NCAR research aviation facility

BULLETIN NO. 4

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The NCAR Electra: Overview and Summary of Capabilities

The four engine NCAR Electra aircraft (see Fig. 1) gives atmospheric scientists a long range and a large payload capability which is particularly suitable for over ocean research and for large scale tropospheric chemistry studies. A brief summary of the Electra's performance figures are given in Table I. RAF *Bulletin No. 7* presents in detail the information needed by scientists to formulate outlines of realistic research flights.

A 4.4 m boom on the nose exposes instruments to air relatively undisturbed by the aircraft. Mounting plates are used in place of some of the cabin windows and on the top and bottom of the fuselage for other equipment which requires exposure to the airstream. A chute is available through which meteorological and oceanographical dropsondes may be dispensed. Several racks in the cabin are available to mount user-furnished instruments. A complete electrical distribution system provides 115 Va.c., 400 and 60 Hz, and 28 Vd.c. power.

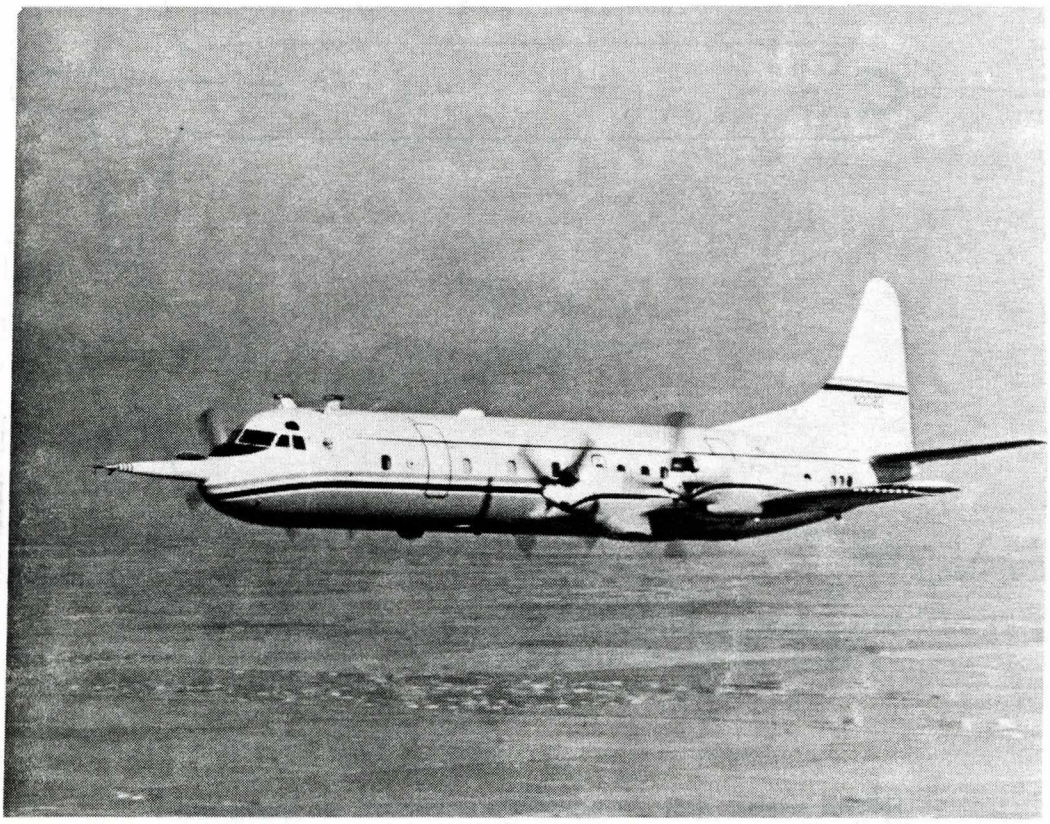

Figure 1 NCAR Electra

The standard research instrumentation aboard the aircraft is quite extensive (see Table 2), including sensors for the measurements of mean and fluctuating components of wind speed ($\overline{u}$, $\overline{v}$, $\overline{w}$ and u', v', w'). Other measurements include ambient temperature and pressure, dew point, water vapor fluctuations, cloud liquid water content, aerosol, cloud and precipitation particle spectra, radiometric