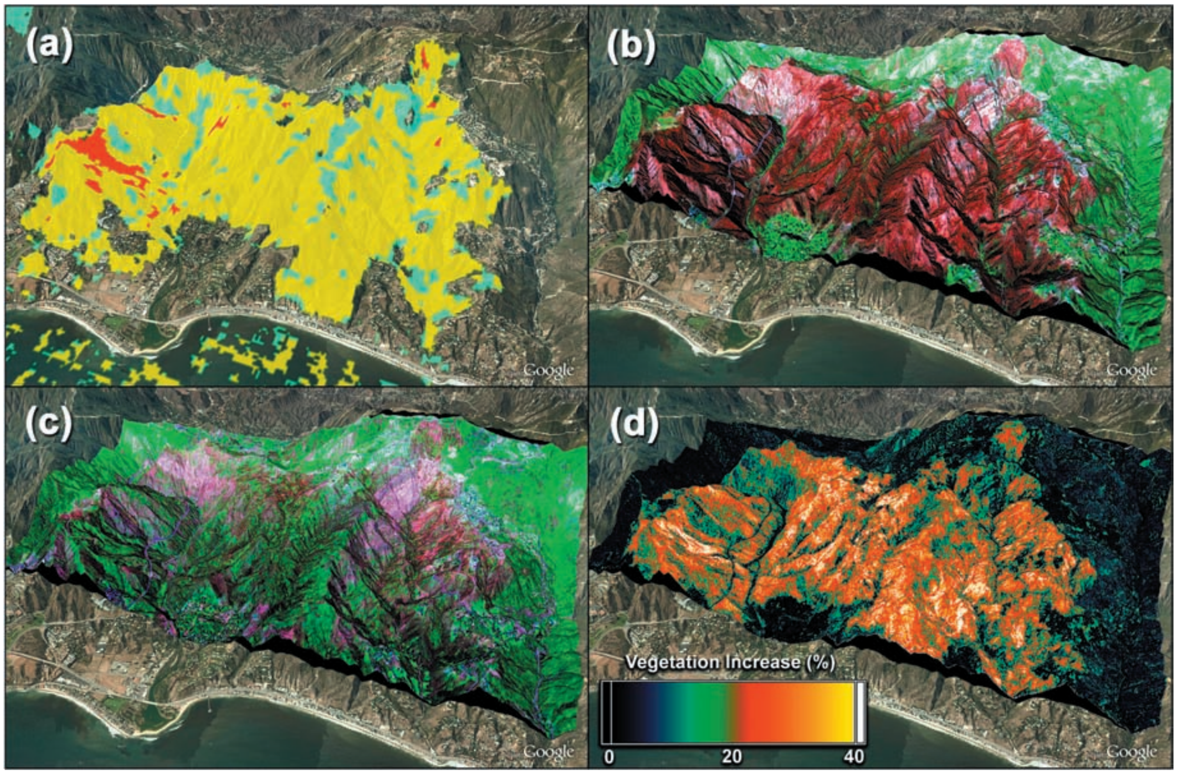
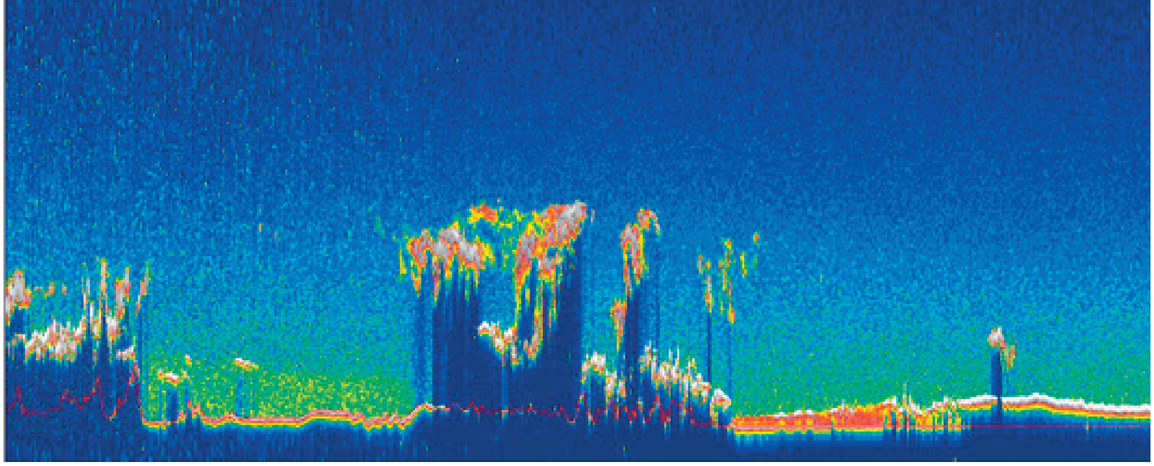


Figure 14
Time-series MASTER imagery of the Canyon Fire site: a) Burned Area Reflectance; b) November, 2007 post-fire IR composite; c) April, 2008 IR composite; d) Vegetation change, 11/07 to 4/08 (Courtesy V. Realmuto, JPL).

carbon and nutrient cycling, and ecosystem response to severe biomass burning events. Proposals for further analysis are expected to be solicited in an upcoming NASA research announcement. The 5-meter resolution geo-located imagery is available to researchers through the NASA DAAC system, or via FTP from the MASTER web site at http://masterweb.jpl.nasa.gov.

CALIPSO: Caribbean Validation Mission



***Science Focus:* Atmospheric Composition**
***Sponsor:* H. Maring NASA HQ**
***Location:* Caribbean**

The LaRC King Air B-200 deployed the High Spectral Resolution Lidar (HSRL) to the Caribbean islands from January 22 through February 3, 2008, for validation of the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) data products from the CALIPSO satellite mission. A flight track map for this mission is shown in Figure 15 (p. 30).

The goal of the science flights was to acquire lidar data with the HSRL to verify the effectiveness of new daytime calibration algorithms being applied to data from the CALIOP lidar. The day calibration algorithms had been adjusted to account for lidar transmit-to-receiver boresight misalignment that occurred as the satellite was heated by the sun on the day side of the orbit. The errors were most pronounced in January in the Northern Hemisphere and peaked near 15° N latitude. The campaign was designed to acquire data from 7° N to 37° N to verify the performance of the correction algorithms over the latitude range where gradients in the boresight-induced errors were the greatest.

The Caribbean region was chosen for the mission based on logistical concerns: achieving the required latitude coverage within the range/duration envelope of the B200. An "island-hopping" strategy was employed to optimally cover the CALIPSO satellite orbit tracks. Temporary bases of operation were located in San Juan, Puerto Rico, St. Croix, U.S. Virgin Islands, and Barbados. The mission, with a total of 13 science flights (42 flight hours), successfully

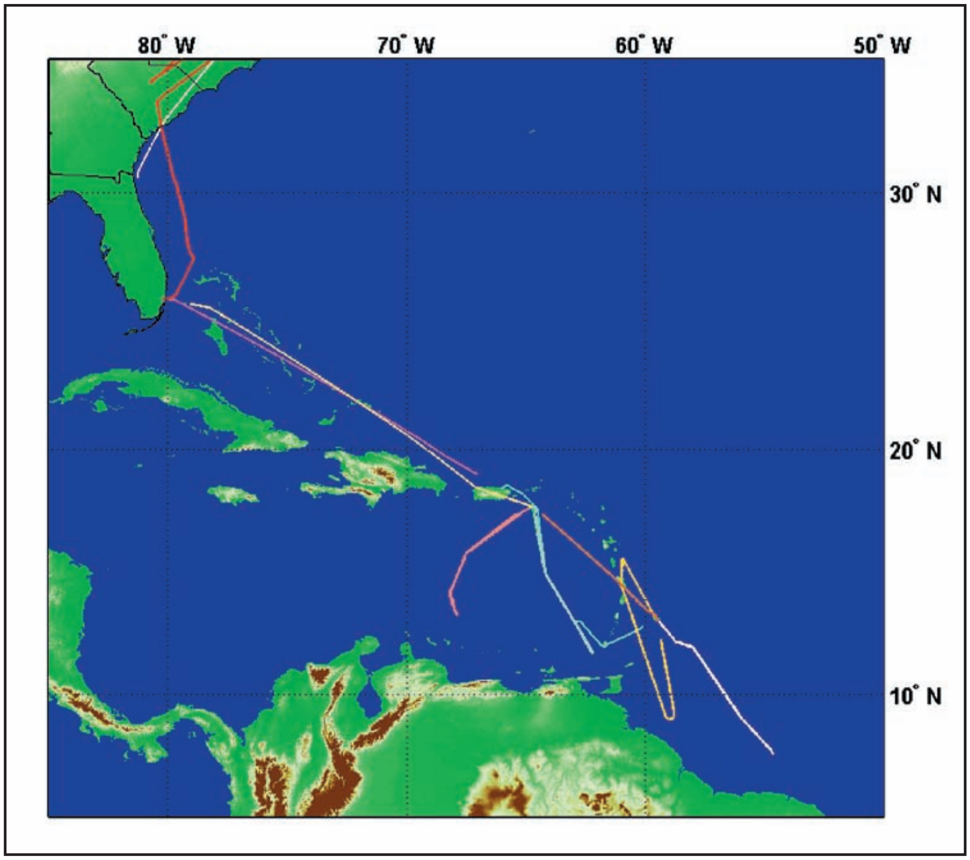
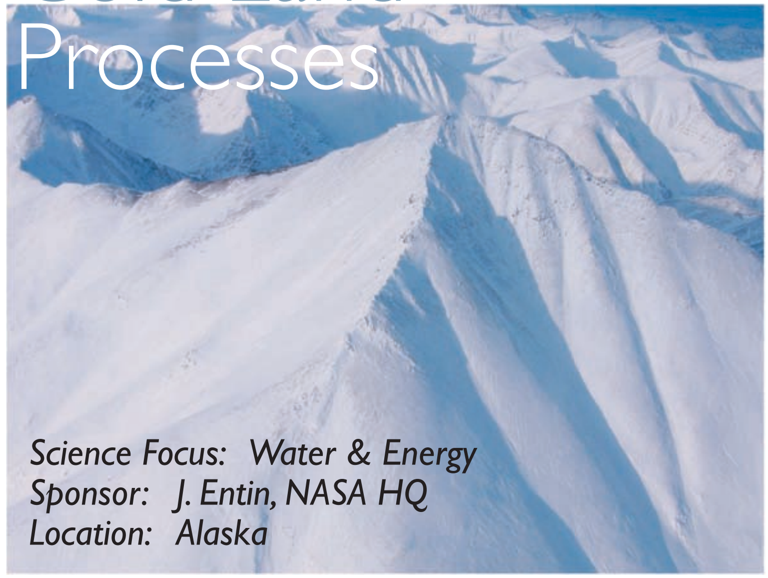


Figure 15
Flight track map for the B200 CALIPSO validation flights conducted from Jan. 22 through Feb. 3, 2008.

validated the new CALIOP calibration algorithms, which are crucial for providing accurate aerosol and cloud retrievals on the day side of the orbit. As an added bonus, the B-200 flew a coordinated pattern with the Wallops P-3B, along a CALIPSO track on the return transit, to acquire coincident data with the HSRL and the Geostationary Imaging Fabry-Perot Spectrometer (GIFS) prototype instrument flown on the P-3. Dr. Chris Hoseteler of NASA Langley was the Principal Investigator for the CALIPSO validation deployment.

URL: http://www-calipso.larc.nasa.gov

Cold Land Processes



Science Focus: Water & Energy
Sponsor: J. Entin, NASA HQ
Location: Alaska

The next increment of the on-going Cold Land Processes Experiment (CLPX) was conducted in November 2007 and Feburary 2008 in Alaska. The primary goal of this mission phase was to develop POLSCAT Ku radar based retrievals algorithms of snow water equivalent in Northern Alaska.

CLPX-II involved the JPL/NASA POLSCAT radar instrument, a Ku-band Polarimeteric Scatterometer. For CLPX-II, POLSCAT was installed on a NASA contracted aircraft, Twin Otter- deHavilland DHC-6. The Twin Otter was chosen due to its proven cold climate operations, and because it is a highly maneuverable, versatile aircraft that is very economical to operate.

The principal investigators of CLPX-II are Don Kline of NOAA NOHRSC (National Operational Hydrologic Remote Sensing Center), Kelly Elders of the USDA U.S. Forest Service, and Simon Yueh and Steve Dinardo of NASA's Jet Propulsion Laboratory. The Cold Land Processes Experiment is sponsored by Jared Entin of the NASA Terrestrial Hydrology program.

POLSCAT successfully flew 29 data flight hours in November 2007, and 45 data flight hours in February 2008, over the Alaska North Slope project sites. These sites included: Chanadalar Shelf, Kuparuk River, and Sag river, Alaska.

URL: http://www.nohrsc.noaa.gov

Images of the Twin Otter and Alaska deployment during CLPX

Figure 16

Figure 19

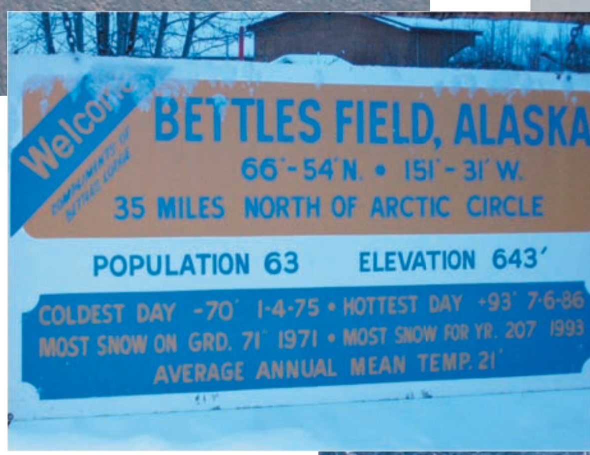
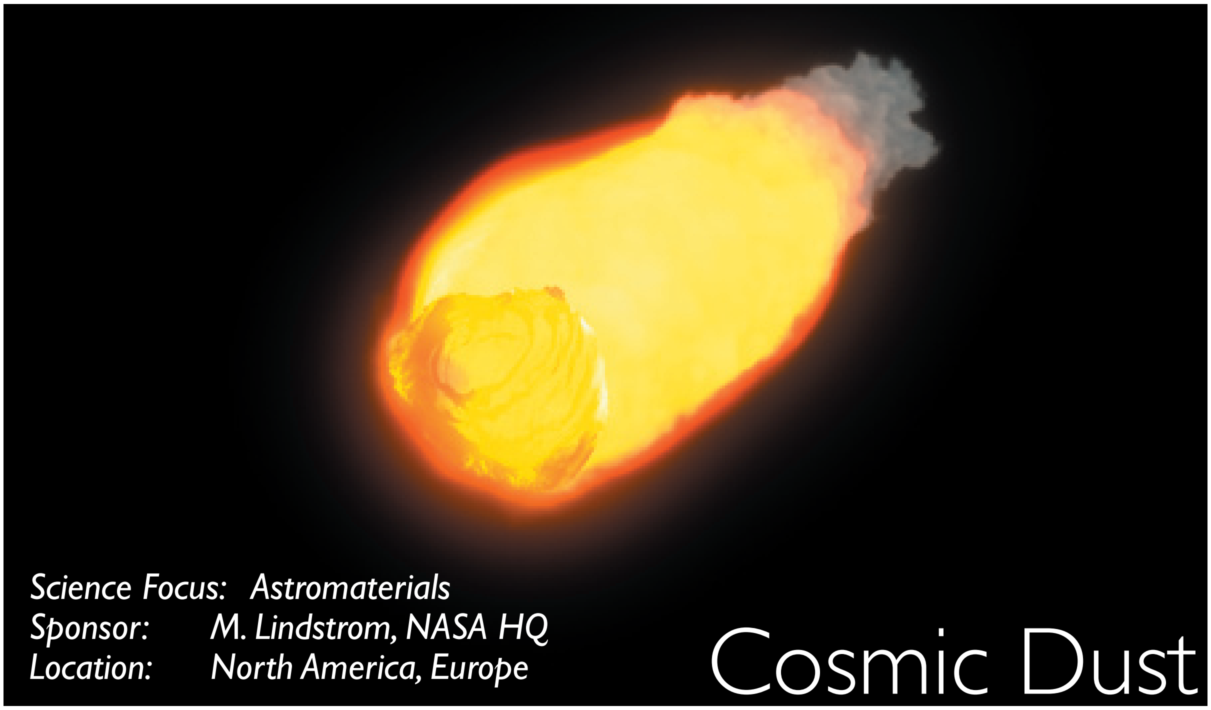


Figure 17

Figure 18



Science Focus: *Astromaterials*
Sponsor: *M. Lindstrom, NASA HQ*
Location: *North America, Europe*

Cosmic Dust Experiment

The Cosmic Dust Laboratory at the Johnson Space Center (JSC) supports the collection and curation of stratospheric dust particles, principally to help scientists study cometary and asteroidal grains that enter the Earth's atmosphere. Many tons of dust grains, including samples of asteroids and comets, fall from space onto the Earth's atmosphere each day. Once in the stratosphere, this "cosmic dust" and spacecraft debris joins terrestrial particles such as volcanic ash, windborne desert dust, forest fire soot and pollen grains, which are also of special interest to scientists.

In 2008, the NASA ER-2 and WB-57F aircraft were again outfitted with special "sticky" collector plates to capture this dust as it fell through the stratosphere. A total of 133 flight hours were performed during multiple dedicated and piggyback flights on the ER-2 (see p. 63) and WB-57, flying primarily over North American sites. Dr. Michael Zolensky of NASA Johnson is the Principal Investigator for the Cosmic Dust Experiment.

Examination of cosmic dust also reveals much about the population of interplanetary dust and orbital debris particles, critical information for engineers planning protection of Space Station against damage from high-velocity dust grains. As a result of NASA's Stardust mission (which returned particles from Comet Wild 2), the demand for samples is at an all time high in the 27-year history of the Cosmic Dust Program. The terrestrial dust collected by the Program are revealing

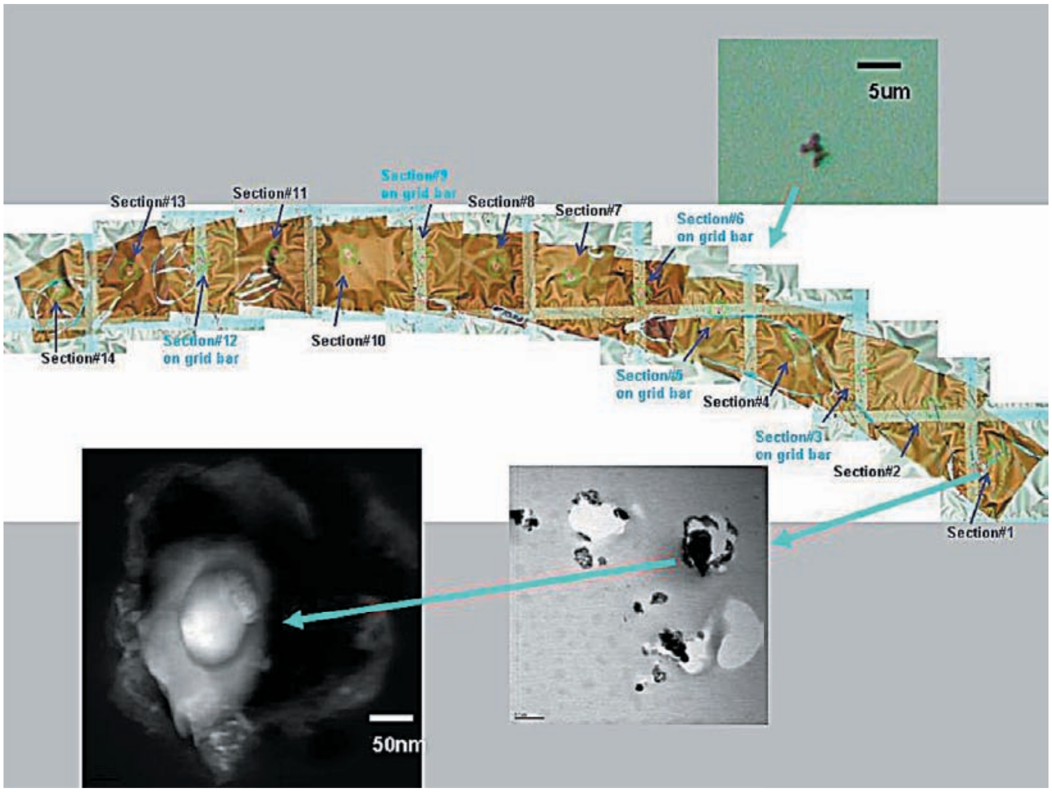


Figure 20
One stratospheric particle (upper right), captured following the Earth's passage through the dust trail left by Comet Grigg-Skjellerup, was embedded into epoxy, microtomed into many 80 nm-thick slices (golden sections arcing from right to left), and examined using a transmission electron microscope to reveal successively higher magnification views of pre-solar matter (bottom two views).

the nature of bacteria that hitch rides across oceans on stratospheric dust grains, revealing how biota spread across the planet. Because of targeted flights during a shower of grains from Comet Grigg-Skjellerup, we have now identified possible samples from a second comet, which appear so far to have the most primitive mineralogy of any known sample. For example, these particles contain the highest concentration of pre-solar stardust grains ever observed (see Figure 20), which means that they preserve the best record of the interstellar cloud of dust and gas from which out solar system formed.

There are plans for future astromaterial collection campaigns in FY09 and beyond, including more potential comet target dates in the next couple of years.

URL: http://curator.jsc.nasa.gov

ESA ATV Reentry

Science Focus: Atmospheric Reentry
Sponsor: A. Roberts, NASA HQ
Location: South Pacific Ocean

The DC-8 team supported an international, multi-instrument, airborne campaign to monitor the safe reentry of the European Space Agency's (ESA) new Automated Transfer Vehicle over the South Pacific Ocean during the early morning hours of September 29, 2008. Along with the NASA DC-8 flight operations team, a science team consisting of members from ESA, SETI Institute, NASA Ames, and scientists from institutions across Europe, gathered high resolution data during ATV reentry. Instruments consisted of high speed video cameras, High Definition TV cameras, high resolution stills cameras, and spectrographic instruments.

Two aircraft participated in the mission, the DC-8 from the Dryden Aircraft Operations Facility and a private Gulfstream V jet operated by H211 LLC. The two aircraft deployed to Tahiti and were based at the Faa'a International Airport, in Papeete, from where the observation flights originated. The DC-8 four-channel Iridium multilink system was used successfully to transmit still pictures and a short video file of the reentry event to ESA in Europe while the DC-8 was returning from the observation mission and still over a thousand miles south of Tahiti. Also, pictures of the event were distributed by ESA to the news media that were then viewed by audiences before the DC-8 landed back in Tahiti.

