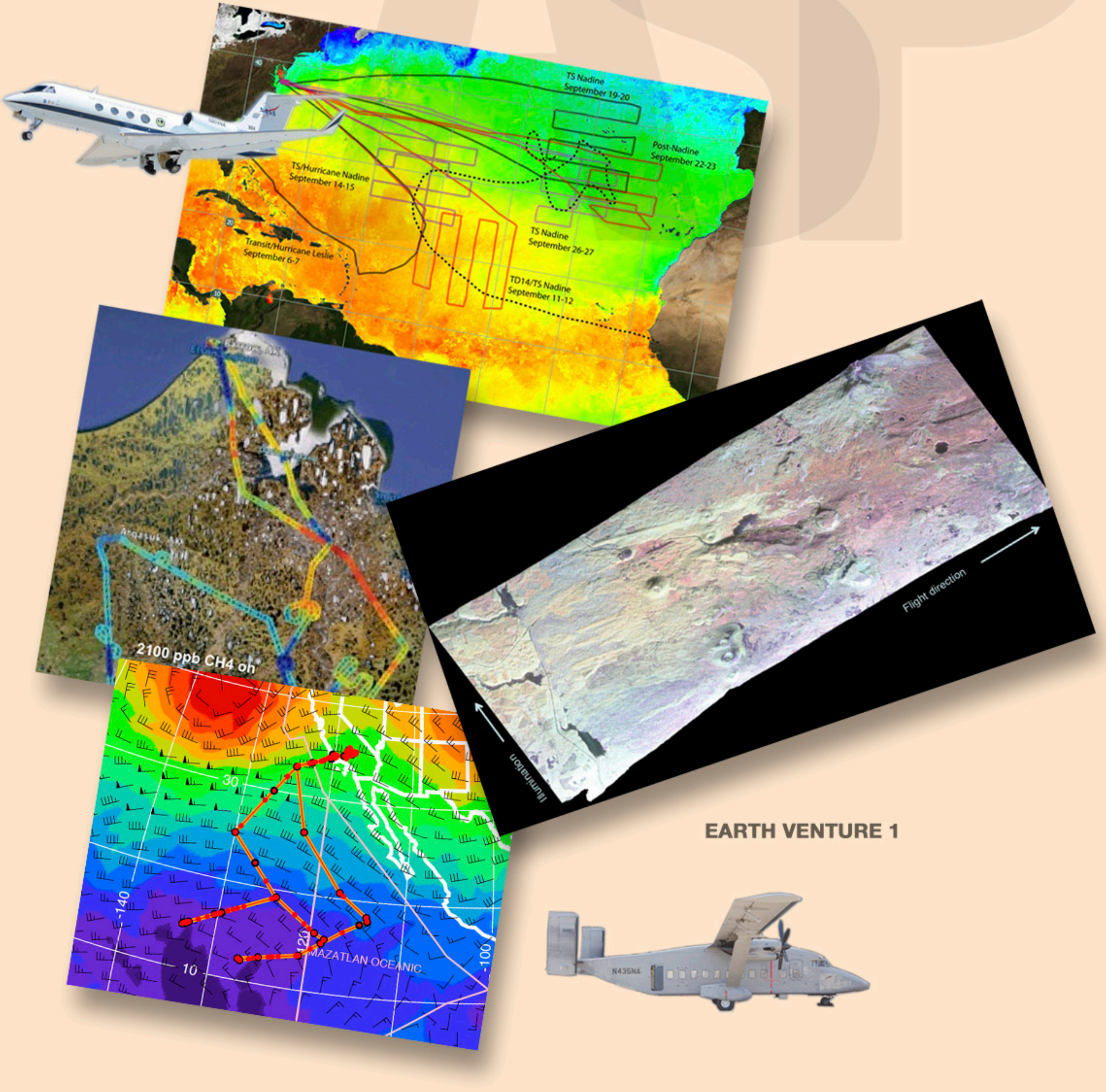
NASA AIRBORNE SCIENCE PROGRAM
2012 Annual Report



EARTH VENTURE 1

Cover caption*: Composite images highlighting Earth Venture-1. (Counter-clockwise from top) HS3 flight tracks in the Atlantic; CARVE team observed* CO_2 *and* CH_4 *on the North Slope; ATTREX flight tracks of first flights in October 2011; first science image from AirMOSS: Geolocated P-band polarimetric image over AirMOSS biome, Metolius (north of Sisters, OR).*

NASA Airborne Science Program

Annual Report

2012

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ASP LEADERSHIP

I'd like to start this year's Airborne Science Program Annual Report by saying thank you to our customers and program people for making this year the busiest on record! We flew over 3800 hours total with over 3300 hours flown for science.

We flew this year for Earth Venture 1: CARVE in Alaska, AirMOSS in California and various states within range of the G-III, and deployed a Global Hawk for the first time to Wallops Flight Facility. In addition, the ICESat-2 MABEL instrument, CATS and CPL flew on the ER-2; AVIRIS next generation, HYTES, and PRISM flew on Twin Otters and let's not forget another exciting deployment of the DC-8 to Chile for Operation IceBridge. We were supposed to head to Thailand for SEAC4RS but that got pushed a year and actually that was probably a good thing with all the other work we ended up doing. It's a testament to the great people that work the program that we accomplished so much in such a safe and effective manner. One person we want to thank specifically is Capt. Phil Hall of NOAA, who has been Global Hawk deputy project manager.

Randy and I thank you for taking the time to read this year's annual report and hope that you find this edition informative, and interesting, as well as thought provoking. What do I mean by thought provoking? Well, take a look at where and why we fly and hopefully it will lead to some new, interesting, and revealing Earth Science. I continue to seek input from you to make this program even more successful and useful for the scientific community. As a reminder: The NASA Airborne Science Program (ASP) exists to enable scientists to achieve NASA Earth science objectives and answer science questions that require the use of airborne platforms and infrastructure. The Program operates and manages a set of capabilities traceable to Earth Science Division requirements.

ASP Vision: Build on our Airborne Science Program foundation, to continually improve our relevance and responsiveness to provide airborne access to the Earth Science community.

Program Mission Statement: ASP enables Earth Science researchers and scientists to improve society's understanding of Earth system science by providing a pre-eminent suite of airborne capabilities that meet NASA Earth science requirements. ASP accomplishes its mission by:

- Fostering a team of energetic, safety-conscious, and customer-focused experts;
- Ensuring the capabilities it offers are safe, affordable, robust, modern, and meet the needs of the Earth science community;
- Continuously improving the relevance and responsiveness of airborne capabilities it makes available to the Earth Science community.

Bruce Tagg
Airborne Science Program Director

I. PROGRAM OVERVIEW

The airborne science program (ASP) is an important element of the NASA Science Directorate and the Earth Science program. ASP supports NASA Earth Science in the following capacities:

- Process studies
- Satellite mission instrument development, algorithm development and calibration and validation activities
- Instrument test
- Workforce development / next generation scientists

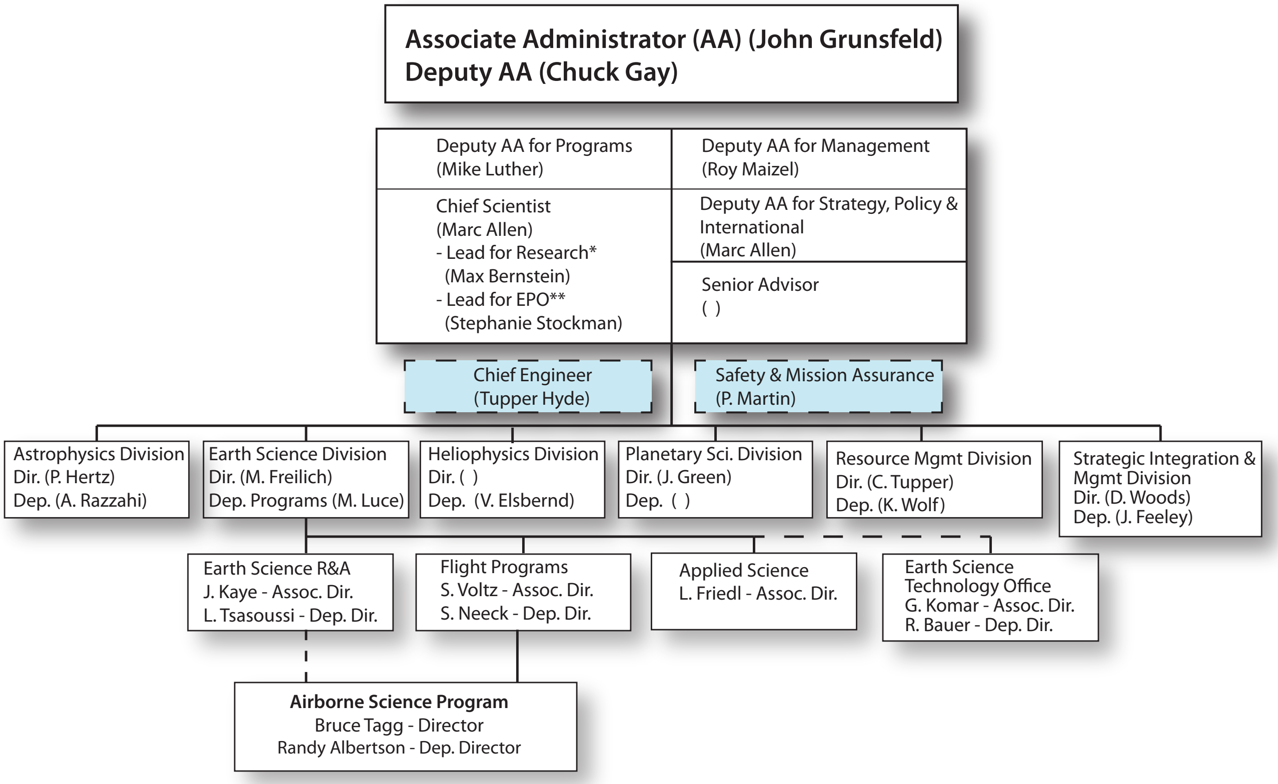


Fig. 1: SMD Organization chart for NASA Science Mission Directorate (SMD).

Structure of the Program

Figure 1 shows the role of the Airborne Science Program within SMD. Figure 2 shows the components of the Airborne Science Program.

The aircraft responsibilities are distributed among the NASA centers where the aircraft are maintained and operated.

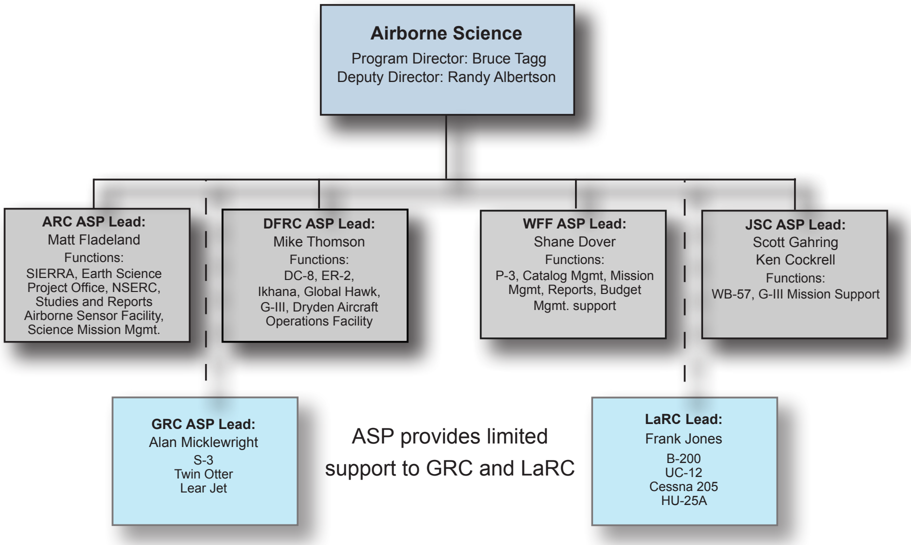


Fig. 2: Airborne Science Program Organization chart

FY2012 Capability Additions

Fig. 3: First landing of Global Hawk at WFF. September 6, 2012.

Highlights of the capability additions to the ASP program in 2012 include the new ability to operate one of NASA's Global Hawk UAS from Wallops Flight Facility (Figure 3). This capability enables the far reach of the Global Hawk across the Atlantic Ocean for hurricane studies and also to the far northern Arctic for cryosphere studies.

Another major capability completed in 2012 is the sensor network, now making tracking available for all core platforms. This system includes a high-speed onboard network to stabilize and improve data telemetry speeds, enable flight tracking, and allow remote instrument operations. The full suite of mission tools is described in Section 5 and online at airbornescience.nasa.gov/MTS.

Flight Request System Summary

The Airborne Science Program maintains aircraft and sensor assets to support the NASA SMD in achieving its science objectives as defined by the President and Congress. The flight request system manages and tracks the allocation of the ASP aircraft and facility sensors. The Science Operations Flight Request System (SOFRS) is a web-based database to facilitate the review and approval process for every airborne science mission using NASA ESD funds, personnel, instruments or aircraft. Requests for these assets and the scheduling of their use are accomplished through SOFRS. This system was designed to allow researchers that are funded by NASA or other agencies to have access to unique NASA aircraft, as well as commercial aircraft with which NASA has made contracting arrangements. The only way to schedule the use of NASA SMD platforms and instrument assets is to submit a Flight Request for approval through SOFRS (http://airbornescience.nasa.gov/).

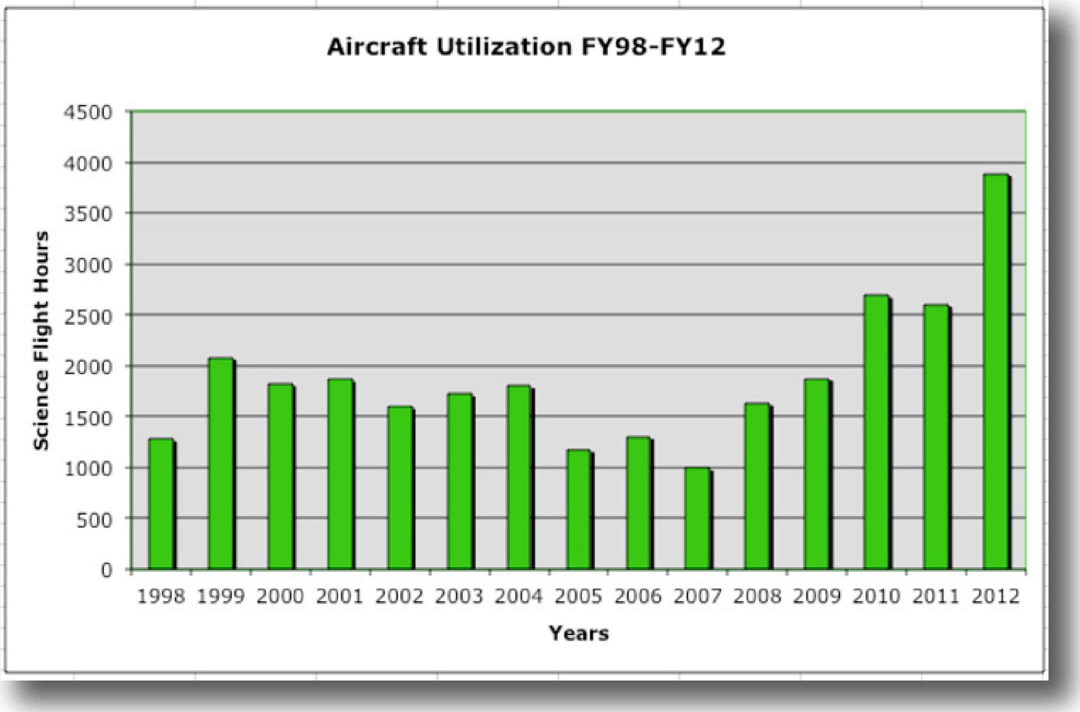


Fig. 4: Total flight hours over the past 15 years (includes science, test, and pilot proficiency.

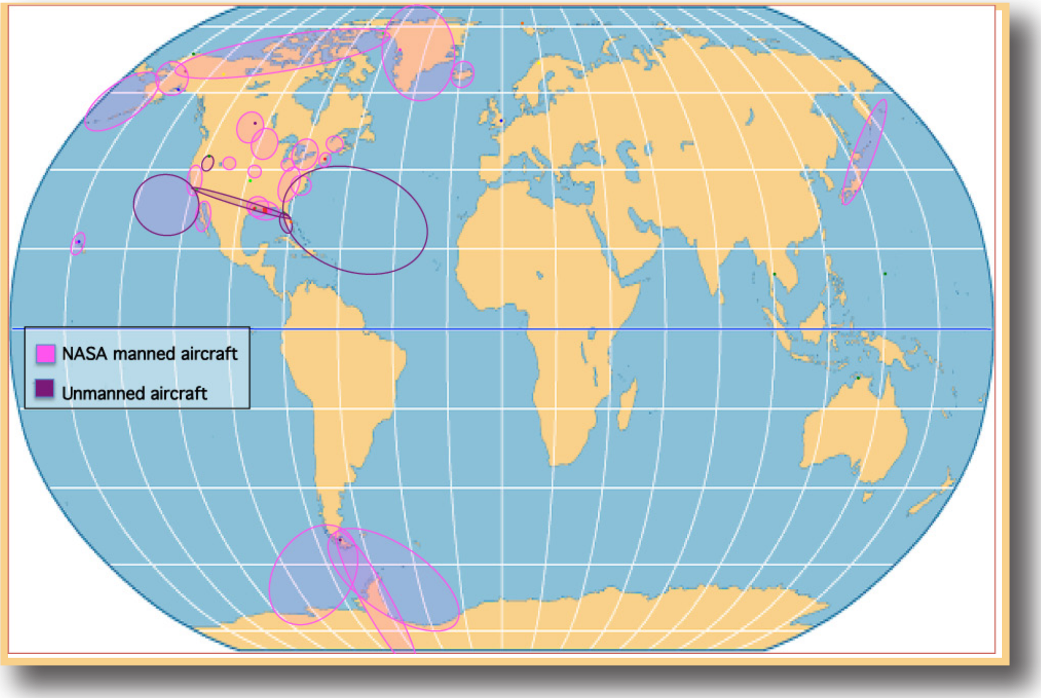


Fig. 5: Locations of airborne campaigns in FY2012

The SOFRS team strives for continuous improvement by improving the interface with users and the data products. In 2012, the focus was again on making additional reports available to HQ from the data collected in the Flight Request System and on making modifications in the flight request to collect additional requested data.

Flight Requests for 2012

The annual Airborne Science Call Letter was distributed in July of 2011. There were 228 flight requests submitted in FY2012. Eighty requests were completed, some were deferred and the rest were withdrawn or canceled depending upon the availability of resources at the time of the request. The details are listed below.

Flight requests were submitted for 16 Airborne Science supported aircraft platforms and 12 other platforms and flew more than 3800 flight hours in all, as shown in Table 1 (Page 6). Several large campaigns were successfully conducted this year (Operation IceBridge, SMAPVEX, HS3, CARVE, GCPEX and more). The flight hours flown are shown in Figure 4. Again in 2012, NASA ASP flew missions around the globe, as indicated in Figure 5.

Aircraft	Total FRs	Total Approved	Total Partial	Total Completed	Total Hours Flown
DC-8	10	7	0	4	533.1
ER-2	36	24	3	15	443.2
P-3	14	7	0	5	410.2
WB-57	5	3	0	3	29.7
Twin Otter	33	14	2	11	429.2
B-200	17	10	0	7	157.2
G-3	36	28	8	16	623.8
Global Hawk	3	2	1	1	219.8
C-23 Sherpa	1	1	0	1	257.9
Cessna 206	2	2	0	2	99.3
Falcon - HU-25	1	1	0	1	75.5
Ikhana	11	0	0	0	0.0
Learjet 25	1	1	0	0	0.0
S-3 Viking	1	0	0	0	0.0
SIERRA	33	2	1	1	31.6
T-34	1	1	0	1	37.6
Other	23	16	1	12	539.7
TOTALS:	**228**	**119**	**16**	**80**	**3887.8**

Table 1: Aircraft, flight requests and total hours flown in FY12, not just SMD.

NOTES:

- Some of this year’s flight request’s total hours include hours flown during FY11 in cases where flight requests were deferred and completed in FY12. This will not be the case in future years, due to the fact we have implemented a system to record partially completed flight request hours in the proper FY.
- These totals are based on the flight request’s log number, and therefore include all flight requests whose log number starts with “12”.
- The “Total FRs” column includes all flight requests that were submitted and whose log number starts with “12”.
- The “Total Approved” column includes flight requests that were set to a status of Approved or Internally Approved at some point.
- The “Total Completed” column includes only flight requests whose final status is Completed or Completed (Pending).
- The “Total Hours Flown” column includes all “Flight Hours Flown” for flight requests with a status of Open, Approved, Internally Approved, Completed, Completed (Pending) or Partial for 2012. For multi-year missions, this may include hours flown in years prior to 2012.
- Other aircraft includes: Alphajet, BAT4, BE-76 Beechcraft Duchess, Purdue University Airborne Laboratory for Atmospheric Research, BT-67 (DC-3T), Cessna 172, CIRPAS Twin Otter, Falcon - HU-25, FS King Air, NSF G-V, Otter DHC-3, Piper Cherokee PA-32, PNNL G-1, RMAX UAV helicopter, SDSU Sky-Arrow, SPAARO (VA Tech UAS), TOI-CARVE, Twin Otter International, UND - Citation, Zeppelin NT, Alphajet, BAT4, BE-76 Beechcraft Duchess, Purdue University Airborne Laboratory for Atmospheric Research, BT-67 (DC-3T), Cessna 172, CIRPAS Twin Otter, Falcon - HU-25, FS King Air, NSF G-V, Otter DHC-3, Piper Cherokee PA-32, PNNL G-1, RMAX UAV helicopter, SDSU Sky-Arrow, SPAARO (VA Tech UAS), TOI- CARVE, Twin Otter International, UND - Citation, Zeppelin NT

II. SCIENCE

The Airborne Science Program conducted over 3300 science flight hours in support of NASA's Earth science missions during FY 2012.

NASA Airborne Science platforms were actively engaged in mission definition and development activities, including instrument development flights supporting future satellite mission definition (Ice, Cloud and Land Elevation Satellite - II (ICESat-2)), gathering ice sheet observations as gap fillers (Operation IceBridge), and serving as technology test beds for Instrument Incubator Program (IIP) missions and satellite calibration and validation (GPM and SMAP). The Airborne Science Program conducted over 20 missions and deployed field campaigns, utilizing more than 16 NASA manned aircraft and unmanned aircraft systems (UASs) to support science and technology investigations across the six Earth science focus areas (Atmospheric Composition, Carbon Cycle and Ecosystems, Climate Variability and Change, Weather, Water and Energy Cycle, and Earth Surface and Interior). Flight hours for the largest missions are shown in Table 2. The program also involved students in many activities. In all, 129 undergraduate and 229 graduate students, representing over 40 universities, directly participated in Airborne Science investigations and student-led flight projects.

Mission	Aircraft	Location	Flight Hours
Operation IceBridge	P-3, Single Otter, Falcon, DC-8	Arctic (Greenland), Alaska, Antarctic	938
UAVSAR	G-III	CONUS, Mexico, Iceland	445
HS3	Global Hawk	Atlantic Ocean, Pacific Ocean	327
CARVE	Sherpa	Alaska	258
SMAPVEX	P-3, Twin Otter, G-III	Manitoba Canada, San Joaquin Valley	191
MABEL	ER-2	Iceland, Canada	212
DC-3	DC-8	Kansas	139
GCPEX	DC-8, Citation	Great Lakes	125
G-LiHT	UC-12B, Cessna 206H	LaRC, WFF, Maine	104
ATTREX	Global Hawk	DFRC / Pacific Ocean	71
DEVOTE	UC-12B, B-200	LaRC	69

Table 2: Summary of major ASP missions in FY2012.

Major Mission highlights

Major accomplishments of the FY 2012 Airborne Science Program include airborne science platforms supporting the Operation IceBridge and the Earth Venture-1 (EV-1) projects, preparation for upcoming satellite missions SMAP, ICESat-2 and GPM, and multiple uses of SAR imagery from the UAVSAR system.

Operation IceBridge (OIB)

Operation IceBridge is the largest airborne survey of the Earth's polar ice ever flown. It is yielding a three-dimensional view of the Arctic and Antarctic ice sheets, ice shelves and sea ice. These flights provide a yearly, multi-instrument look at the behavior of the polar ice sheets to determine their contributions to current and future global sea level rise and help understand the connections changes in sea ice cover and the Earth system.

