The R/V *DISCOVERER* Cruise to Manus Island The BNL Portable Radiometer Package (PRP) Evaluation¹

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Photograph of the R/V *DISCOVERER* in Pago Pago just before departing for the Combined Sensor Program (CSP) cruise to Manus Island. The BNL Portable Radiation Package (PRP) can be seen on a small mast on the starboard flying bridge.

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Summary

Brookhaven National Laboratory installed and operated a Portable Radiation Package (PRP) on the NOAA ship R/V *DISCOVERER* as part of the Combined Sensor Program cruise in the Tropical Western Pacific Ocean. The *DISCOVERER* transported a collection of radiation and atmospheric instrumentation to positions offshore of Manus Island to compare cloud and radiation fields to like instruments measured from a station on the island. The ship sailed NW from Pago Pago, American Samoa, on 14 March 1996 to a latitude of 1°S then due West until it approached Manus Island (2°S and 148°E) on approximately 7 April. The ship then turned SW and approached Manus Island in three steps. This route was reversed during the ship's return to Hawaii.

The PRP package is a compact low-power integration of simple sensors that measure long- and short-wave irradiance from moving platforms. A rapid rotating shadowband radiometer that is designed to provide good estimates of diffuse (sky) radiation even from moving buoys or ships was being evaluated. The PRP provided the only means of making diffuse (sky) radiation measurements from the ship. The CSP cruise provided an excellent opportunity to intercompare the PRP with other like instruments in the TWP locale. The unit was located on the starboard flying bridge which was fully exposed to direct sunlight during the ship's westward transit. When the ship was at its closest approach to Manus, the PRP was moved to the island where careful intercomparison with the Manus instrumentation was conducted.

Acknowledgements

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1 Introduction

The ARM Science Plan [1] provides a clear mandate to provide radiation measurements over the open sea. Outside of a few offshore platforms, such measurements require the use of buoys or ships. Under ARM support the authors are looking into the use of novel instrumentation that has the potential of making necessary optical measurements from moving platforms yet would have low power, small size, and environmental endurance.

The Portable Radiation Platform (PRP) was developed at Brookhaven National Laboratory. The instrument is described in detail below. The prototype instrument was installed on the R/V *DISCOVERER* as part of the Combined Sensor Program (CSP) cruise #DI-96-02.

The objectives for the CSP intercomparison are as follows:

- Compare standard radiometer measurements.
- Evaluate the domed IRT.
- Evaluate the Mini-RSR on a moving platform.

This document is a working document. The intent here is to develop a compendium of information as soon as possible after the experiment. The document will provide as much information as possible in a reasonably readable format so it can be provided to collaborative scientists, program managers, or for our use in data analysis.

1.1 Cruise Description

The ship departed Pago Pago on 15 March 1996 and sailed in a northwestward direction to the equator (Figure 1). The table below summarizes times for the cruise.

Table 1: Time table of events related to the PRP. (timetable)

DATE	J-DAY	hhmm	DESCRIPTION
DISCO TIME SERIES			
960315	75	00:01	Official start time for data analysis
960315	75	02:00	Ship departs Pago Pago
960321	81	07:40	Begin buoy recovery, veer toward south
960322	82	08:30	End buoy recovery, back on track line
960323	83	03:50	Begin Manus station A, 30 KM NE of the island.
960325	85	03:21	End Manus station A
960325	85	05:32	Begin Manus station B, 10 KM NE of the island. 85-225
960326	86	23:45	End Manus station B
9603??	88	00:00	End shipboard time series.
MANUS TIME SERIES			
960329	89	00:00	Begin Manus time series.
960401	92	00:00	Accidental outage, start
960301	92	23:59	Accidental outage, end
960404	95	23:59	End Manus time series

Figure 1: A map showing the cruise trackline and dates.

1.2 Portable Radiation Package – Ship Installation

The PRP was mounted in an exposed location on the starboard side of the flying bridge of the ship (Cover figure and figure 2). The starboard (righthand) side was selected after considering that the ship heading was either west or southwest for the first half of the cruise and the time of year was just after Spring equinox so the sun would be toward the north.

