

6. NCAR/EOL Standard Instrumentation Overview

The NSF/NCAR GV aircraft comes equipped with a package of standard instrumentation that flies on all HIAPER research missions. The measurements made by these sensors form the core of any research program and provide the information necessary to place the aircraft in space and time while characterizing the basic “state” of the local environment. Data from all of these systems are recorded on the HIAPER airborne data system (ADS) and can be displayed onboard, in real time, via the network of display stations.

6.1 State Parameter Sensors

The following table lists types and descriptions of instruments and standard measurements taken onboard the NSF/NCAR GV during flight.

State Parameters Sensors

Measurement		Instrument	Range	Resolution	Accuracy	Response Time
Position	Internal - Latitude and Longitude	Honeywell LASEREF III/IV Inertial Reference Unit (2 units)	global	0.00017 deg	0.164 deg (6 hrs)	0.1 s
	Operational Characteristics: There are several types of errors generally associated with Inertial Reference Unit (IRU) systems which affect the data after a successful alignment. The first one to consider, because it affects every flight, is the navigational position drift. Errors in both positions (LAT,LON) vary in an oscillatory fashion in flight. These oscillations will vary in magnitude from flight to flight, will typically be out of phase, and maintain a period of roughly 84 minutes. This phenomenon is known as the Schuller oscillation and is caused by the fact that the earth is not a true inertial system. Overall performance is judged through final position errors noted upon the completion of each flight. Position errors of less than 1.0 nmi/hr are within normal operating specifications. The Global Positioning System (GPS) is considered to be the most accurate position reference system and is used to correct the inertial reference system (IRS) data for use in the WIND calculations.					
	External – Latitude and Longitude	Garmin Model OEM WASS GPS-16	global	±0.1 m	15 m	1 s
Operational Characteristics: These units are simple receivers that triangulate position (GLAT, GLON) based on signals from multiple satellites maintained by the United States Government. A minimum of three (3) satellites are needed to determine aircraft position. The number of satellites currently being monitored by the system is recorded in the GMODE variable. Satellite coverage continues to improve over time as the number of satellites in orbit increases and a loss of signal is extremely rare. If the combination of individual satellite signals being received varies due to long range transits or sharp aircraft attitude changes, discontinuities in the system's position track can occur. The unit's status function (GSTAT) will provide a diagnostic value that monitors all other problem sources (battery, etc).						
Ground Speed	Vector	Honeywell LASEREF III/IV Inertial Reference Unit (2 units)	0-400 m/s	0.002 m/s	4.115 m/s (6 hrs)	0.1 s
	Operational Characteristics: There are several types of errors generally associated with IRU systems which affect the data after a successful alignment. The first one to consider, because it affects every flight, is the navigational position drift. Errors in the ground speed components (VEW, VNS) vary in an oscillatory fashion in flight. These oscillations will vary in magnitude from flight to flight, will typically be out of phase, and maintain a period of roughly 84 minutes. This phenomenon is known as the Schuller oscillation and is caused by the fact that the earth is not a true inertial system. The Global Positioning System (GPS) is considered to be the most accurate ground speed reference and is used to correct the IRS data for use in the WIND calculations.					
	Vector	Garmin Model OEM WASS GPS-16	0-500 m/s	0.05 m/s	±0.1 m/s	1 s