Data collected during Operation IceBridge helps scientists bridge the gap in polar observations between NASA's Ice, Cloud and Land Elevation Satellite (ICESat) -- which

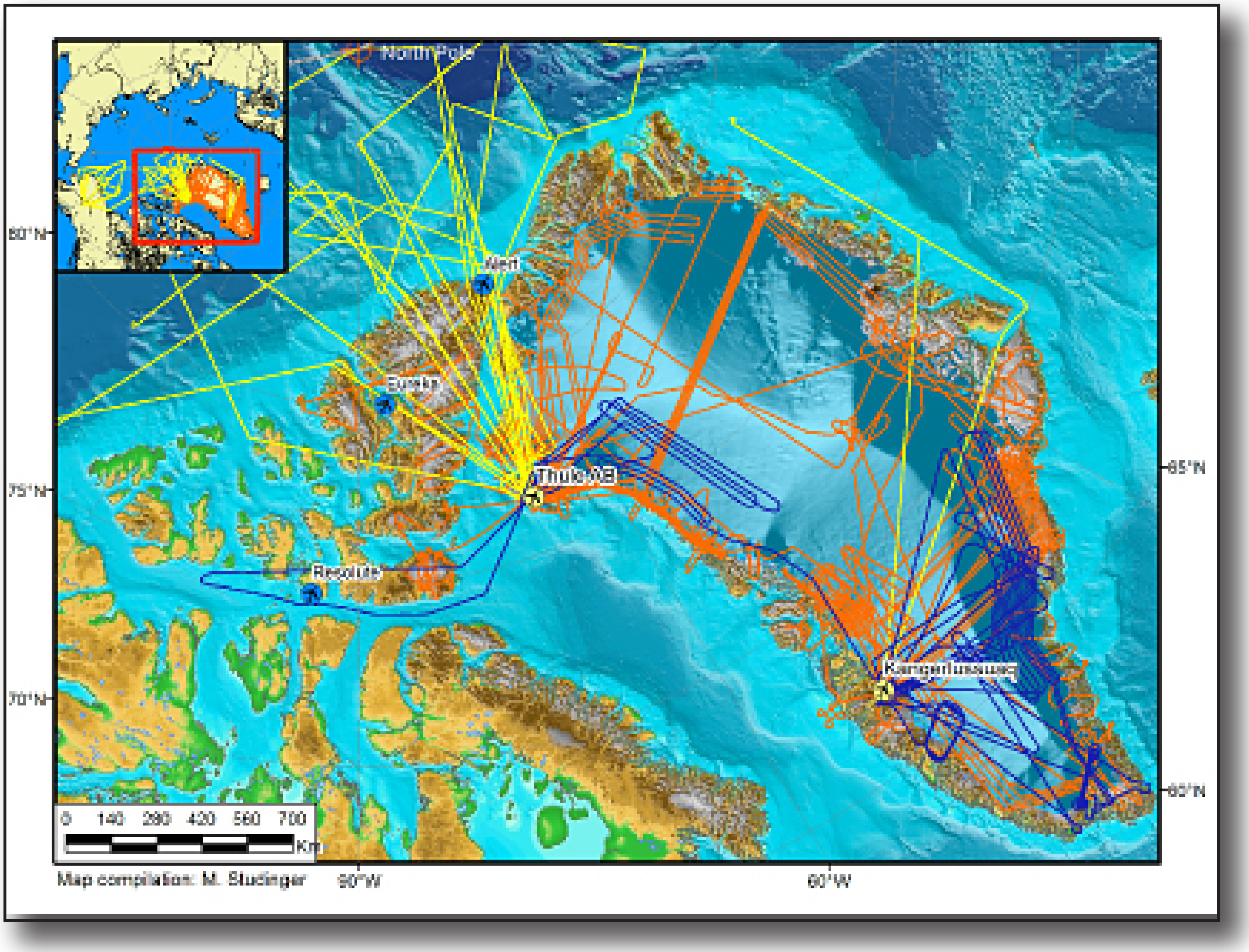


Fig. 6: OIB 2012 flight lines. Orange lines indicate P-3 with ATM flying land ice. Yellow lines indicate P-3 flying sea ice. Blue lines indicate HU-25 Falcon flying LVIS.

Fig. 7: Frozen fjord along northeast coast of Greenland as seen from the P-3. (Photo: Jim Yungel)

stopped collecting science data in 2009 after operating for twice its design lifetime -- and ICESat-2 planned for launch in 2016. Operation IceBridge is critical to ensuring a sustained series of observations of the most dynamic portions of the great Greenland and Antarctic ice sheets. Operation IceBridge is jointly sponsored by the Airborne Science Program and the Earth Science Directorate Cryosphere Program.

During FY2012, the Airborne Science Program conducted two major OIB campaigns including:

> *Arctic Campaign*: This campaign used two ASP platforms (P-3 carrying ATM and HU-25 Falcon carrying LVIS) and one aircraft from the University of Alaska, Fairbanks (UAF) (Otter carrying a laser altimeter) to conduct surveys to measure the change in land and sea ice from Greenland to Alaska to provide insight into the global sea level rise. It is also providing the most accurate measurements ever of changes in Arctic sea ice thickness, which is critical to understanding how changes in the ice are coupled to the ocean and atmosphere. The P-3 and Falcon flew from Thule AB. In total, there were over 600 OIB flight hours in the Arctic. Other missions in the Arctic collaborating with OIB included the ER-2 carrying MABEL and the G-III carrying UAVSAR, both flying from Iceland. Flight lines are shown in Figure 6.
>
> *Antarctic Campaign*: This campaign used one NASA ASP platform (DC-8), one NSF airborne platform (G-V), and a contracted airborne platform from the University of Texas to conduct surveys to measure the change in land and sea ice in the Antarctic to provide insight into the global sea level rise. It covers the most dynamic parts of the Antarctic ice sheet in sufficient detail to yield direct improvements to ice sheet models critical to predicting current and future sea level rise. The flight lines of the Antarctic are shown in Figure 7.

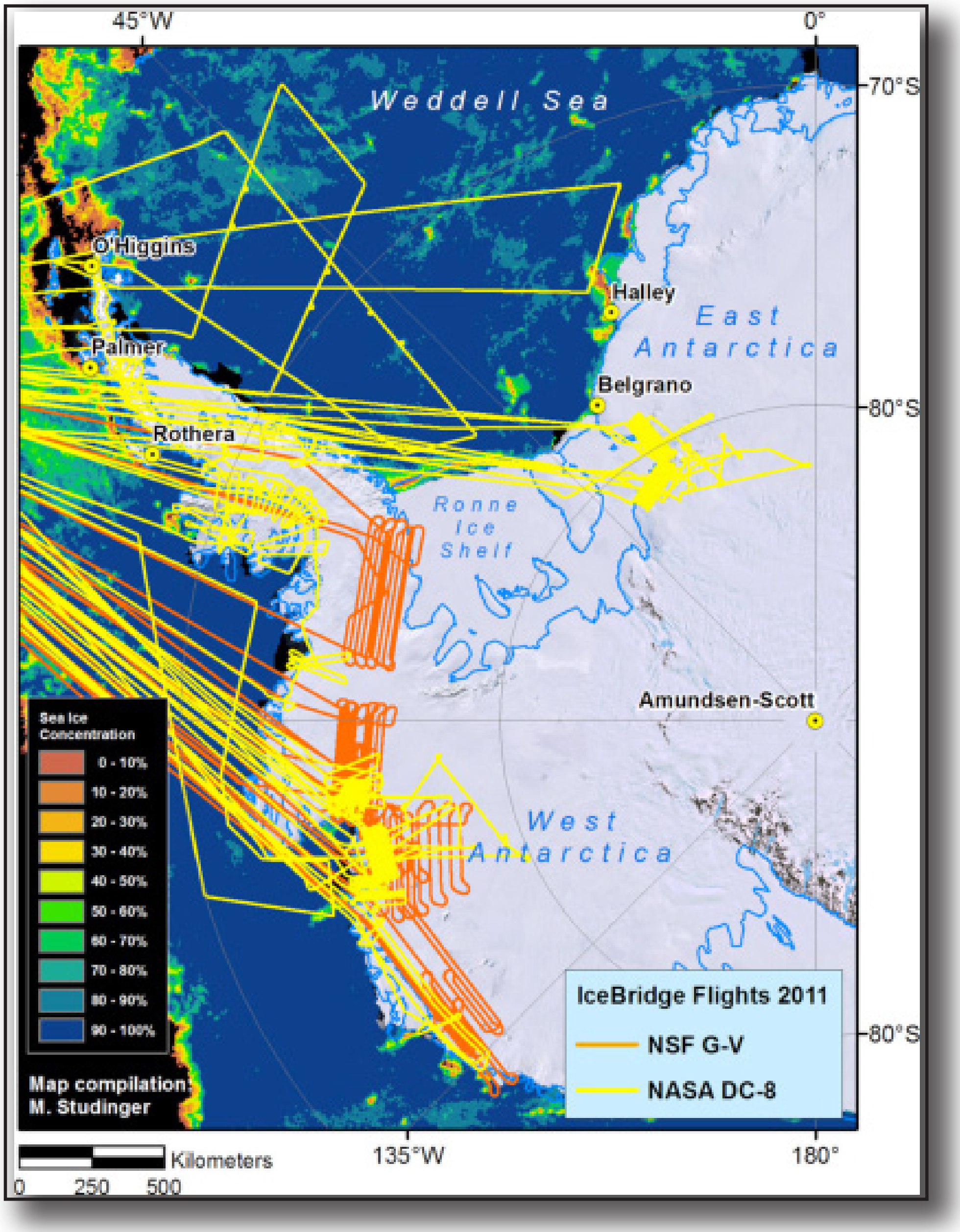


Fig. 8: OIB Antarctic flights in FY 2012 (fall 2011)

Earth Venture - 1

The Earth Science Division established Earth Venture (EV) in 2009 as a new element within the Earth System Science Pathfinder (ESSP) Program. The first project of the Earth Venture series, EV-1, consists of a portfolio of five competitively selected suborbital Earth Science investigations to conduct innovative, integrated, hypothesis or scientific question-driven approaches to Earth system science. During FY 2012, the EV-1 missions conducted the following science investigations:

Hurricane and Severe Storm Sentinel (HS3) – NASA GSFC/ARC

The Hurricane and Severe Storm Sentinel (HS3) EV-1 project planned to deploy the two NASA Global Hawks (GH) to study Atlantic hurricanes this past summer. The goal of the 5-year mission is to improve understanding of the processes that control hurricane formation and intensity change.

One Global Hawk (N872; AV-6) was designated as the environmental aircraft with instruments designed to sample temperature, humidity, winds, and Saharan dust in the storm environment. The second GH (N871; AV-1), designated the over-storm aircraft, had instruments that measure winds and precipitation within the storm.

The first flight was the ferry from the Dryden Flight Research Center (DFRC) to the Wallops Flight Facility (WFF) on Sept. 6-7 during which time the GH flew along the outflow region of Hurricane Leslie, obtaining unprecedented information on the cloud, thermodynamic, and wind characteristics of this difficult-to-observe region of hurricanes. It was the first time a NASA GH took off from Dryden Flight Research Center (DFRC) and landed somewhere else (WFF). Figures 9 and 10 show the Global Hawk at its second home – WFF.

Fig. 9: AV-6 being refueled outside N-159 at Wallops.

Fig.10 : AV-6 taking off from Wallops.

The next five flights were in Hurricane Nadine, the only major storm to occur during the larger portion of the deployment, but one that occurred virtually throughout the period. On Sept. 11-12, the GH overflew Nadine as it first became a tropical depression and then a tropical storm, sampling the environment around the developing storm, including the well-defined Saharan Air Layer (SAL) on the storm's northern and eastern sides. The second flight was on Sept. 14-15 as Tropical Storm Nadine was moving northward in the central Atlantic under the influence of strong vertical wind shear. While dry air was observed to be wrapping into Nadine, initial inspection of the data suggests that it was not of Saharan origin. The vertical wind shear produced a major burst of convection near the center, allowing Nadine to strengthen into a hurricane. The third flight into Nadine occurred on Sept. 19-20 when then Tropical Storm Nadine was near the Azores over cooler waters and under the influence of shear. AV-6 observations showed that Nadine was still a vigorous tropical storm with a well-defined warm core through most of the troposphere. Data from HS3 was used by the National Hurricane Center to maintain Nadine as a tropical storm instead of downgrading the storm to post-tropical status. The last two flights, also in the Azores region on Sept. 22-23 and 26-27, investigated Nadine's interaction with an extra-tropical trough and Nadine's recovery as wind shear decreased and the storm slowly re-intensified. Nadine continued to drift in the eastern Atlantic nearly three weeks after its initial formation. The final AV-6 science flight was a NPP and Aqua under-flight for cal/val on Oct 6.

AV-1 had not previously been used as a science aircraft, so numerous changes were made to the GH infrastructure to prepare for this mission. Unfortunately, delays prevented AV-1 from being deployed to WFF but it was ready to fly from Dryden in November. HS3 conducted one test flight and a successful science flight from DFRC between Nov 1 and Nov 6.

HS3 2012 flew N872 (AV-6) for 7 science flights in the Atlantic and N871 (AV-1) for 1 science flight in the Pacific for a total of 194.9 flight hours. Deployments to WFF with both aircraft are planned for the summers of 2013 and 2014. The flight tracks for HS3 in 2012 are shown in Figure 11.

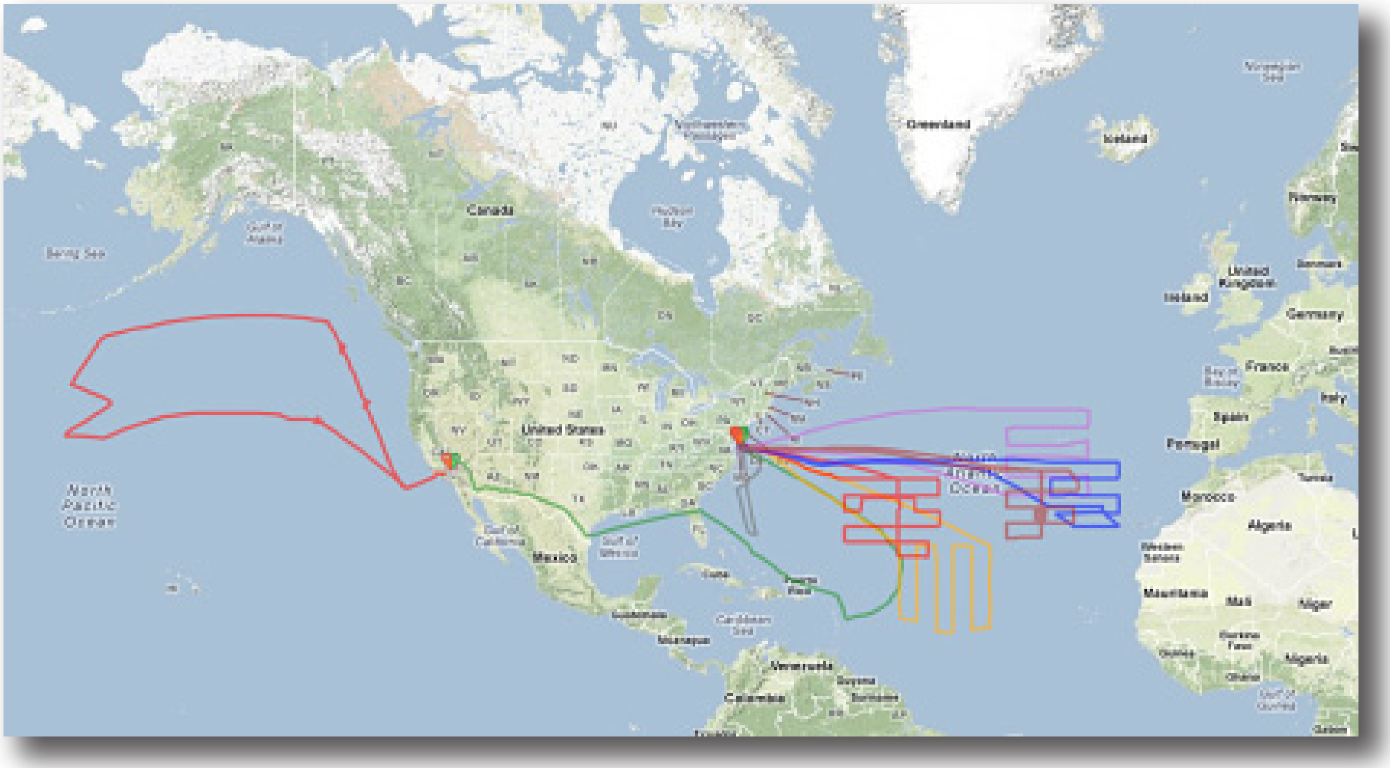


Fig. 11: HS3 2012 Science Flight Tracks. AV-6 flights are shown in the Atlantic, while the AV-1 flight is shown in the Pacific.

Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) - JPL

The carbon budget of Arctic ecosystems is not known with confidence since fundamental elements of the complex Arctic biological-climatologic-hydrologic system are poorly quantified. CARVE is collecting detailed measurements of important greenhouse gases on local to regional scales in the Alaskan Arctic, and is demonstrating new remote sensing and improved modeling capabilities to quantify Arctic carbon fluxes and carbon cycle-climate processes.

The Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) quantifies correlations between atmospheric and surface state variables for the Alaskan terrestrial ecosystems through intensive seasonal aircraft campaigns, ground-based observations, analysis and modeling sustained over its 5-year mission. The data will be used in a multidisciplinary investigation to determine spatial and temporal patterns, sensitivity to change, and potential responses of Arctic carbon budgets to observed and projected climate change.

In January 2012, CARVE's 2011 science payload (version #1) was re-designed, fabricated, integrated and tested in the lab, and then shipped to NASA's Wallops Flight Facility (WFF) for integration onto the new WFF C-23 CARVE aircraft. For four weeks, modifications to the aircraft including: adding air inlets to the side of the fuselage, antennas, probes to the C-23 roof and a complete DC to AC power system were installed. The CARVE's payload version#2 included: The CARVE navigations system, with outside air temperature, relative humidity probe and ozone sensor all being monitored using a wireless iPad; two Picarros real-time gas analyzers (CH4, CO2, CO, H2O); two Programmable Flask Packages (PFP), which are completely protable, fully automated, non-contaminating grab samplers for atmospheric trace gases; and the new Fourier Transformation Spectrometer (FTS), and its vibration isolation assembly.

The CARVE aircraft was deployed to Fairbanks, Alaska from 18 May to 5 October. During that time, the CARVE flight crew traveled up to Fairbanks for two weeks each month and acquire data in various locations including the North slope, Barrow, Prudhoe Bay, Unalakleet, Innoko Valley, Minto Valley, Fort Yukon, Bethel, and Bettles. At the conclusion of the campaign, CARVE flew over 200 science flight hours, in 35 flight days, with 64 flight segments. (Figure 12)

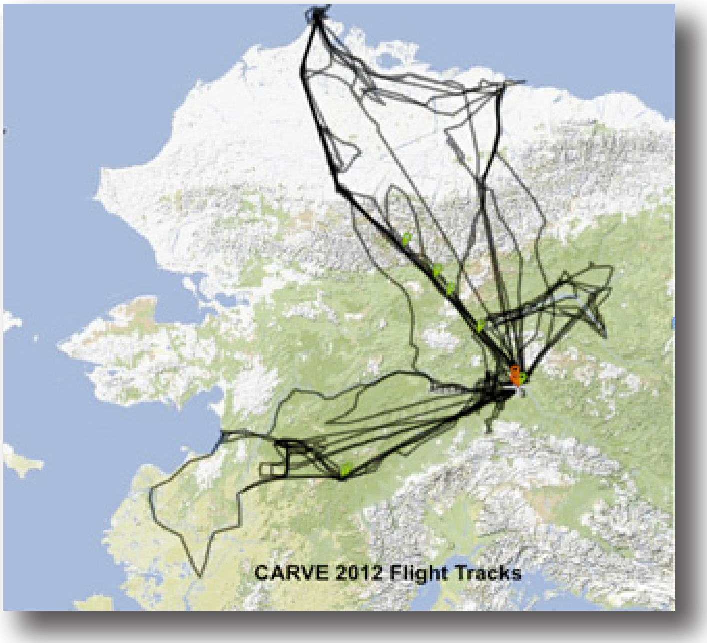


Fig. 12: CARVE mission flight tracks of the C-23 Sherpa.

Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) – JPL, U. of Michigan /USC

North American ecosystems are critical components of the global exchange of the greenhouse gas carbon dioxide and other gases within the atmosphere. To better understand the size of this exchange on a continental scale, this investigation addresses the uncertainties in existing estimates by measuring soil moisture in the root zone of representative regions of major North American ecosystems. Investigators are using NASA's Gulfstream-III aircraft to fly synthetic aperture radar that can penetrate vegetation and soil to depths of several feet. The first science site was flown in September 2012. During 2013 and 2014, the investigation will fly over nine sites in the Continental US, Canada, Mexico, and Costa Rica.

Airborne Tropical Tropopause Experiment (ATTREX) – NASA/ARC

Water vapor in the stratosphere has a large impact on Earth's climate, the ozone layer and how much solar energy the Earth retains. To improve our understanding of the processes that control the flow of atmospheric gases into this region, investigators will launch four airborne campaigns with NASA's Global Hawk UAS.

The flights will study chemical and physical processes at different times of year from bases in California, Guam and Australia. Science flights were flown over the Pacific Ocean from NASA Dryden during November-December 2011. More extensive flights are planned for 2013

Deriving Information on Surface Conditions from COlumn and VERtically Resolved Air Quality (DISCOVER-AQ)/NASA LaRC

The principle objective of the DISCOVER-AQ investigation is to improve the interpretation of satellite air quality observations to enable diagnosis of near-surface conditions DISCOVER-AQ's focus in FY12 was to plan its upcoming 2013 field campaigns in California's Central Valley, which will occur in January and February of 2013, and in Houston, which is scheduled for the summer 2013. DISCOVER-AQ is utilizing NASA's King Air and P-3B research aircraft.

UAVSAR

NASA's G-III, C-20A equipped with the JPL UAVSAR flew more than any other single aircraft in 2012 – 445 hours.

UAVSAR is a reconfigurable, polarimetric L-band synthetic aperture radar (SAR), specifically designed to acquire airborne repeat track SAR data for differential interferometric measurements. Much of the work of the UAVSAR supports the upcoming Earth Radar Mission, the radar portion of DESDynI.

The 2012 missions supported Earth Surface and Interior science interests, terrestrial ecology vegetation interests, and cryosphere measurements. Many of the missions were flown from the home base of the G-III at the Dryden Aircraft Operations Facility (DAOF) in Palmdale, but several of the missions were deployments to other bases.

An example of an earthquake study was the mission to Mexico to survey the Borrego fault, caused by an earthquake in Baja California in 2010. Figures 13 and 14 show the landscape and SAR image, respectively.

Figure 13: This five-foot-high (1.5-meter-high) surface rupture, called a scarp, formed in just seconds along the Borrego fault during the magnitude 7.2 El Mayor Cucapah earthquake in northern Baja California on April 4, 2010. Image credit: Centro de Investigacion Cientifica y de Educacion Superior de Ensenada (CICESE)

Figure 14: The 3-D airborne light detection and ranging (lidar) oblique view of the Borrego Fault, taken from the post-earthquake topographic survey, shows a wide zone of numerous small faults that slice the ground surface and offset the floor of a desert wash surrounding the main fault. The various colors in the landscape represent elevation changes during the earthquake. Image generated in Crusta (keckcaves.org) with 2x vertical exaggeration. Image credit: UC Davis.

Fig. 13: Borrego fault, evident after earthquake

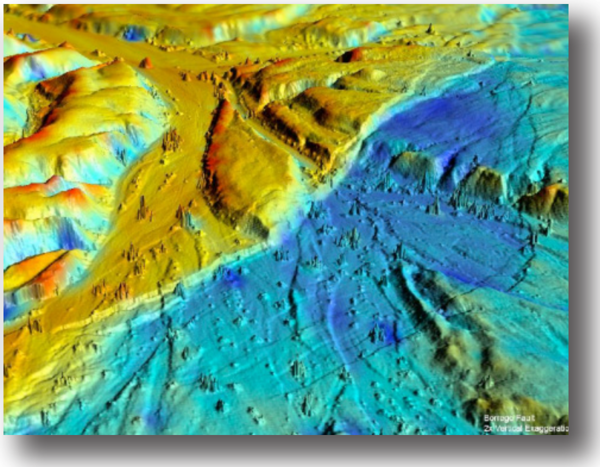


Fig. 14. UAVSAR image of the Borrego fault location

Support to ESD Satellite Missions, including Decadal Survey Missions

One primary purpose of the Airborne Science Program is to support Earth Science satellite missions. This support includes airborne campaigns to collect data for algorithm development prior to launch, to test instrument concepts for satellite payloads or airborne simulators, and to provide data for calibration or validation of satellite measurements or observations once in orbit. In 2012, ASP provided support to Earth Science missions as listed in Table 3. This included significant flight hours for upcoming Decadal Survey missions.

Satellite	How supported	Flight Hours
SMAP	SMAPVEX12	191
GPM	GCPEX	125
ICESat - 2	Flights of MABEL, G-LiHt and GLISTEN-A	321
CALIPSO	DEVOTE project; DC3; Calipso night cal/val	245
ACE	DEVOTE project, AirMSPI; TCAP; Glory project	50
HyspIRI	AVIRIS, AVIRISng, PRISM, HYTES, MAS	174

Table 3: Support to ESD Satellite Missions, including Decadal Survey Mission

SMAPVEX 2012

The Soil Moisture Active Passive (SMAP) mission will provide global soil moisture products that will facilitate new science and application areas. Validation of the suite of SMAP soil moisture and freeze/thaw products is a mission requirement. During the pre-launch phase of SMAP the major concerns related to validation are providing data for the development and evaluation of the SMAP algorithms and establishing the infrastructure to efficiently conduct the post-launch validation in a timely manner. Field campaigns are one of the methodologies that are used for these purposes. In response to the issues identified by the SMAP Cal/Val Working Group, a field campaign SMAP Validation Experiment 2012 (SMAPVEX12) was designed and executed. During the period from early June through mid-July 2012 the campaign took place at field sites in Canada near Winnipeg. The field campaign was sponsored by the SMAP mission, supporting Water and Energy Cycle science.

Two aircraft-based instruments were deployed for SMAPVEX12 on different aircraft: the Passive/Active L-band Sensor (PALS) on a Twin Otter and the Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) on the NASA G-III. The Twin Otter flew locally in Canada. The study site near Winnipeg is indicated in Figure 15. PALS flight lines are shown in Figure 16. The G-III with UAVSAR was deployed to North Dakota for thirty days (June 17-July 17) and was able to complete 14 flights. UAVSAR flight boxes are shown in Figure 17.

Both the weather conditions and instrument performance exceeded expectations resulting in SMAPVEX12 being very successful. The UAVSAR data are being reprocessed to simulate the SMAP radar configuration and will be integrated into algorithm development in the near future. The PALS data is also of particular interest because the instrument closely resembles the SMAP instrument by having both a radar and a radiometer sharing a single antenna viewing the surface at an incidence angle of about 40 degrees.