Computers were set up in an available air conditioned container, shown in figure 3 belonging to Dr. Tim Bates of PMEL. The entire installation required approximately 2 hours. The sun photometer experiment by Penn State was carried out in the same location.

A portable Macintosh computer and color printer were located in the van. Daily data collection, data review, and preliminary data analysis were carried out here.

Figure 2: The PRP located on the R/V *DISCOVERER* flying bridge. The radiation head is approximately 400 mm in diameter. The location of the sensor is not desirable. There are several nearby antennas and the huge ship conning tower which can cause shadow effects or block sky radiation. Special treatment to this problem will be necessary during data analysis.

Figure 3: The PRP installed on the flying bridge. The mast is clamped to the railing. The Zeno data logger is in the large waterproof cannister. The cannister, borrowed from the ARCS equipment, is much larger than necessary, but it is completely waterproof and has waterproof connectors. At the extreme right is the air-conditioned van that was used for data collection and processing.

The large cannister with the Zeno data logger was located on the railing and the RSR logger was attached to the railing. The cannister is part of the ARCS equipment and is used for convenience. The can is largely empty.

The large ship's mast shown in the figure was a problem for the radiation measurements and will have to be accounted for during data analysis. Especially, it should affect the long-wave (heat) radiation measurements and as shown in section 3 below, a suspicious diurnal signal is present.

Figure 4: The PRP prototype sensor head. From left to right the sensors are the rapid rotating shadow-band radiometer, the PIR, the PSP, and the domed IRT. The Eppley radiometers are raised so all optical receptors are at the same level. This prototype unit was fabricated out of marine-grade plywood.

Daily operations. Daily operation of the PRP was minimal, in keeping with the design for an un-attended remotely operating device. Most daily activity centered around downloading files from the computers and making daily plots.

The two data loggers, the Zeno logger and the RSR logger, were downloaded daily as close to 00 UT time² as possible.

Data were entered into an Excel spreadsheet, briefly viewed for obvious errors, then plotted for our daily records.

Almost no cleaning was required as the frequent rain kept any salt deposits washed away.

²NOTE: All times are reported and maintained in universal time (UT). The data time is maintained as a floating-point modified Julian day (day of the year).

1.3 Manus Island Intercomparison

On 28 March 1996 (Jday 88), the PRP was removed from the ship and taken onto Manus Island for a week of intercomparison studies with the island-based instrumentation from Pennsylvania State University (PSU).

Data collection on the island started at 00 UT, 30 March and continued to the end of 4 March (Jday 95). There is one gap in this data caused by a power supply being inadvertently turned off.

The sensor head was mounted to an available meteorological tower at a height of approximately 8 m and well removed from any structures. The computer was set up in the ISS instrument trailer.

Figure 5: The PRP intercomparison installation on Manus Island. Seen from left to right are the Penn State radiometer stand at the far left, the NOAA meteorological tower, a RASS speaker, and the ISS van with 915 MHz antenna on top. The BNL sensor head and Zeno cannister are located in front of the van on a small tower.

Figure 7: Photograph of the IRT with plastic dome for rain protection and a standard IRT in waterproof box. Water on the IRT lens remains for many hours while the dome clears in about ten minutes.

to evaporate off the lens. During analysis, a jump of IRT temperature to ambient temperature is a very sensitive indicator of precipitation. Normally, the lowest temperature measured by the IRT is -60°C . However, often the clear-sky or cirrus brightness temperatures are well below this threshold, rendering the instrument useless. The dome adds a small bias to the incoming weak radiation and raises the brightness temperature above the threshold.

Correction for the dome. Previous tests and the data from this cruise will be used to establish a reasonable correction for the dome. The stated accuracy of the standard IRT is $0.5\text{--}0.9^{\circ}\text{C}$. A thermistor is used to measure the dome temperature in a manner similar to the PIR. Clear sky tests and comparisons with non-domed sensors are encouraging, and we have no reason to believe correction to these accuracies will not be possible.