surface temperature, and geometric altitude. Aircraft position is available from an inertial navigation system and from a Loran C navigational system. Aircraft attitude (pitch, roll, heading), and the horizontal and vertical components of aircraft velocity are available from the inertial navigation system. Angles of attack and sideslip are measured on a boom-mounted gust probe. Other RAF sensors such as visible, infrared and ultraviolet radiometers looking either up or down are available on request. Cloud and precipitation particle spectra information can be obtained from several different RAF-supplied PMS (Particle Measuring Systems) probes. These probes are listed in Table 2. The Electra is capable of flying up to four different PMS probes, either 1-D or 2-D probes. The specific set of instruments flown on a given project is generally a subset of the complete instrumentation list given in Table 2. Refer to other RAF *Bulletins* for details of this equipment. RAF assumes responsibility for installing, calibrating, and maintaining all the requested instrumentation. Considerable freedom is permitted in mounting user-supplied instrumentation on the aircraft.

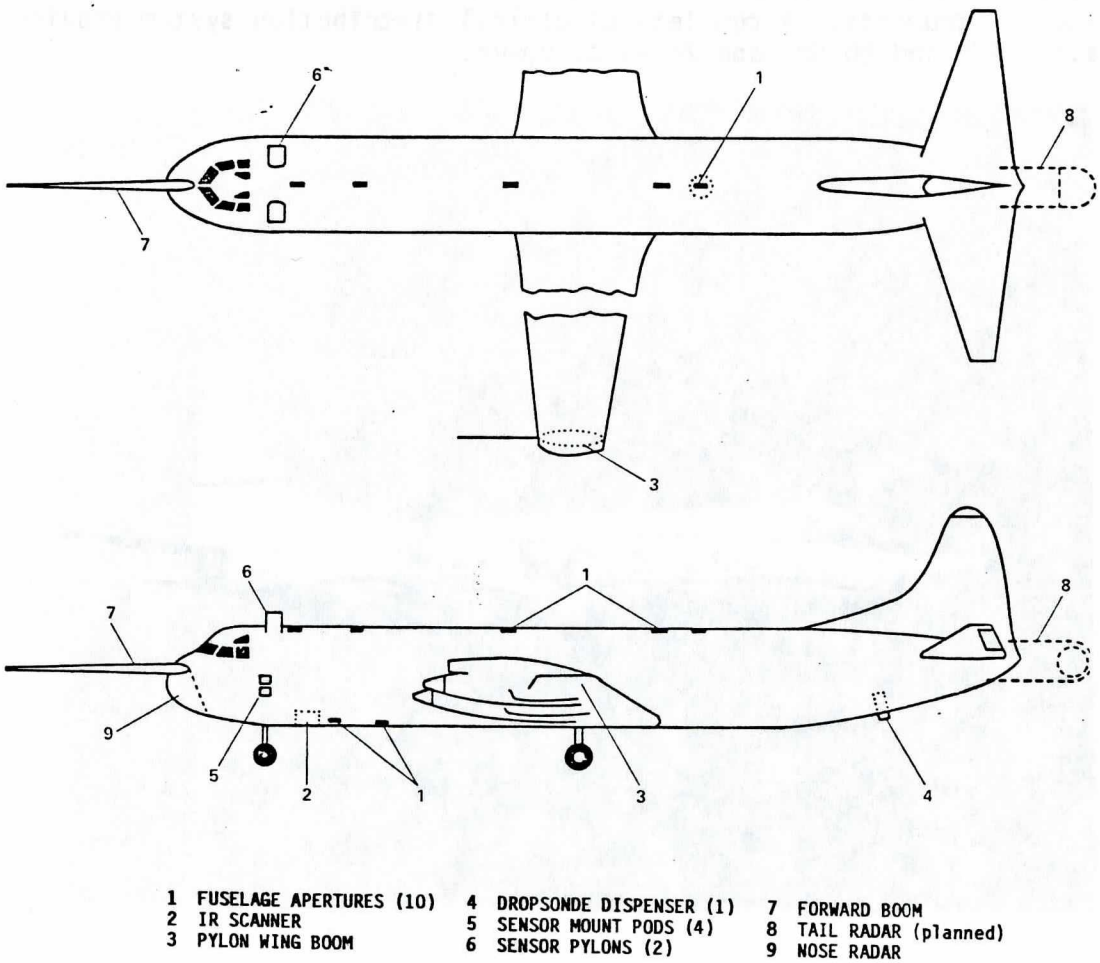

Figure 2 External Configuration of the NCAR Electra

This is described in detail in RAF *Bulletin No. 12*. RAF will supervise the installation of all user-supplied instrumentation to ensure compatibility with existing RAF instrumentation and the data system, and to satisfy aircraft safety requirements. The user-supplied equipment must be designed to satisfy the requirements of RAF *Bulletin No. 13*.