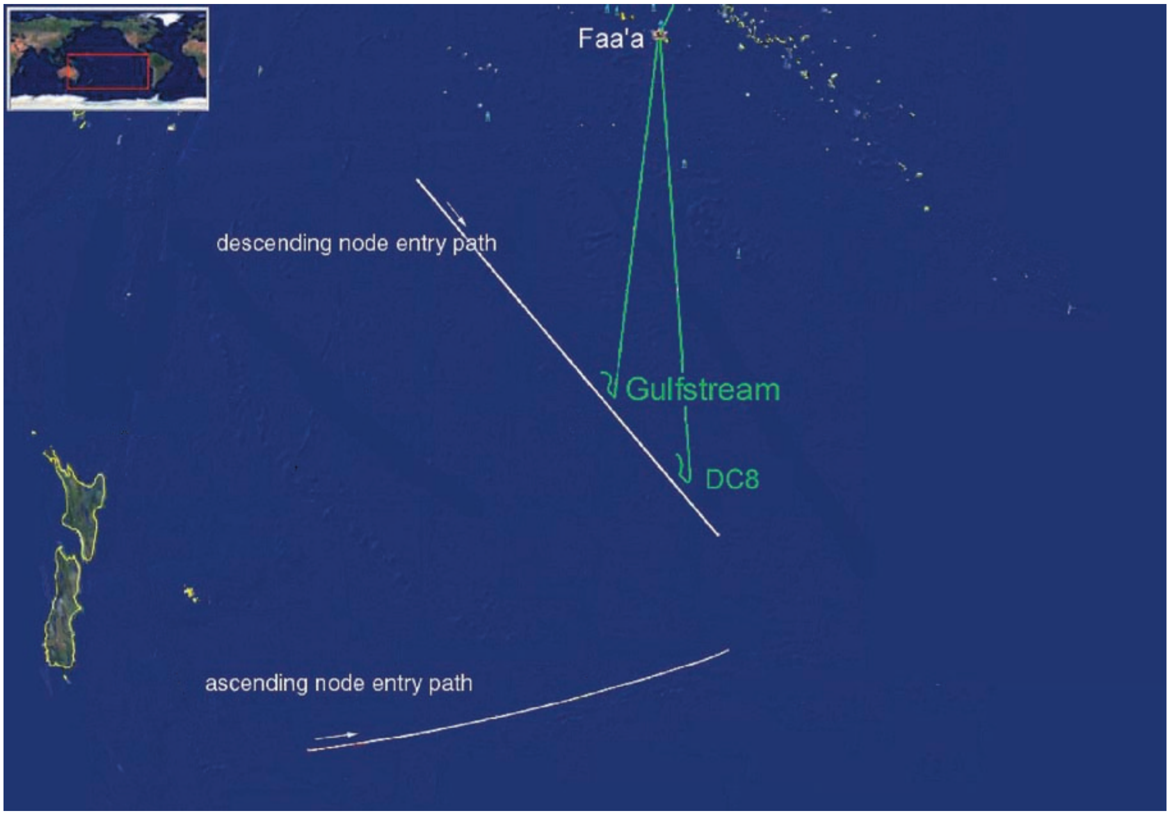


Figure 21
Reentry observation locations for the DC-8 & GV.

In describing the success of the flights, Lead Mission Scientist, Peter Jenniskens of the SETI Institute, said: "Final minutes of ATV were more glorious than we had expected. A big piece continued until deep in the atmosphere and created a bright green fireball with a wake of hundreds of orange fragments. Both aircraft were directed to give us a prime view of the event. The re-entry appeared to be nominal, with the main break-up event close to the predicted time. Kudos to ATV control center. The main break-up event caused a bright flare with a puff of matter left behind. When the ATV finally passed the DC8 aircraft, the fragment train was impressive."

URL: http://atv.seti.org

Photo courtesy of Alejandro Cifuentes-Lorenzen

The ability to accurately model future atmospheric carbon dioxide (CO_2) levels and understand the partitioning of CO_2 between the oceans and terrestrial biosphere are significant research topics in understanding climate change. The Southern Ocean Gas Exchange Experiment (SOGASEX) was a major 2008 field campaign to improve our understanding of the forcing factors of climate change by characterizing air-sea CO_2 fluxes and gas transfer velocities over the open ocean.

SOGASEX was a collaborative mission conducted on the National Oceanic and Atmospheric Administration (NOAA) research vessel Ronald H. Brown. The experiment took place in the southwest Atlantic Ocean in the austral fall of 2008, near the South Georgia Island, in some of the roughest sea states in the world. The Ron Brown departed Punta Arenas, Chile, on February 29, 2008, headed for the study site, and arrived in Montevideo, Uruguay, on April 12, 2008, 43 days later. Thirty-one scientists, representing 22 institutions, comprised the on-board science team. In a departure from the support the ASP normally provides to airborne field campaigns, in this case, our field deployment experience was used to support a ship-borne mission.

SOGASEX obtained important observations on fluxes and gas transfer velocities, along with water chemistry, wave heights and wind speeds, and optical transmittance, and was the first mission of its kind to gather CO_2 flux

Figure 23
The NOAA Research Vessel Ronald H. Brown docked at Port Arturo Prat, Punta Arenas, Chile, February 2008.

Figure 22
SOGASEX science team at sea.

measurements in this remote location and under heavy sea states. While in Chile, the science team provided a tour of the research vessel and science equipment for local students, and conducted interviews with local and national print, radio, and television media outlets. In addition, the on-board scientists wrote a vivid blog of the progression of the science mission and life at sea, which is featured on the mission web site.

"NASA's ongoing effort to understand the global carbon cycle will benefit from the data this cruise produced about the mechanisms that govern gas transfer in this remote part of the world's ocean," according to Dr. Paula Bontempi, manager of the ocean biology and biogeochemistry research program at NASA Headquarters. "NASA's global satellite observations of ocean color that reveal so much about the health of our oceans also will be improved in this region as we validate what our space-based sensors see with direct measurements taken at sea."

[NASA's Aqua satellite makes ocean color observations over the Southern Ocean every few days with the Moderate Resolution Imaging Spectroradiometer. The satellite, launched in 2002, uses six instruments to make global measurements of the atmosphere, land, oceans, and snow and ice cover.]

The logistical issues of departing from and returning to two different countries presented unique challenges to a U.S. based science mission. The tight mission schedule, the wide variety of scientific equipment to be loaded and tested, and the remote operating locations required significant and careful mission and logistical planning by the science and management teams. Overcoming these challenges required close coordination between NASA and NOAA, careful scheduling of shipments, coordination with U.S. Embassies abroad, close attention to the requirements of the host countries, and where required, using Spanish speaking team members to assist with translation and interpretation.

Collaborators on the mission with NOAA and NASA were the National Science Foundation, the Naval Research Laboratory, and several universities and research institutions. Cooperation and support by the governments of Chile, Argentina, the United Kingdom, and Uruguay was key to the overall mission success.

The Ocean Biology and Biogeochemistry Program at NASA Headquarters sponsored the NASA portion of SOGASEX. NASA Ames Research Center, Earth Science Project Office, managed the mission.

URL: http://so-gasex.org

Figure 24
Dr. Carlos del Castillo (right), Johns Hopkins University, is interviewed by Chilean National Television (TVN) in Punta Arenas, Chile during a tour of the NOAA ship Ron Brown. Dr. Paula Bontempi, NASA HQ sponsor, and Dr. Chris Sabine, NOAA, Mission Scientist, look on.

NOVICE

Science Focus: Atmospheric Composition
Sponsor: A. Roberts, NASA HQ
Location: Texas

Aircraft instrument development programs can normally only fund teams to bring the maturity of an instrument to a medium technical readiness level and may not budget the flight hours required to demonstrate an instrument's operational readiness. Often this may not include any dedicated flight hours to test the actual capability of the instrument. In an effort to help alleviate this situation, the Airborne Science Program has dedicated some flight hours for testing a payload comprised of funded instruments needing flight verification. The NewlyOperating and Validated Instruments Comparison Experiment (NOVICE) mission was put together as a series of flights for such airborne instrument testing.

For the NOVICE experiment, a payload of over 14 instruments from NASA, NOAA, and several universities were flown together on the WB-57 aircraft (see Fig. 25) from Ellington Field, Texas, during the first two weeks of September 2008.

Many instruments either require their demonstration flights soon after construction or need additional performance assessments after major modifications. Many of the instruments flown on NOVICE are being designed and tested for future atmospheric missions flying on Unmanned Aerial Vehicles

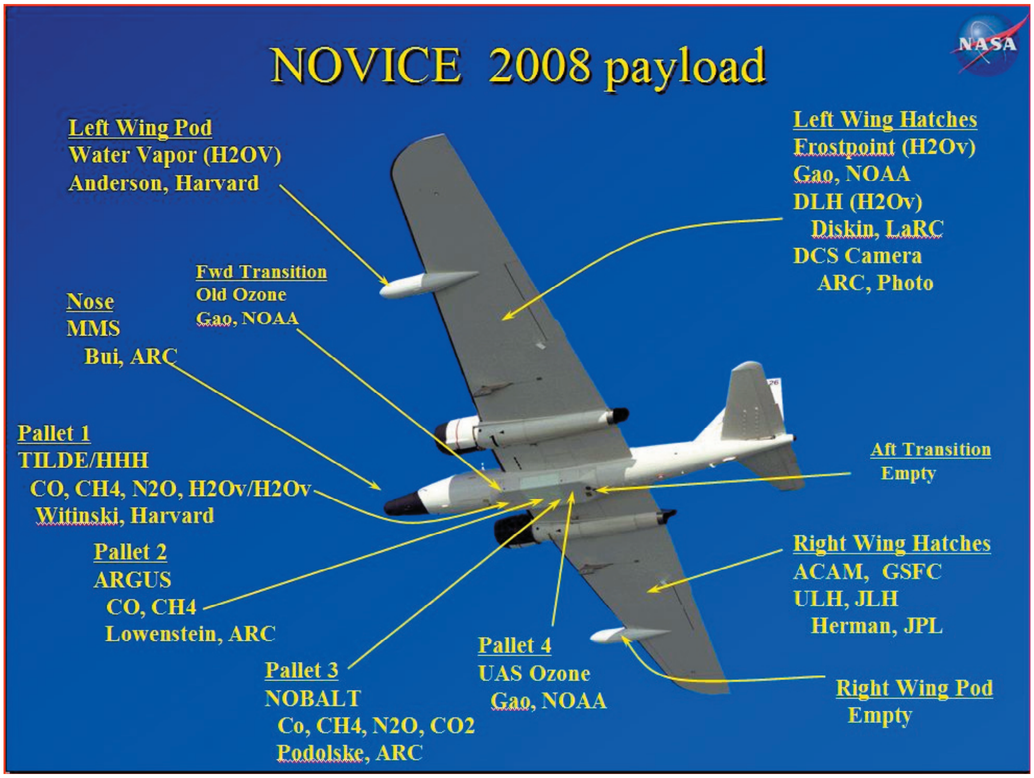


Figure 25
NOVICE instrument payload.

(UAVs), such as the NASA Global Hawk. A few additional, mature instruments were also flown to capture some of the same chemical species for intercomparison measurements.

With the emphasis of the mission being on functional and performance testing, NOVICE allowed the investigators to focus on the engineering and intercomparison components rather than achieving high-quality scientific data and results. This helped these teams elucidate anomalous instrument behaviors, such as offsets, drifts, vibrations, and transient phenomena that cannot always be duplicated in the labs.

Three sorties with a total of 11.3 hours were flown during the NOVICE experiment. This type of innovative test program provides a link between the technology development programs and the actual flight experiments normally performed by NASA. It enables the science instruments to undergo the flight testing required to give these instruments the requisite reliability and accuracy needed for future NASA Earth Science process studies. NOVICE may, in fact, be the prototype for future similar flight opportunites. Dr. Jim Podolske of NASA Ames was the Project Scientist, and the overall mission was managed by ESPO.

URL: http://www.espo.nasa.gov/novice

AIRBORNE SCIENCE

PROGRAM ELEMENTS:

SCIENCE & REQUIREMENTS MANAGEMENT

Program Elements & Execution

Science & Requirements

Flight Requests

Collagorations & Partnerships

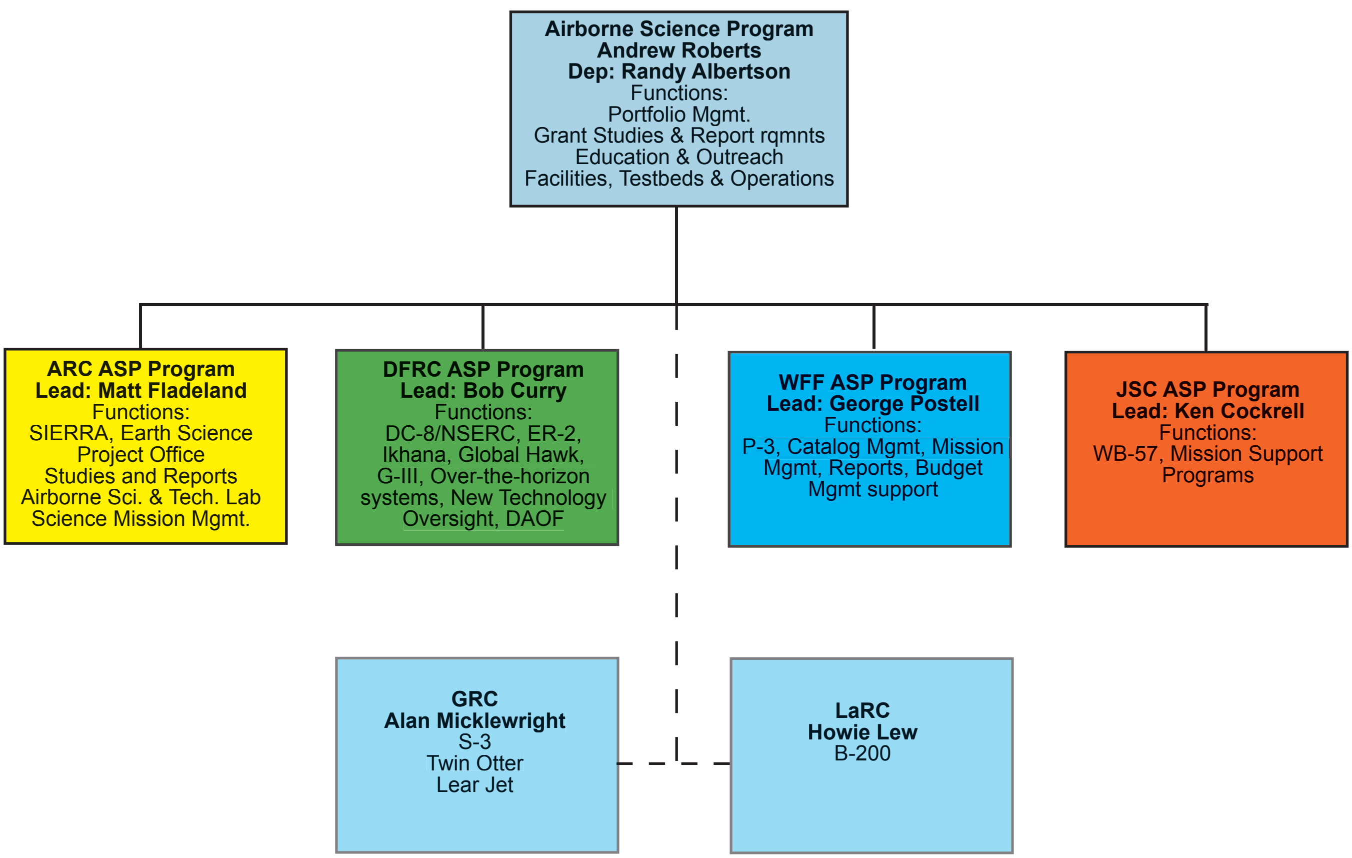
Interagency UAS Coordination

Interagency Working Group for Airborne Data & Telecommunication Systems (IWGADTS)

Joint Airborne Science Sensor Integration Working Group (JASSIWG)

Program Elements and Execution

The Airborne Science Program consists of the following program elements:



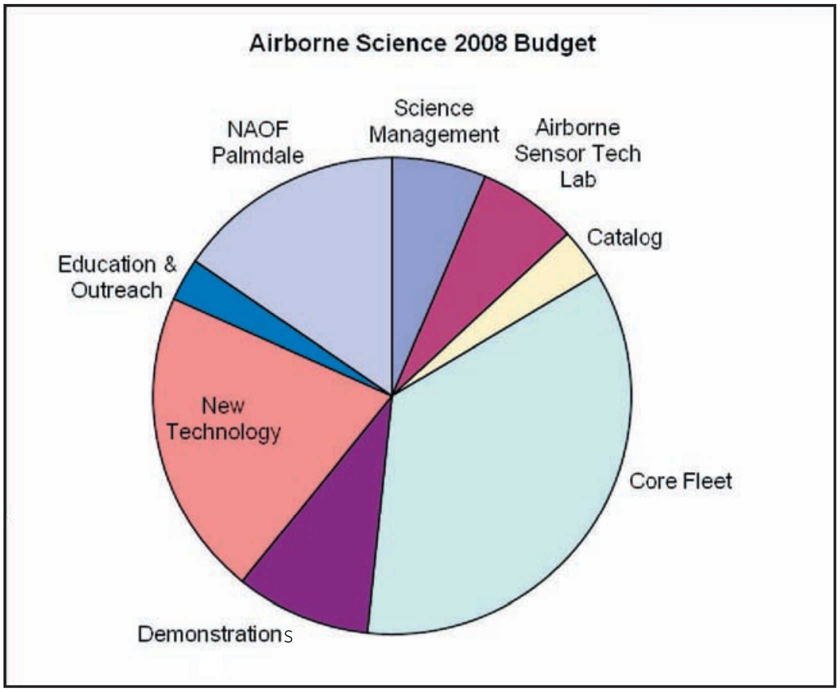


Figure 26
Airborne Science Program budget breakdown

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 when possible. 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 is the lead for airborne science mission management. This includes field campaign management and logistics through the Earth Science Project Office, and sensor support and development of interface standards through the Airborne Science and Technology Laboratory. Ames manages the ASP flight request process, and future mission and platform requirements definitions. Ames also managed the development of the SIERRA under the New Technology and Platform Development effort.

Dryden Flight Research Center leads the operation and maintenance of the core DC-8 and ER-2 aircraft. They also operate and maintain aircraft in the new technology and platform development area, including the Global Hawks, Ikhana and G-III. Another area Dryden has 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.

In 2008, the Airborne Science Program had a budget of $33,056,000, a 29% increase from 2007. Figure 26 (opposite) illustrates how budget was distributed, while Figure 27 (below) illustrates the Program's budget trend since 2005.

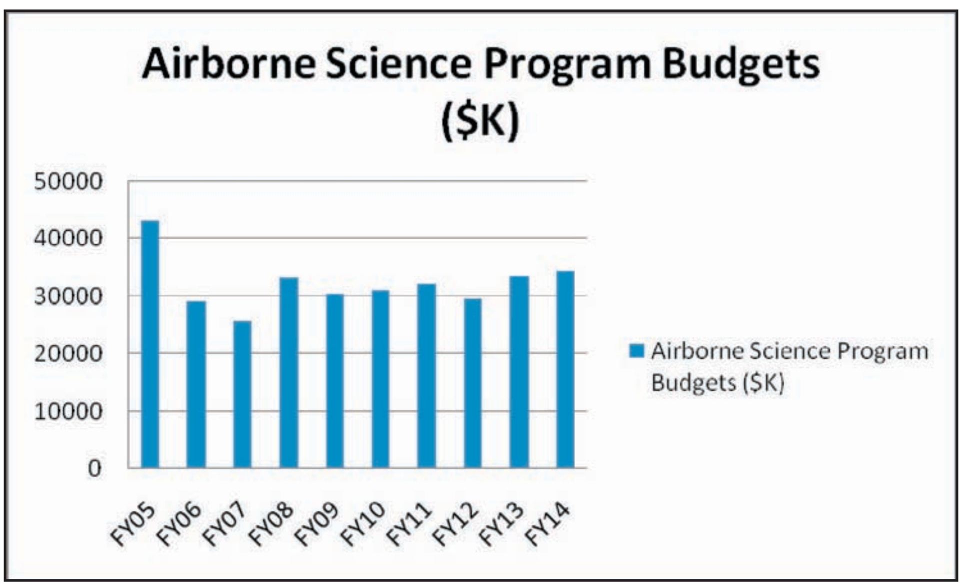


Figure 27
Airborne Science Program recent and projected budgets

Science & Requirements

The Science Requirements & Management program element 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 to the Science Mission Directorate in requirements analysis, flight request tracking and management, and mission concept and science instrument integration development and support. They also manage most of the major Earth Science airborne field campaigns in SMD.

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.

In 2007, the National Research Council published its 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. As the Science Mission Directorate has worked during 2008 to address this mission set, establishing science teams and beginning to plan and design the missions, the Airborne Science program has worked

Mission	Workshop Date	Location
SMAP	October 20-22, '08	Oxnard, CA
DESDynI	October 29-31, '08	Sacramento, CA
CLARREO	October 21-23, '08	Washington, DC
ASCENDS	July 20-22, '08	Ann Arbor, MI
GEO-CAPE	August 18-20, '08	Chapel Hill, NC
HYSPIRI	October 21-23, '08	Monrovia, CA
SWOT	September 17-19, '08	Columbus, OH

Table 1:
Decadal Survey science meetings held in 2008; green indicates first tier or near term missions, and yellow indicates second tier.

SMAP	(Soil Moisture Active-Passive)
DESDynI	(Deformation, Ecosystem Structure and Dynamics of Ice)
CLARREO	(Climate Absolute Radiance and Refractory Observatory)
ASCENDS	(Active Sensing of CO2, Emissions over Nights, Days and Seasons)
GEO-CAPE	(Geostationary Coastal and Air Pollution Events Mission)
HyspIRI	(Hyperspectral Infrared Imager)
SWOT	(Surface Water and Ocean Topography)

in parallel to prepare to support the new missions. A dialogue has been established with the various teams to understand how airborne capabilities may be called on to participate in field studies, to test new simulator instruments, or to provide data for algorithm development or calibration and validation activities. Implementation of the NRC Decadal Survey recommended missions has begun in earnest with the formation of science steering committees for each of the science missions. Table 1 lists the science meetings that were attended by one or more representatives of the Airborne

Science Program

In FY2009, the Program will produce a comprehensive report on information gathered from the meetings above and other sources to provide an overview of requirements for airborne observations in support of the decadal survey recommended missions. This report will include an overview of the missions, airborne instruments, plans for calibration and validation, and a schedule of expected activities and assets.

Flight Requests

The 2008 calendar year was active for the Airborne Science flight request system. Improvements have been made to the Suborbital Science Flight Request (SOFR) system to reflect requested changes in notifications and access. An additional system update will be implemented in June of 2009. SOFRS can be accessed through the website at the following URL: http://airbornescience.nasa.gov.

