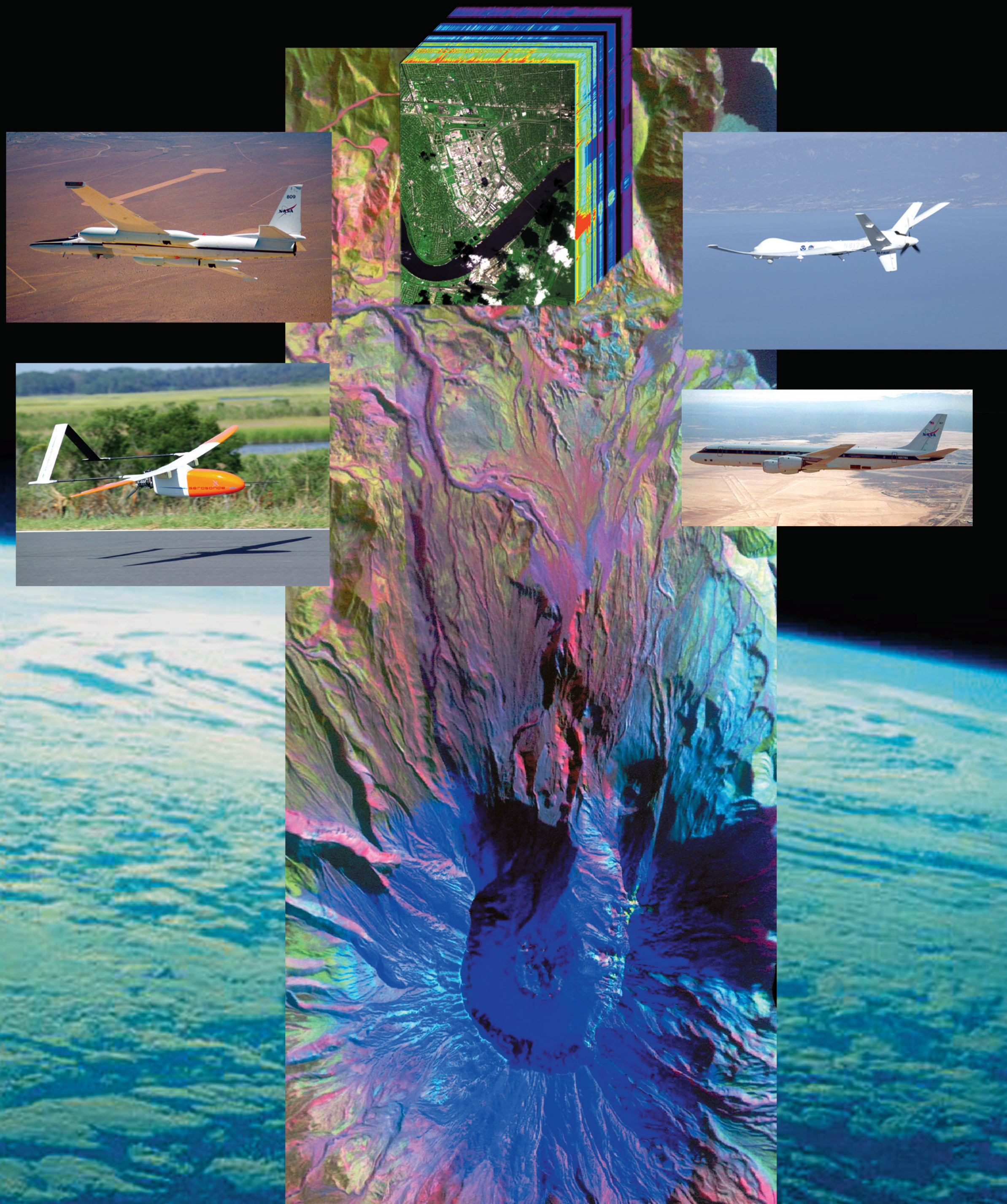
NASA Science Mission Directorate Suborbital Science Program

Annual Report 2004 - 2005



NASA Science Mission Directorate
Earth Science Division

Suborbital Science Program Annual Report 2004-2005

JANUARY 2006

TABLE OF CONTENTS

Introduction

In accordance with NASA's vision statement, "Explore, discover, seek to understand," the Suborbital Science Program seeks to:

- Add to the understanding and prediction of global Earth system changes, especially through accurate interpretation of satellite datasets;
- Establish local-to-global connections between global satellite-based observations and small-scale local observations through the suborbital vantage point;
- Develop, improve, and validate predictive models that are initialized using global satellite data through atmospheric (especially in-situ/ microphysical data) and multi-scale process studies;
- Calibrate and validate satellite data collections through flight demonstrations of new remote sensing technologies and satellite simulator missions;
- Use NASA aeronautics technology, project management skills, and safety culture to adapt air vehicles as Earth observing platforms;
- Test new components, systems and vehicles through flight.

Program Goals

- Support focused science missions that are formulated to implement and follow NASA science roadmaps through competitively selected projects.
- Maintain and evolve an adaptive and responsive suite of platforms selected according to the observational needs and requirements of the science focus areas.
- Infuse new airborne technologies based on advances and developments in aeronautics, information technologies, and sensors systems.

Infrared color composite image acquired with the MASTER airborne simulator over Mount St. Helens. Data acquired Sept. 20, 2004. Blue color indicates snow; other colors show differences in rock and vegetation. MASTER is a joint project between NASA/JPL and NASA/ARC.

- Transfer proven capabilities to research, operational, or commercial operators as widely available facilities for community-driven experiments or operational decision support systems.

Program Implementation

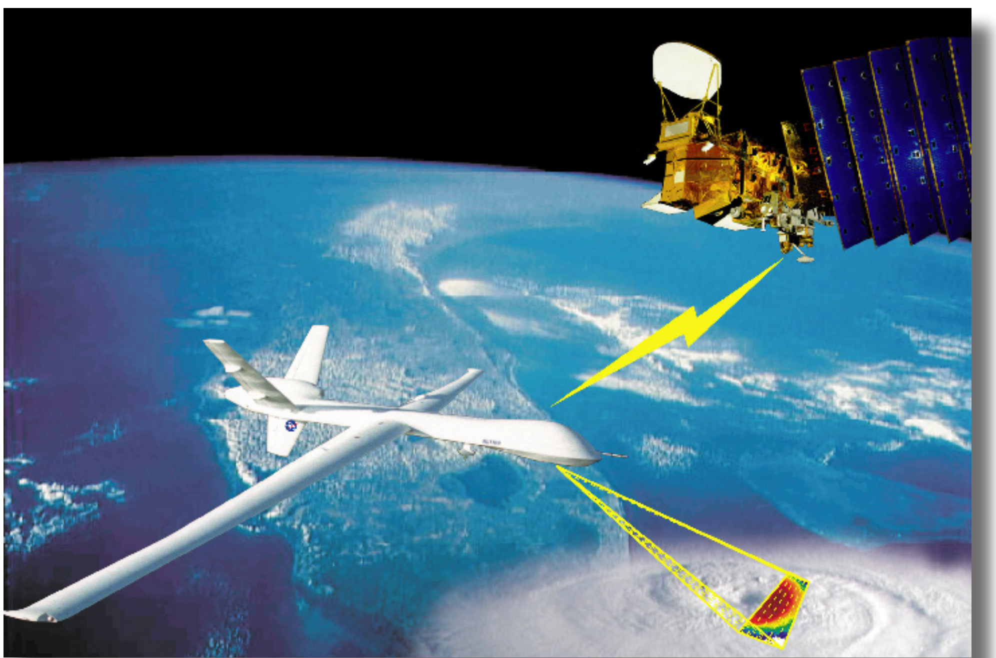
In 2004 – 2005 the Program was restructured and implemented as follows:

Ames Research Center is the lead for suborbital 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 (recently renamed the Airborne Sensor Facility). Ames manages the suborbital science flight request process, future mission and platforms requirements definitions under the Airborne Science Office.

Goddard's Wallops Flight Facility is the lead for managing the catalog aircraft program and safety overview of contracted aircraft. Even though the aircraft may reside at other facilities, Wallops will serve as the main point of contact for funding and tasking of the different platforms. Wallops will continue the work in the field of small class Uninhabited Aerial Systems (UAS) research. Wallops is still operating the low altitude heavy lift P-3B aircraft, and is managing the cooperative agreement for the transition and operation of the DC–8 by the University of North Dakota.

Dryden Flight Research Center is the lead for new technology and prototype aircraft. The focus at Dryden is on advanced mission platform technologies, and UAS development. There is a New Platform Technology program element, which is collecting requirements and building community support for UAS under the civil UAS assessment. The Earth Science Capabilities Demonstration Program is responsible for supporting science missions through the use of large class tactical UAS platforms. Dryden continues to support access to high altitude research through the use of conventional aircraft, including the ER-2 and G-III. Dryden is supporting the DC-8 transition with safety and operations oversight.

The primary goal of the Program restructuring is to bring new capabilities to the science community while continuing to support baseline requirements. Following restructuring, our future goal is to improve the reliability of NASA research aircraft and to provide better access to the fleet. Proactive aircraft management guided by well-defined community requirements will ensure that the program continues to be responsive to evolving needs. The Program will continue to involve the science community in near-term planning, provide published schedules, web-accessible aircraft information and handbooks, and effective lines of communication through the Flight Request system. These steps will demonstrate that the new program structure is achieving its goals of bringing new capabilities to the science community.



Conceptual representation of the NASA Altair UAS in a natural disaster response acquiring multispectral imagery over a hurricane and transmitting the data through a satellite link in real-time to a ground receiving station.

Aircraft Missions and Accomplishments

Intercontinental Chemical Transport Experiment (INTEX-A)

The Intercontinental Chemical Transport Experiment (INTEX-A) was a major NASA science campaign designed to understand the transport and transformation of gases and aerosols on transcontinental and intercontinental scales and their impact on air quality and climate. A particular focus in this study was to quantify and characterize the inflow and outflow of pollution over North America. INTEX-A also provided important validation of satellite observations with ongoing multiple satellite measurement programs, such as Terra and Envisat. The experiment was conducted over the continental United States during the summer of 2004 using a variety of science aircraft. Several coastal and continental sites across North America were selected as bases of operation. The experiment was supported by forecasts from meteorological and chemical models, surface and satellite observations, and ozone probe releases.

The INTEX-A campaign was greatly facilitated and enhanced by a number of concurrent national and international field campaigns. The National Oceanic and Atmospheric Administration (NOAA) is the principal U.S. partner for NASA and fielded coordinated airborne and shipboard platforms. Investigation of the transatlantic transport of ozone and aerosol pollution was done in partnership with European aircraft missions, involving groups from the U.K. (ITOP), France (CNES), and Germany. Synthesis of the combined observations from surface, airborne, and space platforms maximized scientific results and directly benefited scientific understanding of air quality and its relation to climate change.

INTEX was sponsored by the NASA Office of Earth Science Tropospheric Chemistry Program. For more information, see http://cloud1.arc.nasa.gov/intex-na/.

Aura Validation Experiments (AVE)

Aura, the last of NASA's Earth Observing Satellites (EOS), was launched on July 15th 2004. Its mission is to explore the Earth's natural atmospheric variability while understanding its responses to human induced activities. Aura will enable scientists to see how the composition of the atmosphere is changing with a global view not available before.

The Aura Validation Experiments (AVE) are a series of campaigns designed to address specific conditions and regional observations during the lifetime of Aura. The campaigns focused on the transport of gases and aerosols between the troposphere and lower stratosphere and the impact this might have on global air quality and climate change.

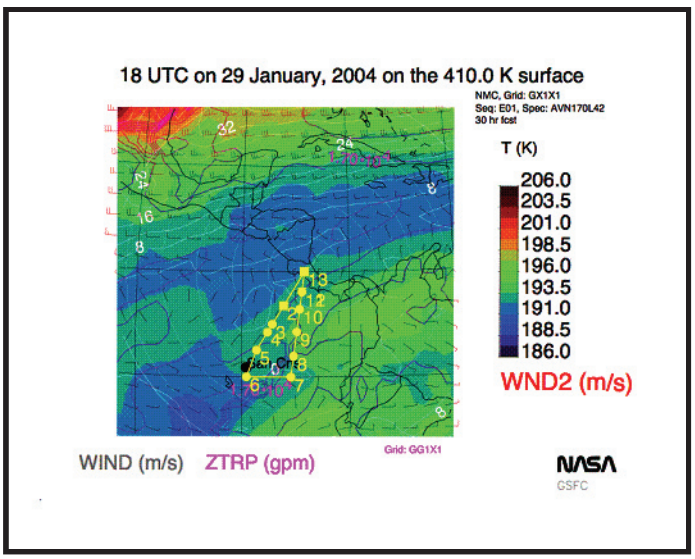
Pre-AVE, conducted in January 2004, was an initial test experiment prior to the launch of Aura. The specific objective was to understand the validation requirements while assessing the operations of the high quality in situ and remote atmospheric instruments and measurements aboard the NASA WB-57 based at JSC and in Costa Rica.

AVE Houston 2004 was the first mission after the successful launch of Aura. Using the NASA WB-57 the mission investigated the Tropical Troposphere Layer, including the relationships of water vapor, ozone pre-cursors and ozone production in order to characterize the mid-latitude upper troposphere and lower stratosphere region.

Polar AVE 2005 was a mission conducted from Portsmouth, N.H. during the January–February timeframe. Using a suite of atmospheric in situ and remote sensing instruments, the NASA DC-8 and high altitude balloons launched from Sweden provided valuable correlative measurements for Aura in the arctic vortex region during winter.

AVE Houston 2005 was based at Ellington Field, TX (JSC) and focused on mid-latitude measurements in the upper troposphere and lower stratosphere during the summer. Using the WB-57 high altitude aircraft, the mission's flights sampled air masses of different origins with an emphasis on measuring water, the largest greenhouse gas.

