

# Airborne Science Programs of the National Science Foundation (USA)

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**Abstract** - The US National Science Foundation supports and utilizes a range of platforms which are made available to its US funded science investigators in the furtherance of airborne science program objectives. As well as providing access to the platforms themselves, NSF also supports their operation, maintenance and infrastructure development. NSF airborne science projects may be deployed worldwide. While these aviation assets and services are available to any NSF supported science efforts, concentration of their use, and oversight of their operation, are housed in the lower atmospheric section of the Division of Atmospheric and Geospace Sciences (AGS), Directorate of Geosciences, and the aviation projects section of the Division of Antarctic Infrastructure and Logistics (AIL), Office of Polar Programs. NSF facilities are available to other US agencies and organizations on a reimbursable cost and non-interference basis. Through the collaboration of US funded investigators, participation of NSF airborne assets in international airborne science projects may also take place.

**Keywords:** atmosphere, meteorology, climate, snow ice, oceanography

## 1. INTRODUCTION

The facilities mix of NSF's airborne assets evolves in response to new science initiatives and objectives, and undergoes regular assessment by various the user communities along with the impetus provided by the research proposal requests of US investigators. Recent field examples of the use of NSF airborne science facilities are discussed here, reflecting ongoing projects from community aircraft operated by the National Center for Atmospheric Research (NCAR) and by the United States Antarctic Program (USAP). It should be pointed out that while the mission hours flown by the Research Aviation Facility (RAF-NCAR) are dominated by research flight hours, the prime mission of USAP aviation hours are for field logistics and transportation, essentially over the entire Antarctic continent. This reflects the prime aviation mission of the two programs. Table A gives a breakdown of recent flight hour activities flown by these two groups.

USAP aviation consists of both NSF owned assets (~ 4 LC-130), along with contract air services (~ 4 rotary winged aircraft : mix of AS350-B2 "squirrels", Bell 212 "hueys"; ~ 3 fixed wing aircraft : mix of DeHavilland DHC-6-300 "Twin Otters", Basler, Turbo DC-3). The NSF LC-130 fleet is operated on behalf of NSF by the 109<sup>th</sup> Airlift Wing of the NY Air National Guard, under direction of the Joint Task Force, Support Forces Antarctica, US DOD. In recent years the USAP program has also enjoyed air support from USAF in the form of C-17 flights for intercontinental logistic and cargo needs. Through cooperation with other Antarctic Treaty members, a mix of other airborne assets may also be available to USAP researchers.

Table A. NSF Flight Hours; USAP, NCAR, UWyoming, FY2009

USAP	Flight Hours (approx)
Twin Otters (KBA)	950
DC-3 (Basler) (KBA)	336
AS350B (PHI)	466
Bell 212 (PHI)	654
LC130 (NYANG)	1,134
UAS - Aerosonde	130
<b>NCAR &amp; UWy.</b>	
NCAR G-V	230
NCAR C-130Q	171
UWyoming Kingair	111

NCAR RAF operated aviation includes a highly modified, large payload platform C-130Q, and a high altitude, high performance instrumented Gulfstream V jet. NSF also operates a Kingair, through the University of Wyoming, and has airborne Doppler radar instrumentation on board a NRL Orion P-3. NSF investigators are also actively involved in the use of arrange of UAS platforms and instrumentation for their research. The two examples of recent missions and ongoing activities discussed below are meant to be illustrative, and not inclusive.

## 2. RECENT ACTIVITY

### 2.1 HIPPO

The "Collaborative Research: HIAPER Pole-to-Pole Observations (HIPPO) of Carbon Cycle and Greenhouse Gases Study" is a multi-investigator, multiyear program with goals to measure cross sections of atmospheric concentrations of important greenhouse gases (GHG) approximately pole-to-pole, from the surface to the tropopause, four times during different seasons over a 3 year period. A comprehensive suite of atmospheric trace gases pertinent to understanding the Carbon Cycle is being measured. HIPPO has transected the mid-Pacific ocean and returned either over the Eastern Pacific, or over the Western Atlantic. The program is intended provide the first comprehensive, global survey of atmospheric trace gases, covering the full troposphere in all seasons and multiple years. Such a unique data set should allow significant modeling and inverse modeling efforts of the Earth's sources and sinks of CO<sub>2</sub> and other GHG. The sampling effort is thus seen to be complementary to both the world's existing surface measurement GHG networks and several satellite programs.