There were 117 flight requests submitted in 2008. Forty-four flight requests were completed, forty-one were rolled over to 2009, and the rest were withdrawn or

Aircraft	Submitted	Total Approved	Total Completed	Total Science Flight Hours Flown
DC-8	8	4	4	292.1
ER-2	25	11	11	148.9
P-3	15	6	3	201.4
WB-57	6	3	1	11.3
Twin Otter	28	14	9	327.4
B-200	14	11	11	415.7
G-3	6	2	1	155.9
Lear 25	2	NA*	1	4.1
Aerosonde	4	2	1	23.5
Ikhana	4	2	2	54.5
J-31	1	0	0	0
SIERRA	2	2	0	0
F-18	1	1	0	0
SAAB 340	1	0	0	0
TOTAL	**117**	**58**	**44**	**1634.8**

Table 2: Summary of FY08 Flight Hours by Aircraft

Key to Table 2:
- Submitted: Flight Request entered into the system
- Total Approved: All flight requests that have been approved.
- Total Completed: Flight requests completed or partially completed.

*Some internally approved Langley B-200 and GRC Learjet 25 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 FY08 totals above.

canceled depending upon the availability of resources at the time of the request. A summary by aircraft is presented in the table below.

Flight requests were submitted for 14 aircraft platforms and the airborne fleet flew more than 1600 flight hours comprising over 360 aircraft sorties during the year.

Also, the annual Airborne Science call letter for FY09 was distributed in June of 2008.

Table 3 shows a histogram for the total hours flown by the program over the last decade. After the sharp decline in 2005, airborne science flight hours are now returning to their historic utilization levels.

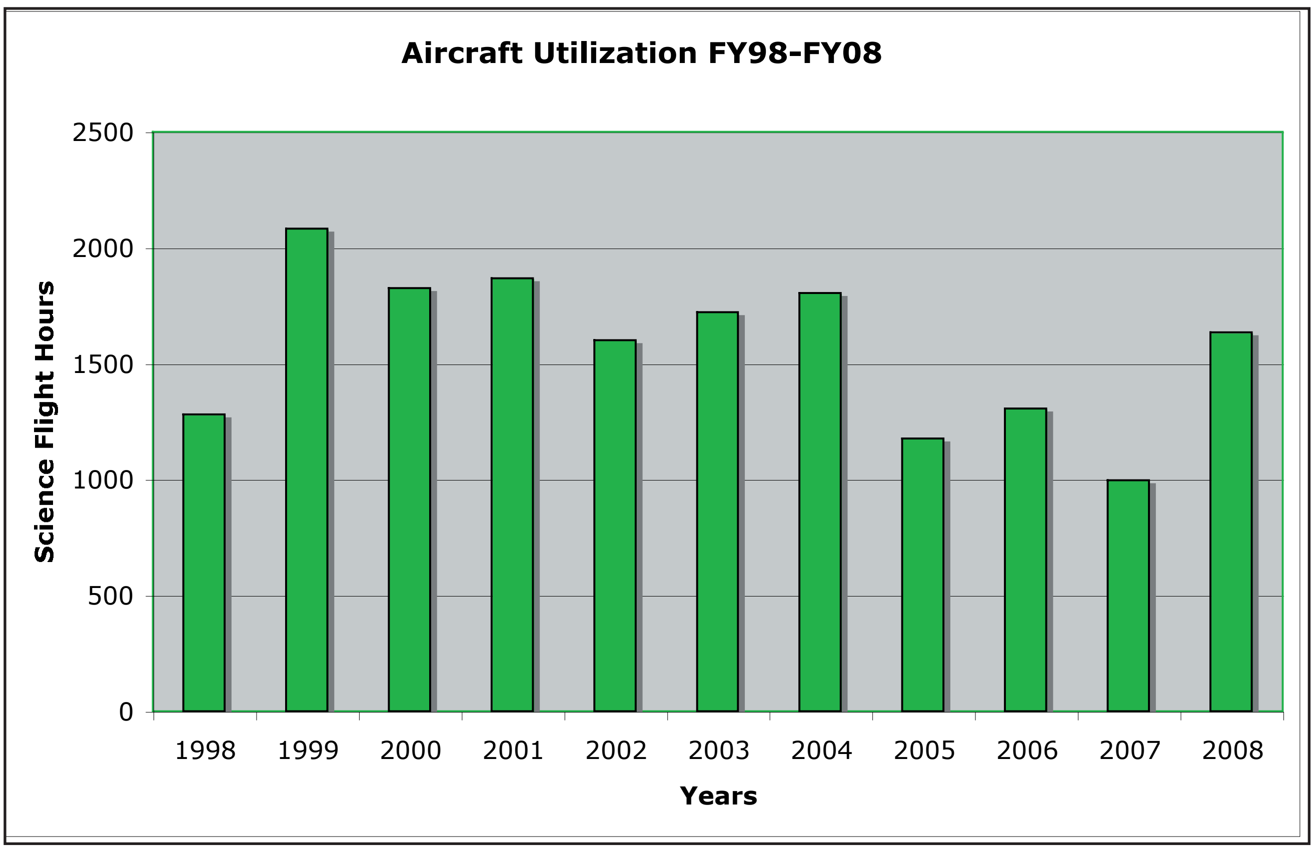


Table 3: Aircraft Utilization FY 98-FY08

Collaborations and Partnerships

The Airborne Science Program significantly broadened its national and international collaborative efforts in 2008. In the first year of the NASA-NOAA-DOE Memorandum of Understanding concerning Unmanned Aircraft Systems for Global Earth Observing System Science Research, two implementing arrangements with NOAA Office of Oceanic and Atmospheric Research were signed and executed. The first continued the collaborative efforts to collect hurricane boundary layer data using the Aersosonde (see p. 71). The second resulted in the completion of the Global Hawk – Pacific 2009 (GloPac) science mission plan, completion of studies with Northrup Grumman Corporation on sensor integration engineering plans and initiating the first NASA Global Hawk Certificate of Authorization. Helping to facilitate this collaboration, NOAA detailed Commander Philip Hall to the Dryden Flight Research Center. While assigned to Dryden, in addition to his duty as a NOAA UAS Deputy Project Manager (DPM), CDR Hall has immersed himself into UAS projects as Deputy DPM for the Ikhana, followed by being the DPM on the Global Hawk project.

Also in 2008, the Program Director initiated action to establish the International Airborne Science Standards Working Group (IASSWG) within the International Society for Photogrammetry and Remote Sensing. The Terms of Reference were approved and the working group will have its first meeting in conjunction with the International Symposium on Remote Sensing of the Environment in May 2009.

Throughout most of 2008, the NASA chaired the Interagency Coordinating Committee for Airborne Geosciences Research and Applications (ICCAGRA). Through this leadership role, NASA made contact with our European counterparts, such as EUFAR (European Fleet for Airborne Research), to get their support for the IASSWG and future collaborative efforts.

The ASP continues to nurture a relationship with the FAA Unmanned Aircraft Program Office (UAPO). This year program members participated on the Small UAS

Rulemaking Committee, including chairing a sub-committee. Additionally the program assigned a full-time resident liaison within the UAPO (see p. 54).

Throughout this past year, Airborne Science has maintained its partner relationships with academia, most notably the University of North Dakota and the University of California, Santa Cruz. UND was instrumental in the success of the ARCTAS mission, expanding its efforts well beyond the DC-8 to provide data and engineering support to the P-3B. UND also developed a much anticipated concept and plan for a 2009 DC-8 Student Mission to provide a dedicated opportunity for a hands-on airborne science learning experience. Through the Airborne Sensor Technology Lab, UCSC personnel are continuing to break new ground in fielding new sensor technologies, such as the AMS, and aircraft science support systems like the NASA Airborne Science Data and Telemetry (NASDAT) system. These accomplishments are described in greater detail in other sections of this report.

The Airborne Science Program also supports other partnerships established through other NASA organizations. A long-standing MOU between NASA and DoD has resulted in numerous emerging technologies being demonstrated in relative environments using the WB-57s, and Dryden entered into a five-year Space Act Agreement with the Northrup Grumman Corporation (NGC) relating to the stand-up and operation of the NASA Global Hawk system. Under this arrangement NGC is providing technical, engineering, maintenance, operations support and the command and control portion of the ground control station. NASA and NGC are each providing approximately half of the project staffing and will share equal access to the NASA Global Hawk system (see p. 79).

For 2009, the program is looking to build on our partnership and collaboration efforts. In partnership with NOAA and NGC, the Global Hawks will accomplish their first missions. Our teaming with UND will fulfill a goal of demonstrating how airborne science platforms can be used to inspire and develop the next generation of Earth science professionals, and we expect to break new ground through the collaborative ICCAGRA, EUFAR and IASSWG efforts.

Interagency UAS Coordination

As the use of Unmanned Aircraft Systems (UAS) for science missions becomes more prevalent within our program, the need for general access to the national airspace system (NAS) has become of utmost importance. Earlier this year, Brenda Mulac from the Airborne Science Program was placed within the Federal Aviation Administration (FAA) Unmanned Aircraft Program Office (UAPO) to act as a liaison between the two agencies, and help NASA's UAS missions gain access to the NAS more efficiently. The primary objective of her liaison position has been to foster a stronger relationship with the FAA by facilitating communications and coordination between the two agencies. The improvement of communications is an effort not only to assist the FAA with understanding the needs of NASA UAS missions, but to also provide NASA UAS mission personnel and scientists with an understanding of FAA processes and requirements.

To better represent the NASA mission and science personnel at the FAA, the liaison has visited several NASA centers to gain an understanding of what UAS projects are ongoing in the agency, as well as to meet with scientists and other interested parties to discuss their mission interests and requirements. Having a working knowledge of the different current and potential UAS projects has allowed the liaison to work more efficiently with the FAA to obtain approved COAs, as well as understand the impacts of potential changes in FAA policy and guidance on NASA's UAS missions.

Certificates of Authorization (COAs)

Currently, the only way to gain access to the NAS is to apply to the FAA for a Certificate of Authorization (COA). The process to obtain a COA is time consuming, potentially delaying a mission if not handled appropriately. In the past, the requirements for a COA were not well understood by NASA, and had resulted in incomplete applications that required more time for the FAA to process and approve. The addition of a NASA contact within the FAA UAPO has provided a much needed interface between the FAA and NASA individuals and projects applying for a COA for their UAS operations. NASA COA applicants can call with questions regarding application information as well as status updates on applications already submitted. The FAA personnel who review the COA applications can contact the liaison with questions concerning possible operations. For upcoming missions, meetings between the FAA program office and the project personnel have been facilitated, allowing potential issues to be identified and discussed prior to the submittal of a COA application. The resulting applications are more complete, and because the FAA is already aware of the mission and its needs, the path to approval is more efficient.

This year, a total of 14 COAs were approved for NASA researchers at five different centers. The most notable of these was the emergency COA issued for the California wildfire flights of Ikhana. The emergency COA was approved within 72 hours of the original request due to hard work of FAA personnel involved, and reflects the developing relationship between the two agencies. An additional 10 COA applications have been submitted and are pending approval.

FAA Activities

As a result of the increased cooperation between the two agencies, the FAA UAPO invited NASA to participate in the Small UAS Aviation Rulemaking Committee (sUAS ARC). The purpose of the sUAS ARC is to develop recommendations for rules to be applied to small UASs. The committee began in June 2008 and is co-chaired by the FAA and industry. The membership of the committee consists of different government agencies, such as DOD and NASA, as well as representatives from the Aircraft Owners and Pilots Association (AOPA), Air Line Pilots Association (ALPA), the Academy of Model Aeronautics (AMA), and industry. The final product of the sUAS ARC is a set of recommendations of what the rules for small UASs should look like (not the rules themselves). A separate Safety and Risk Management Panel (SRMP) will review the recommendations and apply a Safety Management System (SMS) process to assess the safety implications of the recommendations. The final recommendations from the sUAS ARC and the SRMP will be given to the rules and regulations division within the FAA. They will develop draft rules and regulations that will then go out for public comment. Once all comments have been received and addressed, the final set of rules and regulations will be developed. The whole process is expected to take approximately two to three years to complete.

The Airborne Science Program Manager participated as a primary committee member on the sUAS ARC and provided leadership of one of the six working groups formed under the ARC. Several other NASA representatives from various centers participated in the different working groups. In August 2008, NASA hosted a UAS demonstration at Dryden Flight Research Center for the sUAS ARC. Four different platforms were flown, ranging in size from the AeroVironment Wasp, with a wingspan of 2.4 ft, to the Insitu ScanEagle with a wingspan of 10ft. The demonstration provided the membership an opportunity to witness small UAS operations, and gain a better understanding, for example, of the distance at which an observer can maintain visual contact.

NASA has been providing the FAA program office with assistance on projects such as developing guidelines for contingencies for extended range Class A operations. Other projects include a UAS technology demonstration tied to NextGen and related technologies, and ground-based "sense and avoid" assessments. The FAA UAPO has recognized the great wealth of technical expertise within NASA and is welcoming the opportunity to work closely together to achieve more efficient and safer airspace access and operations.

Interagency Working Group for Airborne Data and Telecommunication Systems (IWGADTS)

The Interagency Working Group for Airborne Data and Telecommunications Systems (IWGADTS) was organized at the behest of the Airborne Science Program for the purpose of fostering increased interoperability among airborne platforms and instrument payloads within the government research community. Besides representatives from the various NASA centers, its active members include NSF/NCAR, DoE, NOAA, ONR, and several academic institutions including the University of North Dakota. IGWADTS meets twice yearly to develop recommendations for technical standards to increase infrastructure commonality between airborne platforms and instrument payloads, and to encourage synergy between airborne research programs with similar goals.

Ongoing topics of discussion include standards for real-time data feeds (formats and timing,) the implementation of airborne ethernet networks, and the current status of satellite communication and GPS technologies. A survey of science instrument teams is also underway, gathering information on navigation data and communications/telemetry requirements across the community.

The "IWG-1" standard format for platform navigation data, which originated from this group, is currently being implemented in the next-generation of NASA airborne data systems.

More information may be found at: http://www.eol.ucar.edu/iwgadts.

Joint Airborne Science Sensor Integration Working Group (JASSIWG)

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 name of this working group is the Joint Airborne Science Sensor Integration Working Group (or JASSIWG), and is made up of 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 between 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.

During FY08, the working group held its first meeting and determined the scope and products for the initial phase of effort. The initial products included common formats for instrument Payload Data Packages and Experimenter Handbooks to be used for all airborne platforms, and a summary of platform performance and design characteristics for eleven NASA aircraft. This work was primarily derived from review of existing handbooks, data packages, and experimenter questionnaires. Future work will include an analysis and comparison of instrument design requirements from each platform, with a determination of any feasible commonality that exists across the platforms, with a plan for developing a set of common design guidelines for use by the instrument community. A second working group meeting is planned in mid FY09.

AIRBORNE SCIENCE

PROGRAM ELEMENTS:

AIRCRAFT PLATFORMS

DC-8

ER-2

WB-57

P-3

G-3

Aerosonde

B-200

Catalog Aircraft:
Twin Otter

NASA DC-8

In November 2007, the NASA DC-8 aircraft moved to the Dryden Aircraft Operations Facility (DAOF) located in Palmdale, California where its new base of operations was established (see page 103). The National Suborbital Education and Research Center (NSERC) at the University of North Dakota, under cooperative agreement with NASA, continues to promote and support science operations using the DC-8 Airborne Science Laboratory and has established its presence at the DAOF where it supports instrument integration and mission management activities.

The NASA DC-8 aircraft flew a total of 292 science flight hours during FY08 in support of the ARCTAS, CARB, AMISA, and ATV-1 missions. The aircraft remained reliable throughout the year, successfully accomplishing all planned missions described in other sections of this document.

Technology improvements to the aircraft also continued throughout FY08. Aircraft facilities and hardware upgrades on the DC-8 included:

Installation of a new AIMMS-20 high rate position and attitude system from Aventech Research. The system is capable of 40 Hz pitch and roll and 20 Hz position data good to 1.2 meters. The data is recorded to the on board network servers and backed up on a system data module.

A dependable four channel Iridium multilink system designed by NSERC and ASTL staff was installed prior to the CARB flights in June 2008. The four channel system is capable of 9600 baud communications and provides Xchat services. Examples of in-flight data transfers are upload of GOES weather

Figure 28
DC-8 visits Iqaluit, Nunavut Territory (Baffin Island), Canada during Spring ARCTAS campaign (April 2008).

images, PI-specified modeling and weather products, download of in-flight JPEG images, short video clips, and science data. The system performed very well for the CARB, Phase 2 ARCTAS, AMISA, and ATV-1 missions.

Display software improvements were implemented that increased functionality for investigators at each of their stations.

Looking forward, the aircraft has recently completed a B-Check airworthiness inspection, and is "mission ready" to fly into FY09 and beyond.

URL: http://www.nasa.gov/centers/dryden/aircraft/DC-8

NASA ER-2

NASA operates two ER-2 (806 & 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 October, the ER-2 806 deployed to Kirtland AFB in New Mexico with a new sensor from the Department of Homeland Security, called Chloe-A. The sensor was integrated into the Q-bay and conducted a successful series of test flights flown over White Sand Missile Range, WSMR, in New Mexico. Flights were flown to advance prototype technologies that can enable the defeat of Man-Portable Air Defense Systems (MANPADS) from a persistent, high altitude orbit. The ER-2 flew 9 flights totaling 33.1 flight hours. The ER-2 team received a letter of appreciation from the DHS Under Secretary for Science and Technology, Jay M. Cohen.

In April, the ER-2 806 conducted several flights for the Boeing Corporation, totaling 14 flight hours, carrying a new telemetry sensor for enhanced data downlinks. The aircraft flew in the Edwards and Nellis ranges for the evaluation of the new sensor.

In April, ER-2 809 entered a required 200 hour phase inspection.

In late April, the ER-2 806 uploaded Large Area Collectors (LAC) on its wing and conducted a successful series of science flights from DFRC. Flights were flown to gather cosmic dust particles from Earth's stratosphere, which are examined and cataloged, and then made available to the scientific community for research (see p. 33). The ER-2 flew 5 flights totaling 39.9 flight hours.

In late May, the MODIS/ASTER Airborne Simulator (MASTER) sensor was uploaded into ER-2 806 and flew two calibration flights totaling 8 hours. The second flight included a satellite overpass run. The Airborne Visible and Infrared Imaging Spectrometer (AVIRIS) sensor was flown as piggyback during the MASTER flights.

Starting in June, ER-2 806 flew a series of science flights, a sensor calibration and checkout flight out of Edwards, AFB, totaling 15.1 flight hours. MASTER remained installed as a piggyback for most local flights. Science flights included gathering data over the Santa Monica Mountains in southern California to examine the relationships between hyperspectral indices, live fuel moisture, and soil moisture. Also, data was gathered over central and southern California to establish the feasibility of mapping methane emissions in the lower boundary layer from natural and anthropogenic sources, and to use quantitative estimates of column methane to estimate flux rates and, through repeat flights, establish spatial and temporal variation in methane emissions.

In late June, the ER-2 809 deployed to Westover ARB, in Chicopee, MA, in support of the Westover-AVIRIS campaign for flights over Nebraska, Minnesota, Wisconsin, Michigan and Maryland. 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. As a part of the flight series, science flights were also conducted over sites in British Columbia, Alberta, Saskatchewan, Manitoba and Ontario, Canada. Data will also be used to investigate forest growth, carbon cycling and the interaction between ecosystems and climate. During the Westover-AVIRIS campaign the ER-2 809 flew 13 flights totaling 77.6 flight hours.

To reduce logistic support requirements for aircraft deployments, the UHF, VHF and HF ground radio units were repackaged into a new rack, thus reducing it from a two-rack configuration to a single rack system. The single rack configuration reduces deployment logistics by one box.

The ER-2 project supported several education and outreach events by providing a presentation and demonstration of the high altitude pressure suit. Presentations were made at local schools in the Antelope Valley and participated in recruitment efforts at the California State University at Northridge career fair. Also, we supported the NASA Headquarters booth at the Albuquerque International Balloon Fiesta in New Mexico.

In fiscal year 2009, the ER-2 operations will be relocated from DFRC to the new DAOF facility in Palmdale. This move, along with efforts to share infrastructure with other projects, will allow the ER-2 to continue its on-going cost control measures.

NASA WB-57

Fiscal Year 2008 saw much progress in the WB-57 aircraft program, in the areas of flight hardware improvements, crew training, and science missions.

Both aircraft now have the new landing gear, an adaptation of the F-15E landing gear, anti-skid brakes, and tires. After some time in service, minor modifications were made to the hydraulic line configuration to address minor fluid leaks. The final configuration is now installed on both aircraft.

The new system is proving to be a great improvement to the airplane. Braking power and the anti-skid capability have enabled essentially carefree operations on all runway conditions encountered to date. The brakes and related systems have also been maintenance-free to date. The frequency of brake replacement, due to normal wear, has been greatly reduced, and the time and complexity of replacing a brake is also greatly reduced. The new tires last longer than the original WB-57 tires. In addition, the consumable components (brakes and tires) are readily available in the DOD supply system.

The new landing gear has a higher load-carrying capability than the original, and facilitates the next major aircraft improvement; the addition of ER-2 "Superpods", and an increase in the allowable aircraft gross weight to facilitate carriage of the superpods. 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.

The gross weight upgrade project was begun near the beginning of FY08, and will be completed in the first quarter of FY10.

Three contracts have been awarded to address the modification, which is divided into work units comprising the airframe, landing gear, and superpod adaptation.

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.

The major NASA science mission for the WB-57 in FY08 was the NOVICE (Newly Operational and Validated Instrument Comparison Experiment) mission. Although the mission was a success, there were a few weather-related mission planning challenges. Delaying the arrival of the science teams was considered, as Hurricane Gustav's predicted path included Houston, and the WB-57 was scheduled for evacuation. Luckily, Gustav steered further east and the WB-57 was not relocated.

One test flight and two mission flights were flown, for a total of 11.4 flight hours. There was hope of flying a fourth flight, but Hurricane Ike had Houston in its sights. Late in the afternoon after the last NOVICE flight, the WB-57 was evacuated to El Paso. The Johnson Space Center was scheduled for closure the following day at noon, with much of the local area under a mandatory evacuation order. The science teams, with the help of ESPO, worked diligently to ship out their instruments and support equipment so they could escape the path of the hurricane as well.

Operations in FY08 were heavily weighted towards non-NASA projects. A total of 461 hours were flown supporting systems development and field demonstration tests for independent corporations and other government agencies. These operations were conducted during several U.S. deployments, plus two major deployments outside the United States. The non-NASA flight activity has provided income and operations experience that keeps the WB-57 program robust, viable, and prepared for Airborne Science campaigns.

Finally, an additional 63.5 flight hours were consumed by crew training, functional check flights (FCF) after aircraft maintenance, landing gear test flights, and hurricane evacuation flights. The total flight hours for both aircraft in FY08 was 536 flight hours.

NASA P-3

The P-3B Orion is based at Goddard Space Flight Center's (GSFC) Wallops Flight Facility. The P-3 participated in two major deployment missions during FY08 and two instrument development missions.

