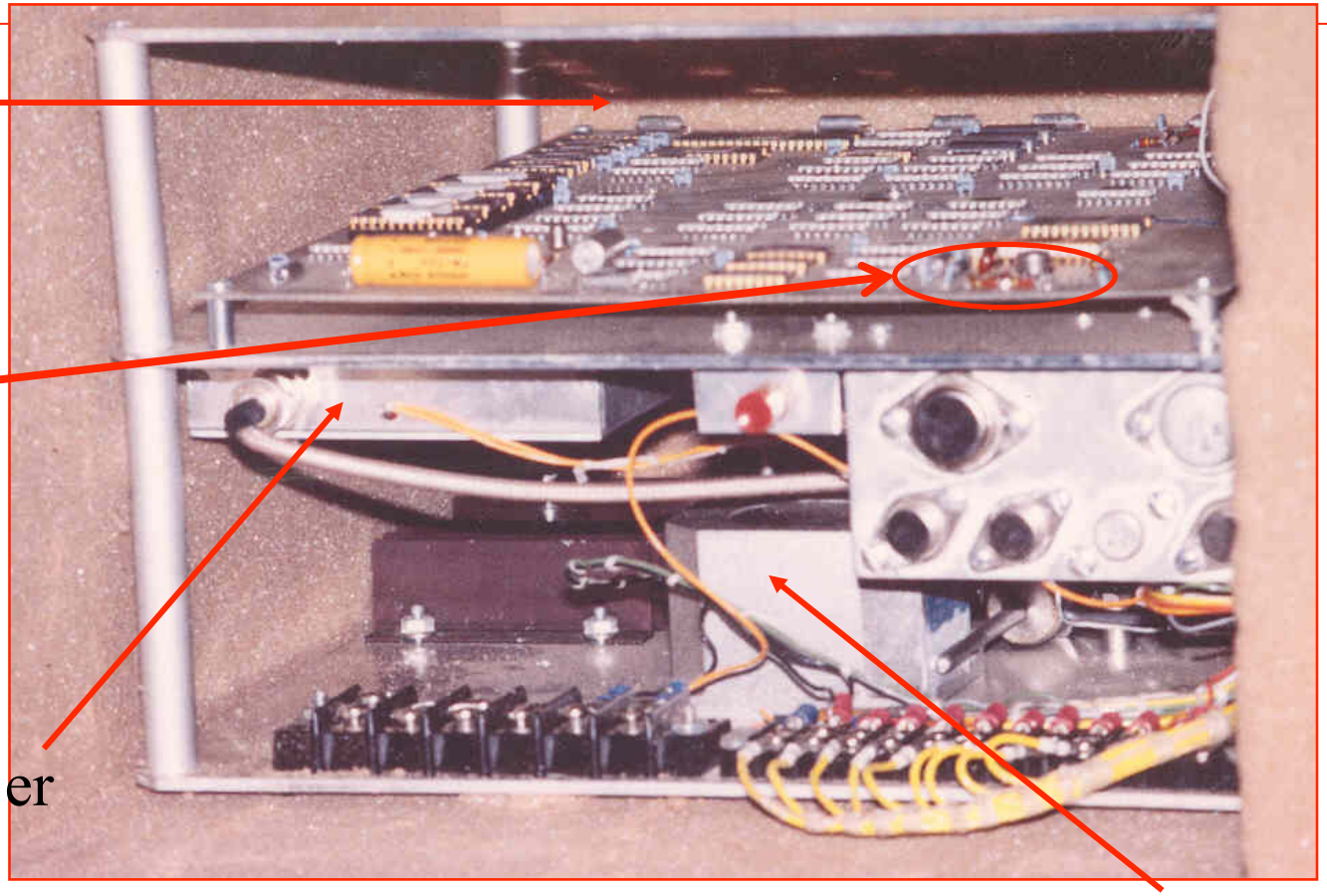
Legacy Calibration of the Automatic Weather Station Model 2 of the United States Antarctic Program

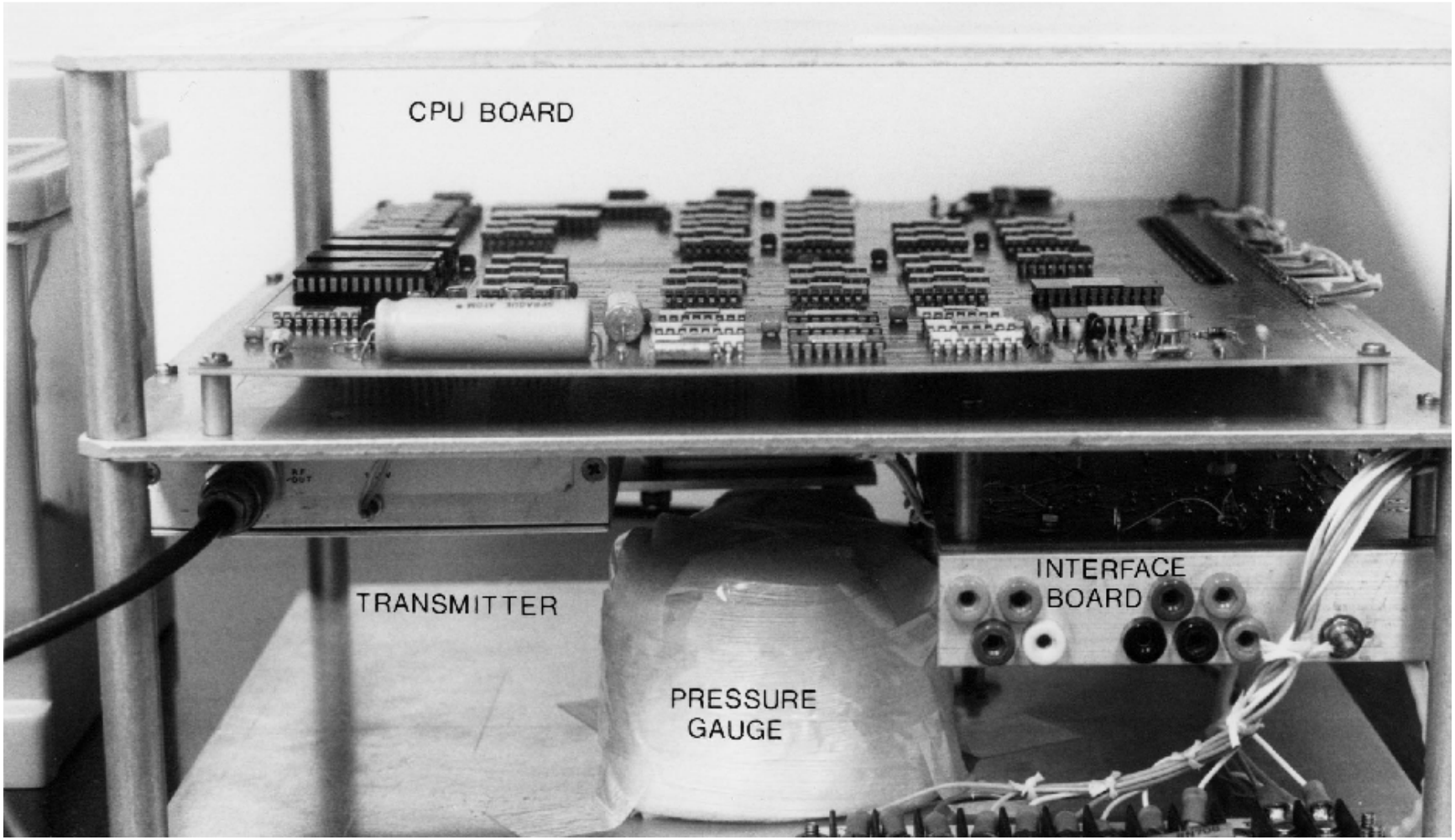
G. A. Weidner[2], J. E. Thom[1] , and M. A. Lazzara[1]
[1]Antarctic Meteorological Research Center
Space Science and Engineering Center
[2]Deparment of Atmospheric and Oceanic Sciences
University of Wisconsin-Madison
Madison, WI, USA