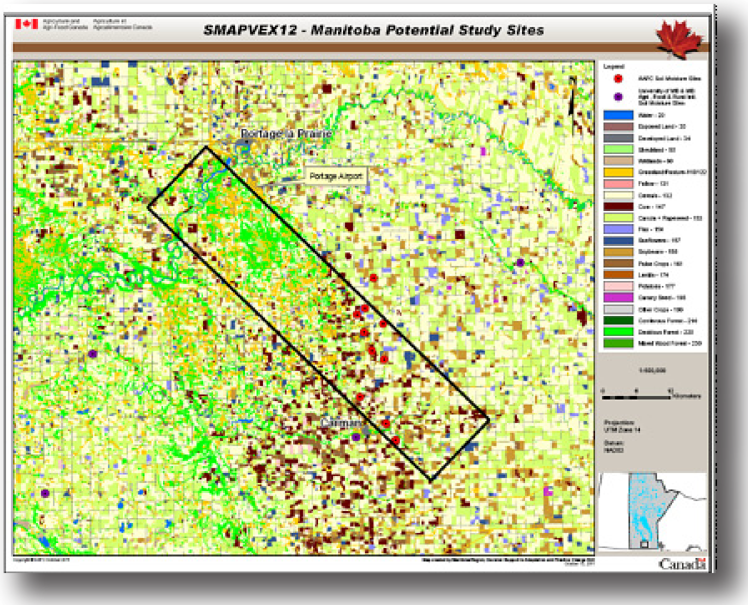


Fig. 15. Location of the SMAPVEX 12 field campaign near Winnipeg, Canada, just north of the North Dakota border.

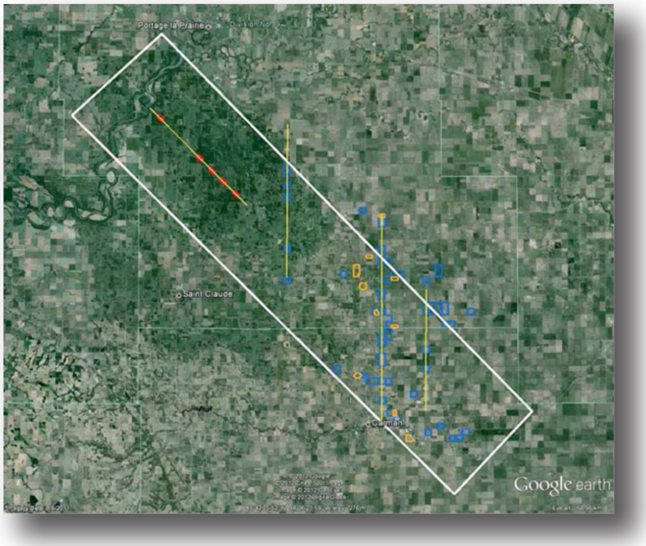


Fig. 16. Location of low altitude PALS flight lines (in yellow).

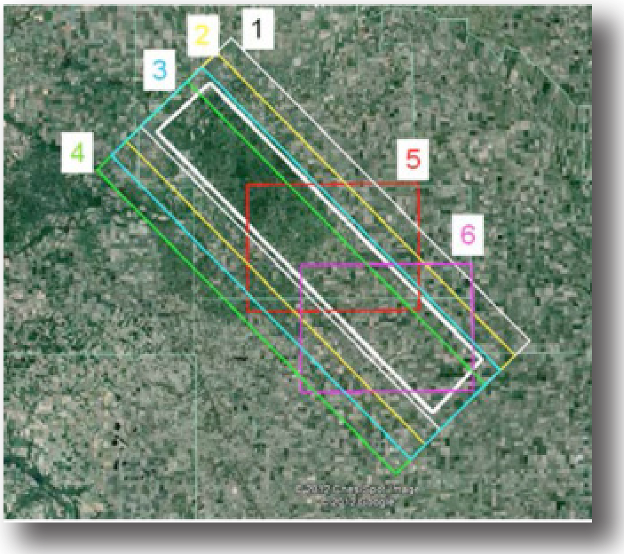


Fig. 17. SMAPVEX12 UAVSAR Coverage Boxes (Study region is the white box at center).

All SMAPVEX12 experiment objectives were satisfied including:

- Observing a wide range of soil moisture conditions
- Observing a wide range of vegetation types and vegetation water content levels

GCPEX

The Global Precipitation Measurement (GPM) radar and radiometer algorithms rely upon ground validation—taking measurements on the ground and comparing them with measurements made from the satellite—to develop, improve, and verify the instrument retrievals. With regard to measurements of frozen precipitation, these datasets are required to characterize the ability of multifrequency active and passive microwave sensors to detect and estimate the amount and rate of snowfall. To test and improve GPM snowfall retrieval algorithms, the GPM Cold Season Precipitation Experiment (GCPEx) field campaign was developed as a joint effort between NASA and Environment Canada (EC). It took place between January 16 and February 29, 2012 (Northern Hemisphere winter), to collect microphysical properties, associated remote sensing observations, and coordinated model simulations of precipitating snow. The GCPEx experiment used an instrumented aircraft—the NASA DC-8—for flights over heavily instrumented ground sites located in and around the EC Centre for Atmospheric Research Experiments (CARE), near Egbert, Ontario in Canada.

NASA's DC-8 aircraft carried the Conical Scanning Millimeter-wave Imaging Radiometer (CoSMIR) and the Airborne Second Generation Precipitation Radar (APR-2) dual-frequency radar. Meanwhile, two in situ cloud microphysics aircraft—meaning that they fly

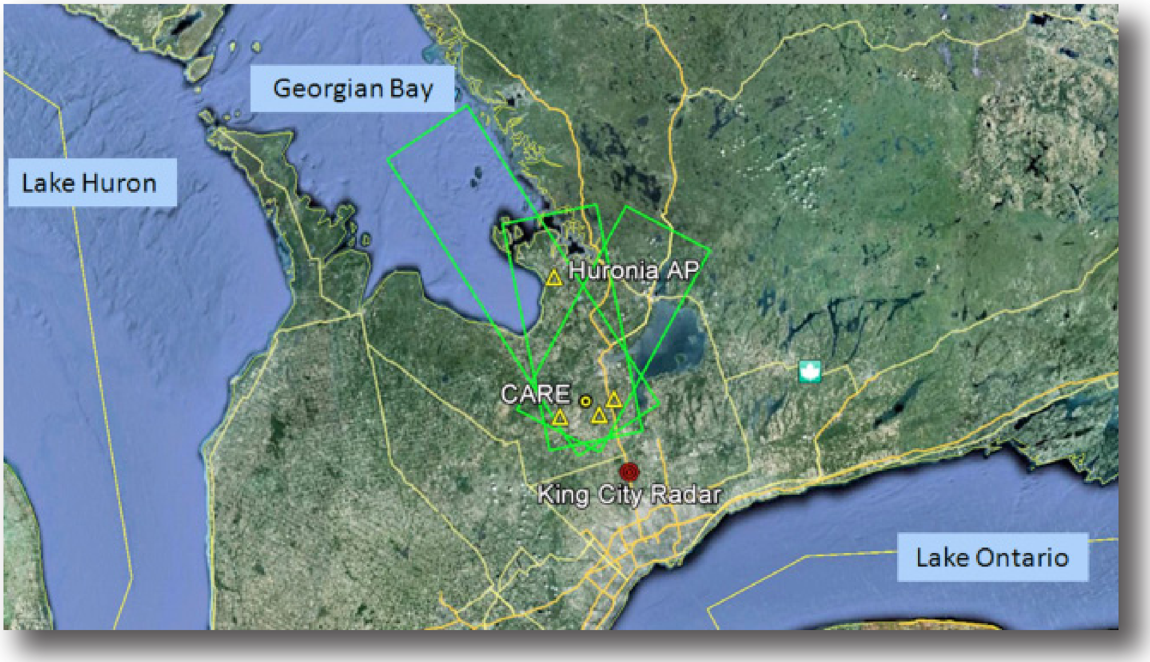


Fig. 18. Location of the DC-8 flights during GCPEX

at the same level and within the clouds and precipitation—surveyed the lower altitudes: the University of North Dakota's (UND's) Citation and the National Research Council of Canada's (NRC's) Convair-580. DC-8 instruments provide a dataset consistent with the viewing angles and radar and radiometer measurements characteristic of the GPM Core Observatory. The DC-8 instruments thus serve as proxy satellite observations that can be compared to other measurements. These DC-8 observations of the integrated column are physically related to the physical processes taking place in the underlying cloud columns—that were sampled by the UND and NRC aircraft—and are subsequently also related to measurements made on the ground via multi-parameter radar and network gauge measurements.

The GCPEX mission was sponsored by the GPM mission and supports the Weather focus area.

ICESat-2

ASP flights also supported the upcoming ICESat–2 mission, by flying MABEL, G-LiHT and GLISTEN-A.

Multiple Altimeter Beam Experimental Lidar (MABEL)

MABEL is a GSFC-developed instrument. The data provided by MABEL are needed for the development of new science algorithms and data reduction methods for the ICESat-2/ATLAS instrument. MABEL development is sponsored by both the ICESat-2 program and the Cryosphere focus area.

In April 2012, MABEL instrument completed an extremely successful deployment to Iceland, acquiring data from most target types of interest to the ICESat-2 mission currently in development by NASA. MABEL used a multi-beam photon counting technique to measure elevation and surface brightness over sea ice, snow fields, glaciers, bare soil, water, clouds, and a few select vegetation targets during transit.

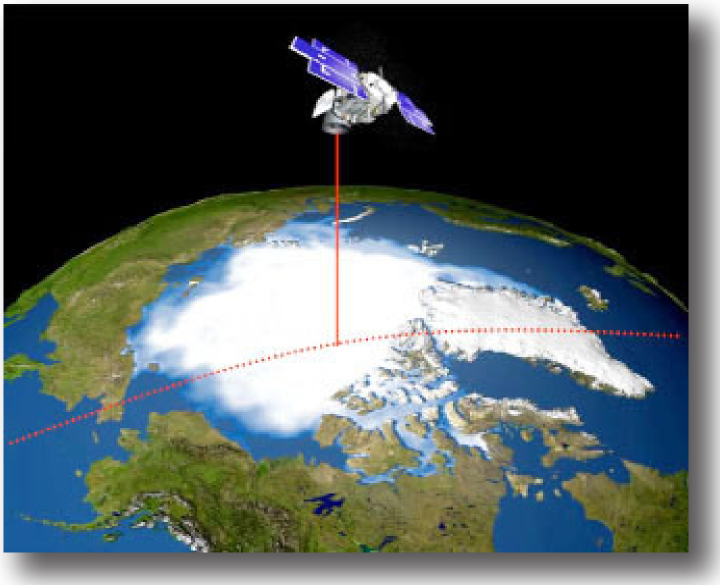


Fig. 19. Schematic diagram of ICESat on a transect over the Arctic. (Image courtesy of Abdalati, et al)

MABEL flew aboard NASA's ER-2 aircraft in 15 flights, collecting over 100 hours of high-quality science data during April 2012 alone. The flight lines are shown in Figure 20. All target types included in the ICESat-2 level 2 requirement set were observed at some point during this deployment.

Altogether in 2012, MABEL flew 212 hours on the ER-2 in two major missions, in the spring to Iceland and Greenland, and in the fall from WFF along the Eastern seaboard.

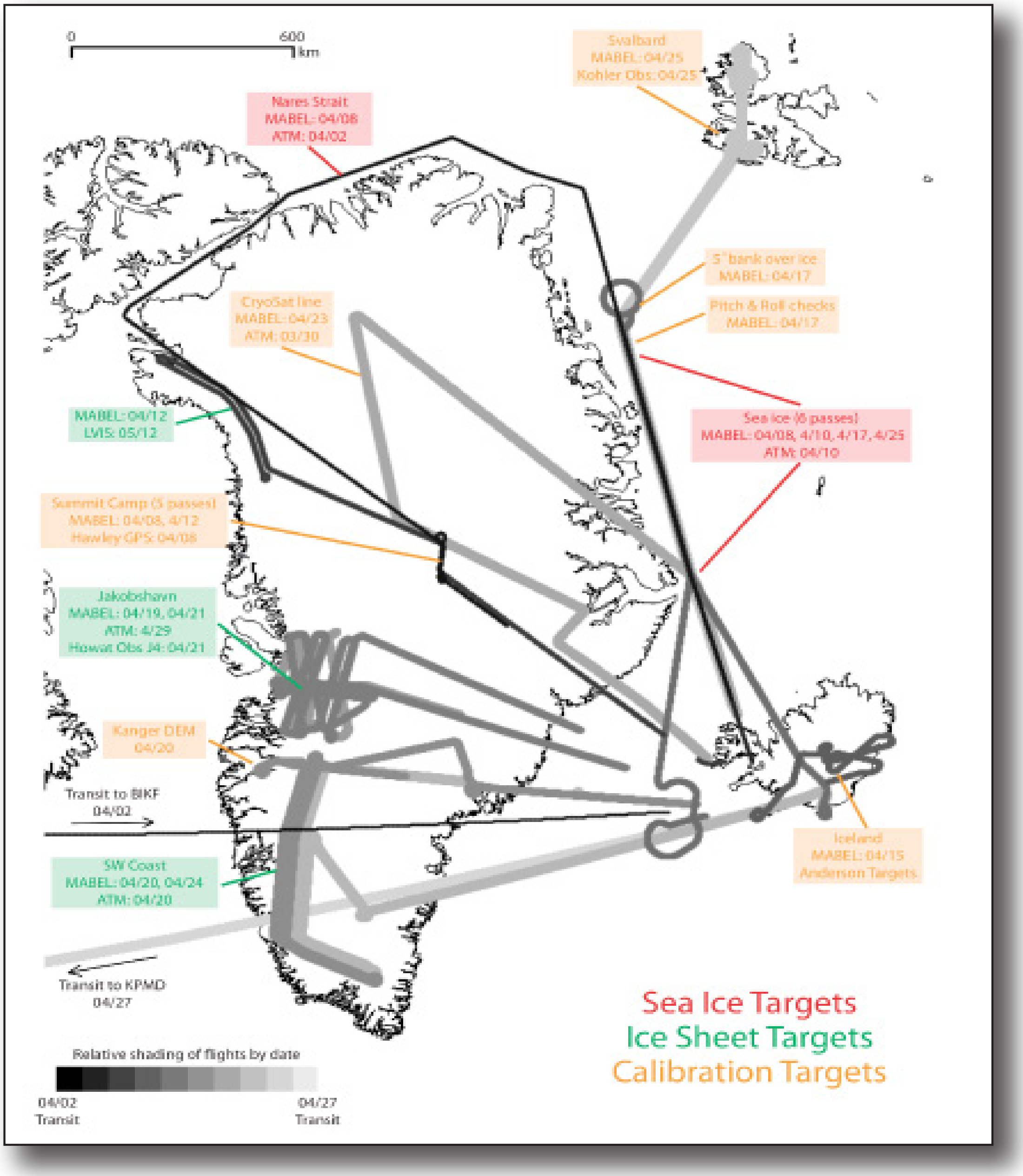


Fig. 20. Summary of the flights made by MABEL aboard the ER-2 during the deployment to Keflavik, Iceland in April 2012. In total over 100 hours of good quality data were collected in15 flights (including transits). Primary targets were in and around Greenland, and many were also measured with the concurrent but separate IceBridge campaign. Map courtesy of K. Brunt.

G-LiHT: Goddard's LiDAR, Hyperspectral, and Thermal airborne imager

G-LiHT is a portable airborne system that simultaneously maps the composition, structure and function of terrestrial ecosystems.

G-LiHT was designed to acquire fine-scale (<1 m), co-registered LiDAR, optical, and thermal data for ecosystem studies while minimizing collection costs. Some features include eye safe lasers, portability (compact, lightweight), single solution GPS-INS, up/downwelling spectrometers, and ease of installation on common aircraft. Because it flies non-ITAR instruments worldwide deployment is simplified.

G-LiHT flights in FY12 were carried out on two LaRC aircraft – B-200 and Cessna 206H, for a total of 104 hours over three missions. The instrument development was sponsored by GSFC, and the flight missions were also funded internally. The G-LiHT system supports both ICESat-2 and HyspIRI science objectives, especially related to vegetation mapping. The map in Figure 21 shows the flight tracks of G-LiHT, along with MABEL and other instruments during a major mission in fall 2012.

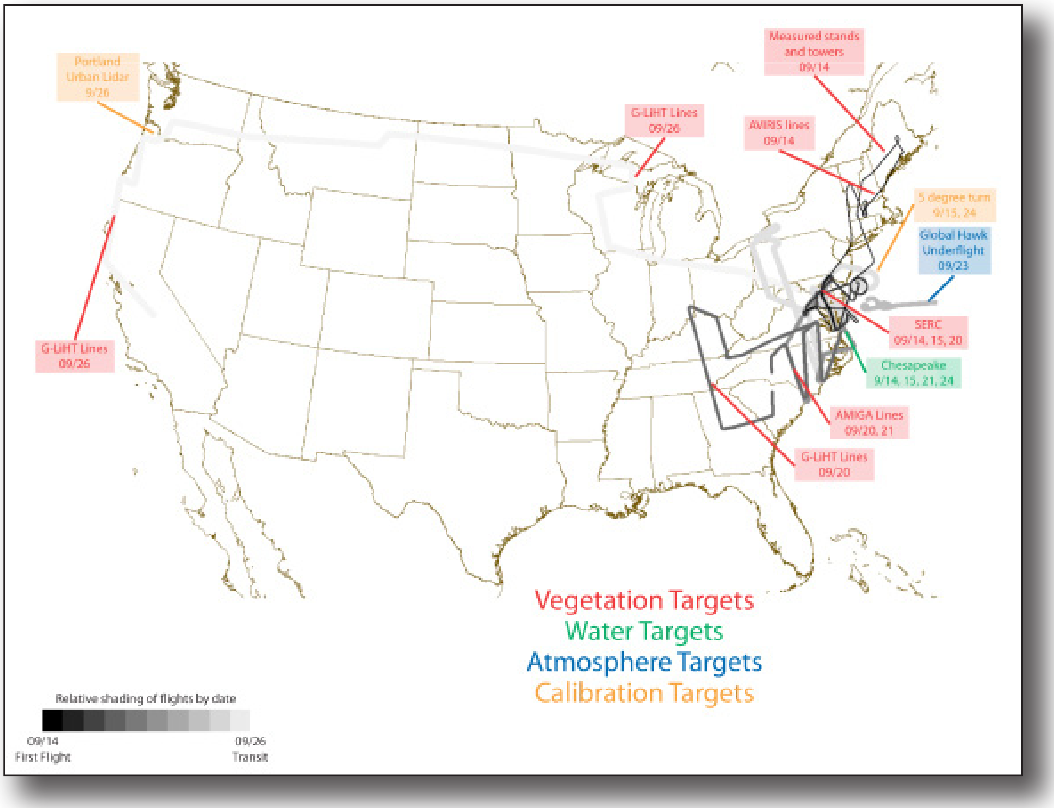


Fig. 21. G-LIHT flight tracks out of WFF. Map courtesy of K. Brunt.

GLISTEN-A

The Airborne Glacier and Land Ice Surface Topography Interferometer (GLISTIN-A), developed by PI Delwyn Moller of Remote Sensing Solutions, is a swath-mapping Ka-band UAVSAR-configured interferometer. The GLISTIN-A has a swath coverage of at least 10 km as compared to the 7.5 km swath of an earlier version flown for IPY in 2009.

On August 8th and 13th, 2012, GLISTIN-A flew on a NASA Gulfstream III (G-III) aircraft for initial engineering flights over the Rosamond Calibration Array in California. The first flight was conducted at a series of altitudes to test instrument sensitivities and the various operation modes including the new ping-pong ability. The flight on August 13th was flown over the corner reflectors at Rosamond at a nominal altitude and operation mode. From there, the G-III flew GLISTIN-A in long lines over California's central valley to provide phase screen data and stability information, as well as a validation and characterization of the system calibration loop.
The August engineering flights proved successful. Data collected was used to produce imagery and interferograms.

The UAVSAR configuration of GLISTIN-A can be transitioned for flight on the GlobalHawk. (GLISTIN-H) – planned for 2013 – where it will be able to provide quality data on ice topography in areas that are often deemed too remote for in-depth study. The information the interferometer collects will compliment the data collected by ICESat-2 to provide the cryospheric science community with timely and complete coverage of the polar regions.

DEVOTE

The Development and Evaluation of satellite ValidatiOn Tools by Experimenters (DEVOTE) project was funded by NASA Science Mission Directorate and Office of Chief Engineer. Its goal was to train early-career and career-transitional employees for participation in future large NASA missions while accomplishing a useful scientific mission.

Fig. 22. The DEVOTE team during a deployment from Boston, MA.

The DEVOTE mission, which took 15 months to complete, exposed 17 scientists and engineers who are early career and career-transitional to an entire mission life cycle. DEVOTE team members collected data with a combination of aircraft-based instruments that have never before been used together. This data will help validate satellite missions CALIPSO and the future ACE (Aerosol-Cloud-Ecosystem) mission that will examine the interaction between clouds and aerosols in the atmosphere.

DEVOTE modified the NASA Langley B-200 aircraft to carry a suite of in situ instruments (Diode Laser Hygrometer (DLH), and the Polarized Imaging Nephelometer (PI-Neph)) and then deployed this aircraft along with a remote sensor suite (HSRL and NASA GISS RSP) aboard the NASA Langley UC-12 aircraft to study aerosol and cloud optical and microphysical parameters. Coincident measurements were taken over AERONET ground sites and along atmospheric satellite ground tracks to demonstrate the ability to utilize these platforms for future scientific measurement campaigns.

Measurements are also useful for evaluating advanced data retrieval algorithms using combined lidar and polarimeter data.

The flight configuration is shown in Figure 23. A total of 69 hours were flown for the DEVOTE mission in FY12.

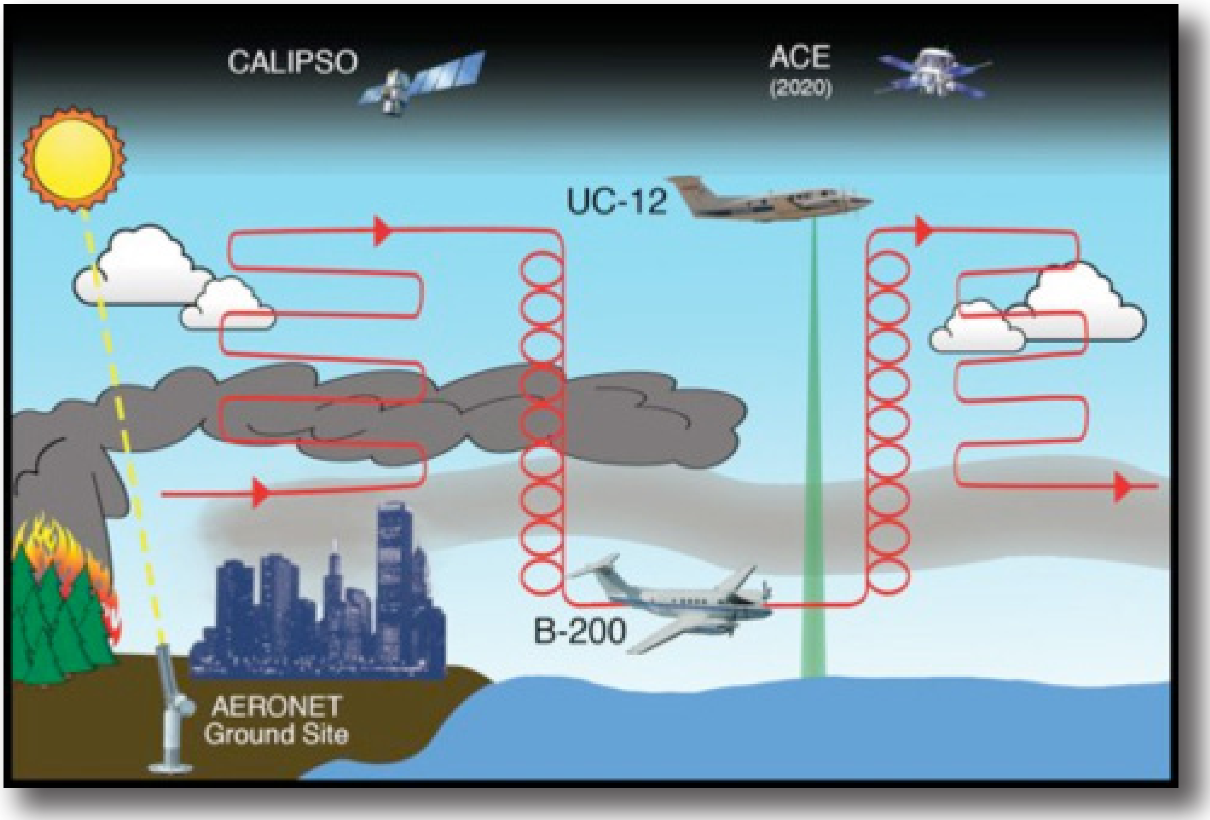


Fig. 23. DEVOTE mission aircraft activities

UAS Missions: A.40

In 2011, NASA selected three Earth Science missions to test the utility of unmanned aircraft systems (UAS) for enabling science measurements.

ROSES solicitation #NNH10ZDA001N-UAS "A.40" resulted in the following three awards.

Mission	PI / Institution	UAS	Study Location
Earthquake Hazards	Jonathan Glen / USGS	SIERRA	Surprise Valley, CA
		SWIFT	Surprise Valley, CA
Sea Grass / Coral Reefs	Stan Herwitz / UAV Collaborative	Bat-4	Cedar Key, FL
		SIERRA	Key West, FL
MIZOPEX	James Maslanik / University of Colorado	Scan Eagle, CUMAV	Oliktok Point, AK
		Ikhana*	Fairbanks, Oliktok

Table 4. A.40 missions selected in 2011.

**Ikhana since changed to SIERRA.*

Earthquake Hazards

The "Long-term earthquake hazards and groundwater resources in a tectonically active region: Critical insights from UAS" project involves a collaboration of USGS, NASA-Ames, and Carnegie Mellon University researchers to design and implement a technique for collecting geophysical data more efficiently and effectively UAS. This is an innovative use of UAS that has the potential to greatly increase the quality, quantity, and resolution of data collected while significantly reducing the costs and risks associated with manned surveys. The team is applying this technique in a geothermal area in Surprise Valley, CA to map faults and fractures in the sub-surface that may be controlling fluid circulation.