Measurement		Instrument	Range	Resolution	Accuracy	Response Time
Attitude	Pitch	Honeywell LASEREF III/IV Inertial Reference Unit (2 units)	±45 deg	0.00017 deg	±0.05 deg (6 hrs)	0.02 s
	Roll		+90 deg	0.00017 deg	±0.05 deg (6 hrs)	0.02 s
	True Heading		360 deg	0.00017 deg	±0.2 deg (6 hrs)	0.04 s
	Vertical Velocity		±200 m/s	0.0095 m/s	±0.15 m/s (6 hrs)	0.02 s
Operational Characteristics: The data defining the basic attitude of the aircraft is obtained directly from the IRU via an ARINC 429 interface. Values of pitch angle, roll angle, true heading and vertical velocity (PITCH, ROLL, THDG, VSPD) are required as inputs to the 3-D wind calculations. Small, systematic errors in some of these parameters can result from the physical positioning of the IRU within the air frame. The alignments of the IRUs are rechecked any time one of the units is removed from the aircraft. Any remaining errors can be identified through the results of the calibration maneuvers used to assess the overall accuracy of the wind measurement system.						
Altitude	Standard Atmosphere Pressure (MSL)		0-16,000 m	2 m	±200 m	0.05 s
	Operational Characteristics: This derived parameter represents an aircraft altitude above sea level based on the National Advisory Committee on Aeronautics (NACA) Standard Atmosphere. Typically a surface pressure of 1013 mb is used to define the sea level reference point. Normal fluctuations in surface pressure can therefore result in errors of +/-200 m. Under certain high pressure conditions near sea level, PALT values can even be negative. In exotic tropical or arctic locations the local lapse can introduce significant errors as well.					
	Pressure Damped Inertial (MSL)	Honeywell LASEREF III/IV Inertial Reference Unit (2 units)	0-16,000	2 m	±150 m	0.2 s
	Operational Characteristics: This value is output directly from the IRU and is derived from a combination of the vertical acceleration of the aircraft and the static pressure. The same basic limitations apply to this measurement (ALT) as apply to PALT, above.					
	Global Satellite (MSL)	Garmin Model OEM WASS GPS-16	0-16,000 m	0.1 m	±10 m	1 s
	Operational Characteristics: This measurement is a direct output of the GPS position system. It takes a minimum of four (4) satellites to provide the data needed to resolve the GPS altitude (GALT). In the event that four satellites are not in range, or if the compliment of satellites being received changes for any reason, discontinuities in the value of GALT will result.					
	Geometric (AGL)*	Stewart-Warner Model 232 Radar Altimeter	0-16,000 m	0.1 m	±10 m	0.2 s
Operational Characteristics: The output from this system is a direct measurement of the true height above the local ground surface. The value of HGM232 should never read less than zero but may fluctuate while the aircraft is holding a constant pressure altitude due to changes in the local terrain. When the aircraft is on the ground, the signal can be very noisy due to high power reflections off of the surface.						

Measurement		Instrument	Range	Resolution	Accuracy	Response Time
Static Pressure	Ambient Pressure	Paroscientific Model 1000 Digiquartz Transducer	50-1,085 mb	0.00001 mb	±0.1 mb	0.02 s
	Operational Characteristics: Instrument is generally not susceptible to outside interference or thermal drift. The corrected value (PSXC) is a derived variable, however, and can be influenced by errors in dynamic pressure (QCX). Calibration: Units are calibrated PRE/POST project using an in house transfer standard.					
	Cabin Pressure	Rosemount Model 1201F Transducer*	250-1,035 mb	0.07 mb	±1.0 mb	0.05 s
	Operational Characteristics: Instrument is susceptible to some thermal drift. This should not be a factor in such a controlled environment. Since there are no aerodynamic effects on this measurement, the raw source output is the final value. Calibration: Units are calibrated PRE/POST project using an in house transfer standard.					
Air Speed	Radome Dynamic Pressure	Mensor Model 6100 Digital Pressure Transducer	0-200 mb (0-250 m/s)	0.00001 mb (0.01 m/s)	±0.02 mb (±0.5 m/s)	0.05 s
	Heated Pitot Dynamic Pressure		0-200 mb (0-250 m/s)	0.00001 mb (0.01 m/s)	±0.02 mb (±0.5 m/s)	0.05 s
	Operational Characteristics: Most common problem is icing (radome). An unheated radome is also susceptible to blockage by ice particles from passage through fairly dense, cold clouds. Such blockages can generally not be cleared until the aircraft descends to an altitude where the ambient temperature is above freezing. Since this is a primary sensor for a number of derived variables, such occurrences could impact those calculations as well. Due to its importance as a reference parameter, redundant sensors are normally flown on each aircraft. The fuselage Pitot installation has good anti-ice capabilities but the radome unit will provide the most accurate values for the WIND calculations. Comparisons should be made with corrected values (QCRC, QCFC) only and differences should remain less than +- 0.5 mb. Calibration: Units are calibrated PRE/POST project using an in house transfer standard.					