Stanford electronics – 1978



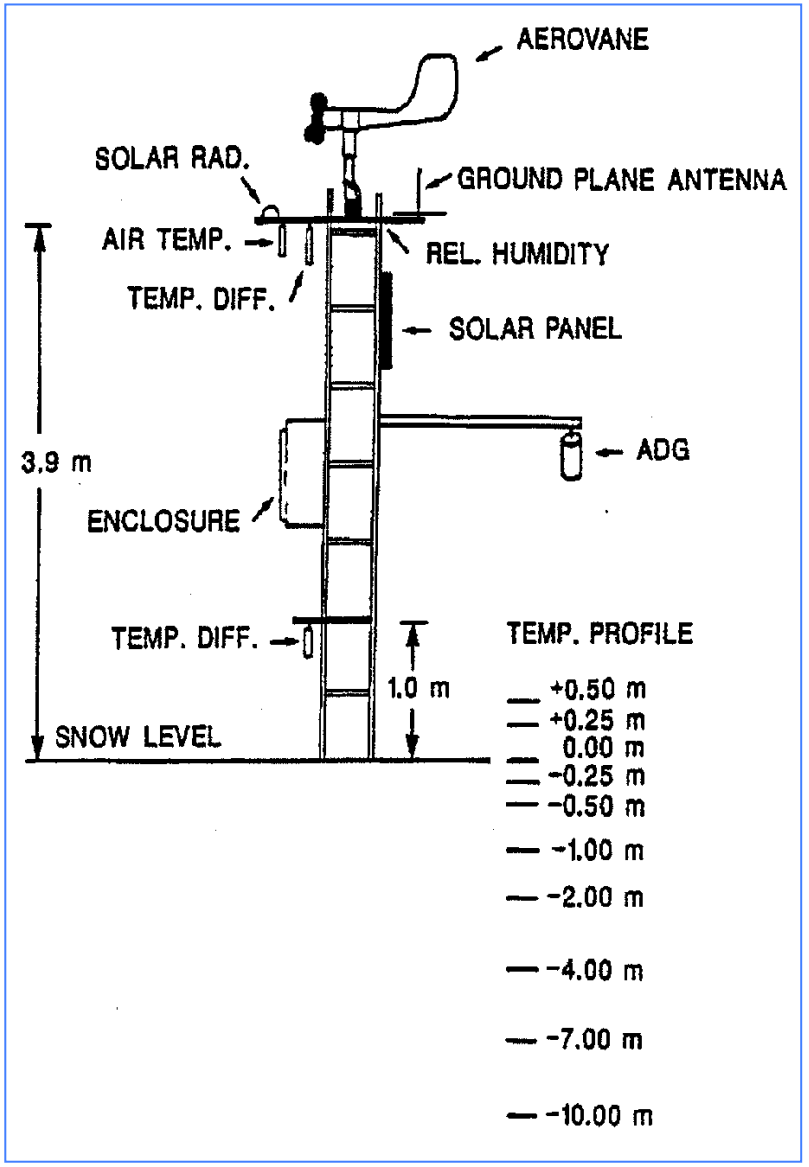
AWS2A Model of the Stanford AWS

AWS2B design UW SSEC

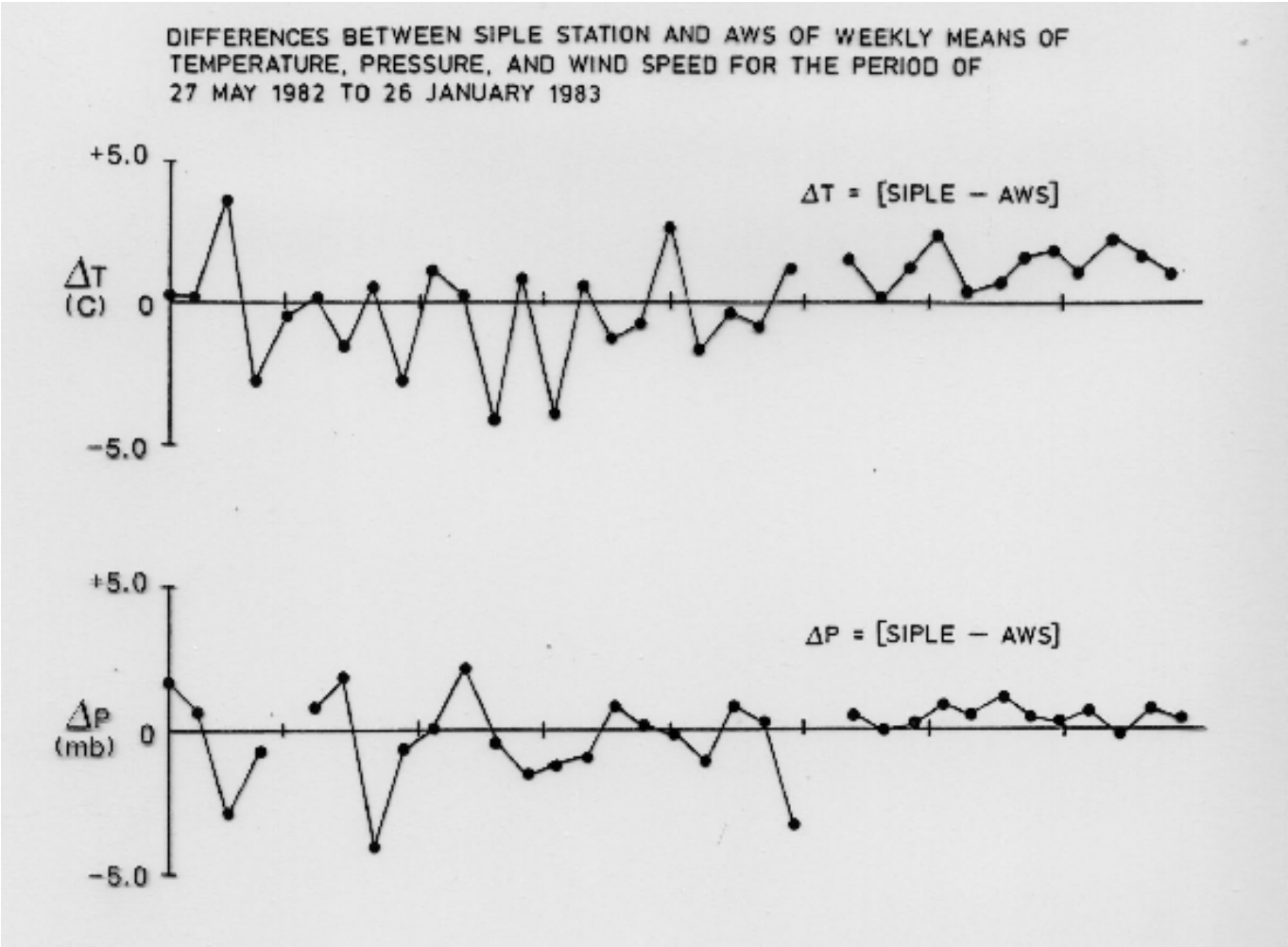


The AWS2B version

- The UW AWS2B as it was designed in the mid 1980's and is in use today.
- It also included an acoustic depth gauge (ADG) that measures the distance to the snow surface, thereby giving a measurement of net snow accumulation.
- An amplifier board was designed in 1980 to enable measurement snow temperature profiles from thermocouples.



Reason for AWS



AWS Hardware check

II. HARDWARE SETUP AND CALIBRATION

A. AWS SETUP

1. ANALOG INPUTS _____
2. DIFFERENTIAL INPUTS _____
3. DIGITAL INPUTS _____
4. TRANSMISSION CYCLE TYPE _____
5. TRAMSMISSION CYCLE TIME _____
6. NOMINAL AMPIFIER GAIN _____

B. CALIBRATION CHECKS

	20 C	
1. CLOCK FREQUENCY	_____	
2. 5 VOLT SUPPLY	_____	_____
3. SENSOR VOLTAGE	_____	_____
4. OSCILLATOR SUPPLY	_____	_____
5. TX VOLTAGE/BAT VOLTAGE	_____	_____
6. A/D -4 SUPPLY VOLTAGE	_____	_____
7. A/D -8 SUPPLY VOLTAGE	_____	_____
8. A/D REFERENCE VOLTAGE	_____	_____
9. A/D FULL SCALE VOLTAGE	_____	_____
10. A/D OUTPUT FOR 0 VOLTS	_____	_____
11. AMPLIFIER SUPPLY VOLTAGE	_____	_____
12. AMP NEGATIVE SUPPLY	_____	_____
13. A/D REFERENCE RESISTOR	_____	_____
14. A/D ZERO OFFSET RESISTOR	_____	_____
15. 1 MHZ OSCILLATOR	_____	_____
16. TRANMITTER FREQUENCY	_____	_____
17. A/D STABILITY	_____	_____
18. AMPLIFIER STABILITY	_____	_____
19. 1MHZ DIGITAL OUTPUT	_____	_____
20. 40 KHZ DIGITAL OUTPUT	_____	_____