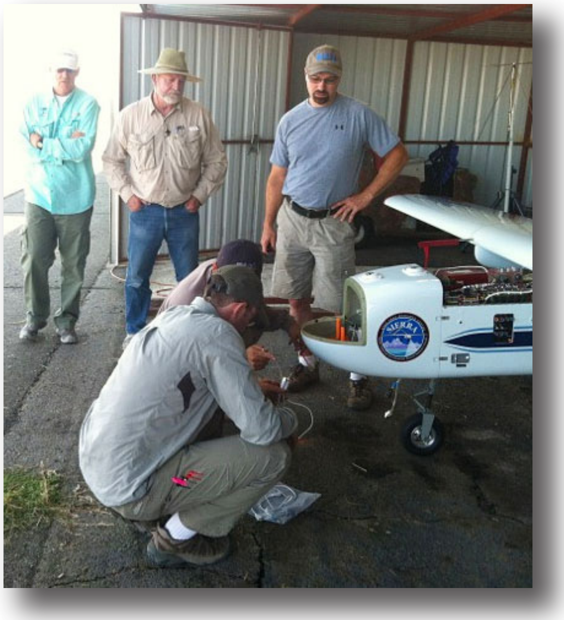


Fig. 24. Project co-principal investigator Jonathan Glen (lower left) with NASA and Geometrics engineers, troubleshooting SIERRA's malfunctioned wireless system Photo: Melissa Pandika

In September 2012, the SIERRA UAS flew a regional survey over the entire valley with detailed flight paths over several targeted areas. "By all measures, the mission was a great success: the data quality and resolution far exceeded our expectations, and the new system functioned even better than we anticipated, allowing us to collect more data than was originally planned," said PI Jonathan Glen. A key outcome from this survey was the discovery that the hot springs correlate with breaks and bends in a buried structure imaged by the magnetic survey (Figure 25) – a finding that could never have been substantiated by ground-based data collection. During 2012, the team also began to prepare a second platform, the Swift UAS that will analyze data from its onboard sensors and continuously optimize its flight path in real time to autonomously investigate features of interest and collect data where it is most needed. The team will return to Surprise Valley with the Swift in September 2013, to test this 'smart'-UAS system and to collect more detailed data in several locations.

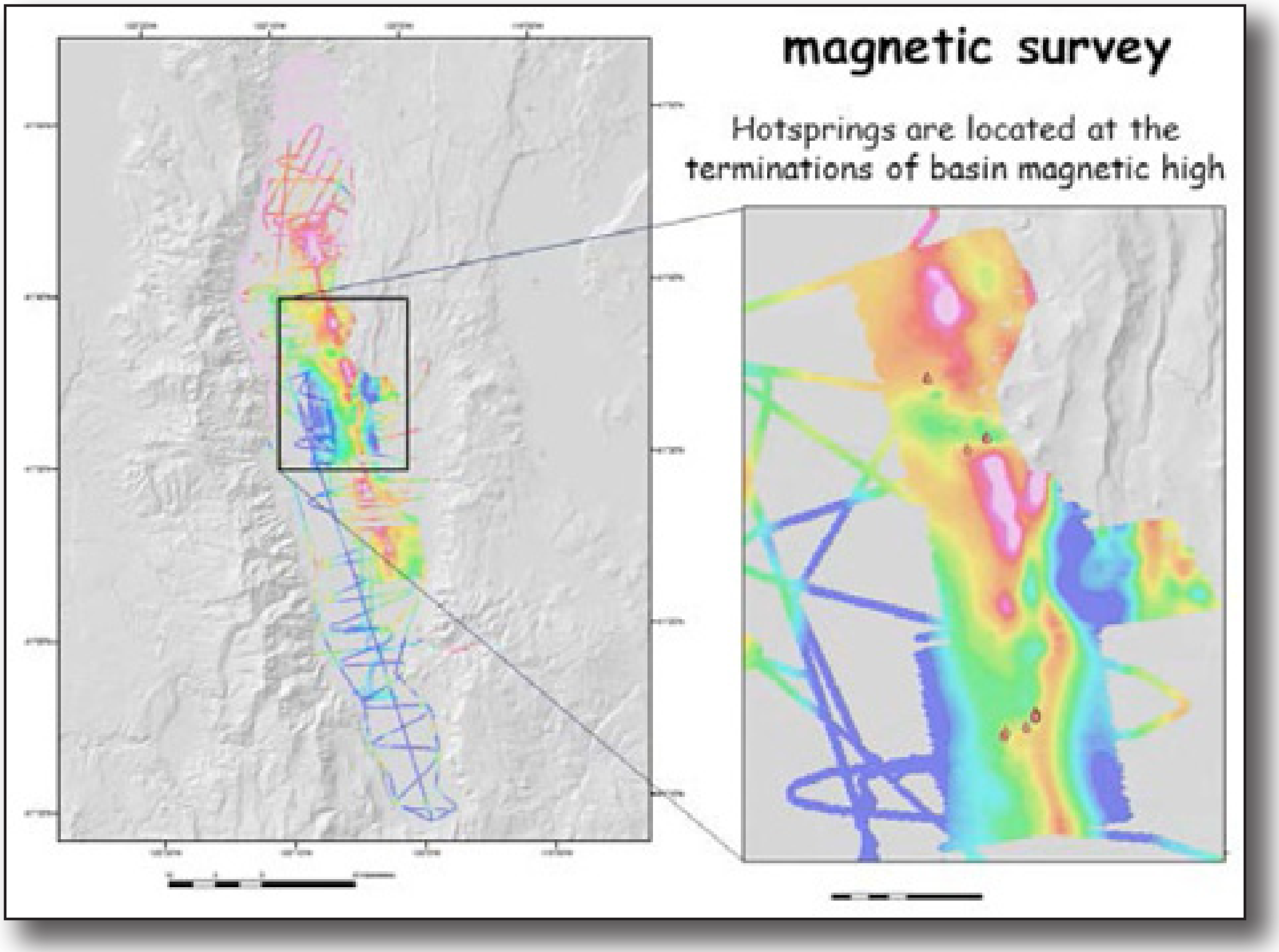


Fig. 25. Magnetic grid derived from data collected by the SIERRA UAS in Surprise Valley, 2012. Hot springs shown as red dots.

Seagrass / Coral Reefs

Another of the projects selected, titled "High Resolution Assessment of Carbon Dynamics in Seagrass and Coral Reef Biomes," is led by Principal Investigator (PI) Stanley R. Herwitz, Ph.D., Director of the UAV Collaborative. Dr. Herwitz is working with his team of Co-Investigators from: the Florida Fish and Wildlife Research Institute; the Institute for Marine Remote Sensing and the Optical Oceanography Laboratory at the University of South Florida; the U.S. Geological Survey's Center for Coastal and Marine Science Center; and the Institute of Marine Affairs of Trinidad and Tobago.

Increased sea surface temperature as well as ocean acidification are expected to cause significant changes in the composition and distribution of shallow water species in the coming decades. The primary goal of the Project is to advance the use of UAS-based hyperspectral and multispectral sensors to acquire high resolution airborne imaging data that characterize current biological conditions and aid in the detection and quantification of possible future changes. Detailed airborne and water-based datasets are currently being assembled from representative seagrass and coral reef sites offshore from the Florida Keys. Another goal of the Project has involved familiarizing the natural science team with leading-edge UAS technology; specifically, increasing their understanding of its potential for airborne data acquisition, while also having them gain a clearer understanding of the challenges imposed by FAA-controlled airspace regulations.

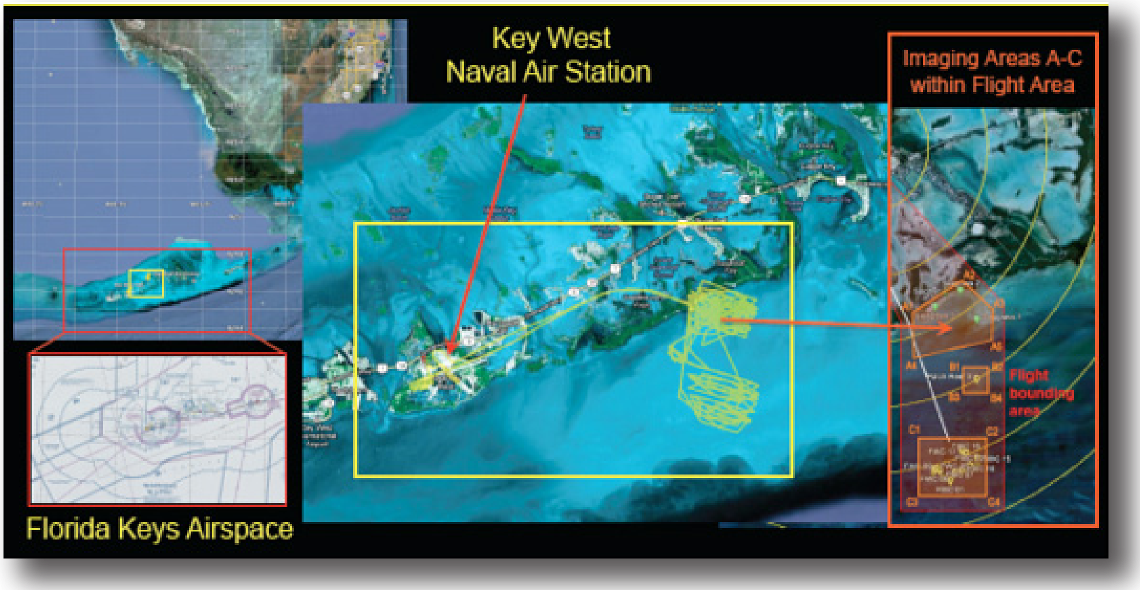


Fig. 26. Location of Seagrass mission at Key West, FL.

The water-based data acquisition effort has involved collecting data from the water column and the ocean bottom using a suite of commercial and in-house constructed instrumentation combined with extensive field sampling. Small-scale and short-term processes that increase our understanding of the spatial distribution and vigor of seagrass and coral are of particular interest. Considerable attention has been directed to the interaction of light with water, the biogeochemical properties of the water column, and the detection of benthic gas (O_2 and CO_2) exchange. UAS flight operations have been implemented to assess how these processes may be measured using airborne datasets.

The SIERRA UAS, operated by the NASA Ames Research Center, was selected to fly a hyperspectral imaging system. The slightly smaller Bat-4 UAS, operated by MLB Company, was flown to collect visible and multispectral imagery. Three UAS Deployments have been completed to date, with a total of 14 UAS flight sequences demonstrating the utility of these "low and slow" platforms for collecting high quality airborne data under varying environmental conditions. Processing of the airborne data has involved the use of advanced targeting algorithms and detailed spectral signature libraries. Concurrent hyperspectral measurements from a manned aircraft have been obtained for independent cross-referencing. The SIERRA UAS will continue to operate in 2013 from the Key West Naval Air Station under an agreement with the U.S. Navy.

In the recent October 2012 Deployment of the SIERRA UAS, more than 320 gigabytes of hyperspectral data were collected. The final UAS Deployment is scheduled for May 2013. Following this upcoming Deployment, the science team will focus on the analysis of the extensive database, and publish the results in peer-reviewed science journals.

MIZOPEX Marginal Ice Zone Ocean and Ice Observations and Processes EXperiment

Recent years have seen extreme changes in the Arctic. Particularly striking are changes within the Pacific sector of the Arctic Ocean, and especially in the seas north of the Alaskan coast. These areas have experienced record warming, reduced sea ice extent, and loss of ice in areas that had been ice-covered throughout human memory. Even the oldest and thickest ice types have failed to survive through the summer melt period in areas such as the Beaufort Sea and Canada Basin, and fundamental changes in ocean conditions such as earlier phytoplankton blooms may be underway. A basic question that is significant for the entire Earth system is whether these regions have passed a tipping point, such that they are now essentially acting as sub-Arctic seas where ice disappears in summer, or instead whether the changes are transient, with the potential for the ice pack to recover. The answer may depend largely on conditions in areas known as marginal ice zones (MIZ); areas where the "ice-albedo feedback" driven by solar warming is highest, ice melt is extensive, and where human and marine mammal activity is greatest.

Despite the significance of the MIZ, basic parameters such as sea surface temperature (SST), sea surface salinity (SSS), and a range of sea ice characteristics are still insufficiently understood in these areas, and especially so during the summer melt period. The project described here, identified collectively as the "Marginal Ice Zone Ocean and Ice Observations and Processes EXperiment" (MIZOPEX), will directly address these information gaps through a targeted, intensive observing campaign that exploits unique capabilities of multiple classes of UAS (NASA Ikhana, In situ ScanEagles, and a microUAS) combined with in-situ sensing and satellite observations. Specific research areas to be addressed using MIZOPEX data are: relationships between ocean skin temperatures and subsurface temperatures and how these evolve over time in an Arctic environment during summer; variability in sea ice conditions such as thickness, age, and albedo within the MIZ; interactions of SST, salinity and ice conditions during the melt cycle; and validation of satellite-derived SST and ice concentration fields provided by AVHRR, MODIS, AMSR-E and the NPP/JPSS VIIRS.

Fig. 27. Location of MIZOPEX mission.

Support to Instrument Development

Another major element of the ASP program is the support of instrument development for Earth Science. Some instruments are developed specifically for manned aircraft or UAS utilization, while many are developed as precursors or simulators for satellite instruments. In 2012, ASP aircraft flew all of the instruments listed in Table 5. Many of these instruments have been developed under sponsorship of NASA's Earth Science Technology Office (ESTO) Airborne Instrument Technology Transition (AITT) program. The chart in Figure 28 (page 30) highlights the airborne successes of the ESTO program in 2012.

Instrument	Sponsor	Aircraft	Flight Hours
A-SMLS	ESTO	WB-57	7
AirMOSS	ASP / EV-1	G-III (J)	64
AirMSPI	ESTO	ER-2	8
AVIRIS ng	Terrestrial Ecology	Twin Otter	102
DAWN	LaRC	B-200	4
eMAS	EOS	ER-2	10
ESFL	AITT	Twin Otter	17
G-LiHT	GSFC	UC-12B, Cessna 206	104
GLISTEN-A	AITT; Earth surface and Interior	G-III (D)	7
HSRL-2	AITT	B-200 (L)	15
HYTES	Earth Science R&A	Twin Otter	20
MABEL	ICESat-2; Cryosphere program	ER-2	212
MAGI (Mineral and Gas Identifier)	ESTO	Twin Otter (W)	17
OAWL	ESTO	WB-57	23
PRISM	ASP; Ocean Biology program	Twin Otter (G)	50
TCAP	Radiation Science program	B-200 (L)	42
		TOTAL:	702

Table 5. ASP Support to Instrument Development

Going Airborne

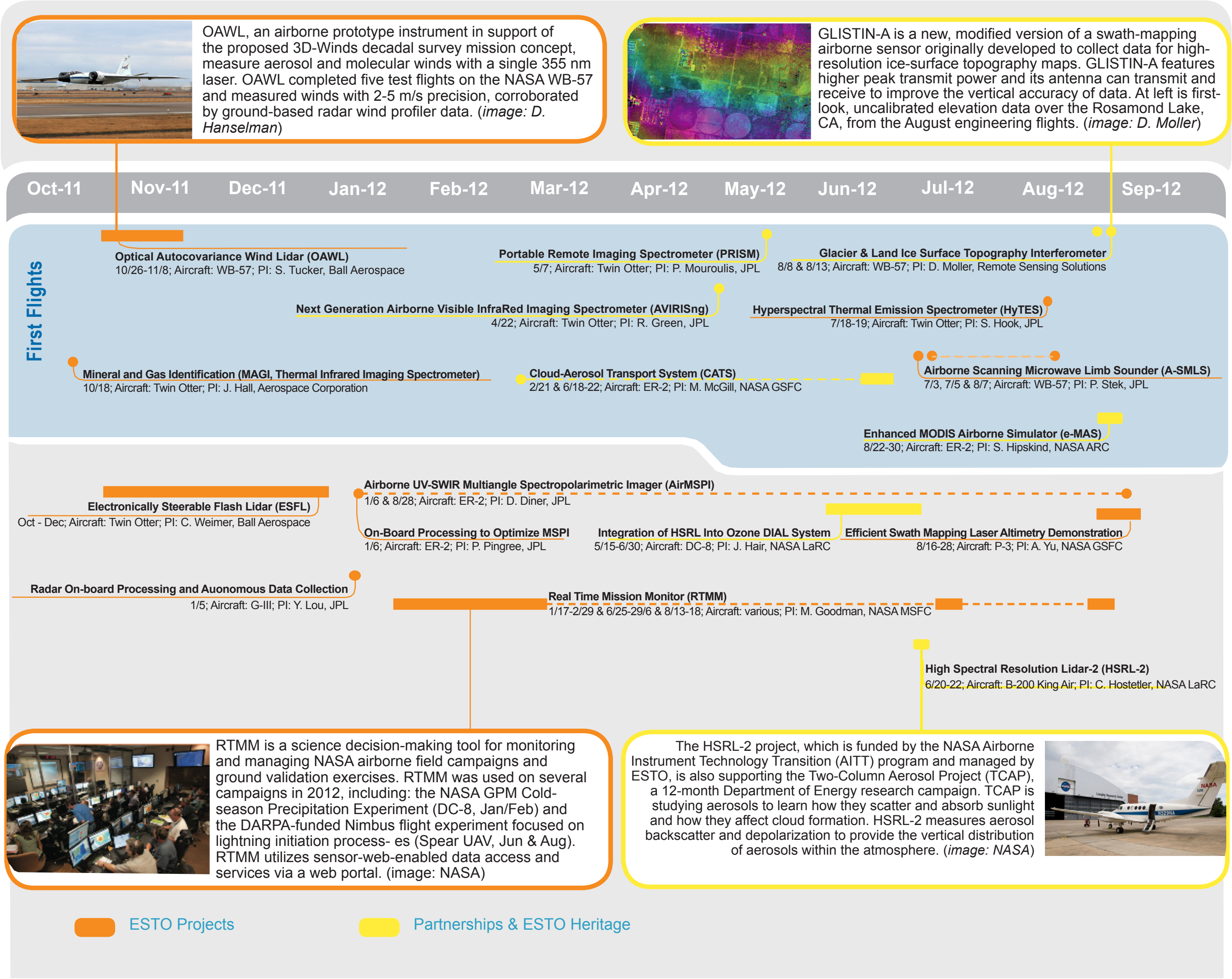
Technologies Take Flight in FY2012

Airborne platforms are often essential to the calibration and validation of emerging technologies. They provide a stepping-stone to reduce risk prior to committing new technologies to space missions. They also enable mature instruments and systems to be rapidly put into service on airborne field campaigns, collecting science data and validating the observations of satellites.

Airborne testing often occurs during, and within the scope of, technology development and funding. In other cases, ESTO has partnered with platform providers - in particular, NASA's Airborne Science Program - to provide follow-on opportunities and manage technology progress from integration to validation.

Since 1998, more than 70 ESTO technologies have been demonstrated onboard airplanes, UAVs (Uninhabited Aerial Vehicles) or high-altitude balloons, loggin hundreds of flight hours in aggregate. As illustrated in the timeline below, FY12 was a banner year for airborne technologies.

At least 17 current projects - ESTO projects as well as partnerships with NASA's Airborne Science and Earth Science Research and Analysis programs - were demonstrated on airborn platforms or flew as part of airborne science campaigns. Nin of these projects flew for the first time in FY12.



OAWL, an airborne prototype instrument in support of the proposed 3D-Winds decadal survey mission concept, measure aerosol and molecular winds with a single 355 nm laser. OAWL completed five test flights on the NASA WB-57 and measured winds with 2-5 m/s precision, corroborated by ground-based radar wind profiler data. (*image: D. Hanselman*)

GLISTIN-A is a new, modified version of a swath-mapping airborne sensor originally developed to collect data for high-resolution ice-surface topography maps. GLISTIN-A features higher peak transmit power and its antenna can transmit and receive to improve the vertical accuracy of data. At left is first-look, uncalibrated elevation data over the Rosamond Lake, CA, from the August engineering flights. (*image: D. Moller*)

RTMM is a science decision-making tool for monitoring and managing NASA airborne field campaigns and ground validation exercises. RTMM was used on several campaigns in 2012, including: the NASA GPM Cold-season Precipitation Experiment (DC-8, Jan/Feb) and the DARPA-funded Nimbus flight experiment focused on lightning initiation process- es (Spear UAV, Jun & Aug). RTMM utilizes sensor-web-enabled data access and services via a web portal. (image: NASA)

The HSRL-2 project, which is funded by the NASA Airborne Instrument Technology Transition (AITT) program and managed by ESTO, is also supporting the Two-Column Aerosol Project (TCAP), a 12-month Department of Energy research campaign. TCAP is studying aerosols to learn how they scatter and absorb sunlight and how they affect cloud formation. HSRL-2 measures aerosol backscatter and depolarization to provide the vertical distribution of aerosols within the atmosphere. (*image: NASA*)

Fig. 28. ESTO Program highlights in 2012. (Source: ESTO Annual Report)

Upcoming Activities

HyspIRI preparatory airborne activities

To begin preparations for the NASA Decadal Survey mission “Hyperspectral Infrared Imager” (HyspIRI), NASA in 2012 solicited proposals for aircraft missions. For these campaigns, NASA plans to fly the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) and the MODIS/ASTER Airborne Simulator (MASTER) instruments on a NASA high-altitude aircraft to collect precursor datasets in advance of the Hyperspectral Infrared Imager (HyspIRI) mission. NASA solicited proposals that would use these airborne data to address one, or more, science or applications research topic aligned with the science questions for the HyspIRI Mission. A goal of this solicitation was to generate important science and applications research results that are uniquely enabled by HyspIRI-like data, taking advantage of the contiguous spectroscopic measurements of the AVIRIS, the full suite of MASTER TIR bands, or combinations of measurements from both instruments. Fourteen proposals were selected for award and will begin flights in 2013. The geographical areas of interest are indicated in Figure 29.

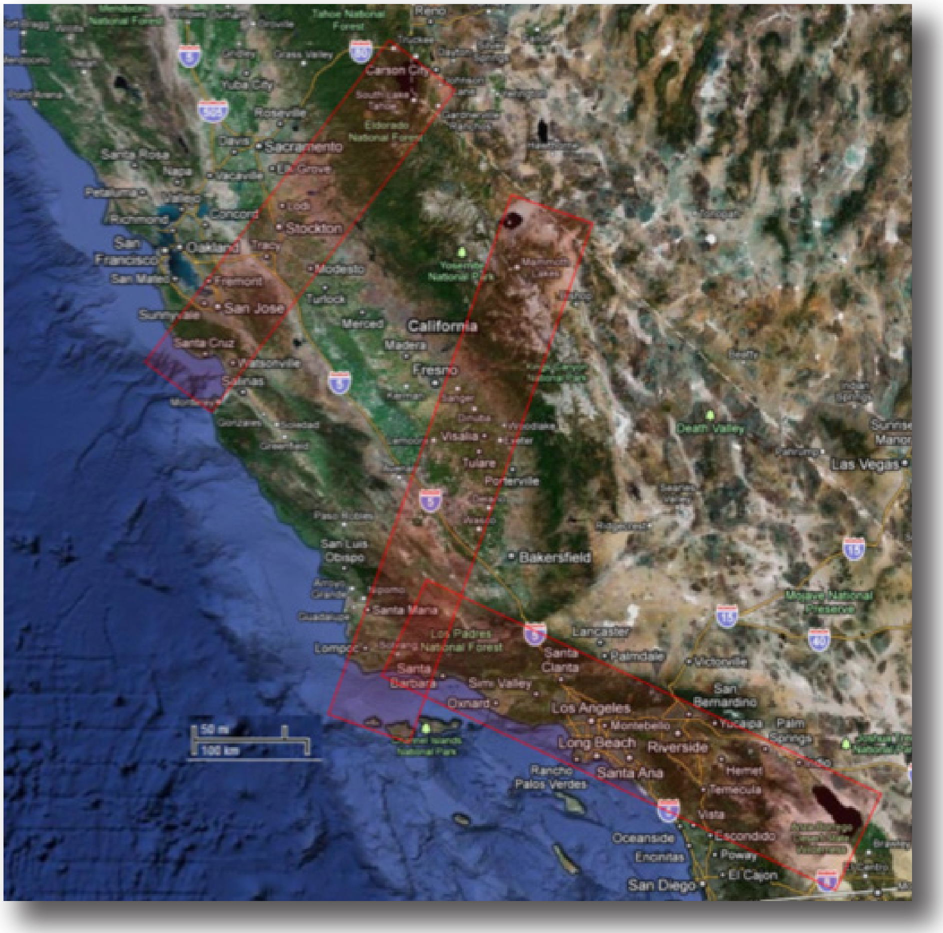


Fig. 29. Flight regions for HyspIRI prepatory airborne activities

EVS-2

The ROSES solicitation for Earth Venture Suborbital - 2, the second round of suborbital missions, 5-year project similar to Earth Venture -1, will be released in late 2013.

