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madison

SPECIFICATION FOR  
A PROTOTYPE BOUNDARY LAYER  
INSTRUMENTATION SYSTEM



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A . P R O T O T Y P E B O U N D A R Y L A Y E R  
I N S T R U M E N T A T I O N S Y S T E M

This document is Part 2 of the  
final SSEC report on Task 3 of  
NOAA Contract E-127-69(N)

## SECTION I

## SCOPE

## 1.1 SCOPE

This specification covers one type of prototype Boundary Layer Instrumentation System (BLIS). The system includes up to five Boundary Layer Instrument Packages (BLIP's), an aerodynamically-shaped balloon, a tether line onto which the BLIP's are fastened, and a winch. The system interfaces with a Shipboard Data Acquisition System. This specification contains modifications to the Shipboard Data Acquisition System which are necessary for compatibility with the prototype Boundary Layer Instrumentation System.

## SECTION II

## APPLICABLE DOCUMENTS

The following documents are part of this specification to the extent specified herein.

1. A combination Wind Direction and Velocity Transducer-WINDAV. T. Bernstein and J. Miller, Proc. NEC, 1969. pp. 840-843.
2. A portable Data Acquisition System (Blue Book). General Electric Company, NOAA Mississippi Test Facility, Bay St. Louis, Mississippi. No date (approx. May, 1971).
3. On the requirements of a Boundary Layer Instrumentation System for the GARP Tropical Experiment. V. E. Suomi and David W. Martin. Final Report on the Boundary Layer Instrumentation Study, Task Order 3 to STAG Contract N-127-69(N). University of Wisconsin, 15 June 1971.
4. MIL-STD-202 Test Methods for Electronic and Electrical Component Parts. 14 April, 1969.

SECTION III  
REQUIREMENTS

### 3.1 PERFORMANCE

The Boundary Layer Instrumentation Package (BLIP) shall provide the capability to transmit to a Shipboard Data Acquisition System data relating to the following meteorological parameters:

	<u>Parameter</u>	<u>Absolute Accuracy</u>	<u>Range</u>
3.1.1	Wind Speed	$\pm 0.08$ meter/second (m/s)	0.5-15 m/s
3.1.2	Wind Direction	$\pm 1^\circ$	0-360 $^\circ$
3.1.3	Pressure	$\pm 0.1$ millibar (mb)	850-1040 mb
3.1.4	Dry Bulb Temperature	$\pm 0.1^\circ\text{C}$	0-50 $^\circ\text{C}$
3.1.5	Wet Bulb Temperature	$\pm 0.1^\circ\text{C}$	0-50 $^\circ\text{C}$
3.1.6	Altitude (optional)	$\pm 2$ meters (m)	200-1500 m

### 3.2 OPERATING CONDITIONS

The performance specifications of Section 3.1 shall be maintained under all normal operating conditions expected in the tropical Atlantic environment for a three month period. In particular the BLIP shall meet the performance specifications under the following conditions:

- 3.2.1 0-50 $^\circ\text{C}$  ambient temperature range
- 3.2.2 0-1500 meter altitude range
- 3.2.3 20%-100% relative humidity range
- 3.2.4 0-15 m/s wind speed range. The BLIS shall be capable of withstanding wind speeds up to 25 m/s.
- 3.2.5 48 hour periods of continuous rain. Accurate dry bulb temperature shall not be required during rain.
- 3.2.6 48 hours of continuous exposure to salt spray without cleaning. In addition the BLIP shall be resistant to corrosion due to salt spray for at least three months of normal BLIS operation.
- 3.2.7 Daily solar radiation exposure
- 3.2.8 Static electricity in the vicinity of the tether line and balloon, except direct arcing.
- 3.2.9 Mechanical shock and vibration caused by normal handling by shipboard crews; and BLIP motion caused by wind, and by balloon and ship motions.

### 3.3 SENSORS

- 3.3.1 Wind speed and wind direction shall be measured by a WINDAV wind speed and wind direction indicator. The WINDAV shall conform to the general electrical and mechanical configuration as given in Document 1; but design details may be altered to improve performance and reduce weight.
- 3.3.2 Pressure shall be measured with an aneroid capsule with an attached capacitive transducer. For use in processing the pressure data, the aneroid temperature shall be measured with a thermistor.
- 3.3.3 Wet Bulb temperature and dry bulb temperature shall be measured with thermistors. All BLIP thermistors shall have time constants of approximately two seconds. The wet and dry bulb thermistors shall have time constants which are equal to within 10 percent, and resistance-vs.-temperature characteristics which are matched to within 5 percent over the 0° to 50°C temperature range. All BLIP thermistors shall operate so that self-heating is limited to a maximum of 0.01°C.

