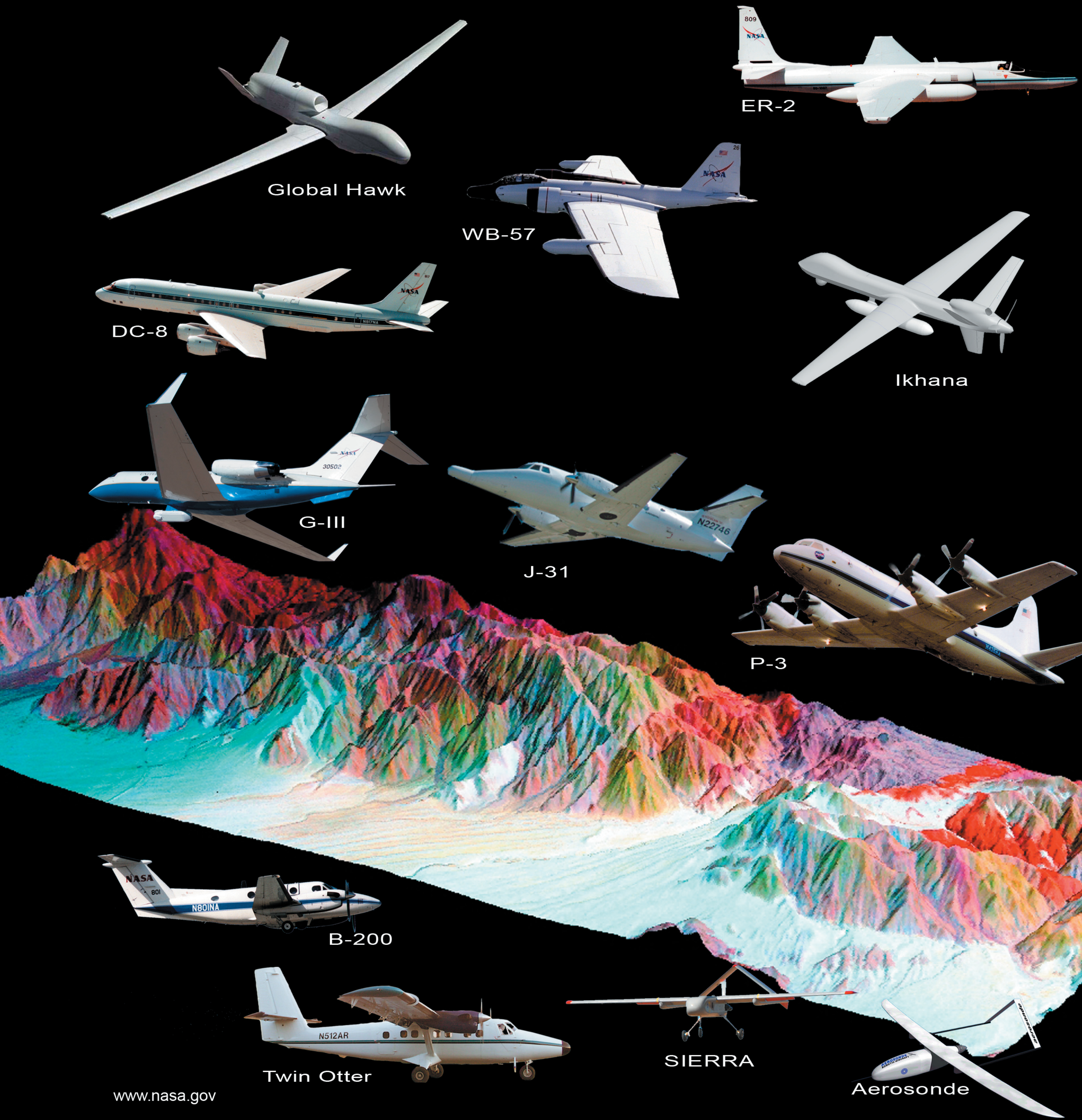
National Aeronautics and Space Administration

Airborne Science Program
2007 Annual Report



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NASA Science Mission Directorate
Earth Science Division

Airborne Science Program Annual Report 2007

MARCH 2008

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EXECUTIVE SUMMARY

The NASA Airborne Science Program (ASP) experienced a very productive year with significant capability improvements being developed and demonstrated, as well as substantial science missions accomplished. ASP supports all phases of the space mission life cycle, by providing platforms for instrument development, enabling calibration measurements during on-orbit checkout, and providing high resolution, complementary measurement opportunities for research & analysis programs. Airborne science missions are also important for educating and training Earth scientists and engineers, by providing flight project experience that is a fraction of the life cycle of space missions (5+ years).

After finishing out the carryover UAS fire and hurricane missions, the year started out with the G-III completing its physical, electrical and autopilot modifications for the UAVSAR and flying test missions to demonstrate the feasibility of precision trajectory control by flying inside a 10-meter tube. These successful flight tests validated the capability to fly the flight characteristics required for UAVSAR data collections.

The Program, working with the NASA SMD Earth science focus area leads, selected and awarded five International Polar Year UAS-focused missions. The missions, which are expected to be completed in the next 3 years, include a sea ice roughness mission using a small UAS, two remote atmospheric sampling sensor development efforts, and two missions to develop and demonstrate UAVSAR glaciology measurement techniques.

The program also continued support for LIDAR surveys of Greenland's fast moving glaciers, continuing a 15-year record of airborne glacier measurements, and demonstrating the capabilities of new instruments graduating from the Earth Science Technology Office's Instrument Incubator Program (IIP).

The ASP also supported two major traditional science campaigns. The first was the Department of Energy-led CLASIC mission over the Atmospheric Radiation Measurement Program's Southern Great Plains site in Oklahoma. This campaign was notable because NASA provided five of the nine aircraft, a significant demonstration of capability by a civil agency. The aircraft included the Program's ER-2 and P-3B, a B-200 from LaRC and two aircraft from the catalog: a J-31 and Twin Otter. These aircraft joined up with assets provided by DOE and others. NASA's other primary campaign was TC-4 in Costa Rica. In Costa Rica, the ASP demonstrated for the first time coordinated fight enabled by REVEAL, real-time over the horizon flight tracking, with satellite overlays and real time retasking technology for all three aircraft while airborne, which was also developed by the program increasing the data collection efficiency.

The flying season closed out with two UAS missions that accomplished truly noteworthy achievements. In its first science mission, the newly-acquired Ikhana fulfilled the long-held expectations of NASA and the U.S. Forest Service for an unmanned system to provide near-real-time data products over extended time frames and range. The Ikhana flew the 2007 Western States Fire Mission, for a total of 56 hours, covering 6 states, and providing near real time usable data from the program's Autonomous Modular Sensor (AMS). The AMS fire sensor images, distributed over the Internet was enabled by the onboard broadband Satellite Communications system and NASA space-science-derived Collaborative Decision Environment technology. This mission was briefed at the White House during real time support producing actionable data to the fire incident commanders. On the East coast, the Aerosonde flew a 17.7-hour mission into Hurricane Noel, spending 7.5 hours collecting boundary layer data from as low as 300 feet above the ocean surface (see Figure 1). This joint mission with NOAA was the first time this kind of extensive data set was acquired from the hurricane edge to the eye at low level.

Fig. 1: Animated illustration of Aerosonde UAS flying into Hurricane Noel.

In between the missions quite a few other significant activities and events took place. In 2007 the Program changed leadership from Cheryl Yuhas to Andrew Roberts, published its science community-derived requirements document, modified the WB-57 with new landing gear and anti-skid brakes, acquired two Global Hawk aircraft in addition to standing up the Ikhana aircraft, and carrying out the first flights of the Sierra UAS jointly with the Naval Research Laboratory. Other programmatic events included modifying the cooperative agreement with the University of North Dakota that returned DC-8 operations and maintenance to NASA, completed the process to establish the Dryden Science Aircraft Operations Facility in Palmdale, California and released a Request for Proposals to further populate the aircraft catalog.
The motivation and dedication of the individuals supporting ASP throughout the agency is what made this program so successful. We had many challenges to keep all these activities producing the high quality data this program is known for and it was many of our unsung hero’s that made the difference.

All in all, the program had a very productive year, meanwhile expanding its capabilities to support future science missions.

INTRODUCTION

During 2007, the people involved in the NASA Airborne Science Program (ASP) showed an uncommon and rarely-found dedication within the government. The challenges the program encountered were huge, but the quick responses and untold hours everyone at every level in this program gave, caused this to be one of our most successful years. This team is spread across many of the NASA field centers and operates in a global environment. Anyone can make a program look good when everything goes right, but it is how personnel perform during difficulties that really demonstrates a team's strength by coming together and then achieving success.

The Airborne Science program continues to operate by its four principal goals:

- Support science missions that further the goal's of NASA's Science Mission Directorate.
- Maintain and evolve a suite of platforms selected according to the observational needs and airborne measurement requirements of NASA programs.
- Infuse new airborne technologies based on advances and developments in aeronautics, information technologies, and sensor systems.
- Develop and upgrade science support systems that enable or maximize the success of the science mission data gathering.

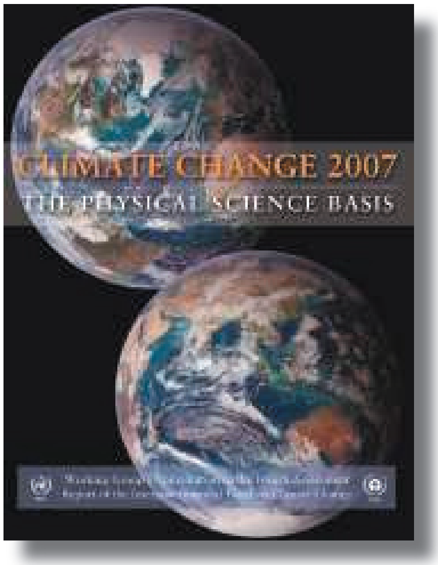
The NASA Airborne Science Program is the world's premier aircraft program supporting Earth science investigations and technology development. During 2007, we flew a number of very difficult and highly successful multi-platform science missions for NASA and other research agencies. In addition, our available capacity and our successful dedicated people have been noted and increasingly utilized throughout other government agencies in support of several highly significant programs of national interest.

For the first time, the ASP published an internal requirements analysis that showed directly traceability of the core aircraft to the science measurements required by national science objectives, demonstrating the need for new capabilities. The analyses in this report are important inputs in determining funding priorities within the program, defining core platforms and catalog composition.

We added new facilities for airborne science assets at Palmdale to include several of the ASP assets as well as SOFIA. We stabilized the DC-8 program maintenance and operations at Dryden with the University of North Dakota continuing the Science and Mission Operations activity. The satellite communication and monitoring of aircraft and data in real time over the Internet became a standard operating approach, allowing maximum mission effectiveness through active airborne asset redirection. The ASP engaged in a discussion with LaRC and GRC to make their airborne assets part of the ASP aircraft catalog. We transferred two Global Hawk UAS aircraft from the military and established a blanket purchase agreement (BPA) with several commercial aircraft vendors.

The Program also initiated an effort to quantify the impact of airborne science on scientific literature through the National Suborbital Education and Research Center (NSERC). A preliminary search using aircraft, sensors, and missions as keywords found 1115 referred journal articles with 15,045 citations from 1978 to 1998.

The increasing importance of the global climate change issue, the effect of more rapidly changing climate parameters, and the requirement for in situ validation, underscores the need for continued airborne measurements. Dramatic changes in arctic sea ice, wildfires, and drought received considerable attention by the public and policy makers. The International Panel on Climate Change (IPCC) received a Nobel Prize based on studies and predictions of climate change, highlighting the importance of this issue for global security (see Figures 2 and 3). Our program couples continued operation of airborne science platforms



CLIMATE CHANGE 2007
THE PHYSICAL SCIENCE BASIS

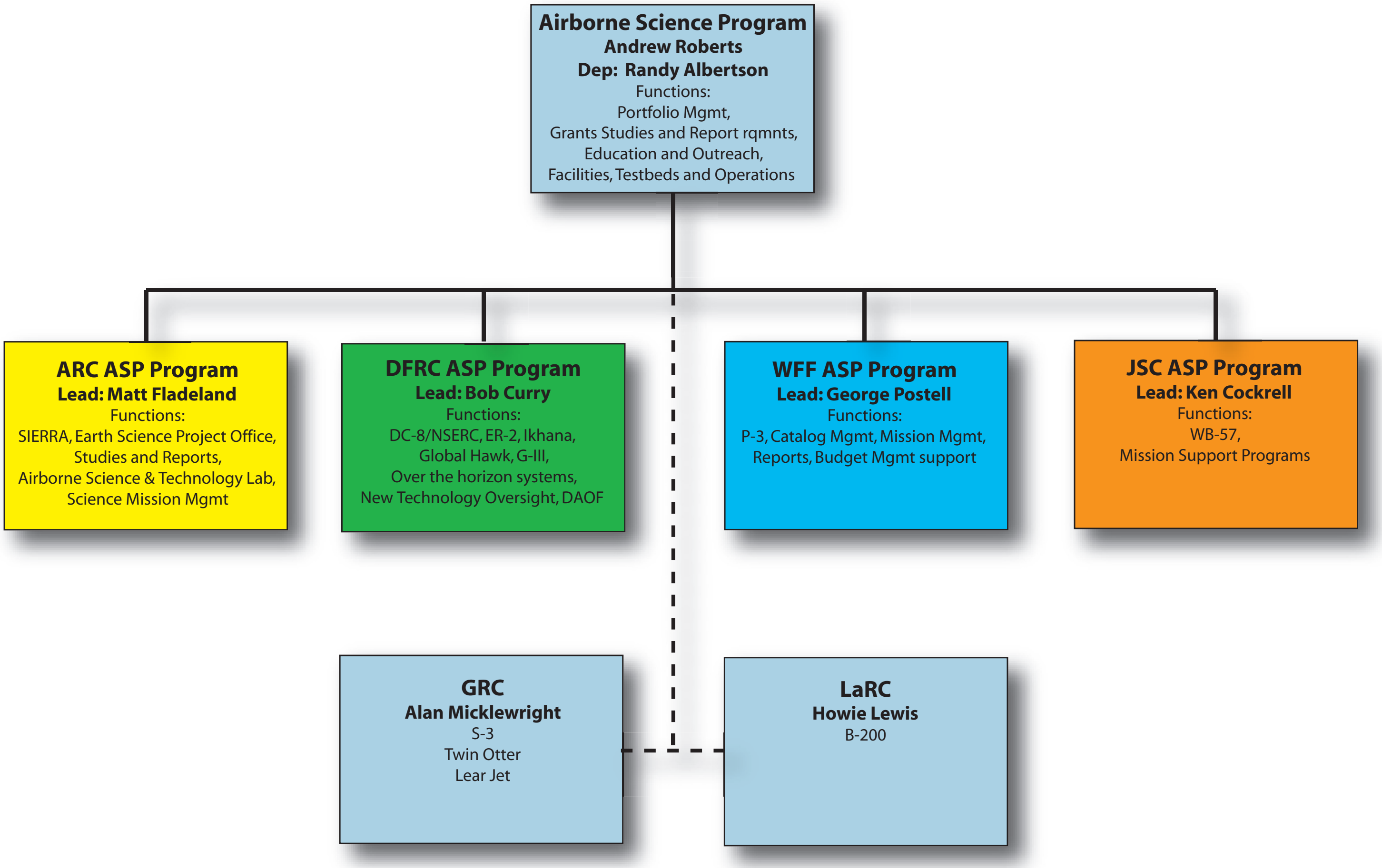
Figs. 2 and 3: (Left) Cover of IPCC report, "Climate Change 2007: The Physical Science Basis; (above) IPCC delegation with Nobel Peace Prize Diploma and Gold Medal at the Oslo Town Hall.

with the evolution of new technologies, and the collection and evaluation of Earth science requirements to forecast future use of program assets. The importance of the airborne program to the agency's mission was also recently endorsed by the Earth Science Subcommittee of the NASA Advisory Committee (NAC) and the Academies Decadal Study on Earth Science.

The NASA Airborne Science Program is well positioned to support the data-gathering needs of the science community to produce accurate guidance on environmental and climate change policy. NASA plays an important role in understanding the Earth System through the collection and analysis of data on ozone, carbon dioxide, fires, dust and aerosols, point source pollution, precipitation and storms, hurricanes, atmospheric trace gases, polar ice, and land changes. While much of this data come from satellites, the data obtained by airborne systems play an essential role in gathering data in a timely manner at critical spatial and temporal resolution for understanding the geophysical processes and interpreting the satellite information. In addition, by operating the ASP program in concert with the science community, the ASP strongly supports the next generation of Earth Scientists, PI's and instrument engineers.

In this ASP annual report for the 2007 fiscal year (October 2006 - September 2007), you will find a summary of the significant accomplishments that were achieved in the Airborne Science Program during the year, short summaries of science missions that were supported, descriptions of currently available platform and sensor assets, new technology, and a discussion of where the program is headed over the next several years. The report details program activities in field campaign mission support, technology development, requirements and aircraft catalog management, sensors, airborne science flight requests, and external partnerships.

PROGRAM EXECUTION



Airborne Science Program
Andrew Roberts
Dep: Randy Albertson
Functions:
Portfolio Mgmt,
Grants Studies and Report rqmnts,
Education and Outreach,
Facilities, Testbeds and Operations

ARC ASP Program
Lead: Matt Fladeland
Functions:
SIERRA, Earth Science Project Office,
Studies and Reports,
Airborne Science & Technology Lab,
Science Mission Mgmt

DFRC ASP Program
Lead: Bob Curry
Functions:
DC-8/NSERC, ER-2, Ikhana,
Global Hawk, G-III,
Over the horizon systems,
New Technology Oversight, DAOF

WFF ASP Program
Lead: George Postell
Functions:
P-3, Catalog Mgmt, Mission Mgmt,
Reports, Budget Mgmt support

JSC ASP Program
Lead: Ken Cockrell
Functions:
WB-57,
Mission Support Programs

GRC
Alan Micklewright
S-3
Twin Otter
Lear Jet

LaRC
Howie Lewis
B-200

Airborne Science Program

The Airborne Science Program (ASP) consists of the following four program elements, described below:

1) Science requirements and management,
2) Platform catalog (core, agency, interagency, commercial)
3) New technologies, and
4) Science instrumentation and support systems.