III. AIRCRAFT

NASA maintains a fleet of aircraft for scientific activities, primarily for Earth Science. The Airborne Science program is responsible for monitoring the status of the aircraft, which are housed at various NASA Centers. Some of the platforms have direct support from ASP for flight hours and personnel. These are the "ASP-supported Aircraft." NASA catalog aircraft are also available for science missions. More information about using the aircraft can be

Airborne Science Program Resources	Platform Name	Center	Duration (Hours)	Useful Payload (lbs.)	GTOW (lbs.)	Max Altitude (ft.)	Airspeed (knots)	Range (Nmi)	Internet and Document References
ASP Supported Aircraft	DC-8	NASA-DFRC	12	30,000	340,000	41,000	450	5,400	http://airbornescience.nasa.gov/aircraft/DC-8
	ER-2	NASA-DFRC	12	2,900	40,000	>70,000	410	>5,000	http://airbornescience.nasa.gov/aircraft/ER-2
	Gulfstream III (G-III) (C-20A)	NASA-DFRC	7	2,610	69,700	45,000	460	3,400	http://airbornescience.nasa.gov/aircraft/G-III_C-20A_-_Dryden
	Gulfstream III (G-III)	NASA-JSC	7	2,610	69,700	45,000	460	3,400	http://airbornescience.nasa.gov/aircraft/G-III_-_JSC
	Global Hawk	NASA-DFRC	30	1900	25,600	65,000	345	11,000	http://airbornescience.nasa.gov/aircraft/Global_Hawk
	P-3B	NASA-WFF	14	14,700	135,000	32,000	400	3,800	http://airbornescience.nasa.gov/aircraft/P-3_Orion
NASA Catalog Aircraft	B-200 (UC-12B)	NASA-LARC	6.2	4,100	13,500	31,000	260	1,250	http://airbornescience.nasa.gov/aircraft/B-200_UC-12B_-_LARC
	B-200	NASA-DFRC	6	1,850	12,500	30,000	272	1,490	http://airbornescience.nasa.gov/aircraft/B-200_-_DFRC
	B-200	NASA-ARC/DOE	6.75	2,000	14,000	32,000	250	1,883	http://airbornescience.nasa.gov/aircraft/B-200_-_DOE
	B-200	NASA-LARC	6.2	4,100	13,500	35,000	260	1,250	http://airbornescience.nasa.gov/aircraft/B-200_-_LARC
	C-23 Sherpa	NASA-WFF	6	7,000	27,100	20,000	190	1,000	http://airbornescience.nasa.gov/aircraft/C-23_Sherpa
	Cessna 206H	NASA-LARC	5.7	1,175	3,600	15,700	150	700	http://airbornescience.nasa.gov/aircraft/Cessna_206H
	Dragon Eye	NASA-ARC	1	1	6	500+	34	3	http://airbornescience.nasa.gov/aircraft/B-200_-_LARC
	HU-25C Falcon	NASA-LARC	5	3,000	32,000	42,000	430	1,900	http://airbornescience.nasa.gov/aircraft/HU-25C_Falcon
	Ikhana	NASA-DFRC	24	2,000	10,000	40,000	171	3,500	http://airbornescience.nasa.gov/aircraft/Ikhana
	Learjet 25	NASA-GRC	3	3,200	1,500	45,000	350	1,200	http://airbornescience.nasa.gov/aircraft/Learjet_25
	S-3B Viking	NASA/GRC	6	12,000	52,500	40,000	450	2,300	http://airbornescience.nasa.gov/aircraft/S-3B
	SIERRA	NASA-ARC	10	100	400	12,000	60	600	http://airbornescience.nasa.gov/platforms/aircraft/sierra.html
	T-34C	NASA-GRC	3	500	4,400	25,000	75	700	http://airbornescience.nasa.gov/aircraft/T-34C
	Twin Otter	NASA-GRC	3	3,600	11,000	25,000	140	450	http://airbornescience.nasa.gov/aircraft/Twin_Otter_-_GRC
	WB-57	NASA-JSC	6	6,000	63,000	60,000+	410	2,500	http://airbornescience.nasa.gov/aircraft/WB-57

Table 6. Airborne Science Program aircraft and their performance capabilities

found on the ASP website at airbornescience.nasa.gov. The annual “call letter” is an excellent source of information and can be found on the website.

The capabilities of the ASP fleet range from low and slow to high and fast, with a wide variety of payload capacities. The aircraft and their performance characteristics are listed in Table 6. The altitude/ endurance characteristics are also shown in Figure 30. The actual flight profiles of the various aircraft can be found in Appendix 4.

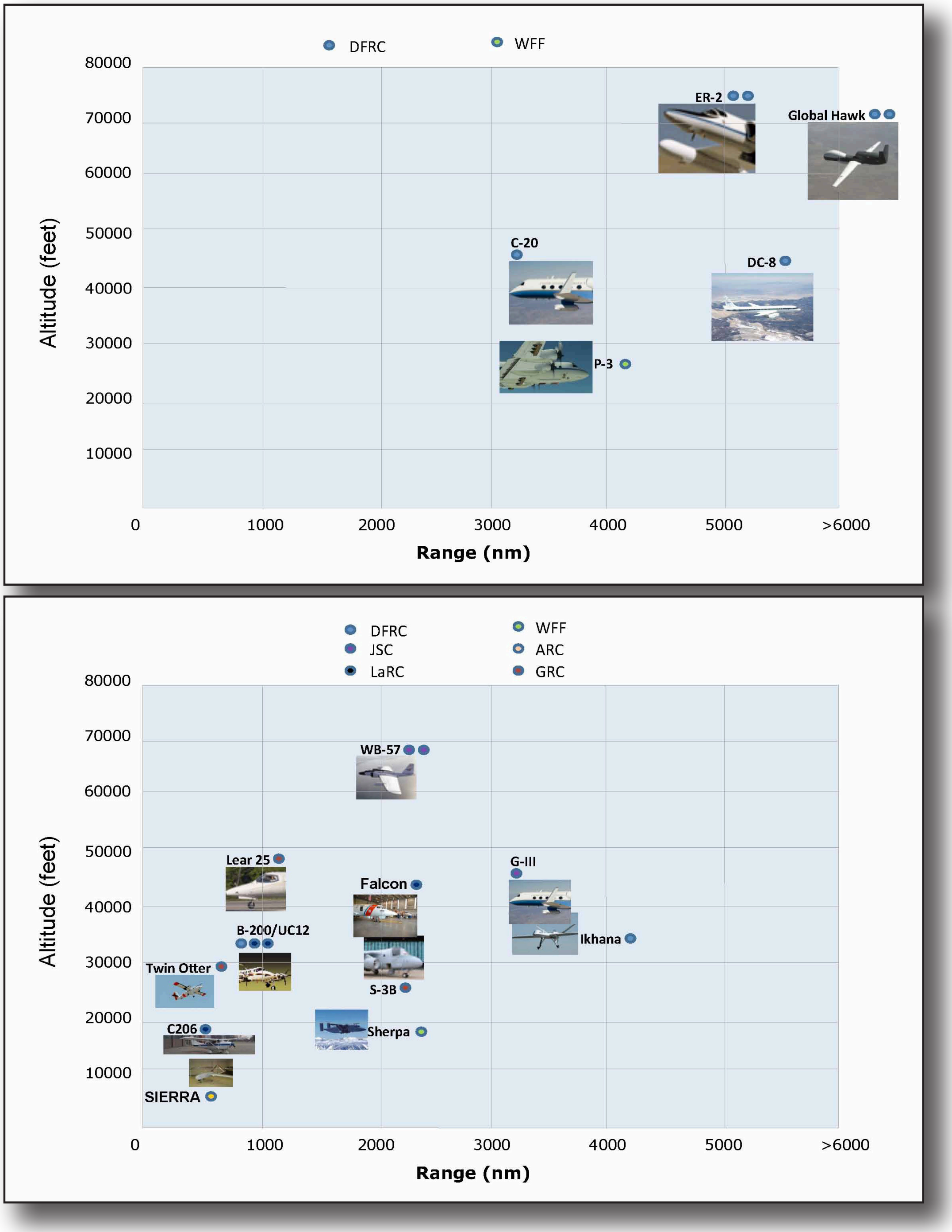


Fig. 30. Flight characteristics of NASA aircraft. Top: ASP-supported. Bottom: Other NASA aircraft.

ASP-Supported Aircraft

The six aircraft directly supported (with subsidized flight hours) by the Airborne Science Program are the DC-8 flying laboratory, (2) ER-2 high altitude aircraft, P-3B Orion, C-20A G-III, JSC G-III, and (2) Global Hawk unmanned aircraft systems (UAS).

DC-8

The NASA DC-8 flying laboratory is a four-engine jet transport aircraft that has been highly modified to support the agency's Airborne Science mission. The aircraft, acquired in 1985, is 157 feet long with a 148-foot wingspan. With a range of 5,400 nautical miles, it can fly at altitudes from less than 1,000 to 42,000 feet for up to 12 hours, although most science missions range six to 10 hours. The DC-8 can carry 30,000 pounds of scientific instruments and equipment and can seat up to 45 experimenters and flight crew.

The DC-8 incorporates a suite of sensors and data systems and provides services that can be tailored to specific missions or instruments. The DC-8 also has Iridium and Inmarsat satellite communications capability. Two Iridium-based communications systems, one for flight crew communications and one for science team communications, a multichannel system for upload of meteorological data, chat messaging, limited data telemetry and live Web page updates are available.

Fig. 31. DC-8 taking off from Puntas Arenas, Chile on route to Antarctica.

The NASA DC-8 flight operations are provided by NASA /Dryden Flight Research Center based out of the Dryden Aircraft Operations Facility in Palmdale, CA. The University of North Dakota National Suborbital Education and Research Center (NSERC) provides science mission operations including payload integration engineering, data display and satcom systems and support, and education and outreach for the program.

Flight hours in FY2012: 544.8 hours

Names and locations of missions flown

- OIB 2011 deployed to Chile - 308.7 flt hrs
- GCPEX deployed to Bangor, Maine - 80.0 flt hrs (Figure 23)
- DC-3 deployed to Salina, Kansas - 139.0
- Pilot proficiency flights - Palmdale - 17.1 flt hrs

Aircraft status, any modifications made in FY12, science benefit / impact of those improvements:

Flight hours in FY2012: 544.8 hours

Names and locations of missions flown

- OIB 2011 deployed to Chile - 308.7 flt hrs
- GCPEX deployed to Bangor, Maine - 80.0 flt hrs
- DC-3 deployed to Salina, Kansas - 139.0
- Pilot proficiency flights - Palmdale - 17.1 flt hrs

Aircraft status, any modifications made in FY12, science benefit / impact of those improvements:

Controller Pilot Data Link Capability (CPDLC) added to cockpit radio communications system inpreparation for SEAC4RS deployment. CPDLC will allow more efficient Air Traffic Control handling of the DC-8 in the very complex Southeast Asian airspace system and in the situation where the aircraft will be requesting numerous route/altitude changes (such as atmospheric chemistry missions).

Fig. 32. DC-8 in GCPEX

Planned or expected short and long maintenance periods in upcoming 5 years:

- DC-8 Heavy Maintenance Check and landing gear change - 10/1/2013-9/30/2014
- C-Check maintenance 10/1/2018 - 10/31/2018

Website: http://www.nasa.gov/centers/dryden/news/FactSheets/FS-050-DFRC.html

P-3

The NASA Goddard Space Flight Center's Wallops Flight Facility operates a P-3 Orion research aircraft to support airborne science research. Wallops Flight Facility has operated the P-3 since 1991 in support of a variety of scientific studies including ecology, meteorology, atmospheric chemistry, cryospheric research, oceanography, soil science, biology, and satellite calibration/validation. The P-3 is also used as a technology test bed for new airborne and satellite instrumentation. The P-3 is a self-sufficient global reaching aircraft that can operate from civilian and military airports to remote areas of the world in support of scientific studies.

Fig. 33. The NASA P-3

The P-3 is a four-engine turboprop aircraft designed for endurance and range and is capable of long duration flights. The P-3 has been extensively modified to support airborne science related activities. Aircraft features include zenith ports, three nadir ports (aft of the wings), and eight P-3 and DC-8 style windows to mount experiments, a tail cone, nose radome and ten mounting locations on the wings. Most of the fuselage ports are contained within the pressurized cabin environment. The unpressurized bomb bay can be converted into experimenter ports via a custom fairing. This fairing creates two large nadir ports and several oblique ports for installation of large sensors and antennas.

A project data system is located on the aircraft and provides aircraft data and video throughout the cabin. This system is also connected to two satellite constellations and provides uplink/downlink capability, internet access, flight tracking, and instant messaging between other aircraft and ground assets. Several sensors are connected to the project data system to provide meteorological and aircraft positional data to experimenters. An engineering data system is also integrated into the aircraft along with an air data boom to gather pertinent flight test data to determine effects of installations on the aircraft's flight envelope.

Flight hours in FY2012: 410

P-3 Missions

- Operation Ice Bridge Arctic - Thule and Kangerlussauq Greenland & Fairbanks, AK
- Student Airborne Research Program - Palmdale, CA
- LIDAR - Wallops Island, VA
- DBSAR/A-LISTS - Wallops Island, VA
-

P-3 Orion Upgrades

New experimenter seats were installed in the aircraft to replace the previous military style P-3 seats. Twenty seats were purchased and installed on custom mounting rails designed to support static and dynamic emergency landing load requirements. All seats have four-point seat belts and are adjustable in the vertical direction. The reduced-weight seats allow for an additional 300lbs of payload capacity.

P-3 Orion Maintenance Activities

- 11/19/12 - 12/31/12 - Annual Maintenance
- 5/6/13 - 6/23/13 - Annual Maintenance
- 8/8/14 - 7/10/15 - Re-wing Effort
- 7/13/15 - 8/14/15 - Annual Maintenance
- 6/1/16-9/1/16 - Depot Maintenance (can be moved to support missions)

Website: http://airbornescience.nasa.gov/aircraft/P-3_Orion

Fig. 34. The NASA P-3 being prepared for a Beaufort Sea survey flight on a chilly morning in Fairbanks, Alaska. Credit: NASA/M. Studinger.

ER-2

NASA operates two ER-2 aircraft as readily deployable high altitude sensor platforms to collect remote sensing and in situ data on earth resources, atmospheric chemistry and dynamics, and oceanic processes. The aircraft also are used for electronic sensor research and development, satellite calibration and satellite data validation. Operating at 70,000 feet (21.3 km) the ER-2 acquires data above ninety-five percent of the earth's atmosphere. The aircraft also yields an effective horizon of 300 miles (480 km) or greater at altitudes of 70,000 feet. Consequently, ER-2 sensors acquiring earth imagery or conducting atmospheric sounding replicate spatial, spectral and atmospheric characteristics of data collected by earth observing sensors aboard orbiting satellites.

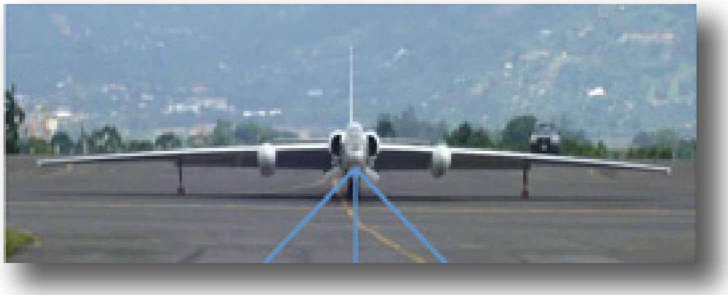


Fig. 35. ER-2 carrying MABEL in the nose, and indicating the instrument swath width.

Flight hours in 2012: 383.9 hours

Missions during 2012: 16 Local missions, based out of Palmdale

Two deployments

- MABEL: Greenland, based in Keflavik, Iceland; TN 806 deployed April 1-27, 2012
- MABEL: Wallops, based at WFF; TN 809 deployed Sept 7-26, 2012

Aircraft system modifications

Both ER-2s were modified in 2012 to include the new NASDAT/EIP system described in Section 4. This will allow significant improvement for real-time monitoring of the science sensors, for both health monitoring and quick-look data analysis.

Upcoming maintenance

600-hour inspection is our significant maintenance down time, TN 809 is 430 hours away and TN 806 will be coming out of the 600-hour inspection in December (2012). Assuming 600 total flight hours per year:

- FY14 – 809 600-hour
- FY15 – 806 600-hour
- FY16 – 809 600 hour
- FY17 – 809 600 hour

Website: http://airbornescience.nasa.gov/aircraft/ER-2

G-III (C20-A) Dryden

The NASA C-20A (Gulfstream 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.

NASA Dryden's G-III is equipped with a self-contained on-board Data Collection and Processing System (DCAPS). DCAPS is designed to allow easy upgrades, addition of add-on systems for expansion, and to operate in both autonomous and manual modes. The aircraft has been used extensively since 2005 to fly JPL's UAVSAR synthetic aperture radar system, which is carried in a pod under the aircraft.

Fig. 36. G-III with UAVSAR during SMAPVEX12.

Flight hours during 2012: 445.5

Missions during 2012:

Hawaii (Deployment)
Iceland (Deployment)
North Dakota (Deployment)
New Orleans (Deployment)
California (Local)
Mexico (Local)
Colorado (Local)

Aircraft system modifications: None in 2012

Upcoming maintenance

- Operations 1/2 and Pod Annual: February 2013: Month Duration
- Yearly Maintenance: October 2013: Month Duration
- Operations 1/3 and Pod Annual: March 2014: Month Duration
- Yearly Maintenance: October 2014: Month Duration
- Operations 1/2 and Pod Annual: March 2015: Month Duration
- Yearly Maintenance: October 2015: Month Duration
- Operations 1/3 and Pod Annual: March 2016: Month Duration
- Yearly Maintenance: October 2016: Month Duration
- Operations 1/2 and Pod Annual: March 2017: Month Duration
- Yearly Maintenance: October 2017: Month Duration

Website: http://airbornescience.nasa.gov/aircraft/G-III_C-20A_-_Dryden

G-III JSC

NASA Johnson Space Center's Gulfstream III (N992NA) is used to transport astronauts returning from Kazakhstan to Houston, Texas after completing missions aboard the International Space Station. In 2011-2012, the aircraft was extensively modified to accommodate the NASA Jet Propulsion Laboratory's P-band Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) instrument in a pod below the fuselage. The interior was also modified to include equipment racks and crew stations for the UAVSAR and Platform Precision Autopilot (PPA) operators. The P-band UAVSAR instrument is used to study North American root-zone soil moisture as part of the Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) project. AirMOSS is part of the NASA Earth Venture-1 (EV-1) program.

Fig. 37. JSC G-III carrying AirMOSS in SAR pod.

Flight hours and Missions during FY2012

63.4 flight hours for AirMOSS - 30.7 hrs pod airworthiness/PPA and 32.7 hrs engineering/calibration, all from the Dryden Aircraft Operations Facility (DAOF) in Palmdale

Aircraft system modifications

JSC completed the AirMOSS modification in January, 2012. The aircraft was modified to allow the airplane to be switched back and forth between the AirMOSS configuration and the astronaut return mission configuration.

Upcoming maintenance

The airplane is undergoing significant maintenance now with engine changes (the current engines are due a "mid-life" inspection) and other required aircraft inspections. We anticipate this effort to take about 45 days. Our long range plan is to use the months of January and February, which are months of minimal AirMOSS activity, for any major maintenance required each year.

Website: http://airbornescience.nasa.gov/aircraft/G-III_-_JSC

Global Hawk

NASA's Dryden Flight Research Center operates two developmental-model Northrop Grumman Global Hawk unmanned aircraft for high-altitude, long-duration Earth science missions. Acquired from the U.S. Air Force, these remotely piloted aircraft are the first and sixth built under the original Global Hawk Advanced Concept Technology Demonstrator development program sponsored by the Defense Advanced Research Projects Agency. The ability of the Global Hawk to autonomously fly long distances, remain aloft for extended periods of time and carry large payloads brings a new capability to the science community for measuring, monitoring and observing remote locations of Earth not feasible or practical with piloted aircraft, most other robotic or remotely operated aircraft, or space satellites.

The aircraft's 11,000-nautical-mile range and 24-hour endurance, together with satellite and line-of-site communication links to the ground control station, allow for eventual worldwide operation. Dedicated satellite communication links provide researchers with direct access to their onboard instrument packages during missions. Researchers have the ability to monitor instrument function from the ground

Fig. 38. Two Global Hawks at DFRC.

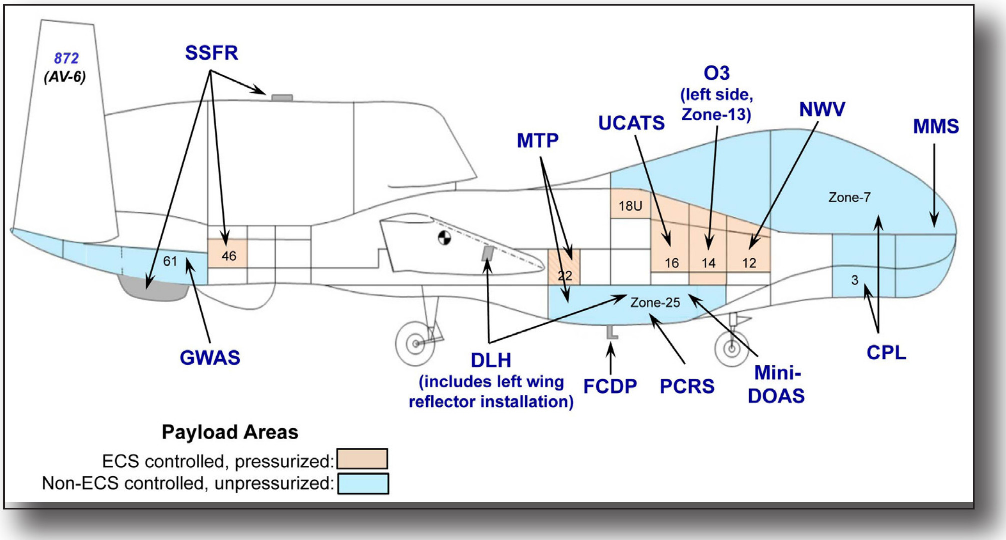


Fig. 39. Global Hawk payload zones with instruments as integrated for ATTREX.

control station and evaluate selected data in real time.

In 2012, the aircraft known as Air Vehicle-1 (AV-1) or TN871 flew its first science mission, as described in the HS3 section. This doubles the capability of the ASP for high altitude, long endurance science missions.

Flight hours in FY2012

- TN871: 56.6 total flight hours, 29.0 science hours
- TN872: 197.5 total flight hours, 165.9 science hours

Missions flown during 2012

- TN871: HS3, flown from Edwards AFB
- TN872: HS3, flown from WFF

Aircraft system modifications

- TN871- The payload support system, including Ku-band communications for the payload capability, was added to the aircraft. Both Global Hawk aircraft now have the same configuration for supporting instruments. Also, Ku -Band ATC communications capability was added.
- TN872- Ku ATC capability was added. This capability greatly improves the connectivity and quality of communications between the pilots and ATC controllers. Shown in Figure 29 are the two payload configurations used in HS3.
- Upcoming mods include pylon installation and Hawkeye pod integration.

Upcoming maintenance

- TN871
  1. 75 cycle inspection, 6 weeks, FY15
  2. 2250 flight hour engine inspection, 6 weeks, FY16
- TN872
  1. 75 cycle inspection, 6 weeks, FY13
  2. 2250 flight hour engine inspection, 6 weeks, FY14
  3. 75 cycle inspection, 6 weeks, FY16
  4. 4000 flight hour engine overhaul, 12 weeks, FY17

Website: http://airbornescience.nasa.gov/aircraft/Global_Hawk

Other NASA Earth Science Aircraft

Other NASA aircraft, as described here and on the Airborne Science website and in the annual ASP Call Letter are those platforms operated by NASA centers, but not subsidized by the ASP program. These are available for science through direct coordination with the operating center.

WB-57

Fig. 40. JSC's 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 near JSC at Ellington Field. Both aircraft have been flying research mission from Ellington Field since the early-1970's, and continue to be an asset to the scientific community with professional, reliable, customer-oriented service designed to meet all scientific objectives.

The WB-57 is a mid-wing, long-range aircraft capable of operation for extended periods of time from sea level to altitudes well in excess of 60,000 feet. Two crew members are positioned at separate tandem stations in the forward section of the fuselage. The pilot station contains all the essential equipment for flying the aircraft while the sensor operator station contains both navigational equipment and controls for the operation of the payloads that are located throughout the aircraft. The WB-57 can fly for approximately 6.5 hours and has a range of approximately 2500 miles.

NASA currently operates two WB-57 aircraft, N926 and N928.

Aircraft manager: JSC

Science Flight hours in FY12: 29.7 hours (dedicated)

Names and locations of missions flown

- Airborne Scanning Microwave Limb Sounder (ASMLS), a NASA JPL payload, flown from Ellington Field, Houston, TX, flown on N928
- Optical Covariance Wind Lidar (OAWL), a Ball Aerospace payload, from Ellington Field on N926.

Aircraft status, modifications made in FY12, impact of those improvements

- N926 currently in Long Maintenance inspection, expected completion Mar 2013.
- N928 currently deployed on a reimbursable mission through Nov 2013.
- N927 is the new third WB-57 aircraft currently being regenerated to flying status, expected mission capable fall 2013.

Modifications to the fleet in FY12 include:

- An updated onboard computer system and network to support payload operations;
- Installation of new communications systems to support payload operations (N928) and to provide fleet commonality
- Completed engineering design for installation of the new next generation Experimenter Interface Panels (EIP) on N927. The installation includes backward compatibility with legacy EIPs.
- Continued assessment and upgrade of legacy aircraft systems to improve reliability and maintainability and initiated contractual activities to prepare for overhaul of the WB-57's TF-33PW11 engines.
- Completed design and began installation of ACES II ejection seat for N927 with installation to follow on N926 and N928 during major inspections
- Completed design of new autopilot system to provide improved reliability and maintainability as well as to provide RVSM capability.

Upcoming maintenance

- N926: Short MX inspection (3 weeks) in 2014, 2016; Long MX inspection (4 months) in 2013, 2015.
- N928: Short MX inspection (3 weeks) in 2014, 2016; Long MX inspection (4 months) in 2013, 2015.
- N927: Short MX inspection (3 weeks) in 2013, 2015; Long MX inspection (4 months) in 2014, 2016.

Website: http://airbornescience.nasa.gov/aircraft/WB-57

B-200 (LaRC)

The twin-turboprop engine plane was built in 1982, but came to NASA Langley from NASA's Marshall Space Flight Center in January 1996. Until recently, researchers used NASA 529 to develop technologies to make airplanes safer, to test a sensor that may improve measurements of the Earth's surface and for program support. Its payload capacity and flexibility make it an excellent instrument platform, so now the aircraft is equipped with a suite of state-of-the-art active and passive sensors, developed at Langley, to help scientists better understand our atmosphere and air quality.

Fig. 41. LaRC's B-200

Among the instruments on board that support projects for NASA's Science Mission Directorate and other government agencies is the NASA Langley High Spectral Resolution Lidar or HSRL. It is used to characterize small particles in the atmosphere called aerosols.

Flight hours during 2012: 92.4

Missions during 2012

- DEVOTE flew from NASA LaRC
- CALIPSO night calibration / validation 2012 flew from NASA LaRC
- Two Column Aerosol project (TCAP) flew from Cape Cod
- HSRL-2 Test flights: NASA LaRC VA&MD

Website: http://airbornescience.nasa.gov/aircraft/B-200_-_LARC

UC-12B (LaRC)

Flight hours during 2012: 38.3

Missions during 2012

- DEVOTE flew from NASA LaRC
- G-LiHT 12 flew from NASA LaRC with missions in VA and MD

Aircraft system modifications

None in 2012

Upcoming maintenance

Active flight status for DAWN. Will be down for annual maintenance until mid-January 2013.