Data are sampled, recorded, and displayed by an onboard computer controlled data system. The data are recorded on 1200' 9 track 1/2 inch magnetic tape at 1600 BPI (PE) using the standard NCAR format. (See *Bulletin No. 9.*) Investigators may have the outputs of their own instruments recorded on this data system along with the standard NCAR instruments. Sampling rates available for all measurements are 1, 5, 50 and 250 samples per second (sps), normally these channels have four-pole Butterworth active filters at cutoff rates of 1, 1, 10 and 50 Hz respectively. The standard RAF "high rate" data set (see *Bulletin No. 9*) is sampled at 50 sps and filtered at 10 Hz and "low rate" data is sampled at 5 sps and filtered at 1 Hz. Sample rate of 250 sps is normally reserved for instrument test and evaluation purposes. The 1 sps rate is normally used for very slow rate and for housekeeping type purposes.

The display computer makes available 8 channels of tabular data (variables displayed in alphanumeric format), statistics, multivariable graphs, histograms, particle images, etc., at variable rates, through an extensive video distribution system throughout the aircraft. Two video hard copy units and a line printer are available for making permanent copies onboard. This display system is under investigator control using a support terminal whereby any of the eight display channels can be modified interactively. A video camera mounted in the cockpit displays the forward view from the cockpit and a weather radar display (AVQ-10) is available on any of the TV monitors in the aircraft. Usually, accompanying Electra programs is a quick-look post flight data processing system. This computer system is used primarily for quality assurance, but is also available for limited data processing.

Data tapes generated during flights are processed by the RAF Data Management Group to produce standard tape and microfilm outputs containing measured and derived variables. The standard processed data tapes contain 10 or 1 sample per second averaged data, or both.

A front-looking and two side-looking video cameras are available for further documentation of the weather situation. A downward-looking camera is also available.

To date, the aircraft has been used for programs in five continents, including Alaska, Hawaii, and various locations across the continental United States.

User Policy

Because of the size and operating cost of the Electra, we must vigorously endeavor to make each flight hour as useful as possible, and principal investigators will be encouraged to plan cooperative use whenever feasible. In those projects where full utilization of the Electra is not planned by the principal investigator, the Aviation Facility will invite the participation of cooperative investigators to the extent that they can

be accommodated within the proposed program without jeopardizing its objectives. This means that, in some cases, slight changes or additions to the basic flight program may be suggested by an associate or secondary investigator to better meet his objectives.

Investigators interested in discussing any use of the NCAR aircraft, including questions on scheduling, may contact the Chief of Project Management at (303) 497-1036.

TABLE I

Electra L-188C Specifications

Engine Power:	4,000 ESHP per engine
Wingspan:	99 ft (30m)
Length:	105 ft (32m) (w/o nose
Cabin Floor Area:	628 ft^2 (58 m^2)
Empty Weight:	65,117 lb (29,537 kg)
Maximum Gross Weight:	116,000 lb (52,665 kg)
Maximum Payload Weight Limit:*	20,883 lb (9,473 kg)
Maximum Landing Weight:	95,650 lb (43,385 kg)
Research Electrical Power:	28 kVA
Fuel Capacity:	6,520 gal (24,678)
Flight Load Acceleration Limit:	2.5 g
Service Ceiling at 100,000 lb (45,000 kg):	28,400 ft (8,700m)
Maximum Operating Altitude:	30,000 ft (9,100m)
Typical Research Range (full fuel at takeoff)	
1,000 ft	1,520 nm
10,000	1,900
20,000	2,405

*Available for crew, NCAR and user-furnished equipment, and cargo.

* * *

Please Note: The figures quoted for payload, range and altitude are maximums that may be reduced due to high temperatures, extensive IFR weather conditions or other factors too numerous to list here. Each project is planned and executed according to the circumstances prevailing at the time. See RAF *Bulletin No. 7.* for more details on Electra flight planning.