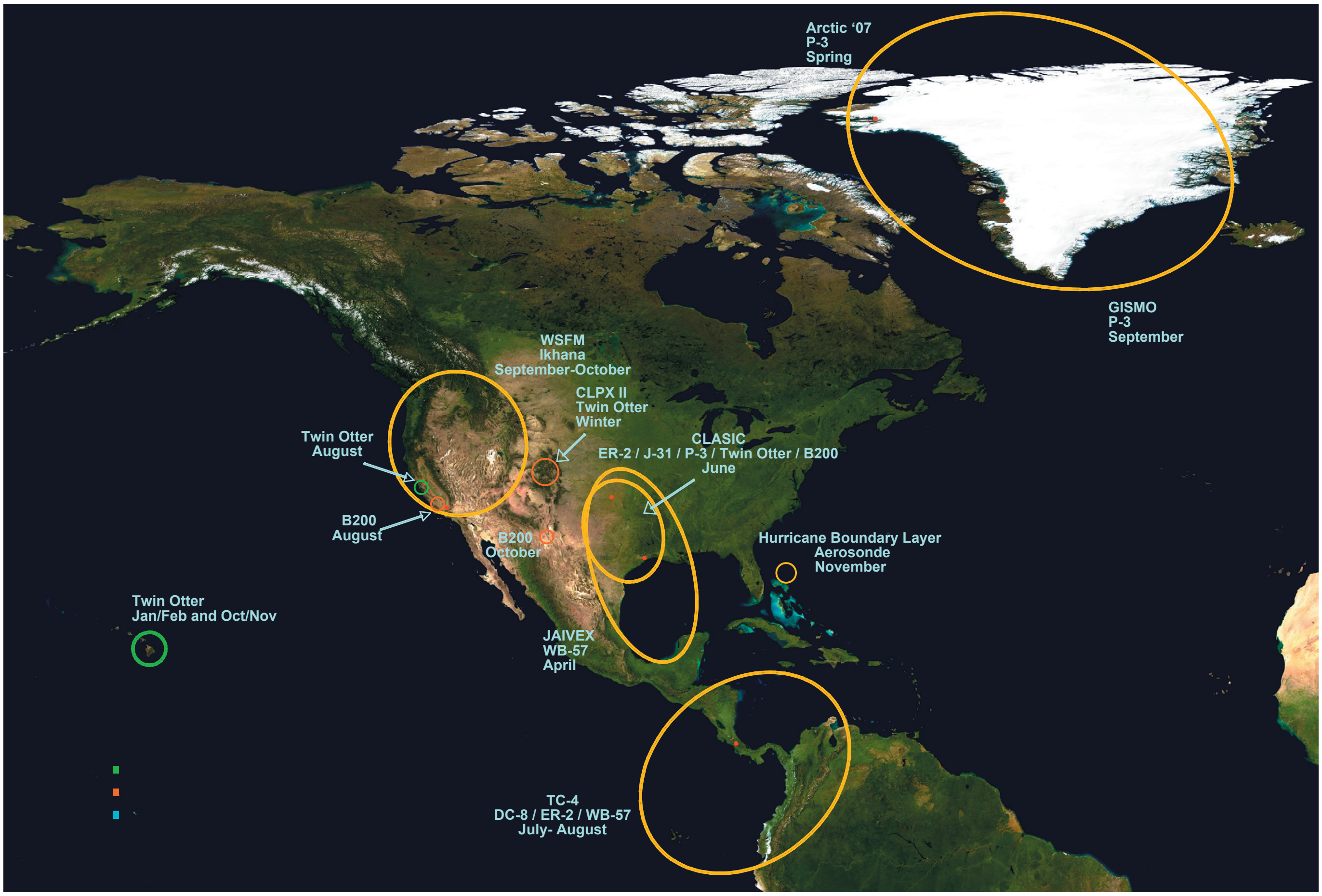
NASA Headquarters is responsible for determining program direction and content through the strategic planning and budget formulation process. The program office is the interface to the Science Missions Directorate ensuring that program activities and investments support the broader agency when possible. Implementation of the major program elements takes place at the various research center.

Ames Research Center is the lead for airborne science mission management. This includes field campaign management and logistics through the Earth Science Project Office, and sensor support and development of interface standards through the Airborne Science and Technology Laboratory (formerly the Airborne Sensor Facility). Ames manages the airborne 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 managed 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.

SCIENCE MISSIONS & ACCOMPLISHMENTS



2007 Airborne Campaigns

Arctic 2007

The Arctic 2007 mission was conducted from May 1-12, 2007 using the NASA P-3 aircraft flying the Airborne Topographic Mapper (ATM) over the Greenland polar region (see Figure 4). ATM surveys have been conducted almost annually since 1993 to provide baseline data on ice mass balance, rates of change, and more recently to assist in validating ICESat data products. The mission goals for Arctic 2007 were to complete topographic mapping of the selected ice-sheets using LIDAR and to test a newly designed and built radar ice-sounder. Site selection for lidar surveys was prioritized on outlet glaciers known to have recently thinned rapidly in southern Greenland, and those starting to thin in northern Greenland.

Instruments flown during Arctic 2007:

- Airborne Topographic Mapper 3, 4 (ATM3 & 4) - William Krabill (PI); NASA Wallops Flight Facility
- Pathfinder Advanced Radar Ice Sounder (PARIS) – Dr. Keith Raney (PI); Johns Hopkins University Applied Physics Laboratory

The prototype Johns Hopkins Applied Physics Laboratory ice-sounder was developed as part of the NASA Earth Science Technology Office (ESTO) Instrument Incubator Program (IIP). The PARIS instrument was successful in data collection at altitudes varying from 1,500 ft AGL to FL 250 (see Figure 5). The chief

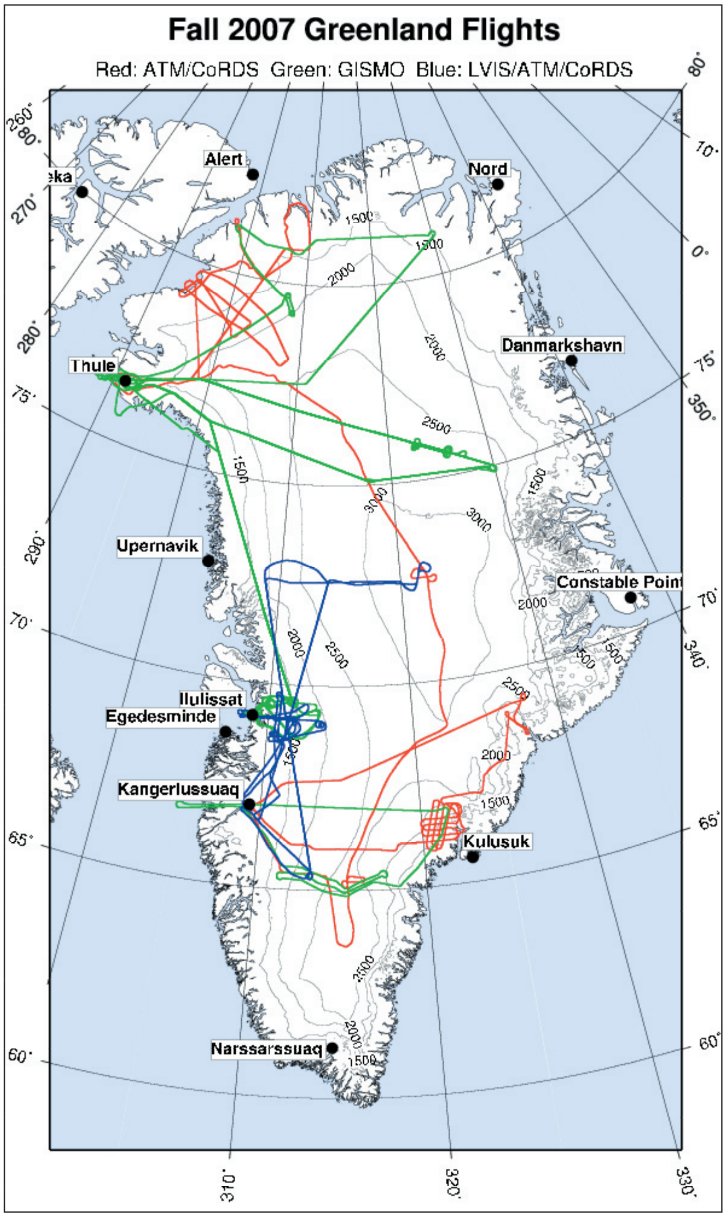


Figure 4: ATM flights accomplished during the Arctic 2007 mission.

experimental objective (obtaining a bedrock reflection through 3 km of ice while flying at 7.5 km ASL) was easily met.

These missions were sponsored by the NASA Earth Science Technology Office Instrument Incubator Program and the NASA Cryospheric Sciences Program. The surveys are conducted with special thanks to the Greenlandic Department of Environment and Nature. The mission was based from Thule Air Force Base and Kangerlussuaq. All mission objectives were achieved for an extremely successful program. Seven mission flights were flown in Greenland. The total mission flight time was 69 hours.

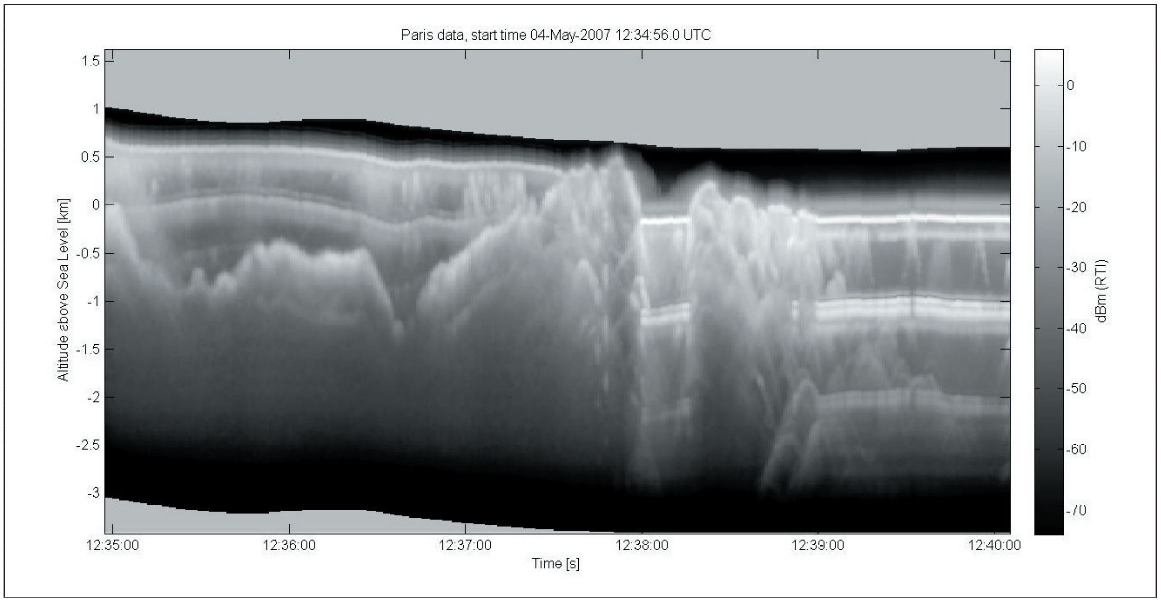


Figure 5: Sample data from the PARIS instrument.

Flight tests of the Carbon Airborne Observatory (CAO)

A Twin Otter was contracted by WFF to fly a new sensor suite consisting of a hyperspectral imager and a waveform LIDAR developed by Greg Asner of the Carnegie Institute in Palo Alto in support of the NASA Terrestrial Ecology Program. While the system was developed through funding by Keck and NSF, the concept was borne from flights of AVIRIS and LVIS by ASP that demonstrated the utility of vegetation reflectance coupled with structural information derived from LIDAR.

These flights mapped the location and impacts of five highly invasive plant species across 221,875 ha of Hawaiian ecosystems, identifying four distinct ways that these species transform the three-dimensional (3-D) structure of native rainforests. Biological invasions contribute to global environmental change, but the dynamics and consequences of most invasions are difficult to assess at regional scales.

The preliminary data from this system showed that three invasive tree species decrease the forest volume occupied by native mid-canopy and understory plants, while one understory invader excludes native species at the ground level throughout the forest. A fifth invasive nitrogen-fixing tree facilitates the spread of a mid-canopy alien tree, which subsequently inhibits regeneration of native plants at all canopy levels. In conclusion that this diverse array of alien plant species, each representing a different growth form or functional type, is changing the fundamental 3-D structure of native Hawaii rainforests.

Cloud and Land Surface Interaction Campaign (CLASIC)

A number of NASA aircraft and instruments played an integral part of the Cloud and Land Surface Interaction Campaign (CLASIC) experiment in June and July, 2007. CLASIC was a multiplatform mission sponsored in-part by the NASA Water and Energy Cycle Program under Jared Entin.

The P-3 was based in Oklahoma City from June 11 to July 4, 2007. The Polarimetric Scanning Radiometer (PSR) instrument, (Principal Investigator Dr. Albin Gasiewski., University of Colorado), uses extremely sensitive microwave receivers to produce high resolution images of the Earth's oceans, land, ice, clouds, snow pack, and precipitation. For CLASIC, PSR was used to obtain soil moisture data and develop soil moisture maps from C- and X-band brightness maps over the CLASIC grid during at least one NASA Aqua overpass. The PSR instrument was flown over 10 predetermined flight lines in Oklahoma during 8 flights totalling 68 flight hours. During the CLASIC campaign, Oklahoma and Northern Texas experienced exceptional levels of rainfall. The NASA P-3B flew two sorties over the Red River flood area of Texas to provide the first-ever maps of soil moisture and flooded areas to help support forecasting and relief efforts.

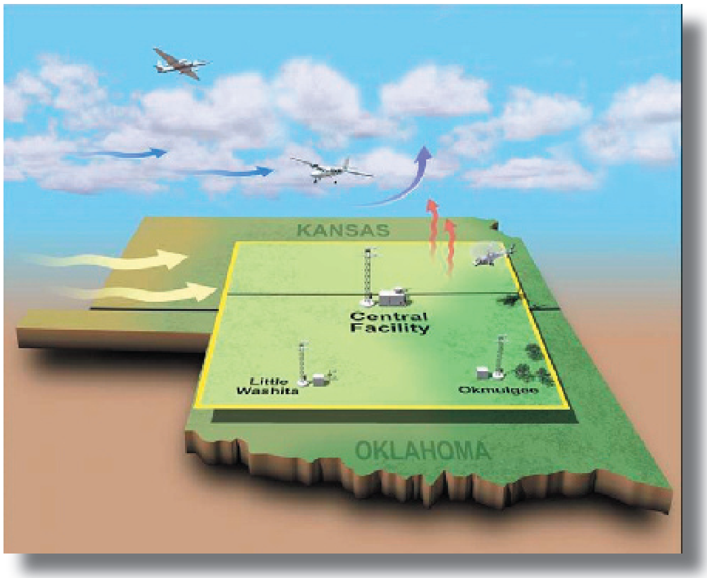


Fig. 6: Flights over super sites in US Dept. of Energy Southern Great Plains.

The Sky Research Jetstream-31 NASA catalog aircraft (Figure 7) carried NASA's Cloud Absorption Radiometer (CAR) used by CLASIC scientists to acquire multiangular and multispectral observations of scattered light by clouds and aerosols, and provided bidirectional reflectance of various surfaces, and imagery of cloud and Earth surface features in support of EOS satellite validation. These measurements will help improve model parameterization of land surface reflectance and address up-scaling needs for comparison with satellite measurements, in addition to looking at the influence of clouds on surface directional reflectance. A total of 10 science flights were flown, which were designed to cover two super sites located in the US Department of Energy Southern Great Plains (Central Facility and Little Washita) in Oklahoma (see figure 6).

A Twin Otter was contracted to assist with another goal of CLASIC, which was to evaluate a new aircraft-based passive and active L band microwave instrument (PALS-II), which could be the prototype of the next generation satellite instrument (i.e.. SMAP). The JPL/NASA PALS-II instrument, a passive and active L band radiometer/radar includes a new lightweight, flat-panel, dual polarization, dual frequency planar array antenna. The goals for PALS-II, included demonstration of the new planar antenna, passive/active algorithm development, and polarimetric analyses. In support of the CLASIC-PALS mission, the PALS-II instrument flew a total of 97 flight hours of which 85 hours were science data flight hours over the Oklahoma project area.

CLASIC-PALS is supported by Dr. Jared Entin, Program Manager for NASA's Terrestrial Hydrology Program. Dr. Tom Jackson was the principal investigator. Dr Simon Yueh was the instrument scientist, and Steven Dinardo was the instrument and mission manager.

For more information: www-esd.lbl.gov/ARMCarbon/clasic.html

Figure 7: The J-31 landing at Ponca City Municipal Airport, Oklahoma. The CAR instrument is housed in the nose cone and views the earth and sky through a 190° aperture.

Cold Land Processes Field Experiment II (CLPX II)

NASA’s Cold Land Processes Field Experiment-II (CLPX-II) mission took place in Colorado during the Winter of 2006-2007. The primary goal of the mission was to develop Ku radar based retrieval algorithms of Snow Water equivalent (SWE). CLPX-II utilized the JPL/NASA PolScat radar instrument, a Ku-band Polarimeteric Scatterometer on the NASA-contracted Twin Otter. The Twin Otter was chosen due to its proven cold climate operations and because it is a highly maneuverable, versatile aircraft that is very economical to operate. In support of the FY 2007 CLPX-II campaigns, the PolScat instrument flew a total of 51 flight hours, of which 41 hours were science data flight hours over the Steamboat Springs, Colorado project area.

Twin Otter International provided PolScat instrument installation engineering and safety under the supervision of Twin Otter’s FAA Designated Engineering Representative before the first engineering check flight. Wallops flight facility provided mission readiness with the Mission Readiness Review (MRR). JPL provided instrument safety with pre-ship review and crew safety by reviewing JPL’s employee certification/training. All JPL crewmembers had the following training: FAA medical certification for hypoxia training, water, and land survival. In addition, JPL provided each crewmember with Red Cross first aid, CPR and AED training.

CLPX-II is supported by Dr. Jared Entin, Program Manager for NASA’s Terrestrial Hydrology Program. Mission personnel were: Dr Don Cline, principle investigator, Dr Simon Yueh, Instrument scientist, and Steven Dinardo, Instrument and mission manager.

Fore more information: www.nohrsc.nws.gov/~cline/clpx.html
www.nsidc.org/data/clpx/

Cosmic Dust Collection

The Cosmic Dust Laboratory at the Johnson Space Center (JSC) supports the collection and curation of stratospheric particulate matter to help scientists study cometary and asteroidal grains that enter the Earth's atmosphere. As a result of the Stardust mission, 2007 saw the greatest demand for samples in the 25 year history of the program. Many tons of dust grains, including samples of asteroids and comets, fall from space onto the Earth's atmosphere each day. Once in the stratosphere this "cosmic dust" and spacecraft debris joins terrestrial particles such as volcanic ash, windborne desert dust and pollen grains. In 2007, the NASA ER-2 and WB-57F aircraft were outfitted with special sticky collectors for Mike Zolensky (JSC) to capture this dust as it fell through the stratosphere.

Examination of cosmic dust also reveals much about the population of interplanetary dust and orbital debris particles, critical information for engineers planning protection of Space Station against damage from high-velocity dust grains. The terrestrial dust and spacecraft debris particles are of considerable interest to atmospheric scientists and climatologists, since they influence some global atmospheric reactions. For the first time scientists are confident of the identity of the cometary grains collected in Earth's stratosphere. In addition, because of targeted flights during a shower of grains from Comet Grigg-Skjellerup, we have now identified possible samples from a second comet, which have a mineralogy and isotopic chemistry distinct from any other astromaterials (see Figure 8). If this result is borne out by future analyses, then these targeted Cosmic Dust Collection Program collections can rightly be termed a cheap sample return mission to a specific comet.

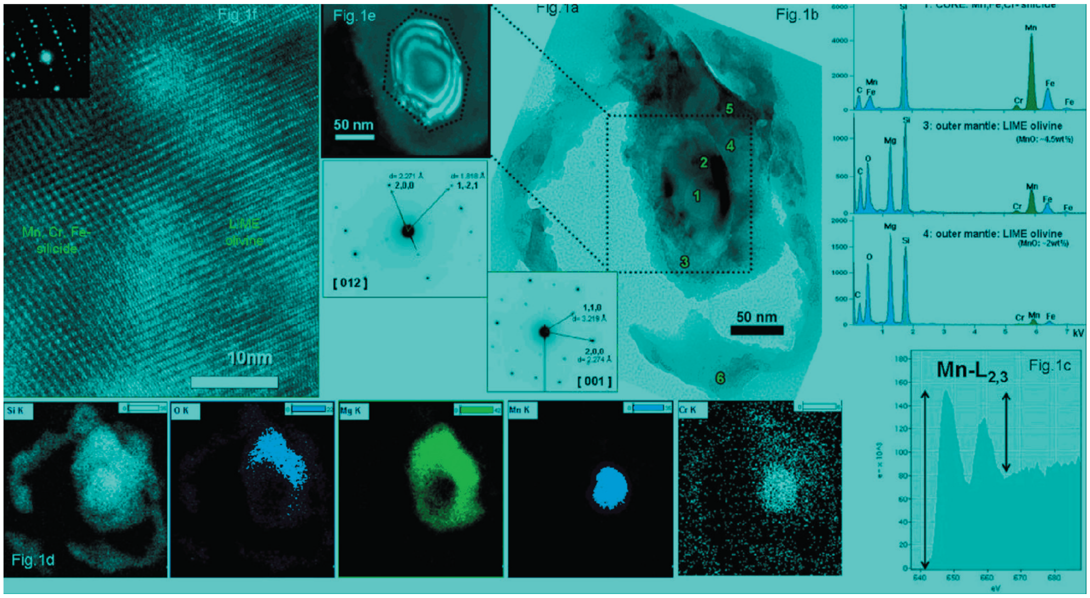


Figure 8: A bright field transmission electron microscope (TEM) micrograph of a MnSi-Ca rich olivine shell in a cosmic dust particle believed to be from Comet Grigg-Skjellerup.