Website: http://airbornescience.nasa.gov/aircraft/UC-12B

Fig. 42. LaRC's UC-12B

B-200 (Dryden)

NASA Dryden's Super King Air B-200 has been used for science since 2008. It has the same performance as the LaRC B-200, but has been outfitted with different ports and other features.

Flight hours and Missions during 2012

12.5 hours for a Fires mission in Southern California

Aircraft system modifications

Integration of AirSWOT to fly in 2013

Website: http://airbornescience.nasa.gov/aircraft/B-200_-_DFRC

Fig. 43. DFRC's B-200

Cessna 206H

Flight hours during 2012: 99.3

Missions during FY2012

- G-LiHT 2011 Mid-Atlantic Campaign
- G-LiHT 12 flew from NASA LaRC: VA and MD

Upcoming maintenance

Active flight status for DAWN. Will be down for annual maintenance until mid-January 2013.

Website: http://airbornescience.nasa.gov/aircraft/Cessna_206H

Fig. 44. Cessna 206H

Fig. 45. C-23 Sherpa aircraft during CARVE

C-23 Sherpa

The NASA Goddard Space Flight Center's Wallops Flight Facility owns a C-23 Sherpa research aircraft available to support airborne science research. The C-23 is used to perform scientific research, provide logistics support on an as-needed basis to other airborne science missions, and can be used as a technology test bed for new airborne and satellite instrumentation. This aircraft is also available to support range surveillance and recovery operations as needed. The C-23 is a self-sufficient aircraft that can operate from short field civilian and military airports to remote areas of the world in support of scientific studies and other operations.

The C-23 is a two-engine turboprop aircraft designed to operate efficiently, under the most arduous conditions, in a wide range of mission configurations. The large square-section cargo hold, with excellent access at both ends (four side fuselage doors and aft cargo ramp), and a 7000 pound payload, offers ready flexibility to perform a variety of missions. The aircraft also has 22 cabin windows as well as a nose cargo area available for installations.

Fig. 46. The CARVE payload version.

Flight hours: 258

C-23 Sherpa Missions: CARVE - Fairbanks, AK

C-23 Sherpa Upgrades: FY12 was the first year the C-23 Sherpa aircraft flew in support of NASA science missions. The aircraft was acquired in January 2012 and modified to support the CARVE mission (see Figure 45). An 8" diameter nadir port was installed as well as two 3" diameter camera nadir viewports. A forward-looking cockpit camera was installed for experimenter purposes. An experimenter power station was installed to convert 24VDC aircraft power to 115V 60HZ experimenter power. Experimenter GPS and XM satellite antennas were installed as well as cockpit mounted tablet PC's to support science navigation requirements.

Twin Otter (GRC)

The Twin Otter, DHC-6, is a versatile aircraft capable of flying various mission profiles with an array of instruments. The aircraft has instrument mounts on both wings as well as numerous fuselage mounting points. It is an economical aircraft for missions flown below 20,000' at speeds of around 90 to 140 knots.

Flight hours and Missions during 2012

15.6 hours for PRISM test flight in May 2012

Aircraft system modifications

Reduction of legacy weight from Twin Otter (removal of wire, systems, etc)---Impact to Science: less weight = more time aloft.

Upcoming maintenance forecast


Fig. 47. The GRC Twin Otter outside its hangar.

N607NA Twin Otter

CY13	Feb-Mar	June, Sept
CY14	March	June-Aug
CY15	Feb, June	
CY16	Mar, June-July	Sept
CY17	June	Sept

Website: http://airbornescience.nasa.gov/aircraft/Twin_Otter_-_GRC

HU-25C Falcon (LaRC)

The HU-25C is a modified business jet that has served as a search and rescue platform for the US Coast Guard since the 1980's. NASA LaRC acquired this aircraft in 2011 for service that provides a medium altitude, medium range platform for remote sensing instruments development and satellite support. Payload accommodations include a nadir camera port, large side looking search window ports, side looking radar hard points, and a drop hatch.


Fig. 48. HU-25C Falcon deployed from LaRC during ICE-Bridge

Flight hours and Missions during 2012

75.5 during Operation IceBridge. Falcon flew from Kangerlussuaq & Thule, Greenland.

Aircraft system modifications

The Falcon, operated by NASA LaRC, joined the fleet in 2012. Upgrades for science included:

- Installed research power distribution system
- Installed GPS antenna
- Installed Applanix antenna
- Installed SATCOM antenna
- Installed commercial weather radar
- Modified existing nadir portal to accommodate research instruments
- Enabled cabin to accommodate research pallets

Upcoming maintenance

Down for ACCESS modifications and upload until mid-January 2013.

Website: http://airbornescience.nasa.gov/aircraft/HU-25C_Falcon

SIERRA

Operator: ARC

The Sensor Integrated Environmental Remote Research Aircraft (SIERRA) is a medium-class, unmanned aircraft system (UAS) that can perform remote sensing and atmospheric sampling missions in isolated and often inaccessible regions, such as over mountain ranges, the open ocean, or the Arctic/Antarctic. UAS missions are of particular value when long flight durations or range-measurement requirements preclude a human pilot or where remote or harsh conditions place pilots and high-value aircraft at risk. Designed by the U.S. Naval Research Laboratory and developed at NASA's Ames Research Center, the SIERRA is well suited for precise and accurate data collection missions because it is large enough to carry up to 100 pounds of scientific instruments for up to 600 miles yet small enough not to require a large runway or hangar.

Science Flight hours in FY12: 17

Fig. 49. The SIERRA and field crew in Surprise Valley, 2012.

Names and locations of missions flown

Long-term Earthquake Hazards and Groundwater Resources in a Tectonically, PI Jonathan Glen. Location: Surprise Valley, California

High Resolution Assessment of Carbon Dynamics in Seagrass and Coral Reef Biomes, PI: Stan Herwitz. Location: Key West, Florida

Aircraft status

Operational, in mission prep

Modifications made in FY12 and impact of those modification for science

- Designed and built new wing tip and boom mounts for payloads
- Modified autopilot to enable transponder switch
- Installed 421.5Mhz radio for LOS redundancy
- Installed shielded Iridium antennae
- Fabricated enclosure and installed upgraded Novatel/IMU
- Fabricated power supply and server driver card boxes
- Designed, built, and tested an engine test stand.

Planned or expected short and long maintenance periods in upcoming 5 years

- Major inspections occur every 100 hrs
- Ongoing inspections every 50 hrs including engine mounts
- Cylinder inspection is conducted after every flight.

Plans for FY2013

- March mission to Costa Rica for ASTER algorithm validation using Dragon Eye UAV
- May mission to Key West Florida for final flights of Seagrass mission

Website: http://airbornescience.nasa.gov/aircraft/SIERRA

Ikhana UAS

The Ikhana is a remotely piloted General Atomics Predator B that was acquired by NASA to serve as an aeronautical research aircraft and to serve the Earth Sciences community. The Ikhana measures 36 feet in length, and has a wingspan of 66 feet. It has a maximum takeoff weight of 10,000 pounds. The payload capability of Ikhana is 2000 plus pounds (external) and more than 800 pounds (internal). Where possible, sensor payloads are integrated into wing-mounted pods to minimize aircraft downtime and allow rapid reconfiguration. Ikhana can operate at altitudes from 500 feet to above 40,000 feet with endurances above 24 hours.

Fig. 50. The Ikhana

Ikhana dd not fly for NASA science in 2012.

Website: http://airbornescience.nasa.gov/aircraft/Ikhana

IV. AIRCRAFT CROSS-CUTTING SUPPORT AND IT INFRASTRUCTURE

Aircraft support entails aircraft facility instrument operations and management, engineering support for payload integration, flight planning and mission management tools, flight navigation data hardware and software support, in addition to flight data archiving and distribution.

Cross-cutting support for ASP missions is managed at Ames Research Center and is supported by the University of California-Santa Cruz Airborne Sensor Facility, and University of North Dakota-NSERC. Specific activities include providing facility instruments, satellite communications and telemetry, and mission tools.

ASP Facility Science Infrastructure

The Airborne Science Program provides a suite of facility instrumentation and supporting systems for community use by NASA investigators. These are listed in Table 7. They include stand-alone precision navigation systems; and a suite of digital tracking cameras and video systems. The Airborne Sensor Facility (ASF) at Ames Research Center, including engineers embedded at NASA Dryden, primarily support these systems. The ASF also operates a community instrument calibration facility under the supervision of the EOS Program, which supports a variety of NASA airborne remote sensing systems with spectral and radiometric characterizations. The NASA Earth Science Division, through the EOS Project Science Office and the Research and Analysis Program, also maintains a suite of advanced imaging systems that are made available to support multidisciplinary research applications. Access to any of these assets is initiated through the ASP Flight Request process. A state-of-the-art real-time data communications network is being implemented across the Airborne Science Program core platforms. Utilizing onboard Ethernet networks and satellite communications systems, it is intended to maximize the science return from both single-platform missions and complex multi-aircraft science campaigns. It also leverages the extensive data visualization software developed for the NASA DC-8 aircraft, together with data synthesis technologies funded through ESTO and Applied Science Program grants.

Airborne Science Program Facility Equipment		
Instrument/Description	**Supported Platforms**	**Support group/location**
DCS (Digital Camera System) 16 MP color infrared cameras	DC-8, ER-2, Twin Otter, WB-57, B200	Airborne Sensor Facility / ARC
DMS (Digital Mapping System) 21 MP natural color cameras	DC-8, P-3B	Airborne Sensor Facility / ARC
POS AV 510 (3) Applanix Position and Orientation Systems DGPS w/ precision IMU	DC-8, ER-2, P-3B, B200	Airborne Sensor Facility / ARC
POS AV 610 (2) Applanix Position and Orientation Systems DGPS w/ precision IMU	DC-8, P-3B	2 Airborne Sensor Facility / ARC, 1 at WFF
HDVIS High Definition Time-lapse Video System	Global Hawk UAS	Airborne Sensor Facility / ARC
LowLight VIS Low Light Time-lapse Video System	Global Hawk UAS	Airborne Sensor Facility / ARC
EOS and R&A Program Facility Instruments		
Instrument/Description	**Supported Platforms**	**Support group/location**
MASTER (MODIS/ASTER Airborne Simulator) 50 ch multispectral line scanner V/SWIR-MW/LWIR	B200, DC-8, ER-2, P-3B, WB-57	Airborne Sensor Facility / ARC
Enhanced MAS (MODIS Airborne Simulator) multispectral scanner (38 ch) + VSWIR imaging spectrometer (192 ch)	ER-2	Airborne Sensor Facility / ARC
AVIRIS-ng Imaging Spectrometer (380 - 2510nm range, Δλ 5nm)	Twin Otter	JPL / JPL
AVIRIS Classic Imaging Spectrometer (400 – 2500nm range, Δλ 10nm)	ER-2, Twin Otter	JPL / JPL
UAV_SAR Polarimetric L-band synthetic aperture radar, capable of Differential interferometry	G-III, Global Hawk (2013)	JPL / JPL
NAST-I Infrared imaging interferometer (3.5 – 16µm range)	ER-2	U Wisconsin / LaRC
Satellite Communications systems on ASP aircraft		
Sat-Com System Type / Data Rate (nominal)	**Equipped Platforms**	**Support group / location**
Ku-Band (single channel) / > 1 Mb/sec	Global Hawk & Ikhana UAS	NSERC / DFRC
Inmarsat BGAN (two channel systems) / 432 Kb/sec per channel	DC-8, WB-57, P-3B, S-3B, DFRC B200, (ER-2 in 2013)	Airborne Sensor Facility / DFRC
Iridium (1 – 4 channel systems) / 2.8 Kb/sec per channel	Global Hawk, DC-8, P-3B, ER-2, WB-57, G-3, SIERRA, others	Airborne Sensor Facility, NSERC /ARC

Table 7: Airborne Science Program Cross-Cutting Infrastructure and Capabilities

The sensor network architecture includes standardized instrument interface protocols, a new common Experimenter Interface Panel (EIP), and an airborne network server and satellite communication gateway known as the NASA Airborne Science Data and Telemetry (NASDAT) system. These capabilities are now operational on the Global Hawk UAS, DC-8, P-3B, ER-2, aircraft.

Satellite Communications Systems

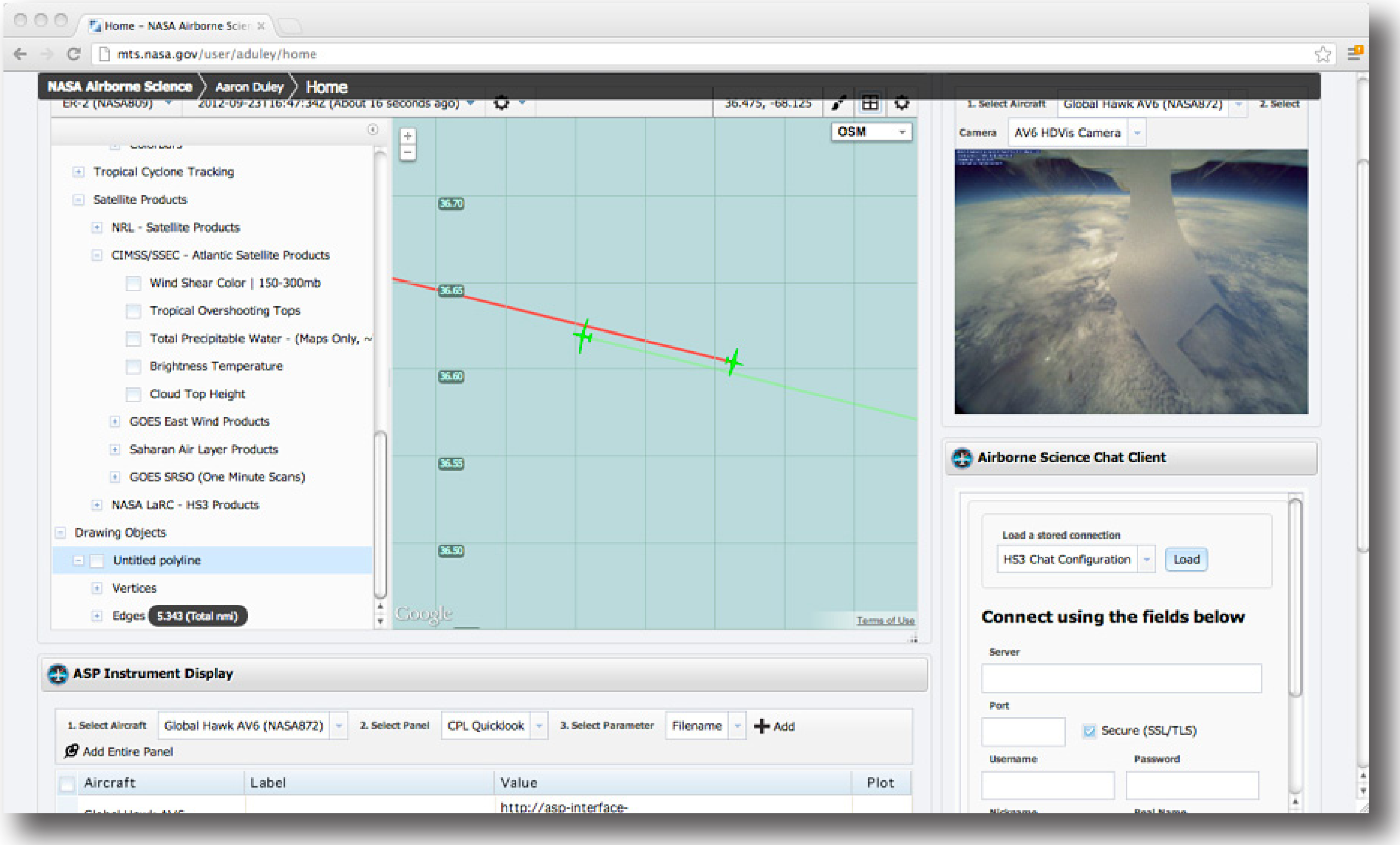
Several types of airborne satellite communications systems are currently operational on the core science platforms. High bandwidth Ku-Band systems, which use a large steerable dish antenna, are installed on the Global Hawk and Ikhana UAS. New Inmarsat BGAN (Broadband Global Area Network) multi-channel systems, using electronically-steered flat panel antennas, are now installed on many of the core aircraft. Data-enabled Iridium satellite phone modems are also in use on most of the science platforms as well. Although these have a relatively low data rate, unlike the larger systems, they operate at high polar latitudes and are light weight and inexpensive to operate.

Mission Tools

The Mission Tools Suite (MTS) is a set of web-based tools developed to support various activities within the NASA Airborne Science Program. MTS targets a number of key objectives. First, deliver a common operating picture for improved shared situational awareness to all participants in NASA's Airborne Science missions. These participants include scientists, engineers, managers, and the general public. Second, encourage more responsive and collaborative measurements between instruments on multiple aircraft, satellites, and on the surface in order to increase the scientific value of these measurements. Third, provide flexible entry points for data providers to supply model and advanced analysis products to mission team members. Fourth, provide data consumers with a mechanism to ingest, search and display data products. Finally, embrace an open and transparent platform where common data products, services, and end user components can be shared with the broader scientific community.

Prior year accomplishments included operational mission support roles for the Hurricane and The Mission Tools Suite (MTS; formally known as COMPASS) is a set of web-based tools developed to support various activities within the NASA Airborne Science Program. MTS targets a number of key objectives. First, deliver a common operating picture for improved shared situational awareness to all participants in NASA's Airborne Science missions. These participants include scientists, engineers, managers, and the general public. Second, encourage more responsive and collaborative measurements between instruments on multiple aircraft, satellites, and on the surface in order to increase the scientific value of these measurements. Third, provide flexible entry points for data providers to supply model and advanced analysis products to mission team members. Fourth, provide data consumers with a mechanism to ingest, search and display data products. Finally, embrace an open and transparent platform where common data products, services, and end user components can be shared with the broader scientific community.

Prior year accomplishments included operational mission support roles for the Hurricane and Severe Storm Sentinel (HS3) and Airborne Tropical Tropopause Experiment (ATTREX) missions, as well as project support roles for Operation Ice Bridge (OIB). Because the NASA Airborne Science Program provides unique opportunities for students and teachers to connect with ongoing earth science research campaigns, in FY12, an education and public outreach (EPO) version of MTS was introduced. MTS-mini is a scaled down version of the full version of MTS aimed at supporting core K-12 classroom science curriculum. The tool permits teachers and students to watch a live camera feed from an aircraft, track an aircraft's location, plot data and chat live with HS3 mission scientists, pilots, and Airborne Science educational staff. In addition to MTS and the MTS EPO tool, the ASP Aircraft Public Tracker has also been improved to better accommodate campaign specific requirements. A link to the Aircraft Tracker is located on the Airborne Science Home Page. Looking forward into FY13, MTS and related tools will again be used to support HS3, ATTREX, OIB including a number of additional projects to include DISCOVER-AQ, PODEX and SEAC4RS.


mts.nasa.gov/user/aduley/home

1. Select Aircraft: Global Hawk AV6 (NASA872)

Camera: AV6 HDVis Camera

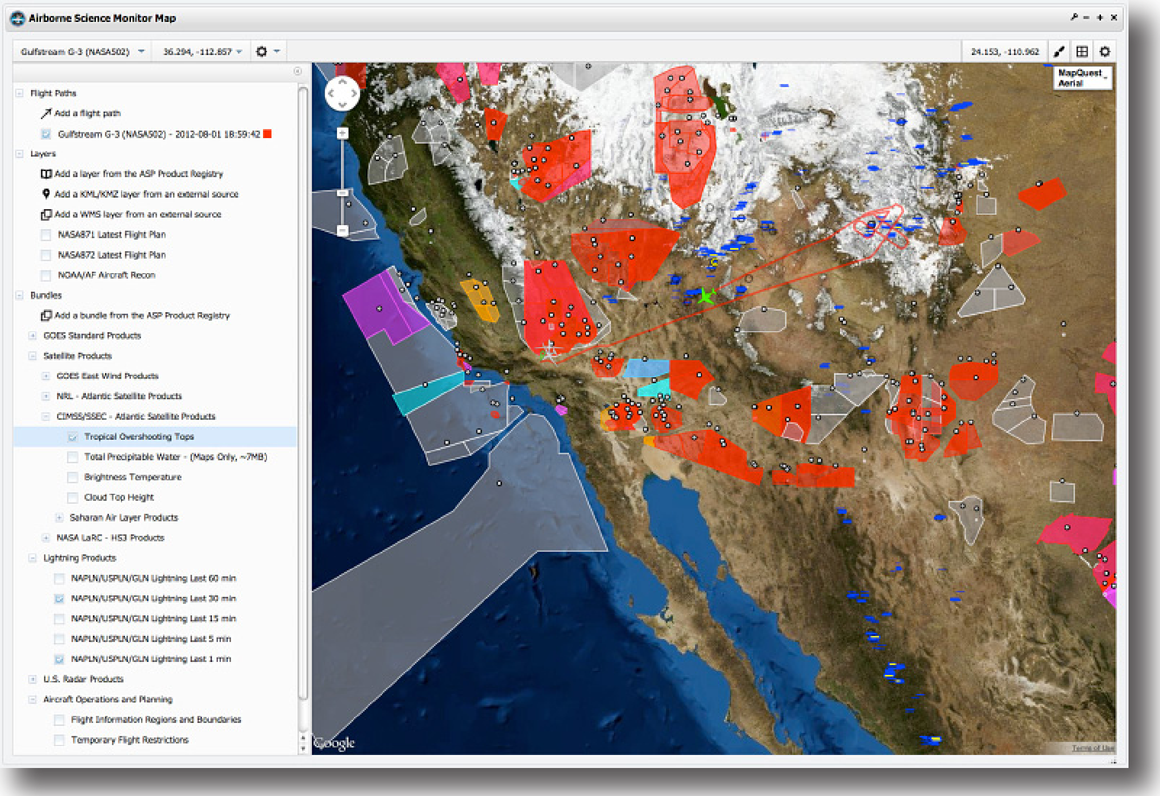
Load a stored connection: H53 Chat Configuration

Edges 5.343 (Total nmi)

1. Select Aircraft: Global Hawk AV6 (NASA872) 2. Select Panel: CPL Quicklook 3. Select Parameter: Filename

☑ Secure (SSL/TLS)

Fig. 51. MTS interface, including aircraft monitor, chat and instrument display tools



Flight Paths
  Add a flight path
  ☑ Gulfstream G-3 (NASA502) - 2012-08-01 18:59:42
Layers
  Add a layer from the ASP Product Registry
  Add a KML/KMZ layer from an external source
  Add a WMS layer from an external source
  ☐ NASA871 Latest Flight Plan
  ☐ NASA872 Latest Flight Plan
  ☐ NOAA/AF Aircraft Recon
Bundles
  Add a bundle from the ASP Product Registry
  GOES Standard Products
  Satellite Products
    GOES East Wind Products
    NRL - Atlantic Satellite Products
    CIMSS/SSEC - Atlantic Satellite Products
      ☑ Tropical Overshooting Tops
      ☐ Total Precipitable Water - (Maps Only, ~7MB)
      ☐ Brightness Temperature
      ☐ Cloud Top Height
      Saharan Air Layer Products
    NASA LaRC - HS3 Products
  Lightning Products
    ☐ NAPLN/USPLN/GLN Lightning Last 60 min
    ☑ NAPLN/USPLN/GLN Lightning Last 30 min
    ☐ NAPLN/USPLN/GLN Lightning Last 15 min
    ☐ NAPLN/USPLN/GLN Lightning Last 5 min
    ☑ NAPLN/USPLN/GLN Lightning Last 1 min
  U.S. Radar Products
  Aircraft Operations and Planning
    ☐ Flight Information Regions and Boundaries
    ☐ Temporary Flight Restrictions

Fig. 52. MTS monitor interface.

New Instruments

During FY2012, a number of new remote sensing instruments were test flown for science use with the Earth Science and ASP communities. The instruments, along with their descriptions and status are listed below.

AVIRIS-NG

Next Generation Airborne Visible Infrared Imaging Spectrometer This new imaging spectrometer makes measurements of spectral radiance from 380 to 2510 nm at 5 nm spectral resolution. It incorporates new technologies (e.g., an all-reflective Offner design) in order to achieve a factor of two improvement in Signal to Noise Ratio and spectral resolution relative to the legacy AVIRIS instrument, together with a significant reduction in mass and volume.

AVIRIS-NG flew over 100 hours in FY2012 and will fly again In 2013 and 2014.

E-MAS

Enhanced Version of the MODIS Airborne Simulator Modifications to the existing MAS instrument to increase calibration accuracy, and provide extended spectral resolution and coverage. Intended primarily for atmospheric research, it includes a new cryo-cooled infrared spectrometer with added bands at 6.7 and 7.3um, together with a bore-sighted VNIR/ SWIR Offner imaging spectrometer with 10 nm spectral resolution.

E-MAS flew 10 test hours in FY2012 and is scheduled for flight in SEAC4RS in 2013.

PRISM

The Portable Remote Imaging Spectrometer (PRISM) is a small VNIR imaging spectrometer optimized for coastal ocean science. It features 3nm spectral resolution over a 350 – 1050nm range, unprecedented sensitivity and dynamic range, very high Signal to Noise Ratio, and low polarization sensitivity. It also includes a two-band SWIR radiometer (1240 and 1640 nm) for atmospheric correction.

PRISM flew over 50 hours in FY2012 and is available for science. It is scheduled for a summer 2013 mission.

UAVSAR – Global Hawk

Uninhabited Aerial Vehicle Synthetic Aperture Radar on Global Hawk The two self-contained L-band radar pods will be installed on the Global Hawk UAV, enabling single pass polarimetric interferometry. The system will measure the vertical structure of ice and vegetation; and generate precision topographic maps. The very long range of the Global Hawk will enable measurements in the Polar Regions and other remote areas. The system is currently flying on a G-III aircraft.

NAST-I

The airborne NPOESS Airborne Sounding Testbed-Interferometer (NAST-I) is a high spectral and spatial resolution interferometer sounding system that was developed in support of the Cross-track Infrared Sounder (CrIS) flying on the Suomi National PP Satellite, as well as for a variety of other atmospheric research programs. The NAST-I covers a spectral range from ~ 600-2900 cm-1 (3.5-16 microns) yielding more than 9000 spectral channels of radiance emission information. The system is scheduled for aircraft integration and flight in 2013.