The Aura satellite measurements are making great strides in our understanding and modeling of air quality on a global scale. Aura and AVE are supported by NASA's Atmospheric Composition Focus Area of the Science Mission Directorate. More information can be found at http://aura.gsfc.nasa.gov and http://www.espo.nasa.gov

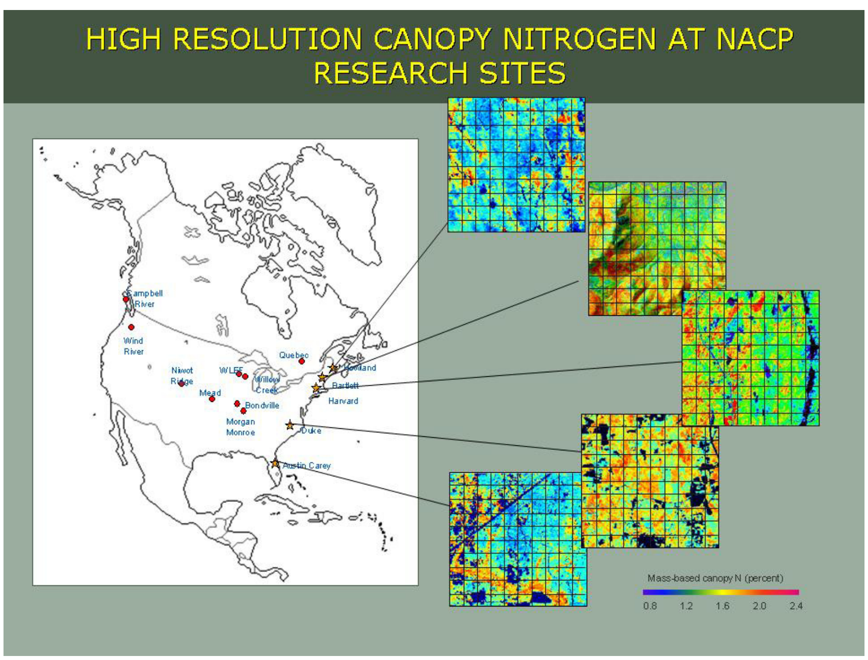


Flight path for fourth Science Flight (1-29-04) of the WB-57 during pre-AVE deployment to Costa Rica.

North American Carbon Program (NACP)

The NACP focuses on the carbon-containing gases CO_2, CH_4, and CO and on carbon stocks in North America and adjacent ocean basins. The program responds to the NAS report by seeking scientific understanding of sources and sinks for CO_2, CH_4, and CO, and of changes in carbon stocks needed to meet societal concerns and to provide tools to policy makers. The NACP will ultimately enable sustainable carbon management by developing proven scientific tools to diagnose past and current sources and sinks of greenhouse gases, and to predict future contributions from North America and adjacent ocean basins. The program will inform future decisions on policies to reduce net emissions of CO_2 and CH_4, and to enhance sequestration of carbon through land management or by other means.

As part of the field program element of the NACP, there is the airborne field program element. The Suborbital Program supported the NACP with airborne remote sensing campaigns for individual investigations. In particular, airborne hyperspectral data was collected using the AVIRIS on the ER-2, WB-57 and Twin Otter. Data was collected over several carbon flux towers in North America. Additionally, data was collected in the Southwestern United States to study carbon sequestration in shrub range lands in Utah and Arizona.



For more information, go to:
http://www.nacarbon.org/

AVIRIS Hawaii Twin Otter

Bill Clark, Pilot, Greg Asner, Mission Scientist, and Michael Eastwood, Instrument Manager.

From January 6 to February 28, 2005, ecologists, biogeochemists, remote sensing specialists, and resource managers came together in Hawaii with two goals – to forward the science of quantitative ecological remote sensing, and to better understand the ecological impacts of invasive species on Hawaii's unique and threatened ecosystems.

This event involved experts from the science, engineering and technology sectors. Intensive field studies ranged in focus from molecular to landscape scales and were matched by an equally intensive aircraft campaign – imaging ecosystems with advanced spectral and spatial remote sensing technologies. Ground or aircraft work spanned more than 20 of the 35 globally relevant ecosystems found throughout the world, from arid desert to wet rainforest. The initial campaign, from days in the field studying plant structure and chemistry, to the human "sky reports" that facilitated the in-flight management of the mission, was a critical aspect of tactical ecosystem analysis with remote sensing.

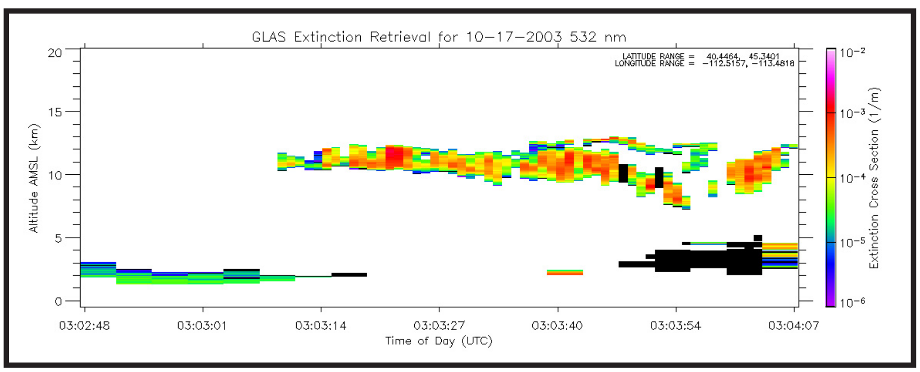
A NASA contracted Twin Otter aircraft was deployed with the AVIRIS and DCS sensors to support the mission.

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

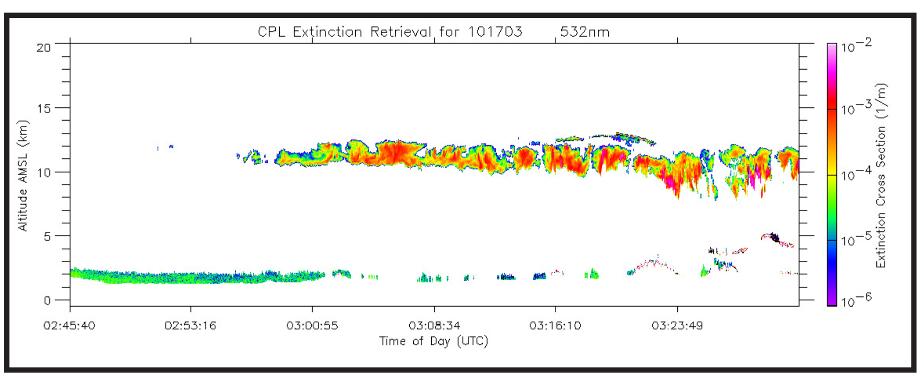
IceSAT - GLAS Validation

ICESat (Ice, Cloud, and Land Elevation Satellite) is the benchmark Earth Observing System mission for measuring ice sheet mass balance, cloud and aerosol heights, as well as land topography and vegetation characteristics.

The ICESat mission is providing multi-year elevation data needed to determine ice sheet mass balance as well as cloud property information, especially for stratospheric clouds common over polar areas. It also provides topography and vegetation data around the globe, in addition to the polar-specific coverage over the Greenland and Antarctic ice sheets. A number of airborne missions were flown with lidar systems to validate the Geoscience Laser Altimeter System (GLAS). For more information, go to: http://www.csr.utexas.edu/glas/



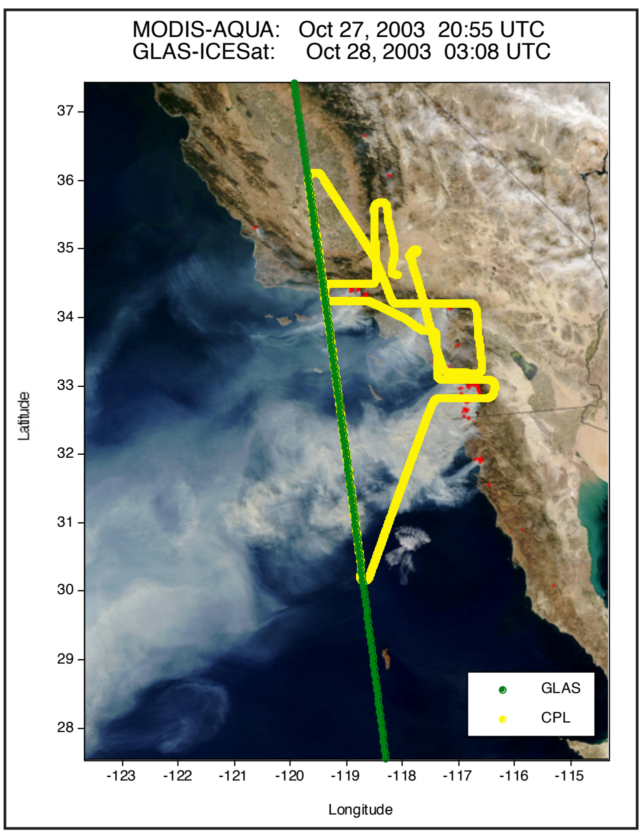
IceSAT GLAS satellite data



Cloud Physics Lidar data collected with the ER-2

ER-2 Cloud Physics Lidar: Southern California Wildfires

Shortly after the launch of IceSAT, the Cloud Physics Lidar (CPL) instrument, together with MASTER, was flown on the ER-2 from Dryden Flight Research Center, California. These flights were the initial validation of the GLAS instrument. In addition to the IceSAT underflights data was collected over the Southern California Wildfires to support validation of the atmospheric data products from GLAS. The GLAS data was compared to airborne underflights of the CPL during this unique smoke opportunity as part of a validation experiment. The CPL has known layer identification and optical retrieval performance. GLAS data products, including calibrated attenuated backscatter profiles, layer identification, and optical depth, are compared to simultaneous aircraft lidar retrievals with similar model assumptions with a goal toward validating GLAS retrievals.



MODIS image wih overlay of IceSAT track (green) and ER-2 flight track (yellow).

Arctic Ice Mapping (AIM)

Airborne Terrain Mapper (ATM) surveys occurred on the Chilean Navy P-3 in Antarctica in collaboration with the Centro de Estudios Cientificos in Chile during November 2004. In May 2005, ATM flew on a contracted Twin Otter in Arctic Canada and Greenland. Additionally, data was collected in Alaska, supported by both the US Army Corps of Engineers and the NASA Cryospheric Program, and in collaboration with the University of Alaska. Surface elevations, derived from the ATM surveys, were compared to earlier estimates, which were also compared to recent data from ICESat, including estimates from Svalbard. During the Greenland, Canada, and Antarctic missions, the group from the University of Kansas also measured ice thickness using a synthetic aperture radar. During 2004-2005 the ATM was flown three different P-3s which include the NASA, NRL, and Chilean P-3. All of these missions supported the IceSat GLAS.

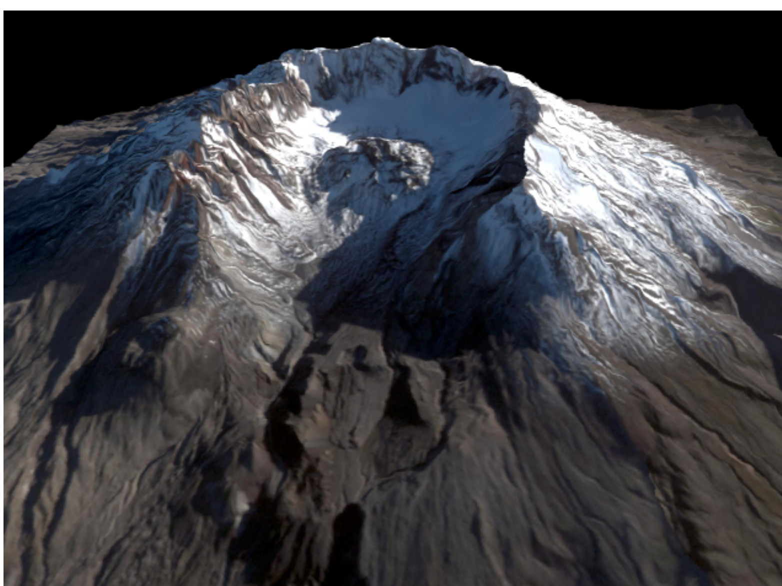
NRL P-3B during Argentinian deployment in November 2004.

Mount St. Helens

In September and October 2004, Mt. St. Helens Volcano erupted and several suborbital science data collections occurred during this volcanic activity. The MASTER sensor was deployed on the Sky Research Caravan along with an Optech Lidar. In total, there were five flights over the course of four days. During that time, imagery indicating thermal anomalies and daily sequential acquisition data were merged with elevation data collected with the Lidar. Subsequent processing created an animation of the bulging dome in the crater.

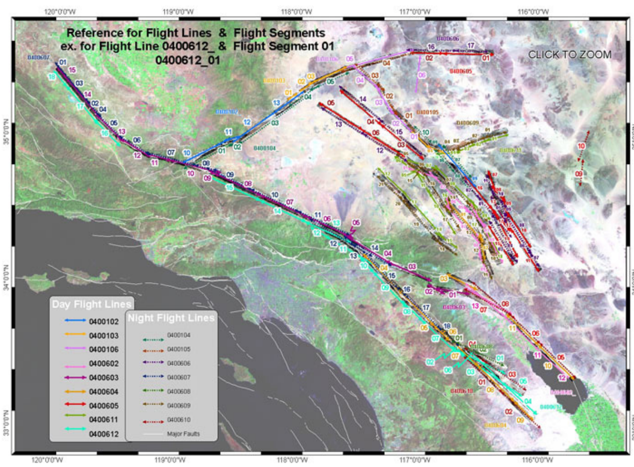
AirSAR was on board the DC-8 Aircraft travelling to Alaska during the volcanic activity in October 2004. The AirSAR was able to collect data, both in route and returning from Alaska, over Mt. St. Helens. This data has been archived at the JPL for scientists to access for volcanic studies.

For more information, go to: http://masterweb.jpl.nasa.gov/special/msh.htm



3-D visualization of Mount St. Helens. Visualization produced by combining a natural color image produced from MASTER airborne simulator with a DEM produced from ASTER data. Data acquired Sept. 24, 2004. MASTER is a joint project between NASA/JPL and NASA/ARC, ASTER DEM courtesy of Mike Ramsey; Visualization courtesy of Vince Realmuto.