The first instrument development mission was a series of local flights from Wallops for the Johns Hopkins APL Geostationary Imaging Fabry-Perot Spectrometer (GIFS). The DFRC Research Environment for Vehicle Embedded Analysis on Linux (REVEAL) and the P-3 Aircraft Data System (PDS) on-board data systems were also tested during this flight series.

The first major deployment of the year was the spring phase of the ARCTAS mission (see page 9). All mission objectives were met with a total of 72.9 flight hours in support of the spring deployment.

The second major deployment of the year was the ARCTAS – Summer 2008 phase, a follow-on mission to the spring phase. The focus of the summer mission was the study of boreal forest fire aerosol emissions. In conjunction with the ARCTAS Summer deployment, a flight in support of the California Air Resources Board (CARB) was completed. A total of 98.1 flight hours were flown in support of the ARCTAS-Summer and CARB programs.

The fourth and final mission for FY08 was the Soil Moisture Active-Passive – Validation Experiment 2008 (SMAP-VEX'08). Two NASA L-Band Radiometers were tested and flown on the P-3 for a soil moisture study on the Delmarva Peninsula, conducted in conjunction with a USDA in-situ data collection and JPL PALS instrument flights. The mission successfully flew 20.9 science hours.

A major upgrade to the P-3 in FY08 was the implementation of a real-time air to ground data communication system, and which played a particularly important role during the summer phase of ARCTAS. This system is comprised of two parts. The REVEAL system, provided by the Dryden Flight Research Center, is a 6-channel

Figure 29
P-3 on ramp prior to departure from Thule Air Base, Greenland, April 2008.

Iridium (with two channels of GPS) satellite ethernet based data distribution system. REVEAL consists of two instrumentation boxes and servers all located in the overhead bin area of the P-3. An Iridium antenna "farm" is permanently mounted to the aircraft at location FS480.

REVEAL allows investigators to receive real time situational awareness using the following capabilities:

- Real time flight tracking on the aircraft and on the ground using Google Earth.
- Instant messaging capability between multiple aircraft and ground based assets.
- Access to the Internet in flight (2400 baud connection).
- Transfer of data between multiple aircraft and ground based assets via a ground based server.
- Data distribution throughout the P-3 cabin using ethernet connections.

A University of North Dakota data system is also located in the overhead P-3 bins next to REVEAL. This system uses three of the six Iridium channels to perform a backup uplink/downlink function for REVEAL. Switching between the two systems is automatic and invisible to the investigator viewing the data stream.

The P-3 flew a total of 228 flight hours in support of the airborne science program in FY08.

NASA G-3

During FY 2008, the DFRC Gulfstream III (C-20) aircraft flew 43 sorties for 146 flight hours supporting the integration and testing of System 1 of the Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR). The UAVSAR is a pod-mounted L-band polarimetric imaging radar, designed and built by the Jet Propulsion Laboratory to perform repeat-pass interferometric measurements. An electronically steerable antenna is used to compensate for aircraft motion and reduce phase errors. Within the aircraft system, a Platform Precision Autopilot (PPA) controls the flight path of the aircraft to within a 10-meter variation from the programmed flight path. These two systems work together to allow very precise repeat pass interferometric measurements. A second, identical system has been developed and will be tested and used for science missions in FY 2009.

Testing of the PPA was completed in January of 2008, and subsequent testing of the UAVSAR began. Flights were initially conducted over corner reflector arrays at the Rosamond Dry Lake in the Mohave Desert of California. Additional flight lines were collected over the Hayward and San Andreas Faults, the Salton Sea, Long Valley, Kings Canyon, and Mt. St. Helens. The data demonstrated the instrument to be one of the finest of its kind in the world. The subset of an image below shows the caldera of Mt. St. Helens with two merging glacier lobes (center left). The UAVSAR is expected to produce imagery supporting breakthrough science in the areas of surface deformation, volcanoes, ice movement, and vegetation structure.

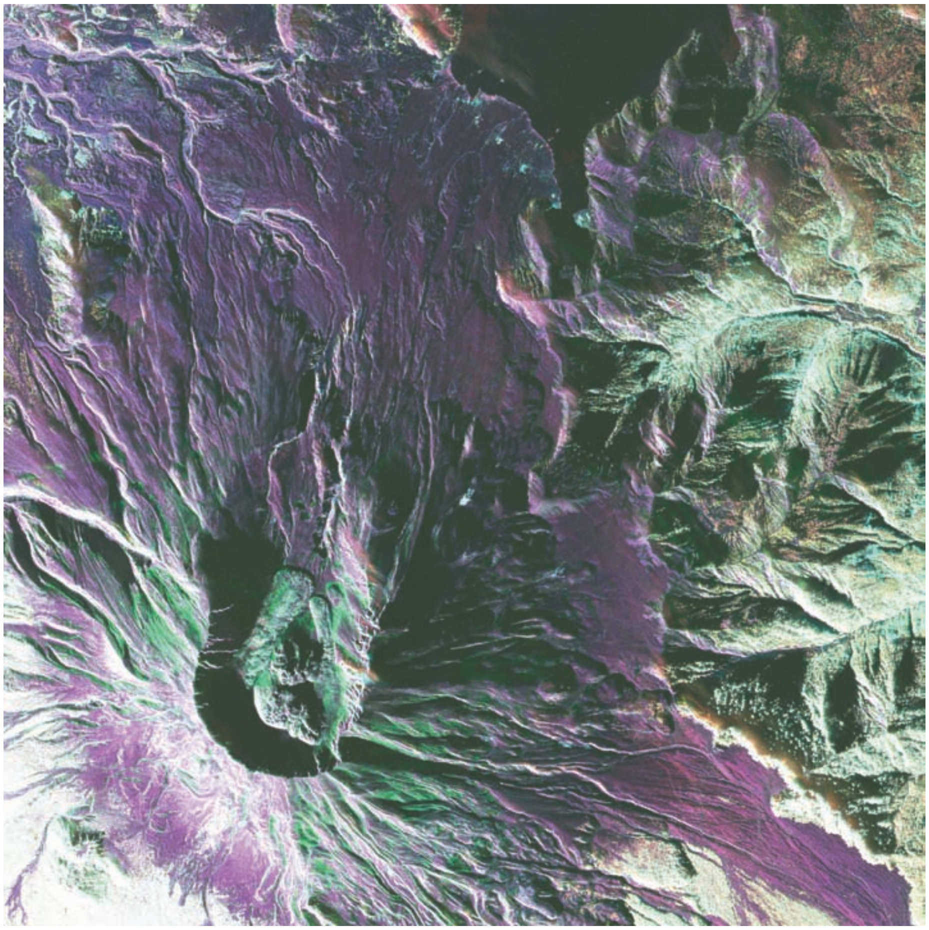


Figure 30
Mt. St. Helens Caldera (Image courtesy JPL UAVSAR project.)

Testing of the UAVSAR System 2 is scheduled for FY 2009. Planned improvements to the G-II include:

- The addition of a REVEAL system to the G-III for remote interaction with the instrument.
- An onboard processor for UAVSAR.
- A backup PPA system.
- A shortened instrument pylon.

The shortened pylon will enable operations from remote deployment sites, and near-term deployments are planned for Greenland, Alaska, Maine, and Florida. A prototype Ka-band derivative of the UAVSAR will also be developed and tested on the G-III during FY 2009.

URL: http://www.nasa.gov/centers/dryden/research/G-III/index.html

Aerosonde

The Aerosonde Mark 3 aircraft, with its proven low altitude, long duration flight characteristics was chosen for further evaluation during the 2008 NOAA/NASA Hurricane Demonstration Project.

Figure 31
Aerosonde Landing at WFF during a training flight.

Unfortunately, no tropical storms entered the area of approved operations and no mission hours were expended during the 2008 season.

Extensive gains have been made in granting airspace access and diplomatic approvals for Aerosonde UAS operations to take place outside of the United States and the U.S. National Airspace. The Aerosonde flight vehicles remain operationally available for scientific research.

NASA B-200

The Research Services Directorate (RSD) at the NASA Langley Research Center (LaRC) operates a Beechcraft King Air B-200 and a similar aircraft, a former military UC-12B. The aircraft are based at NASA 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 B-200 aircraft are ideally suited for small to midsized instruments that need dedicated profiles, or that need to be operated in conjunction with other instruments in this or other aircraft.

The two aircraft incorporate the following features and systems: GPS navigation systems, weather radar, uplinked weather information and TCAS in the cockpit; 29 × 29-in. and 22 × 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 was acquired this past year to enhance the overall navigation system capabilities of the aircraft. An in situ sampling head, outside air temperature probe, and hygrometer probe were installed on the exterior of the UC-12B 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 B-200 and 31,000 ft for the UC-12B. However, the aircraft are not 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-lb 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 integrated and flown four research payloads:

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

Conceptual designs for integration of NASA Goddard Space Flight Center's Laser Vegetation Imaging Sensor (LVIS) and NASA Ames' MODIS Airborne Simulator (MASTER) onto either aircraft also were also completed. FY08 mission accomplishments included over 260 research flight hours on the following missions:

- Local CALIPSO validation flights with HSRL and RSP.
- CALIPSO Caribbean deployment with HSRL.

Figure 32
NASA B-200 on ramp in Yellowknife, Northwest Territories, July 2008, during ARCTAS summer deployment.

- Arctic Research of the Composition of the Troposphere from Aircraft and Satellite (ARCTAS I) to Pt. Barrow and Fairbanks, Alaska with HSRL.
- ARCTAS II deployment to Yellowknife, Canada with HSRL and RSP.
- B-200 deployment to Birmingham, Alabama for the Environmental Protection Agency (EPA) with HSRL and RSP.
- Initial local research flights on the UC-12B 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.

For the EPA mission mentioned above, the B-200 flew 11 sorties from September 16-19 and again from October 12-16, 2008. The EPA was conducting an intensive air quality experiment with several ground-based instruments distributed around the city of Birmingham. The objective of the mission was to acquire vertically-resolved profiles of aerosol optical properties with the LaRC High Spectral Resolution Lidar (HSRL) over EPA ground sites, and upwind and downwind of those sites, to better assess transport into and out of the region, provide a greater spatial context for the ground-based measurements, and determine the degree to which the ground-based instruments capture the aerosol loading in the column. Overall, 11 flights were conducted for a total of 34 flight hours. The mission was considered a success by the EPA, and similar collaborations between NASA and the EPA are being planned for the future.

Anticipated activities for FY09 include CALIPSO validation flights across a wide range of latitudes, ASCENDS development flights, MASTER and LVIS integrations, and possible further EPA missions.

Twin Otter

Twin Otter International aircraft participated in several missions during FY08. The first mission was the Cold Land Processes Experiment (CLPX)-II (Alaska), that was conducted during two phases in December and February, for the Terrestrial Hydrology Program. Twin Otter International provided 165 hours of flight support to the Terrestrial Hydrology Program for CLPX-II.

The second mission of the year was the AVIRIS Hawaii 2008 Campaign during October 2007 to January 2008 for the Terrestrial Ecology Program. This was an investigation of the effects of invasive species on ecosystems. The mission suffered significant weather delays, but was successful in the end. A total of 52 hours were flown in Hawaii in support of the Terrestrial Ecology Program.

In total, Twin Otter International supported the Airborne Science Program for 321 flight hours in FY08.

AIRBORNE SCIENCE

PROGRAM ELEMENTS:

NEW TECHNOLOGIES & PLATFORM DEVELOPMENT

Global Hawk

Ikhana

UAVSAR Trajectory Control

SIERRA

ESTO

Mission Planning Tools

Common Data & Comm Systems

Global Hawk

NASA is establishing a significant enhancement to its current suite of airborne capabilities by acquiring the high-altitude, long duration Global Hawk unmanned aerial system. The two NASA Global Hawk aircraft (871 & 872) were manufactured under the original Defense Advanced Research Projects Agency (DARPA) Advanced Concept Technology Demonstration (ACTD) Program, and are based at the Dryden Flight Research Center. Global Hawk vehicle 871 was the first Global Hawk aircraft ever manufactured, and is a well-proven air vehicle that has flown more than 500 hours, including flights to and from Europe. Global Hawk 872 was the sixth air vehicle manufactured and has flown less than 200 hours. During 2008, a phase inspection was completed on vehicle 872, and was begun on vehicle 871.

The Global Hawk system is the only available UAS with performance specifications suitable to meet certain high altitude, long endurance science payload objectives. 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 air vehicle has numerous existing payload compartments and the potential for adding wing pods. The vehicle has the capacity to provide science payloads with substantial margins for payload mass, volume, and power in these payload spaces.

In April 2008, NASA Dryden and Northrop Grumman Corporation (NGC) established 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. During the standup of the program, the aircraft are being modified with a new independent airborne and ground integrated system for command, control, and communications (C3) with payloads.

A fixed NASA Global Hawk Operations Center (GHOC) is being developed at Dryden, which is configured to independently support air vehicle and payload operations. The Flight Operations Room (FOR) of the GHOC will consist of workstations occupied by the personnel responsible for the flight control and management of the air vehicle operations. An adjacent Payload Operations Room (POR) will consist of workstations occupied by the personnel responsible for the various air vehicle payloads. The POR personnel can monitor payload status, receive payload data, and control their individual payloads.

Flight operations of the Global Hawk are scheduled to begin during the second quarter of FY09 and research flights are scheduled to begin during the third quarter. The first Global Hawk science campaign will be 2009 Global Hawk Pacific (GloPac) mission

Figure 33
NASA Global Hawk #872 in front of Hangar 4801 at the Dryden Flight Research Center.

Ikhana

NASA Dryden Flight Research Center's Ikhana aircraft illustrated some if its capabilities when it flew fire-imaging missions in the summer of 2008. NASA and the U.S. Department of Agriculture Forest Service partnered to obtain imagery of the wildfires in response to requests from the California Department of Forestry and Fire Protection, the California Governor's Office of Emergency Services and the National Interagency Fire Center.

The Ikhana imaged almost 4,000 square miles from Santa Barbara north to the Oregon border during a flight on July 8. In as little as 10 minutes, the flights provided critical information about the location, size and terrain around the fires to commanders in the field. 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 2008, the NASA Suborbital Science Program within the Science Mission Directorate was Ikhana's primary customer, using the aircraft for Earth science studies. 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. The Suborbital Science Program uses both manned and unmanned aircraft to collect data within the Earth's atmosphere, complementing measurements of the same phenomenon taken from space and those taken on the Earth's surface.

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.

The Ikhana also was used for research on the use of fiber-optic wing shape sensors (FOWSS) located along the top of the Ikhana wing surface. The sensors provide about 2,000 strain measurements in real time and show the shape of the aircraft's wings in flight. Fiber optic sensors offer weight reduction that has potential for reducing costs and improving fuel efficiency.

The potential for weight reduction, however, is but one small part of the picture. This technology also opens up new opportunities and applications that would not be possible with conventional technology. For example, the new sensors could enable adaptive wing-shape control - the concept of changing a wing's shape in flight to take advantage of aerodynamics and make the aircraft more efficient.

Six hair-like fibers located on the top surface of the Ikhana's wings provide about the strain measurements in real time. The fibers are so small that they have no significant effects on aerodynamic lift and weigh less than two pounds. The fiber optic sensors themselves are so small that they could eventually be embedded within composite wings in future aircraft.

There are no funded Earth Science related support planned for FY2009.

Figure 34
Ikhana during pre-flight checkout at NASA Dryden Flight Research Center.

UAVSAR Trajectory Control

A Platform Precision Autopilot (PPA) has been developed to enable an aircraft to repeatedly fly nearly the same trajectory hours, days, or weeks later. This capability allows accurate earth deformation measurements through precise repeat-pass interferometry, a key element for the success of the NASA Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR) program. The PPA uses a novel approach to interface with the NASA Gulfstream III by imitating the output of an Instrument Landing System (ILS) approach. This technique minimizes, as much as possible, modifications to the baseline GIII. In addition, the safety features of the aircraft's autopilot are retained. The PPA finished all phases of flight testing in early 2008.

Objective

The objective of the PPA is to enable repeat pass flights within a five meter radius tube over a 200 kilometer course in conditions of calm to light turbulence for over 90 percent of the time. In order for JPL's synthetic aperture radar to generate the best images, it is important to operate on a steady platform. Hence, as a secondary goal, the PPA has to minimize motion of the GIII during data collection runs. The end product is a "care-free, user-friendly" autopilot suitable for deployment and operation by the flight operations engineer.

Approach

The PPA uses a Kalman filter to generate a real-time navigation solution with information from the GIII systems and a differential GPS unit located in the UAVSAR pod. The real-time position solution is used to compute commands (Guidance and Control modules) which in turn drive two modified ILS testers. The ILS tester units produce modulated RF signals fed to the onboard navigation receiver. These correction signals then allow the GIII autopilot to fly a simulated, constant-altitude ILS approach to meet the PPA requirements for UAVSAR operations.

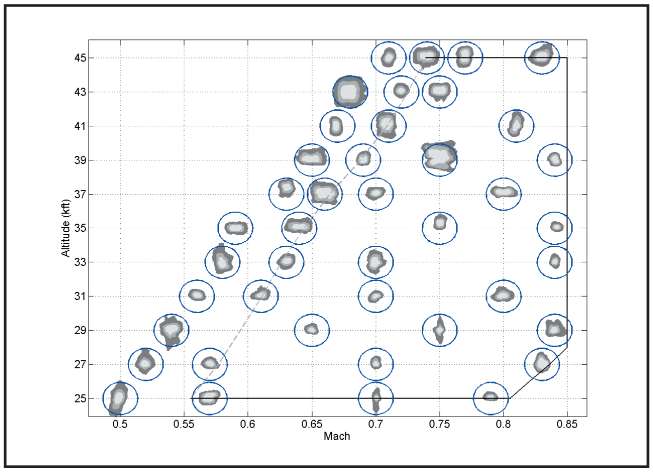


Figure 35
Flight Envelope with contours encompassing 90% of flight time at each flight condition

NASA Dryden built a GIII engineering simulation for development and evaluation of the PPA. A Monte Carlo capability was also developed in parallel with the GIII simulation to examine the PPA performance in the presence of vehicle and atmospheric uncertainties. In early 2007, flight testing of the PPA began. Cycle 1 flights were designed to evaluate modeling of the GIII and associated systems including the navigation receiver, Flight Director, and factory GIII autopilot. Cycle 2 flights were designed to map out the flight envelope and determine the flight conditions where the requirements are met.

Results

The five meter radius tube requirement was met for the majority of flight conditions. Figure 35 shows results from the Cycle 2 evaluation flights. The circles at each flight condition represent the five meter radius tube. Generally, there was adequate performance to keep the GIII inside (or within a meter) of the tube boundary over 90% of the time for each flight segment. It was also observed as a rule that tighter control, as reflected in more time spent closer to the tube center, was seen at higher Mach numbers.

The Euler rates were all within the desired range during each flight segment for more than 90% of the time at each flight condition. Figure 36 shows the rates for representative altitudes ranges, low (25k to 31k ft.), mid (33k to 39k ft), and high (41k to 45k ft.), as a function of Mach number. As a general, rule roll rate was lower at higher dynamic pressures.

Status

The PPA completed flight testing in January 2008. The precision autopilot demonstrated the capability to provide a stable platform that can repeatedly fly a predefined trajectory within the tolerances prescribed (five meter radius tube) over a 200 kilometer track. It is currently operating on the NASA GIII in UAVSAR flights throughout California. Future plans for the PPA involve deployment over Greenland to aid in ice sheet measurements and integration into the Stratospheric Observatory for Infrared Astronomy (SOFIA) program.

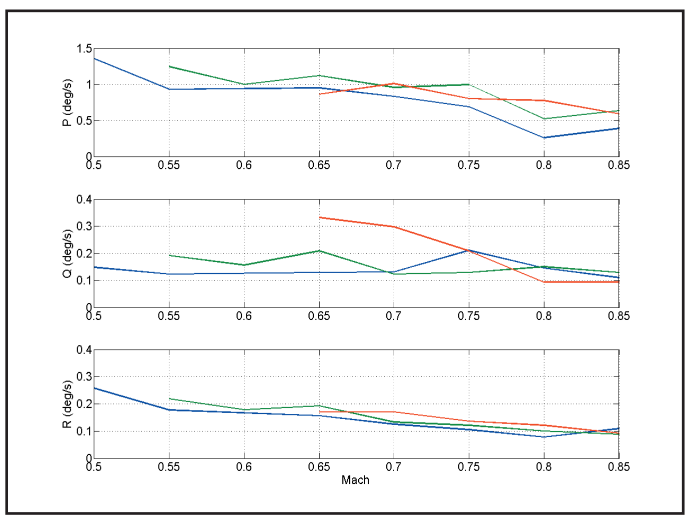


Figure 36
Ninety percentile Euler Rates vs. Mach for low (25k to 31k ft), mid (33k to 39k ft), and high (41k to 45k ft) altitude ranges.

SIERRA

The Sensor Integrated Environmental Remote Research Aircraft (SIERRA) is an unmanned, fixed-wing aircraft 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.

The team continued to progress towards the first flight of a science payload, logging nearly 25 hours of flight testing on the aircraft during FY2008. Ground testing and taxi testing were performed at Moffett Field, CA, with additional engine/taxi tests being performed at Truckee, CA for cold weather validation. Flight testing was conducted within the Fort Hunter Liggett restricted airspace and at Crow's Landing under an FAA Certificate of Authorization.

Designs were completed and configuration control board reviews were conducted for the first flight payload. The first payload will consist of three instrument packages:

- *Ice roughness profilometer and INU.*
  PI: James Maslanik, University of Colorado at Boulder.
- *Pyrometers, pyronometers, and a microspectrometer for ocean color.*
  PI: Geoff Bland, GSFC/WFF.
- *Hyperspectral imager and high resolution tracking camera.*
  PI: Steve Dunagan, NASA/ARC.

In FY2009, the SIERRA will be upgraded to include a differential GPS (DGPS) for providing precise and accurate position data to the payloads. An Iridium satellite communications modem will also be installed into the autopilot and ground station for over-the-horizon command and control. The project is partnering with an NASA Aeronautics project, led by Corey Ippolito of NASA Ames, to install a PC/104 terminal in the nose for flight experiments. The team will also be finalizing plans and beginning implementation on a fuel capacity upgrade that will likely entail adding additional fuel bladders to the center wing section to increase range and endurance.

Anticipated missions in the next year include an airborne ecological assessment of the island of Yap (Federated States of Micronesia), in partnership with the USFS, and ice roughness measurements of Arctic sea ice based from Svalbard Norway, in support of a NASA-funded UAV-IPY project. In preparation for this activity, the team plans cold weather operations testing in California, Utah, or North Dakota.

Technology Demonstrations

In 2008, the Airborne Science program has teamed with several investigators funded by the Earth Science Technology Office (ESTO) to develop instrument technologies through demonstration flights on ASP platforms.

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 environement, increased technology readiness levels can be demonstrated, bringing the development one step closer to being mission ready. Since 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.

Airborne demonstration instruments also have evolved through the Airborne Instrument Technology Transfer (AITT) program and other initiatives to the point where they provide calibrated science data used for developing science algorithms and calibration of on-orbit instrument data.