As an indicator of cloud fraction. The IRT signal time series can be used as a statistical measure of cloud fraction, assuming advection of the cloud field. The contrast between cloud and sky on a partly cloudy day, or between clouds at different altitudes, is large at these wavelengths. Given the almost invariant temperature profiles of the TWP, the IRT serves as an excellent indicator of cloud base height.

Figure 8: Example of an IRT comparison between domed and non-domed (reference) sensors. Samples were logged each second during a period of time that began as clear sky then became partly cloudy. The top graph shows the raw measurements and the bottom shows the corrected domed IRT. The reference IRT does not register the low radiation values during the clear sky periods while the domed unit shows the presence of cirrus. (irtcompare)

2.3 Rapid Rotating Shadowband Radiometer

The RSR design that has been developed for the PRP has been derived from designs at SUNY Albany [3] and Penn State [2]. The basic instrument (Figure 9) is comprised of a 12-VDC 10 rpm motor in a sealed housing. An 18 mm wide semicircular shadow band is attached to the motor shaft and undergoes a full rotation approximately once each 5–6 seconds. A reed relay signals when the arm is at its nadir position.

A Li-Cor radiation sensor is mounted with its optical diffuser at the center of the shadowband sphere. The Li-Cor sensor uses a silicon cell photo detector and has a response time to changing intensity of approximately one millisecond. The 100 millisecond shadow is easily detected by the sensor (Figure 10).

The computer performs the following tasks: (a) Sense the arm nadir position and read the global, whole-sky radiation value. (b) Wait until the arm reaches a level position with the horizon. (c) Take samples at 20 Hz rate while the arm sweeps across the upper hemisphere.

Figure 9: A photograph of the rapid rotating shadowband radiometer prototype unit. The arm rotates a full circle each 5 seconds approximately. The Li-Cor sensor response time is about 1 msec. The shadow is detected by rapid sampling and searching for a minimum reading. (rsrphoto)

(d) Compute sweep statistics from the 20 Hz samples. The computations must be done in less than approximately one second. (d) Wait for the next nadir signal.

The sweep statistical algorithm has performed well in field exercises, and gives a stable set of measurements. Under continued investigation in this proposal, we expect real-time processing might change. Statistical calculations are performed on measured voltages, $v_i, i = 1, 2, \dots, 60$. Conversion to radiation units occurs at a later time. First the average and standard deviations, μ and σ_{sweep} , of the sweep data are computed. Next, the dip ratio is computed:

$$r_{\text{dip}} = \frac{v_{\text{min}}}{\sigma_{\text{sweep}}}$$

where v_{min} is the minimum measurement in the sweep. If $r_{\text{dip}} > 2.6$ the dip is classified as a shadow. If it is less than 2.6 the sweep has no discernible shadow.

A composite is developed by stacking all sweeps with shadows over a one-minute period. An array of size 60 holds the composite sweep. Each individual sweep array is shifted so its minimum value lies over the 30th point in the composite array. Then the sweep is added to the composite. Overlap points at the ends of the sweep are not counted. Finally, at the end of each minute, the mean and standard deviation for each composite point are computed. The following 187 data

are computed at the end of each minute:

- V_G The mean global value measured when the arm is in nadir position.
- σ_G The standard deviation of the global measurement.
- N_c The number of sweeps with discernible shadows.
- V_S The mean shadow value. If $N_c < 2$, then $V_s \equiv V_G$
- R_{dip} The mean dip ratio for all sweeps with shadows.
- $\bar{\mu}$ The mean of all sweep means.
- $\bar{\sigma}$ The mean standard deviation for all sweeps.
- N_i The number of composite values for index i , $i = 1, 2, \dots, 60$
- C_i The composite mean for each index. If $N_i \leq 2$, $C_i = -99$.
- σ_i The standard deviation for i th index. If $N_i \leq 2$, $\sigma_i = -99$.

Figure 10: The fast response of the Li-Cor sensor is shown in this series of instantaneous samples of the sensor during a cloudless day. The shadow is easily discerned. The “shoulder” values are the values just on each side of the dip.