2004 Southern California Fault Mapping

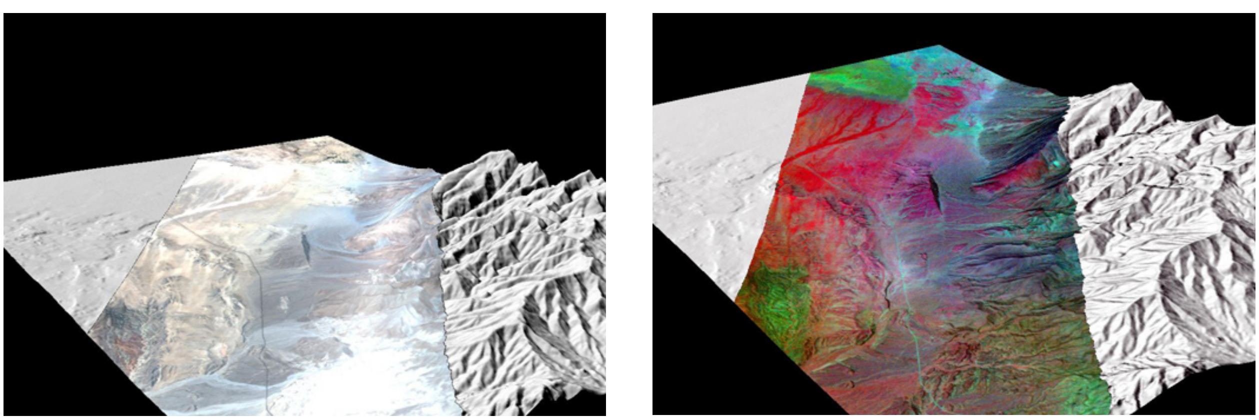


As part of a study initiated by the University of California, Los Angeles, and the Jet Propulsion Laboratory, an extensive portion of the Southern California Fault system was acquired with MASTER using the Deartment of Energy B200. Data collections began in October 2003, and were completed in August 2004. These data are enhanced with high precision geolocation information.

The high spatial resolution and spectral characteristics coupled with day/night coverage provide a means to distinguish mineral composition differences along the fault structures. These differences are helping to document the slip history along these faults.

The overview map (above) depicts the location of flight lines for the project. Data collected during daylight hours are represented by solid lines, predawn acquisitions are identified with dashed lines.

For more information, go to: http://masterweb.jpl.nasa.gov/special/scf.htm



Sample imagery portraying the San Jacinto Fault is shown above. It depicts MASTER data draped over a 10m digital elevation model: natural color composite (l.) and de-correlation manipulation of thermal data (r.), depicting distinct areas of mineralization (Image and map credit to J. Harvey, UCLA.)

Soil Moisture Experiment 2004 (SMEX04)

One of the key goals of the Soil Moisture Experiment 2004 (SMEX04) is to improve algorithms of current and future NASA microwave sensors by incorporating estimates of vegetation water content (VWC) from MODIS. One method to get VWC from MODIS is to use indices such as the Normalized Difference Infrared Index (NDII). AVIRIS, onboard NASA's ER-2 Aircraft, was specifically requested for SMEX04 because VWC is directly calculated from hyperspectral data using biophysical principles. Shown here are several flightlines of AVIRIS data over the SMEX04 Arizona study area, which are then used to test potential algorithms for estimating VWC from MODIS.

SMEX04 Flight Calendar

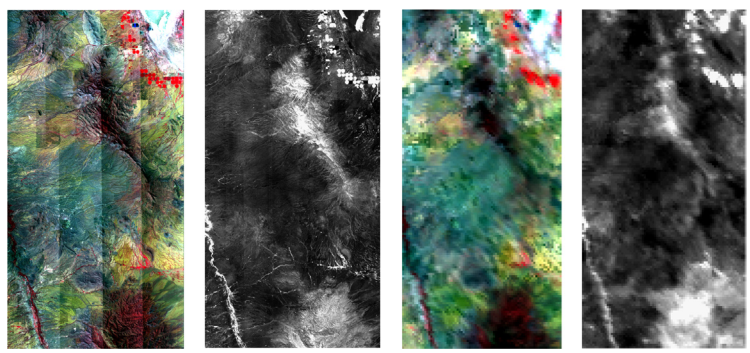
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Week 1	8/1 *Day 214*	8/2 Orientation Meeting *Day 215*	8/3 SM *Day 216*	8/4 SM *Day 217*	8/5 SM & P-3 *Day 218*	8/6 SM *Day 219*	8/7 SM & P-3 *Day 220*
Week 2	8/8 SM & P-3 *Day 221*	8/9 SM & P-3 *Day 222*	8/10 SM & P-3 *Day 223*	8/11 SM *Day 224*	8/12 SM & P-3 *Day 225*	8/13 SM & P-3 *Day 226*	8/14 SM & P-3 *Day 227*
Week 3	8/15 SM *Day 228*	8/16 SM *Day 229*	8/17 Picnic *Day 230*	8/18 SM *Day 231*	8/19 SM *Day 232*	8/20 SM *Day 233*	8/21 SM *Day 234*
Week 4	8/22 SM *Day 235*	8/23 SM *Day 236*	8/24 SM & P-3 *Day 237*	8/25 ER-2 SM & P-3 *Day 238*	8/26 SM & P-3 *Day 239*	8/27 P-3 *Day 240*	8/28 *Day 241*

SM – Soil Moisture Sampling
P-3 – P-3 Flight
ER-2 – ER-2 Flight

The intention of SMEX04-NAME is to enhance the terrestrial hydrology component of the North American Monsoon Experiment (NAME) by advanced soil moisture measurements. An intensive ground and aircraft field campaign took place during August 2004 that provided validation of the in situ and satellite products. An intensive ground and aircraft field campaign took place during August 2004 that provided validation of the in situ and satellite products. SMEX04-NAME also addressed important algorithm and validation issues for existing satellite based soil moisture products from the Advanced Microwave Scanning Radiometer (AMSR) and future low frequency instruments.

In support of the SMEX 04 the Suborbital Science Program provided multiple aircraft flights. The ER-2 was flown from Dryden Flight Research Center with the MODIS Airborne Simulator (MAS) and AVIRIS in July and August of 2004. During the same time frame, the NASA P-3 was flown with the NASA 2DSTAR, NOAA P-Band Scanning Radiometer (PSR) in Mexico during the intensive field campaign. Both flight campaigns required coordination between the U.S. government and Mexican authorities. This was a highly successful international cooperation.

For more information, go to: http://hydrolab.arsusda.gov/smex04/



The above imagery is a composite of airborne and satellite imagery from the SMEX 2004 Arizona Test Site: AVIRIS at 20 m (left), AVIRIS 20 m VWC (second from left), MODIS 1 km (second from right), and MODIS 1 km NDII (right).

Tropical Cloud Systems and Processes (TCSP)

The 2005 Atlantic hurricane season produced extensive damage to the U.S. and other countries with the most named storms (26) ever recorded in history. During this active hurricane season, NASA's Weather Focus Area of the Science Mission Directorate, in close collaboration with NOAA's Hurricane Research Division and the Costa Rican Center for Advanced Technology launched the Tropical Cloud Systems and Processes (TCSP) Experiment.

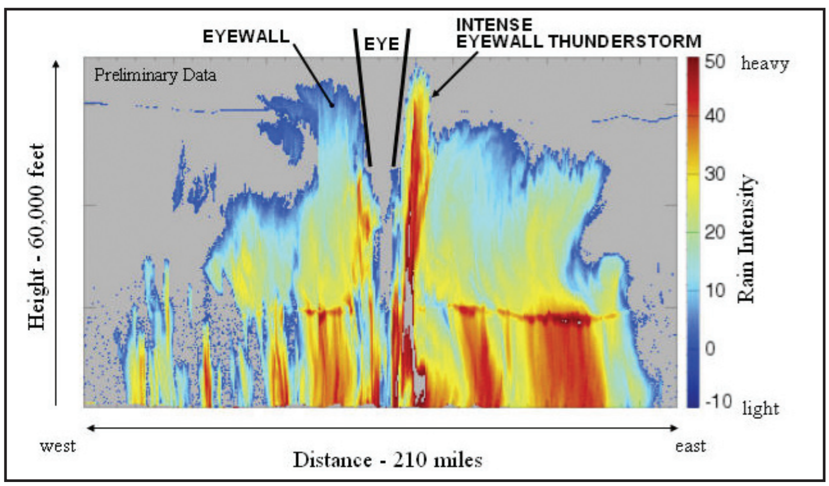
Based from San Jose, Costa Rica, TCSP scientists collected measurements on the origins and transformation of the tropical cyclones in the Gulf of Mexico and eastern Pacific. TCSP focused their study on the dynamics of these rapidly developing tropical cyclones to help address the key science objectives of the cyclone's structure, rainfall, intensification, and life cycle of these destructive storms by using unique measurement capabilities including multiple satellites, aircraft, balloons, and an ensemble of detailed numerical models.

The TCSP mission employed the unique abilities of the NASA ER-2, the two NOAA WP-3Ds, and the Aerosonde UAS, which enabled scientists to make the critical measurements of the temperature, humidity, precipitation, and wind information of these storms. These measurements will enable and support the development of a more accurate and timely warning system that could eventually help safeguard properties and lives.

Among some of the other storms, TCSP was able to closely observe the rapid genesis of Hurricane Dennis in a region where formation was known to be rather rare. It witnessed unusual and violent eye wall storms within Hurricane Emily and, through multiple back-to-back sorties, was able to monitor the entire lifespan of tropical storm Gert.

The Aerosonde upon take-off in Costa Rica.

This new study, like the previous successful series of Convection and Moisture Experiments (CAMEX) conducted from 1998 to 2001, continues the unique use of the aircraft available from NASA's Earth Science Suborbital Program. These assets enable the researchers to collect the rich data set needed to better understand these destructive storms. The TCSP mission included participants from five NASA centers, NOAA's Hurricane Research Division, and over 12 universities and partner agencies from around the world. See the TCSP web page at: http://camex.nsstc.nasa.gov/tcsp/index.html.



ER-2 Doppler radar (EDOP) views detailing the super-anatomy of Hurricane Emily during NASA's TCSP Experiment. Above is a verticl slice showing rain structure across the entire storm at 1:30-2:00 a.m. CST, July 17, 2005. (PI: Dr. Gerald Heymsfield, NASA GSFC)

Atlantic THORPEX Regional Campaign (ATReC)

The Observing-system Research and Predictability Experiment (THORPEX): is a ten-year international research program, under the auspices of the World Meteorological Organization/World Weather Research Program, to accelerate improvements in short-range (up to 3 days), medium-range (3 to 7 days) and extended-range (week two) weather predictions. THORPEX will examine connections between predictability and observing-systems, to establish the optimum observing system configuration to produce significant improvements in forecasts of high-impact weather.

During THORPEX, the ER-2 was deployed to Bangor, Maine to conduct flights for the Atlantic THORPEX Regional Campaign (ATReC). This international campaign combined flights with the NASA ER-2, NOAA G-IV and University of

NASA ER-2

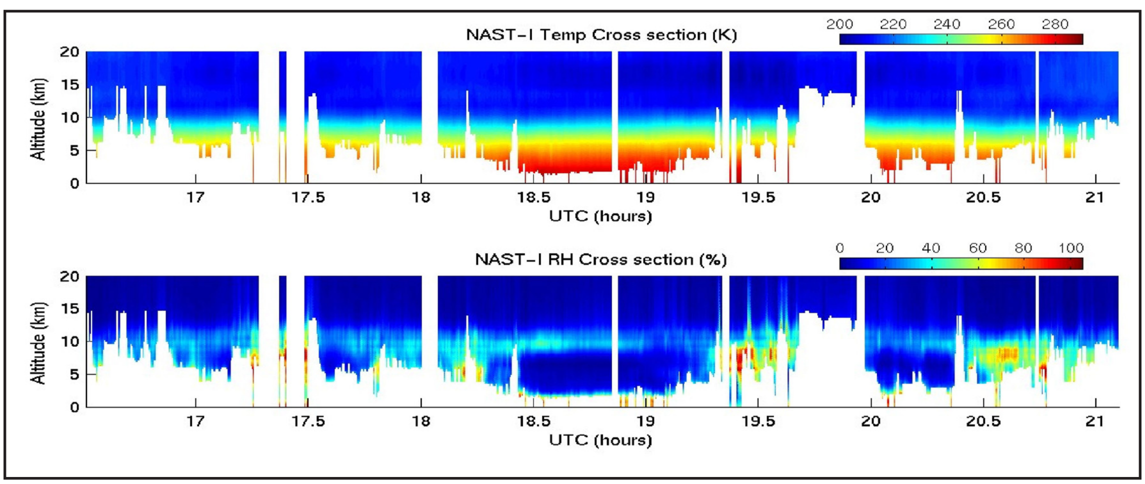
NOAA Gulfstream

UND Citation

North Dakota Citation, as well as coordinating with the European Composite Observing System. The remote sensing and in situ data was used as input to numerical weather models on both sides of the Atlantic to evaluate improvements to storm predictions.

The ATReC experiment was the second in a series of oceanic observation campaigns over the Atlantic. Instruments flown on the ER-2 for ATReC were the NAST-I, NAST-M, Scanning–HIS, CPL, FAST O3, and MAS, for a total of 67 ER-2 flight hours that were funded by the NASA Aviation Safety Program and the NASA/NOAA/DOD Integrated Program Office (IPO). Results showing the impact of the additional ATReC observations on the European Center for Medium Range Weather Forecasts (ECMWF), UK Met Office and National Centers for Environmental Protection Global Forecast Systems weather forecasts were presented at the First International THORPEX Symposium in Montreal, Canada. This campaign was extremely well-coordinated between multi-agencies and international partners, including NASA, NOAA, ECMWF and the UKMet Office.