### 3.4 MECHANICAL DESIGN

- 3.4.1 The BLIP shall consist of a mount which shall fasten to a tether line of a balloon, and of an instrument package which shall fasten to the mount with a quick-connect mechanism.
- 3.4.2 The total weight of the BLIP, including batteries and psychrometer water, shall be held to a minimum constant with required performance. In no case shall the weight exceed 750 grams.
- 3.4.3 The BLIP case and mount shall be made of lightweight non-wettable materials; and shall be painted high-reflectance white.
- 3.4.4 To limit anemometer cosine error, the BLIP shall be so designed that for all wind speeds up to 15 m/s the WINDAV is held horizontal to within 8 degrees such that the combined WINDAV wind speed error does not exceed  $\pm 0.08$  m/s.
- 3.4.5 The BLIP shall have a single battery pack which can be changed by one man in less than thirty seconds, and a psychrometer water supply which can be replenished by one man in less than one minute.
- 3.4.6 The antenna shall be a horizontal half-wave dipole aligned normal to the wind. The antenna shall be made of a flexible, resilient material, or otherwise designed, so as to protect it and its mount from accidental breakage.
- 3.4.7 The psychrometer wet bulb water flow rate shall be adequate to keep the wet bulb wick uncontaminated by salt spray. The BLIP shall contain a 48 hour water supply. The wick shall be positioned downstream to avoid changing the humidity of the airstream past the wet bulb thermistor. The wet and dry bulb thermistor mounts shall



be so designed that the heat conduction through the mount is minimized. The wet and dry bulb thermistors shall be shielded from direct solar radiation without obstructing the natural ventilation of the thermistors caused by the wind.

An alternative to shielding shall be to have unshielded wet and dry bulb thermistors, and one each unshielded black and white thermistor with known emissivities to calibrate out the radiation error.

In either case the error caused by solar radiation shall be included in the  $0.1^{\circ}\text{C}$  temperature error limit.

3.4.8 The aneroid capsule shall be mounted and enclosed so as to minimize temperature and dynamic (wind) pressure errors.

### 3.5 DATA FORMAT

3.5.1 Each measurement shall be transmitted in the form of a pulse code. Each measurement code group is hereafter referred to as a word.

3.5.2 Each word shall be time multiplexed for transmission.

3.5.3 The system shall be capable of multiplexing up to 16 words per frame of data.

3.5.4 A data frame shall start with a frame sync signal. The frame sync signal shall be a voltage waveform as shown in Figure 1c.

3.5.5 The frame sync shall be followed by a hard-wired seven-bit BLIP identifier word. The identifier word shall be unique for each BLIP on a ship.

3.5.6 Sixteen data words follow sequentially after the BLIP identifier word. An entire frame (frame sync, BLIP identifier word, and 16 PCM data words) shall be transmitted approximately every second. The exact frame frequency shall be the sixteenth division by two of the clock frequency, and shall be greater than 0.866 seconds.

3.5.7 The 16 possible words for each frame shall include one word for each of the following parameters:

1. Wet bulb temperature
2. Dry bulb temperature
3. Aneroid temperature
4. Electronics package temperature
5. Pressure
6. Wind direction count
7. Wind speed count

8. High reference resistance
9. Low reference resistance
10. High reference capacitance
11. Low reference capacitance

Of the five remaining channels, four shall be allocated to resistance sensors and one to a capacitive sensor.

- 3.5.8 Data words shall be 14 bits long. All 14 bits shall be significant for wind speed and wind direction. Eleven bits shall be significant for all other data words (i.e., there shall be eleven bits of resolution).
- 3.5.9 Each logical-1 and logical-0 bit shall have waveforms as shown in Figures 1a and 1b respectively.