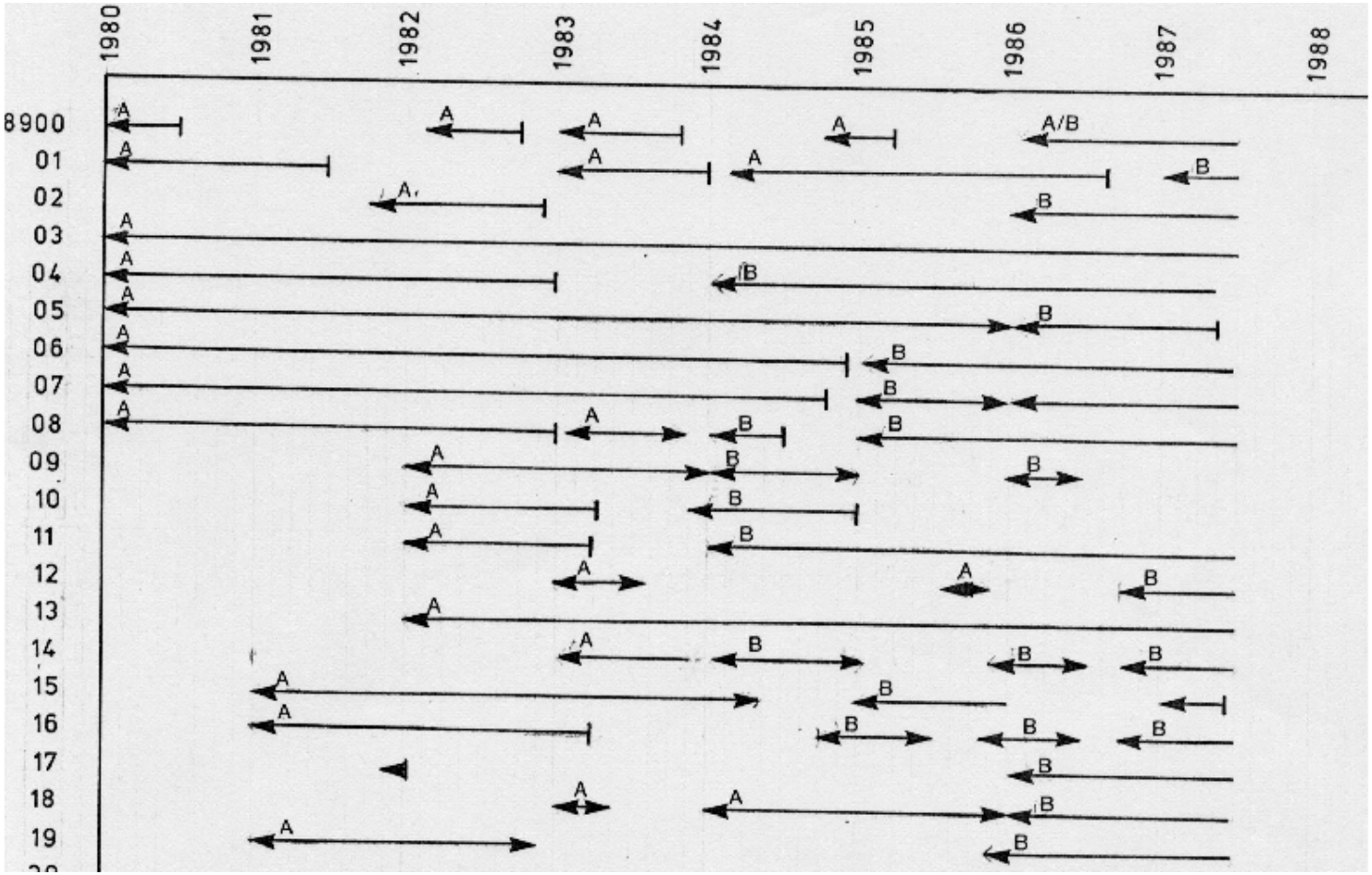
AWS2A Measurements

- Pressure – counts for 5.120 seconds (two counts)
- 1 MHz reference oscillator for 0.1 mb accuracy
- Temperature - Ratiometric with precision resistor
- Accuracy of +/- 0.5 C over temperature range
- Wind speed to 0.25 meters per second
- Wind direction to +/- 1.5 Degrees
- Humidity (HMP14) +/- 5% at best

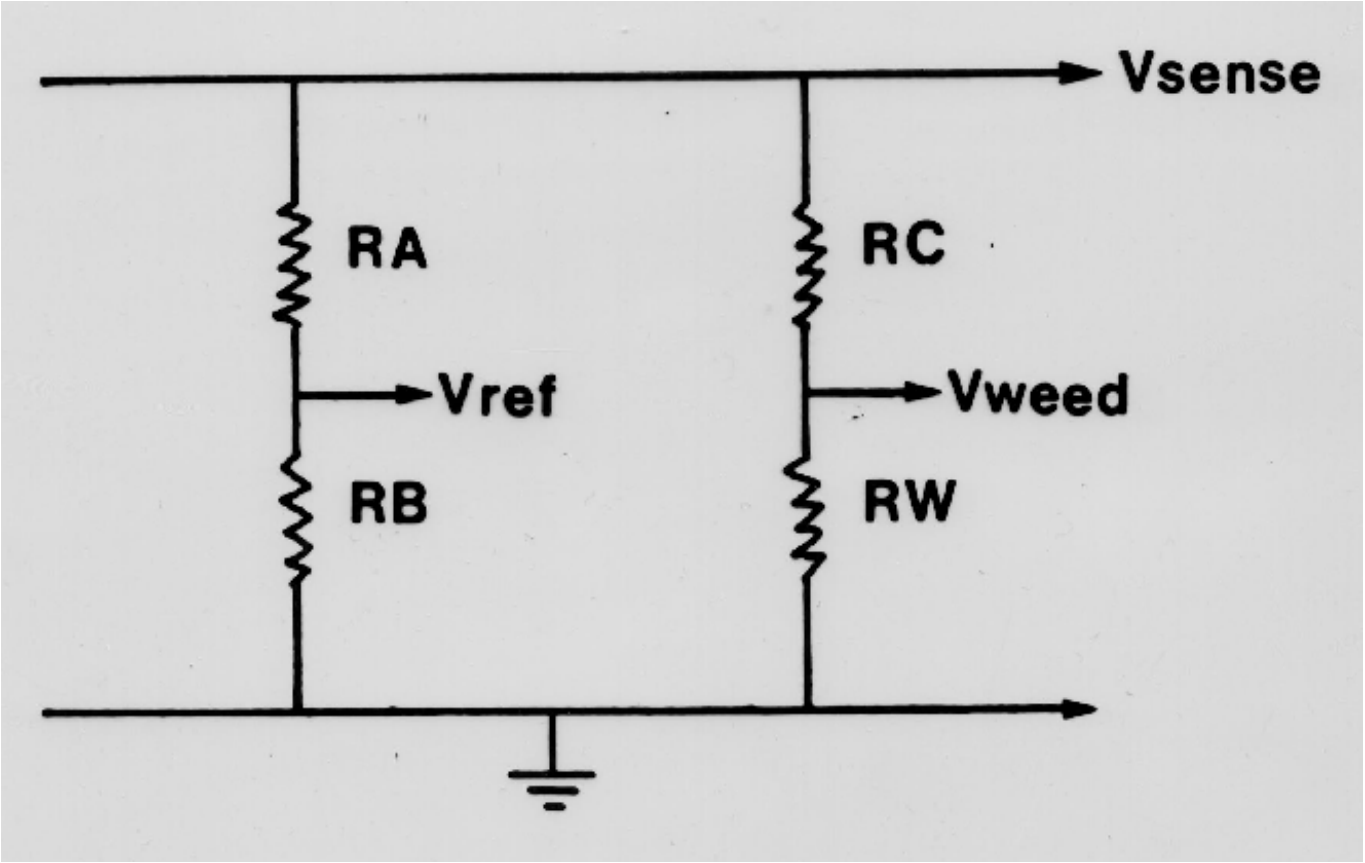
AWS2B Measurements

Variable	Sensor	Specifications
Air Pressure	Paroscientific Model 215 A	Range: 0 to 1100 hPa Resolution: 0.050 hPa Accuracy: +/- 0.2 hPa (0.2 hPa/year long term drift)
Air Temperature	Weed PRT Two-wire bridge	Range: to -100 C minimum Resolution: 0.125 C Accuracy: +/- 0.5 C
Humidity	Vaisala HMP-35A (and other models)	Range: 0 to 100% Resolution: 1.0 % Accuracy: +/- 5.0 % down to -55 C Corrections possible for lower temperatures
Wind Direction	10 K Ohm pot.	Range: 0 to 355 Degrees Resolution: 1.5 Degrees Accuracy: +/- 3.0 Degrees
Wind Speed	Bendix/Belfort RM Young Hydro-Tech	Resolution/Accuracy: 0.25 +/- 0.5 m/s Resolution/Accuracy: 0.20 +/- 0.5 m/s Resolution/Accuracy: 0.33 +/- 2%
Temperature String	Thermocouple Two junction Copper-Cons.	Resolution: 0.06 C Accuracy: +/- 0.125 C

AWS2A retirement



Weed temperature bridge



Temperature calibration

- A fixed calibration point for the AWS was chosen to be 0.0 C.
- A 1000 ohm (at 0.0C) PRT was selected as the temperature sensor.
- In order to set the PRT to 0C for a particular AWS, a 0.05% resister was substituted for the PRT and the AWS temperature output was observed.
- The output was set to 0C by setting an offset value in the AWS onboard software that compensated for the variation of the resistors in the bridge from their stated values.
- Typical “errors” from the PRT calibration table were less than 1.0 C over the temperature range from 25C to -75C.