For more information, go to: http://www.mmm.ucar.edu/uswrp/programs/thorpex.html



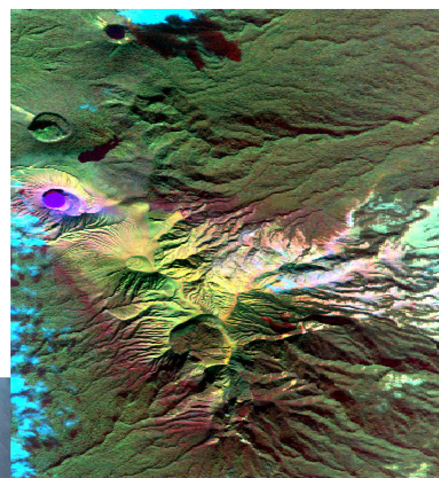
Data collected with NASA Langley's NAST-I sensor that was flown on the ER-2 during ATREC.

CARTA-II

The Second Costa Rican Airborne Research and Technology Application (CARTA-II) occurred in February and March 2005. The NASA WB-57 was deployed to San Jose, Costa Rica for a total of six weeks. Sensors on board included the NASA MASTER (50-channel Aster Simulator); the commercial 128-channel hyper-spectral scanner HyMap, the RC-30 metric camera, and a Cirrus digital camera system (DCS). This suite of sensors produced a valuable dataset of high spectral resolution, visible-thermal infrared data for researchers. This was a systematic survey of the entire country of Costa Rica with over 80% of the country imaged by this imagery. All of the data was delivered to the Costa Rican government for educational and research purposes.

During the CARTA-II mission the DOE B-200 was deployed to Costa Rica with the Laser Vegetation Imaging System (LVIS). The LVIS was flown to characterize vegetation structure and phenology. It is unique in that it can characterize both the canopy height and underlying terrain using a wave-form lidar methodology. The B-200 was deployed for a total of three weeks during March 2005. Data was acquired over tropical forest sites, including the La Selva Long Term Ecological Reserve (LTER).

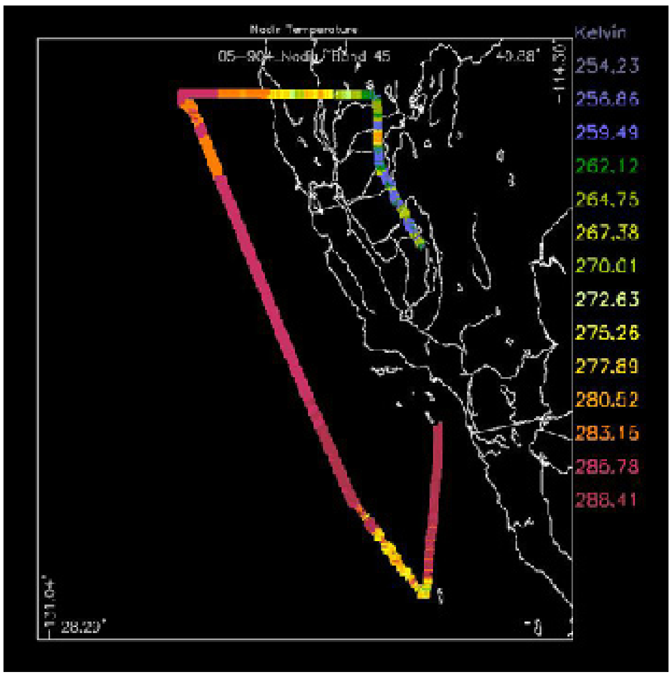
Both deployments were supported by the NASA Interdisciplinary Science Program.



Data collected with the DCS camera of volcano and coastline areas in Costa Rica.

Special Sensor Microwave Imager/Sounder (SSMIS) Calibration

The Conical Scanning Millimeter Infra-Red Radiometer (CoSMIR) together with the MODIS Airborne Simulator (MAS) were flown as part of a wide comprehensive calibration and validation study of the Special Sensor Microwave Imager Sounder (SSMIS), a microwave radiometer onboard the Defense Meteorological Satellite Program (DMSP) F-16 satellite. The SSMIS, built by Northrup-Grumman Electronic Systems, measures the earth's upwelling partially-polarized radiances in 24 channels covering a wide range of frequencies (19 – 183 GHz) in a conical scan geometry, maintaining uniform spatial resolution, polarization purity and common fields-of-view for all channels across the entire swath. The technical efforts of this study were led by the Naval Research Laboratory.



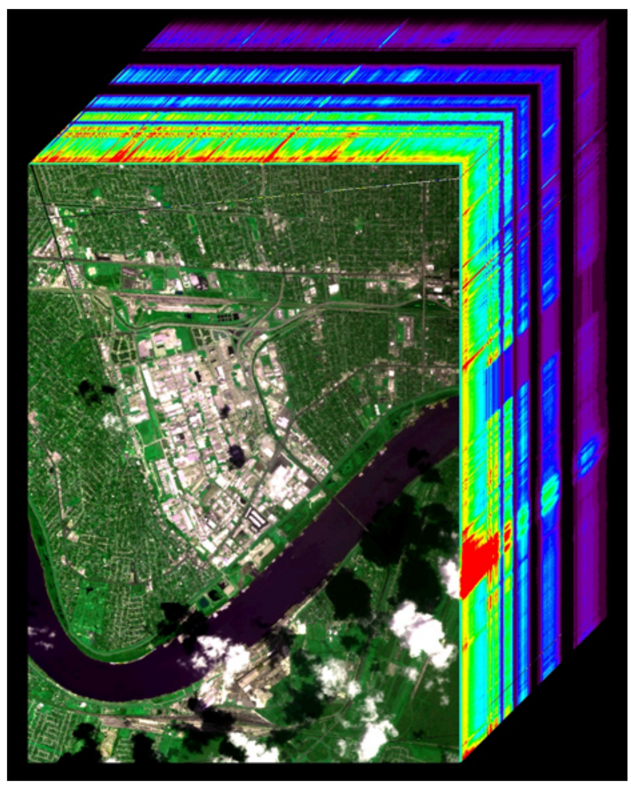
CoSMIR was designed to match the tropospheric sounding channels of SSMIS. It contains four radiometers operating between 50-183 GHz. Its unique ability to provide both conical as well as cross track imagery allows for an increased atmospheric path length and produces increased brightness temperatures. MAS records image data in 50 spectral regions from 0.4-14.4um. The MAS sensor was also flown to provide high spatial resolution thermal data in the 8-14um region in order to track temperatures along the aircraft's nadir track.

The High Altitude ER-2 day/night missions were based out of Dryden and targeted the coastal region of California and open ocean. Data were collected in March and December 2004 and again in March 2005. This project was successful, flying over 59 hours in 11 flights. Flights flown in Spring 2004 revealed significant calibration discrepancies in multiple SSMIS channels. These discrepancies were later confirmed with additional measurements and analysis.

Hurricane Katrina Disaster Assessment

In collaboration with the Department Of Defense (DOD), NASA flew the WB-57 over Louisiana and Mississippi in the weeks after the Hurricane Katrina Disaster. The Airborne Visible and Infra Red Imaging Spectrometer (AVIRIS) was installed on the NASA WB-57 at Ellington Field, Houston, TX shortly after Hurricane Katrina struck. The damaged areas were within an hour flight time from Ellington Field. The data collection was flown to support the relief efforts of the local, state and federal governments.

The hyperspectral capabilities of AVIRIS enhanced the location of possible oil and chemical spills, and possible damage to other levees in the New Orleans area. The AVIRIS data was used to: locate oil toxin spills, assess distressed vegetation damage, assess beach erosion damage, and provide a baseline of the overall surface chemistry. The goal of the flights was to support relief efforts in the effected regions, for both environmental and ecological impact. Additionally, this unfortunate rare opportunity will provide the science community invaluable data to aid and understand future such occurrences. There is the potential for a follow on data collection in the Spring of 2006. Future AVIRIS collections will be compared with the baseline data for change detection over the hurricane impacted area.



The above image is a hyperspectral image cube of the flooded New Orleans area. The color dimensions represent the 224 wavelength channels from the AVIRIS instrument.

Central American AirSAR

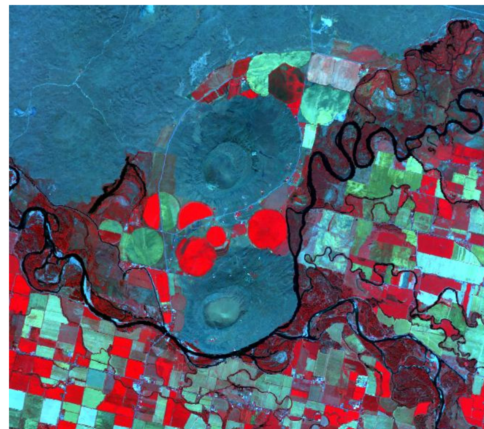
The NASA DC-8 deployed to San Juan Santa Maria, Costa Rica, and Punta Arenas, Chile during March 2004. The primary objectives of the campaign were to use JPL's AirSAR (Airborne Synthetic Aperture Radar) sensor to characterize past and present human impacts on the landscape in Central America, and to collect interferometric topographic imagery of the ice fields of Patagonia, South America and the Antarctica Peninsula. More than a dozen separate flight requests were satisfied with data sets collected on tropical forest profiles, vegetation height in mangrove swamps, the estimation of discharge from the Usumacinta River, forest and savannah mapping, ocean currents, and mars analogs.

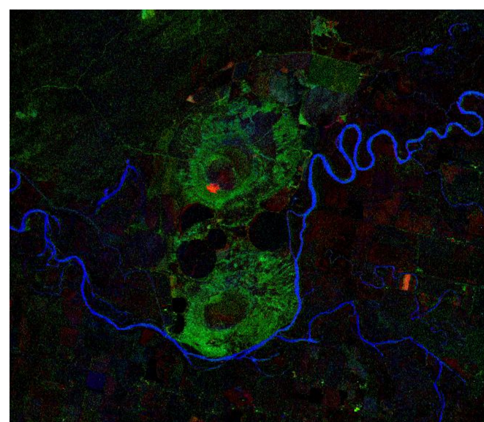
A total of four local flights were flown from Costa Rica, and four local flights from Chile. A grand total of 103 science flight hours were flown. Several Airborne Science records were set during this deployment. This was the farthest south that AirSAR data has ever been acquired, and the most airborne radar data ever collected over Antarctica. One of the flights set the record for the most AirSAR data ever collected in one flight. Three of the sorties out of Punta Arenas were blessed with unusually clear weather allowing collaborative data to be collected with the DC-8's digital IR camera.

The Costa Rica data focused on forest structure and hydrological features, and the detection of subcanopy and subsurface archeological structures, while the Chilean data provided additional information on the potential impact of the Patagonia ice fields and Antarctic ice flows on global sea level rise. AirSAR is unique in its ability to provide a combination of fine resolution imagery and long wavelength radar with the capacity of subcanopy and subsurface penetration. Additionally, it provides elevation data with high vertical and horizontal accuracy, and interferometric measurements of centimeter accuracy of vegetation and surface roughness. These capabilities are unavailable on any existing spaceborne or commercial observational platform. The measurements contributed greatly to the understanding of anthropogenic ecosystems in the Mesoamerican environment, provided a means for discovery of new archeological sites, and helped to demonstrate and enhance the application of the AirSAR in tropical regions with complex terrain and dense vegetation. The high-precision topographic data over the ice fields made it possible to determine that ice thinning rates shown by SRTM data from 1975 to 2000 continues at present.

Planetary Analogs

In 2004 several data sets were collected to look at Moon and Mars analogs here on Earth. These missions were flown in preparation for future satellite observations of both planetary bodies. AVIRIS data was collected from both the ER-2 and Twin Otter in preparation for both the CRISM instrument on the Mars Reconnaissance Orbiter (MRO) and the Discovery Moon Mineral Mapper Sensor on the Indian Space Agencies Chandra platform. Airborne Topographic Mapper (ATM) Lidar data was collected to validate results from the Mars Orbiter Laser Altimeter (MOLA), an instrument aboard NASA's Mars Global Surveyor (MGS).

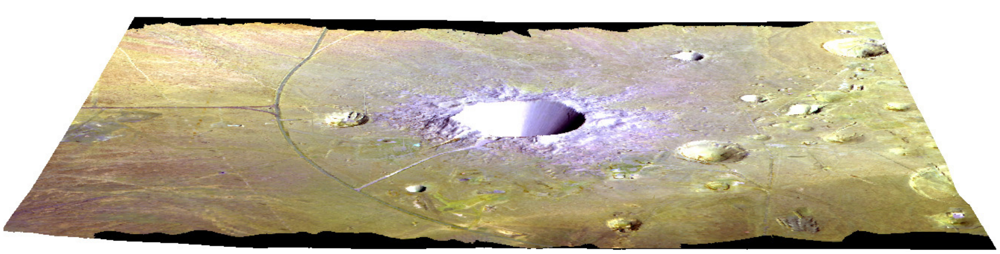




AVIRIS data collected over Menan Buttes: (top) 3 band color composite, and (bottom) classified image showing location of volcanic tepha (in red).

The Craters of the Moon site in Idaho were overflown with the AVIRIS on the ER-2. The region contains volcanic tephra structure at the Menan Butte. This site has volcanic structure that was created due to a water and magma interaction. This type of water interaction is a similar scenario to Martian Landscapes, and allows for mapping of minerals that would be found on subsequent analysis of Mars data sets.

The Nevada Test Site Nuclear Explosion Craters were overflown with a Twin Otter on two different dates. ATM looked at structure while AVIRIS was used to observe crater mineralogy. This data has been co-registered through the geo-correction of the data from the instruments high resolution geographical positioning systems (GPS) and inertial navigation unit (INU). The co-registered data are viewed above (below). These nuclear explosion craters are thought to have similar structure and mineralization as would be found on lunar and Martian impact craters.



Catalog Aircraft Activities

NASA Owned Assets

ER-2

NASA operates two ER-2 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 and development, 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. Consequently, ER-2 sensors acquiring earth imagery or conducting atmospheric sounding replicate spatial, spectral and atmospheric characteristics of data collected by earth observing sensors aboard orbiting satellites.

In fiscal year 2004 the ER-2 aircraft were able to support a total of 88 sorties and 324.4 flight hours. In January, one of the ER-2 aircraft was flown to Arizona for paint removal in preparation for its Periodic Depot Maintenance (PDM) which continued throughout the fiscal year 2005. PDM is a major overhaul of all systems on the airframe, and removed one of the ER-2 from service. Since there are 2 ER-2 aircraft, it was still possible to acquire data with the operational ER-2 in 2004 and 2005. In April, the other ER-2 was asked to be present at the March AFB Open House.