Some of the more significant demonstration flights conducted this past year include:

GIFS

GIFS (Geostationary Imaging Fabry-Perot Spectrometer) is a tunable triple-etalon Fabry-Perot Imaging Spectrometer developed for cloud characteristics and surface pressure imaging onboard geostationary satellites. An engineering flight conducted in January successfully demonstrated the GIFS prototype engineering performance and its spectral scanning technique on the NASA P-3.

CO_2 Sounder

The NASA Goddard CO_2 Sounder team successfully conducted airborne engineering tests of their CO_2 Laser Sounder instrument in October by making airborne

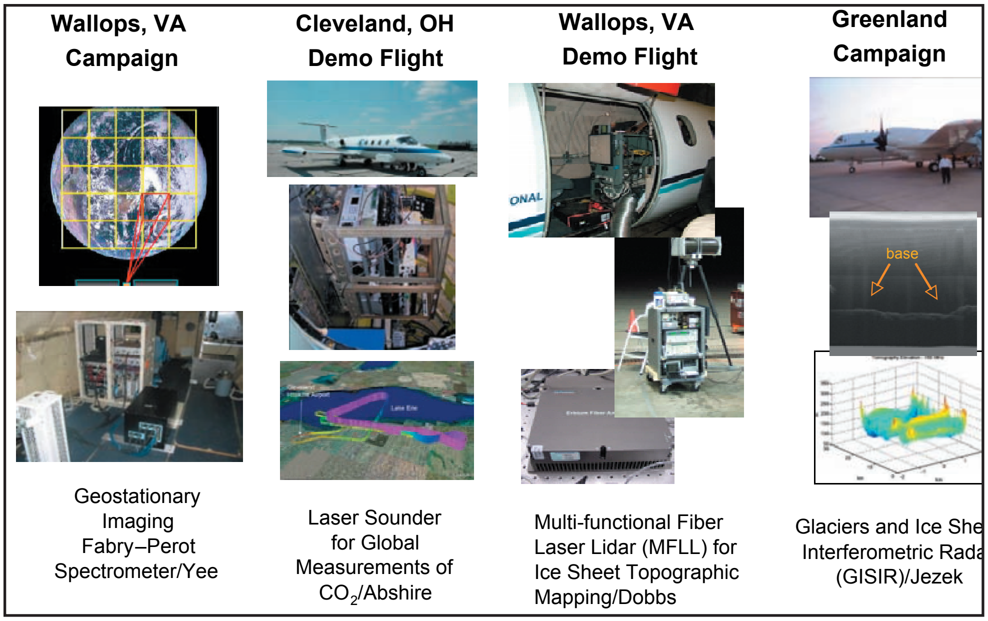


Figure 37
ESTO Supported Instruments, Aircraft, and Sample Data.

measurements in the vicinity of Cleveland, Ohio on the NASA Glenn Learjet 25. The CO_2 Sounder is a technology development effort to develop an instrument to enable high accuracy (< 1 ppm) global maps of CO_2 mixing ratios in lower troposphere, as needed by the ASCENDS mission.

GISIR

The purpose of the Global Ice Sheet Interferometric Radar (GISIR) is to develop and test radars (150 Mhz & 450 MHz) and algorithms for imaging the base of the polar ice sheets, and to develop 3-D topography of the glacial bed. Flights were conducted in the Fall of 2007 and Summer of 2008 over Greenland using both the P-3 and Twin Otter to make 3-D topographic representations of the basal properties of Greenland using both interferometric and tomographic SAR techniques.

Multi-functional Fiber Laser Lidar (MFLL) for Ice Sheet Topographic Mapping

The MFLL implementation is a multi-functional system capable of topographic ranging, aerosol/clouds sensing, and atmospheric profiling that promises a roughly factor of ten reduction in size, mass, power, cost, and development risk over existing approaches. The MFLL was tested over Wallops, Virginia using the NASA B-200 aircraft.

A total of approximately 50 flight hours were flown in FY08 in support of ESTO technology demonstrations.

Mission Planning Tools

REAL TIME MISSION MONITOR

System Overview

The Real Time Mission Monitor (RTMM) is a situational awareness tool that integrates and displays satellite, airborne and surface data sets including geostationary imagery, passive microwave products, radar, sondes, lightning, current weather information, modeled forecast outputs, and vehicle state data (e.g., aircraft navigation, satellite tracks and instrument field-of-views) during airborne science missions. RTMM optimizes science and logistic decision-making during airborne missions and field experiments by presenting timely data and graphics to the users to improve real time situational awareness of NASA's mission assets.

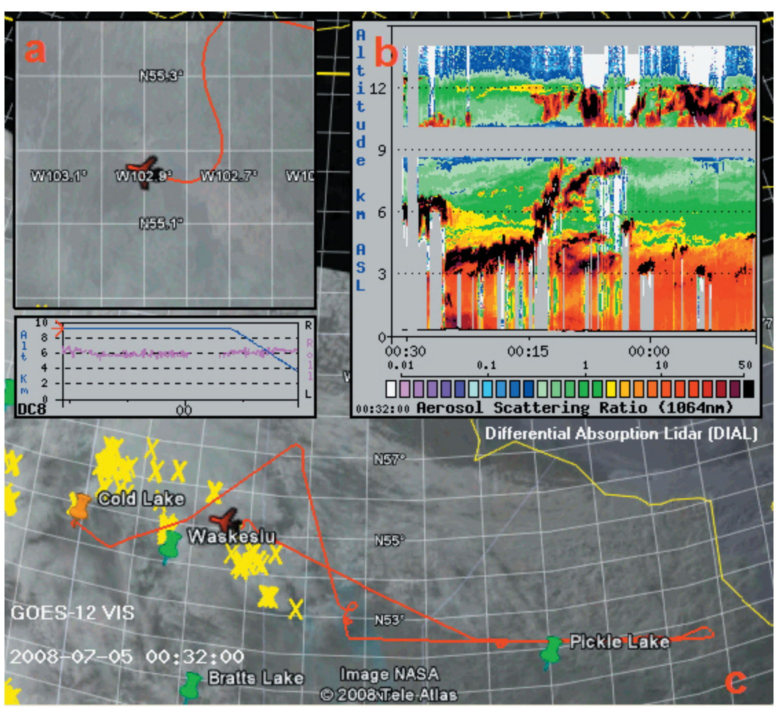


Figure 38

RTMM composite showing (a) zoom in on DC-8 flight track, (b) coincident DIAL curtain viewer depicting clouds and aerosol layers, (c) DC-8 track overlaid on GOES visible with lightning strikes in yellow during an ARCTAS Summer flight on July 6, 2008.

RTMM is web-accessible, password protected, network application for use by anyone connected to the Internet. RTMM uses the Google Earth application as the end-user visualization package (i.e., easily accessible to users) but relies on a diverse distributed network of background data sources all connected by the Internet and managed by a set of web-based applications. RTMM employs many useful application tools that simplify the management of assets and decision-making process during airborne Earth science missions. To paraphrase the old BASF television commercial "RTMM doesn't make the airborne science, it makes the airborne science better."

RTMM is useful in all three phases (pre-flight planning, in-flight situational awareness and adaptation, and post flight review) of an airborne mission. In the pre-flight phase, scientists can help plan flight patterns, flight leg durations, and coordinate aircraft waypoints with simultaneous satellite overpasses and/or other aircraft. In-flight, RTMM is used to facilitate the real time decision-making process to optimize the flight science goals. Scientists aboard the aircraft and on the ground can locate the aircraft and overlay the position with real time atmospheric data updates. Post-flight, RTMM can be used like a digital video source to replay any part of the mission as animations from take-off to landing.

Impact to Science in Field Programs

Over the last several years, the use of RTMM in NASA Airborne Science Program has fundamentally changed how scientists participate in airborne field campaigns. From the scientist's point of view, there is a new way to participate in doing science. This paradigm shift is evident in all three phases of the mission, but is particularly evident in both the pre-flight and in-flight phases. RTMM expands the sphere of participants by providing an easy, accessible means to view and acquire data, and interact with the missions as they are happening. Working closely with the Global Test Range project at NASA Dryden, RTMM uses satellite-based aircraft-ground network communications, creating a suborbital telepresence and sensor web to exchange data and information between the aircraft and ground operations, and from aircraft to aircraft. RTMM brings in data and images from a wide variety of NASA sources, other federal agency sites, academic organizations, and commercial data providers and integrates them in a widely available visualization package. This allows a larger number of people to be actively engaged in the mission as it happens. Participants, whether at a ground operations center, aboard the aircraft, or at their home institutions, all have simultaneous access to the same information.

RTMM Application in 2008

The RTMM proved its value in the field as it supported program managers, scientists, and aircraft personnel during several 2008 NASA field deployments. The first two 2008 RTMM deployments were in support of the ARCTAS spring and summer experiments. In both experiment phases, RTMM monitored the long range DC-8 and P-3 flights to Thule, Greenland and across the arctic region. In 2008, RTMM continued to evolve and add functionality. RTMM provided GOES visible, infrared, and water vapor products, multi-satellite infrared composites, lidar, lightning cloud-to-ground detection, MODIS fire detection products, FSU Weather Research

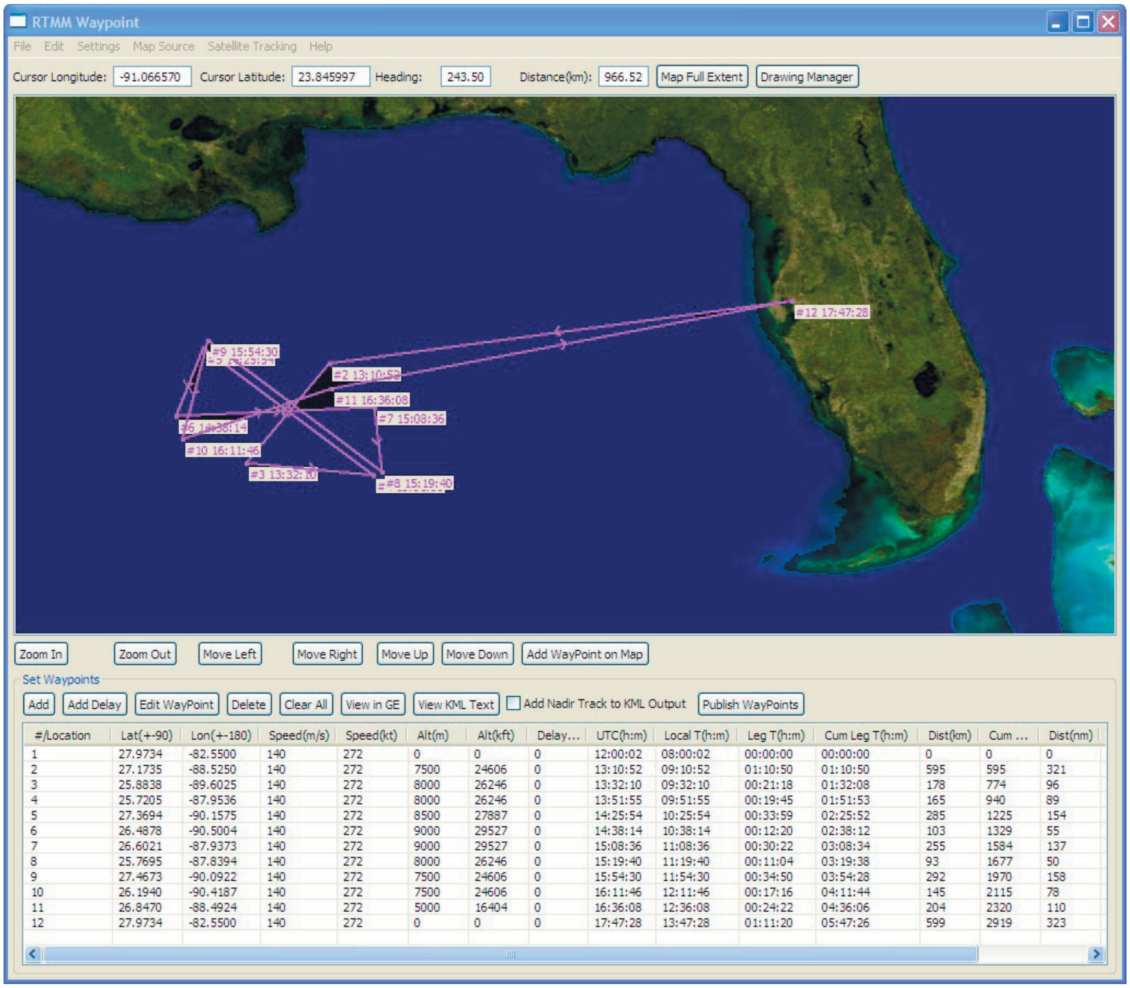


Figure 39

Waypoint Planning Tool depicting interactive point-and-click flight plan with legend cumulative flight information detailed in a spreadsheet-like summary table.

& Forecasting model forecasts, GEOS-5 weather and aerosol model forecasts, and NEXRAD radar products. RTMM added to its growing list of aircraft tracked and monitored during science flights. The NASA P-3, B-200, CV-580 and Twin Otter aircraft were tracked for the first time (in addition to the DC-8) and plane-to-plane transfers of lidar data demonstrated the capability to transmit and share data from one plane to another in real time. The plane to plane data transfer was first implemented with the Differential Absorption Lidar (DIAL) instrument which flies aboard the DC-8. During ARCTAS, scientists on the NASA P-3 did not have a lidar onboard but they were interested in the aerosol layers that the DC-8 DIAL lidar was viewing. The RTMM team developed a lidar curtain viewer that enabled scientists on the ground and on the P-3 to view the DIAL curtain plots (Fig. 38, p. 89, upper right insert). In a similar manner, curtain plots from the

B-200 High Spectral Resolution Lidar were successfully transferred in-flight from the B-200 to the P-3.

After the completion of ARCTAS, RTMM provided mission monitoring capabilities to the NASA Soil Moisture Active Passive (SMAP) science team in support flights of the NASA P-3 and Twin Otter for the SMAP Validation Experiment (SMAPVEX). In a very short time, the RTMM was adapted for the SMAPVEX flights (e.g., added regional NEXRAD and MODIS total precipitable water products subsetted over the mid-Atlantic). RTMM supported 11 flight days during the period from 29 September to 13 October 2008.

Waypoint Planning Tool (WPT)

The RTMM team's extensive experience in NASA airborne field campaigns taught us a lot about the needs and requirements of mission scientists for planning and conducting missions. One of the outgrowths of deploying RTMM in the field was the recognition that mission scientists needed a better way to plan an aircraft mission in situ. Planning an airborne mission requires data, information and knowledge from a wide variety of sources. Information about the desired direction, speed and altitude of the plane, loiter times, predictive satellite overpass times, current and fore-casted weather data, background maps, and flight restricted areas are some of the parameters that need to be factored in when making a flight plan.

The RTMM team developed a planning tool that integrates all of these parameters and combines them with a simple point-and-click user interface to enable a mission scientist to quickly and efficiently plan and edit a flight plan. The scientist selects the aircraft and takeoff times for the mission being planned, and then uses a mouse to select the various legs of the flight. The software automatically calculates flight leg and cumulative distances and times. Individual legs can be edited for location, aircraft speed, altitude and delay times, etc. They can be altered graphically by grabbing a midpoint or endpoint and "rubber banding" them to a new location. Alternatively, the flight legs can be edited in an "Excel-like" spreadsheet by entering specific values in an individual row and/or columns. Figure 39 (p. 91) depicts a hypothetical flight plan for the P-3 that is flying "figure 4s" through a tropical storm. Note the individual flight leg information displayed in the spreadsheet listing. Upon completion of the flight waypoints definition, the result is easily sent directly to the RTMM for display and integration with the full set of monitoring features.

Common Data & 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. Not only aircraft position, but actual data from the payload instruments 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 bi-directional links can 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 previously demonstrated on the DC-8 aircraft using Iridium satellite phone modems, and were further refined in 2008 on both the DC-8 and P-3 during the ARCTAS missions.

Figure 41 (pg. 94) shows an overview of the new airborne communications architecture. Key elements of this new communication architecture include an onboard ethernet

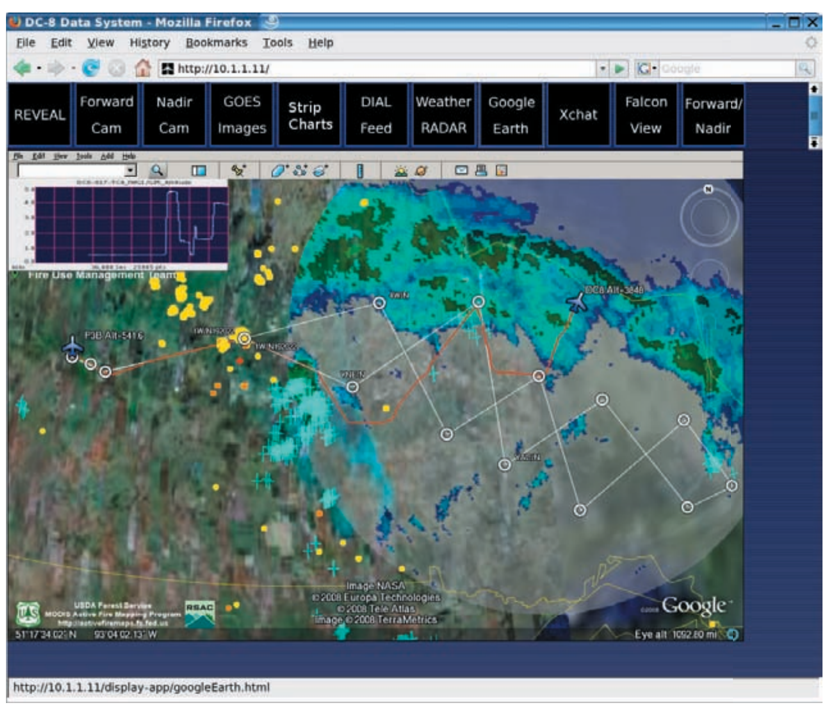


Figure 40

A screen shot from the DC-8 in-flight science data system during one of the ARCTAS missions in Canada. The flight tracks of the DC-8 and P-3, together with weather radar, MODIS satellite fire detections and lightning strike data, are overlain on a Google Earth background.

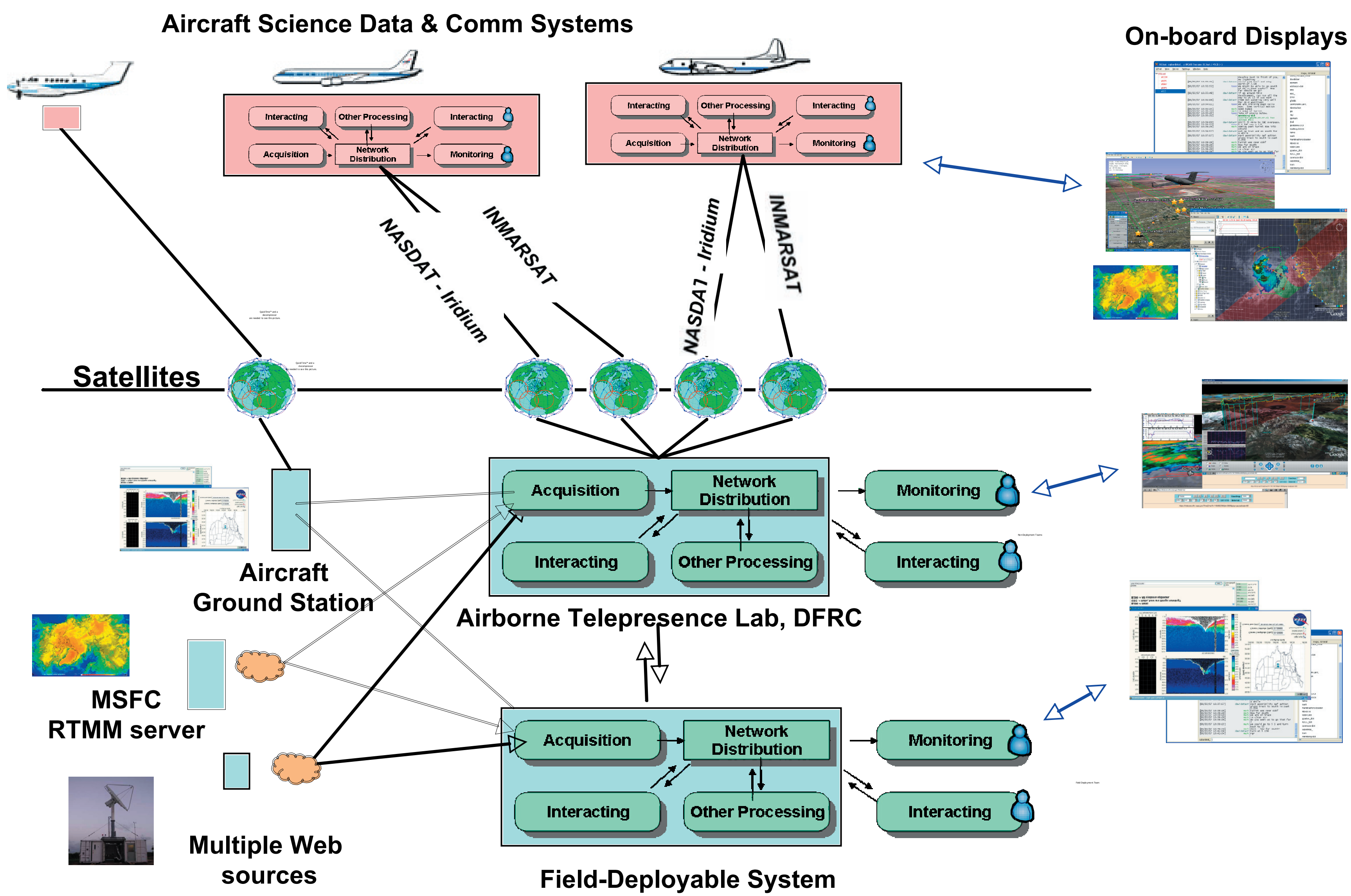


Figure 41
Notional Airborne Science Real-time Data and Communications Architecture

network linking the payload instruments to a common server, and a user-transparent satellite communications 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 IWGADTS. Data visualization tools, customized to the individual instrument types, are also essential to present the information to the science teams in a useable form for decision-making. NSERC and the Real Time Mission Monitor team at Marshall Space Flight Center are jointly developing the software to achieve this. Elements of the NASA Collaborative Decision Environment (CDE) will also be incorporated to foster communication and data sharing with extended science teams across the Internet. Derived from software used at NASA Ames to manage the Mars planetary rovers, and adapted to airborne platforms for the Western States Fire Missions, the CDE promises to greatly expand data accessibility, enabling investigators around the world to actively participate in airborne science missions.

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 NASA Dryden on the REVEAL project, the next-generation of these systems will be called the NASDAT (NASA Airborne Science Data and Telemetry) system and is scheduled to deploy in late 2009. Accompanying this will be a new standard Experimenter Interface Panel (EIP), which will provide electrical power, network communications, and the state data feeds to the various aircraft payload areas.