AWS Temperature sensors

Sensor →	Weed PRTD	HMP45	HMP155	CSI RTD
AWS sensor	AWS2's	AWS2's CSI AWS	CSI AWS	CSI AWS
Alpha	0.003902	0,00385	0.00385	0.00375
Accuracy at 0.0C	+/- 0.250 C	+/- 0.03 C	+/- 0.03 C	+/- 0.03 C
Valid Temperature Range	Calibrated over the temperature range -75C to 20C	Calibrated over the temperature range -40C to 20C	Calibrated over the temperature range -80C to 20C	Calibrated over the temperature range -50C to 50C
Accuracy over Temp Range	+/- 0.5C	+/- 0.5C	+/- 0.5C	+/- 0.5C

Remember that the stated accuracy does not account for errors due to improper circuit set up or the issue of radiation shields.

Summary for Weeds

- All Weed temperature probes returned in the last three years are within the stated +/- 0.5C accuracy at 0.0C
- All Weeds will be matched to respective AWS electronics and cycle down to -60C in an environmental chamber.

	Calibration	
Chamber T	Resistance/ Temperature	AWS Temperature
22 C	1000 / 0 C	-0.125 C
+/-0 C	1000 / 0 C	0.000 C
-20 C	1000 / 0 C	0.000 C
-40 C	1000 / 0 C	0.125 C
-60 C	1000 / 0 C	0.250 C

Sample Table: Byrd AWS 0.0 C

Temperature calibration in chamber

Temperature In Chamber	Resistance temperature +/- 0.125 C	Observed AWS T	Resistance temperature +/- 0.250 C	Observed AWS T
22 C	1000 / 0 C	-0.125 C	903.6 /-24.25	-25.000 C
+/-0 C	**1000 / 0 C**	**0.000 C**	903.6 /-24.25	-25.000 C
-20 C	1000 / 0 C	0.000 C	**903.6 /-24.25**	**-24.875 C**
-40 C	1000 / 0 C	0.125 C	903.6 /-24.25	-24.750 C
-60 C	1000 / 0 C	0.250 C	903.6 /-24.25	-24.750 C

Humidity

- Vaisala series of humidity probes
- HMP 14 1979-1982
- HMP 31UT 1983-1989
- HMP 35A 1989-1999
- HMP 45A/D 1999-2009
- HMP155 2009 –

- Each model improved on performance. Recalibrated a HMP35A deployed on Ross Ice Shelf for three years … within 2% of original calibration.

HMP45

•RH Measuring range: 0.8 to 100% RH
•RH Output scale 0 to 100% RH equals 0 to 1 VDC
•RH Accuracy at +20 C against factory references: +/-1% RH
•Field calibration against references: +/-2% RH (0 to 90 %RH); +/-3 %RH (90 to 100% RH)
•RH Typical long-term stability:< 1% RH / year
•RH Temperature dependence: +/-0.05% RH/ C
•RH Response time (90% at +20 C): 10s with membrane filter

Humidity Probe Summary

Probe	Power	Drain	Op Temp	Accuracy	T coeff.	Drift
HMP31UT	3.6 VDC regulated from AWS	13ma	-40 to 80C	+/- 2% to 80% +/- 3% from 80% to 100%	3% max over temp range	Less than 2 % per year
HMP35	7-35 VDC	<4ma	-40 to 60C	+/- 2% to 90% +/- 3% from 90% to 100%	+/- 0.04 % per deg T or 4% max	Less than 1% per year
HMP45	7-35 VDC	<4ma	-40 to 60C	+/- 2% to 90% +/- 3% from 90% to 100%	+/- 0.05 % per deg T or 5% max	Less than 1% per year

- One returned HMP31UT from Marilyn this season:
  Lab reference HMP45A read 37%
  Marilyn HMP 31UT read 40% (this is after 25 years)

- HMP35A summary for 2011 and 2012 for room temperature only.
- HMP 35A # HMP45 reference reads 42%
- 1: 47
- 2: 44
- 3: 45
- 4: BAD
- 5: 44
- 6: 43
- 7: BAD
- 8: 43
- 9: 45

- Yet to be done is a calibration at over the temperature range of 20C down to -60 C.
- Note that below -40C these probes act more like a temperature probe

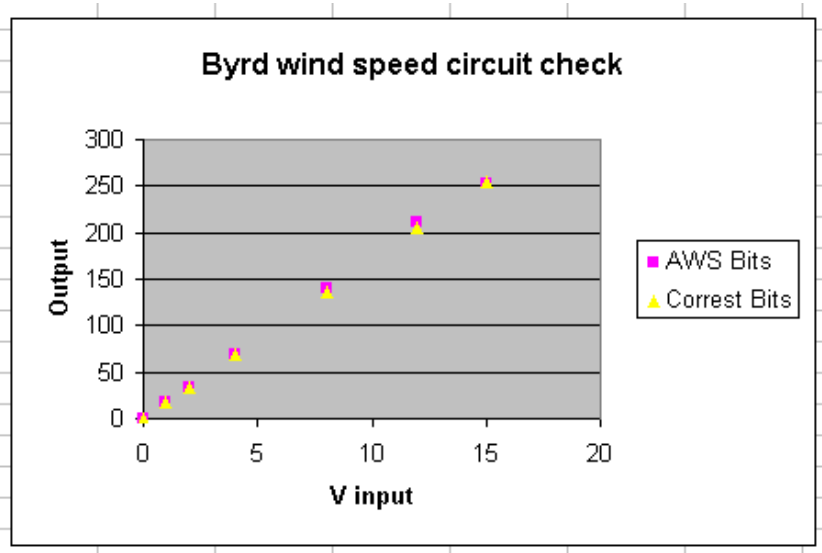
Wind Speed and Direction

- Wind Sensors for the AWS2 stations all required a voltage output.
- Wind sensors typically failed at various rates depending on their location.
- All CPU board A/D circuits were “identical” so that wind sensors could be swapped without regard to AWS unit.