Typically, flights are essentially direct point-to-point routes with ongoing altitude changes. Usually there are two maximum altitude ascents per flight, one in the first half and one in the second half, depending on the ability of the ATC to support altitude changes. Most of the flight legs have been conducted below RVSM (usually 28,000 ft) in order to allow the G-V to go up and down constantly, collecting data at different altitudes throughout the troposphere. Ideally the flight would take off and go to FL430 for 15 min, then descend below RVSM and proceed in a sawtooth pattern between FL270 and FL100 with a 1,500 ft/min climb/ascent rate, then climb to FL450 near the end of the flight for about 15 min, descend and proceed to the next landing point.

A wide range of instrumentation both integral to the NSF/NCAR G-V and modified from existing measurement programs was incorporated into the flights. Many of the instruments were automated, conserving space. Key parameters included carbon dioxide, atmospheric water vapor, black carbon aerosols.

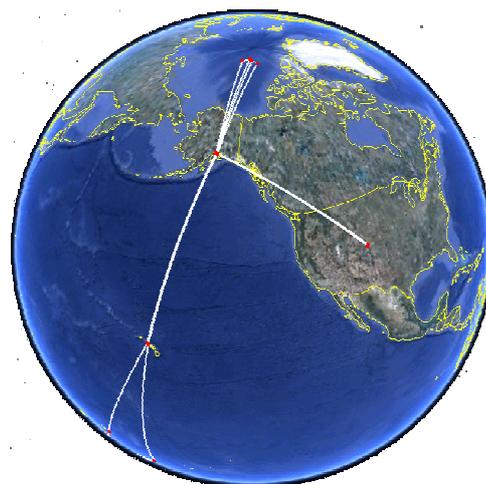


Fig 1. Flight path of one HIPPO mission leg over the northern and central Pacific. Path extended to CHC, New Zealand and the Antarctic continent (~ 67 S)

<b>Data System</b>	Aircraft Position, Velocity, Attitude
	Static, Dynamic Pressure
	Temperature, Flow Angle Sensors
<b>Water Vapor</b>	DEW Point, VC SEL water Vapor
<b>Cloud Physics</b>	PMS Liquid Water
	Raw Icing-Rate Indicator
<b>Wing Stores</b>	UH SAS
	Microwave Temperature Profiler
<b>Photography</b>	Forward Camera
<b>Chemistry</b>	Carbon monoxide, carbon dioxide
<b>Specialized</b>	Cloud Droplet Probe
(user supplied)	Ozone ; Whole Air Sampler
	NOAA/PANTHER /UCATS
	Harvard QC Laser
	Airborne Oxygen
	NOAA Soot Photometer

Table B. Typical HIPPO measurement configuration included systems standard to the NSF G-V along with additional user supplied instrumentation.

### 2.2 Development of a Common Science Support Pod for USAP LC-130.

At a workshop held at NSF (Sep 2004), the need for long range research platform aircraft to operate in Antarctica was recommended by the atmospheric and geosciences communities. At the time, the provision of a dedicated airframe for research purposes was considered to be problematic. With the recent increasing availability of LC-130 flight hours in the USAP program, and the growing identification of various scientific

opportunities, the topic has been revisited. The skied landing capability of the existing LC-130 aircraft is considered to be the ideal platform. It is noted that other research aircraft platforms would require significant staging and deep field support for their effective use. The LC-130 aircraft have the advantage that they are all ready on site and supported on continent, and have proven themselves capable of travelling anywhere in Antarctica. The only negative to their use for research purposes centers on the extensive effort and operational coordination required to modify the aircraft to the kinds of configurations usually requested by researchers. A solution that minimized the impact on the LC-130 airframe, and would greatly simplify the integration of research projects was sought.