Global Ice Sheet Mapping Orbiter (GISMO)

The GISMO 2007 mission was conducted from September 6-25, 2007 using the NASA P-3 aircraft flying multiple payloads over the Greenland polar region. Mission data were collected to measure both surface and subsurface topography of the ice-sheet for mass balance determination.

GISMO 2007 tested a newly developed NASA Instrument Incubator Program (IIP) sensor, developed by the University of Ohio Byrd Polar Research Center and the University of Kansas. The protoptype ice-sounder was developed as part of the NASA ESTO IIP. Remote sensors that were flown include:

- Global Ice Sheet Mapping Orbiter (GISMO) - Dr. Kenneth Jezek, Ohio State University; PI.
  - VHF and UHF mode Synthetic Aperture Radar using dual, wing-mounted di-pole set antennas transmitting either a 150 or 450 MHz, 2 Kw (max.) signal designed to produce a 3-D topographic image of the ice layers and glacial subsurface.
- Airborne Topographic Mappers 3, 4 (ATM3 & 4) - William Krabill, NASA Wallops Flight Facility
  - Scanning ranging laser instrument developed at GSFC/Wallops for the Greenland ice sheet project.
- Coherent Antarctic Radar Depth Sounder (CARDS) – Dr. Prasad Gogineni, Kansas University; PI
  - 150 MHz ice-sounder previously flown in Antarctica and Greenland primarily used for glacial bedrock profiling.
- Laser Vegetation Imaging Sensor (LVIS) – Bryan Blair, NASA Goddard Space Flight Center; PI
  - LVIS has been utilized as a medium-high altitude scanning altimeter to measure topography and surface vegetation features and was flown to test its use as a high-altitude, high resolution topographic altimeter.

The GISMO team's primary technical objectives were to acquire data at 150 and 450 MHz operating frequencies over a variety of glacial regimes. GISMO collected data with 6 receiving antennas and 2 transmitting antennas to produce interferometric SAR image pairs with variable baselines, to acquire tomographic data, and to acquire data for multi-aperture beam formation investigations. All of the experimental configurations where designed to test the effectiveness of different clutter rejection schemes to determine whether radars operating at high altitude or from space can reliably sound through the polar ice sheets and image the base. The experiments were also designed to characterize surface and volume clutter across different glacial regimes (such as the dry northern interior ice sheet, the seasonally melted central and south ice sheet, and crevassed zones) and to try and estimate total radar attenuation through the ice sheet by incorporating calibration measurements over the ocean. GISMO data tracks flown are shown in Figure 9. Figure 10 shows a final product of the 3-D image.

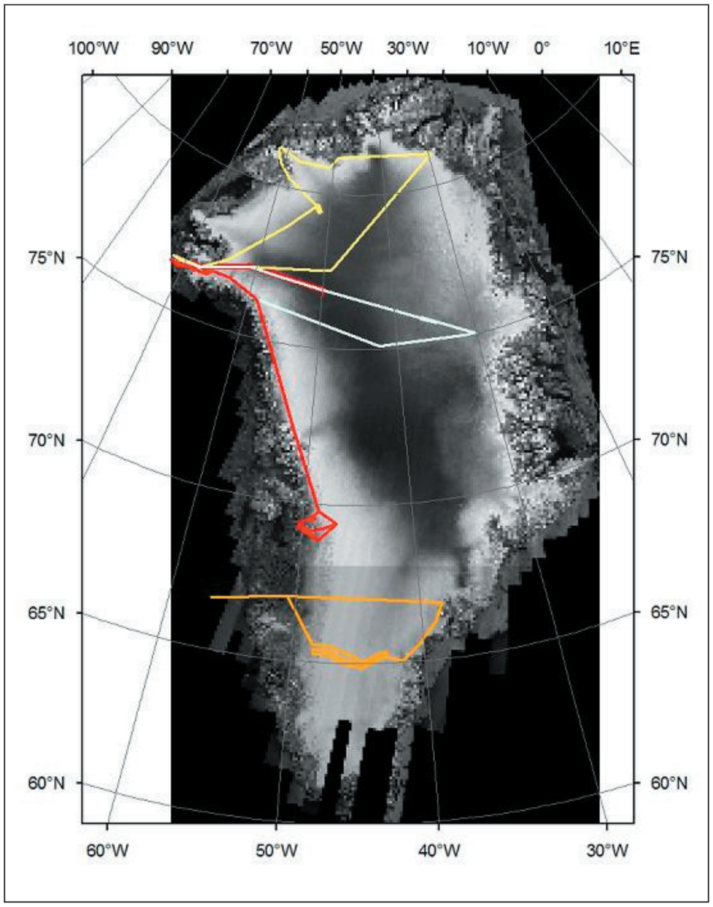


Figure 9: Flight tracks of GISMO data collections.

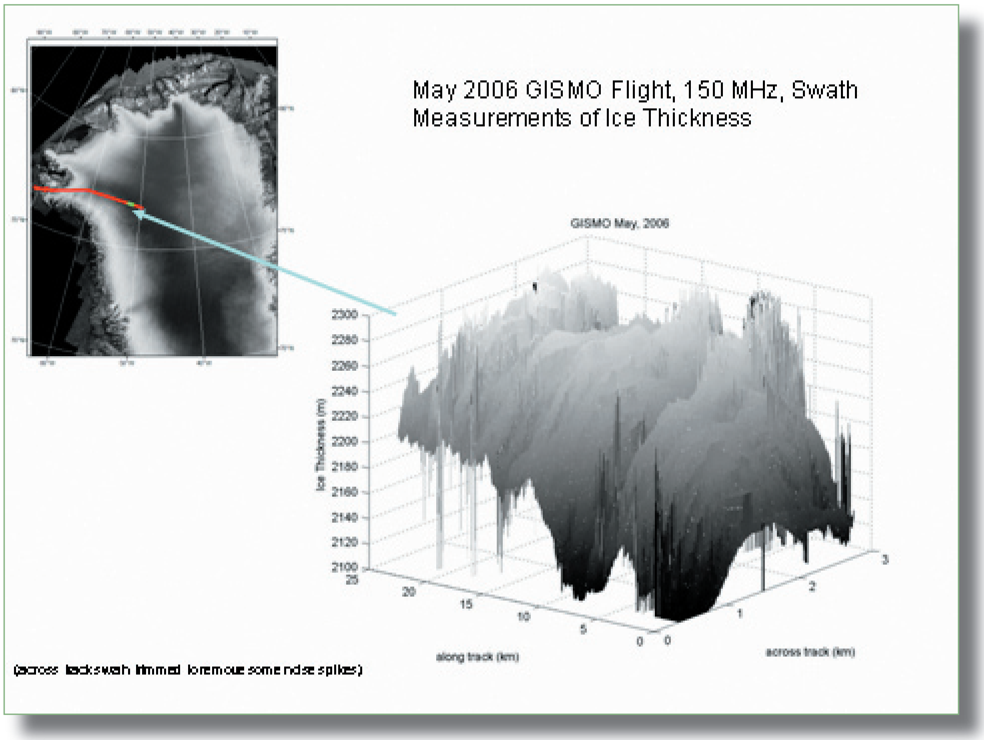


Figure 10: Preliminary data from the GISMO L-band radar for measuring ice thickness flown on the NASA P-3

Joint Airborne IASI Validation Experiment (JAIVEx)

The Joint Airborne IASI Validation Experiment (JAIVEx) was a US-European collaboration focusing on validation of radiance and geophysical products from MetOp-A Infrared Atmospheric Sounding Interferometer (IASI) and Aqua (AIRS/AMSU) Atmospheric Infrared Sounder (AIRS). The field phase of JAIVEx was conducted out of the JSC Ellington Field (EFD) in Houston, TX, between 14 April – 4 May, 2007. The NASA WB-57 and UK FAAM BAe146-301 aircraft, well-instrumented with remote and in-situ sensors, flew coordinated sorties over the DOE ARM CART site and Gulf of Mexico region during MetOp-A and A-train overpasses. The campaign was very successful with 10 coordinated flight days being implemented, and preliminary results show very impressive measurement validation inter-comparisons. Campaign data are proving to be very useful for IASI and AIRS product validation, and are serving to further refine methodologies for future advanced sounder validation activities (e.g., NPP & NPOESS CrIS). Participants on the US portion of the team included members from NASA LaRC, University of Wisconsin, Massachusetts Institute of Technology (MIT), and MIT-Lincoln Laboratory (LL). NASA LaRC was responsible for science leadership and field experiment coordination; WB-57 flight planning and platform/science interface issues; NAST-I implementation, flight operations, and data processing; and radiance and geophysical product inter-comparison studies.

One important goal of JAIVEx was to inter-compare MetOp-A operational measurement capability with that provided by the A-train of advanced NASA research satellites. Although the orbits of the MetOp and the A-Train are about four hours apart, some of the aircraft flight sorties permitted under-flight of both the MetOp and A-train satellites within a single aircraft flight. The aircraft sensors can be used as a relative calibration transfer reference for each of the satellite systems (e.g., the difference between MetOp-A and aircraft measurements can be compared to the difference between A-train and aircraft measurements) in order to account for space and time difference between the measurements from the two satellite systems. An example of this capability is shown in Figure 11, which compares spectral radiance measurements from NAST-I vs. IASI (MetOp-A) and NAST-I vs. AIRS (Aqua). Post-deployment analysis of JAIVEx data is continuing to demonstrate high quality spectral radiance and geophysical products being produced from IASI.

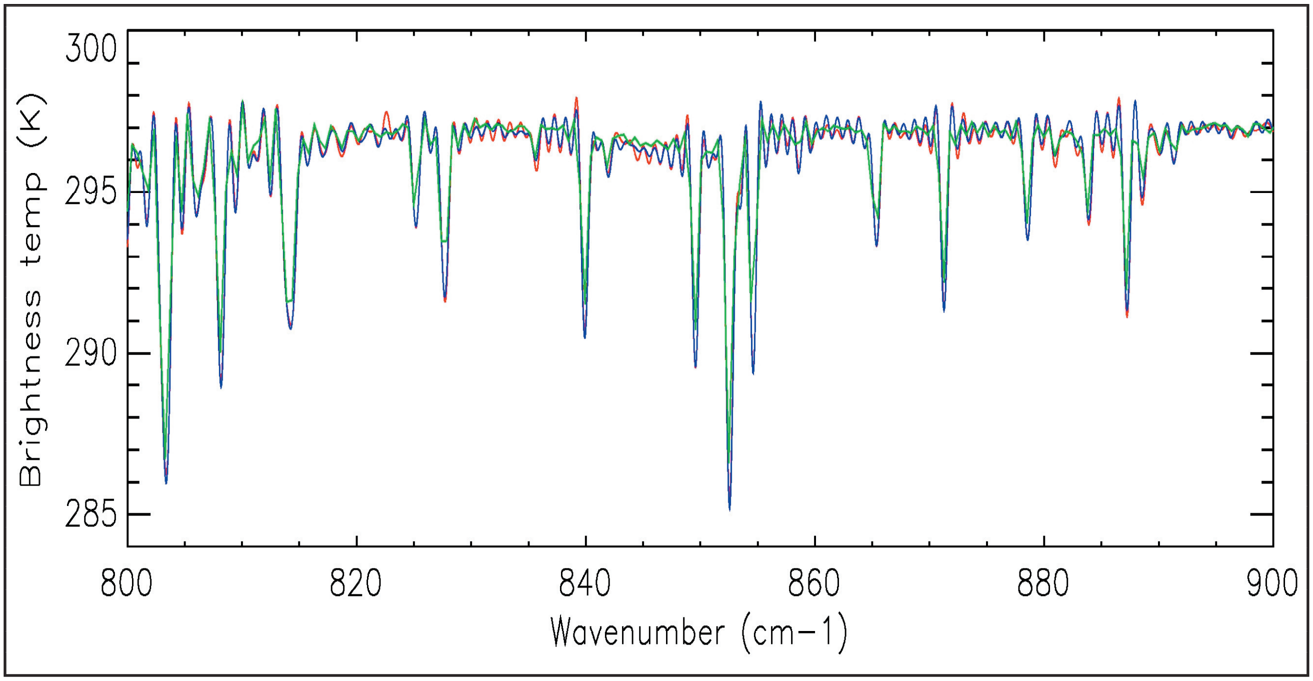


Fig 11: Comparison of spectral radiance measurements from NAST-I vs. IASI (MetOp-A) and NAST-I vs. AIRS (Aqua). The blue curve represents NAST-I reduced to the spectral resolutions of IASI and AIRS, respectively

Flight test of Raman Airborne Spectroscopic Lidar (RASL)

The new Raman Airborne Spectroscopic Lidar (RASL) developed by David Whiteman and team (GSFC) had it first flights from June 18 - August 4, 2007 aboard a NASA ASP contracted B-200 (Dynamic Aviation) to test the use of lidar simultaneous measurements of water vapor mixing ratio and aerosol backscatter/extinction/depolarization. These flights were coordinated with the Water Vapor Variability Satellite/Sondes 2007 (WAVES 2007) Aura validation campaign. The goals of WAVES-2007 were to provide quality data for validation of the Aura and Aqua sensors, to study regional water vapor and aerosol variability as they relate to satellite retrievals, to perform instrument intercomparison studies and to study mesoscale meteorological systems. RASL contributed to each of the goals by performing underflights of TES and CALIPSO, overflying different ground-based sensors and capturing a unique dataset during the occurrence of a low level jet event that influence regional air quality. This project was supported by the NASA ESTO Instrument Incubator Program. The B-200 flew 14 flights and approximately 36 flight hours

Flight test of Radar Synthetic Aperture Thinned Array (RADSTAR) A/P

The RadSTAR A/P mission was conducted on the P-3 from NASA WFF January 30 – February 21, 2007 to compare new and legacy instruments from the NASA WFF airfield using the NASA P-3. A total of six instruments were flown during RadSTAR A/P and are listed as follows with the associated institution and Principal Investigator:

- Radar Synthetic Aperture Thinned Array – Active (RadSTAR – A) - Dr. David Levine, Dr. Peter Hildebrand (NASA GSFC)
- Radar Synthetic Aperture Thinned Array – Passive (RadSTAR- P) - Dr. David Levine (NASA GSFC/ University of Massachusetts)
- Airborne Topographic Mapper IV (ATM-4) - William Krabill (NASA WFF)
- Polarization-Modulated Gas Filter Correlation Radiometer (PM-GFCR) - ? PI- (NASA LaRC)
- UAS MicroSpectrometer – James Yungel (NASA WFF)
- Turbulent Air Motion Measurement System (TAMMS) – John Barrick (NASA LaRC);

The RadSTAR-A instrument is an airborne L-Band radar developed at NASA GSFC that combines electronic beam steering and digital beam-forming to allow the implementation of different scanning techniques. This technology will enable a combined radar/radiometer system that jointly uses a single, dual frequency antenna with cross-track scanning capabilities and no moving parts. The goal is to enable single aperture measurements of important Earth science applications such as ocean salinity, soil moisture, sea ice, and surface water among others. ATM4 (see Arctic 2007 above) was flown during RadSTAR- A/P to test software upgrades prior to the Arctic 2007 mission flights. The NASA PM-GFCR was a prototype of an instrument for measuring boundary layer CO at 2.3 μm. The MicroSpectrometer is a small fiber optic spectrometer designed to be operated from small UAV to measure ocean upwelling radiance, ocean color parameters, and derived chlorophyll and dissolved organic matter concentrations

The mission was sponsored by the NASA HQ Hydrology Program under Jared Entin. Four successful data flights were completed from Wallops and all instruments performed as designed.

Tropical Composition, Cloud and Climate Coupling (TC-4)

The NASA Tropical Composition, Cloud and Climate Coupling (TC-4) mission was a major 2007 field campaign and was based in Costa Rica and Panama. TC-4 was a comprehensive study of the tropical atmosphere to identify and quantify the atmospheric processes there, particularly in the tropical tropopause transition layer. Understanding these processes is essential to the study of climate change and ozone depletion. This complex multi-aircraft mission made some of the first measurements of particle properties and water vapor in the subvisible cirrus clouds and obtained data that should help to clarify the amount of water in the upper atmosphere and the sizes of ice crystals in the tops of cirrus clouds.

TC-4 involved 3 NASA aircraft, 2 radars, a ground research trailer and balloons collecting atmospheric data. The three NASA aircraft (DC-8, WB-57 & ER-2) were flown from the Juan Santamaria International Airport in Costa Rica and carried over 60 highly specialized instruments that collected both in-situ and remote-sensing data (see Figure 12).

NASA's ER-2, equipped with remote sensing instruments similar to those on satellites, was used to fly above the clouds. NASA's WB-57 equipped with in situ instruments was used to penetrate the mid to

Figure 12: TC-4 aircraft on tarmac in San Jose, Costa Rica.

upper level clouds while the NASA's DC-8 equipped with remote sensing and in-situ instruments was used to provide chemistry and cloud measurements, including the tropical tropopause transition layer and stratosphere for satellite validation.

The DC-8 completed 11 science flights for a total of 105 flight hours, and flew 9 of those flights coordinated with the ER-2. The ER-2 completed 11 science flights for a total of 87 flight hours. The WB-57 completed 4 science flights for a total of 29 flight hours and 3 of those flights were coordinated flights between all 3 aircraft. There were also 292 balloons launched from Costa Rica, Panama and the Galapagos Islands in support of TC-4. Scenes from TC-4 are shown in Figures 13, 14, and 15.

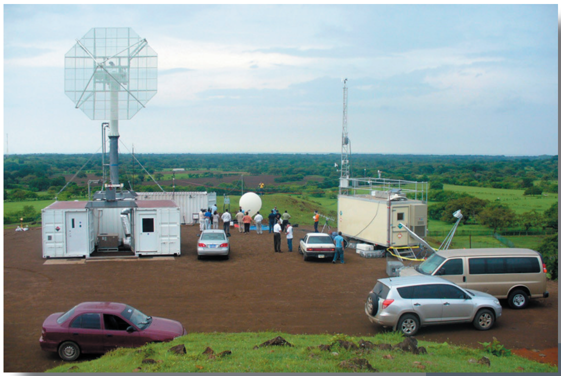


Fig. 13 (above, left) NASA's Polarization (NPOL) radar collected data and provided weather information for the research flights over the Panama Bight. Fig. 14 (above, right) Radiosondes collect temperature, relative humidity and wind data; AND ozonesondes collect water vapor, ozone and temperature data. Balloon launches were made from San Jose, Costa Rica as part of the Ticosonde Program and other sondes were launched from Las Tablas Panama and the Galapagos Islands. Fig. 15 (far right) University of Oklahoma's Shared Mobile Atmospheric Research and Training (SMART) radar provided local weather data in San Jose for aircraft support.

Over 300 scientists, engineers, and mission / support personnel were based in Costa Rica and Panama from mid-July through mid-August, 2007. This large international experiment united researchers from 8 NASA centers, over 14 U.S. and International universities, and more than 20 U.S. and international agencies. NASA aircraft and their teams are shown in Figures 16, 17, and 18. Support from the U.S. Air Force for airlifts and supplies was essential.

NASA Headquarters Earth Science Division Atmospheric Composition Focus Area sponsored this mission through its Research and Analysis Programs and Satellite Missions. Drs. Michael Kurylo and Hal Maring, NASA HQ, were the Program Scientists and Drs. David Starr, Goddard Space Flight Center (GSFC) and Brian Toon, University of Colorado, Boulder were the Mission Scientists.