The new EIPs will be first installed on the Global Hawk, initially hosted by a modified REVEAL box, pending the availability of the new NASDAT units. 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 will allow the mission pilot to monitor and control the power and basic functionality of each instrument individually. A separate telemetry link module is also being developed to interface with the high-speed Ku-band sat-com system slated for the Global Hawk. The link module will also include mass storage for buffering science data, and a dedicated payload computer for onboard processing with mission-specific software. This flight hardware is being developed at the Airborne Science and Technology Lab (ASTL) at NASA Ames.

This overall communications and data-sharing concept will be initially demonstrated on the Global Hawk UAS during its first science missions in 2009, with the associated visualization and web-based tools being hosted in the Global Hawk Operations Center at NASA Dryden. It will then be gradually implemented across the NASA airborne science fleet as platforms are upgraded and satellite communications systems become more widely available.

AIRBORNE SCIENCE

PROGRAM ELEMENTS:

SCIENCE INSTRUMENTATION, FACILITIES & SUPPORT SYSTEMS

ASTL

DAOF

Airborne Sensor Technology Lab

This element of the Airborne Science Program encompasses the development and operation of facility instrumentation and ancillary systems for community use by NASA investigators, as well as general instrument engineering and payload integration support for the program. The ASTL operates the MODIS and ASTER Airborne Simulators (MAS and MASTER) in conjunction with the EOS Project Science Office and JPL. Other facility systems include the Autonomous Modular Sensor (AMS) for UAS platforms, and various tracking cameras and precision navigation systems for mission documentation. This group is also leading the development effort for the next-generation of airborne science data networks for the Program, and the associated internet-based "sensor web" environment, which is intended to increase the measurement potential of the various platforms. In addition, the lab operates a NIST-traceable calibration facility, which supports a variety of NASA airborne sensors and radiometers with measurements in the visible through thermal infrared region. Additional tasks include data processing, and sensor flight planning services for approved remote sensing flight requests. The ASTL is staffed by the Univ. of California, Santa Cruz, and is part of the NASA Ames UARC (University Affiliated Research Center.) It is jointly supported by the EOS PSO and the Airborne Science Program. A summary of 2008 engineering and data collection activities follows.

The Airborne Science and Technology Laboratory at NASA Ames is an element of the Airborne Science Program, and is responsible for the development and operation of facility instrumentation and ancillary systems for community use by NASA investigators. It also provides engineering support for the integration of new science instrumentation onto the NASA aircraft. The facility instrument systems managed by ASTL include the MODIS and ASTER Airborne Simulators (MAS and MASTER,) the Autonomous Modular Sensor (AMS) for UAS platforms, and various tracking cameras and navigation systems for mission documentation.

This group is also leading the development of next-generation of airborne science data networks for the program, and the associated internet-based "sensor web" environment, to increase the measurement potential of the various platforms. In addition, the lab operates a state-of-the-art infrared instrument calibration facility,

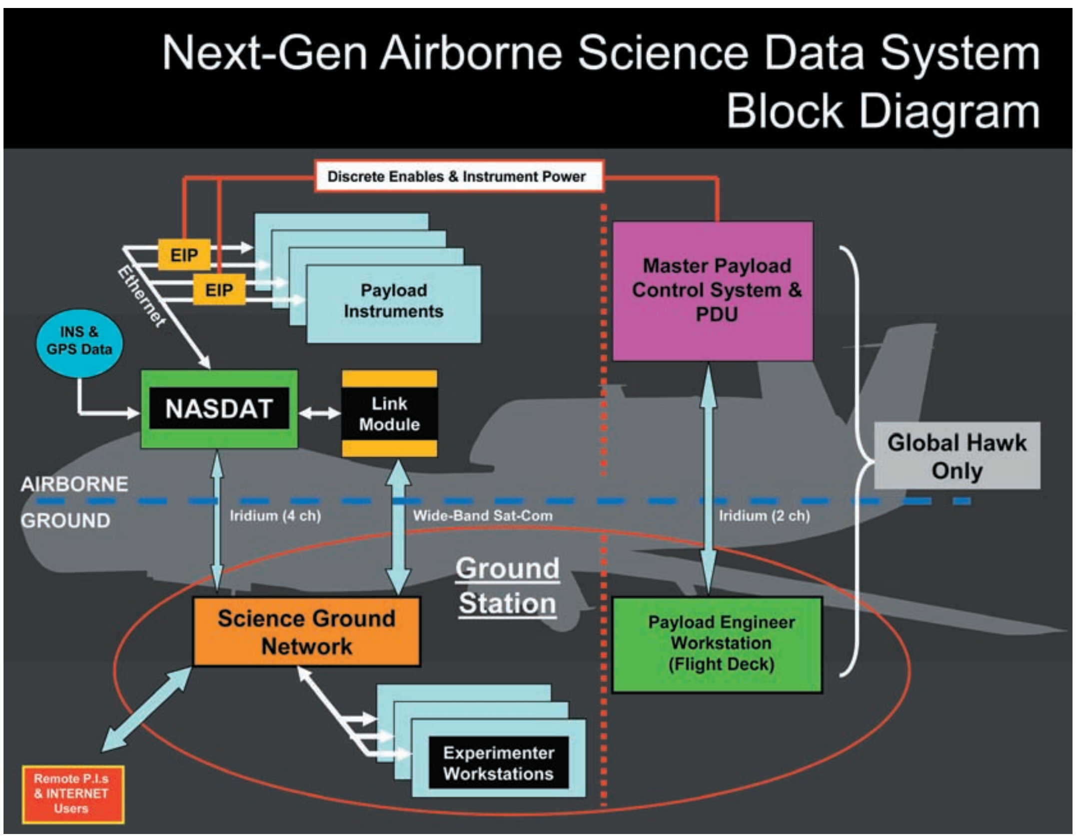


Figure 42
Data flow and flight hardware components for the future standard airborne data systems (Global Hawk-specific subsystems to the right).

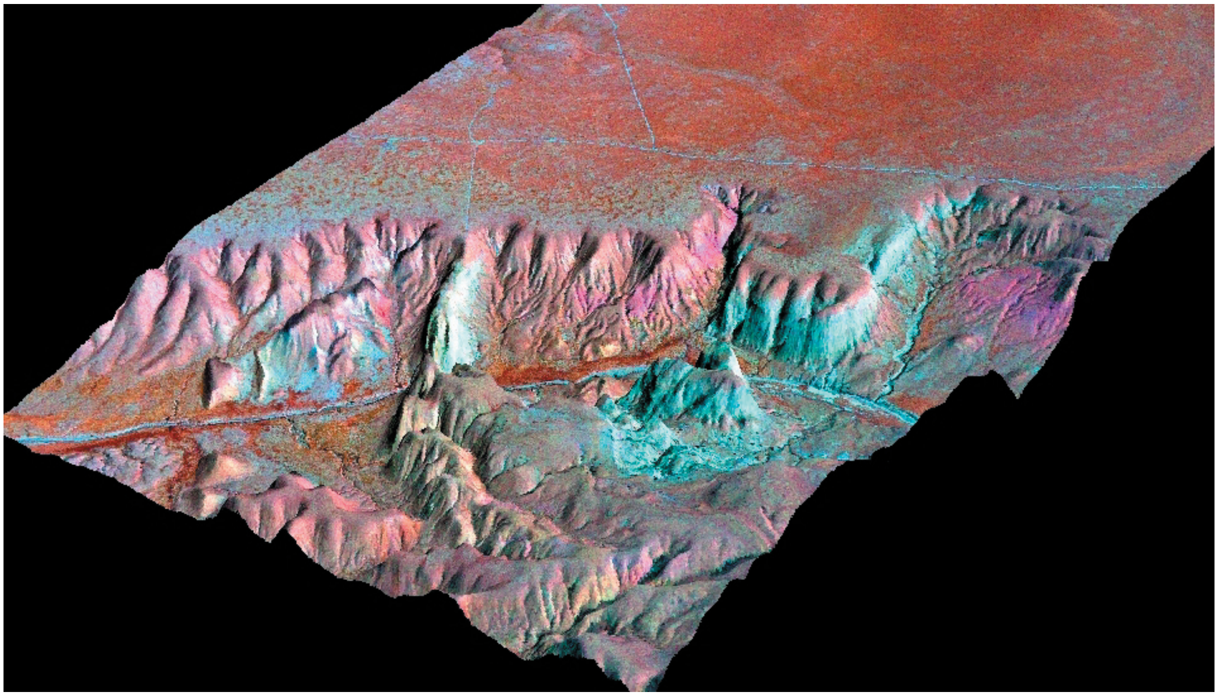


Figure 43
Taken Oct. 4, 2007, 2-meter resolution MASTER imagery of Sevillita, NM.

which supports a variety of NASA airborne sensors and radiometers. Additional tasks include data processing services and sensor flight planning for approved remote sensing flight requests. The ASTL is managed by the University of California, Santa Cruz, and is part of the NASA Ames University Affiliated ResResearch Center (UARC).

Global Hawk Payload Systems Project

Working in conjunction with the Global Hawk team at Dryden Flight Research Center, the design and implementation of the payload power and communications infrastructure for this major new science platform began in 2008. The airborne hardware elements under development at the ASTL include the new NASDAT system (NASA Airborne Science Data and Telemetry unit;) new Experimenter Interface Panels providing power, communications, and state data feeds; and a Master Payload Control System/Power Distribution Unit (MPCS/PDU) that allows the mission pilot to monitor and control the power and basic functionality of each instrument. A separate telemetry Link Module is also being built to interface with the high-speed Ku-band sat-com system slated for the Global Hawk. (See the New Technology section for related information.)

A video tracking camera system is also being developed for the new Global Hawk UAS. This will be a wide field-of-view, time-lapse device that will be used by the science teams to evaluate conditions in real-time around the aircraft

Engineering: MAS (MODIS Airborne Simulator) Status

After more than 650 high-altitude missions on the ER-2, the MAS sensor was taken out of service for an extensive re-fit. It is anticipated to be available for use again in late 2009. A project to design and build a next-generation data system for the MAS and related instruments was also begun, with support from the EOS-PSO.

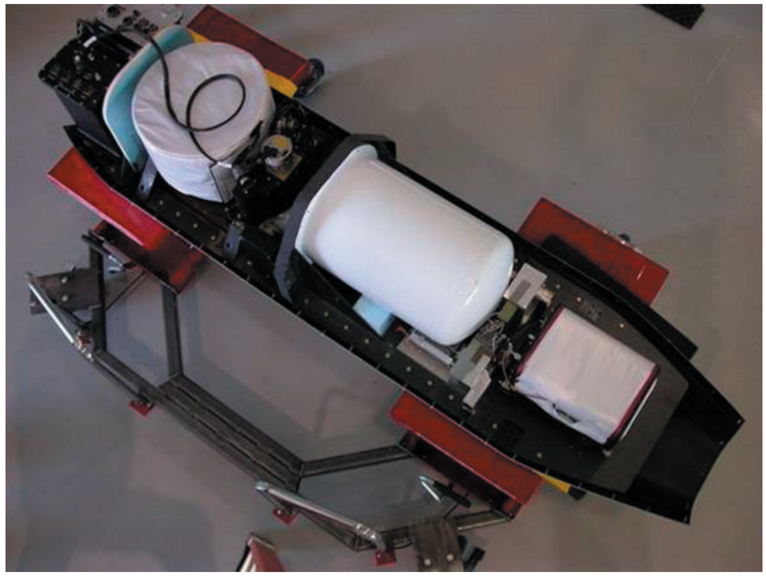


Figure 44
The AMS sensor as configured for the Ikhana UAS sensor pod, for the Western States Fire Missions.

MASTER (MODIS/ASTER Airborne Simulator)

Three sequential acquisitions were conducted on the DOE B-200 aircraft of the major 2007 Southern California fire scars to document the ecological impact of severe wildfires (see page 27). Other MASTER data collections included an Sudden Oak Death study site in Big Sur, CA, Monterey Bay algal blooms, and day/night thermal IR missions over the city of San Francisco to study urban heat island effects. A ten-year time series was also continued over the USDA long-term study sites near Jornada, New Mexico, to develop remote sensing of techniques for desert hydrology, and for using ASTER and MODIS thermal infrared data to study surface energy balance. MASTER was also flown on the ER-2 over calibration sites in Nevada for the EOS PSO.

AMS (Autonomous Modular Sensor)

The final series of Western States fire missions were conducted with the AMS mounted in a wing pod on the Ikhana UAS (see page 23). Multiple fires across California were imaged with this multispectral system, and real-time fire data products were generated onboard the aircraft and relayed to users on the ground via an internet-based data distribution network. Testing and integration of a higher performance Applanix POS/AV geo-location system was conducted simultaneously. The AMS sensor is currently being re-configured for atmospheric research missions on the Global Hawk UAS, and an Ocean Color

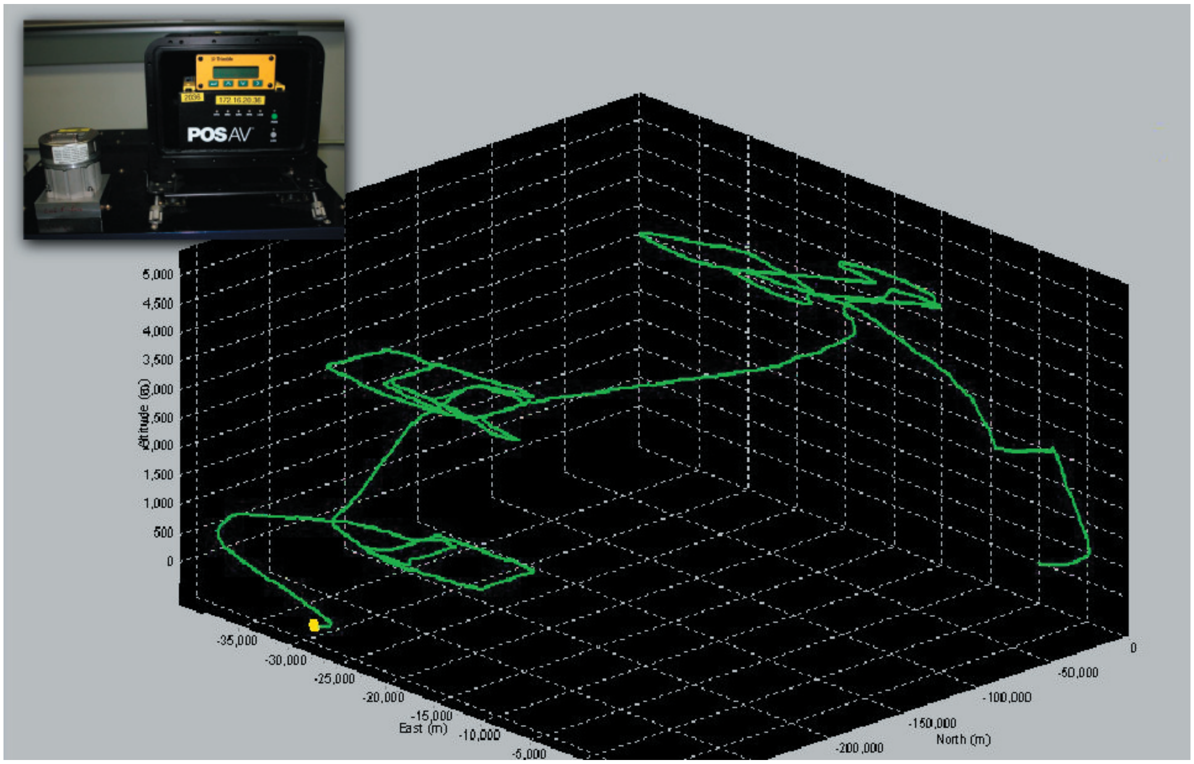


Figure 45
B-200 aircraft trajectory derived from the POS/AV system (Jornada/Sevillita, NM MASTER flight, 10/22/08).

Imager (OCI) spectrometer module is scheduled to be completed in 2009.

POS/AV (Aircraft Position/Orientation System)

These precision, stand-alone navigation and attitude measurement systems are used to support the MASTER and AMS facility instruments, as well other new sensors being developed by the agency under the ESTO instrument incubator program. One POS system was integrated with the new MFLL (Multi-functional Fiber Laser Lidar) ice-sheet mapping system from ITT Corporation, and flown on a commercial B-200 aircraft. Another system was installed on the Glenn Research Center Learjet to support test flights of the new Swath Imaging Multi-polarization Photon-counting Lidar (SIMPL) from the Goddard Space Flight Center.

Other Program Support Activities

Flight planning services for the JPL AVIRIS 2008 Twin Otter flight requests were provided, with over 50 site plans being developed for that commercial catalog aircraft. Flight Readiness Reviews for those,

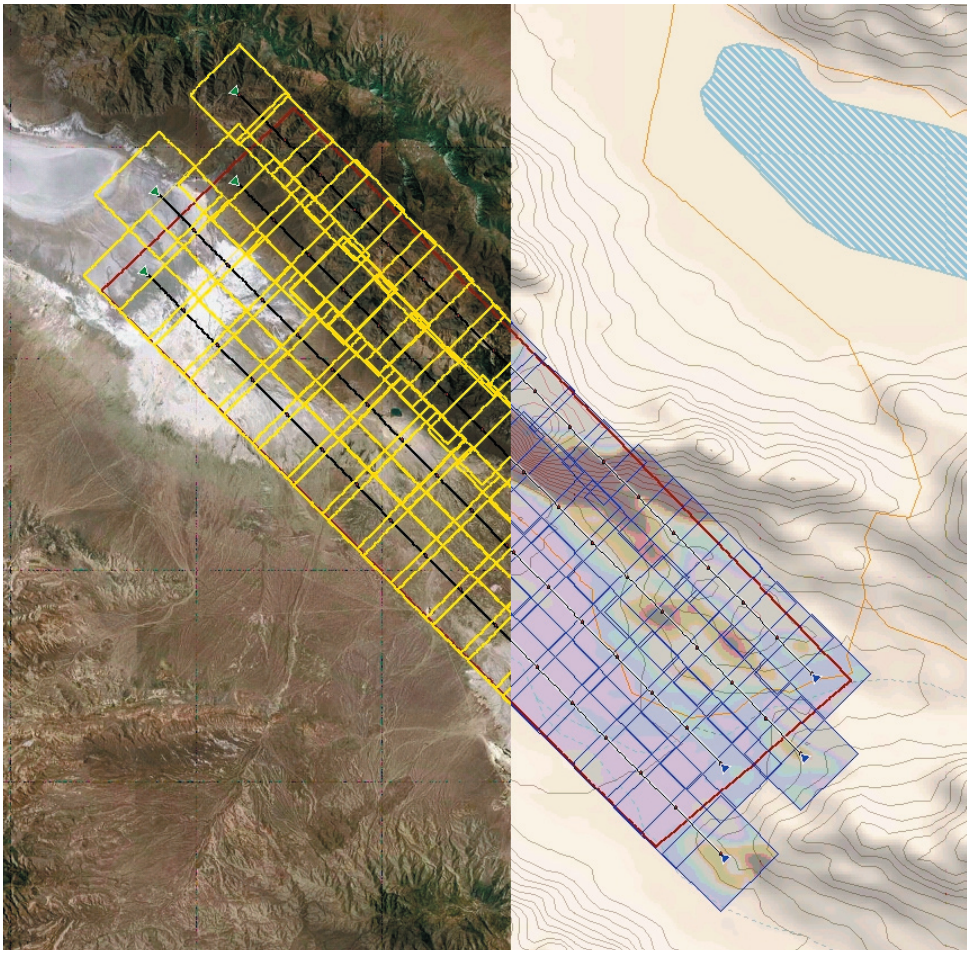


Figure 46
Typical AVIRIS/Twin Otter Sensor Flight Plan, as prepared by the ASTL (Dixie Valley, NV, 2008)

together with the JPL PALS sensor missions on the same aircraft, were also supported. Engineering services included the design and fabrication of a mounting system for the new NOBALT air-sampling system on the WB-57 aircraft for the NOVICE missions. This included the development of a stress analysis package and related documentation for the JSC airworthiness review.

As part of NASA's response to the recent Decadal Survey, the MASTER and AVIRIS sensors together have been identified as an airborne precursor to the proposed HyspIRI satellite system. Data mining of coincident MASTER and AVIRIS (and HyMap) archival data was performed, which will be used by the HyspIRI science team for concept development. The two sensors are slated to be flown together on the ER-2 over selected sites as this effort develops over the next several years.

Dryden Aircraft Operations Facility

NASA DC-8 overflies Dryden Aircraft Operations Facility, Palmdale, California.

Fiscal year 2008 marked a key event for NASA Airborne Science flight operations with the stand-up of the Dryden Aircraft Operations Facility (DAOF). The DAOF is located in Palmdale, California, about 70 miles northeast of downtown Los Angeles. NASA has leased the facility, which consists of over 210,000 square feet of hangar space and an equivalent amount of working space for offices, labs, conference accommodations, and storage from Los Angeles World Airports for 20 years. NASA's DC-8, ER-2s and G-III aircraft will be based at this new facility, along with the Stratospheric Observatory For Infrared Astronomy (SOFIA) aircraft.

The DAOF is located on public land adjacent to the U.S. Air Force Production Flight Test Installation (Plant 42), and has access to two 12,000-foot runways and other support facilities maintained at this extensive aerospace complex. The Palmdale location offers easy access to hotels, restaurants, stores, shipping, and airline facilities.

The DAOF provides a safe and secure environment for visiting scientists and technicians to check out and prepare sensor and instrumentation systems for flight. Approximately 7,000 sq. ft. of laboratory space has been configured to support multiple science teams during the upload process. Simulated aircraft power (28VDC, 400 Hz and 60 Hz) with appropriate connectors, allows functional testing of experimenter equipment in the lab prior to integration onto the aircraft. High power laser operations, hazardous chemical handling, compressed gasses and cryogens can all be accommodated. NASA security procedures at the DAOF provide rapid processing and access for science visitors from around the world. The facility can be made available around the clock during mission uploads and operations.

Throughout FY08, the NASA DC-8 aircraft conducted its flight operations out of this new facility. The DAOF laboratory, office, and hangar space supported over 100 scientists this year as ARCTAS, CARB, AMISA, and the ATV-1 science missions were prepared and executed from this facility. The National Suborbital Education and Research Center at the University of North Dakota, under a cooperative agreement with NASA, has also established itself at the DAOF in support of DC-8 science mission operations.

During FY09, the remainder of lab facilities and office space will be completed and the ER-2 and G-III aircraft will begin science operations from the new facility. The DAOF is expected to serve as a world-class facility to support airborne science missions for years to come.

Media, Education & Outreach

NASA Earth Science activities continue to generate a high level of interest by the media and general public, and the Airborne Science Program often finds itself at the front line of this interest. This is due not only to the curiosity we all have about understanding the state of the planet, but also in the tangible, and visceral, appeal aircraft and aviation have on the public. To support and respond to this interest, the airborne team actively works with the public affairs offices at the NASA centers and Headquarters to prepare and distribute press releases, conduct press conferences and interviews, and update public access web sites, so that the science data and operations are accessible to both the scientific community and the public. Moreover, we continuously reach out to the local communities, wherever our travels may take us, to show them what NASA is doing and how the unique scientific assets at our disposal are contributing to the study of our planet.