Measurement	Instrument	Range	Resolution	Accuracy	Response Time	
Ambient Air Temperature	Fast Response System	Rosemount Model 102AL TAT Sensor (2 units)*	-80 to +40 C	0.006 C	±0.5C	0.02 s
	<p>Operational Characteristics: All ambient temperatures are derived parameters which are dependent upon the total temperature measured by the sensor and the reference dynamic pressure (QCX). This parameter must also be examined when troubleshooting atypical behavior. The most common problems are loss of flow due to icing of the sensor housing or evaporative cooling of the sensing element resulting from cloud/precipitation penetrations. These errors in in-cloud temperatures can be as large as 0.5 to 1.0oC and will always appear as negative biases.</p> <p>Calibration: Units are calibrated PRE/POST project using an in-house variable resistance decade box in place of the sensing element. The platinum wire sensing elements are certified annually using an in-house transfer standard and temperature bath.</p>					
	All Weather System	HARCO Model 100990-1 De-iced TAT Sensor (2 units/4 outputs)	-80 to ±40 C	0.006 C	±1.0 C	0.2 s
<p>Operational Characteristics: Basically the same instrument as "A" except for the addition of deicing heaters to the sensor housing. Instrument response is slightly slower than the unheated version.</p> <p>Calibration: Units are calibrated PRE/POST project using an in-house variable resistance decade box in place of the sensing element. The platinum wire sensing elements are certified annually using an in-house transfer standard and temperature bath.</p>						

Measurement	Instrument	Range	Resolution	Accuracy	Response Time	
Humidity	Tropospheric Reference	Buck Research Model 1011C Hygrometer (2 units – direct & dew point)	-75 to ±50C	0.006 C	±0.5 C (td>0); ±1.0 C (Td<0)	0.2 s-10 s
	<p>Operational Characteristics: This system provides a direct measurement of the ambient dew point temperature (DPLC, DPRC). Chilled mirror dew point sensors are relatively slow and primarily limited by their cooling and optical trigger components. Random drift or rapid oscillations in the signal can be indicators of a balance problem. The inlet housing is unheated and susceptible to flow restrictions caused by icing conditions. Large dew point depressions (ATX - DPRC) >20 cause extreme forcing of the Peltier cooling system in this unit and can result in instrument lag times as great as 30 seconds. This can be very important during rapid soundings or when flying in very dry air near the top of the troposphere. Data collected during cloud penetrations should result in dew point depressions on the order of $0 < (ATX - DPRC) < 1^{\circ}C$. Negative in cloud depressions indicate either poor calibration or possible element wetting of the reference temperature sensor. When the sensor output falls below $0^{\circ}C$, the system (DPL, DPR) is really producing a frost point temperature. The corrected data have been converted into an equivalent dew point temperature.</p> <p>Calibration: Units are calibrated PRE/POST project using an in-house variable resistance decade box in place of the sensing head. The optical sensing head is certified annually by the manufacturer.</p>					
	Stratospheric Reference (Direct-Absolute Humidity)*	Spectrasensors Open Path TDL Absorption Hygrometer	0.001-10 g/m3	0.0002 g/m3	5 to 10%	1 s
<p>Operational Characteristics: Absolute humidity is measured by the method of optical absorption of 1.368 um emitted from a diode laser source. A multipass Herriott cell pattern is employed to provide a 4 m optical path length. The enhancement in sensitivity enables a 1 ppmv detection limit (.0002 g/m3 at 200 mb and 193K). The high spectral selectivity of the diode allows an extremely selective measurement, including discrimination against liquid water interference. In certain mechanical environments, correlated optical noise can be observed in the signal. Collection of each scan over the entire absorption peak minimizes the resultant degradation in instrument performance.</p> <p>Calibration: The instrument is calibrated before and after each project, with occasional in-field calibrations, as necessary. The output from a pressure-controlled LI-COR dew point generator is provided as input to a pressure-controlled dynamic dilution system. This flow system will supply a known water vapor stream to the instrument. The calibration gas is introduced into the inlet of a leak-tight flow cell, which is sealed between the surfaces of the optical housings. The instrument response is measured at several pressure, temperature and humidity combinations.</p>						