More information on the TC-4 mission is available at http://www.espo.nasa.gov/tc4/

Aircraft and their teams: Fig. 16 (clockwise, upper left) DC-8; Fig. 17 (upper right) WB-57; and Fig. 18 (left) ER-2.

Western States Fire Mission (WSFM)

The Western States Fire Missions (WSFM) in 2007 demonstrated emerging technologies related to real time disaster event monitoring using NASA developed sensor systems, data telemetry systems, improved real-time data analysis technologies, and utility of the new Ikhana UAS platform (Figure 19). These flights were part of the Wildfire Research and Applications Partnership (WRAP) project. The project was a partnership between NASA Ames Research Center, the US Forest Service, and the

Fig. 19: Ikhana with AMS sensor in wing pod on its way to Southern California fires.

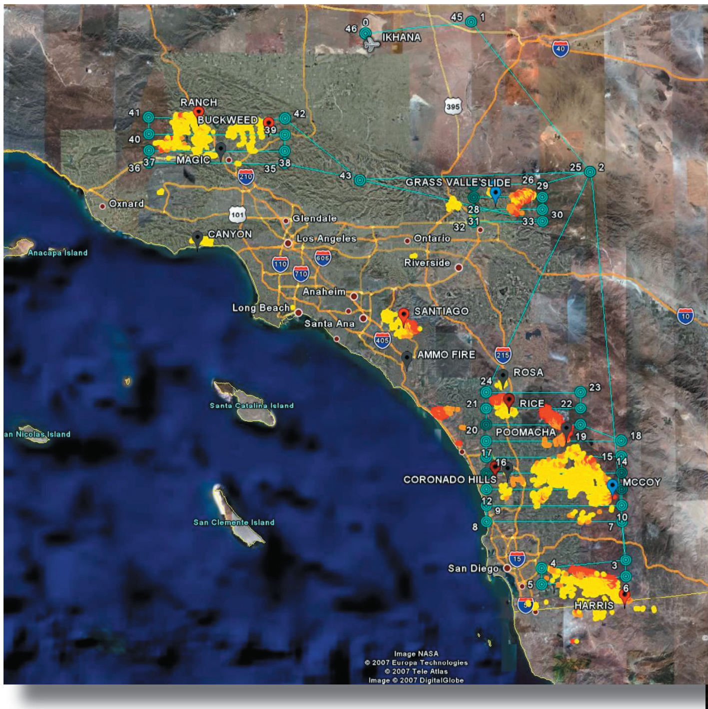


Fig. 20: Flight plan in the Collaborative Decision Environment (CDE).

Fig. 21: San Diego county emergency operations center (EOC) shown using CDE for planning operations.

National Interagency Fire Center (NIFC), designed to test and evaluate NASA-derived sensor data products and workflows in real world disaster monitoring exercises. This mission demonstration was funded by the Applied Science Program, Disaster Applications focus area, and the Airborne Science Program.

The derived flight mission objectives included: broad access to National Air Space (NAS) (to image priority fires), 24 hour endurance (to allow frequent revisits, over many fires), operations at FL430 (in NAS, out of traffic), vertical profiling (to get higher resolution imagery), and the ability to engage emerging fire targets (i.e., respond to priority events). The newly developed Autonomous Modular Sensor, configured with the appropriate wildfire detectors and interactive interfaces, was flown on the new NASA Ikhana UAS equipped with a broadband satellite communications system. A Collaborative Decision Environment (CDE) was developed as a data visualization and mission-planning tool. (A flight plan is seen in the CDE in Figure 20.)

The Ikhana team secured a Certificate of Authorization (COA) that allowed the payload to collect data from FL 230-250 to enable both long endurance, and high-resolution imagery. Image products, geo-registered on board were downloaded to Ames servers and made available to Incident Command Centers at each of the fires (Figure 21). On many occasions we supported the incident teams with onsite technical support, assuring full access to data. Integration in the NAS appeared seamless and drew few comments from other aircraft operating in the vicinity.

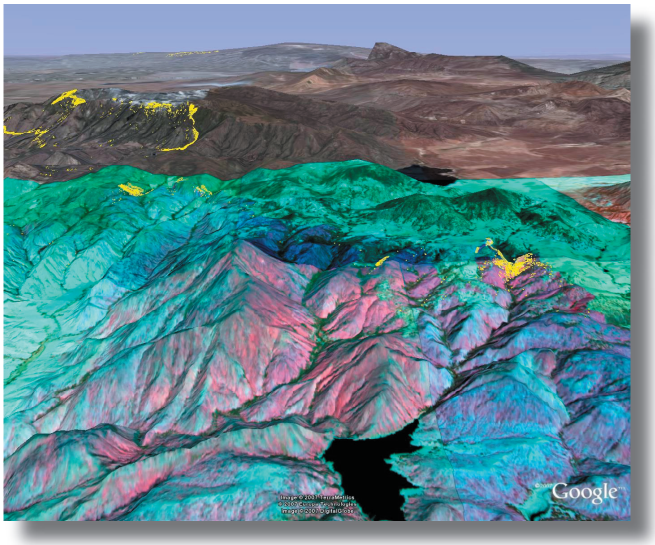


Fig. 22: NASA AMS-Wildfire sensor data collected from the Ikhana UAS over the McCoy Fire on Oct. 24, 2007. This 3-D drape of three-channel thermal data also details the fire hot spots in yellow, derived from a real-time hot-spot detection algorithm operating on the sensor data. In the near-background (looking north), hot spot detections of the Witch-Poomacha are visible.

In response to the Southern California fires, the team flew an additional four emergency flights at the request of the California Office of Emergency Services, NIFC, and the Department of Homeland Security (DHS). These flights took place over five days, averaging about 8 hours each flight. The team flew 31 fire complexes, providing both fire front imagery and derived fire perimeters (Figure 22), as well as some Burned Area Emergency Response data products.

In total, the WSFM 2007 missions entailed eight missions (89 hours) imaging 57 fires in six western states, ranging from Mexico to Canada, and the Pacific to the Rocky Mountains. The missions were a success, meeting all the science mission objectives, and exceeding the expectations of the Tactical Fire Remote Sensing Advisory Committee (TFRSAC).

For more information on the Western States Fire Mission see http://geo.arc.nasa.gov/sge/WRAP/

PROGRAM ELEMENTS

Science Requirements and Management

A continuing goal of the Program is to ensure that the composition of the aircraft catalog and investments in new technologies are directly and clearly traceable to current and planned science mission requirements. Requirements are collected and validated in partnership with the three key stakeholder groups within the earth science community: (1) scientists who need measurements to answer science questions, (2) mission scientists and managers of space flight missions who need data for satellite calibration and/or validation, and (3) engineers and developers of new instruments in need of test flight or operations..

Near term requirements are gathered primarily through the online flight request system as well as inputs from mission science teams, conferences and scientific literature. The need for airborne observations related to priority SMD missions is tracked using a 5-year plan, updated annually, and by frequent communications with the NASA Earth Science Program Managers.

For longer-term requirements, the program engages in a systematic process of collecting requirements from conferences, workshops, publications and interviews. Requirements gathered include platform altitude, endurance, range, and payload capacity, as well as telemetry, navigation data recorders, multidisciplinary sensors, and science-support systems. From this information an analysis determines which platforms achieve those measurements or observations (see Figures 24 and 25) in addition to identifying where capability gaps exist. Once science requirements are gathered and properly reviewed, they provide a critical input to technology development efforts, and ultimately, enable effective management of the aircraft catalog and new technologies elements. Results from the first round of this process were published in the Suborbital Science Requirements document, released this year, which demonstrated how national science objectives are met using airborne platforms (Figure 23).

Fig. 23: In 2007, NASA published a requirements document indicating the spectrum of capabilities sought by scientists and met by the Airborne Science Program.

In addition, conferences, publications, workshops, and interviews all provide inputs to the science requirements documents. Requirements gathered include platform altitude, endurance, range, and payload capacity, as well as telemetry, navigation data

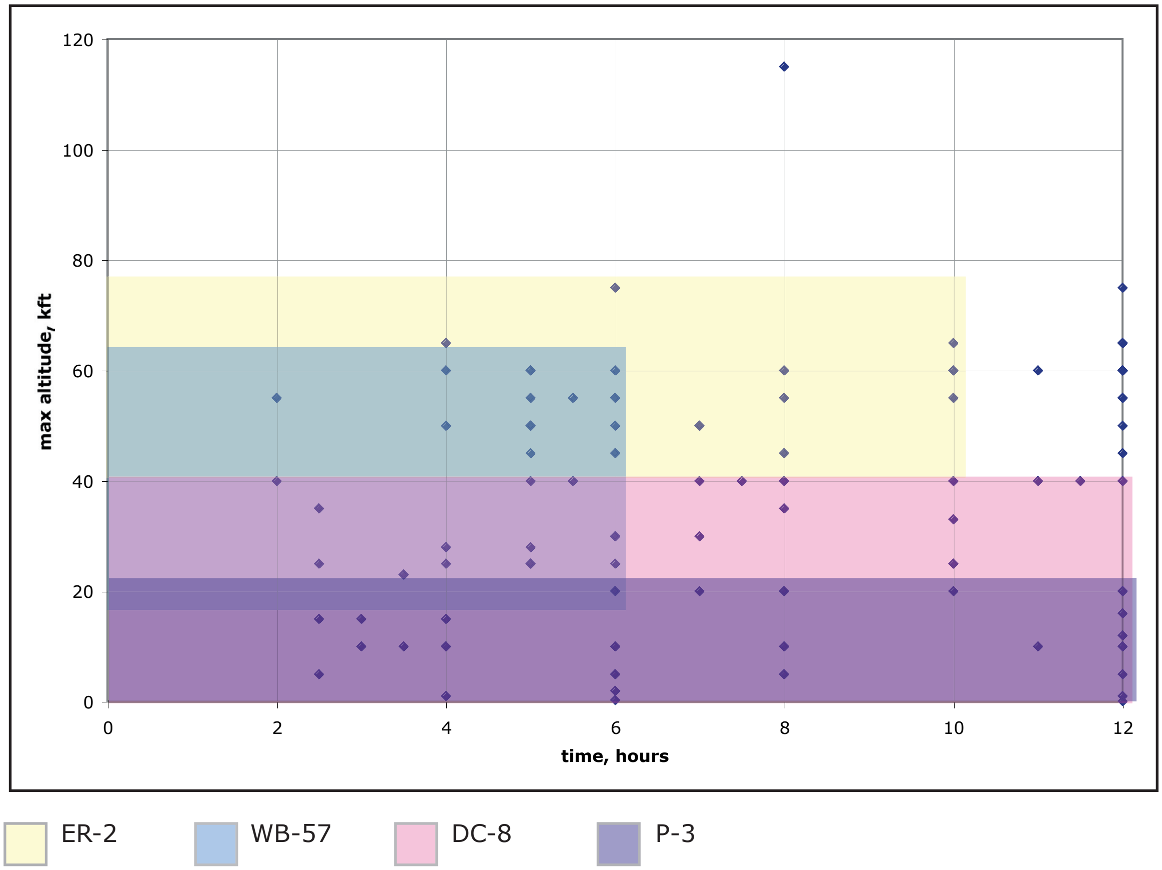


Figure 24: Generalized manned aircraft capabilities compared with altitude and endurance requirements for Earth Science missions of 12 hours or less in duration. All the aircraft are capable of expanding their lower altitude data collection range but these are their nominal regimes.

recorders, multidisciplinary sensors, and science-support systems. We determine which platforms achieve those measurements or observations (see Figures 24 and 25). Once science requirements are gathered and properly reviewed, they provide a critical input to technology development efforts, and ultimately, enable effective management of the core, catalog and new technologies elements.

The ASP 5-year plan provides an annual update on the near to mid-term requirements for the Program from the agency's science disciplines and flight projects. The most recent plan was developed in September 2007 through inputs from Science Focus Area Program Managers, scientists, and mission managers. Near-term activities primarily consist of major campaigns in each discipline, sensor development and testing, interagency science campaigns, and algorithm development or calibration and validation needs for upcoming space missions. A 5-year planning meeting is held each year in the late summer to provide

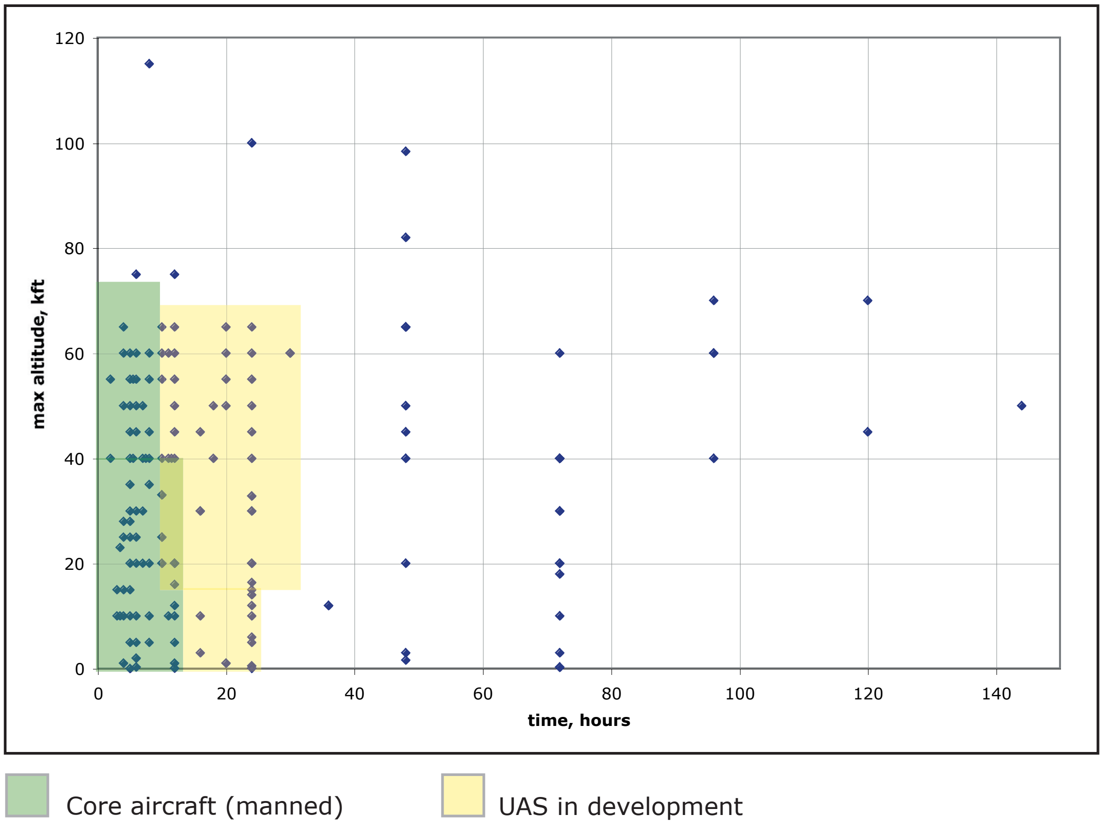


Figure 25: Generalized unmanned aircraft capabilities compared with altitude and endurance requirements for expected Earth Science missions over the next decade.

important information on the need to sustain certain platforms while potentially moving others to a reimbursable status. It also provides input to schedules for the organizations that operate the aircraft.

The Airborne Science Technology Roadmap was initiated in the last quarter of FY06, producing a work plan, a working group charter, and technology road maps in six areas, for which capability requirements have been identified. The goals of this activity are to 1) assess the requirements for new aircraft and sub systems within the Earth Science community, 2) recommend technology solutions for the science requirements; 3) provide guidance on the priorities for future development and deployment of airborne systems. Subject matter expertise for aircraft and subsystems was gathered through technical working groups that were convened to provide guidance on meeting specific capabilities. The product of this effort are technology acquisition strategies to ensure that capabilities not currently available are met in a timely matter. The six technical areas are: manned aircraft systems, unmanned aircraft systems (UAS), UAS in the National Airspace, power and propulsion, payload systems and communications, and ground-based mission planning and visualization tools

Mission Concepts and Management

The Earth Science Project Office (ESPO) at Ames also provides support to the Airborne Science Program in requirements analysis, flight request tracking and management, and mission concept and science instrument integration development and support. They also manage most of the major Earth Science airborne field campaigns in the Science Mission Directorate.

Aircraft	**Submitted**	**Total Approved**	**Total Completed**	**Total Flight Hours Flown**
DC-8	5	1	1	104.8
ER-2	10	4	3	190.4
P-3	17	11	10	250.9
WB-57	6	2	2	83.8
Twin Otter	18	15	7	171.7
B-200	8	4	3	55
Caravan	2	1	1	7.3
G-3	1	1	0	0
J-31	8	1	1	22.8
Aerosonde	11	2	1	11
Altair	5	5	5	98.4
Ikhana	1	1	0	46.5 + 32.6 for Oct flts
Blank	14	4		10
TOTAL	92	47	34	996.1
KEY				
Submitted:	Flight Request entered into the system			
Total Approved:	All flight requests that have been approved			
Total Completed:	Flight requests completed or partially completed.			

Table 1: Flight Requests for 2007.

Flight Requests

The 2007 calendar year was active for the Flight Request System. The Airborne Science Flight Request System is more user friendly and can be accessed through the program website (http://airbornescience.nasa.gov).

There were 92 flight requests in 2007. Thirty-four flight requests were completed and the rest were rolled over to 2008, withdrawn or canceled, depending upon the availability of resources at the time of the request. The details are listed below.

Ten different aircraft platforms completed the various flight requests and flew more than 996 flight hours in all. One very large international field campaign (TC-4) was successfully conducted this year as well as several other large campaigns (CLASIC, GISMO, Arctic etc.).

Program Bibliography

In an effort to quantify the importance of NASA aircraft to the earth science community, NASA asked the University of North Dakota's National Suborbital Education and Research Center (NSERC) to begin work on a NASA Airborne Science bibliography. Scopus (www.scopus.com), an on-line database product of Elsevier Publishing Co., was used to conduct the first search. Scopus currently contains 33 million references and is continuously updated with references date back to 1869. Scopus contains references from 15,000 peer-reviewed journals representing all the sciences, in addition to conference proceedings, book series, trade publications, and other sources. From the keyword searches of aircraft, past missions, and airborne instruments, approximately 1150 journal articles, 140 conference papers, 50 review papers and 65 notes, reports and others were collected. Each journal article abstract was read to confirm its relevance to NASA Airborne Science and roughly 20% of the references were removed from the bibliography because they did not pertain to NASA Airborne Science. Abstracts for the conference papers, review papers, notes, and other documents have not yet been read to confirm their relevancy and these references are not currently included in the bibliography. Future efforts will use other databases including Web of Science to continue a catalogue of scientific literature that was enabled by NASA Airborne science.

New Technology

The New Technology Element supports ASP through demonstrations of unmanned aircraft system that support Earth Science studies. The scope of projects in this area are to identify and demonstrate new technologies that address Earth science measurement requirements, unique or selected related technologies through flight experimentation and demonstration. Typically we expect that New Technology investments only last up to three years and then move in to our core capabilities or into the catalog as reimbursable programs.

Some examples of efforts within the ASP New Technology element include:

- Modifications to the NASA Gulfstream III to serve as a platform for UAVSAR, including a Platform Precision Autopilot system and structural modifications to allow installation of the UAVSAR instrument system pod to the belly of the aircraft.

- The Research Environment for Vehicle-Embedded Analysis on Linux (REVEAL) team supported TC-4 by upgrading the DC-8 science data system.

- The NASA/NRL Sensor Integrated Environmental Remote Research Aircraft (SIERRA) UAS team achieved first flight with the goal of a low cost, medium payload (<100 lbs), medium endurance (<24 hr) platform for dangerous (i.e., wildfire, hurricane) and remote locations (i.e., Arctic, open ocean).

- Two USAF Global Hawks were transferred to the NASA fleet and these aircraft are being developed for their first missions in FY09 starting with the UAVAVE mission

- Ikhana UAS with the AMS in the wing pod sending near realtime fire location and perimeter data products to fire camps.