WS calibration for Byrd

AWS 8903 from Byrd with new zero offset installed

V input	V A/D	AWS Bits	Correct Bits
0	0	0	0
1	0.067	17	17
2	0.134	34	34
4	0.268	70	69
8	0.536	140	137
12	0.804	211	206
15	1.005	252	255
14.3	0.957	251	245
14.4	0.964	252	247

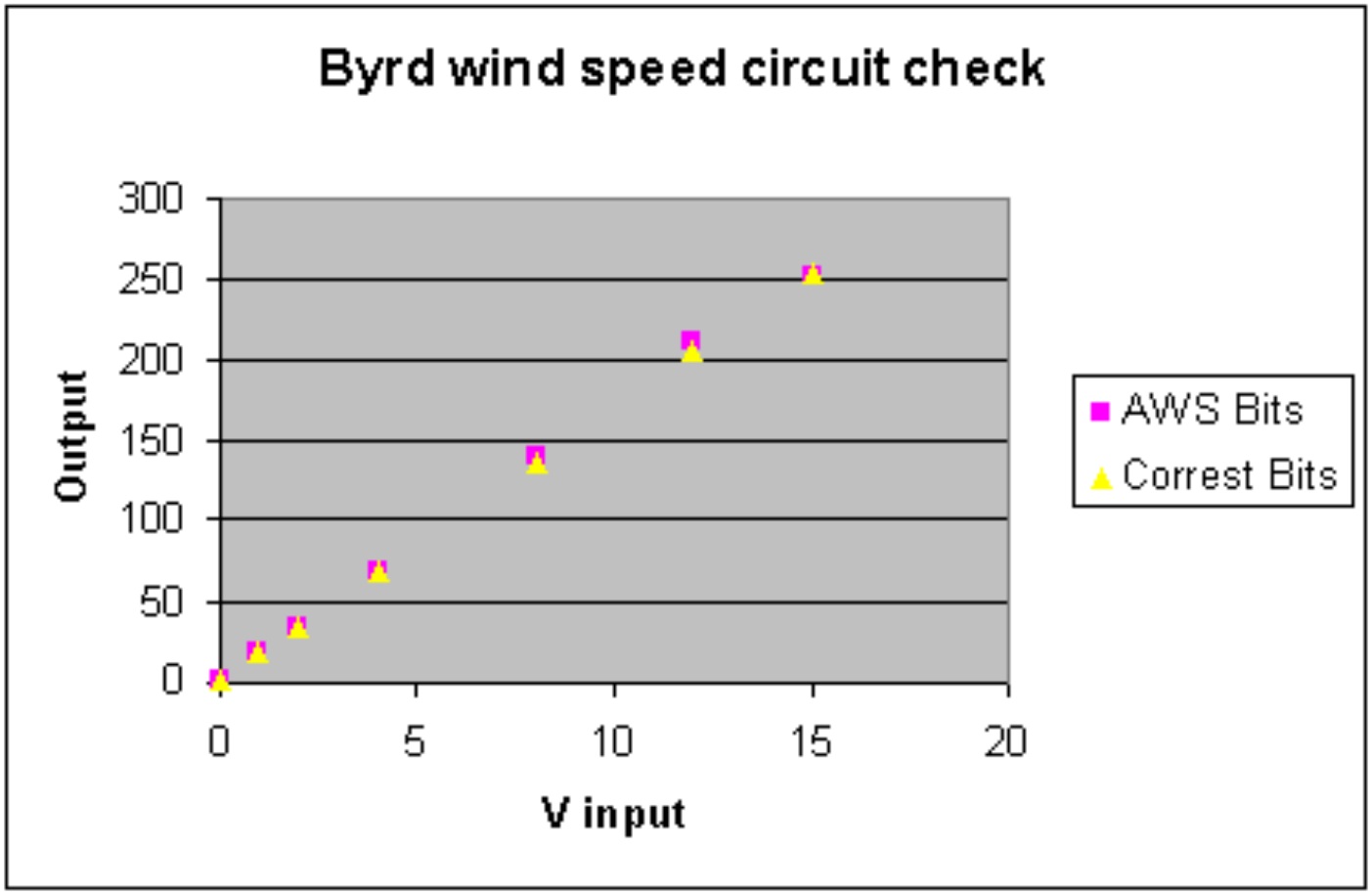


Note that the number of bits output by the AWS does not reach the full scale value of 255 or HEX FF.

Also note that the zero offset is 1% (82Kohms over 820 ohms) of the negative supply for the A/D or 1% of -3.66 volts which is Voffset = -0.036 which agrees with the max reading at 0.964. That is full scale of 1 volt is 0.964 + 0.036 = 1.00 VDC

The output is linear and the maximum error for wind speed assuming calibrated Aerovane would be 2% at 14.4 volts output which is within specs for the Bendix aerovane.

Below is the simulated wind speed calibration for the AWS2B form Byrd Station.



Paroscientific 215A

PERFORMANCE

MODEL NO:	PRESSURE RANGE
215 AW	0 TO 15 PSIA (0.10 MPa)
223 AW	0 TO 23 PSIA (0.16 MPa)
230 AW	0 TO 30 PSIA (0.21 MPa)
245 AW	0 TO 45 PSIA (0.30 MPa)

REPEATABILITY (AVERAGE ABOUT MID-POINT)	0.005% FULL SCALE
HYSTERESIS (AVERAGE ABOUT MID-POINT)	0.005% FULL SCALE
ACCELERATION SENSITIVITY (UNDER FULL SCALE PNEUMATIC PRESSURE LOAD–0.005% FULL SCALE/G WORST AXIS)	0.0038% FULL SCALE/G
TEMPERATURE NULL SHIFT (AVERAGE DEVIATION OVER 100°F EXCURSION ABOUT TURN AROUND POINT)	0.0004% FULL SCALE/°F (0.0007%/°C)
TEMPERATURE SENSITIVITY SHIFT	0.0026%/°F (0.0049%/°C)
VIBRATION SENSITIVITY	NEGLIGIBLE
SUPPLY VOLTAGE SENSITIVITY	NEGLIGIBLE

CHARACTERISTICS

NOMINAL FREQUENCY AT ZERO PRESSURE	40 KHZ
NOMINAL FREQUENCY AT FULL PRESSURE	36 KHZ
SIZE (EXCLUDING FITTINGS)	.895 x 1.585 x 1.585 INCHES (2.27 x 4.03 x 4.03 CM)
WEIGHT	6 OUNCES (0.17 Kgm)
POWER REQUIREMENTS (OPERATES FROM +35 VOLTS MAX. TO +6 VOLTS MIN. EXCEPT –051 OPERATES FROM +15 VOLTS MAX. TO +6 VOLTS MIN.)	+6 VOLTS, 0.001 AMPERE