Immediately following the March AFB Open House, the ER-2 began an aggressive flight schedule in support of the Large Area Collectors. The Large Area Collectors is an instrument designed to collect upper atmospheric dust using a "sticky-plate" design. During these missions, the ER-2 flew 43.6 hours in seven flights over a span of only 12 days. In August, the ER-2 was deployed with the AVIRIS and DCS instruments to Robins AFB in Georgia. It managed to accomplish four flights immediately following Hurricane Charley, which passed by the day after the ER-2 deployed. Sites included Pamilco Sound, NC, Shenodoah National Forest, Southern Florida. During the deployment; data was collected over Puerto Rico and was flown in a single 12 hour flight. This 12 hour flight demonstrated that the ER-2 can support the extended operational range, which was 8-10 hours in prior years.

In June, 2005 the ER-2 deployed to San Jose, Costa Rica in support of The Tropical Cloud Systems and Processes Experiment (TCSP). During TCSP, the ER-2 flew 12 science flights, including three missions to Hurricane Dennis, two missions to Hurricane Emily, three missions to Tropical Storm Gert and an eastern Pacific mesoscale complex that may possibly have further developed into Tropical Storm Eugene. These missions highlighted the unique capabilities of the ER-2 to attain the altitudes needed to clear the top of storms and provide long enough flight time to capture the requisite data. During the entire TCSP Mission, the ER-2 flew 16 sorties for 107.2 hours and it was all accomplished In 41 days.

In 2005, the operational ER-2 flew for a total of 40 sorties and 158.4 flight hours. In fiscal year 2006 the ER-2 operations will be re-located from Hangar 1623, to a new facility at the Dryden Flight Research Center. This move along with efforts to share infrastructure with other projects will allow the ER-2 to reduce its hourly flight cost from recent years.

DC-8

The NASA DC-8 Airborne Laboratory Program had been operated at NASA/Dryden Flight Research Center from 1997 to 2004 acquiring data for airborne science research. The platform aircraft provides for a wide variety of experiments, collects data in support of scientific projects, and serves the world scientific community. Included in this community are NASA, federal, state, academic, and foreign investigators.

In response to an unsolicited proposal, NASA entered into a cooperative agreement with the University of North Dakota (UND) on June 2, 2005 to establish the National Suborbital Education and Research Center (NSERC) with the DC-8 flying laboratory as the centerpiece. The vision is to more fully and cost effectively utilize the DC-8 by embedding the aircraft into the University Community and expanding the field of researchers and research organizations which utilize the aircraft for the ultimate benefit of the scientific community and society. The cooperative agreement with UND allows NASA to explore the feasibility of this model of operation collaboratively while allowing the University an opportunity to demonstrate its ability to generate new business expanding the missions and utilization of the aircraft. Key aspects of this agreement include continuing the NASA aircrafts' record of safe operation and continuing to meet NASA's mission objectives for the aircraft. NSERC was established and dedicated by the North Dakota Governor and Congressional delegation on November 7, 2005 after the arrival of the plane to UND.

Rick Shetter, NSERC Director (l.), conducting tour of aircraft with North Dakota Senator Byron L. Dorgan (c.) and Congressman Earl Pomeroy (r.).

The NASA Johnson Space Center (JSC) in Houston, Texas is the home of the NASA WB-57 High Altitude Research Program. Two fully operational WB-57 aircraft are based near JSC at Ellington Field. Both aircraft have been flying research missions since the early 1960s, and continue to be an asset to the scientific community with professional, reliable, customer-oriented service designed to meet all scientific objectives.

During January 2004 the WB-57 was deployed to Costa Rica for Pre Launch Aura Validation Experiment (AVE). In April-May it flew the MidCix campaign. In May test flights of the WB-57 Ascent Video Experiment (WAVE) with PUMA were flown. From June – September the WB-57 was down for an avionics upgrade & phase maintenance. In October-November the aircraft flew the AVE Houston, to validate the satellite post launch. During November the aircraft flew the first of two missions with the NOAA Polarimetric Scanning Radiometer (PSR) instrument for a Water Mission, and that was part 1 of 2. In November and December a series of test flights were flown for both the CARTA payload and Harvard Water Isotopes instrument.

WB-57 Pilot and Program Manager Andy Roberts (JSC), AVIRIS Operator Scott Nolte (JPL) and AVIRIS Technician Lindley Johnson (JPL).

In January of 2005 the WB-57 continued test flights for the CARTA payload and Harvard Water Isotopes instrument. February through April the WB-57 was deployed to Costa Rica for the CARTA 2 Mission. In May there were a series of WAVE test flights in preparation for the Space Shuttles return to flight. June was the Houston AVE. In July the Water Isotope Intercomparison flights were flown. At the end of July the WAVE sensors collected imagery of the STS-114 launch. In August the WAVE program attempted to image the STS-114 reentry with one WB-57 in Houston, and another was deployed to Costa Rica. Data was not collected due to the shuttle landing at Edwards, California and not Cape Canaveral, Florida. In August the PSR test flight and the AVIRIS sensors were integrated for the first time into the WB-57. As the AVIRIS test flights were occurring in September, Hurricane Katrina devastated the Gulf Coast. The WB-57 was able to overfly the region to support assessment of the region with hyperspectral data. The second half of September continued AVIRIS flights in the Mid-West, Rocky Mountains, and a short deployment to Ames Research Center.

P-3B

NASA P-3B in flight.

NASA Wallops Flight Facility operates a Lockheed Martin P-3B for low altitude heavy lift airborne science missions. The P-3B has a long history of supporting cryosphere studies, and due to the long range of the aircraft, it is able to support ice sheet studies in both the Arctic and Antarctica polar regions. The P-3B has supported active optical remote sensing missions using Lidar instruments such as the Airborne Terrain Mapper (ATM). The heavy lift capability of the airframe is able to support passive microwave instruments, such as NOAA's Polarimetric Scanning Radiometer (PSR), NASA's 2-DSTAR, and the JPL polarimetric scatteromete (POLSCAT) instruments. These passive microwave instruments have flown missions to study soil moisture, and calibration and validation of the spaceborne Advanced Microwave Scanning Radiometer (AMSR-E).

During 2004-2005 the NASA P-3B was not flying due to maintenance issues. In order to support earth science missions, the Naval Research Laboratory's (NRL) P-3 was used under a Memorandum of Understanding (MOU) between NASA and NRL. The NRL P-3 flew the SMEX04 and SMEX05 missions, and the Palmer Peninsula, Antarctica Mission to validate the ICESAT GLAS sensor.

The former NASA P-3B support contract expired in 2005. Now the airframe is being serviced by Aero Union of Chico, California. Aero Union specializes in the P-3 airframe, and it has restored the P-3B to a healthy airworthy state. The aircraft will be available in 2006 for the first time in several years. The first mission will be the Arctic 2006 mission to Barrow, Alaska in March 2006. The primary objective will be to validate space based sea ice measurements.

Contracted Aircraft

Proteus

The Proteus is a high-altitude, multi-mission aircraft that has been used to support airborne science activities in recent years. NASA has developed two external centerline pods and other specialized equipment for instrument integration. One pod provides twice the equivalent payload accommodation of the ER-2 Q-Bay in a tandem arrangement; the other is tailored to support operation of the NAST-I instrument suite.

The Proteus aircraft with NASA Double-Q Bay pod shown landing at Mojave Airport, Calfornia.

In June of 2004, two hyperspectral imaging systems were integrated into the 'double Q-Bay' pod for a series of flights over calibrated target sites. This provided a unique opportunity to obtain concurrent data from the NASA JPL, Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) and the HyMAP hyperspectral imager owned and operated by HyVista Corporation.

Later in the year, the NAST-I, NAST-M, S-HIS, FIRSC, Micro-MAPS instruments were integrated to support a series of atmospheric science missions. The instruments were integrated in Mojave, California, and check flights were completed in the local area. The Proteus with its experimental payload deployed to the Langley Research Center in July and participated in NASA's INTEX mission and NOAA's New England Air Quality campaigns. After returning from Langley, the airplane transited to Naples, Italy, to participate in the Aerosol Direct Radiative Impact Experiment (ADRIEX) and continued on to Cranfield, England, to collect data as part of the European AQUA Thermodynamic Experiment (EAQuaTE). The airplane flew 65 flight hours in support of the European campaign.

In 2005, Proteus was used to demonstrate advanced collision avoidance systems; an enabling technology for more widespread application of uncrewed air systems (UAS). This work, sponsored by the NASA ACCESS 5 project office, involved the integration and evaluation of 2 cooperative collision avoidance sensors. Although the Proteus is a piloted vehicle, it can be controlled from a ground station to simulate UAS operations.

A Gulfstream III was used during these tests to simulate an intruder aircraft. During the course of the testing, six geometrically different near-collision scenarios were evaluated. These six scenarios were each tested using various combinations of sensors and collision avoidance software. Proteus flew a total of 21.5 hours and conducted 49 successful test points.

The Proteus continues to be available to airborne science investigators under a contractual arrangement with NASA Dryden Flight Research Center.

NASA Double Q-Bay Pod showing installation of NASA-JPL AVIRIS and Commercial HyMap Hyperspectral Remote Sensors.

King Air B-200

The King Air B-200 in front of the hangar at NASA Ames Research Center.

In May 2004, the King Air B-200 flew the MASTER sensor over the Jorando and Sevillita Long Term Ecological Reserve in New Mexico, in support of a soil moisture. Day/Night diurnal datasets were collected for JPL at Death Valley, California to study thermal inertia. Further MASTER data was collected at Montrose, Colorado and Green River, Utah for the USGS to study the Mancos Shale Rock formation.

Another MASTER installation occurred on the King Air B200 for a campaign in August 2004, the Southern California Fault assessment project for UCLA, JPL, and USGS. In addition the campaign flew for the University of Washington and JPL at Panimant Valley, California, and Providence, California, for Day/Night diurnal data collection for thermal inertia studies.

In March 2005 the Laser Vegetation Imaging System (LVIS) was integrated and flown on the King Air B-200. This was the first time LVIS was installed on the B-200, and was flown for three weeks as part of interdisciplinary study in Costa Rica. This mission occurred during the same time as the CARTA–II mission.

Jetstream-31

As part of INTEX-A in July – August 2004 the J-31 was deployed to New Hampshire in support of NASAs Radiation Science Program. The payload supported the International Consortium for Atmospheric Research on Transport and Transformation (ICARTT) experiment with the Ames Airborne Sunphotometer (AATS-14), Solar Spectral Flux Radiomete (SSFR), Nav/Met Data System (NAV-Met) and POS-AV System (POS-AV). A Total of 90 science hours were flown. In September 2005 the J-31 supported a DOE experiment at the Atmospheric Radiation Measurement-Cloud and Radiation Testbeds (ARM-CART) Southern Great Plains Site, Oklahoma for a two week mission, with AATS-14, SSFR, RSP, NAV-Met, and POS-AV.

Jetstream-31

Cessna Caravan

In September and October 2004, MASTER and a commercial LIDAR flew day and night missions over Bluff Creek, California, to study thermal inertia over riparian habitats. The Caravan then began acquiring data over Mount St. Helens for JPL and USGS. The Caravan was scheduled to acquire MASTER data for a USGS study of the Mount St. Helens eruption debris field. Coincidently, the volcano became active and consequently multiple MASTER/Lidar data flights were flown over the crater. These data sets were used to characterize the growth of the lava dome in the crater to include an animation of the dome's growth.

Twin Otter

The Twin Otter aircraft has been used by AVIRIS and ATM instrument science teams for many years. Initially both instruments were flown on one of the NOAA owned and operated Twin Otters. Since then both instruments have been integrated and flown on commercially owned Twin Otters.

In the first month of fiscal year 2004, AVIRIS and the Twin Otter were completing the collection of preliminary North American Carbon Program datasets. Post monsoon data was collected in the Southwestern United States, in particular in Arizon, Utah, New Mexico, and Nevada. During the same campaign, AVIRIS was based in Southern California during the Southern California wildfire seasons, and was able to collect high spatial and spectral resolution data over active fires.

In the spring of 2004, AVIRIS was flown on the Twin Otter during another campaign in April and May. Data was collected over the Rocky Mountains in Colorado to measure the effects of dust on snow melt. AVIRIS data was also collected over Utah to trace the sources of the dust. In response to an Diesel Oil spill in the San Francisco Bay Area, AVIRIS was flown to the Suisun Marsh and data was acquired to measure the impact of this spill on the wetlands. AVIRIS data was then collected at Los Alamos, New Mexico to study carbon uptake by the pine forests, and in particular prior to the monsoon season. A total of 40 hours were flown to support NASA funded science flight requests during the spring campaign.

At the end of fiscal year 2004, AVIRIS flew again on the Twin Otter. Datasets were collected in Colorado to support validation of the ASTER sensor on the EOS Terra Spacecraft. Data was collected over the Nuclear Explosion Craters at the Nevada Test Site for Planetary Analogs studies here on Earth. The fall campaign then continued on into fiscal year 2005, and the contract was extended to support the flights in the new fiscal year. Data was collected over

Los Alamos, New Mexico after the Southwestern Monsoon to complete the seasonal requirement for this investigation. Then the Twin Otter and AVIRIS flew many sites in the San Francisco Bay Area for wetlands studies. The campaign was completed with calibration flights at Ivanpah Playa, California and Cuprite, Nevada. A total of 45 hours were flown to support NASA funded science flight requests during the fall mission.

In the winter of fiscal year 2005 from January through March, the Twin Otter was deployed to the Hawaiian Islands to support a tropical ecology study with the AVIRIS. AVIRIS was shipped to Hawaii on a commercial airlift, while the Twin Otter flew the 15 hour one way transit from Camarillo, California to Oahu, Hawaii. Due to headwind considerations, the Twin Otter was delayed for 2 weeks while waiting for favorable wind conditions. The AVIRIS sensor was installed at Dillingham Field on the North Shore of Oahu. Even with the 2 week delay, the mission was a huge success with sites flown on Hawaii, Kauai, Oahu, Maui, and Molokai. A total of 48 hours were flown for funded NASA Science Flight Requests.