Unmanned Aerial Vehicle Synthetic Aperture Radar (UAV-SAR)

The Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR) project began as an Instrument Incubator Program (IIP) out of the NASA Earth Science Technology Office (ESTO) Program Office. Working with ASP, JPL chose the aircraft platform, planned structural modifications to the aircraft, design/build the instrument pod, and design/implement the Platform Precision Autopilot (PPA) to enable repeat pass capability. The UAVSAR project is a four year program consisting of a 3 year phase in which the radar instrument was designed and fabricated, the aircraft platform was selected, the aircraft modified structurally to allow carrying the pod mounted instrument, a pod is fabricated to contain the radar instrument, the aircraft made repeat pass capable, and the entire system flight tested to verify requirements were met. As of this time, the program has completed the initial three years activities and has progressed to its fourth year where currently the radar and PPA are operational on the Gulfstream III aircraft. The balance of this fourth year will be used to collect repeat pass data, improve system robustness, and validate that the scientific objectives of the sensor are being met.

The Platform Precision Autopilot (PPA) for Repeat Pass Interferometry

A Platform Precision Autopilot (PPA) has been developed to enable an aircraft to repeatedly fly nearly the same trajectory hours, days, or weeks later. The required trajectory is a five meter radius tube up (ten meter diameter tube) to two hundred kilometers long. This capability allows precise repeat-pass interferometry for the UAVSAR program. The PPA consists of guidance, navigation, and Proportional Integral & Derivative (PID) control modules. Precise navigation is achieved using an accurate global differential GPS developed by JPL. The PPA uses a novel approach to interface with the aircraft (Gulfstream III) by imitating the output of an Instrument Landing System (ILS) approach, thus retaining the safeguards in the aircraft's autopilot. Limitations of the ILS interface, such as noise, scaling, biases, and variable rate limiting, had to be overcome. Testing of the PPA involved a linear simulation, nonlinear simulation, Monte Carlo analysis, hardware-in-the-loop testing, ground testing, and flight testing. Flight testing has demonstrated the ability of the PPA to keep the aircraft, while on the front-side of the power curve, within a five meter radius tube greater than ninety percent of the time, even in the presence of light turbulence.

The UAVSAR Instrument

NASA's Jet Propulsion Laboratory designed and built a reconfigurable, polarimetric L-band synthetic aperture radar (SAR), specifically designed to acquire airborne repeat track SAR data for differential interferometric measurements. Differential interferometry can provide key surface deformation measurements, important for studies of earthquakes, volcanoes and other dynamically changing phenomena. Using precision real-time GPS and the Platform Precision Autopilot, the system is able to fly predefined paths with great precision. The radar is fully polarimetric, with a range bandwidth of 80 MHz (2 m range resolution), and supports a 16 km range swath. The antenna is electronically steered along track to assure that the antenna beam can be directed independently, regardless of the wind direction and speed. Other features supported by the antenna include elevation monopulse and pulse-to-pulse re-steering capabilities that enable some novel modes of operation. The system will nominally operate at 45,000 ft (13800 m). The system has been designed to support a wide range of science investigations including cryospheric studies, vegetation mapping and land use classification, archeological research, soil moisture mapping, geology and cold land processes.

Upgraded DC-8 Data Acquisition and Scientist Interface

This year the National Suborbital Education Research Center (NSERC) and NASA Dryden's REVEAL team collaborated on the design and implementation of a new payload network infrastructure for the DC-8 Airborne Laboratory. By reworking old wiring harnesses and replacing old technology, the DC-8 lost nearly a ton of weight and gained space on the floorplan for a dedicated Mission Scientist station.

The REVEAL system replaced the legacy ICATS data system without requiring any changes to PI instruments. A gigabit fiber optic ring network now serves the experimenter stations with 100Mbit/sec access to on-board services. RS-232 feeds are provided via Ethernet-to-serial converters. The old data monitors have been replaced by high resolution web-based touchscreen LCD monitors, now mountable in experimenters racks. Additional web-oriented displays are enabled in the Housekeeping rack and even in the cockpit and navigator's station.   The camera infrastructure on the aircraft has been replaced with digital webcams, now accessed via a digital video recorder with network server and time query capabilities. Additional cameras enable greater level situational awareness for cargo pit activities. The Mission Scientist station offers multiple high resolution displays and enables the Mission Scientist to communicate with ground personnel via file transfer, text chat, and voice, using IRIDIUM-based connections to ground servers.

Global Hawk

Two Global Hawk aircraft (AV-1 and AV-6) will soon be based at the Dryden Flight Research Center. After two years of negotiating terms with the USAF, the transfer of ownership of the two aircraft from the USAF to NASA was completed in late September 2007. The aircraft were transferred to NASA in a near flight-ready condition (see Figure 26). Standardized payload interfaces in the various payload bays will be added to the aircraft. A second beyond-line-of-sight (BLOS) command and control communications link will be added to the NASA Global Hawk system to provide redundancy for BLOS flights. A ground control station will be assembled during FY08 in the Research Aircraft Integration Facility at Dryden.

Fig. 26: The newly transferred Global Hawk UAV.

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

The two NASA Global Hawk air vehicles were manufactured under the original Defense Advanced Research Projects Agency (DARPA) Advanced Concept Technology Demonstration (ACTD) Program. The AV-1 is a well-proven air vehicle that has flown more than 500 hours, including flights to and from Europe. The AV-6 was the sixth air vehicle manufactured and has flown less than 200 hours.

Ikhana

The Ikhana aircraft was ferried to NASA DFRC on June 28, 2007, following 6 months of pilot, ground crew, and system monitoring training at the manufacturer's facility (see Figure 27). The NASA team completed a ground vibration test, aerodynamic prediction, and structural analysis to support integration of a sensor pod for the WRAP mission. Currently the pod is cleared to carry payloads up to 300 lbs and the avionics bay is cleared to carry no more than 350 lbs. Further analysis is expected to increase the allowable payload to 500 lbs or more. The ground control station (GCS) also completed final integration and now includes 7 monitoring stations, an intercom system, 4 phone lines, redundant power, and fiber optic networks connecting the GCS with line-of-sight command and control antenna located near the runway. The project has taken deliveries of aircraft spares and sufficient ground support equipment to maintain the aircraft.

Fig. 27: The Ikhana.

The NASA team has modified the aircraft to accept up to 8 additional back-up batteries, giving the aircraft more than 3 hours of emergency power. This increases the safety of the aircraft/payload and reduces the risk to the public during long duration missions. In early 2008, the aircraft will be equipped with an experimenter Ethernet network that will connect payloads with a 64 GB solid-state data recorder and common time server. A powered L1/L2 GPS antenna will also be available for up to 8 payloads.

The project team cleared several reviews covering initial operations of the aircraft, clearance of the pod, and operations on the Edwards Air Force Base airfield. The WRAP project team was issued a COA from the FAA to conduct fire remote sensing flights in the western US. Although the COA came with restrictions (e.g. 3-day advance flight plan) it authorized unprecedented flexibility in flight operations over the western United States. To meet a COA requirement, the project also developed an electronic flight bag display giving the pilot simultaneous overlays of aircraft position, navigation maps, and weather information.

During FY07, 46 flights were completed, totaling 145 flight hours. Seven flights (including 4 long durations mission totaling 56 hours) were conducted in support of the very successful Western States Fire Mission. Wildfire mapping missions as long as 20 hours were flown from DFRC to fires in Idaho, Montana, Wyoming, Washington, Oregon, and California.

Ikhana is the first General Atomics MQ-9 equipped with the new digital electronic engine control (DEEC), which allows lower fuel flow at altitudes up to 40,000 ft A high altitude flight was completed that verified that the aircraft can achieve missions of more than 29 hrs, with greater than 16 hours above 40,000 ft while carrying the external pod with a 300 lb payload. Additional flights in FY2008 will fully document the aircraft's high altitude performance.

The project has completed development of the Airborne Research Test System (ARTS) hardware and software, and is currently completing Ikhana flight control changes to allow the ARTS system to autonomously control the aircraft. The ARTS will allow the aircraft to host experimental flight control and payload processing software.

The Sensor Integrated Environmental Remote Research Aircraft (SIERRA)

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

The NASA Ames team, in partnership with L-3 Vertex, completed assembly and ground engine tests for SIERRA-1 and SIERRA-2. A new ducting system was installed to draw air flow using the propeller to ensure engine cooling during ground tests and taxi. SIERRA-2 cleared the Airworthiness and Flight Safety Review Board (AFSRB) at NASA ARC and achieved first flight in early October 2007 (see Figure 28).

In 2008 the SIERRA will undergo continued envelope expansion testing in addition to the installation of a Cloudcap Piccolo II autopilot system. A gimbal system will also be installed to enable stabilized imagery small camera systems. The first science flight will likely be to test a new version of the Meteorological Measurement System (MMS) flown on the ER-2, WB-57, and DC-8 by Paul Bui (NASA). The team is also working on the integration and testing of a small, active L-Band radar system with applications to Water and Energy Cycle and Cryospheric science focus areas.

Fig. 28: The SIERRA in its first radio controlled flight over Fort Hunter-Liggett, CA, Oct. 18, 2007.

Mission Planning Tools

The Program continues to support the development of advanced planning, scheduling, and visualization tools that improve the efficiency of flight planning, data acquisition, and multi-aircraft coordination while facilitating realtime collaboration among scientists, managers and assets at different locations.

For the WRAP missions (see page 33), the CDE architecture, originally designed for JPL Mars Rover mission operations, was transferred to a Google Earth™ interface to provide near realtime data products within the context of other datasets with a common interface. Aircraft position, flight plan, airspace boundaries used together with MODIS active fire detections, and the previous days airborne data allowed the flight team to coordinate with the FAA on the optimum flight path. In the TC-4 mission (see page 30), the Real-time Mission Monitor (RTMM) was used to provide weather data products and aircraft position information for mission scientists and project managers. In both cases these systems provide an important link between the aircraft teams and the mission scientists.

Instrument Telepresence Capabilities

The REVEAL team at NASA Dryden has demonstrated the capability to assemble multiple instruments on all classes of airborne science platforms into a system-of-systems that offers new capabilities for science teams to coordinate and communicate with each other and with their respective instruments. The result is greater situational awareness in less time and thus the ability for field deployment teams to adapt and optimize their efforts to extract greater value from every flight hour invested.

From a REVEAL hardware perspective, several years of prototype tweaking on the “Altair-Class” REVEAL design finally converged on a production enclosure for larger UAS vehicles, accommodating up to six encapsulated Iridium modems.

From an operations view, the prior year offered the first opportunity to support three parallel missions on separate aircraft, but the TC-4 deployment this year marked the first time three platforms were supported in parallel for a single mission. 2007 also marked a heavy support load for ER-2 missions: AVIRIS, MASTER, S-HIS, LAC, and CLASIC each provided opportunities for testing latest capabilities and/or adapting to instrument-peculiar needs. Note that the software integration tasks for instrument-specific needs are often platform independent.

At the end of the 2007 reporting period, efforts to extend REVEAL-enabled telepresence capabilities to the Global Hawk and other UAS’s were getting underway.

Platforms: Core

Core platforms are those unique aircraft assets that cannot be replaced or found readily available with minimal modifications in other agencies. The WB-57 and the ER-2 are high altitude flyers above 50,000 feet with specialized modifications to support airborne science payloads. The DC-8 and P-3, although available from other sources, have had extensive modifications to support the science community and would cost millions to replicate in other platforms. This core concept approach protects the investment the agency has made to insure our ability to fulfill our congressionally mandated science objective requiring airborne observations. Over the next two years, the Global Hawk aircraft will be added to the Core fleet, again due to its unique aspects. The advantage of these aircraft are that the science community only pays a subsidized rate since the ASP funds the basic infrastructure to support the availability of these platforms.

DC-8

The DC-8 Flying Laboratory, operated by the University of North Dakota, supported the TC-4 in 2007 (see page 30) flying a total of 104.8 hours.

A number of important upgrades were completed in FY2007 including upgrades to the avionics and improved accommodations for science payloads on the DC-8, shown in Figure 29. The Flight Management System was upgraded from 1-B to 1-F. A new Terrain Awareness Warning System and Digital Aircraft Flight Recorder were installed to meet FAA requirements. New Navigation Units with FM Immunity were installed to meet European Standards. To improve communications during missions, new Digital COMM / NAV Control Panels and IRIDIUM air/ground satellite phones were installed for the flight crew. Improvements to payload accommodations included Purge gas lines added to all four pods new 12-gauge shielded wiring run to all four pods to accommodate new higher current probe requirements and quadrex ethernet wiring run from the cabin to wingtip pods to accommodate high speed data transfer.

In FY2007 the cooperative agreement between UND and NASA was amended to change the base of operations to the Dryden Flight Research Center. The NSERC at UND will still manage the Science and Mission operations.

Fig. 29: DC-8 airborne science laboratory soars over the Dryden Flight Research Center upon its return to the center, Nov. 8, 2007.

ER-2

NASA operates two ER-2 (806 & 809) aircraft as high altitude sensor platforms to collect remote sensing and in situ data on Earth resources, atmospheric chemistry and dynamics, and oceanic processes (see Figure 30). The aircraft also are used for electronic sensor research, development and demonstrations, satellite calibration and satellite data validation. Operating at 70,000 feet (21.3 km) the ER-2 acquires data above ninety-five percent of the Earth's atmosphere. The aircraft also yields an effective horizon of 300 miles (480 km) or greater at altitudes of 70,000 feet.

In October of 2007, the ER-2 806 conducted a approximately 18 hours of different flights for the following instrument teams: AVIRIS, MODIS Airborne Simulator (MAS), MODIS/ASTER Airborne Simulator (MASTER), and Scanning High Resolution Interferometric Sounder (S-HIS). MAS/MASTER/SHIS flight sorties included a Lake Tahoe satellite underpass. In mid-November, ER-2 806 conducted a 2.1 hour post-calibration AVIRIS flight. In early February, ER-2 806 flew a pilot proficiency flight which included a Search and Rescue mission looking for Microsoft Executive Jim Gray. The mission was flown for 5.2 hours and covered the ocean off of Central California.

ER-2 809 was down the 1st quarter of FY07 to conduct a required 400 hour phase inspection and successfully flown soon after. In May, the ER-2 809 uploaded Large Area Collectors on its wing and conducted a successful series of science flights from DFRC. Flights were flown to gather cosmic dust (CD) particles from Earth's stratosphere which are examined and cataloged, and then made available to the scientific community for research. The ER-2 flew 4 flights totaling 29.1 flight hours.

Fig. 30: ER-2 lifts off from Edwards Air Force Base on a CALIPSO/CloudSat validation instrument checkout flight.

In June, The ER-2 806 deployed to Ellington, TX, in support of the Cloud LAnd Surface Interaction Campaign (CLASIC) for flights over Oklahoma (see page 20). The campaign was very challenging and it was impacted due to thunderstorms in the region but team was able to get flights off and gathered good data for experimenters. During the CLASIC campaign the ER-2 806 flew 14 flights totaling 68.1 flight hours. Also, during the CLASIC campaign, the project was able to support a flight over the Washington DC area for the Missile Defense Agency (MDA) in a non-impact basis to CLASIC.

In July, the ER-2 809 deployed to San Jose, Costa Rica, in support of the Tropical Composition, Cloud and Climate Coupling (TC-4) campaign (see page 30). During TC-4, the ER-2 809 flew 14 flights totaling 88.2 flight hours.

In fiscal year 2008 the ER-2 operations will be re-located from DFRC hangar 4840, to a new facility in the city of Palmdale - site 9. This move along with efforts to share infrastructure with other projects will allow the ER-2 to continue and maintain it's reduce hourly flight cost.

WB-57

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 at JSC's Aircraft Operations Division, part of the JSC Flight Crew Operations Directorate, at Ellington Field. Both aircraft have been flown by NASA on various research missions since 1974, and continue to be a valuable asset to the scientific community with professional, reliable, customer-oriented service.

The WB-57 aircraft participated in two large-scale, coordinated scientific campaigns in FY07. The Joint Airborne Infrared Atmospheric Sounding Interferometer Validation Experiment (JAIVEx) which took place from April 14 to May 4, 2007 at Ellington Field in Houston, Texas (see page 26). On board the WB-57 flew the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Aircraft Sounder Test-beds (NAST) I (for Interferometer) and M (for microwave), along with the Scanning High-resolution Interferometer Sounder (S-HIS). NAST-I is a scanning interferometer which measures emitted radiation. NAST-M is a passive microwave spectrometer. S-HIS is a scanning interferometer which measures emitted thermal radiation at high spectral resolution. The WB-57 and the United Kingdom's Facility for Airborne Atmospheric Measurements (FAAM) BAE 146 aircraft flew their respective payloads simultaneously and coincident with European Meteorological Operations (MetOp) satellite passes in several geographic locations. The data that the campaign obtained was considered a great success by all parties involved.

Fig. 31: The WB-57 in its hangar during TC-4 deployment from Costa Rica.

The second major campaign was the Tropical Composition, Cloud and Climate Coupling (TC-4) conducted from San Jose, Costa Rica in concert with the NASA ER-2 and University of North Dakota DC-8 aircraft, as well as a ground-based radar system (see page 30). The WB-57 (Figure 31) demonstrated its lifting capability by flying as many as 25 sensors and experiments simultaneously, and to an altitude of 60,000 feet. Participation in TC-4 was foreshortened by an aircraft problem prior to the deployment, but the WB-57 team displayed its ability to respond to adversity by addressing the problem in time to participate in three coordinated flights from Costa Rica.

A notable upgrade to the WB-57 in FY2007 was the installation of new landing gear. The modification included the replacement of the original lower piston-axle, wheels, brakes with those from the F-15E Strike Eagle. The new system improves stopping power, maneuverability on the ground and its ability to operate from wet runways with the incorporation of the F-15E's anti-skid braking system. The program suffered a setback with the failure of test-specific hydraulic system and the subsequent fire. However, a new fitting was designed, the system completed its testing, and the new landing gear was placed in service in October, 07. The landing gear upgrade is important, not only because it improves ground handling and performance, but because it will enable the next major upgrade; an increase in the allowable take-off weight. The increased weight will allow the airplanes to carry a full complement of science instruments without having to down-load fuel to remain within weight limits, enabling longer science mission flights.

P-3

The P-3 is based at Goddard Space Flight Center's (GSFC's) Wallops Flight Facility (WFF). The P-3 participated in three major missions during FY07 and one instrument development mission.

The first mission was a series of local instrument development flights from Wallops for the GSFC RadSTAR-A/P instruments, in addition to piggyback instruments.

The first major mission of the year was the Arctic 2007 based out of two locations in Greenland in order to do a lidar survey of the ice sheet. The detailed objectives are described elsewhere in this report. All mission objectives were met with a total of 48.8 science flight hours in support of Arctic 2007. (The P-3 is shown in Figure 32.)

Fig. 32: P-3 taking off from Thule airport.

The second major mission of the year was the Cloud and Land Surface Interaction Campaign (CLASIC) that involved flying the Polarimetric Scanning Radiometer (PSR). This mission was performed with a quick turnaround with two weeks between the "go ahead" and the deployment in an effort to backup the ER-2 due to engineering challenges involved with integrating the PSR. There were 59.0 science hours flown supporting CLASIC.

The third and final mission for the year was to fly the Global Ice Sheet Mapping Orbiter (GISMO) Earth Science Technology Office (ESTO) funded Instrument Incubator Program (IIP) on a makeup flight to Greenland after instrument problems prevented it making the Arctic 2007 mission. A separate summary of the mission is available within this report. The mission successfully flew 87.9 science hours.

No major P-3 upgrades were performed in FY07. The P-3 flew a total of 290.1 flight hours in support of the Airborne Science Program.

Platforms: Catalog

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

Aerosonde

The Aerosonde is based at Goddard Space Flight Center's (GSFC's) Wallops Flight Facility (WFF) under a Cooperative Agreement and a separate contract with AAI Corporation. Once again for 2007, NASA in a collaborative venture with NOAA conducted the Hurricane Boundary Layer mission based in Key West, FL with an alternate site out of NASA Wallops. The complete details on this mission are contained elsewhere in this report.