Fig 2. Installation of a SABIR<sup>R</sup> system specialized mission mounting system allows integration of sensors and instrumentation to be installed in existing aircraft doors without permanent modification to the host aircraft.

NSF, USAF and Air National Guard are currently evaluating the SABIR (Special AirBorne-mission Installation and Response System ) arm technology concept. This is a mounting system that allows for the deployment of instrumentation pods, attached to the airframe through modifications to aircraft doors (see Fig. 2) or hatches. An extensible door mounted pod can be deployed in clear air below the slipstream of the fuselage. Power to externally mounted sensors and comms from the instrument pod are supplied through the modified hatch, yet in a non-integrated manner into the LC-130 cargo bay. Several potential benefits accrue from this design. These include an essentially roll-on, roll-off capability of the instrumentation pods, both internally to the aircraft cargo deck, yet with a

minimum of aircraft modification. This significantly reduces sensor and instrumentation integration efforts, such as may be required for wing stores, pods or fuselage mounted instrumentation. Further, provision for common instrumentation pods, yet with provision of a varying sensor payloads suited to mission needs, opens up the possibility of common flight testing, clearances and approvals. The development of a common science pod that eliminates pod flight analyses yet still allows integration of unique science instruments and payloads and their integration into specific data and operator consoles internal to the aircraft is ongoing.

## 2.2.1 Development of Crevasse Detection Radar

One of the first applications chosen for investigation of the utility of the SABIR arm concept is focused on the provision of a crevasse detection radar system for use during deep field skied LC-130 aircraft operations.



Fig 3. Avoidance of unsafe landings during deep field landings on the Antarctic continent has high operational value and the associated technology is also capable of generating valuable scientific data.

Under a separate NNSF MRI (Major Research Instrumentation award), researchers from Columbia University are additionally integrating a suite of imaging sensors for ice sheet research. The *icePod* system will consist of a suite of imaging sensors mounted in an external pod carried on NSF's LC-130's to map the surface and subsurface ice topography of ice sheets, ice streams and outlet glaciers. The instrumentation system will include a scanning laser altimeter for precise measurements of the ice surface, visible and infrared imaging

cameras to document the ice surface structure and temperature, and an ice-penetrating radar to recover the ice thickness and constrain the distribution of liquid water at the ice sheet-bed.

Geo-referencing of the measurements will be provided by precision GPS satellite data integrated with inertial technology. This effort will design, build, calibrate, test and commission the instrument over a five-year period. The goal of the *icePod* instrumentation is that the sensor system will become a facility operated for the science community and the data will be made available through a NSF supported polar data center.

At present development of other suites of instrumentation for different science application (e.g. atmospheric chemistry and cloud microphysics) are being contemplated.

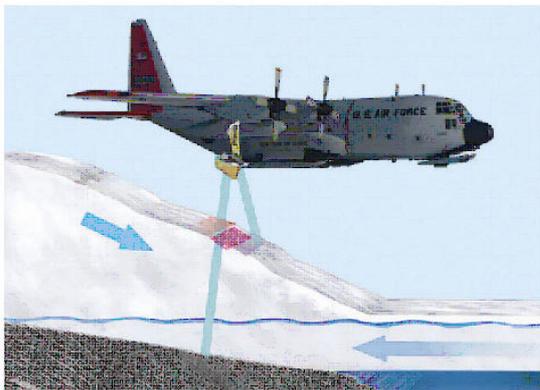


Fig 4. Schematic of instrumented LC-130 and icePod sensor suite acquiring data over ice –sheet margin.

### 3. CONCLUSION

Changing research needs require flexible and adaptable use of airborne platform assets such as fixed wing aircraft mentioned here. Commonality of instrument purpose (eg. the HAIPER G-V instruments), along with the systems for their cross platform deployment (e.g. pods and wingstores is one means of reducing the integrations costs and efforts of airborne instrumentation. Another approach is the use of micro sensors on UAS (unmanned aircraft systems).