A commercial Twin Otter was flown to Greenland and Arctic Canada to support the Arctic Ice Mapping work to support IceSAT/GLAS validation. The campaign flew the ATM Lidar systems to measure Glacial Ice Sheet dynamics. This campaign was flown in the May of 2005, and flew a total of 90 hours. In late summer the ATM instrument was installed on another commercial Twin Otter, and flew a mission to Alaska. The goal with this mission was to measure the retreat of the Hubbard Glacier and the impact on Yakutat, Alaska if the glacier does retreat. The Alaskan flights were joint funded by the Army Corps of Engineers and the NASA Cryosphere Program. After the Alaska flights, the Twin Otter and ATM flew sites in the Mojave Desert region of California to study river drainages for the USGS. A total of 50 hours were flown on the Alaska and California campaign during September 2005.

New Technologies and Prototype Aircraft

Unmanned Aerial Systems (UAS)

Altair: NOAA-NASA Coastal California Mission

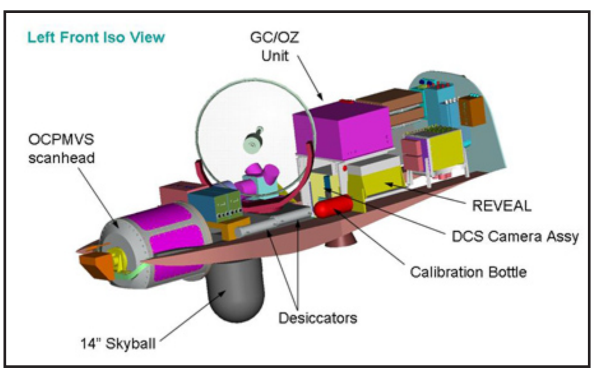
The ALTAIR UAS completed 5 flights for NOAA's science and operations demonstration mission. The most recent flights were on November 14-15 (18.4 hours) and November 16 (7.7 hours). The 18+ hour flight demonstrated the potential of a UAS to fly long missions to remote areas. The last flight, over the Channel Islands National Marine Sanctuary, demonstrated the surveillance capabilities of the platform and the ability of the platform to perform coastal remote sensing missions. It further demonstrated the capability to safely integrate into the National Airspace System down to altitudes of 7000 ft.

With an 86 foot wingspan, the ALTAIR's endurance, reliability and payload capacity provide the capability to improve mapping, charting and other vital environmental monitoring in remote areas, such as the NW Hawaiian Islands and Alaska. In California, the aircraft's capabilities will improve forecasts and warnings of natural disasters, such as winter flash floods and related fatal mud slides. Real-time imagery is fed to the aircraft's ground command center from which the aircraft is piloted.

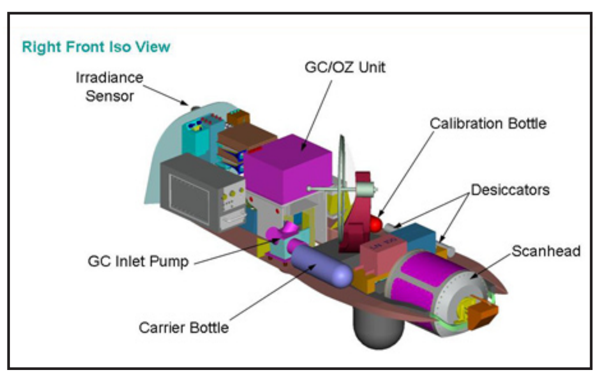
A primary goal of this first demonstration is to evaluate UASs for future scientific and operational requirements related to NOAA's oceanic and atmospheric research, climate research, marine sanctuary mapping and enforcement, nautical charting, and fisheries assessment and enforcement. The ALTAIR can carry an internal 660 pound payload to 52,000 feet for over 24 hours.

The payload of sensors included:

- Ocean Color Sensor images to improve fisheries management through better assessment of eco-system health, including improved forecasting and warnings of harmful algal blooms.
- Ozone Sensor Measurements to help determine ultraviolet vulnerability.
- Gas Chromatograph Measurements to help scientists estimate greenhouse gases potentially associated with climate change and global warming.
- Passive Microwave Vertical Sounder to help determine when flash flood warnings must be issued.
- Digital Camera System to facilitate shoreline mapping, habitat mapping and ecosystem monitoring, including spill and aquatic disease tracking and assessing land-based discharges and marine mammal distribution and abundance.
- Electro Optical/Infrared Sensor to provide non-intrusive, maritime surveillance for fishery and marine sanctuary enforcement. Current aerial surveillance has a short survey range and is noisy, dangerous, infrequent and not cost-effective.

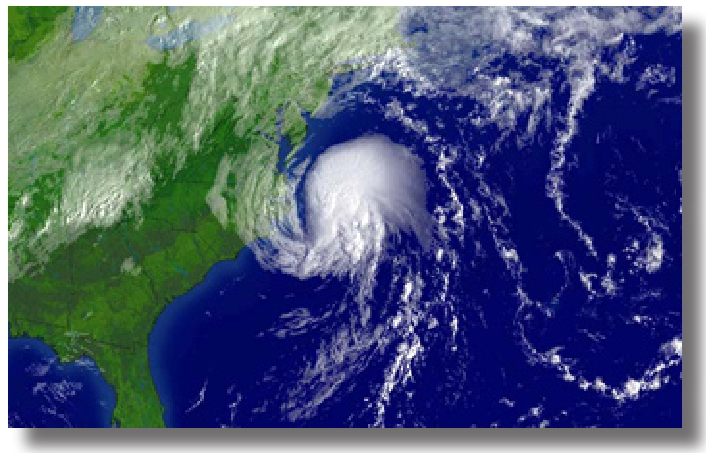


Schematics of the Altair™ NOAA NASA payload.



Aerosonde: Hurricane Ophelia

NASA, NOAA and Aerosonde North America teamed up to mark a new milestone in hurricane observation on September 16, 2005 as the Aerosonde, an unmanned aircraft, flew into Hurricane Ophelia. The Aerosonde UAS provided the first detailed observations of the near-surface, high wind hurricane environment, an area often too dangerous for manned aircraft to observe directly. This partnership with NASA, NOAA and Aerosonde led to a successful mission. This collaboration collected a low-level dataset for hurricane researchers, and also demonstrated the potential for a future UAS operational capability.



The Aerosonde was launched from NASA's Wallops Flight Facility, Wallops Island, Virginia, on September 16, 2005. Wallops provided basing and pre-mission validation and testing of the unmanned aircraft and its support systems prior to its deployment into the storm. In addition, NASA and Aerosonde staff monitored and controlled the flight from Wallops.

The Aerosonde platform that flew into Ophelia was specially outfitted with sophisticated instruments used in traditional hurricane observations, including instruments such as mounted Global Position System (GPS) dropwindsonde and a satellite communications system that relayed information on temperature, pressure, humidity and wind speed every half second in real-time. The Aerosonde also carried an infrared sensor that was used to estimate the underlying sea surface temperature. All available data were transmitted in near-real time to the NOAA National Hurricane Center and Atlantic Oceanographic Meterological Laboratory (AOML). The data collected during the flight was used in the operational forecast for that day.

The successful use of satellites and aircraft have been important tools in the arsenal to understand tropical cyclones. Detailed observations of the near-surface hurricane environment have been elusive because of the severe safety risks associated with low level manned flight missions. The main objective of the Aerosonde project addresses this significant observational shortcoming by using the unique long endurance and low-flying attributes of the unmanned Aerosonde observing platform, flying at altitudes as low as 500 feet. NASA pioneered the use of Aerosondes in earlier tropical convection experiments in 2001 and 2005, but this was the first time the Aerosonde actually flew into a hurricane. Ophelia provided the perfect text case as it was a minimal hurricane within flight range of Wallops.

The environment where the atmosphere meets the sea is critically important in hurricanes as it is where the ocean's warm water energy is directly transferred to the atmosphere just above it. The hurricane/ocean interface also is important because it is where the strongest winds in a hurricane are found. Observing and ultimately better understanding this region of the storm is crucial to improve forecasts of hurricane intensity and structure. Enhancing this predicting capability would not only save the U.S. economy billions of dollars, but more importantly, it could save many lives.

The Aerosonde upon launch from the roof of a truck.

This concept of the Aerosonde as a small, robust unmanned autonomous system, or UAS, arose directly from the need for observations in dangerous areas such as the hurricane surface layer. The goal of this flight for NOAA was to use the data in forecasting hurricane intensity. There is a requirement to get continuous low-level observations near the air-sea interface on a regular basis.

Ikhana (Predator-B)

In the Native American Choctaw language, the word “ikhana” means intelligent, conscious, or aware. This made it the perfect word to represent the aircraft NASA has selected to demonstrate technologies seeking to make unpiloted aircraft more intelligent and autonomous. In FY05, NASA initiated the procurement of a Predator-B aircraft that will host the flight demonstration of these advanced autonomy technologies, namely: Intelligent Mission Management (IMM) and Integrated Vehicle System Management (IVSM). The demonstrated reliability of the Predator-B will allow experimenters to focus on research instead of the platform and permit FAA-approved operations in the National Airspace (NAS).

Illustration of the Ikhana, courtesy of General Atomics.

The Earth Science Capability Demonstration Project (www.nasa.gov/centers/dryden/research/ESCD/) is developing the aircraft modifications that will provide a rapidly reconfigurable test system for hosting technologies that require interaction with the aircraft systems and sensor payloads. The Airborne Research Test System (ARTS) will have the authority to “fly” aircraft without inputs from ground control using any of three modes: waypoint-based navigation, standard autopilot hold modes, or pilot stick/rudder/throttle commands. The ARTS system will also be networked with the aircraft payload bay and each of the wing pylon stations. The ARTS can use the sensor data as part of the decision making process in determining the mission plan and relay sensor data to the ground control station, where the data can be networked to remote sites. The project intends to use externally mounted pods to carry payloads whenever possible. This approach has numerous benefits including: integration and checkout at the developer’s work site, integration without the need for the aircraft, quicker payload upload to the aircraft, and ability to rapidly reconfigure and deploy the aircraft (e.g., disaster management).

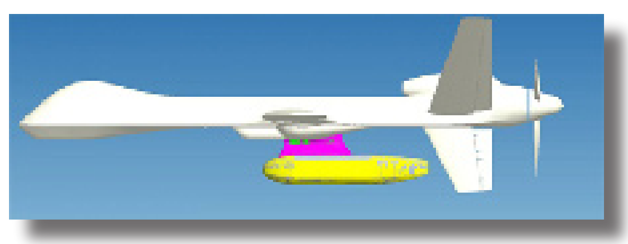


Illustration of Ikhana with pod-mounted multri-spectral sensor. (Illustration courtesy of General Atomics.)

In FY 2007 the project will combine the IMM and IVSM technology to perform an autonomous fire hunting and mapping mission in cooperation with the US Forest Service over the Western United States. The aircraft will autonomously plan and replan the mission conduct as needed based on objectives and priorities established by the fire commanders using the ARC developed Collaborative Decision Environment. The pod-mounted multi-spectral sensor will provide near real-time images to fire commanders. During 24-hour missions, pilot hands-on time is expected to be limited to take off and landing.

In FY05, the aircraft was procured along with satellite communications equipment, ground support equipment, ground control station, and a limited set of spares. A Concept of Operations Document was generated to identify the logistics of operating and maintaining the aircraft at NASA DFRC. A Training Plan was also developed to assure that NASA personnel gain adequate experience. Project pilots have completed ground school and are participating with the manufacturer in flying the Altair™ aircraft in support of NASA Earth Science missions. Maintenance teams have completed the Predator mechanics course, engine course, and are preparing for the upcoming avionics course. The system requirements review was successfully completed, establishing the baseline for the research modifications that will be made to the aircraft. Contracts for support from the aircraft manufacturer and provider of the ARTS system have been established. Drafts of the Software Management Plan, Software Development Plan, Risk Management Plan, and System Safety Plan are being reviewed. In addition, the contract for the design and development of the sensor pod was awarded.

In FY06 the operations team will complete the design of the research systems. The ARTS hardware and software will complete PDR, CDR, and functional testing. In addition, software modifications to the basic aircraft flight controls will allow the ARTS to control the aircraft. The mobile ground control station will be assembled and verified. In the fourth quarter NASA will take delivery of the aircraft and begin research modifications.

Ikhana in production at General Atomics manufacturing facility.

UAVSAR and G-III Cooperative Research Platform

A Grumman Gulfstream III (G-III) business jet is being modified and instrumented by NASA's Dryden Flight Research Center to serve as a test bed for a variety of flight research experiments under the Multi-Role Cooperative Research Platform project. The twin-turbofan aircraft provides long-term capability for efficient testing of subsonic flight experiments for NASA, the U.S. Air Force, other government agencies, academia, and private industry. The aircraft, which carried the military designation of C-20A, was obtained from the U.S. Air Force in 2003.

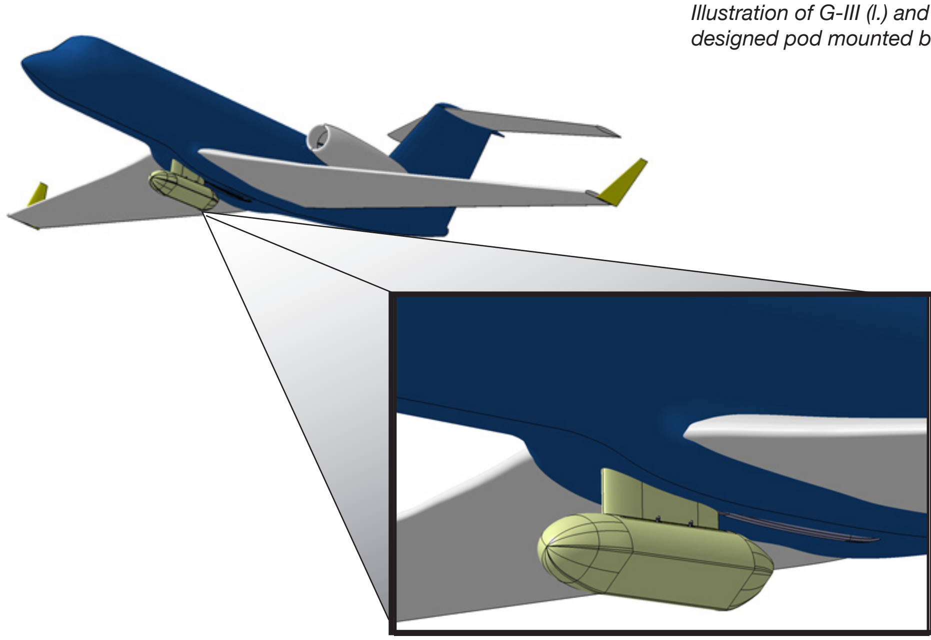
When modifications are complete, NASA G-III will be equipped with a self-contained on-board Data Collection and Processing System (DCAPS). This embedded instrumentation system allows for automated configuration setups to reduce required engineering support for each mission. It includes primary and backup systems to assure mission reliability, with the backup system available for use concurrently as a second a system when needed. DCAPS is designed to allow easy upgrades, addition of add-on systems for expansion, and to operate in both autonomous and manual modes.