Aerosonde flew a total of 5.0 flight hours in support of the Airborne Science Program and NOAA in FY07 in preparation for this mission.

Figure 33: Aerosonde launched into flight.

B-200 (Department of Energy)

The Department of Energy's Remote Sensing Lab in Las Vegas, Nevada, operates two King Air B200 aircraft which are made available to the Airborne Science Program through an interagency agreement. In August, the aircraft provided continued support for the Southern California Fault assessment project. This was the third year in a continuing and expanded effort to conduct seismic research. The project is an ongoing collaboration between NASA, JPL and the University of California, Los Angeles. Day/night missions were flown to acquire MODIS/ASTER Airborne Simulator (MASTER) data over a series of fault structures throughout the Mojave Desert. The day/night image pairs provide the means to distinguish subtle mineral composition differences. These differences are used to quantify the cumulative slip history of each fault.

In the 2007 fiscal year a DoE B200 aircraft flew 13 hours in support of Airborne Science Program earth science research projects.

Figure 34: DoE B-200.

NASA B-200 (LARC)

NASA's Langley Research Center (LaRC) operates a Beechcraft King Air B-200 that has been recently modified with two nadir-viewing ports (29x29" and 22x26") and the installation of research-supporting subsystems, such as electrical power distribution, TCAS, GPS and satellite phone communications. Since December of 2005, the aircraft has flown approximately 400 hours in support of six major atmospheric field missions.

The twin-engine turboprop nominally flies mission profiles up to 28,000 ft but with prior coordination is capable of conducting operations in the National Airspace System up to the aircraft's service ceiling of 35,000 ft Currently the aircraft can carry a 1000 lb payload, a crew of three (pilot, co-pilot, and one system operator) and remain airborne for 4 hours covering approximately 800 nautical miles. The aircraft is currently limited by a maximum certified take-off weight of 12,500 lb. (Efforts are currently underway to allow for up to a 1000 lb increase in the take-off weight.) With a total fuel consumption rate at altitude on the order of 400-500 lbs per hour there is a direct trade-off between increasing passengers, payload, or endurance. The B-200 is based at the Langley Research Center in Hampton, Virginia, and the operations team and has experience deploying the aircraft in both domestic and international field missions. The supporting flight organization works closely with the science customers to optimize missions to meet research requirements within operational flight capabilities and constraints. The B-200 and the LaRC

Figure 35: NASA B-200

operations team provides an efficient and effective operational platform for small to medium sized science payloads, especially those with unique integration requirements, dedicated flight profiles, coordinated flights with other platforms, or flight patterns in congested airspace.

The LaRC Airborne HSRL was the primary instrument on the B-200 for the missions conducted in 2007. Field missions supported in 2007 include the EPA-sponsored San Joaquin Valley Experiment, the DOE-sponsored Cumulis Humilis Aerosol Processing Study (CHAPS), and the CALIPSO and Twilight Zone (CATZ) campaign.

Plans for 2008 include four field missions deploying the LaRC HSRL: flights in the Eastern Seaboard in early January to acquire validation data for the Applied Physics Lab GIFS instrument being developed under the Instrument Incubator Program, CALIPSO validation flights in the Caribbean in late January, and the ARCTAS April (Alaska) and July (Canada) missions. The GISS Research Scanning Polarimeter (RSP) will also deploy with the HSRL on the July ARCTAS mission. Also planned for 2008 are demonstration flights for the ACCLAIM CO2 sensor and the JPL-LaRC ALHAT instrument. Interfaces are also currently being investigated to support future flights of the Ames MASTER and the Goddard LVIS instruments.

Dynamic Aviation A-90

A Dynamic Aviation A-90 aircraft based out of Bridgewater, Virginia, supported the Airborne Science Program on two missions in FY07. The Raman Airborne Spectroscopic Lidar (RASL) had it first flights supported by the NASA Instrument Incubator Program (IIP) and the GSFC Earth Science Technology Office (ESTO). It is the first airborne lidar to offer simultaneous measurements of water vapor mixing ratio and aerosol backscatter/extinction/depolarization. In addition to the development flights was participation in the Aura validation campaign, WAVES 2007 (Water Vapor Variability Satellite/Sondes 2007), that was staged at the Howard University Research Campus in Beltsville, MD.

The Dynamic Aviation aircraft supported ESTO with 42.0 flight hours.

Figure 36: Dynamic Aviation A-90.

Gulfstream III Multi-Role Cooperative Research Platform

The NASA Gulfstream III (G-III) is a business jet that has been structurally modified and instrumented by NASA's Dryden Flight Research Center to serve as a multi-role cooperative research platform for the earth science community and a variety of flight research customers. This particular aircraft, which carried the military designation of C-20A, was obtained from the U.S. Air Force in 2003.

Figure 37: G-3 in flight over Edwards AFB with UAVSAR pod installed.

The NASA G-III is equipped with a self-contained on-board Data Collection and Processing System (DCAPS). DCAPS was developed to enable processing, distributing, displaying and archiving aircraft flight data and customers' experimental data in real time. 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. DCAPS is designed to allow easy upgrades, addition of add-on systems for expansion, and to operate in both autonomous and manual modes. Additionally, the aircraft features a video collection/ distribution system, satellite phone, and an upgraded 120-amp electrical power system.

The G-III airframe has been structurally modified to accommodate installation of an instrument pod weighing as much as 1200 lbs on the external bottom of the aircraft. The pod mounting is a standard MAU-12 ejector rack interface which is very common among military aircraft pods and thus will allow this aircraft to use a number of different pods for carrying instruments external to the aircraft. Electrical power and signal connectivity between the aircraft cabin and the pod is available. Currently the NASA G-3 is supporting development of the Unmanned Air Vehicle Synthetic Aperture Radar (UAVSAR) underdevelopment by JPL.

The aircraft features a Platform Precision Autopilot (PPA). The PPA guides the aircraft using Differential Global Positioning System and aircraft Inertial Navigation System information. The PPA allows the aircraft to repeatedly re-fly any given the flight path to an accuracy of within five meters. With the PPA engaged, the UAVSAR is able to acquire repeat pass data.

The G-III’s maximum takeoff weight with full fuel and passengers/cargo is 69,700 lbs. The aircraft is powered by two Rolls-Royce Spey F113-RR-100 turbofan engines, each producing 11,400 pounds (5,170 kg) of thrust. Empty, the airplane weighs about 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 (527 mph), and its top speed is 576 mph (501 knots; Mach 0.84). Its maximum operating altitude is 45,000 feet. The G-III can carry up to 12 passengers and has a range with a full load of passengers or equipment of about 3,400 nautical miles (4,000 statute miles).

During FY07 the G-III performed over 100 hours of flight operations related to development of the UAVSAR and associated subsystems. The G-III was engaged in pylon & pod flight envelope validation flights, pod/ground clearance test operations, Platform Precision Autopilot development flights, and UAVSAR engineering development flights. The G-III also supported the TC-4 campaign by shuttling a critically needed replacement science instrument from California to Costa Rica. FY08 is shaping up to be a busy year as the G-III continues to support UAVSAR engineering development and science validation flights; and has completed Platform Precision Autopilot flight envelope performance validation flights.

Sky Research Caravan

The Cessna Caravan 208, owned by Sky Research, is based in Ashland Oregon, and was used under contract by NASA for low altitude earth science research. In June 2007 the Caravan flew five hours in support of instrument development and established instrument science. The Autonomous Modular Sensor (AMS) UAS system was flown on the Caravan over controlled burns at Fort Hunter Liggett as a UAS pre-flight engineering test. The test flight validated recent software and hardware modifications prior to installing AMS on the NASA Ikhana UAS. Subsequently the AMS was used on multiple Ikhana flights supporting the western states fire missions flown in August and September 2007.

Figure 38: Sky Research's Cessna Caravan.

Sky Research J-31

Figure 39: Sky Research's Jetstream-31.

The British Aerospace Jetstream-31 is owned and operated by Sky Research in Ashland Oregon. In June, the J-31 was configured with the Cloud Absorption Radiometer (CAR), and Applanix Position and Orientation System (POS). The aircraft deployed to Ponca City Oklahoma in support of the Department of Energy Cloud and Land Surface Interaction Campaign (CLASIC) (see page 20). CLASIC was a multi-aircraft campaign involving DoE, NASA, CIRPAS and other airborne science platforms. The CAR measured spectral and angular distributions of scattered light by clouds and aerosols, and provided bidirectional reflectance of various surfaces. CAR derived surface BRDF and column aerosol properties of different atmospheric layers and validated satellite retrievals of surface BRDF.

The J-31 flew 33 hours in support of radiation science research during the 2007 flight season.

Twin Otter

Twin Otter International in Grand Junction, CO participated in four missions during FY07 using a Twin Otter aircraft. The first mission was the CLPX-II (Colorado) that was conducted during three phases in December, January, and February for the Terrestrial Hydrology Program. Twin Otter International provided 49.6 hours of flight support to the Terrestrial Hydrology Program for CLPX.

The second mission of the year was the AVIRIS Hawaii 2007 Campaign during January-February 2007 for the Terrestrial Ecology Program. A total of 51.8 hours were flown in Hawaii in support of the Terrestrial Ecology Program.

During In May-July the Cloud and Land Surface Interaction Campaign (CLASIC) mission was conducted out of Oklahoma City, OK with the JPL PALS instrument as a Twin Otter payload. The mission was part of the larger CLASIC mission sponsored by the Department of Energy (DOE). A total of 96.0 hours were flown during CLASIC for the Terrestrial Hydrology Program.

Figure 40: Twin Otter.

All totaled, Twin Otter international supported the Airborne Science Program on these missions for a total of 256.6 hours.

Science Instrumentation and Support Systems

This element of the ASP encompasses the development, operation, and demonstration of new and core science instruments, and related science support subsystems. In addition, it provides engineering support for new instrument integrations onto the core and catalog aircraft, and strives to increase the portability and interoperability of sensors and systems between platforms. This activity is primarily centered at the Airborne Science and Technology Laboratory, located at the NASA Ames University-Affiliated Research Center, and run in collaboration with the University of California at Santa Cruz. The ASTL has been supporting airborne measurements for the NASA science community for over 20 years. It conducts a range of airborne science support activities, from Instrument design, fabrication, and calibration, to sensor operations, flight planning, and data processing.

The new Autonomous Modular Sensor (AMS) system was developed in FY06 for use on large UAS platforms, such as the Ikhana Predator-B or the Global Hawk. This year the system was further refined during the Western State Fire Missions and a subsequent series of emergency response flights over wildfires in southern California. A total of 14 sorties were flown on the UAS. The concepts of extended autonomous operation, extensive on board data reduction, and sat-com-based networking were fully demonstrated this year. A key element in this system is a combined data reduction and high-speed telemetry module, which will be a fundamental building block for future science missions on these platforms. (Fig. 41)

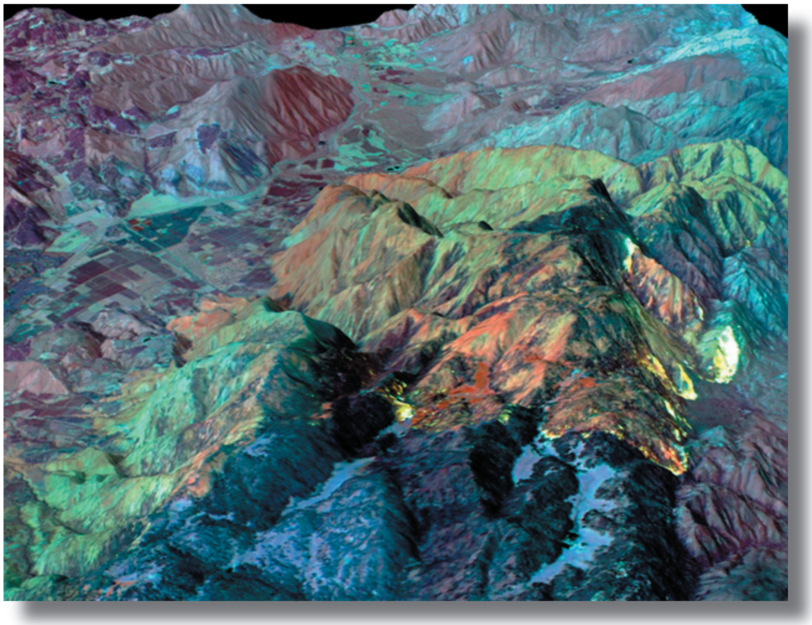


Fig. 41 AMS imagery acquired 28 October 2007, over the Poomacha Fire, north-east of San Diego California. It is a thermal mid-IR, and shortwave IR composite of an active fire line. The data have been geo-located and draped over a 10m digital elevation model.

The hardware and software infrastructure developed on this project are directly applicable to the observation of other rapidly evolving phenomena with a long-duration UAS as well (e.g. hurricane evolution, the development convective systems, tracking algal blooms or oil spills, etc.)

The requirements gathering and design work for a new general-purpose airborne navigation data recording and distribution system was begun this year. This is a collaborative project involving several field centers and leverages Dryden’s existing REVEAL hardware and software architecture. The new system will be a functional replacement for the aging navigation data recorders now in use on ER-2 and WB-57 while providing the flexibility needed to adapt to advances occurring elsewhere on the payload network. The new airborne data system is network-savvy and, like the REVEAL system, facilitates platform interoperability through common network interfaces and services for science instruments.

A new nadir-viewing time-lapse digital video camera installation was successfully tested on the ER-2 during the TC-4 deployment (Fig. 42). This is intended for visual scene context documentation, in support of the primary science payload. The higher-resolution still-frame DCS camera system was also further refined, this year on the WB-57 and B200 aircraft.

Engineering support was provided to various instrument teams, including integrations of the ARGUS and HyMap systems on the WB-57. In support of the NASA Applied Science WRAP project, ASTL worked with the Ikhana team to design a window into the Ikhana sensor pod, together with an instrument mounting structure (Fig. 43).

Fig. 42 MVIS video frame acquired during TC-4 flight 07-9030, 9 August 2007.

ASTL personnel also provided flight planning services and mission logistics for various remote sensing missions on the ER-2, B-200, Caravan, and Ikhana.

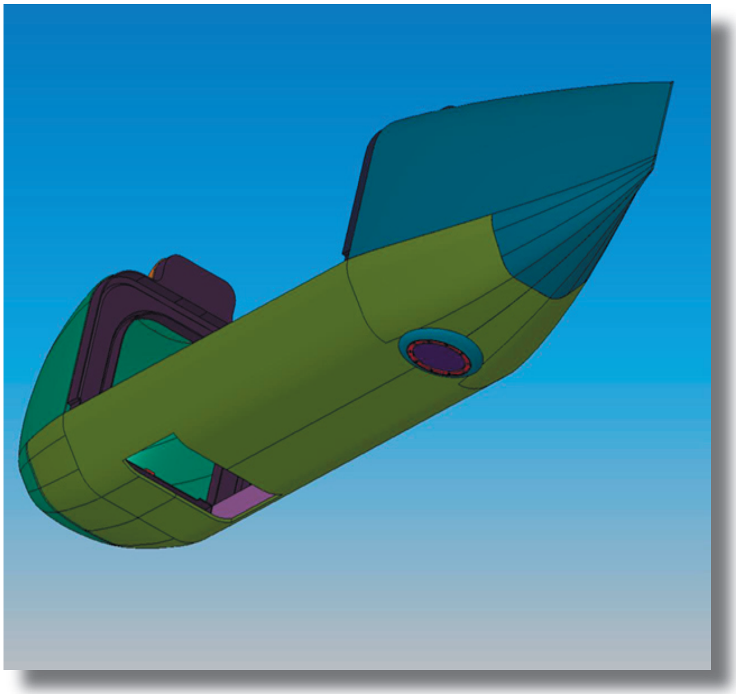


Fig. 43 Design for 5" aft window to be added to the Ikhana sensor pod tray.

The ASTL operates the MODIS and ASTER Airborne Simulators (MAS and MASTER) in conjunction with the EOS Project Science Office and JPL. These two systems were flown on a total of 44 science missions in FY07, including the TC-4 experiment (Fig. 44), and various multi-disciplinary process studies onboard the ER-2 and DoE. B-200, aircraft. . A large scale NASA campaign to acquire data/night MASTER data with the DoE B-200 over the extensive seismic fault systems of southern California was completed in August (Fig 45). These instruments are also are made available to the NASA science community through the Flight Request process.

The ASTL also maintains a suite of facility assets for the Airborne Science Program, including stand-alone precision navigation systems (Applanix POV-AV IMU/DGPS units), video and DCS digital tracking cameras, and environmental housings for instrument packaging. This utility hardware is available for community use via the Flight Request process.

The ASTL Calibration Laboratory is a community resource that is co-funded by the Airborne Science and EOS programs. It performs NIST-traceable spectral and radiometric characterizations of remote sensing instruments.

Recent additions to the lab include a precision transfer radiometer for calibrating radiometric sources and a high-temperature cavity blackbody. The lab also provides portable radiance sources (integrating hemispheres) and a portable ASD spectrometer to support field experiments. Instruments utilizing the lab this year included the AATS-14 and SSFR radiometers, MAS, MASTER, AMS, and the LCROSS Lunar

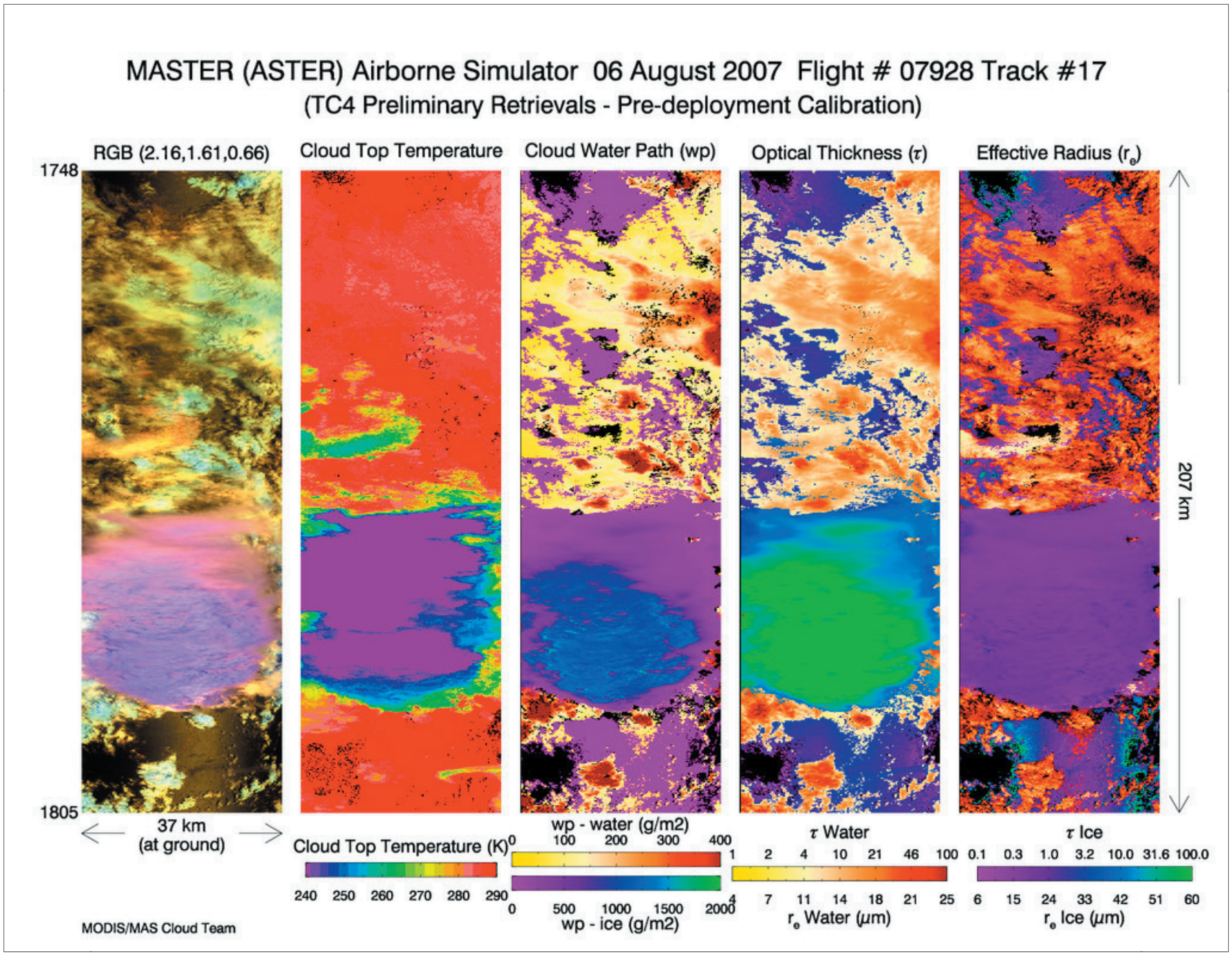


Fig. 44 MASTER Level-2 science products, produced in the field during TC-4 by the GSFC MODIS team.