Media

As in past years, media coverage of airborne science was significant and included television, radio, internet, and newspaper stories, not to mention a couple of fascinating "from the field" blogs. There are now even 'You Tube' videos posted from the cockpits of several of the NASA planes. Coverage was particularly intensive for the ARCTAS mission and the California wildfire support flights.

NASA issued two press releases for ARCTAS, one in April and one in June. In addition, press events and interviews were conducted during both deployments, which generated a lot of coverage. In the U.S., articles on the mission appeared in the New York Times, Washington Post, Christian Science Monitor, Science Daily, the Anchorage Daily News, and the St. Louis Post Dispatch. In Canada, several TV and radio interviews were conducted, including an interview for the Canadian Broadcasting Corporation (CBC) North Radio One from Yellowknife in the Northwest Territories. Due to the concern regarding fires during the summer, and the importance for protection of people and property, coverage by CBC, was especially extensive. In addition to Canada, news articles were also published in several countries, including Mexico, Nicaragua, Germany, Austria, and Italy (Fig. 48, p. 109).

Coverage of the California wildfires was also extensive. Visits to NASA Ames by California Governor Arnold Schwarzenegger and Director of Homeland Security Michael Chertoff were covered by nearly every Los Angeles and San Francisco Bay Area

Figure 47
Summer cadets for the Royal Canadian Air Force line up to tour NASA's DC-8 while deployed at the 4 Wing Base in Cold Lake, Alberta, July 2008.

television station and newspaper, as well as at the national level by USA Today and United Press International. In addition, a documentary on the wildfires and the role of the Ikhana support in the wildfire mapping is currently being developed by the Discovery Channel.

Education & Outreach

The Program continues to be an active participant in national conferences and workshops, such as those conducted by the AGU, AIAA, and the AUVSI annual Unmanned Systems Conference. Our Airborne Science and Technology Lab at NASA Ames continues to develop high-quality informational handouts and displays to communicate the goals, capabilities, and resources of the program for use at these conferences.

Much of the program's educational outreach activities are managed by the National Suborbital Education and Research Center (NSERC) at the University of North Dakota (UND). NSERC staff and faculty had a booth at the youth conference "Odyssey of the Mind" in Baltimore, Maryland, an event to showcase creative problem-solving opportunities in a K-12 student competition forum. The NSERC booth, which included a large model of the DC-8, introduced these students to the Airborne Science Program research and aircraft.

In September 2008, NSERC participated in the Salute to Youth event at the DAOF hangar in Palmdale, CA. This event invited local-area 9th graders to the hangar to view the DC-8 and SOFIA. Students were also able to view the DC-8 on the ramp as it was being prepared for departure on a mission. NSERC also had a video presentation of the DC-8 during the ARCTAS campaign to draw attention to how the DC-8 is utilized as a research aircraft.

NSERC has also funded graduate student research and promoted the use of DC-8 mission data for this research. For example, a UND graduate student used data collected onboard the DC-8 during the INTEX-B mission for her thesis titled, "A Study of Asian Dust Events using Surface, Satellite, and Aircraft Measurements during INTEX-B". This student, funded with an NSERC fellowship, successfully defended this thesis to earn her Master of Science from the Department of Atmospheric Sciences in May 2008.

During 2008, NSERC also laid the foundation for the first student mission aboard the DC-8. This mission, called the Student Airborne Research Program (SARP), will take place for six weeks during the summer of 2009. The primary goal of the SARP mission is to motivate and strengthen the nation's future workforce in Earth system science and related fields. The program will give students the opportunity

Figure 48
ARCTAS press article samples in multiple languages.

for hands-on experience of an end-to-end scientific mission using NASA research aircraft and instrumentation, in this case, the DC-8. As a part of this mission, university faculty will assist the students in collecting data with airborne research instruments, and will guide the installation, operation, sample analysis, and data reduction for these instruments. The students, however, will be the in-flight main operators of these instruments. NSERC staff will also video-record lectures and make them available in accessible forms to faculty members for use as curriculum modules and to student groups who may be interested in future participation.

WETMAAP Project

NASA also continues to support the WETMAAP (Wetland Education Through Maps and Aerial Photography) project. WETMAAP, developed by Chadron State College and the USGS National Wetlands Research Center, conducts wetlands training sessions for educators and professionals in ecological concepts, technological skills, and methods of interpretation necessary for understanding and assessing wetland and upland habitat change. Training sessions explore wetlands using aerial photography, satellite imagery, and wetland maps, and introduce traditional mapping technology into the classroom. 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.

Through use of the WETMAAP website (www.wetmaap.org), educators can increase their ability to promote student awareness of, and interest in, wetland and relevant ecological issues. The website is an accessible source for satellite images, aerial photography, topographic maps, workshop outlines, and other Internet sources.

In 2008, the WETMAAP team conducted field visits to Panama in February and Wallops Space Flight Facility in May to develop new study sites for future workshops. As a result, two Panama WETMAAP workshops, including field trips, were conducted

Figure 49
Field Trip, Panama Training Session, July 31, 2008.

in Panama City in July and August, with 25 participants in each session. A study site and workshop were also developed for the Trinity River Delta in Texas near Johnson Space Center. Two workshops were conducted in November 2007 and May 2008, involving a total of 35 local teachers and students from Stephen F. Austin State University in Nacogdoches, TX.

This past year, results from the Fort Clatsop, OR workshop were presented at the American Society of Photogrammetry and Remote Sensing annual conference in Portland, OR. In addition, the Weweantic River, MA workshop results were presented at the Association of American Geographers annual conference in Boston.

Both the Science Mission Directorate at NASA HQ and the field centers continue to maintain supporting web sites which are regularly updated with airborne mission and aircraft news. In 2008, the program also instituted a quarterly airborne science newsletter to keep our community updated on the latest program developments and activities.

In FY09, the Airborne Science Program is planning several outreach-related activities in conjunction with the 33rd International Symposium on Remote Sensing of Environment (ISRSE), to be held in Stresa, Italy.

Recognition & Awards

2008 was the inaugural year for the internal Airborne Science Program awards. The purpose of the awards are threefold: (1) to show appreciation for actions resulting in benefit to the program, (2) to recognize ASP team members who perform service above and beyond the call of duty, and (3) to recognize external advocates, partners, and collaborators for their contributions to ASP. Awards are intended to be a source of distinction and pride for individual accomplishments or group achievements in the field of airborne science at NASA.

Nominations for the program awards are accepted in the following categories: Leadership, Engineering, Team Achievement, Outstanding Achievement, Sustained Excellence, Project/Mission Management, and Technician/Mechanic.

This past year, we received ten nominations from most of the NASA Centers, as well as NSERC. An awards board reviewed all nominations, deliberated the merits of each, and forwarded recommendations for five awards to the Program Manager for a final approval.

Of course, the program and its personnel receive many other awards and recognition both inside and

Engineering Excellence:
Adam Webster, NSERC

Team Achievement:
DC-8 Instrument Integration Team, DFRC

Outstanding Achievement:
Steve Gaines, ARC

Sustained Excellence:
Mike Fitzgerald, UARC, ARC

Project Mission Management:
ESPO Team, ARC

outside of NASA. This past year, NASA Group Achievement Awards were given for the TC4 and WRAP missions, and similar awards have been approved for the ARCTAS, SOGASEX, and NOVICE missions. In addition, the Wildfire Research and Applications Partnership (WRAP) between NASA Ames and the U.S. Forest Service has been chosen as the 2009 recipient of the Federal Laboratory Consortium (FLC) for Technology Transfer's Interagency Partnership Award. This award recognizes the efforts of employees from at least two different government agencies who have collaboratively accomplished outstanding work in the process of transferring a technology.

Looking Ahead to FY09 and Beyond

The Airborne Science Program strives to be relevant to our science users, who help set the future direction for this Program. We are making a long-term commitment to the improved portability of instruments. With that comes the development of standard interfaces for power, data distribution, control, and vehicle state data to the sensors throughout our fleet of science research platforms.

In addition, we have several significant platform enhancements planned in FY09, including work to build on our new Global Hawk Unmanned Aerial System to add a long endurance, high altitude operational system for supporting the science community. We also plan to stand up the G-III with the UAVSAR and Sierra UAS into full operational capabilities. The WB-57 in 2009 will increase its gross weight and add Superpods, in addition to the current Spearpods, allowing for greater science payload, while still carrying a full load of fuel, to improve its endurance and range capability.

We are developing a standardized integration system between our platforms and sensors; in the form of investigator guides, reporting processes, and developing procedures that will be acceptable to all the NASA centers for airborne science instrument airworthiness. Another area that ties into our standard interface systems is building a robust over-the-horizon telemetry and communication system to support our campaign telepresence and sensor web systems. Finally, we are rolling out our new web-based flight request process, which should give us an improved response and tracking capability for our science users.

Our program remains vibrant, relevant, and committed to the science community, and we expect these investments will allow us to continue reducing the cost to fly while increasing the data yield for each hour of flight.

APPENDICES

In Memoriam

Airborne Program History

Five-Year Plan

Acronyms & Abbreviations

APPENDIX A
In Memoriam

Steven E. Gaines

January 16, 1949 - October 22, 2008

Steve Gaines, one of the original members of the NASA Ames Earth Science Project Office (ESPO), and a major contributor to the airborne science community, died this past October after a brief battle with cancer. He was 59.

Steve is best known for his tireless work managing the data from the major NASA airborne field campaigns. Steve, along with Steve Hipskind, developed the data exchange format standards that came to bear his name. He was well known and had friends around the world, largely through his work on the field campaigns, and through the adoption of his format standards by other groups both nationally and internationally. In the late 1980's, with the encouragement of Michael Prather, then managing the Atmospheric Composition, Modeling and Analysis Program at NASA HQ, Steve became an early leader in adopting CDROM for the dissemination of the airborne datasets, before CDROM technology was in common use. Steve also helped pioneer the use of local and wide area networking, and later the use of the internet, to facilitate field campaigns and the sharing of the datasets. Because of Steve's relentless implementation of data exchange standards, often as "chief nag" to the participating scientists, he could claim an imprint on the enormously successful scientific productivity of the airborne campaigns.

Steve began working at NASA Ames in the late 1970's as a student at San Jose State University in the Meteorology program. He eventually earned both a B.S. and M.S. from San Jose State, the latter under the guidance of Dr. Chris Riegel. Steve worked for many years as a scientific programmer and data analyst under Dr. Ed Danielsen, culminating in the highly successful Stratosphere-Troposphere Exchange Project in Darwin, Australia in 1987. Later that same year Steve did yeoman's work with Adrian Tuck on the Airborne Antarctic Ozone Expedition (AAOE) in Punta Arenas, Chile. The AAOE CDROM that Steve edited, along with Wink Winkler from the NOAA Aeronomy Lab, was one of the NASA artifacts selected for inclusion in the time capsule, buried at NASA Ames in 1989 in celebration of the 50th anniversary of Ames' founding.

Apart from his dedication for his work, Steve was also a passionate sailor, who built and renovated his own sailboats. Many of his friends and colleagues had memorable outings with Steve on the San Francisco Bay in his cutter rig, Pinocchio.

Steve was well liked and respected by all who knew him. Most memorable were his dedication to his work and his unwavering integrity. He was incredibly touched by the outpouring of love and support from all of his friends and colleagues over the last two months of his life. He will be sorely missed.

APPENDIX B

Airborne Program History

Origins of an Airborne Earth Science Program at NASA

The NASA Airborne Science Program has supported the study of Earth from space since the time of the Gemini program and continues to do so today in support of ongoing and planned earth observing satellite missions. Over the years, airborne science measurements have provided humanity with a better understanding of our ozone layer, high-resolution maps of land resources, and measurements within evolving air masses to understand the chemistry and dynamics of our changing atmosphere.

In an effort to recognize the past giants of this program, upon whose shoulders the current team now stands, this and future reports will highlight individuals that have served NASA and our nation in the past.

We thank Olav (Ole) Smistad for contributing to this second installment of the history of the airborne science program at NASA. Ole worked in the Gemini Experiments Office at the manned Spacecraft Center in Houston in the early sixties. From that program, Leo Childs and Harold Toy acquired the Convair 240 which flew its first mission in 1964. From that first mission, Ole headed the JSC Aircraft Office, which added the C-130B and NP-3A, as well as the WB-57s, which still fly out of JSC. Much of the early Landsat sensor design criteria development, and the evolution of an international remote sensing community, happened during this time. Ole stayed with the Airborne Office until the Program was moved to Ames and Wallops in 1982.

The following is an excerpt of his account of the early years.

Figure 50
Ole Smistad

The founding of the Earth Observations Aircraft remote sensing program in NASA occurred at the Manned Space Center (MSC)(now Johnson Space Center) in November of 1964 with two visionaries with technical and engineering backgrounds, Leo Childs and Harold Toy. Harold obtained a Convair 240 (CV 240) aircraft, and Leo acquired some surplus Department of Defense (DOD) photographic and scanning sensor systems. The pair approached NASA Headquarters with a plan for an airborne remote sensing system program. The CV 240 was a much traveled two engine (reciprocating) aircraft MSC utilized as a platform to test radars for the Lunar Excursion Module (LEM) lunar landing. When the flight test program was completed and prior to the time the aircraft was to be declared surplus, these two fellows seized upon the opportunity and promoted its use for aircraft remote sensing for earth observations. This was quite visionary for the time when one realizes it is now a vital global program, although they undoubtedly did not have that far-reaching a vision at the time. They also were also aware there was a keen interest within the Office of Space Science and Applications (OSSA) in obtaining this capability. Now the desire, opportunity, and people all came together in an enthusiastic manner to make it happen.

The first aircraft, the CV 240, was gradually modified to accommodate six Earth-looking sensor systems. The growing sensor complement included the 13.3 GHz scatterometer, metric and multiband cameras, UV imager (AAS7), thermal scanner (RS 7), infrared thermometer (PRT5), and ancillary data systems. The cameras and scanning systems were of DOD surplus origin. The scanners for the most part were not calibrated systems. The CV 240 remained in service through August of 1969, at which time it was replaced by a Lockheed C-130. In December of 1965, in response to growing investigative and data requirements, a Lockheed P-3A was acquired on loan from the Navy, and became operational early in 1967. These two aircraft, along with the CV 240 (until 1969), were used to acquire data from low and intermediate altitudes early in the program. In late FY1969 (fiscal years were then from July through June), an agreement with the Air Force permitted flight time aboard an Air Weather Service (RB) WB-57F aircraft for the high altitude phase of the program, which became operational in July 1969.

The primary responsibility for the aircraft program rested with the Office of Space Science and Applications (OSSA) at NASA headquarters. The role of the MSC was essentially implementation and operations and that of OSSA scientific requirements, investigator selection, contracts and funding, reporting, and oversight of the program with selected academic institutions, other government organizations, and the aircraft program at MSC. Other activities at MSC included sensor and ground data systems definition and development, principal investigator coordination and management, sensor operation and maintenance, mission management and support, aircraft operation and maintenance, data acquisition, software development, and data reduction, processing, quality screening and dissemination.

The funding for the above mentioned functions was allocated from the OSSA science budget and provided for a level of contractor support at MSC for aircraft, sensor, and data reduction activities. MSC was an Office of Manned Space Flight (OMSF) center and provided the funding of the program civil service personnel utilized, but not funded by, OSSA. The program was quite successful, with funding in 1965 of $200,000 supporting 11 missions, to $10,900,000 in 1970 supporting 53 missions at 190 test sites. Staffing (CS and contractor) increased from 22 to 236 in 1970. By the phase out of the Aircraft Program at MSC/JSC, over 600 medium and high altitude data acquisition missions were successfully flown.

The dramatic increases in budget levels, missions, and data acquisition flights from the 1965 to 1970 period were due to added capabilities resulting from acquisition and modification of additional medium and high altitude aircraft, and increased principal investigator participation. This was due to both airborne and space investigations (i.e., Skylab/ERTS), major electronic sensor development and test programs to support crucial scientific requirements, such as band selection for the Earth Resources Technology Satellite (ERTS, later renamed LandSat) for which a major contribution was the MSC-developed 24 channel scanner, and development of multifrequency passive microwave sensor systems for use in agriculture, oceanography, and arctic investigations.

The MSC organizations that were involved in the program included:

- Earth Observations Aircraft Program Office (overall program management).
- Earth Observations Division (science disciplines).
- Engineering and Development Directorate (sensor technology and operation and engineering support).
- Flight Operations Directorate (development and implementation of electronic data processing programs).
- Photo Technology Lab (photo processing).
- Flight Crew Operations Directorate (aircraft operations).
- Engineering Division (aircraft and support hardware design and fabrication).
- Space Flight Meteorology Group (test site weather forecasting).

The OSSA Program Manager at the inception of the program through 1970 was a gentleman by the name of John Koutsandreas (Kouts), the "Mad Greek", with a drive and genius for budget augmentation, as well as program expansion, both domestic and international. He was a Marine in every sense of the word. John worked for Ted George, who in turn worked for Len Jaffe, who headed the OSSA Applications Division. Kouts was the father of the first budgets (and their dramatic increases in funding), which in the early days were buried, in another unrelated OSSA budget line item in a place where you couldn't find them, and were vulnerable to being raided by other OSSA programs without notification, which they were. John worked the agency and congressional committees to establish a unique budget line item, UPN 640, which was annually funded as a stand-alone congressional line item and could not be raided by others. I think it was established about FY67, but can't remember exactly.

Kouts left the Agency sometime in 1970, as I remember, and moved on to the Las Vegas office of the newly formed EPA. Here Kouts started an EPA aircraft remote sensing program for enforcement purposes. At this time, Barney Nolan became the Headquarters' Program Manager for the Aircraft Program. Barney had served in the USAF in WWII and flew "left seat" as an active pilot in the 8th Bomber Command in Europe, which is enough right there to get anyone's respect. Barney and I had an excellent relationship, and he was a good manager. This meant that he kept the budget supported, sent us money, kept the Headquarters demons off, and left us alone to do our job. He remained in that capacity until 1978. We remain friends to this day.

The flight program started with relatively minor flight activity utilizing the CV 240, and increased in 1967 with the addition of the P-3A, and again in 1969 with the first missions of the WB-57 and the C-130. The CV 240 was phased out in August of 1969 due to advancing obsolescence, limited range (due to the weight of the required sensor complements), and changing program mission requirements.

Earth Observations Aircraft Program activities were conducted in close cooperation with participating governmental agencies, which had extensive research programs and responsibilities in their particular scientific disciplines. These agencies were known as "user-agencies," referring to their use of earth resources data applied to their areas of responsibility. The role of the user agencies in the aircraft program extended to their direct participation in the formulation and execution of the program activities. In general, all geographic areas chosen for study were selected by these investigators. The agencies, in general, funded their own manpower, civil service and contractor. NASA provided the aircraft data acquisition and processing funding.

The early participants in the program included university, civilian governmental agencies, and the U.S. Navy. This was later expanded to include international participation. The universities were funded by OSSA to provide scientific discipline, sensor technology and unique software expertise, as well as sponsoring earth looking science investigations. Thus, the applications portion of OSSA initiated the institutional foundation of the earth observations remote sensing program in the United States and was enabling for the development of the satellite-sensing program as we know it today. The sensor and discipline teams, funded by OSSA, worked together to assure that sensor data outputs, spectral and spatial, were correlated to discipline needs. The discipline teams were organized along traditional lines such as agriculture/forestry, oceanography, hydrology, and geography. There were counterpart scientists within

MSC/JSC for coordination, education, and capture of knowledge for use in implementation of remote sensing programs emanating within the Agency itself. The sensor teams were generally organized along "spectral lines", such as active and passive microwave, camera, various scanner systems, etc. A lead university headed both types of teams with several other universities in direct support. These people were all leaders in their field and are deserving of recognition as pioneers in earth observations remote sensing. They were spread throughout the country.

An annual planning and scheduling meeting was instituted in 1969 to bring the participants together, inform them of the current program status and future planning, solicit inputs for improvements or need for additional/revised capabilities, and review a suggested flight program for the next fiscal year based on user agency, university, and research institution flight requests for that period. The various inputs from these participants, together with internal agency requests, were then reviewed and prioritized with the assistance of OSSA, and the original flight program was revised accordingly. There were allowances made for contingencies and revised/additional flight requests during the year. This was always 'beat' against the budget constraints and established priorities.

Figure 51
First Annual Planning Session at MSC in 1971.Notice the young Smistad (center right) and Nolan (center left) in photo. Others: J. Algranti, Aircraft Operations Office (far left) and M. Holter, Earth Observations Divisions (far right).

The Aircraft and Their Sensor Systems

Convair 240 (CV 240-NASA 926)

The CV 240 was acquired in 1964 and phased out in 1969. The aircraft was limited in altitude and range because of the heavy load of sensors and instrumentation. The test altitudes were in the region of 10,000 feet, and the operating range was 4 hour/800 mile flights. Even so, it conducted missions in all regions of the United States, as well as Alaska and Iceland. She was a grand old girl. When she was returned to the surplus pool she was immediately claimed by another agency, and may still be flying. In general, the onboard sensors were not developed specifically for this program, and although limited for many uses, they provided a wealth of knowledge, orientation, and training for scientists, sensor development teams, applications, and operations personnel.

Lockheed P-3A (NASA 927)

The P-3A was acquired on loan from the Navy in December of 1965, and after a period of modification to accept down looking

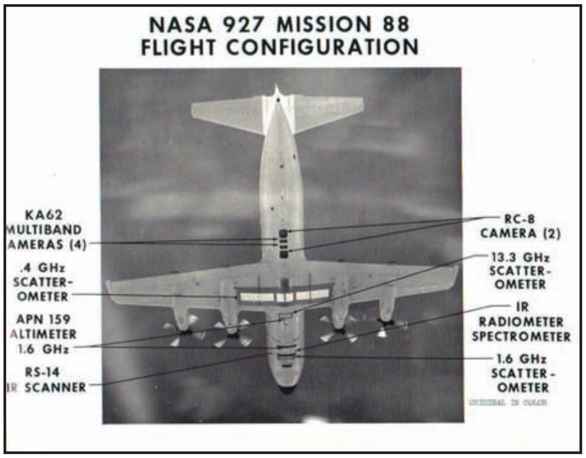


Figure 52
Early remote sensing payload on NASA P-3 927.

sensors, became operational early in 1967. The P-3A, affectionately known as "Baby", was an early prototype from the Lockheed Electra program that had been modified for testing in the P-3 ASW programs. It had about 9 feet (or so) removed from amidships from its original fuselage for this P-3 development program and was aircraft #003, as I remember. There were only two built before her. It came with as-built red line drawings which presented challenges when it came to recertification after modifications, especially changes to the electrical system necessary to integrate program remote sensing systems. The maximum altitude was 30,000 feet, with mission duration of 7 hours and a range of about 2000 miles. It was sent off to Wallops when the program phased out of JSC in July of 1982 and was primarily used for their range program and some small Wallops remote sensing projects. Sensors included large format cameras, active and passive microwave sensors, and an infrared scanner.