The custom DCAPS system installed on the G-III was developed to enable processing, distributing, displaying and archiving aircraft flight data and customers' experimental data in real time. In addition, it features a video collection and distribution system, satellite communications systems, including airborne Internet capability, satellite phones, an upgraded 120-amp electrical power system and an infrared-capable pilot's heads-up display. The telemetry system can receive and relay data in S, Ku and L-band frequencies. In its commercial versions, the G-III's basic role is that of an executive business aircraft. The C-20A military versions serve in a similar capacity for high-level government and military officials. Empty, the unmodified airplane weighs 38,000 lbs. The aircraft has a wingspan of just over 77 feet, is about 83 feet long and just over 24 feet tall. Normal cruise for the aircraft is 459 knots at a maximum operating altitude of 45,000 feet. Top speed is 561 mph (903 km/h) (Mach 0.85). It has a range with a full load of passengers or equipment of about 3,400 nautical miles.

The G-III aircraft has been selected to support initial development of the Unmanned Air Vehicle Synthetic Aperture Radar (UAVSAR) which when combined with Repeat Pass Precision Navigation capability will allow for Repeat Pass Interferometry (RPI) data collection. Ultimately RPI capability will be employed on Unmanned Aircraft Systems (UAS) aircraft and is a widely anticipated tool for the solid Earth research community.   UAVSAR is an Earth Science Capabilities Demonstration project jointly sponsored by NASA's Science Mission Directorate, Aeronautics Mission Directorate, and the Earth Science Technology Office. The Jet Propulsion Laboratory is lead in developing the UAVSAR instrument and NASA Dryden is lead in developing the Platform Precision Autopilot both of which will initially be implemented on the G-III aircraft. The minimum goal is to achieve the ability to repeatedly navigate the aircraft within a predefined ten meter tube flight path and then thru system refinements ultimately achieve one meter tube precision.

The synthetic aperture radar will be flown on the G-III in a specially designed pod that will be interoperable with UAS aircraft in the future. In order to support the installation of the UAVSAR pod, the G-III airframe is being structurally modi-

Illustration of G-III (l.) and detail of specially designed pod mounted beneath (inset).



fied to incorporate a MAU-12 ejector rack on the bottom of the fuselage. This unique GIII modification will remain available for use by future projects. Below is a drawing of the G-III with the UAVSAR pod mounted, and then an enlarged view of the pod. A precision navigation system is currently in the design phase which is planned to interface to the Instrument Landing System on the G-III aircraft. A Simulation which describes the G-III's performance, stability & control, and handling qualities is also in development at Dyrden and will support precision navigation system algorithm development

Deliverables to date are completion of a UAVSAR pod design study, completion of a GIII modifications and UAVSAR pod requirements document, releasing to industry a Request for Proposal on the GIII modifications and UAVSAR pod, selecting a contractor and establishing a contract for GIII modification and the design/fabrication of the UAVSAR pod, completion of the Precision Autopilot Systems Requirement document, completion of the Precision Autopilot Systems Requirement Review, co-development of an integrated project schedule between Dryden and JPL, and successfully completing Preliminary Design Reviews of the UAVSAR pod design, GIII aircraft structural modifications designs, and the Platform Precision Autopilot system design. The UAV Synthetic Aperture Radar system successfully completed a Critical Design Review.

Suborbital Telepresence: Over the Horizon Communications

The Over-the-Horizon Communications “Suborbital Telepresence” Project (OTH) within Earth Science Capabilities Demonstration (ESCD) is focused on network connectivity for globally reliable tele-operation and tele-control of instruments and vehicles. The objective of OTH is to deliver affordable and sustainable capabilities and prototype systems architecture for networks of airborne instruments. The OTH Project delivered a proof-of-concept global instrument telepresence capability, with demonstrations during both the NOAA/Altair UAV science flights off the west coast of the United States and the TCSP science mission to Costa Rica to study tropical storms and hurricane formation.

The centerpiece of the OTH Project this year is the vehicular system component called the Research Environment for Vehicle-Embedded Analysis on Linux, or REVEAL. Two flightworthy REVEAL systems, with demonstrations on the piloted ER-2 high altitude science platform and Altair UAV were constructed and flown, with a third unit in the assembly stage. REVEAL is a dynamically reconfigurable gateway between the on-board instruments and wireless communication paths to and from aircraft. The REVEAL units provide data needed for situational awareness displays and manages communications between researchers and science instrument packages.

REVEAL leverages a network link via the Iridium satellite constellation between the aircraft and ground systems. The meager 2400 bits-per-second nominal data rate proved to be robust enough to allow multiple streams of status data to coexist with interactive traffic required to monitor and query multiple instruments on the vehicle. Earth science researchers paying for flights on the ER-2 and Altair were very pleased with the value added by telepresence capability delivered by the project. The extended OTH team that participated in the effort includes researchers at NASA Marshall Space Flight Center (Huntsville, Alabama) and Creare, Inc. (Hanover, New Hampshire).

Progress was also made this year toward demonstrating optimized multi-channel Iridium tailored for high altitude UAVs. This progress involved design and construction of a low volume/low weight packaging technique for an arbitrary number of Iridium transceivers. From a software perspective, NASA Dryden engineers collaborated with NASA JPL under a Memorandum of Understanding (MOA) with the U.S. Navy to implement the open-standard Spacecraft Communication Protocol Standards (SCPS) protocol suite over Iridium. Flight testing of an optimized multichannel Iridium gateway is scheduled for FY06, and this will achieve a maximum data rate of 14,000 bit-per-second. The Navy partnership is connected to the DoD's Integrated Network-Enhanced Telemetry (iNET) Program; goals include evolving interoperable architecture and implementation between NASA's and DoD's use of networks for aeronautical flight test operations.

The vision for airborne network architecture involves disruption-tolerant routing across multiple link technologies (similar to networking in space). While Iridium is global reach and well-suited to the airborne environment, the bandwidth constraints do in fact justify integration of Iridium network links with faster network link technology. Consequently, another effort under ESCD/OTH this year is a project dubbed "HiWAND" (High-rate Wireless Airborne network Demonstration) and adapts existing broadcast telemetry infrastructure used for nearly a half century by government test ranges to implement a line-of-site networking capability of approximately 10 Mbps. Successful flight demonstration toward the end of this year will allow implementers to expand communication scenarios with a variety of air-to-air and air-to-ground capabilities using telemetry equipment. HiWAND will use a NASA King-Air as a UAV surrogate for this flight demonstration.

New Sensor Technology and Standards

The Airborne Science and Technology Laboratory

The ASTL is located at the NASA Ames University-Affiliated Research Center, and is run in collaboration with the University of California at Santa Cruz. It is engaged in enabling and performing airborne measurements for the NASA science community. It has functions for technology development, science support, sensor operations and calibration, and is actively developing standard interfaces and protocols for the cross-platform portability of NASA airborne instrumentation.

The AMS Scanhead, configured for the Altair Wildfire Mission.

Much of the technology development work in FY05 was directed toward the Altair/Predator-B UAV platform. An Autonomous Modular Sensor (AMS) system was completed, which will provide a remote sensing imagery for land, ocean, and atmospheric studies. The AMS, which will be initially demonstrated on the Western States Wildfire mission in 2006, includes re-configurable spectral bands, and extensive onboard processing and networking capabilities. It will be carried in an external Common Sensor Pod, which is designed to accommodate a wide variety of other instrumentation.

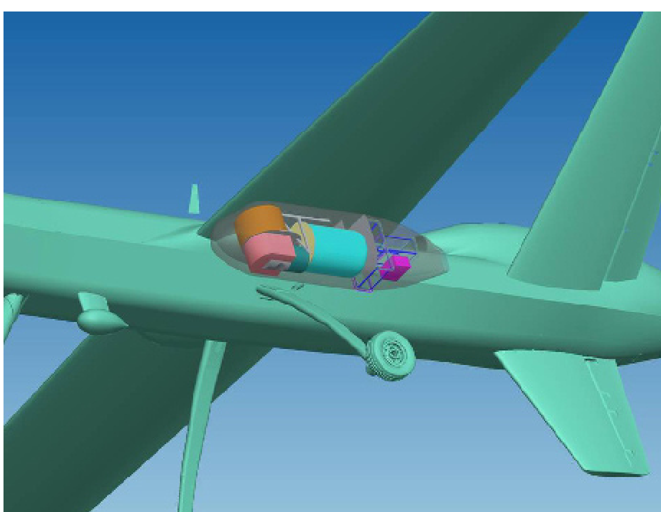


Diagram showing the AMS in the Modular Sensor Pod for the Altair/ Ikhana. (Illustration courtesy of General Atomics)

An outgrowth of the AMS project is a standard telemetry interface module, which can manage high bandwidth data of up to 40 Mbs from multiple sensors across the Ku-Band satellite links on Altair, Predator-B, or Global Hawk, to web servers on the ground. It provides commercial interface protocols to the client sensors on board the UAV, and is designed to be both platform-independent, and transparent to the data users on the ground. An expanded version of this, expected to be ready for the Guam TC-4 Altair mission in 2007, will include multiple programmable processors to enable a demonstration of the intelligent sensor web concept.

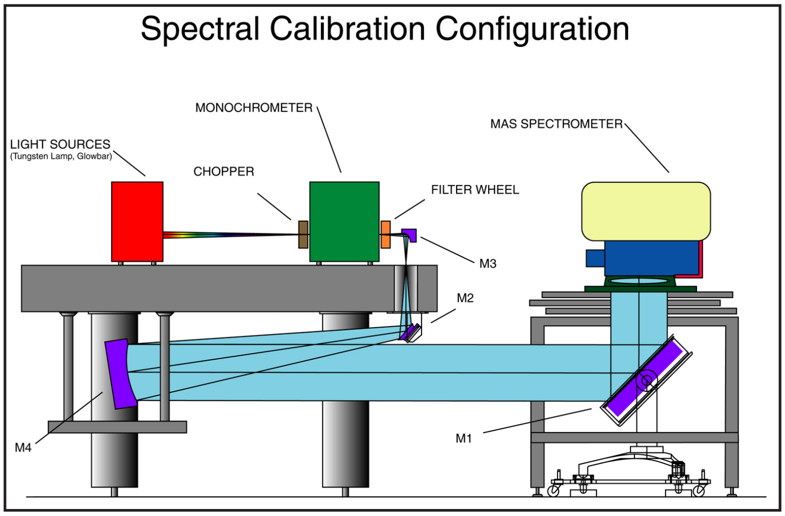


Diagram of optical bench and collimator in the ASTL Califration Lab.

Valuable operational experience was gained with the Altair during the 2005 NOAA missions, on which over 100 GBytes of DCS camera data were collected. Several trained engineering technicians are now available to assist with the integration of science payloads on this class of UAV platform.

The ASTL also operates several facility assets for the SSP, including stand-alone precision navigation systems (Applanix POV-AV IMU/DGPS units), Cirrus/DCS digital tracking cameras, and telemetry and aircraft navigation data interface hardware. This utility hardware is available for use by authorized SMD investigators. The lab also operates the MODIS and ASTER Airborne Simulators (MAS and MASTER) for the EOS program, which are made available to other NASA scientists by prior arrangement.

The ASTL Calibration Laboratory is a community resource that is co-funded by the Suborbital Science and EOS programs. It performs NIST-traceable spectral and radiometric characterizations of remote sensing instruments. New capabilities added this year included a transfer radiometer for calibrating radiometric sources, and a high-temperature cavity blackbody. The lab also provides portable radiance sources (integrating spheres) and an ASD spectrometer to support field experiments.

Suborbital Science Program Studies

Suborbital Science Missions of the Future

Community Workshops

The Suborbital Science Program was restructured in FY04 to optimize science return while simultaneously investing in UAS. The first step was to engage the science community to determine the best applications of UAS for Earth science, through workshops and the peer review process. In 2004 NASA held a community workshop – "Suborbital Science Missions of the Future" - for all six of NASA's Earth science focus areas. The workshop was dedicated to designing future UAS-based missions. More than 35 roadmap-based missions were derived during this workshop.