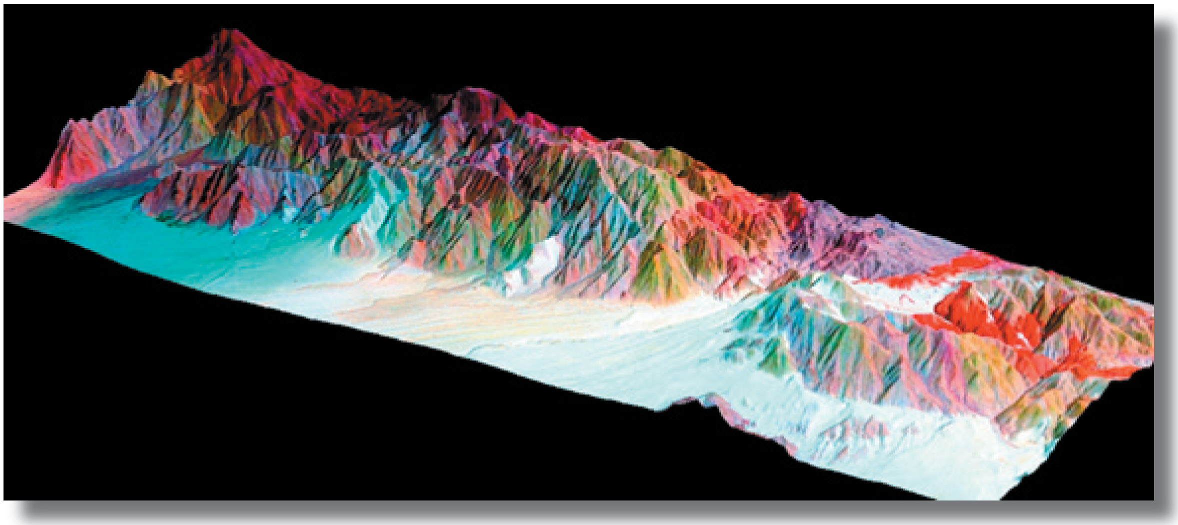


Fig. 45 MASTER imagery acquired 1 September 2007, over the Buillion Fault, east of Victorville California. This 3-D image consists of thermal, mid-IR, and visible bands, highlighting geologic structure.

COLLABORATIONS AND PARTNERSHIPS

The Airborne Science Program works closely with many other organizations to provide Earth Science activities for the nation. In 2007, a major partnership with the US Forest Service continued with the success of the Wildfire Research and Applications Program (WRAP), and the Western States Fire Mission (WSFM) in particular. Additional collaborators through the WRAP Tactical Fire Remote Sensing Advisory Group (TFRSAC) include Bureau of Land Management (BLM) and National Interagency Fire Center (NIFC). During the late fall fires, NASA also worked with the California Office of Emergency Services.

Another major partner has been National Oceanic Atmospheric Administration (NOAA). The ASP collaborated with NOAA on the Aerosonde Hurricane Boundary Layer mission. NOAA has also detailed a full-time officer to NASA DFRC to serve as deputy project manager of the Ikhana UAS. Also, working with DOE and the University of Colorado, NASA organized a major workshop on Civil Applications of UAS.

In the rapidly evolving area of unmanned systems, the Program is also working closely with other agencies and industry to ensure that these advances benefit the earth science community. A partnership with the Naval Research Lab to field a medium class, long range UAS successfully completed its Army Fuze Safety Review Board (AFSRB) and first flight. Another important partnership involves bringing the two Global Hawks to Dryden requiring significant collaboration with the US Air Force.

The international press was very interested in TC-4 and the Costa Rican and Panamanian press in particular followed this mission. A media day open house was conducted and TV stations (NPR, Japan TV, Reuters TV etc), local print media and radio stations attended, along with 100 guests of the Embassy. The significance of TC-4 was further evidenced when the President of Costa Rica and the US Ambassador attended. A media day in Panama was very well attended. Both media day events included tours for local school children.

Fig. 46: TC-4 Media Day dignitaries (left to right): NASA Program Manager Michael Kurlyo; Prof. Eugenia Flores, Minister of Science & Technology; Presidency Minister Rodrigo Arias; Costa Rican President Oscar Arias; Mernando Berrocal, Minister of Public Safety; U.S. Ambassador Mark Langdale; Pedro Leon, Director, National Center of High Technology.

EDUCATION AND OUTREACH

In 2007, the Airborne Science Program supported a number of relevant conferences. A particularly broad effort involved the 31st International Symposium on Remote Sensing of the Environment (ISRSE) held in Costa Rica. Program personnel held a one-day workshop to introduce participants to the use of Unmanned Aircraft Systems for Remote Sensing and Environmental applications. More than thirty students attended, many of them college students from Central American universities. Demonstrations of UAS flights and data acquisition over near-by coffee fields also took place during the week-long conference. In addition, two UAS-related paper sessions were organized to present science opportunities. Beyond the ISRSE, the Program was present at the 2006 Fall AGU, 2007 AUVSI, 2007 AIAA Infotech@Aerospace, and 2006 TAAC conferences. On the SIERRA project, Yoshino Sugita, an aerospace student from the University of California at Davis, assisted with autopilot programming and drawings prior to first flight.

Fig. 47: UAV Remote Sensing Workshop students view the Vector P at Tobias Bolanos airport in Costa Rica during the ISRSE Conference.

IN MEMORIAM

This last year we mourned the loss of two pilots who for 20 years were instrumental in making this such a successful program. These pilots were true aviators, flying myriad of aircraft and developing many of the techniques we use today for our airborne science activity. Ed Lewis flew the DC-8, Lear Jet, C-130 and the Kuiper; and Steve Feaster flew and managed to save the WB-57 program numerous times and also trained all the current WB-57 crews. The dedication that these two had to the program was infectious and can be seen throughout our organization today.

Fig. 48 (above): Airborne Science Assistant Chief Pilot Ed Lewis.

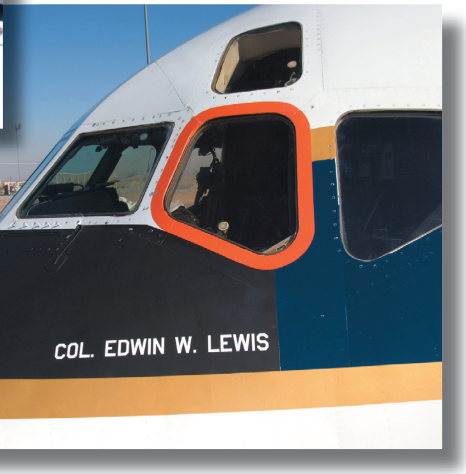


Fig. 49: NASA's modified DC-8 now carries the name of the late Edwin W. Lewis below its cockpit window, a tribute to his 18 years piloting the unique science laboratory.

Prior to his untimely death in a light plane crash in November 2007, Edwin W. Lewis Jr. served NASA for 18 years as a research pilot at Dryden and at Ames. Lewis flew a variety of research and mission support aircraft during his career at NASA including the DC-8 , a modified Gulfstream III, Beechcraft B-200 King Air, Lockheed YO-3A, and the Beechcraft T-34C Turbo Mentor, a C-130B, the C-141A Kuiper Airborne Observatory, the DC-8, UH-1, SH-3, King Air, Lear 24, T-38A, T-39G and YO-3A . He served as Dryden's Aviation Safety Officer and he was a project pilot for Ames' 747 and T-38 programs.

Lewis began flight training as a Civil Air Patrol cadet in 1951, ultimately earning his commercial pilot's certificate in 1958. He entered the U.S. Air Force through the Reserve Officer Training Corps. Following pilot training he was assigned to Moody Air Force Base, Georgia, as an instructor pilot, for both the T-33 and T-37 aircraft. He served in Vietnam from 1965 through 1966, where he was a forward air controller, instructor and standardization/evaluation pilot, flying more than 1,000 hours in the O-1 "Bird Dog."

Lewis separated from the regular Air Force and joined Pan American World Airways and the 129th Air Commando Group, California Air National Guard (ANG) based in Hayward, Calif. During his 18 years with the California ANG he flew the U-6, U-10, C-119, HC-130 aircraft and the HH-3 helicopter. At the time of his military retirement with the rank of colonel, Lewis was commander of the 129th Air Rescue and Recovery Group, a composite combat rescue group. During his 22 years as an airline pilot, he flew the Boeing 707, 727 and 747. He took early retirement from Pan American in 1989 to become a pilot with NASA.

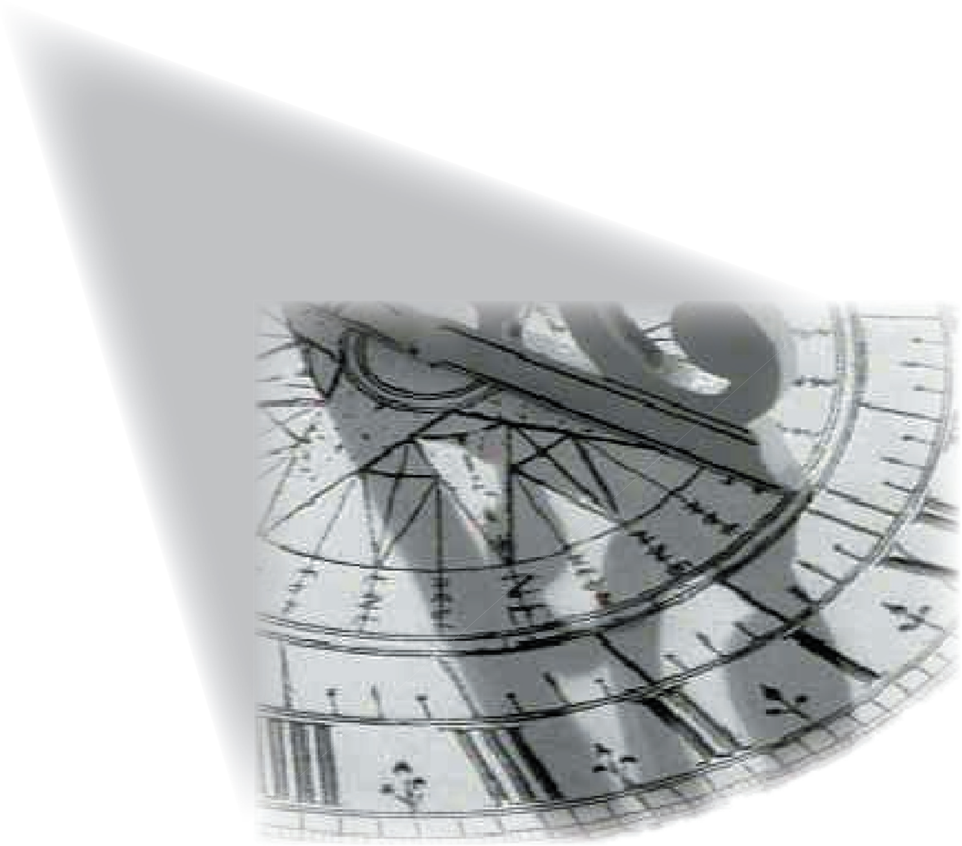
Lewis had also been active in the Civil Air Patrol for more than 50 years, serving as the organization's California and Pacific Region commander and national vice commander. He had also received numerous awards during his military career, among them the Distinguished Flying Cross.

Stephen Feaster died on August 22, 2007 at his home in Albuquerque after a courageous battle with cancer. Born December 3, 1946 in Wichita, KS to J. D. and Maxine Feaster, Steve was a graduate of the United States Air Force Academy with a degree in aeronautical engineering. He served his country as an F-111 combat pilot in Viet Nam and after his military service, he joined NASA JSC as a research pilot and flew almost every aircraft that NASA operates including the WB-57. He was instrumental in building the WB-57 program to what it is today. His attention to detail and dedication made him a great asset to the program. Steve is survived by his wife, Jan and his sons Max, Carl, and Daniel. He will be greatly missed.

Fig. 50: Steve Feaster and family.

To honor these and past leaders of this program, NASA is working with NSERC and other past and present partners to build a history of the program. The intention to document past experiences to ensure the program can build on what they learned.

LOOKING AHEAD TO FY08 AND BEYOND



The Airborne Science Program has seen much of the foundation being put in place this year to position us for the future. Some of these items include the establishment of a new airborne science facility at Palmdale to house a significant portion of SMD's aircraft fleet, thereby stabilizing several programs. A major shift in the program is the transfer of the UND Cooperative agreement to DFRC since the DC-8 will now be housed at Palmdale; this was accomplished in a cooperative manner with UND who will maintain science and mission operations responsibility, while DFRC is responsible for the maintenance, flight operations and government project oversight.

Another major cornerstone to our program is the transfer of two Global Hawk aircraft from the USAF. NASA is the first non-DOD organization to have Global Hawks. These aircraft will allow us to have the most powerful airborne science high-altitude long-endurance aircraft operationally available to perform missions that scientists could previously only dream of.

Another major accomplishment of the program was to release a requirements document which makes clear the marching orders for where our program should focus our investments and where we should be moving toward in satisfying the needs of our science customers, this document has already been sited as a standard in the agency for mission directorates to establish their aviation requirements. Activities in 2008 for the Science Management and Requirements element will include upgrading the flight request system and requirements matrix databases to generate more routine reporting, polishing the Airborne Science Program web portal, beginning a systematic update of requirements in line with the Decadal Survey and new instrument testing, and following up the technology roadmapping efforts.

The establishment of the Blanket Purchase Agreement allows us to have a readily available commercial fleet of aircraft to augment and expand our capabilities that the science community requires on short notice. The other cornerstone to really build our program within NASA is the strengthening of our relationship with LaRC and GRC, giving their aviation departments a seat at our table. These fundamental changes to our program put us in much better position to support the airborne science needs of the Agency.

Many of the new technologies which the airborne science program has invested in are now starting to transition to operations. This includes the new DC-8 Investigator Interface systems which improves the situational awareness of all the investigators as well as the new avionics improving the situational awareness and ability of the aircrew to support the science requirements. The core fleet is moving to the IGW1 data distribution and transmission standard for interagency airborne science aircraft. A new data distribution system for aircraft state information is being developed allowing for transmission of data through satcom systems. The real time monitoring of missions has become almost standard with Google

Earth® backdrop for tracking and accomplishing collaborative decision activity to maximize our science results during flight.

The WB-57 new landing gear opens the doorway to a much more robust platform for the science community by being the first step to achieve the gross weight increase and superpod additions which will be needed and completed by TC-4 Guam in 2010.

The Sierra UAS flew its initial development flights and will give us increased small UAS payloads. By modifying the G-III to consistently (<99%) fly within a 3D 10 meter tube to perform repeat pass interferometry, we will allow a new approach for accomplishing high precision 3D earth surface mapping with the UAVSAR system.

The repair effort over the last few years to the P-3 has paid off and allowed it to be a real workhorse this year, including responding with a quick reaction to an added mission for a one-month deployment with only one and a half week warning. Over the next few years we have full P-3 programs planned to utilize this aircraft.

Our UAS programs are maturing at a rapid rate. As an example of that maturation, the Ikhana with the NASA-developed AMS wildfire sensor was instrumental in supporting disaster managers with observations of wildfires in the Western U.S. and specifically during the Southern California firestorms of October 2007. During the Western States Fire Mission the Ikhana delivered critical fire data to fire managers on complexes extending from Mexico to Canada and from the Rockies to the Pacific Ocean. During the Southern California firestorms FEMA requested our assistance in supporting data collections over those regions as well. The AMS data was sent in real time to fire incident managers who were utilizing the imagery to direct resources to battle the fires and protect countless homes. This high visibility mission series garnered intense interest and recognition from state and federal agencies, including the California Governor's Office of Emergency Services, FEMA, DHS and the White House.

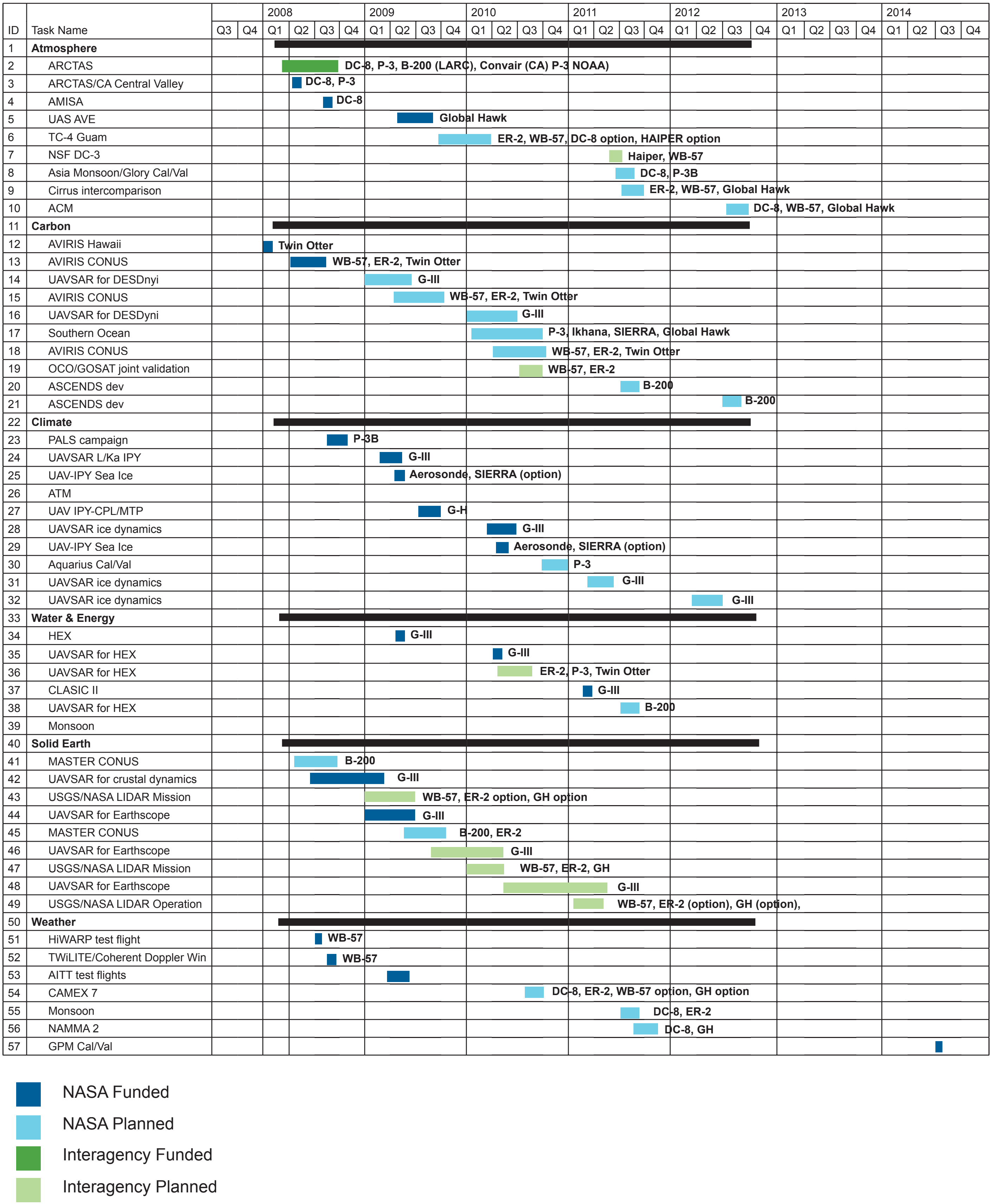
In addition, we flew an Aerosonde UAS from the edge of Hurricane Noel to the eye between 500 and 300 feet. We were able to perform several vertical profiles in the storm from 300 to 5000 feet. This was a remarkable joint mission with NOAA in performing our first opportunity to monitor the Hurricane Boundary Layers processes. These successful UAS missions flying in the National Airspace along with our addition of the Global Hawks are the result of years of effort working with multiple agencies, universities and industry to be able to fly missions that now allow UAS programs to truly obtain data that have previously been out of the reach of the science world.