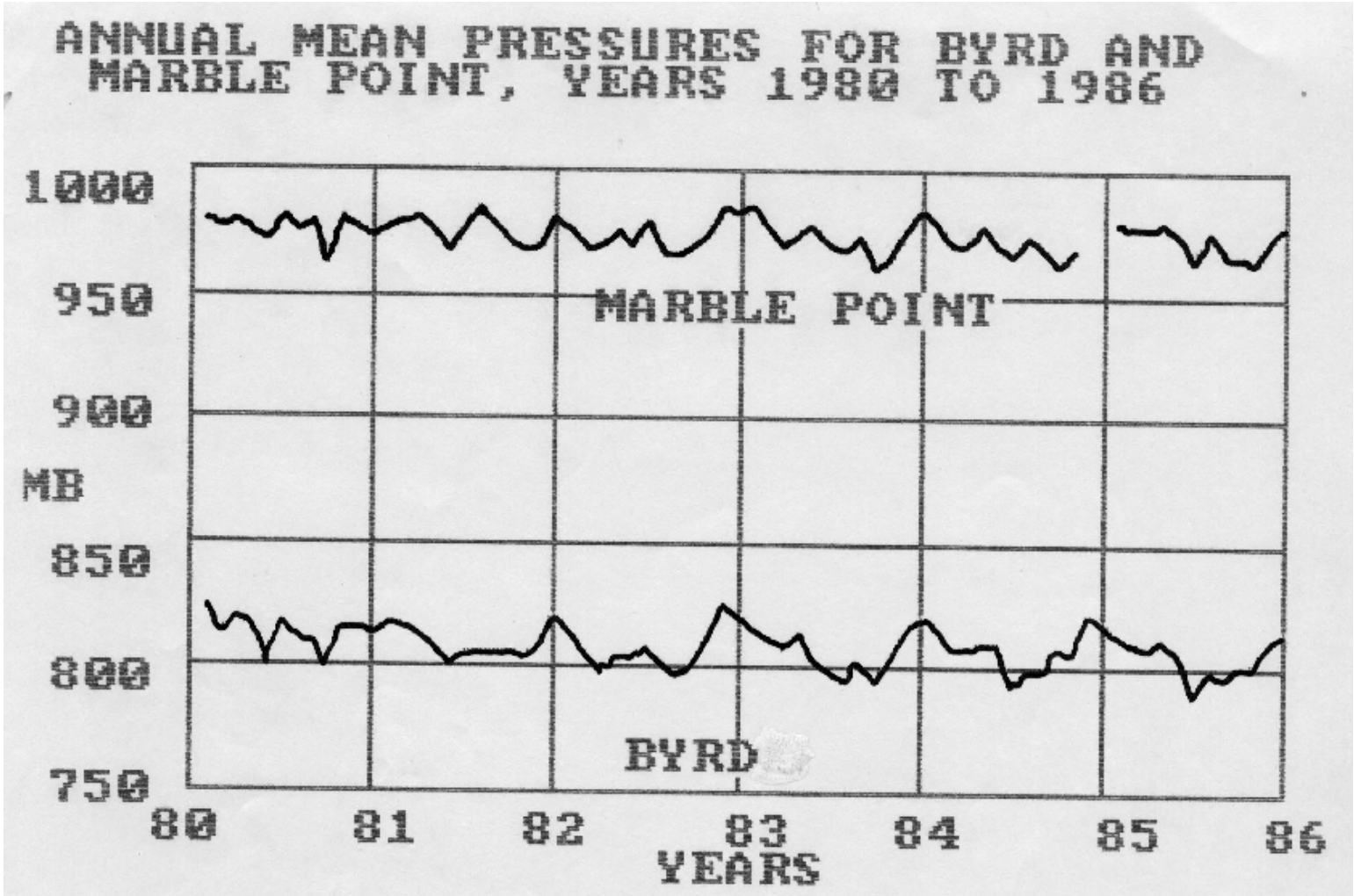
OUTPUT SIGNAL IS A NOMINAL SQUARE WAVE OF 4 VOLTS AMPLITUDE PEAK TO PEAK, CAPACITIVELY COUPLED, WITH SOURCE IMPEDANCE LESS THAN 750 OHMS. NOTE: WIDE OPERATING VOLTAGE RANGE IS PERMITTED BY USE OF A CURRENT DEVICE IN THE POWER SUPPLY CIRCUITRY. OUTPUT POWER STAGE IS NOT CURRENT LIMITED AND WILL DRAW CURRENT AS REQUIRED BY THE LOAD ON THE OUTPUT.