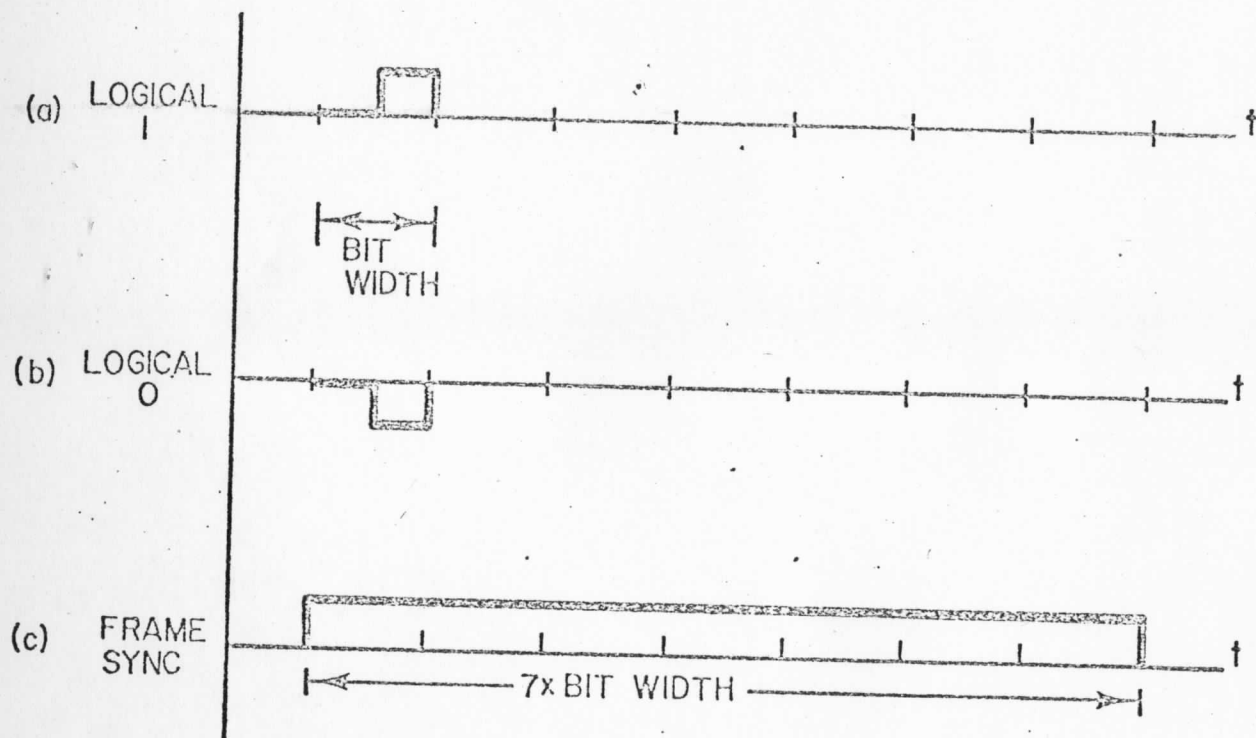


FIG. 1: DATA BIT AND SYNC FORMATS



## 3.6 ELECTRICAL DESIGN

- 3.6.1 The BLIP shall operate with a bipolar battery supply for a period of 48 hours. Total power consumption shall be no more than 0.24 watts. The batteries shall consist of mercury cells for temperatures above 5°C, and silver cells for temperatures below 5°C. The battery voltage shall change no more than 10 percent from its open circuit voltage at 25°C over its entire operating temperature range (0° to 50°C for silver cells, 5°C to 50°C for mercury cells) for 48 hours.
- 3.6.2 The sensors shall be electronically multiplexed by a sequencer controlled by an internal clock.
- 3.6.3 The clock shall be crystal controlled with a fundamental frequency (f) of approximately 78 KHz, and with a stability of 0.005 percent over the 0-50°C temperature range. A frequency divider chain shall provide the necessary timing and counting frequencies.
- 3.6.4 The thermistor and calibration resistor resistances shall be converted to digital words by a specialized A/D converter consisting of a dedicated tone burst generator (wherein the number of pulses produced is related to sensor resistance) and a counter. The A/D conversion error shall be consistent with the overall temperature accuracy requirement of Section 3.1. In addition, and A/D conversion errors, including quantization error, of the wet and dry bulb temperatures,  $T_w$  and  $T_d$ , shall be such that the error in temperature difference,  $T_d - T_w$ , is less than  $\pm 0.1^\circ\text{C}$ .
- 3.6.5 The aneroid and reference capacitors shall be converted into digital words with an A/D converter consisting of a dedicated tone burst generator and the same counter as specified in Section 3.6.4. The A/D conversion error, including quantization error, shall be consistent with the overall pressure accuracy requirement of Section 3.1.
- 3.6.6 The wind speed measurement shall consist of a count of the number of pulses, with frequency (approximately 1229 Hz) equal to the sixth division by two of the crystal clock frequency ( $f_0/64$ ), which occur in one cycle of the WINDAV sine wave. The count shall begin at the next positive-going zero-crossing of the sine wave and end at the next positive-going zero-crossing. This count is transferred to a dedicated 14-bit buffer register at the end of each WINDAV cycle.
- 3.6.7 The wind direction measurement shall consist of a count of the number of pulses, with frequency equal to the sixth division by two of the crystal clock frequency, which occur between the positive-going zero-crossing of the WINDAV sine wave and the closure of the reed switch. This count is accumulated in the same counter as is specified in Section 3.6.6, but is transferred to a dedicated 14-bit buffer register at the closure of the reed switch.