Correction for the Arm. During the shadow, the arm blocks a portion of the sky. This error is corrected by the same technique as the SUNY MFRSR [3]. Given a composite sweep with the minimum set at index 30, the measurements at indices 27,28,32,33 are averaged and called the **shoulder value**, V_A . The three measured composite means, V_G , V_S , and V_A are combined to compute V_{dif} and V_{direct} , the diffuse and direct beam values.

Fixed platform data. An example of data taken during clear-sky conditions at BNL is shown in Figure 11. The sensor was set up in an approximate N-S orientation. The graph of i_{dip} is stable and increases as the sun moves across the sky. This statistic is a good indication of the ability of the sensor to recognize the dip. During clear skies, $r_{dip} > 4$.

Figure 11: Example of the rapid rotating shadowband radiometer one-minute statistics during a very clear-sky period during the winter of '96 at BNL. Note very low values for shadow radiation, a clear indication of the spectral sensitivity of the Li-cor sensor.

3 PRP Data files

This section provides information on the current raw and processed data files which were developed from the cruise.

3.1 Zeno Data Files

The Zeno data logger was read each day near 00 UT. The file naming convention was:

PRP96jjj

where:

jjj is the julian (year) day (001-366 for 1996)

An example of some lines from the file generated from a Zeno x-modem download is as follows:

```
96/03/13,23:46:59,TWP-OCEANPRPRAD,1291.84,13.71,1314.58,1272.67,5.76,5.45,6.44,
26.55,26.56,26.57,28.11,28.11,28.13,434.39,0.77,435.91,432.81,4.94,0.47,
5.99,3.83,35.90,33.61,12.39,14.19,
96/03/13,23:47:59,TWP-OCEANPRPRAD,1296.46,13.98,1313.87,1261.70,6.00,4.78,3.19,
26.62,26.63,26.64,28.22,28.23,28.22,433.24,0.93,434.73,430.93,5.52,0.41,
6.39,4.47,35.88,33.61,12.35,14.23,
96/03/13,23:48:59,TWP-OCEANPRPRAD,1260.74,14.27,1279.46,1228.50,2.34,1.54,2.12,
26.69,26.70,26.70,28.21,28.21,28.21,432.29,0.93,434.05,430.75,4.82,0.59,
5.75,3.27,35.84,33.51,12.35,14.24,
96/03/13,23:49:59,TWP-OCEANPRPRAD,1218.87,5.93,1229.48,1207.03,1.20,1.50,1.35,
26.73,26.74,26.74,28.25,28.26,28.28,431.13,0.88,432.86,429.59,3.56,0.46,
4.47,2.47,35.90,33.51,12.35,14.26,
96/03/13,23:50:59,TWP-OCEANPRPRAD,1178.42,13.81,1209.15,1163.64,-0.17,-0.19,-0.84,
26.77,26.80,26.81,28.32,28.33,28.37,429.79,0.77,431.72,428.40,3.38,0.40,
4.23,2.55,35.98,33.51,12.35,14.26,
```

The comma separated variables are identified by referring to the Zeno configuration program file in Appendix B on page 43. The output variables are identified by the "DATA" records in the Zeno configuration file. After the word "PRPRAD", the variables are as follows:

- 1-4. The PSP mean, standard deviation, maximum, and minimum values based on a one-minute mean of one-sec samples. Units are W m^{-2} .
- 5-7. Three 20-sec means of the PIR thermopile voltage. Units are W m^{-2} .
- 8-10. Three 20-sec means of the PIR case thermistor resistance. Units are $^{\circ}\text{C}$.
- 11-13. Same for the dome thermistor.
- 14-17. The corrected PIR long-wave global irradiance: mean, standard deviation, maximum, and minimum. Based on a one-minute average of one-second samples. Units are W m^{-2} .
- 18-21. The IRT brightness temperature mean, standard deviation, maximum, and minimum. Based on a one-minute average of one-second samples. Units are $^{\circ}\text{C}$.
22. IRT dome temperature one-minute mean value. Units are $^{\circ}\text{C}$.
23. Zeno internal temperature inside the case. Units are $^{\circ}\text{C}$.
24. Internal (regulated) battery voltage. Units are volts.
25. External (un-regulated) battery voltage. Units are volts.