Lockheed C-130B (NASA 929)

The C-130 was acquired on loan from the Air Force in 1968 (I think) and underwent significant modifications to accommodate several new sensor systems, was recertified, and commenced data acquisition in September of 1969. It had an interesting history. It had been utilized by the NASA Langley Research Center (LaRC) as a boundary layer test aircraft for some time and had a beefed up wing (leading edge). It was transferred to JSC after conclusion of that program. The cost to return the wing to the original configuration was prohibitive so a worldwide search (we didn't have 'eBay' then) found a set of C-130 wings in Zambia. One of their military aircraft had been attacked by rebels while on the apron; some of the crew killed, and the plane was pretty well shot up. The program purchased the wing sections and transported them by barge to the States and onto JSC. The wing replacement was performed at LTV in Greenville, Texas, where the extensive airframe modifications required for sensor integration were also performed. It came out of modification and flight certification test in August of 1969 and as mentioned above, flew her first mission the next month. The C-130 was sent off to NASA Ames Research Center, along with its and other sensor systems listed for the P-3A, when the program phased out of JSC in summer of 1982 (I'm pretty sure). The C-130 sensor complements included several cameras, active microwave scatterometers, infrared and multi-spectral scanners, and other instruments such as PRT-5 radiation thermometers, inertial navigation system, and closed-circuit TV.

WB-57F (NASA 925)

In September of 1968, by agreement with the USAF, the Earth Observations Aircraft Program phased in a WB-57F operated by the 58th Weather Reconnaissance Squadron (WRS) at Kirtland AFB in Albuquerque, New Mexico. It became operational in July of 1969, after modifications to incorporate a removable NASA earth observations sensor pallet, which was integrated into the large open volume previously utilized as the bomb bay. The rotating bomb bay door was removed and allowed relatively easy modification and integration of a NASA sensor pallet.

Figure 53
WB-57F Showing Universal Pallet System (UPS)

In 1968 we had contracted with the Air Force to operate a WB-57F for the high altitude portion of the earth observations program at JSC, which resulted in many NASA missions being conducted with Air Force (58th WRS) personnel in the front seat, and Air Force or NASA personnel in the rear seat as sensor operators/navigators. In 1972, Air Force budget constraints resulted in the aircraft being transferred to NASA, with hangering and flight operations out of Ellington Field. When the Air Force exited the program in 1974, they transferred the aircraft to NASA and JSC and the aircraft was renumbered NASA 925. At this point, NASA JSC personnel occupied front and rear seats. The aircraft was modified at General Dynamics in Fort Worth, Texas, to accept the large sensor pallet. This aircraft was operated out of Ellington Field until retirement in 1982. It currently resides in the Pima Air Museum in Tucson, Arizona.

At the phase out of the Air Force program in 1974, NASA also acquired another WB-57F, NASA 926. This aircraft was modified to accept the Universal Pallet System (UPS), described in following paragraphs, and conducted many missions in support of high altitude and spacecraft missions (Skylab, ERTS/Landsat) until the phase out of the Earth Resources Aircraft Program at JSC in the summer of 1982. It continues in service today.

In 1973, the Department of Energy approached NASA to support their Project Airstream (atmospheric sampling of nuclear test debris) flight program for which support was being discontinued by the Air Force. This program involved in-situ sampling along a flight track from Alaska to the tip of South America. An interagency agreement was drafted and approved which moved that WB-57F to JSC and Ellington Field, making a total of two aircraft in the NASA inventory.

This aircraft was designated NASA 928. It was later converted to support high altitude test programs for various government agencies, including DOD, and continues in operation to this day.

At 45+ years of age, NASA 926 and NASA 928 are the only two WB-57Fs still flying in the world today. The WB-57F high altitude aircraft has operating altitude capabilities well in excess of 60,000 feet. I remember on one mission flown out of JSC to photograph the comet Kahoutek as it passed by, the aircraft reached an altitude of 69,000 feet, although with a reduced fuel load.

The WB-57F provided another critical dimension to the data acquisition program by closely simulating data acquisition from an orbiting spacecraft from its normal operating altitude of 60,000 feet and above. At above 90% of the earth's atmosphere, the range of sensor performance is extended and performance from orbital altitudes can be more easily extrapolated.

University of Michigan C-47

A contract with the Environmental Research Institute of Michigan (ERIM) from FY69 through the first part of FY72 (as I remember) enabled the aircraft program to obtain multi-spectral data with the ERIM multi-spectral scanner. This multi-spectral data collection system was composed of four detector assemblies, one installed at each end of two dual-channel scanners that provided calibrated radiation references through 18 multi-band data channels in the 0.3 to 14.0 micrometer wavelength region. The system was an airborne imaging system that registers the spectral properties of a terrain scene in absolute measurements. The airborne system was installed in a C-47 aircraft operated by the Willow Run Laboratories.

It was a very important tool for the remote sensing program as it provided the first integrated scanning system for simultaneously viewing a spectrum range of interest to the remote sensing community. It also provided the design criteria critical for the selection of the 24 bands for the program Multi-spectral Scanner and Data System (MSDS) design that was introduced into the flight program in the third quarter of FY71. The MSDS flight program provided the decision-making data for selection of the ERTS (later renamed Landsat) spectral bands. The C-47 sensor complements includes several cameras, two double ended multi-spectral imagers and a radiation thermometer.

Bell 47G Helicopter (NASA 949)

The Bell Helicopter was incorporated into the program in 1973 to support ground truth data collection for various missions and was ferried/flown from Ellington Field to the test sites, primarily in the Midwest. Very long ferry flights. A Skylab S-191 prototype field spectrometer system was integrated into the vehicle and was used for providing calibration data during underflights of Skylab. The Bell was a contributor to the Earth Resources Aircraft Program until it was phased out in 1982.

Sensor Development

From the initial six rudimentary remote sensing instruments on board the CV 240, the program progressed to the development and testing of more than two dozen advanced sensors. These sensors were evaluated both for their capabilities for airborne remote sensing science and data requirements, but also for their potential use as spaceborne systems such as the initial earth resources and weather satellites.

In the September of 1968 JSC contracted with the Bendix Corporation of Ann Arbor, Michigan, for the development of a 24-channel Multi-spectral Scanner and an associated Data System (MSDS). This development was funded by UPN 640, the Earth Resources Aircraft Program. The system was ground-breaking in many respects, and was crucial and enabling in design and band selection for the impending launch of the LandSat satellite. The principal objectives of the MSDS data acquisition program included:

- Acquiring multi-spectral data simultaneously.
- Establishing the various spectral bands that provide useful information for a variety of disciplines.
- Defining means of correlating the recorded images with radiometric and spectrometric laboratory and field measurement data.
- Gathering correlative measurements with data from other sensors on the ground, aboard aircraft, and spacecraft.

The sensor system was integrated into the C-130 aircraft and flight-tested during late 1970, if I remember correctly.

International Cooperation

Starting in the seventies, concentrated effort was directed towards finding ways to improve the management of the environment, to ensure the quality of life for all inhabitants of the planet earth. Attention had already been focused on those applications of space technology that direct tangible direct benefits for society in general. Surveys of the earth's resources from spacecraft and aircraft were then receiving particularly close attention. Since those programs by their very nature were global in scope, their success could best be achieved if conducted on an international scale. Considerable thought had already been given to ways to involve other nations, through multilateral agreements, to carry out earth survey activities.

An earth survey program that was thought to have great promise for widespread economic benefits was the Earth Resources Technology Satellite (ERTS) program. The program represented the first U.S. effort to obtain earth data from space on a regular and continuing basis.

The first U.S. involvement in an international program of Earth observations was initiated in February 1968, when cooperative aircraft survey research programs were negotiated with Mexico and Brazil. The programs were divided into four implementation phases extending through June of 1970. The objectives were to familiarize personnel from these countries with the acquisition, processing, reduction, and analysis of remotely sensed Earth resources data.

Personnel from both countries were integrated into the program at JSC. The scientists and engineers were familiarized with the earth survey programs and findings by their integration into the JSC Earth Resources Aircraft Program. The personnel were instructed on the analysis of data collected by the various aircraft sensors in the various spectral bands and the various pattern recognition tools that had been developed by that time. They then participated in mission planning for the acquisition of that data and participated in the airborne mission, both on-board the P-3A aircraft, and in gathering ground truth data. They then participated in the reduction and analysis of that data with assistance of the JSC discipline scientists and technical personnel.

The next phase of the program was to return to their home countries and plan remote sensing data acquisition missions in their various disciplines at their test sites with JSC science and technical support. After this was completed JSC, earth resources aircraft and personnel deployed to test sites in both countries and flew data acquisition missions with on-board participation of their own personnel utilizing the P-3A. Data was processed at JSC and returned to the participants at which time JSC earth resources scientists assisted in the analysis. The final step was for both countries to establish their own earth survey programs, replete with aircraft, sensors, and data processing and analysis capabilities. This was accomplished. It was a start for Central and South American countries to establish remote sensing capabilities to manage their natural resources. It was a very productive pilot program, with the program objectives successfully accomplished.

APPENDIX C
Five-Year Plan

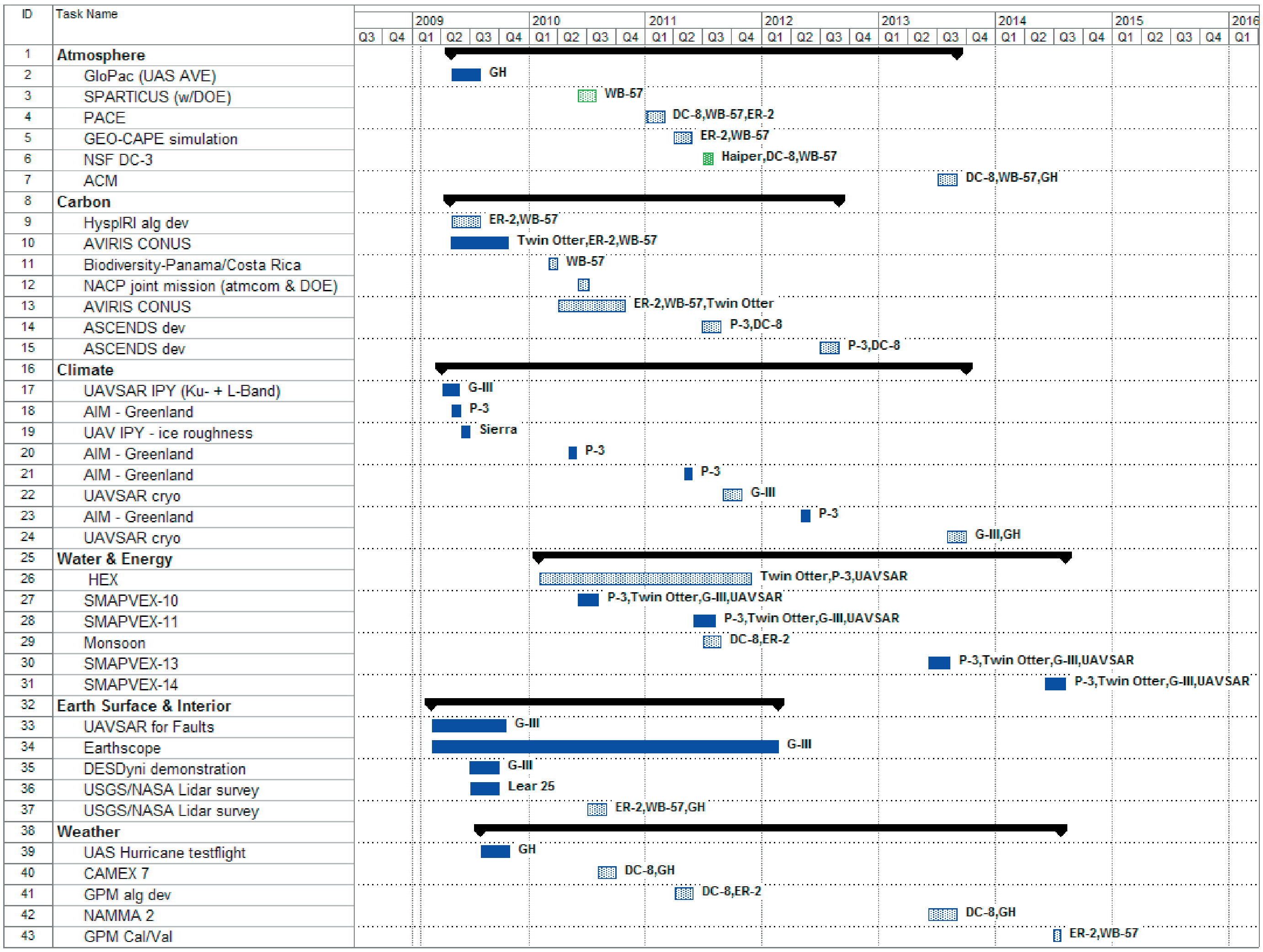


Table 4

Airborne Science Program 5-Year Plan

APPENDIX D
Acronyms & Abbreviations

A

AAOE	Airborne Antarctic Ozone Experiment
AATS	Ames Airborne Tracking Sunphotometer
ACCLAIM	Advanced Carbon/Climate LAser International Mission
ACR	Advanced Ceramics Research
AFB	Air Force Base
AGU	American Geophysical Union
AIAA	American Institute of Aeronautics and Astronautics
AIMMS	Advanced Integrated Meteorological Measurement System
AITT	Airborne Instrument Technology Transfer
ALPA	Airline Pilots Association
AMISA	Arctic Mechanisms of Interaction between Surface and Atmosphere
AMA	Academy of Model Aeronautics
AMMA	African Monsoon Multidisciplinary Analyses
AMPI	Airborne Multispectral Polarization Imager
AMS	American Meteorological Society
AMS	Autonomous Modular Sensor
AMSR	Advanced Microwave Scanning Radiometer
ASTER	Advanced Spaceborne Thermal Emission & Reflection Radiometer
AOD	Aerosol Optical Depth
AOPA	Aircraft Owners and Pilots Association
ARC	Ames Research Center
ARCTAS	Arctic Research of the Composition of the Troposphere from Aircraft and Satellites
ARTS	Airborne Research Test System
ASCENDS	Active Sensing of CO2, Emissions over Nights, Days and Seasons
ASCOS	Arctic Summer Cloud Ocean Study

ASD	Analytical Spectral Devices
ASTL	Airborne Science and Technology Laboratory
ASP	Airborne Science Program
ATM	Airborne Topographic Mapper
ATV	Automated Transfer Vehicle
AUVSI	Association for Unmanned Vehicle Systems International
AVIRIS	Airborne Visible & Infrared Imaging Spectrometer

B

BRDF	Bi-Directional Reflectance Distribution Function

C

CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarization
CALIPSO	Cloud Aerosol Lidar & Infrared Pathfinder Satellite Observation
CA-OES	California Office of Emergency Services
CAR	Cloud Absorption Radiometer
CARB	California Air Resources Board
CBC	Canadian Broadcasting Corporation
CDE	Collaborative Decision Environment
CDF	California Department of Forestry
CDROM	Compact Disc Read Only Memory
CHAPS	Cumulus-Humilus Aerosol Processing Study
CIMH	Caribbean Institute for Meteorology
CIRES	Cooperative Institute for Research in Environmental Sciences
CLARREO	Climate Absolute Radiance and Refractory Observatory
CLPX	Cold Land Processes Experiment
CNES	Centre National d'Études Spatiales
COA	Certificate of Authorization
COBALT	Carbon mOnoxide By Attenuation of Laser Transmission
CONOPS	Concept of Operations

D

DAOF	Dryden Aircraft Operations Facility
DC3	Deep Convective Clouds and Chemistry

DCS	Digital Camera System
DESDynI	Deformation, Ecosystem Structure and Dynamics of Ice
DFRC	Dryden Flight Research Center
DHS	Department of Homeland Security
DOD	Department of Defense
DOE	Department of Energy
DSS	Decision Support System

E

EIP	Experimenter Interface Panel
ETL	Environmental Technology Laboratory
EOS	Earth Observing System
EPA	Environmental Protection Agency
ESA	European Space Agency
ESCD	Earth Science Capability Demonstration
ESPO	Earth Science Project Office
ESTO	Earth Science Technology Office
EUFAR	European Fleet for Airborne Research

F

FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FIR	Flight Information Region
FLC	Federal Laboratory Consortium
FOR	Flight Operations Room
FSU	Florida State University

G

GCS	Ground Control Station
GEO-CAPE	Geostationary Coastal and Air Pollution Events Mission
GHG	Greenhouse Gas
GHOC	Global Hawk Operations Center
GIFS	Geostationary Imaging Fabry-Perot Spectrometer
GLAS	Geoscience Laser Altimeter System
GOES	Geostationary Operational Environmental Satellite

Go-MACCS	Gulf of Mexico Atmospheric Composition and Climate Study
GPS	Global Positioning System
GSFC	Goddard Space Flight Center

H

HIRDLS	High Resolution Dynamic Limb Sounder
HSI	Hyper-spectral Imaging
HSRL	High Spectral Resolution LIDAR
HyspIRI	Hyperspectral Infrared Imager

I

IASSWG	International Airborne Science Standards Working Group
ICCAGRA	Interagency Coordinating Committee for Airborne Geosciences Research and Applications
ICARTT	International Consortium for Atmospheric Research on Transport & Transformation
ICC	Incident Command Center
ICESat	Ice, Cloud and Land Elevation Satellite
IIP	Instrument Incubator Project
ILS	Instrument Landing System
INDS	Intelligent Network Data Server
INMG	Institute of Meteorology & Geophysics
INTEX	Intercontinental Chemical Transport Experiment
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
JPEG	Joint Photographic Experts Group
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center

L

LAABS	Langley Airborne A-band Spectrometer
LAC	Large Area Collectors
LALE	Low Altitude, Long Endurance
LaRC	Langley Research Center
LIDAR	Laser Imaging Detection & Ranging
LIST	Lidar Surface Topography
LVIS	Laser Vegetation Imaging System

M

MACC	Multi-Agency Coordination Center
MANPADS	Man-Portable Air Defense Systems
MAPIR	Marshall Airborne Polarimetric Imaging Radiometer
MAS	Modis Airborne Simulator
MASTER	Modis/Aster Airborne Simulator
MILAGRO	Megacity Initiative: Local and Global Research Observation
MLS	Microwave Limb Sounder
MODIS	Moderate Resolution Imaging Spectrometer
MOU	Memorandum of Understanding
MPCS	Master Payload Control System

N

NAC	NASA Advisory Committee
NAS	National Academy of Sciences
NAS	National Airspace System
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NASDAT	NASA Airborne Science Data and Telemetry
NAST-I	NPOESS Aircraft Sounder Testbed Interferometer
NAST-M	NPOESS Aircraft Sounder Testbed Microwave
NAST	NPOESS Aircraft Sounder Testbed
NATIVE	Nittany Atmospheric Trailer and Integrated Validation Experiment
NCAR	National Center for Atmospheric Research

NESC	NASA Engineering Safety Center
NEXRAD	Next Generation Radar
NGC	Northrup Grumman Corporation
NIFC	National Interagency Fire Center
NOAA	National Oceanic and Atmospheric Administration
NOVICE	Newly-Operating and Validated Instruments Comparison Experiment
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NRL	Naval Research Laboratory
NSF	National Science Foundation
NSERC	National Suborbital Education and Research Center

O

OCI	Ocean Color Imager
OMI	Ozone Monitoring Instrument
ONR	Office of Naval Research
OTH	Over the Horizon

P

PALS	Passive/Active, L/S-band
PARIS	Pathfinder Advanced Radar Ice Sounder
PDS	P-3 Aircraft Data System
PDU	Power Distribution Unit
POLARCAT	Polar Study using Aircraft, Remote Sensing, Surface Measurements and Models, of Climate, Chemistry, Aerosols, and Transport
POLSCAT	Polarimetric Scatterometer
POR	Payload Operations Room
POS	Position & Orientation System
PPA	Platform Precision Autopilot
PSR	Polarimetric Scanning Radiometer

R

RadSTAR-A	Radiation Synthetically Thinned Aperture Radar-Active
REASON-CAN	(Earth Science) Research, Education & Applications Solutions Network Cooperative Agreement Notice

REVEAL	Research Environment for Vehicle-Embedded Analysis on Linux
RFI	Radiofrequency Interference
RPI	Repeat Pass Interferometry
RSD	Research Services Directorate
RSP	Research Scanning Polarimeter
RTMM	Real Time Mission Monitor
RVSM	Reduced Vertical Separation Minimum

S

SACC	Sacramento Area Coordination Center
SAR	Synthetic Aperture Radar
SARP	Student Airborne Research Program
SBIR	Small Business Innovation Research
SCOAR	Scientific Coordinating Commission for Oceanographic Research
SERDP	Strategic Environmental Research and Development Program
SETI	Search for Extraterrestrial Intelligence
SIERRA	System Integration Evaluation Remote Research Aircraft
SIMPL	Swath Imaging Multi-Polarization Photon-Counting Lidar
SMAP	Soil Moisture Active-Passive
SMAPVEX	Soil Moisture Active-Passive Validation Experiment
SMD	Science Mission Directorate
SMS	Safety Management System
SOFIA	Stratospheric Observatory for Infrared Astronomy
SOFRS	Suborbital Science Flight Request System
SOGasEx	Southern Ocean Gas Exchange Experiment
SOLVE	SAGE-III Ozone Loss and Validation Experiment
SRMP	Safety & Risk Management Panel
SSFR	Solar Spectral Flux Radiometer
SWOT	Surface Water and Ocean Topography

T

TC4	Tropical Composition, Cloud & Climate Coupling Experiment

TCAS	Traffic Collision Avoidance System
TES	Thermal Emission Spectrometer
TOGA	Tropical Ocean Global Atmosphere
TPS	Thermal Protection System
TTL	Tropical Tropopause Layer

U

UARC	University Affiliated Research Center
UAS	Unpiloted Aircraft Systems
UAV	Unmanned Aerial Vehicles
UAVSAR	Unmanned Air Vehicle Synthetic Aperture RADAR
UCATS	UAS Chromatograph for Atmospheric Trace Species
UCLA	University of California, Los Angeles
UND	University of North Dakota
UNOLS	Universal National Oceanographic Laboratory System
USDA	United States Dept. of Agriculture
USGS	United States Geological Survey
UTLS	Upper Troposphere and Lower Stratosphere
UWI	University of West Indies

V

VIIRS	Visible Infrared Imager/Radiometer Suite
VSLS	Very Short-lived Species
VWC	Vegetation Water Content

W

WAVE	WB-57 Ascent Video Experiment
WETMAAP	Wetland Education Through Maps and Aerial Photography
WFF	Wallops Flight Facility
WPT	Waypoint Planning Tool
WRAP	Wildfire Research and Applications Partnership
WSFM	Western States Fire Mission