Table 6.1. State Parameters Sensors

6.2 Three-Dimensional Winds System

The three-dimensional winds system consists of five (5) static ports on the aircraft radome. One is located at the radome stagnation point. The other four (4) ports are equally spaced around a circumferential section of the radome with two (2) aligned vertically and the other two (2) aligned horizontally. Measurements derived from these ports are described below:

Three-Dimensional Winds System

Measurement		Instrument	Range	Resolution	Accuracy	Response Time
Attack Angle	Radome Differential Pressure	Mensor Model 6100 Digital Pressure Transducer	0-150 mb	0.00001 mb	±0.015 mb	0.05 s
	<p>Operational Characteristics: Most common problem is icing (radome). An unheated radome is also susceptible to blockage by ice particles from passage through fairly dense, cold clouds. Such blockages can generally not be cleared until the aircraft descends to an altitude where the ambient temperature is above freezing. The raw inputs for these measurements are ADIFR and BDIFR for attack and sideslip, respectively. There are no redundant sensors for either system.</p> <p>Calibration: Units are calibrated PRE/POST project using an in house transfer standard.</p>					
Sideslip Angle	Radome Differential Pressure	Mensor Model 6100 Digital Pressure Transducer	0-150 mb	0.00001 mb	±0.015 mb	0.05 s
	<p>Operational Characteristics: Most common problem is icing (radome). An unheated radome is also susceptible to blockage by ice particles from passage through fairly dense, cold clouds. Such blockages can generally not be cleared until the aircraft descends to an altitude where the ambient temperature is above freezing. The raw inputs for these measurements are ADIFR and BDIFR for attack and sideslip, respectively. There are no redundant sensors for either system.</p> <p>Calibration: Units are calibrated PRE/POST project using an in house transfer standard.</p>					
Winds	Horizontal Components		0-100 m/s	0.012 m/s	±0.5 m/s	0.05 s
	Vertical Components		-20 to +20 m/s	0.012 m/s	±0.1 m/s	0.05 s
	<p>Operational Characteristics: Ambient wind data from HIAPER are derived from measurements taken with the radome wind gust package. Direct measurements of attack, sideslip and true airspeed are combined with the aircraft attitude and ground speed data to derive the three-dimensional wind field along the aircraft's path. As is normally the case with all airborne wind gust systems, the ambient wind calculations can be adversely affected by either sharp changes in the aircraft's flight attitude or excessive drift in the onboard IRS. Turns, or more importantly, climbing turns are particularly disruptive to this type of measurement technique. Wind data reported for these conditions should be used with caution.</p> <p>Special sets of in-flight calibration maneuvers are conducted periodically during a field deployment to aid in the performance analysis of the wind gust measurements. The calibration data can identify any systematic biases in the pitch, sideslip, true heading, and true airspeed parameters. These offsets can then be removed from the final data set. Drift in the IRS accelerometers are removed using an algorithm that employs a complementary high-pass/low-pass filter that removes the long term drift by correcting the aircraft ground speed components with the accurate GPS reference data, while preserving the shorter term fluctuations measured by the IRS.</p>					

Table 6.1. Three-Dimensional Winds System