CABIN PRESSURIZATION ON THE ELECTRA

Aircraft altitude	Cabin pressure differential (cabin - outside pressure)
5,000 ft	0 to 5.1 "Hg
10,000	0 to 9.2
15,000	5.3 to 13.0
20,000	8.5 to 13.3
25,000	11.0 to 13.3

Table 2

NCAR Electra N308D
Aircraft Instrumentation

VARIABLE MEASURED	SYMBOL	INSTRUMENT TYPE	MANUFACTURER & MODEL NO.	Combined Performance of Transducer, Signal Conditioning, and Recorder		
				Range	Accuracy	Resolution
Aircraft Latitude	ALAT	Inertial Nav. Sys.	Litton LTN-51	±90°	≤ 1.0 nm per flt. hour	0.0014°
Aircraft Longitude	ALON	Inertial Nav. Sys.	Litton LTN-51	±180°	≤ 1.0 nm per flt. hour	0.0014°
Aircraft Latitude	CLAT	Loran-C System*	Advanced Navigation Inc. ANI-7000	±90°	0.19 km	0.0002°
Aircraft Longitude	CLON	Loran-C System*	Advanced Navigation Inc. ANI-7000	±180°	0.19 km	0.0002°
Aircraft Ground Speed	XVI,YVI	Inertial Nav. Sys.	Litton LTN-51	0 to 400 m/s	≤ 1.0 knot per flt. hour	0.04 m/s
Aircraft Vertical Velocity	VZI	Inertial Nav. Sys.	Litton LTN-51	±200 m/s	±0.10 m/s	0.012 m/s
Aircraft True Hdg.	THI	Inertial Nav. Sys.	Litton LTN-51	0 to 360°	±0.05°	0.00275°
Aircraft Pitch Angle	PITCH	Inertial Nav. Resolver	Litton APD 917055	45°	±0.05°	0.00275°
Aircraft Roll Angle	ROLL	Inertial Nav. Resolver	Litton APD 917055	45°	±0.05°	0.00275°
Inertial Platform Heading	PHDG	Inertial Nav. Resolver	Litton APD 917055	45°	±0.05°	0.00275°

*Not worldwide coverage.

Table 2

NCAR Electra N308D
Aircraft Instrumentation (1)

VARIABLE MEASURED	SYMBOL	INSTRUMENT TYPE	MANUFACTURER & MODEL NO.	Combined Performance of Transducer, Signal Conditioning, and Recorder		
				Range	Accuracy	Resolution
Static Pressure	PSW PSB	Variable Capacitance	Rosemount, Inc 1201F	300 to 1035 mb	±1 mb*	0.07 mb
Static Pressure (cabin)	PCAB	Variable Capacitance	Rosemount, Inc 1201F	600 to 1035 mb	±1 mb*	0.07 mb
Static Pressure	PSFD	Oscillation Frequency (digital output)	Rosemount, Inc 1501	300 to 1035 mb	±1 mb	0.034 mb
Indicated Airspeed	QCW QCB	Variable Capacitance	Rosemount, Inc 1221	0 to 125 mb	0.7 mb	0.006 mb
Indicated Airspeed	QCG	Variable Capacitance	Rosemount, Inc 850L-2 (pitot) 1332D	0 to 125 mb	0.5 mb	0.02 mb
Total Air Temperature	TTF, TTB	Platinum Resistance	Rosemount, Inc 102E2AL	-60 to 40°C	±0.5°C	0.006°C
Total Air Temperature (Deiced)	TTFH	Platinum Resistance	Rosemount, Inc 102DB, 102CV	-60 to 40°C	±1.0°C	0.006°C
Total Air Temperature (Fast Response)	TTKP	Platinum Resistance	NCAR Developed	-60 to 40°C	±0.5°C	0.006°C

*Assuming transducer is exposed to <1°C/min rate of temperature change.
(1) Degradation of accuracies of certain sensors can be expected when flying through visible visible moisture or under icing conditions.

Table 2

NCAR Electra N308D
Aircraft Instrumentation (1)