- 3.6.8 The wind speed and wind direction counts shall be accumulated during the same WINDAV cycle.
- 3.6.9 The modulo-360° wind direction ambiguity shall be removed in the data processing rather than in BLIP hardware.
- 3.6.10 The data words and identifier word shall be transferred by suitable logic commands to a parallel-in, serial-out shift register. The shift register contents shall be shifted out by a clock signal derived from the crystal clock.
- 3.6.11 The shift register output code stream shall be bit-formated to correspond to Figures 1a and 1b.
- 3.6.12 The formated bit stream shall frequency modulate (FSK) a 400 MHz transmitter. The radiated power output shall be 5 mW into a 50 ohm load. Overall efficiency shall be greater than ten percent. Frequency stability shall be better than 7.5 ppm over a 0° to 50°C temperature range. Residual AM shall be less than ten percent modulation, including modulation due to the rotating WINDAV. The frequency deviation shall be no more than ± 1500 Hz about the center frequency. The center frequency shall be tunable from 360 MHz to 440 MHz. Spurious harmonics shall be greater than 20 db below the tuned frequency. There shall be sufficient isolation between the antenna and the oscillator so that the rotating WINDAV causes no more than a five percent change in the frequency deviation of the transmitter.

### 3.7 BALLOON

- 3.7.1 The lifting platform shall be a tethered, aerodynamically-shaped balloon with at least 21 kg of static lift at 100% RH throughout a 48 hour flight. The balloon shall use helium gas, and shall not need replenishment more often than that at 48 hour intervals.
- 3.7.2 The balloon shall be capable of attaining an altitude of 1500 meters with static lift alone. The balloon shall maintain its aerodynamic shape and meet all performance specifications throughout a 48 hour flight and under the following operating conditions:
  - 3.7.2.1 0-50°C ambient temperature range
  - 3.7.2.2 0-1500 meter altitude range
  - 3.7.2.3 20%-100% relative humidity range
  - 3.7.2.4 0-25 m/s wind speed range
  - 3.7.2.5 Daily exposure to solar radiation
  - 3.7.2.6 Static electricity, except direct arcing
  - 3.7.2.7 Continuous exposure to rain
  - 3.7.2.8 Continuous exposure to salt spray
  - 3.7.2.9 Mechanical shock and fatigue caused by normal handling by ship-board crews; and by wind and ship motion.

3.7.3 The balloon shall be capable of making thirty flights as described in Sections 3.7.1 and 3.7.2.

3.7.4 The balloon shall have sixty feet of 1/2-inch I.D. soft rubber tubing attached to the balloon gas inlet for the purpose of topping-off the balloon.

### 3.8 TETHER LINE

3.8.1 The tether line shall be made of nylon. The line shall have a breaking strength of at least 800 pounds after eight days exposure to the environmental conditions stated in Sections 3.7.2.1 through 3.7.2.9. The line shall have an 8 to 15 percent elongation at 200 pounds tension. The line shall not be wettable.

3.8.2 The tether line shall possess charge dissipators, conductive or protective coatings or deposits, or other means of insuring that the current in the tether line due to atmospheric electricity will not break the tether line. The presence of the atmospheric electricity protection shall not affect the performance specifications of the line as stated in Section 3.8.1.

3.8.3 The line shall be one continuous piece, 2000 meters long; and shall weigh no more than 16.0 kg including the atmospheric electricity protection. The line shall be no less than 0.100 inches in diameter and no more than 0.250 inches in diameter.

### 3.9 WINCH

The purpose of the winch shall be to pull in and pay out the tether line. The winch shall have the following features:

3.9.1 A fairlead or similar mechanism for pulling-in and paying-out line at vertical angles of 0 to 90° and for azimuth angles of 0 to 360°.

3.9.2 A motor-driven capstan for the purpose of limiting tension in the tether line during pull-in. The motor shall be a dc variable-speed reversible motor. The capstan drive shall be reversible for paying out; but in this mode the motor shall act only as a torquer (to counteract the inertial load of the capstan), not as a power drive.

3.9.3 A drum for storing the tether line. The drum shall store at least 2000 meters of line. The drum shall have a dc reversible motor acting as a brake during pay-out. The tension in the line on the drum during pull-in shall be adjustable up to twenty pounds of force.

3.9.4 A mechanism to distribute the line evenly on the drum. This device shall be adjustable to handle tether lines of from 0.100 inches to 0.250 inches in diameter.