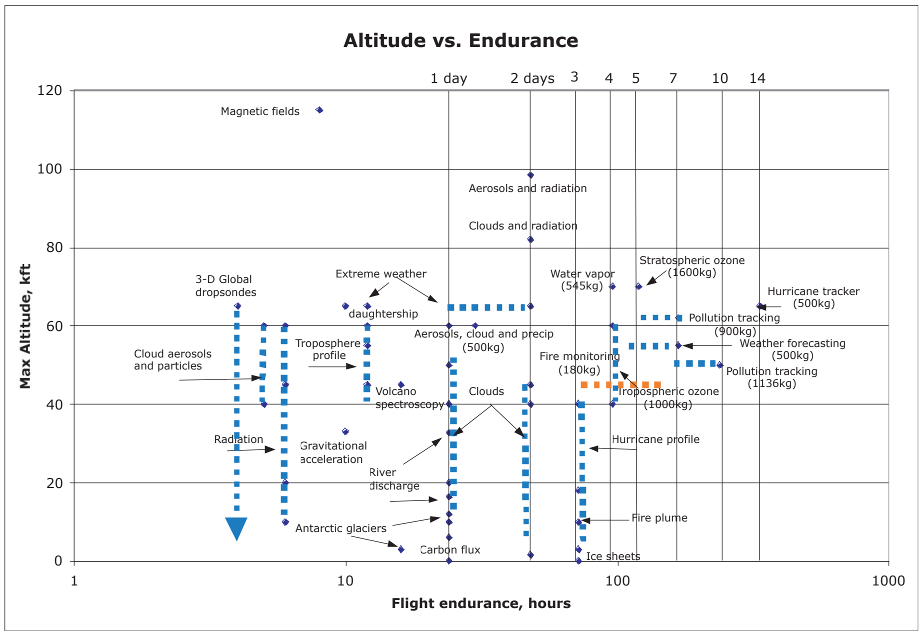
Also in 2004, two workshops were held jointly with NOAA and DOE on the specific topic of UAS research in Climate Change. Additional workshops were subsequently held in 2005 to further develop UAS mission plans in other areas. A third jointly sponsored Climate Change workshop will be held in early 2006.

The mission concepts have been studied to determine the system requirements to accomplish these missions using UAS. The outcome of the requirements analysis is being documented by NASA in a Civil UAS Assessment that seeks to create a roadmap for relevant technology development.

In addition to the workshop effort, the Suborbital program funded two directed studies, one to look at cyrospheric applications of UASs particularly for ice sheet measurements, and the other to research climate change-related measurements of carbon dioxide flux in the Southern Oceans. These two studies have been published and are available.

As a result of the process described above, many potential missions have been identified and requirements have been translated into performance needs for platform, sensor, and other systems. The potential missions serve research needs and also society needs through applied science and operational activities. It is important to note that NASA's efforts are concentrated on the more fundamental research and demonstration end of the spectrum. Potential missions address all of NASA's major Earth Science activities.

The flight requirements for the identified mission concepts are indicated in the chart shown below. Note that there are numerous missions for which vertical profiles are desired. This can be accomplished using multiple platforms, or a platform which can perform the profiling. The idea of using mother-ship / daughter-ship combinations with redocking or expendable sondes was also suggested for vertical profiling.



Some general results of this data gathering include the following:

Observation	Location	Altitude	Duration/Range	Payload	Comm.	Autonomy	Other
Varied, but many groups interested in cloud physics	Worldwide; varied; including both poles, oceans and land	Surface to 80k ft.	5 hrs. to 2 weeks some loiter capability transoceanic distances	20 to 3,500 lb. Active and passive Dispensible In-situ and remote Smart and recoverable expend-ables	Nearly all OTH Some inter-platform	Necessary, especially for tracking phenomena Very applicable to planetary exploration	Many missions with multiple, coordinated platforms Frequent deployment/ short turn around

Suborbital Science Requirements Analysis

Based on the raw requirements information collected from the Suborbital Science Missions of the Future Workshop in July of 2004, a requirements analysis assessment was undertaken. This study was developed and conducted by the Jacobs Sverdrup Corp. and the NASA Earth Science Project Office. The purpose of the study was to organize available requirements information on future suborbital missions into a consistent analytical framework to help guide existing and future suborbital platform requirements. Also, developing a systems engineering-based analysis for Earth Science requirements would allow for periodic reassessments as new requirements emerged, with the ability to assess the impact to suborbital asset planning, management, and capability transition.

The study collected, organized, and reviewed over 300 Earth Science measurement requirements. These were assigned to about 40 mission types (based on altitude, flight time, etc.) It assessed the feasibility of obtaining required measurements with existing and proposed suborbital platforms (primarily aircraft). In addition, performance data was collected for 45 potential aircraft types and was used in the requirements assessment. The analytical model used a first order aircraft performance estimator which calculated aircraft performance parameters based on each requirement, and were then mapped to the performance of the platform type database (e.g., existing platform, such as the ER-2).

Roughly 3/4 of the requirements collected had sufficient data to provide meaningful analysis. (However, the requirements were not an exhaustive set across the six NASA earth science focus areas, so additional requirements collection is still required). Roughly 30% of the requirements exceeded known aircraft performance capabilities. The primary driver for this was long flight durations (e.g., beyond 48 hrs). When durations were constrained to 12 hrs or less, and mission ranges to 5,000 nm or less, multiple options of aircraft were identified to support most requirements.

Some other summary observations of the collected requirements:

- Payload weights below 2000 lbs, often below 500 lbs (however, analysis not did not manifest multiple payloads per flight).
- Flight durations either from 12-24 hours or above 48 hours.
- Mission range beyond 1,000 nm with a large number beyond 5,000 nm.
- Altitudes below 40,000 feet and above 69,000 feet, but not many in between.
- Flights required more than once per week.

While the study made an important contribution to a more formal and organized requirements assessment, and demonstrated a consistent analysis methodology and output, additional work is still needed. The requirements set needs to be further assessed for completeness (i.e., gap analysis). The requirements should be further assessed against the realism and projected timeframe required to obtain desired future platforms. Most importantly, collection and analysis of suborbital earth science requirements should be formalized to enable on-going Suborbital Program assessment and trade-off analyses.

The Suborbital Science program initiated in 2005 the process to determine UAS capabilities required for applications in the civil sector. The objectives of the activity are:

- To determine and document potential future civil missions for all UAVs based on user-defined needs;
- To determine and document the technologies necessary to support those future missions;
- To discuss the present state of the platform capabilities and required technologies; identifying those in progress, those planned, and those for which no current plans exist (i.e., to find the gaps); and
- To provide the foundations for development of a comprehensive civil UAS roadmap

The structure of the study is designed to complement the Office of the Secretary of Defense UAV (sic) Roadmap. It is being developed in collaboration with NOAA, DOE, DOD and other agencies. The application areas being addressed are: Earth Science, Land Management, Homeland Security and Commercial uses. An initial draft of the document is available online at: http://www.nasa.gov/centers/dryden/research/civuav/index.html

Appendix A:

Platform Characteristics*

Platform Name	Center	Duration (Hours)	Useful Payload (lbs)	GTOW (lbs)	Max Altitude (ft)	Airspeed (knots)	Range (Nmi)	NASA-User Cost Per Flight Hour	Internet and Document References
ER-2	NASA-DFRC	12	2,900	40,000	>70,000	410	>5,000	$3,700	http://www.nasa.gov/centers/dryden/research/AirSci/ER-2/
WB-57	NASA-JSC	6	6,000	63,000	65,000	410	2,172	$3,500	http://jsc-aircraft-ops.jsc.nasa.gov/wb57/
Proteus	NASA-DFRC	18	2,200	12,500	>60,000	280	1,500	$4,000	http://www.scaled.com/projects/proteus.html
Gulfstream III (G-III) (mil: C-20A)	NASA-DFRC	7	2,610	45,000	45,000	459	3,400		
DC-8	NASA-GSFC-WFF	12	30,000	340,000	45,000	450	5,400	$4,000	http:///.nasa.gov/centers/dryden/research/ÅirSci/DC-8/
S-3B, Viking	NASA-GRC	>6	3,958	52,539	35,000	370	2300	$3,600	http://www.fas.org/man/dod-101/sys/ac/s-3.htm
King Air B-200	NASA-ARC	6.75	2,000	14,000	32,000	221	1883	$2,000	
P-3B	NASA-WFF	12	15,000	135,000	30,000	330	3,800	$3,000	
Cessna Caravan	NASA-ARC	5	1500	7,300	27,600	171	1000	$1,015	http://www.skyresearch.com/
Jetstream-31 (J-31)	NASA-ARC	6	3,000	15,322	25,000	225	2,200	$1,750	http://www.skyresearch.com/
DHC-6 Twin Otter	NASA-GSFC-WFF	7	5,000	12,000	25,000	160	500	$1,500	http://www.twinotter.com
Predator-B (Ikhana)	NASA-DFRC	30	3,000	10,000	52,000	171	3,500		
Altair	NASA-DFRC	24	750	7,000	52,000	171	3,400		
Aerosonde	NASA-WFF	30	6	28	20,000	60	1875		http://www.aerosonde.com/
Learjet 25	NASA-GRC	3	7,600	15,000	42,000	452	1,436	$2,500	http://www.nasa.gov/centers/glenn/testfacilities/learjet.hgml

* The data shown above generally represent demonstrated mission capacilities and may not represent aircraft limits. In some cases, the performance parameters cannot be achieved concurrently.

Appendix B:
Platform Contacts

Facility	State	Contact Name	Contact Phone
NASA Platforms:			
DC-8	ND	Anthony Guillory	757-824-2161
ER-2	CA	Jacques Vachon	661-276-5318
G-III	CA	Walter Klein	661-276-3243
Learjet 23	OH	Bill Rieke	216-433-2036
Learjet 25	OH	Bill Rieke	216-433-2036
P-3B	VA	Anthony Guillory	757-824-2161
Twin Otter	OH	Bill Rieke	216-433-2036
S-3	OH	Bill Rieke	216-433-2036
WB-57F	TX	Shelly Baccus	281-244-9807
NASA UAV:			
Aerosonde	VA	Anthony Guillory	757-824-2161
Altair	CA	Frank Cutler	661-276-3998
Global Hawk	CA	Frank Cutler	661-276-3998
Predator-B	CA	Brent Cobleigh	661-276-2249
NASA Contracted Aircraft:			
Caravan	OR	Jeff Myers	650-604-3598
Jetstream J-31	OR	Jeff Myers	650-604-3598
King Air	NV	Jeff Myers	650-604-3598
NRL P-3	MD	Anthony Guillory	757-824-2161
Proteus	CA	Bob Curry	661-276-3715
Twin Otter	CO	Anthony Guillory	757-824-2161

Appendix C:
Acronyms

A

Advanced Microwave Scanning Radiometer	AMSR
Aerosol Direct Radiative Impact Experiment	ADRIEX
Airborne Research Test System	ARTS
Airborne Science and Technology Laboratory	ASTL
Airborne Synthetic Aperture RADAR	AirSAR
Airborne Terrain Mapper	ATM
Airborne Topographic Mapper	ATM
Airborne Visible and Infrared Imaging Spectrometer	AVIRIS
Ames Airborne Tracking Sunphotometer	AATS
Analytical Spectral Devices	ASD
Atlantic THORPEX Regional Campaign	ATReC
Atmospheric Radiation Measurement	ARM
Aura Validation Experiment	AVE
Autonomous Modular Sensor	AMS

C

Centre National d'Études Spatiales	CNES
Cloud Physics Lidar	CPL
Conical Scanning Millimeter Infrared Radiometer	COSMIR
Convection and Moisture Experiment	CAMEX
Critical Design Review	CDR

D

Data Collection and Processing System	DCAPS
Defense Meteorological Satellite Program	DMSP
Department of Defense	DOD
Department of Energy	DOE
Digital Camera Systems	DCS
Dryden Flight Research Center	DFRC

E

Earth Observing System	EOS
Earth Science Capability Demonstration	ESCD
European AQUA Thermodynamic Experiment	EAquaTE

F

Far Infra Red Sensor for Cirrus	FIRSC
Fast Response Ozone	Fast O3
Federal Aviation Administration	FAA

G

Global Positioning System	GPS
Geoscience Laser Altimeter System	GLAS

H

High-rate Wireless Airborne Network	HiWAND

I

Ice, Cloud and Land Elevation Satellite	ICESat
Inertial Navigation Unit	INU
Integrated Network Enhanced Telemetry	INET
Integrated Vehicle Systems Management	IVSM
Intelligent Mission Management	IMM
Intercontinental Chemical Transport Experiment	INTEX
Intercontinental Transport of Ozone and Precursors	ITOP
International Consortium for Atmospheric Research on Transport and Transformation	ICARTT

J

Jet Propulsion Laboratory	JPL
Johnson Space Center	JSC

L

Laser Vegetation Imaging Systems	LVIS
Long Term Ecological Reserve	LTER

M

Mars Global Surveyor	MGS
Mars Orbiter Laser Altimeter	MOLA
Mars Reconnaissance Orbiter	MRO
Megabits per second	Mbps
Memorandum of Understanding	MOU
Micro-Measurement of Air Pollution from Satellites	Micro-MAPS
Moderate Resolution Imaging Spectrometer	MODIS
Modis Airborne Simulator	MAS
Modis/Aster/Airborne Simulator	MASTER

N

National Academy of Science	NAS
National Aeronautics and Space Administration	NASA
National Airspace	NAS
National Oceanic and Atmospheric Administration	NOAA
National Polar-orbiting Operations Environmental Satellite System	NPOESS
National Suborbital Education and Research Center	NSERC
Naval Research Laboratories	NRL

Normalized Difference Infrared Index	NDII
North American Carbon Program	NACP
North American Monsoon Experiment	NAME
NPOESS Aircraft Sounder Interferometer	NAST-I
NPOESS Aircraft Sounder Microwave	NAST-M
NPOESS Aircraft Sounder Testbed	NAST

O

Over the Horizon	OTH

P

Polarimetric Scanning Radiometer	PSR
Polarimetric Scatterometer	POLSCAT
Preliminary Design Review	PDR

R

Radio Detection and Ranging	RADAR
Repeat Pass Interferometry	RPI
Research Scanning Polarimeter	RSP

S

Scanning High-resolution Interferometer Sounder	S-HIS
Second Costa Rican Airborne Research and Technology Application	CARTA-II
Shuttle RADAR Topographic Mission	SRTM
Soil Moisture Experiment	SMEX
Solar Spectral Flux Radiometer	SSFR
Spacecraft Communications Protocol Standards	SCPS
Special Sensor Microwave Imager/Sounder	SSMIS

T

The Observing-system Research and Predictability Experiment	THORPEX
Tropical Cloud Systems and Processes	TCSP
Two Dimensional Synthetic Aperture RADAR	2DSTAR

U

Uninhabited Aerial Systems	UAS
United States Geological Survey	USGS
University of North Dakota	UND
Unmanned Air Vehicle Synthetic Aperture RADAR	UAVSAR
Vegetation Water Content	VWC

W

WB-57 Ascent Video Experiment	WAVE