VARIABLE MEASURED	SYMBOL	INSTRUMENT TYPE	MANUFACTURER & MODEL NO.	Combined Performance of Transducer, Signal Conditioning, and Recorder		
				Range	Accuracy	Resolution
Dewpoint Temperature	DPB DPT	Thermoelectric Hygrometer	EG&G 137-C3-S3	-50 to +50°C	±0.5°C>0°C* ±1.0°C<0°C	0.006°C
Absolute Humidity	VLA	Lyman-alpha Hygrometer	NCAR Developed LA-3	-45 to +30°C	±5%**	0.2%
Radiometric Sfc. Temperature	RSTB RSTT	Bolometric Radiometer	Barnes Engr. Co. Optitherm	-20 to +75°C	±1.0°C	0.005°
Angle of Attack	AFIXL AFIXR	Fixed Vane (Strain Gauge)	NCAR Developed	±10°	±0.2° (relative)	0.003°
Angle of Sideslip	BFIXT BFIXB	Fixed Vane (Strain Gauge)	NCAR Developed	±10°	±0.2° (relative)	0.003°
Infrared Radiation	IRB IRT	Pyrgeometer 4 to 45 μm (Silicon Dome)	Eppley PIR	0 to 600 W/m^2	------	0.40 W/m^2
Visible Radiation	SWB SWT	Pyranometer .285 to 2.800 μm (Clear Dome WG7)	Eppley PSP	0 to 1500 W/m^2	------	0.12 W/m^2
Ultraviolet Radiation	UVB UVT	Photometer .295 to .385 μm	Eppley TUVR	0 to 200 W/m^2	-----	0.12 W/m^2

*If Relative Humidity is >11%.
**With periodic baselining.
(1) Degradation of accuracies of certain sensors can be expected when flying through visible moisture or under icing conditions.

Table 2

NCAR Electra N308D
Aircraft Instrumentation

VARIABLE MEASURED	SYMBOL	INSTRUMENT TYPE	MANUFACTURER & MODEL NO.	Combined Performance of Transducer, Signal Conditioning, and Recorder		
				Range	Accuracy	Resolution
Geometric Altitude	HGM	Radio Altimeter	Sperry Rand RT-221	0 to 762m	±1.5m, 0-30m ±8m, 30-150m ±53m, 150-762m	0.1m
Geometric Altitude	HGME	Radar Altimeter	Stewart-Warner	0 to 21,000m	±9.7m	0.1m
Cloud Liquid Water Content	LWC	Hot-wire	Johnson-Williams LWH (Cloud Technology)	0 to 5 g/m^3	------	0.005g/m^3
Cloud Liquid Water Content	PLWC	Heated-wire	PMS-CSIRO King Probe	0 to 5 g/m^3	------	0.006g/m^3
Ice Detector	RICE	Accretion of Cloud Droplets	Rosemount, Inc 871F	0 to 0.5mm incre-ments	------	0.0005mm
Photography	-----	VHS Video Color Cameras: Forward-looking, Minolta Camera: Model K500S. Images recorded on JVC BR-6200U VCR. Left and right side, GE camera: Model 1CVK 5032E. Images recorded on GE Model 1CVK 5022X VCR.			Up to six hours of recording (w/wo voice) per cassette.	
Temperature, Moisture, Pressure and Winds		FGGE dropwindsonde system*	Tracor, Inc.	between 8.0 km flight level & ocean surface	------	------

*Available through special arrangements.

Table 2

NCAR Electra N308D
Aircraft Instrumentation (1)

VARIABLE MEASURED	SYMBOL	INSTRUMENT TYPE	MANUFACTURER & MODEL NO.	Combined Performance of Transducer, Signal Conditioning, and Recorder		
				Range	Accuracy	Resolution
Aerosol Spectrum	ASASP	Laser Spectrometer	Particle Measuring Systems, Inc.	0.12 to 3.12 μm	-----	0.025 to 0.375 μm (progr. weighted)
Cloud Droplet Spectrum	FSSP	Laser Spectrometer	Particle Measuring Systems, Inc.	0.5 to 45 μm	-----	Selectable 0.5,1,2,3,μm
Cloud Droplet Spectrum	260X	Laser Spectrometer	Particle Measuring Systems, Inc.	10 to 620 μm	-----	10 μm
Cloud Droplet Spectrum	200X	Laser Spectrometer	Particle Measuring Systems, Inc.	20 to 280 μm	-----	20 μm
Hydrometeor Spectrum	200Y	Laser Spectrometer	Particle Measuring Systems, Inc.	300 to 4,500 μm	-----	300 μm
Cloud Particle Spectrum (2D)	2D-C	Laser Spectrometer	Particle Measuring Systems, Inc.	25 to 800 μm	-----	25 μm
Hydrometeor Spectrum	2D-P	Laser Spectrometer	Particle Measuring	200 to 6,400 μm	-----	200 μm

(1) Degradation of accuracies of certain sensors can be expected when flying through visible moisture or under icing conditions.