V. STRATEGIC PLANNING

The Airborne Science Program maintains and operates a diverse fleet of aircraft and infrastructure that support a diverse and evolving stakeholder community.

ASP leadership conduct a yearly strategic planning meeting in order to ensure the program maintains currently-required capabilities, renews these assets as new technologies become available, and extends the observational envelope to enable new earth science measurements. The program also plans strategically by looking at past experiences through formal meetings to discuss lessons learned following all major campaigns.

Requirements for Program assets are collected and communicated through the Program flight request system (http://airbornescience.nasa.gov/sofrs), the annual 5-yr schedule update, and through ongoing discussions with Mission and Program managers and scientists.

Strategic planning in the program is focused on the following areas:

- Core Aircraft – maintenance, upgrades, determining future composition
- Observatory management - improved tools for managing assets and requirements while improving the service to science investigators
- New Technology – bringing new technologies to observational challenges including application of advanced telemetry systems, on-board processing, IT mission tools, and new platforms

Requirements update

ASP personnel monitor upcoming science missions for potential airborne needs to support

- Algorithm development
- Instrument test
- Calibration and validation activities.
- Process studies

Participation in science team meetings and program reviews in 2012 to describe ASP capabilities and collect requirements information are listed in Table 9.

Activity
• ASP 5-yr Schedule Forecast Meeting at HQ
• Participation in NOAA River Observing workshop (telecon)
• Member of Terrestrial Ecology Airborne Science Working Group (Intermediate participation in HyspIRI Science team and Steering Group monthly telecons)
• Review of ESTO project requirements
• Participation in OIB science team meeting
• Participation 2012 HyspIRI Products Symposium
• Participation in "International Workshop on Greenhouse Gas Measurements from Space" (OCO-2 and ASCENDS)
• Decadal Survey Pre-formulation review
• SMAP 3rd Cal/Val workshop

Table 8. Activities to support ASP requirements information gathering

In 2012, the Program also began a formal update of the ASP requirements report. Input to the activity was requested from each of the NASA science centers (GSFC, LaRC, MSFC, ARC, and JPL) in the form of a survey. Preliminary results have been circulated within the program for review and an ASP Requirements meeting will be held in spring 2013.

5-Year Plan

A five-year plan is also maintained by the Program for out-year planning and scheduling. A graphical copy is shown in Appendix 2, depicting plans by science area and aircraft platform. Significant maintenance periods for the various aircraft are also indicated.

VI. EDUCATION, OUTREACH AND PARTNERSHIPS

Student Airborne Research Program 2012

The fourth Student Airborne Research Program (SARP) was held during June, July and August 2012. NSERC manages and implements SARP for NASA. The 8-week program was designed to expose and engage advanced undergraduate and early graduate students to NASA research and airborne science and engineering. The program was based at both at the NASA Dryden Aircraft Operations Facility in Palmdale, CA for the preparation and execution of five three-hour research data flights on the NASA P-3B, and at the University of California Irvine for data analysis and interpretation.

Fig. 53. Dr. Jack Kaye lecturing during SARP 2012.

Fig. 54. SARP 2012 students, mentors, faculty and staff pose in front of the P-3B before the science flights on Tuesday June 26, 2012.

The program contained the following elements:

- An introductory student poster session. The 32 participants (shown in Figure

45) from 30 different universities in 23 states (shown in Figure 46) presented their varied research interests to other participants, lecturers, and SARP faculty and staff.

- Lectures on NASA research programs, the Airborne Science Program, instrumentation, meteorology, atmospheric chemistry research, remote sensing techniques, oceanography, agricultural practices, instrument integration, airborne data systems, and sustainability and the environment.

- Experiences with instrument integration, flight planning, and data collection on five, three-hour science flights on the NASA P-3B.

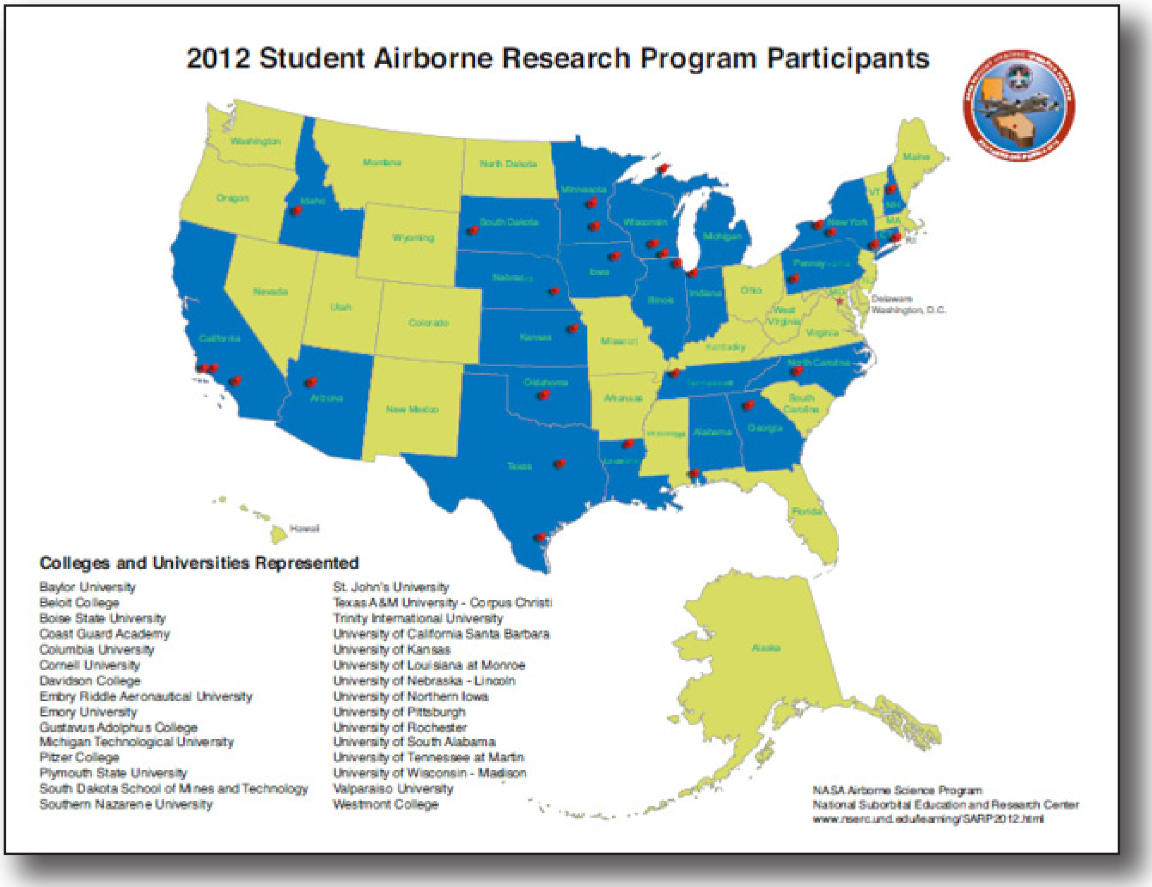
- Research projects included atmospheric science, air quality, oceanography, and land use topics.

- Multispectral remote sensing and in situ sampling techniques were employed.

- Field trips for ground truth validation of the airborne measurements

- Formal presentation of results and conclusions took place at the conclusion of the program

- Eight SARP 2012 participants presented first-author conference abstracts on the results of their research at the American Geophysical Union (AGU) Fall Meeting in San Francisco.



2012 Student Airborne Research Program Participants

Colleges and Universities Represented

Baylor University
Beloit College
Boise State University
Coast Guard Academy
Columbia University
Cornell University
Davidson College
Embry Riddle Aeronautical University
Emory University
Gustavus Adolphus College
Michigan Technological University
Pitzer College
Plymouth State University
South Dakota School of Mines and Technology
Southern Nazarene University
St. John's University
Texas A&M University - Corpus Christi
Trinity International University
University of California Santa Barbara
University of Kansas
University of Louisiana at Monroe
University of Nebraska - Lincoln
University of Northern Iowa
University of Pittsburgh
University of Rochester
University of South Alabama
University of Tennessee at Martin
University of Wisconsin - Madison
Valparaiso University
Westmont College

NASA Airborne Science Program
National Suborbital Education and Research Center
www.nserc.und.edu/learning/SARP2012.html

Fig. 55. Colleges and Universities represented in SARP 2012

Outreach

HS3: Public Outreach

The Hurricane and Severe Storm Sentinel Project (HS3) held several outreach events at Wallops Flight Facility and Dryden Flight Research Center during late summer 2012. Marilyn Vasques, HS3 Project Manager, spoke to the local community at the Wallops Visitor Center at the mission's start. (Figure 56) A cadre of local teachers visited each center for a few days in early August (Figure 57); they returned to their classrooms ready to teach students about NASA's hurricane science and to track HS3 flights on line. Dozens of students chatted real time with HS3 personnel during 6 of the flights. They used 'MTS Mini' -- a trimmed-down version of Airborne Science Mission Tools Suite, the same interface used by pilots and scientists to monitor conditions and plan flights. In addition, Wallops Flight Facility hosted an Educators Day, a Congressional Staffers visit, and a Media Day in which 17 members of the national and international press received information about the Global Hawks and HS3 science. The media event generated a number of articles in the scientific and lay press (http://espo.nasa.gov/missions/hs3/content/Links).

Fig. 57. Teachers learn about NOAA GH from pilot Jon Neuhaus in August 2012.

Fig. 56. HS3 Project Manager Marilyn Vasques below the Wallops Visitors Center in August 2012.

Earthquake Hazards UAS Project: USGS Public Outreach

As part of our field session in 2012, the Earthquake team supported two public events on Wednesday, September 5, 2012 for the Surprise Valley Mission. At these events the team provided a forum for schools and the general public where they could find information and talk to the scientists and engineers involved in the project. The schedule was as follows:

We held a 4-hour open house at the Cedarville airfield, led by Anne Egger (CWU) and Randy Berthold, the SIERRA mission manager. This event drew over 70 students and at least that many residents – amounting to ~20% of the

Fig. 58. Anne Egger speaking to high school students at open house.

Figure 59. A young visitor and SIERRA.

local population (Figures 58). The SIERRA aircraft was made available as a static display staffed by the SIERRA flight team.

Egger also gave a 2-hour evening public lecture sponsored by the Surprise Valley Rotary Club at the Surprise Valley Community Church, Cedarville. Post dinner a talk was provided by the science and flight teams about why we are working in Surprise Valley and what has been learned. The open forum "Q&A" addressed questions of relevance and applicability of the research.

In addition to these activities, we had near-continuous interaction with the public while we were in the field. This outreach was critical to the project, establishing positive relations with the local community and aiding a number of logistical issues while performing our mission. It has also fostered a very positive perception of NASA, the USGS, CWU, and collaborative scientific endeavors like ours.

Operation IceBridge Classroom Connections

During the Operation IceBridge Antarctica 2012, 49 classroom chats reached 728 students from across the US and Chile. Middle school student, Yerko Ignacio Valenzuela, is shown in Figure 60 in front of the MTS mini website in his classroom in Punta Arenas, Chile. He and his classmates and teacher used the MTS mini website to chat live with IceBridge scientists and crew who were flying in the DC-8 over Antarctica.

Fig. 60. Middle school student, Yerko Ignacio Valenzuela, in front of the MTS mini website in his classroom in Punta Arenas, Chile

Partnerships

A significant partnership maintained by NASA's Airborne Science Program is with the National Oceanographic and Atmospheric Administration (NOAA), particularly in the operation of UAS, where a Memorandum of Agreement has been in place since 2008. This close working relationship is primarily focused on joint missions using the NASA Global Hawks, for both the ATTREX and HS3 missions. This partnership has pushed the envelope of UAS science internationally, as suggested in Figure 61.

NOAA Corps pilots are certified pilots on NASA Global Hawk, and the NASA Global Hawk Deputy Project Manager is Captain Phil Hall of the NOAA Corps. NASA and NOAA are also working together on the MIZOPEX arctic project described previously.

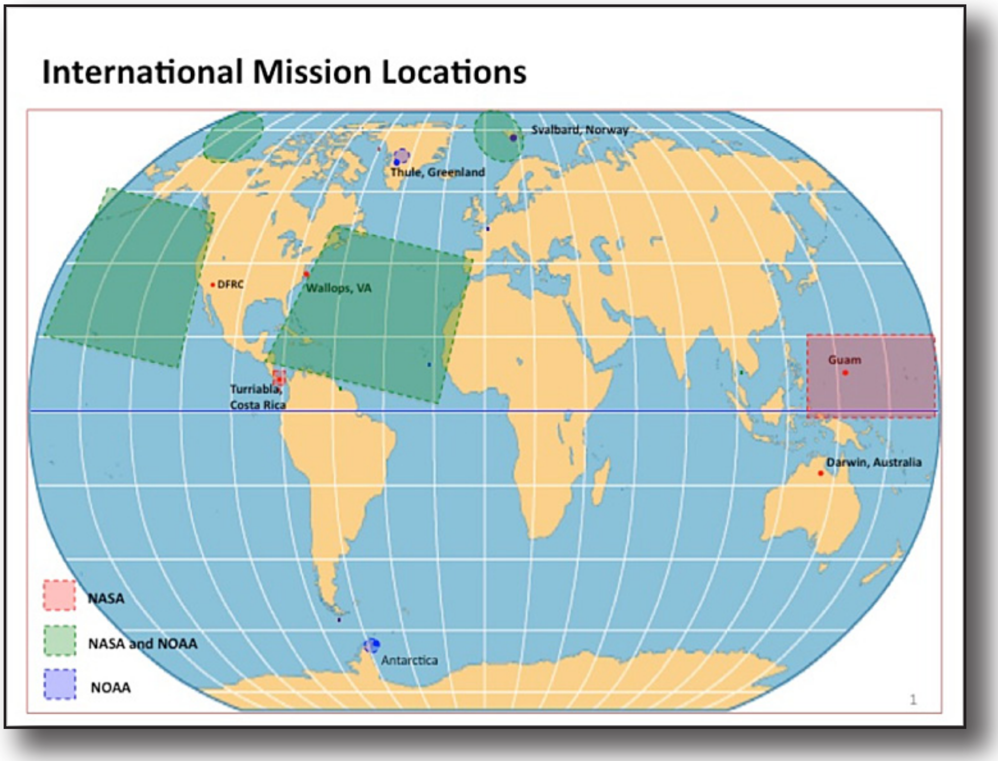
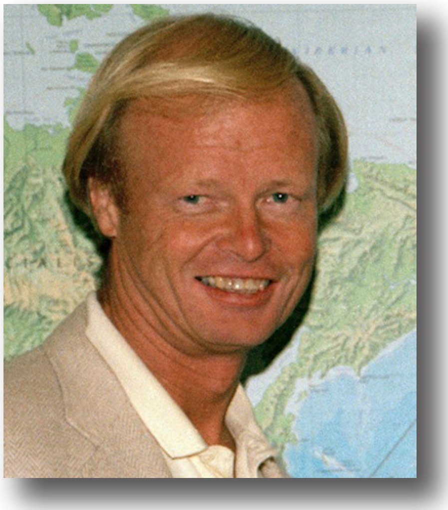


Fig. 61. International cooperative missions between NASA and NOAA.

Appendix A: Historical Perspective

John Arvesen



Introduction

The original 1958 NASA charter was updated in 1976 to promote the study of the Earth and Earth systems from the unique vantage point of space. NASA's Earth observing satellites make the critical measurements that characterize the chemical and dynamical processes that shape our planet, our environment, atmospheres, oceans, and crustal structure.

The building of space-borne remote sensing systems have many challenges, ranging from the need for operations in extreme environments, to capturing key scientifically defendable data. The Airborne Science Program provides a critical bridging capability. The development of new satellite remote sensing technologies is complex, iterative and expensive. New sensor developments often benefit by testing key technologies in airborne simulators. High altitude observations, above most of the atmosphere, better simulate observations from space, reflecting the distortions from water vapor and other constituents. Airborne data, with higher spatial and temporal resolution, help verify and validate models of the processes that drive our environment, giving greater confidence that we understand the global systems we observe from space.

John Arvesen started at Ames in 1957, and was a key player in the evolution of a robust and highly productive High Altitude observational capability. John's team led major missions all over the world. John also helped create a world-class sensor lab to complement the aircraft capability.

Author's perspective

John was interviewed by Jim Weber, Randy Albertson, and Matt Fladeland at the Marriott Hotel in San Francisco the 15th of December 2009 as part of an Airborne Science Program activity to capture the history of the program. The oral history was recorded and then transcribed shortly afterwards.

This summary, contributed by Steve Wegener, attempts to highlight some of the important activities and contributions that occurred during John's tenure with the program. I have used the Weber December 2009 interview of John as the basis of this historical perspective.

This summary, highlighting John's history at Ames, was augmented by the author's own extensive work with the Ames science aircraft operations group and the umbrella Airborne Science program.

My intention was to capture a flavor of the NASA high altitude program as it ramped up to maturity, and share some of the highlights. I've often provided context to frame events from the interview, and hopefully make the reading more enjoyable.

Fortunately, many of the readers of this ASP Annual Report have an understanding of the scope of the Airborne Science Program, and can appreciate many of John's challenges in context. I encourage you visit the ASP history page to download John's interview and enjoy a more intimate insight into the program than I'm able to capture here.

John Arvesen's tenure

John's adventure with NASA began in October of '57, when he was a freshman at Berkeley, majoring in Engineering Physics, and looking for a summer job. One opportunity of interest was an Intern Program with NACA (National Advisory Committee for Aeronautics) at the nearby Moffett Field. About the same time, Russia surprised the world with Sputnik and the race was on. John took the internship (in Flight Research) as NACA became NASA. It was during this internship that John fell in love with aircraft.

After graduating in 1960, John officially joined NASA, working in the Space Thermal Protection Branch, where part of the effort involved simulating the environment in Earth's orbit. His involvement with spectroscopy and radiometry led to his first taste of Airborne

Fig. 62: John's favorite photo from his tenure with the High Altitude Aircraft Program, taken during a very narrow time window in 1989 when the HAAP converted a USAF TR-1 loaner into our the third NASA ER-2. The additional aircraft was needed to meet the high level of flight activity at that time.

Fig. 63: During the 1987 ER-2 and DC-8 Antarctic Ozone Expedition, photos of NASA aircraft were presented to the Chilean Air Force host.

Science on the Convair 990 Solar Constant Expedition in 1967.

John recalls the Convair 990, later named Galileo I, was purchased in '65, with the '67 Goddard/ Ames mission one of the first. Bob Cameron was head of the Airborne Missions Branch at Ames, which included Earl Peterson.

Earth Science was starting to become very important within NASA. The public was behind it. Ames thoroughly supported Earth observation, and at that point, John developed a method to detect ocean chlorophyll by measuring a blue-green spectral ratio, and included verification on a low altitude aircraft.

About 1972, in an effort to see if it was possible to detect chlorophyll from high altitude, John participated in the Convair 990 Ocean Color Mission. Success at 40,000 feet spawned advances in Earth science sensor development and airborne observational capabilities, and Ames was at the middle of it all. John was in the right place at the right time

John was doing this in the Thermal Protection Branch, as a side project. There wasn't any Earth Science going on at Ames, so he was, luckily, allowed to continue. Then in '74-'75, as Apollo was winding down, John transferred over to Space Sciences Division. Earth Sciences was coming up pretty heavily on the horizon within NASA. In 1976 Congress changed the NASA charter to include the Upper Atmospheric Research Program and study of the Earth.

In 1976 Marty Knutson asked John to join his group as the sensor systems manager, and he jumped at the chance. Marty was the Branch Chief. Earl was assistant branch chief, and John was brought in to develop and manage the sensor systems that went on the two U-2 aircraft.

At that point, scientists discovered that chlorofluorocarbons might be harming our atmosphere. They hadn't discovered the ozone hole, that had not occurred yet, but they were very concerned about chlorofluorocarbons harming ozone. John got involved with creating an atmospheric sampling system, using a cryogenic sampler onboard the U-2 airplane.

At the time, John was also involved with the transition to digital scanners, simulating the Landsat Thematic Mappers. John's sensor group developed the Thematic Mapper Simulator (TMS).

As it was clear that the Air Force was phasing out the original U-2, in favor of a larger version called the TR-1, NASA was an early adaptor. The first TR-1 was delivered in June 1981, the first one off the line and NASA named it the ER-2 (Earth Resources)

In 1985 the Ozone Hole was discovered over Antarctica, and NASA responded with the first Ozone mission, the Airborne Antarctic Experiment (AAOE) in 1987, out of Punta Arenas, Chile. The success of the AAOE and the appearance of a developing ozone hole over the Arctic as well drove two more Ozone missions, first AASE, (January 1989) from Stavanger, Norway, then AASE 2, (1991-92) from Fairbanks and Bangor ME.

Later, John helped build up a balloon experiment with the same payload system that he had on the U-2 and flew it on a balloon out of Palestine, Texas. At 120,000 feet he saw the tail-off the chlorofluorocarbon due to the breaking apart in the ultraviolet as it got above the ozone layer. Nobody put all this information together until they discovered the ozone hole over Antarctica, and then it was like a Manhattan project to really find out what was causing it.

Ozone depletion became a research priority. In 1987 the Airborne Antarctic Ozone Experiment (AAOE) flew, built on the highly successful Stratospheric-Troposphere Exchange Project (STEP), which successfully provided a better description of how natural and man-made chemicals move from their tropospheric sources to the stratospheric ozone shield. AAOE was a multi aircraft campaign (with the DC-8) designed to obtain a data set that can be used to address the probable causes for ozone depletion, over the Antarctic, AAOE was flown from Punta Arenas, Chile in the fall of 1987.

These were risky flights, south from the southern end of Chile, out over open water and then the ice pack, in a single engine aircraft. This was a risk issue that proceeded, without incident. Scientifically, the mission was a huge success, where everything went well. The Harvard group with their chlorine oxide instrument got the smoking gun that proved that CFCs were the culprit in ozone destruction. It may be the only time in history that just getting absolutely scientific proof of something brought about such a change. It led directly to the Montreal Protocol, which banned CFCs and brought changes that have reversed the trend of ozone loss over the poles, impacts that are being seen today.

Insights from the Antarctic compared to the northern hemisphere in the subsequent AASE missions to the ARCTIC in 1989 and 1992. This model of instrument-rich, multi-aircraft survey missions has set the standard to airborne science investigations for some time.

John started managing the sensor shop for Marty, primarily the U-2 sensors, but other systems were developed and flown on the other Ames airborne science aircraft. John and Jeff Myers grew it into a world-class remote sensing sensor facility

John was continually looking for ways to enhance the utility of the high flyers. In the mid ‘90s, John acquired a high bandwidth TDRSS link for the ER-2. Developed by the Air Force, the StarLink System provided for real time communications from sensors in flight, demonstrating the capability by bringing real time fire imagery to the forest service. Because the service was expensive, the user community was slow to embrace the need. It took some ten years before NASA scientific community began to utilize real-time remote sensing data.

In the early '90s, John, now Branch Chief of the High Altitude Mission Branch, brought on Andy Roberts as Chief Engineer and Gary Shelton as Mission Manager, both destined to play a major part of NASA's Airborne Science Program.

As the U-2 was no longer in production, John, with Air Force and Lockheed encouragement, set out to test and document the aircraft performance. NASA set eight climb and altitude records with the U-2C in two different weight classes, and they still stand today, reaching 72,000 feet.

In 1992, Dan Golden came on the scene and hardily promoted unmanned aircraft as the future, as well as consolidating NASA's aircraft activity at Dryden. While unmanned aircraft have slowly evolved as capable science platforms, consolidation brought the end of an era to Ames, when the science aircraft went to DFRC.

John retired in 1997, after 40 years at Ames, a little before the aircraft were transferred to Dryden.

Summary

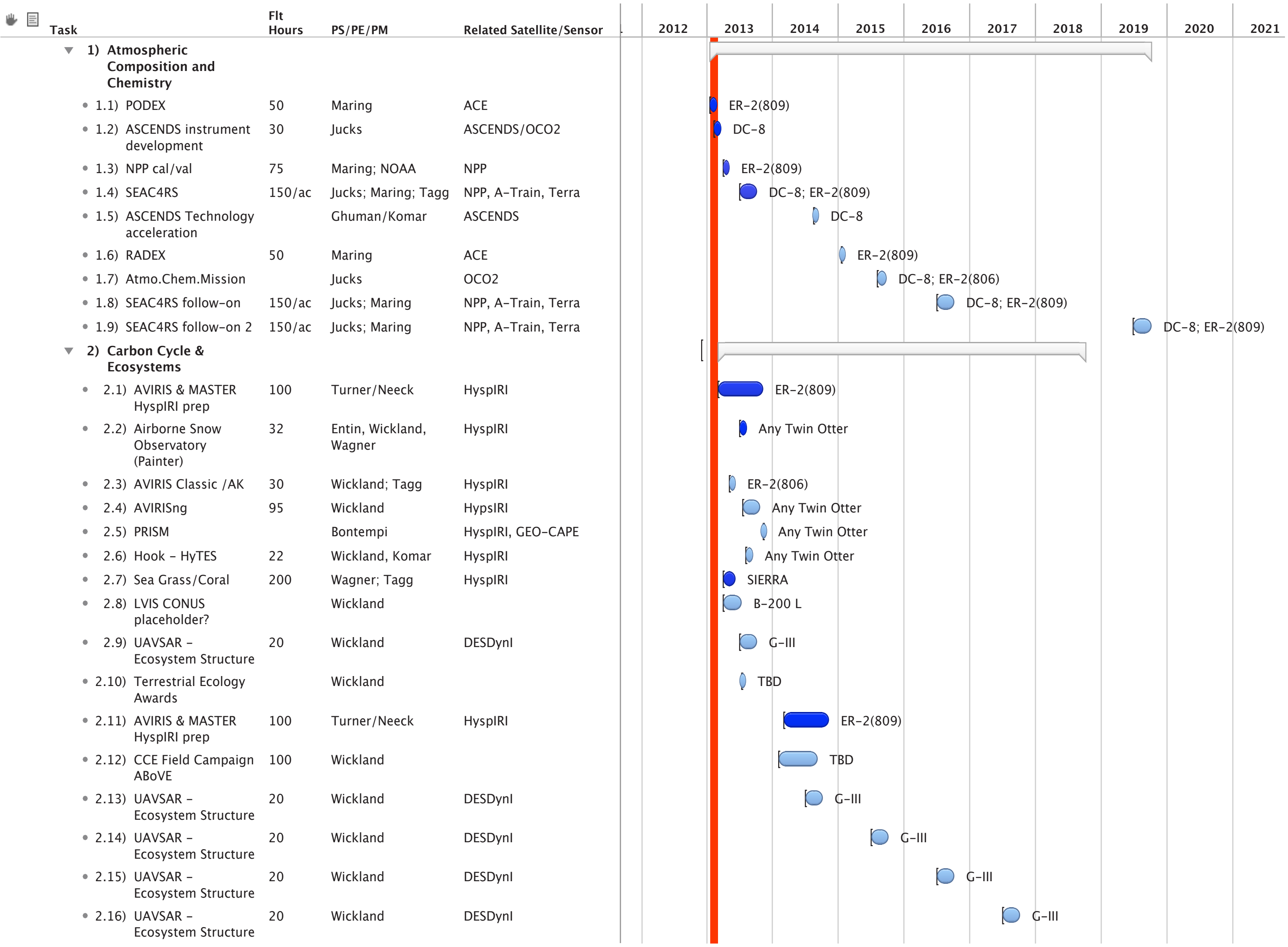
John was the right guy, in the right place at the right time. Starting at Ames as NASA embraced Earth Science, John worked to build up a high altitude remote sensing capability that saw major scientific advances that changed man's impact on the environment. John's smooth management style fostered an effective team approach that could accommodate several customers simultaneously. John's team provided a one-stop shop for high altitude missions, providing platforms, and sensors, including planning, integration, permitting, and logistics.