UAS-related IPY activities planned for 2008 include flights of Aerosonde out of northern Canada, and instrument development and flight planning for Global Hawk and UAV-SAR.

Our available capacity on NASA aircraft is being utilized on a reimbursement basis by multiple agencies throughout the government. This is essential to allow us to operate the program at a manageable cost to NASA, thus saving platforms that science uses to accomplish our primary mission at affordable costs. Some of these reimbursable operations have supported the other agencies' critical sensor development and demonstration requirements both nationally and internationally. During this last year we received reimbursement from DOD, DARPA, OSD, DoS, USGS, DOE, NOAA and DHS. In fact, our support of DHS Science and Technology on the ER-2 received presidential acclamation. We expect to continue supporting reimbursable activities, keeping this program a truly cost effective national asset.

All the activity that the Airborne Science Program has embarked on will strategically position this organization to support the science data collection needed to understand Global Climate Change affects and model development. In combination with NASA's satellite program, we will be able to calibrate and validate the agencies space assets. In addition, the Airborne Science Program will be able to rapidly place advanced sensors or obtain greater resolution spatial and temporal data for our science customers. They need the data to build the models that will make predictions, which will in turn advise our policy makers and support our societal needs. The opportunities are grounded by the realization that the Airborne Science Program can make a difference in the lives of everyday people through the science discoveries enabled by NASA's airborne assets, and that addressing many compelling and complex science questions are made possible through the Program's dedicated people and capabilities.

Appendix 1: Airborne Science Program Five Year Plan



Appendix 2:

The Origins of an Airborne Earth Science Program at NASA

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

In an effort to recognize the past giants of this program, upon whose shoulders the current team now stands, this and future reports will highlight individuals that have served NASA and our nation in the past. We thank Bernard (Barney) Nolan for contributing to this first installment of the history of the airborne science program at NASA. He was the first NASA HQ manager for airborne science in 1970.

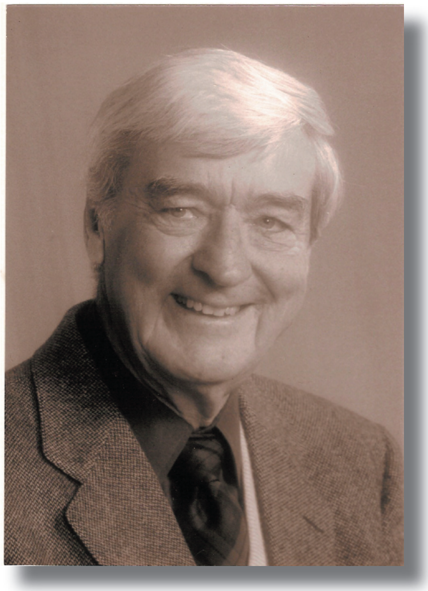


Fig. 51: Bernard (Barney) Nolan.

Before taking the helm as NASA airborne science manager, Nolan was chief of program review for Office of Space Science and Applications (OSSA), with a background as an Air Force pilot and experience in aircraft accident investigations. His past work included work on a string of Delta launch vehicle failures. During this period he worked with Vince Johnson, Deputy of Engineering for OSSA, as a member of the Delta Failure Review Board, which he chaired. Johnson later became Chief of Engineering and asked Nolan to be the first manager of the geophysical research aircraft programs at NASA centers.

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

During the late 1960s and early 1970s NASA was involved in airborne observations at several NASA centers including Ames Research Center (ARC), Glen Research Center (GRC, then Lewis Research Center), Wallops Flight Facility (WFF) and Johnson Space Center (JSC). These airborne research activities were primarily tuned to providing airborne platforms for remote and in situ sensing devices.

Aircraft operations at ARC consisted of a Convair 990 (Figure 52) and a Learjet primarily to support atmospheric science activities such as those of Bill Nordberg at Goddard Space Flight Center (GSFC). Headquarters (HQ) involvement at the time would be through the staff scientist who would have oversight of that activity assuring a focus on the scientific data output. The aircraft also supported emerging remote sensing investigations leading to Landsat (then the Earth Resources Technology Satellite). The Ames CV 990 and Learjet also supported an array of astronomy projects thus adding a space science component.

Fig. 52: The mid-altitude Convair 990 research aircraft over Lake Tahoe, 1976.

The JSC OSSA-funded effort included three aircraft operating from Ellington AFB: a P3A, C-130 (Figure 53), and a WB-57F. The latter was initially operated by the USAF for NASA under an agreement but later acquired by NASA when the USAF operation folded. Project management at JSC in 1970 was under Ole Smistad; the HQ program manager was John Koutsandreas. At that time, the project then was called the Earth Resources Aircraft Program (ERAP). In addition to the sensor packages flown in the JSC aircraft, there was a component of sensor development included in the JSC project. Two in particular come to mind: a Bendix 24 channel multispectral scanner to be flown in the C-130, and the SIS, a scanning interferometer/spectrometer, to be flown in the P3.

At the time JSC airborne support for emerging remote sensing activities included not only NASA but also several scientists in other agencies: USGS, NOAA, U.S. Army Corps of Engineers, and USDA. Funding for the aircraft operations and data acquisition that provided remote sensing data to the various interagency investigators was covered exclusively by NASA. There was no pay-to-play process imposed on the other agencies at the time. Eventually this would be an issue and the process changed in subsequent years. Flight requirements from the NASA and interagency investigators were defined at semi-annual meetings conducted by Smistad at JSC. I attended these meetings and, as I recall, the FY1970 funding for UPN 640 was $11 million, a laughable amount in today's market.


Fig. 53: The C-130 in front of hangar at then NASA Lewis Research Center in 1974.

In the spring of 1971, a crop blight infestation hit the country's corn belt. There was widespread public interest in the problem as well as congressional interest on Capitol Hill, especially with representatives of the corn growing states. We received urgent requests for aircraft coverage in those states to get color infrared images that distinguished healthy from infested fields. The JSC aircraft were used to acquire extensive photo imagery in these areas. The HQ lead person on the scene was Dr. Arch Park. All this had the effect of drawing attention to what we were doing with aircraft as well as a practical demonstration of remote sensing capabilities on the large scale, multispectral and temporal coverage promised by Landsat.

At this juncture, Landsat was in the late stages of development and less than two years from launch. The scientific thrust for the JSC aircraft was Earth resources. This anticipated the satellite imagery that the Landsat Multi Spectral Scanner (MSS) and Return Beam Vidicon (RBV) would acquire for about 200 investigators who needed these data for their investigations. It is important to note that these investigators were not yet exposed to the characteristics of the multispectral images that would be supplied by the Landsat MSS.

Also in 1971, great interest was expressed by HQ staff in acquiring high altitude aircraft capability. ARC's Airborne Science Office was lobbying for a C-141 to be equipped with a 36 inch infrared telescope for astronomical observations well above the bulk of the Earth's atmosphere. This effort would eventually bear fruit. The C-141 acquired by NASA was added to the USAF production contract by Lockheed who was pursuing the idea of promoting a commercial market. At the time, I was involved in the acquisition of the C-141 as the OSSA contact at headquarters.

The Earth resources thrust for the high altitude platform was motivated by a need to simulate Landsat and also to obtain in situ measurements in the upper atmosphere. It was known at the time that the USAF was phasing out the U-2C, and the prospect for acquiring one for NASA's airborne research activities was now possible. Negotiations for acquiring a surplus U-2C began in earnest in the spring of 1971 under Dr. John De Noyer, then head of the Earth Resources Division of OSSA. With assistance from NASA's Interagency Affairs Office, we initiated a plan to make that goal a reality. I handled the documentation and prepared the justification as to how the aircraft would be used to support the program. The justification offered by Park and De Noyer was to conduct a simulation of the Landsat MSS. Test sites would be established in the key areas of the east and west sections of the country, thought best to support most investigations. There was a good deal of resistance among NASA senior management: the Gary Powers incident was fresh in their memories and the spy plane perception that was associated with the aircraft. However, John Naugle, then head of OSSA, supported the operational planning. The acquisition ultimately wound its way through many staff iterations to approval by the NASA administrator for not one, but two U- 2Cs to be transferred from the USAF inventory. Issues such as recruiting pilots and general logistical support for the aircraft and ground equipment surfaced among the staff but these were resolved in due time.

Fig. 54: U-2 aircraft, photographed May 6, 1960, at DFRC with fictitious NASA markings to support cover story for CIA pilot Gary Powers, shot down over the Soviet Union on May 1.

Where to base the U-2s was a topic of much discussion during this period. I intended to position both aircraft at Ellington AFB as a component of the JSC Earth Resources Aircraft Program. However, JSC management favored conducting the high altitude effort with the WB-57F, thereby offering comparisons of performance, especially the greater payload capacity of the aircraft, the two man crew, and concerns over the safety record of the U-2. Hans Mark resolved that problem very quickly by offering to have the two U-2s based at ARC.


Fig. 55: Marty Knutson, U-2 Project Manager, during media day for arrival of U-2 aircraft at ARC in 1971.

Marty Knutson, an experienced U-2 pilot, now entered the scene as the ARC project manager. What remained at this juncture was the interagency agreement with the USAF for the transfer of the two aircraft. I handled the paperwork in this process and the requisite extensive staff coordination. Knutson made the necessary USAF contacts to define areas that needed to be addressed for continuing logistics support for the aircraft. He came to HQ in the summer of 1971 for this purpose. Together, we worked the agreement through the NASA staff coordination process and ultimately hand-delivered the agreement to USAF Headquarters.

Knutson came on board with Jim Barnes (Figure 55), Bob Erickson (Figure 56), and Ivor “Chunky” Webster (Figure 57), all seasoned U-2 pilots. Knutson made it very clear that he was to be one of the pilots. He brought with him some people and a host of support equipment for the aircraft in addition to an array of camera systems. When I first saw all this I was utterly amazed and have yet to understand how he did it, nor did I ask any questions. Knutson tied logistics support for the aircraft into the USAF/Lockheed maintenance system and worked out the deployment scenarios for operating over test sites on both coasts, special fuel (JP7) included. He also resolved the problem of

U-2 pilots (left to right): Jim Barnes (Fig. 55), Bob Erickson (Fig. 56), and Ivor "Chunky" Webster (Fig. 57).

simulating Landsat MSS data by ganging together four Hasselblad cameras with film selections to follow the MSS wavelengths as closely as possible. Following that, a film processing and archiving facility was set up at ARC to handle the data acquired.

The Ames U-2s routinely provided simulated Landsat MSS data to investigators right up to the time the satellite was launched in 1972. Additionally, with permission of Mark and the acquiescence of HQ staff, Knutson fielded and supported requests from the governors of Alaska and Arizona for reimbursable wall-to-wall high altitude photo mapping of their states.

From where I sat at this time, operations at both JSC and Ames were effective and trouble free. My primary focus was on providing a seat of advocacy, addressing broad requirements, fielding congressional and other inquiries, reporting progress, resolving issues requiring staff attention, defending the program, and preparing annual justification for funding requirements.

Fig. 59: ER-2 in front of ARC hangar in 1977 with a display of the possible payload configurations.

The early 1970s was an era when the applications program got hot in the public eye and on Capitol Hill. In 1972 OSSA became the Office of Space Science (OSS), and the applications programs were set up in a new Office of Space and Terrestrial Applications (OSTA), thereby giving those emerging programs emphasis. Chuck Mathews headed the new office. The JSC aircraft were still supporting an array of Earth resources investigations. In addition, JSC and ARC aircraft also acquired photographic coverage of tornado, hurricane, and earthquake damage that caught the public's interest well outside of NASA's principal focus on space. With applications flourishing in the public eye and becoming a buzz word for supporting programs, Mathews decided to establish lead centers for disciplinary programs and to take advantage of the wealth of expertise at NASA centers. JSC became the lead center for Earth Resources (ERAP) and Goddard for Atmospheric Research.

However, Mathews was always concerned about the lack of oversight for the diverse aircraft activities at various NASA centers and decided to set up another lead center for aircraft at Ames. Ed Gomersall was brought in from NASA HQ to head that new office. His task was to gather some visibility over the diverse airborne support for research tasks at the centers, including those at Lewis and Wallops. Gomersall had a small staff for this purpose when he set up shop at ARC. Gomersall was able to inventory the sweep of aircraft support activity across the centers and developed an effective flight request methodology for users. He also led an unasked for study of the economics of U-2 versus Landsat coverage of the U.S. Meanwhile, I dealt directly with Smistad who continued to run JSC's ERAP, as well as Marty Knutson and Don Mulholland at ARC. It was business as usual.

The loss of Galileo 1 in a mid-air collision at Ames on April 13,1973 ushered in another shift in the Airborne program. The deaths of 11 of our people was a traumatic experience for the Airborne Science Office at Ames, then led effectively by Don Mulholland who called me at home to inform me of the accident. I, in turn, called Mathews. Mulholland lost no time in launching an effort to find a replacement for Galileo. Mulholland's persistent efforts located a CV990 aircraft in Indonesia. However, the aircraft only could be restored to operations with a complete overhaul. The issue was funding. Mathews agreed to fund the recovery effort through the 640 program and gave the go ahead to acquire the aircraft. The aircraft was purchased and flown to Hong Kong, with the gear down, to an overhaul facility before it arrived at ARC fully operational. The operation became an integral part of the 640 program.

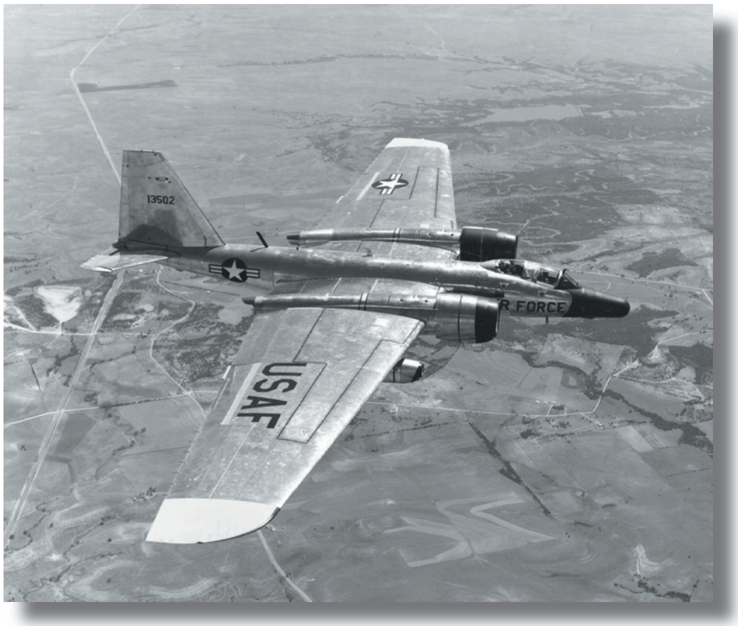


Fig. 60: USAF's WB-57F.

With all this, I recognized a shift in the support role of the airborne program and promoted efforts to include other geoscience disciplines in addition to Earth resources, in particular the atmospheric sciences. Unlike the JSC aircraft and the Ames U-2s, Galileo provided a shirtsleeve environment for investigators along with view ports and racks for their sensing devices as well as an onboard data recording system. Atmosphere and astronomy were among the disciplines supported. This gave new emphasis to the program as an interdisciplinary facility, and the NASA user community was embraced accordingly. I have always regarded this expansion of the user community as a significant turning point in the evolution of the program.

In 1973 we were approached by the Department of Energy to take over WB-57F operations for Project Airstream, which was being discontinued by the USAF. I was involved along with Smistad in developing the necessary interagency agreement with DOE for the operational phase of the project. Airstream was designed to monitor atomic tests. It involved high altitude flights along a north-south track spanning the West Coast to Panama with sensors that captured in situ air samples aimed at detecting airborne debris of atomic tests. A second WB-57F aircraft was acquired from the USAF by JSC for Project Airstream, and the effort went forward smoothly.

By 1974 another shift in airborne support requirements appeared with the evolving Space Shuttle program. The NASA HQ program offices were all busy defining experiment packages that would be flown in the Shuttle's payload bay in Spacelab's system of habitable modules and pallets. Mathews recognized the CV990 operation at ARC as a prototype of the Spacelab/Shuttle environment. At the same time, the Airborne Science Office at Ames under Mulholland was promoting a concept of using an aircraft to simulate the Spacelab operational environment by isolating the participating scientists (later defined as payload specialists) in an aircraft for up to seven days but conducting actual experiments in a series of flights. The basic idea was to observe their interaction and define the interface with the flight crew. A prototype Spacelab simulation mission was conducted with the Ames Learjet. By the end of 1974 planning for an expanded effort involving the European Space Agency (ESA) with the CV 990 was in progress. It was called Airborne Science/Spacelab Experiments System Simulation (ASSESS). The mission was completed successfully at Ames in June 1975 after which our European partners pressed for a second ASSESS mission. Approval was given to conduct ASSESS II in late 1975. I was designated as the OSTA program manager and worked with Bill Armstrong of the Office of Manned Space Flight to provide oversight for the mission. We worked with Dai Shapland of ESA. ASSESS II was flown in May 1977.

As planning for the Space Shuttle unfolded, managing the integration of Spacelab payloads at the NASA HQ level ushered in new dimensions in organization structure and staffing. As a result of my involvement with CV 990 operations and ASSESS II in particular, Mathews looked my way when he decided to organize a focal point for Spacelab payload integration within OSTA. Mathews handed me the task of writing a functional statement and job descriptions for this purpose, and I was given the job of leading the new staff activity. Gar Misener and Ray Arnold were assigned to work with me. The airborne program was folded into this new office, and I continued my role as program manager but was also assigned as program manager for Spacelab 2 and one of the Shuttle orbital test flights for which experiments were planned.

The Mathews era ended in 1976. He was succeeded by Bradford Johnson who was hired by senior management for his marketing background. Landsat was flourishing, and becoming an operational rather than an experimental system. Enter the Earth Resources Operational System (EROS). The idea was to transfer the operational program to the Dept. of the Interior and set up an EROS data center at Sioux Falls, South Dakota, where Landsat data products would be archived and sold to the public.

Johnson’s tenure lasted for a year. He was succeeded by Tony Calio in late 1977. Sam Keller, who was a good friend of the airborne program, became his deputy. This was a time of transition for me. Also, it was a time when an issue surfaced about how best to maintain and manage aircraft involved in space science and applications programs. Conventional thought in the senior staff was to consolidate these assets at a single location (as I wanted to do with the U-2s at JSC) thereby producing savings in maintenance contracting and logistics. A committee was formed to study such prospects and Calio asked me to participate for the OSTA. The committee’s thinking was to develop a scenario for putting it all together. I found myself in a quandary, negative to the basic idea and with split loyalties to the groups at JSC and Ames. I realized at the time that I was being ruled by emotions driven by loyalty, and could not be objective. In a sense, I became part of the problem. Well within the retirement threshold, I began to consider stepping aside.

It was at this point that my tenure as the manager of the airborne program ended. The Shuttle payload integration office was now run by Charles Pellerin and the airborne issues were under his aegis.