Table 3

NCAR Electra N308D
Specifications for Air Velocity Components

VARIABLE MEASURED	SYMBOL	INSTRUMENT TYPE	RANGE	ACCURACY (m/s) Short-term (<10 min)	ACCURACY (m/s) Long-term (t in hrs)	RESOLUTION	UPPER LIMIT FREQUENCY RESPONSE (Hz)
Wind vector horizontal component*	UI, VI	Input from gust probe and INS	0+100 m/s	±0.1	±(1.0+0.5t)	0.012 m/s	10
Wind vector vertical component*	WI	Input from gust probe and INS	±15 m/s	±0.1	---	0.012 m/s	10
Wind direction horizontal	WD	Input from gust probe and INS	0+360°	$+COT^{-1}(UI/VI)$		---	10

Note:
*RAF computed winds are actually a combination of the mean and fluctuating components, i.e. $UI = \overline{UI} + UI'$, when gust probe is present.

Table 4

Typical List of Parameter Display Capabilities
On Board the Electra

Parameter Name	Symbol
RAW INS Latitude (deg)	ALAT
RAW INS Longitude (deg)	ALON
Aircraft Pitch Attitude Angle (deg)	PITCH
Aircraft Roll Attitude Angle (deg)	ROLL
Raw Dynamic Pressure (Wing) (mb)	QCW
Raw Dynamic Pressure (Boom) (mb)	QCB
Raw Static Pressure (Wing) (mb)	PSW
Raw Static Pressure (Fuselage Digital) (mb)	PSFD
Raw Static Pressure (Boom) (mb)	PSB
Raw Total Temperature (Boom Rosemount) (°C)	TTB
Raw Total Temperature (Fuselage Deiced Rosemount) (°C)	TTFH
Dew/Frost Point Temp (Right, Top) (°C)	DPT
Dew/Frost Point Temp (Right, Bottom) (°C)	DPB
Raw Lyman-alpha Hygrometer Output (Vd.c.)	VLA
Raw J-W Liquid Water Content (g/m^3)	LWC
Raw PMS-King Liquid Water Content (g/m^3)	PLWC
Downward SW Irradiance (WG-7) ($Watts/m^2$)	SWB
Upward SW Irradiance (WG-7) ($Watts/m^2$)	SWT
Angle of Attack (Gust Probe) (deg)	AFIXL, AFIXR
Angle of Sideslip (Gust Probe (deg)	BFIXT, BFIXB
Corrected Dynamic Pressure (Wing) (mb)	QCWC
Corrected Dynamic Pressure (Boom) (mb)	QCBC
Corrected Static Pressure (Wing) (mb)	PSWC
Corrected Static Pressure (Fuselage, Digital) (mb)	PSFDC
Corrected Static Pressure (Boom) (mb)	PSBC
NACA Pressure Altitude (m)	PALT
Ambient Temperature (Boom Rosemount) (°C)	ATB
Ambient Temperature (Fuselage Deiced Rosemount) (°C)	ATFH
Aircraft True Airspeed (Wing) (m/s)	TASW
Aircraft True Airspeed (Boom) (m/s)	TASB
Absolute Humidity (g/m^3) (Thermoelectric, Top)	RHOTD
Corrected J-W Liquid Water Content (g/m^3)	LWCC
Corrected Downward IR Irradiance ($watts/m^2$)	IRTC
Corrected Upward IR Irradiance ($watts/m^2$)	IRBC
Attack Angle (Rosemount) (deg)	AKDF
Sideslip Angle (Rosemount) (deg)	SSDF
Wind Vector East Gust Component (m/s)	UI
Wind Vector North Gust Component (m/s)	VI
Wind Vector Vertical Gust Component (m/s)	WI
Wind Vector Longitudinal Gust Component (m/s)	UX
Wind Vector Lateral Gust Component (m/s)	VY
Horizontal Wind Direction (deg)	WD
Horizontal Wind Speed (m/s)	WS
Distance East of Start (km)	DEI
Distance North of Start (km)	DNI
Damped Aircraft Vertical Velocity (m/s)	WP3
Mixing Ratio (g/kg)	MR
Icing Detector (V dc)	RICE
Potential Temperature (°K)	THETA
Equivalent Potential Temperature (°K)	THETAE
Relative Humidity (%)	RHUM
Specific Humidity (g/kg)	SPHUM
Virtual Temperature (°C)	TVIR
Virtual Potential Temperature (°K)	THETAV

* * *

PMS probe derived parameters such as: concentrations, histograms, dispersion factor, liquid water content, reflectivity factor, etc. are available in real time.