John's appreciation of the value of remote sensed data, his love of aviation, his smooth people skills, and his professional work ethic, served as a great foundation to create and grow NASAs world-class high altitude airborne science capability.

I've attempted to highlight some of the foundational activities that have molded the high altitude program into a world-class capability, still valuable and productive today. I want to encourage the reader to visit the ASP website and see how the program is relevant today.

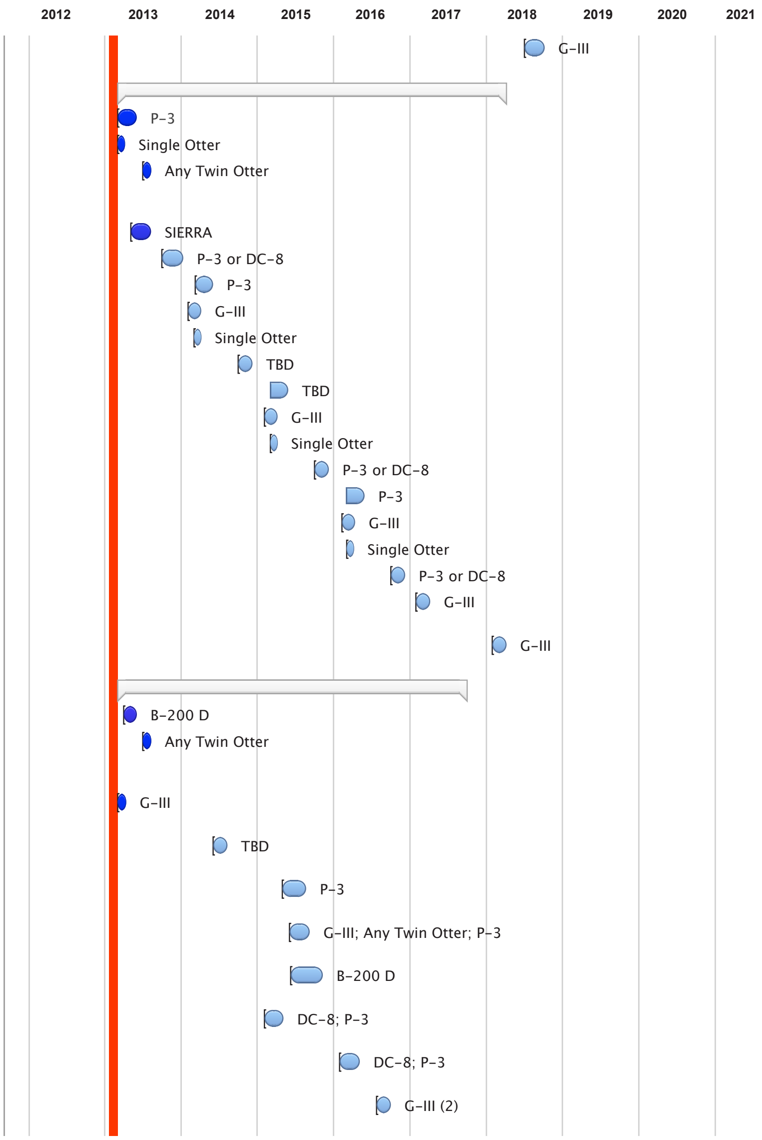
Contributed by Steve Wegener

Appendix B: 5-Year Plan

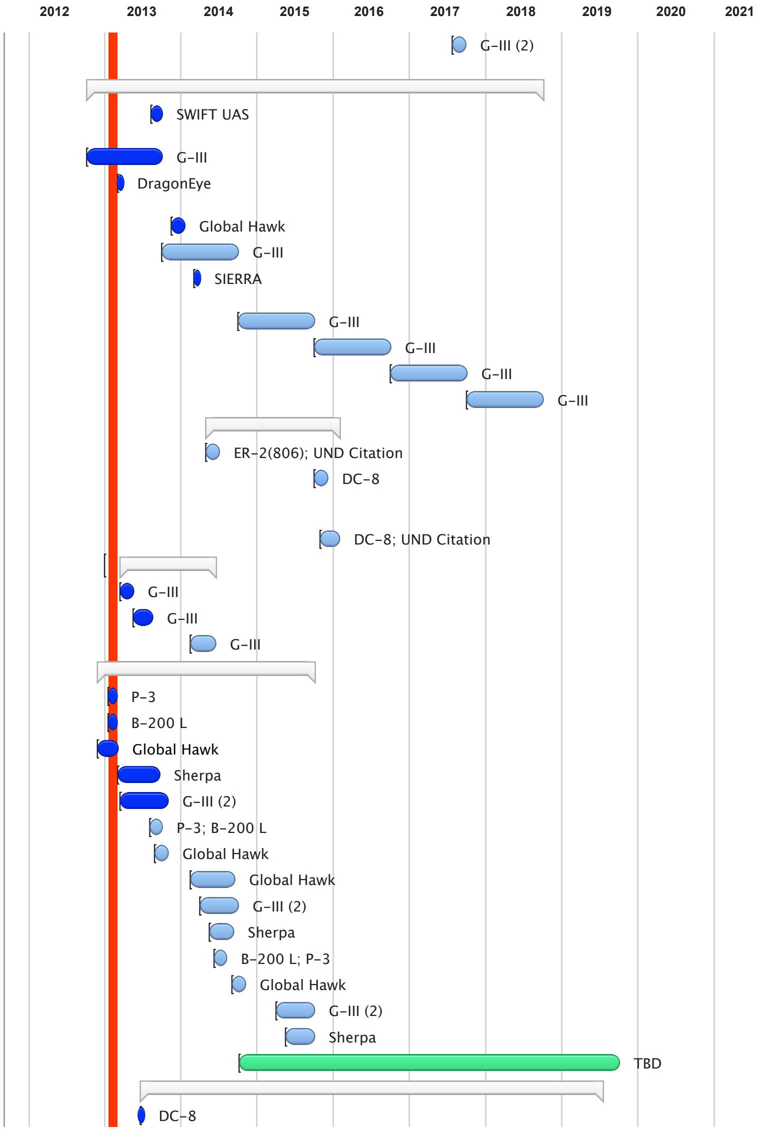


Task	Flt Hours	PS/PE/PM	Related Satellite/Sensor
1) Atmospheric Composition and Chemistry			
1.1) PODEX	50	Maring	ACE
1.2) ASCENDS instrument development	30	Jucks	ASCENDS/OCO2
1.3) NPP cal/val	75	Maring; NOAA	NPP
1.4) SEAC4RS	150/ac	Jucks; Maring; Tagg	NPP, A–Train, Terra
1.5) ASCENDS Technology acceleration		Ghuman/Komar	ASCENDS
1.6) RADEX	50	Maring	ACE
1.7) Atmo.Chem.Mission		Jucks	OCO2
1.8) SEAC4RS follow–on	150/ac	Jucks; Maring	NPP, A–Train, Terra
1.9) SEAC4RS follow–on 2	150/ac	Jucks; Maring	NPP, A–Train, Terra
2) Carbon Cycle & Ecosystems			
2.1) AVIRIS & MASTER HyspIRI prep	100	Turner/Neeck	HyspIRI
2.2) Airborne Snow Observatory (Painter)	32	Entin, Wickland, Wagner	HyspIRI
2.3) AVIRIS Classic /AK	30	Wickland; Tagg	HyspIRI
2.4) AVIRISng	95	Wickland	HypsIRI
2.5) PRISM		Bontempi	HyspIRI, GEO–CAPE
2.6) Hook – HyTES	22	Wickland, Komar	HyspIRI
2.7) Sea Grass/Coral	200	Wagner; Tagg	HyspIRI
2.8) LVIS CONUS placeholder?		Wickland	
2.9) UAVSAR – Ecosystem Structure	20	Wickland	DESDynI
2.10) Terrestrial Ecology Awards		Wickland	
2.11) AVIRIS & MASTER HyspIRI prep	100	Turner/Neeck	HyspIRI
2.12) CCE Field Campaign ABoVE	100	Wickland	
2.13) UAVSAR – Ecosystem Structure	20	Wickland	DESDynI
2.14) UAVSAR – Ecosystem Structure	20	Wickland	DESDynI
2.15) UAVSAR – Ecosystem Structure	20	Wickland	DESDynI
2.16) UAVSAR – Ecosystem Structure	20	Wickland	DESDynI

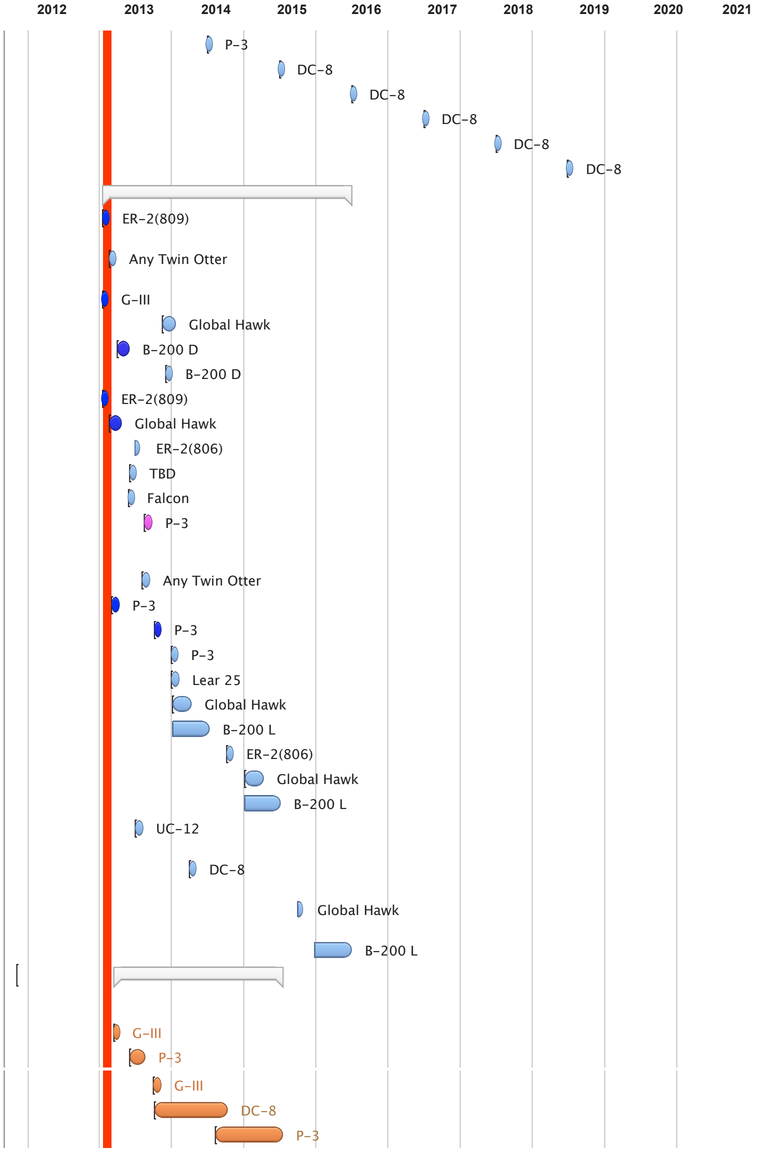
Task	Flt Hours	PS/PE/PM	Related Satelite/Sensor
2.17) UAVSAR – Ecosystem Structure	20	Wickland	DESDynI
3) Cryospheric Science			
3.1) OIB Greenland 2013	300	Wagner; Tagg	ICESat 2
3.2) OIB Alaska 2013			
3.3) Airborne Snow Observatory (Painter)	32	Entin, Wickland, Wagner	HyspIRI
3.4) MIZOPEX	100	Wagner; Tagg	ICESAT 2
3.5) OIB Antarctica 2013	250	Wagner; Tagg	ICESAT 2
3.6) OIB Greenland 2014	300	Wagner; Tagg	ICESat 2
3.7) OIB Iceland 2014	30	Wagner	
3.8) OIB Alaska 2014			
3.9) OIB Antarctica 2014	250	Wagner; Tagg	ICESat 2
3.10) OIB Greenland 2015	300	Wagner; Tagg	ICESAT 2
3.11) OIB Iceland 2015	35	Wagner	
3.12) OIB Alaska 2015			
3.13) OIB Antarctica 2015	250	Wagner; Tagg	ICESat 2
3.14) OIB Greenland 2016	300	Wagner; Tagg	ICESAT 2
3.15) OIB Iceland 2016	35	Wagner	
3.16) OIB Alaska 2016			
3.17) OIB Antarctica 2016	250	Wagner; Tagg	ICESat 2
3.18) UAVSAR Greenland or Iceland	35		
3.19) UAVSAR Greenland or Iceland	35		
4) Water and Energy Cycle			
4.1) Moller – AIRSWOT	35	Entin, Lindstrom	SWOT
4.2) Airborne Snow Observatory (Painter)	32	Entin, Wickland, Wagner	HyspIRI
4.3) SMAP Argentina validation sites	6	Entin	SMAP, Aquarius
4.4) Water quality field campaign	30	Entin, Turner	HyspIRI, ACE
4.5) Rotating PALS flight test	70	Entin	SMAP
4.6) SMAPVEX–15 Cal/val	50	Entin	SMAP
4.7) Acrtic Hydrology 13B001		Entin	SWOT
4.8) Snow Field Campaign–15	50	Entin	
4.9) Snow Field Campaign– 16	50	Entin	
4.10) RZSM – ESA Collaboration	30	Entin	



Task	Flt Hours	PS/PE/PM	Related Satelite/Sensor
4.11) RZSM – ESA Collaboration	30	Entin	
5) Earth Surface & Interior			
5.1) Fault Detection–Glen	50		
5.2) UAVSAR – 13	290	Dobson; Tagg	DESDynI
5.3) Costa Rica – volcanic plumes	30	LaBrecque	HyspIRI / ASTER
5.4) Moller – GISTENA		AITT	ICESat 2, L-band SAR
5.5) UAVSAR – 14	290	Dobson; Tagg	DESDynI
5.6) Costa Rica – volcanic plumes	30	LaBrecque	HyspIRI / ASTER
5.7) UAVSAR – 15	290	Dobson; Tagg	DESDynI
5.8) UAVSAR – 16	290	Dobson; Tagg	DESDynI
5.9) UAVSAR – 17	290	Dobson; Tagg	DESDynI
5.10) UAVSAR – 18	290	Dobson; Tagg	DESDynI
6) Weather			
6.1) IPHEX	86	Kakar; Neeck	GPM
6.2) Atmospheric Dynamics mission (Antarctica)		Kakar; Neeck	
6.3) OLYMPEX (GPM c/v)	100	Kakar, Neeck	GPM
7) Applications			
7.1) Sac–Delta w UAVSAR	25	Friedl; Dobson	
7.2) CA–DWR w UAVSAR	32.5	Friedl; Dobson	
7.3) CA–DWR w UAVSAR	60	Friedl; Dobson	
8) Earth Venture 1			
8.1) DISCOVR–AQ – 13	40	Maring; Tagg	GEO–CAPE
8.2) DISCOVR–AQ – 13	100	Maring; Tagg	GEO–CAPE
8.3) ATTREX–13	200	Jucks; Tagg	
8.4) CARVE – 13	336	Wickland; Tagg	
8.5) AirMOSS – 13	30	Entin; Tagg	SMAP
8.6) DISCOVR–AQ – TX	100	Maring; Tagg	GEO–CAPE
8.7) HS3 – 13	327	Kakar; Tagg	
8.8) ATTREX–14	200	Jucks, Tagg	
8.9) AirMOSS – 14	326	Entin; Tagg	SMAP
8.10) CARVE – 14	336	Wickland; Tagg	
8.11) DISCOVR–AQ – 14	100	Maring, Tagg	GEO–CAPE
8.12) HS3 – 14	327	Kakar; Tagg	
8.13) AirMOSS – 15	300	Entin; Tagg	SMAP
8.14) CARVE – 15	336	Wickland; Tagg	
9) Earth Venture EVS–2		Maring; Tagg	
10) Education			
10.1) SARP 2013	14	Kaye; Tagg	



Task	Flt Hours	PS/PE/PM	Related Satelite/Sensor
10.2) SARP 2014	14	Kaye; Tagg	
10.3) SARP 2015	14	Kaye; Tagg	
10.4) SARP 2016	14	Kaye; Tagg	
10.5) SARP 2017	14	Kaye; Tagg	
10.6) SARP 2018	14	Kaye; Tagg	
10.7) SARP 2019	14		
11) New Techology			
11.1) Schmidt / Radiometer	8	AITT	NPPOESS
11.2) Weimer / Lidar forest carbon	35	AITT	DESDynI
11.3) Moller – GlistenA	22	AITT	ICESat 2
11.4) Moller – GISTENA		AITT	ICESat 2
11.5) Moller – AIRSWOT	112	SBIR	SWOT
11.6) Moller – AIRSWOT		SBIR	SWOT
11.7) EXRAD science			
11.8) UAVSAR/LVIS–GH	50	Dobson; Tagg	DESDynI; ICESAT 2
11.9) Diner		Komar	ACE
11.10) Reising IIP		Komar	SWOT
11.11) Geo–TASO/Leitch		Komar	GEO–CAPE
11.12) Geo–TASO/Leitch	piggy back on DAQ	Komar	GEO–CAPE
11.13) Hook – HyTES	22	Wickland, Komar	HyspIRI
11.14) ECO–SAR		Komar	DESDynI
11.15) ECO–SAR		Komar	DESDynI
11.16) Durham – WISM	16	Komar	SLCP
11.17) Abshire IIP		Komar	
11.18) UAVSAR–GH –14	50	Dobson; Tagg	DESDynI
11.19) HSRL/PRISM – 14		Bontempi; Tagg	ACE
11.20) Racette – ACERAD		Komar	ACE
11.21) UAVSAR–GH –15	50	Dobson; Tagg	DESDynI
11.22) HSRL/PRISM – 15		Bontempi; Tagg	ACE
11.23) Prasad/ CarbonHawk		Komar	ASCENDS
11.24) Prasad/ CarbonHawk		Komar	ASCENDS
11.25) Prasad/ CarbonHawk		Komar	ASCENDS
11.26) HSRL/PRISM – 16		Bontempi; Tagg	ACE
12) Maintenance schedules / platform unavailable			
12.1) G–III maintenance		DFRC	
12.2) P–3B Maintenance		WFF	
12.3) G–III maintenance		DFRC	
12.4) DC–8 Maintenance		DFRC	
12.5) P–3B ReWing		WFF	



Appendix C: Acronyms

A-SMLS	Airborne Scanning Microwave Limb Sounder
AAOE	Airborne Antarctic Ozone Experiment
AASE	Airborne Arctic Stratospheric Expedition
AB	Airbase
AERONET	AErosol RObotic NETwork
AFB	Air Force Base
AGU	American Geophysical Union
AirMOSS	Airborne Microwave Observatory of Subcanopy and Subsurface
AirMSPI	Airborne Multiangle SpectroPolarimetric Imager
AITT	Airborne Instrument Technology Transition
ALIST	Airborne Lidar Surface Topography Simulator
AMSR-E	Advanced Microwave Scanning Radiometer - Earth Observing System
APR-2	Airborne Precipitation Radar-2
ARC	Ames Research Center
ASF	Airborne Sensor Facility
ASP	Airborne Science Program
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATLAS	Atmospheric Laboratory of Applications and Science
ATM	Airborne Topographic Mapper
ATTREX	Airborne Tropical Tropopause Experiment
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Airborne Visible/Infrared Imaging Spectrometer
CARVE	Carbon in Arctic Reservoirs Vulnerability Experiment
CATS	Cloud-Aerosol Transport System
CFC	chlorofluorocarbon
CH4	methane

CIRPAS	Center for Interdisciplinary Remotely-Piloted Aircraft Studies
CO	carbon monoxide
CO2	carbon dioxide
CONUS	Contiguous United States
CoSMIR	Conical Scanning Millimeter-wave Imaging Radiometer
CPDLC	Controller Pilot Data Link Capability
CPL	Cloud Physics Lidar
CrIS	Cross-track Infrared Sounder
DAOF	Dryden Aircraft Operations Facility
DAWN	Doppler Aerosol WiNd lidar
DBSAR	Digital Beamforming Synthetic Aperture Radar
DCAPS	Data Collection and Processing System
DEVOTE	Development and Evaluation of satellite ValidatiOn Tools by Experimenters
DFRC	Dryden Flight Research Center
DISCOVER-AQ	Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality
DLH	Diode Laser Hygrometer
eMAS	Enhanced MODIS Airborne Simulator
EOS	Earth Observing System
ESD	Earth Science Division
ESFL	Electronically Steerable Flash Lidar
ESPO	Earth Science Project Office
ESSP	Earth System Science Pathfinder
ESTO	Earth Science Technology Office
EV-1	Earth Venture-1
EVS-2	Earth Venture Suborbital-2
FTS	Fourier Transformation Spectrometer
G-LiHT	Goddard's LiDAR, Hyperspectral & Thermal Imager
GCPEX	GPM Cold-season Precipitation Experiment
GISS RSP	Goddard Institute of Space Science Research Scanning Polarimeter

GH	Global Hawk
GLISTIN-A	Airborne Glacier/Land Ice Surface Topography Interferometer
GPM	Global Precipitation Measurement
GSFC	Goddard Space Flight Center
H2O	water
HS3	Hurricane and Severe Storm Sentinel
HSRL	High Spectral Resolution Lidar
HyspIRI	Hyperspectral Infrared Imager
HYTES	Hyperspectral Thermal Emission Spectrometer
ICESat	Ice, Cloud,and land Elevation Satellite
IT	Internet
JPL	Jet Propulsion Laboratory
JPSS	Joint Polar Satellite System
JSC	Johnson Space Center
LaRC	Langley Research Center
LiDAR	Light Detection and Ranging
LVIS	Laser vegetation imaging sensor
MABEL	Multiple Altimeter Beam Experimental Lidar
MAGI	Mineral and Gas Identifier
MIZ	Marginal Ice Zone
MIZOPEX	MIZ Observations and Processes EXperiment
MODIS	Moderate Resolution Imaging Spectroradiometer
MSFC	Marshall Space Flight Center
MTS	Mission Tool Suite
NASDAT/EIP	NASA Airborne Science Data Acquisition and Transmission/ Experimenter Interface Panel
NAST-I	NPOESS Airborne Sounding Testbed-Interferometer
NOAA	National Oceanic and Atmospheric Administration
NPP	NPOESS Preparatory Project
NPOESS	National Polar-orbiting Operational Environmental Satellite System

NRC	National Research Council
NSERC	National Suborbital Education and Research Center
NSF	National Science Foundation
O2	oxygen
OAWL	Optical Autocovariance Wind Lidar
OIB	Operation IceBridge
OWA	Outlook Web Access
PALS	Passive/Active L-band Sensor
PFP	Programmable Functional Panel
PI-Neph	Polarized Imaging Nephelometer
PNNL	Pacific Northwest National Laboratory
PODEX	Polarimeter Definition Experiment
ROSES	Research Opportunities in Space and Earth Sciences
SAR	Synthetic Aperture Radar
SARP	Student Airborne Research Program
SDSU	San Diego State University
SEAC4RS	Southeast Asia Composition, Cloud, Climate Coupling Regional Study
SIERRA	Sensor Integrated Environmental Remote Research Aircraft
SMAP	Soil Moisture Active-Passive
SMAPVEX	Soil Moisture Active-Passive Validation Experiment
SMD	Science Mission Directorate
SOFRS	Science Operations Flight Request System
SPAARO	Small Platform for Autonomous Aerial Research Operations
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
STEP	Science, Technology and Exploration Program
TCAP	Two-Column Aerosol Project
TDRSS	Tracking and Data Relay Satellite System
TIR	Thermal Infrared

UAF	University of Alaska Fairbanks
UAS	Unmanned Automated System
UAV	Unmanned Aircraft Vehicle
UAVSAR	UAV Synthetic Aperture Radar
UND	University of North Dakota
VIIRS	Visible Infrared Imager Radiometer Suite
WFF	Wallops Flight Facility

Back cover caption: *The small town of Qaanaaq on the northwestern coast of Greenland, 100 km north of Thule, is one of the northernmost settlements in the world. The P-3 passed Qaanaaq at high altitude en route to a sea ice mission north of Ellesmere Island in Canada.*

NASA AIRBORNE SCIENCE PROGRAM

OPERATION ICEBRIDGE