- 3.9.5 A counter which measures the amount of line off of the drum. The counter shall read out in meters. The meter shall measure unattended line length to within  $\pm 5$  percent accuracy.
- 3.9.6 Ratchet-equipped hand cranks attached to the capstan and to the drum through clutches, in the event of an electric power failure.
- 3.9.7 An electrical control system which allows both manual and automatic operation of the winch. In the automatic mode the equipment shall be capable of cycling through ascent and descent patterns of the type described in Document 4. The automatic sequences shall be programmable by means of panel controls of (1) the length of line to be payed-out by the winch (0 to 2000 m), (2) the winch pull-in rate (0 to 2 m/s), (3) the length of line to be pulled in by the winch (0 to 2000 m), (4) the holding time interval between winchings (0 to 24 hours), and (5) the number of winching intervals per cycle (0 to 10). The control system shall have an automatic stop and a warning indication when an incompatible winching sequence has been programmed. The automatic mode shall have a manual override capability. The control system (in both the manual and automatic modes) shall have a provision for automatic logging of the time history of the winching.
- 3.9.8 The winch shall be designed to minimize fraying, twisting, stretching, abrading, or other damage of the tether line. Other design considerations shall be: (1) operator safety and convenience, (2) adequate grounding of the tether line for static electricity protection, (3) a mount suitable for welding to the deck of a ship, and (4) quick replacement of all parts which are likely to wear or fatigue during normal operation (e.g., pulleys, line guides, and bearings).
- 3.9.9 All electrical motors and devices on the winch shall conform in design, construction and installation to the electrical codes of the vessels on which they shall operate.

### 3.10 SHIPBOARD DATA ACQUISITION SYSTEM

NOTE: Shipboard Data Acquisition System is currently under development by the General Electric Company at the NOAA Mississippi Test Facility, Bay St. Louis, Mississippi. The specifications given below relate only to the changes in the GE system which would be necessary for compatibility with the BLIP. Document 2 is the most recent description of the GE system.

- 3.10.1 Frame sync shall be accomplished by integrating the demodulated bit stream, resetting the integrator on each negative-going edge, and threshold detecting the presence of the sync pulse.
- 3.10.2 There shall be a separate receiver for each BLIP. Each BLIP receiver shall be tunable from 360 MHz to 440 MHz, and shall have

a 3 db bandwidth of 3.5 KHz. The receiver rms voltage sensitivity shall be better than -90 dbm. Each receiver shall have an automatic frequency control.

- 3.10.3 The tape recorder interface shall include the capability of inserting, by command of the operator, ship identification, ship position, and sensor serial numbers onto the tape.

## SECTION IV

## QUALITY ASSURANCE PROVISIONS

- 4.1 All performance requirements for the BLIP, the balloon, the tether line and the winch shall be verified by testing, analysis or demonstration. The supplier shall submit for approval to the customer a detailed test plan one month prior to testing. All test results shall be documented.
- 4.2 For test purposes the balloon shall be loaded with weights simulating five prototype BLIP's. The balloon shall be filled with helium gas. The test program shall be conducted at 100% relative humidity; or the effect of 100% humidity shall be compensated for if the actual humidity is not 100%.
- 4.3 All BLIP electronic circuitry and subsystems shall undergo bench and 0-50°C thermal tests to assure that performance specifications are met.
- 4.4 All electronic subsystems shall operate and meet performance specifications during and after exposure to a high humidity (90% RH) atmosphere at 40°C for a period of one week.
- 4.5 All meteorological sensors shall be calibrated with standards available at the NOAA Mississippi Test Facility, or other test center with standards traceable to the NBS.
- 4.6 The entire BLIP shall undergo bench and thermal tests as per Section 4.4. In addition the BLIP shall satisfy performance specifications during wind tunnel tests with winds up to 15 m/s. The BLIP shall satisfy performance specifications after being subjected to test conditions of MIL-STD-202, Method 101c (Salt Spray), Method 103B (Humidity), Method 106C (Moisture Resistance) and Method 201A (Vibration), except where those test conditions are modified by Sections 3.2, 4.3 and 4.4.
- 4.7 The BLIP shall be tested under conditions of heavy rainfall (not less than 4 inches per hour) for 48 hours. During the course of the test there shall be no degradation in performance due to the rainfall, except that an accurate dry bulb measurement is not necessary.
- 4.8 The nylon line shall have a breaking strength greater than 800 pounds after undergoing humidity testing as per Section 4.4, and after salt spray testing as per MIL-STD 202, Method 101C. The tether line shall survive a static electricity test. The test method is to be determined.