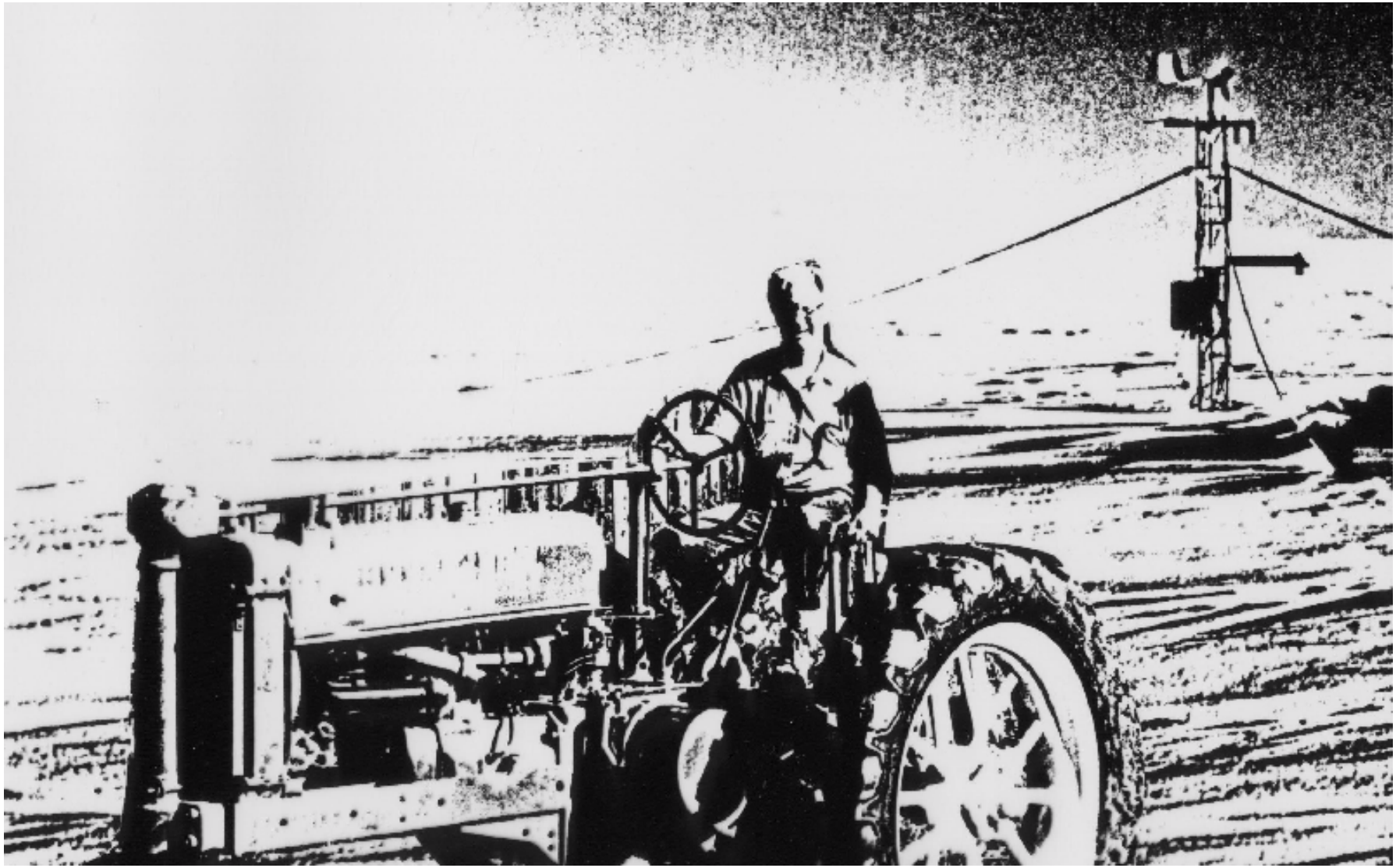
ENVIRONMENTAL

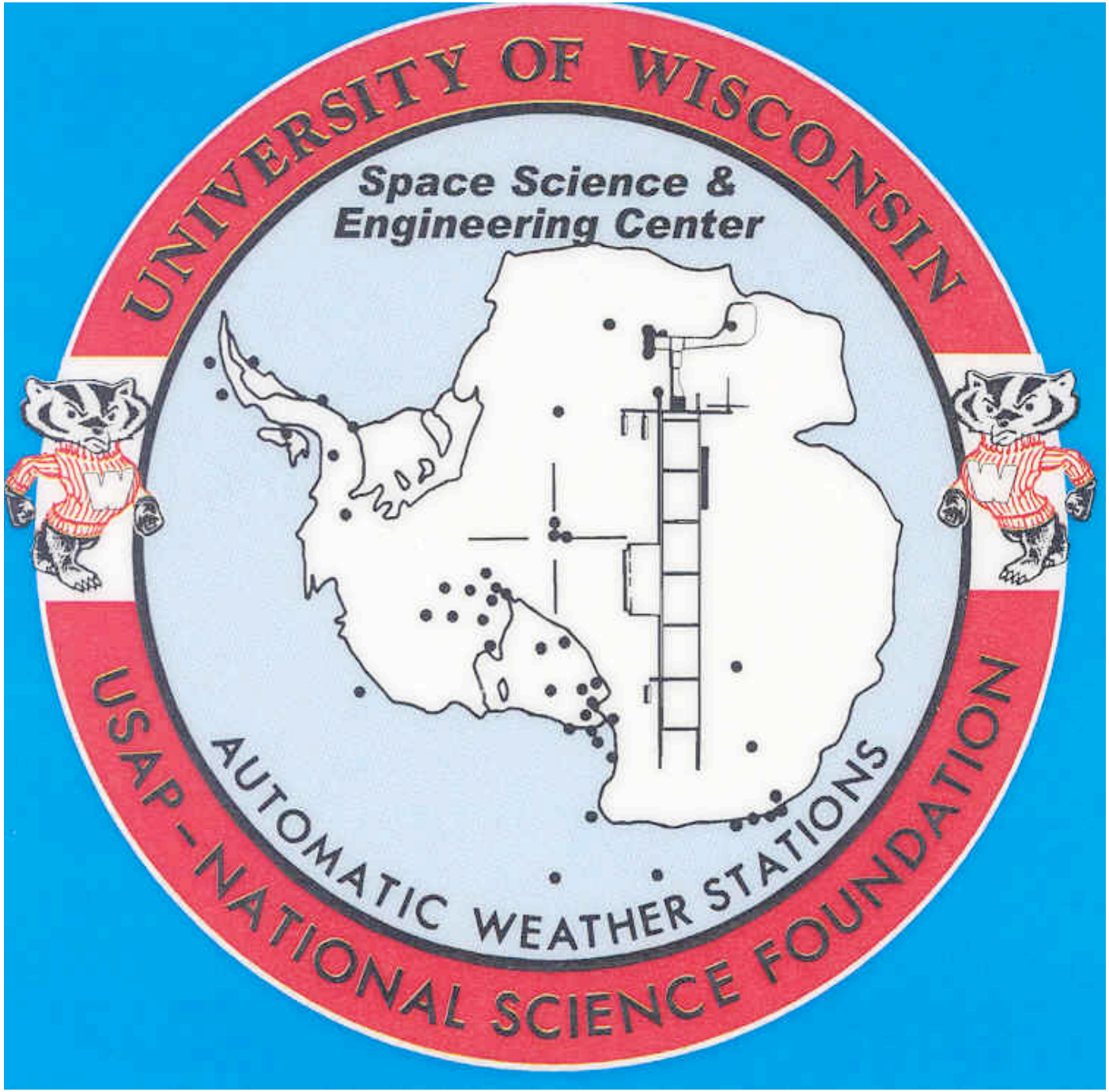
OVERPRESSURE	1.2 x FULL SCALE
*OPERATIONAL TEMPERATURE RANGE	–65°F TO +225°F (–54°C TO +107°C)
*IF TRANSDUCER IS OIL FILLED BY MANUFACTURER MINIMUM OPERATING TEMPERATURE WILL BE	–40°F (–40°C)
OPERATIONAL VIBRATIONAL SPECTRUM (CAUTION: DO NOT EXCEED 500 HZ UPPER FREQUENCY LIMIT)	MIL-E-5400, CURVE III

- The only pressure sensor used for all AWS2 stations has been the Paroscientific model 215A pressure transducer. The 215A coupled with the AWS2 provided an initial accuracy of +/-0.1 hPa. There have been four generations (my classification) of 215As, with each generation achieving better accuracy and lower long term drift. The long term drift results in an error in pressure with a negative bias due to out gassing in the reference vacuum chamber and water vapor migration through sealants in early models (later generations solved this problem).
- The output signal is a frequency (nominal 40 KHz) that is a function of both the air pressure and the temperature. Early models required a separate temperature measurement which the AWS2 provided with a Weed PRT laid against the outer case of the 215A. Later 215A models incorporated an onboard temperature sensor at the point of the pressure sensor. However, all AWS2B units continued to use the Weed PRT temperature to compute the pressure from the observed output frequency of the 215A.
- The early 215A models (the original 20 or so gauges purchased for the AWS2A units) that have been returned for calibration have a long term drift of between 2 and 6 hPa over 30 years. Second and third generation models have shown a drift of around 2 to 3 hPa over 15 to 20 years. The latest generation of 215A have less than 2 hPa of drift observed over 10 years.

Early pressure checks



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Space Science &
Engineering Center
AUTOMATIC WEATHER STATIONS
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