3.2 RSR Data Files

The RSR data logger was read each day near 00 UT. The file naming convention was:

```
rsr96jjj.dat -- a data file with 1-min avgs and composite sweep.
rsr96jjj.sum -- summary file, only 1-min averages.
```

where:

jjj is the julian (year) day (001-366 for 1996)

RSR Data File. An example of some lines from the data file generated from the RSR data logger are as follows:

```
58      1  -99  -99
59      1  -99  -99
    74.9275000  744  744  60  678  7  34.8  262  3.98
0       7   727  359
1       7   730  360
2       7   731  358
3       7   732  358
  . . .
```

```
56      0  -99  -99
57      0  -99  -99
58      0  -99  -99
59      0  -99  -99
    74.9281944  745  745  60  639  8  34.6  238  3.88
0       8   637  361
1       8   637  361
2       8   638  362
3       8   638  361
```

Summary file An example of some lines from the summary file generated from the RSR data logger are as follows:

```
74.0163889  12  12  60  673  10  28.5  433  3.75
74.0170833  13  13  60  731  10  28.3  431  4.05
74.0177778  14  14  60  725  10  28.5  424  4.03
74.0184722  15  15  60  742  10  28.7  484  3.87
74.0191667  16  16  60  679  10  29.2  436  3.44
74.0198611  17  17  60  618  10  29.3  440  3.16
74.0205556  18  18  60  611  10  30.3  417  3.02
74.0212500  19  19  60  616  10  30.7  451  2.89
74.0219444  20  20  60  645  10  30.8  447  2.99
74.0226389  21  21  60  715  10  30.7  480  3.25
```

3.3 Navigation Files

A set of ASCII navigation files were taken from the ship. The files provide time, position, heading, speed, course, pitch, roll, and heave from the Ashtech Inc. differential GPS system. Data are taken at approximately a 1-sec rate.

The raw navigation files are stored in a directory named "NavData." The file names correspond to the year and Julian day in the form

Nav96jjj

where jjj is the Julian day (075 to ???).

An example of the Nav files is given below:

```
1996,78.0003,78,.0003125,000025,-2.00599,179.60986,3,1.3,262.1,016.1,
    268.45,-000.36,-002.08,267.071442,+00263,
1996,78.0004,78,.0004282,000035,-2.00598,179.60912,3,1.3,271.4,016.0,
    271.78,+000.28,+003.20,268.392853,-00489,
1996,78.0005,78,.0005440,000045,-2.00597,179.60837,3,1.3,276.9,015.9,
    272.02,-000.62,-000.04,269.750000,-00044,
```

Note the line breaks in the middle of records do not exist in the actual files.

Header File. The following file was provided as a header to the ship's navigation files:

```
*.nav - Julian Time Stamp YR, DECIMAL DAY, DAY, DECIMAL MINUTES
Trimble Time HHMMSS
Trimble Latitude DECIMAL DEGREES
Trimble Longitude DECIMAL DEGREES
Trimble Status 3=PCODE
Trimble HDOPS LOW=GOOD
Trimble True Course Over Ground DECIMAL DEGREES
Trimble Speed Over Ground (Knots) KNOTS
Ashtek Heading DECIMAL DEGREES
Ashtek Pitch DECIMAL DEGREES
Ashtek Roll DECIMAL DEGREES
Average Trimble Course Over Ground DECIMAL DEGREES
HRP Heave MILLIVOLTS
```

Matlab Navigation File All the raw nav files were read into a Matlab program to create a 1-min record for the complete cruise. The output matlab binary file is called Nav1Min.mat. Each record has six fields:

1. Julian Day float point number.
2. Latitude. Negative numbers mean °S.
3. Longitude. negative numbers mean °W.

4. True course over ground (Trimble GPS).
5. True speed over the ground (Trimble GPS).
6. Ship actual heading (Ashtek Diff GPS).

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5 Acronyms and Glossary

ARCS: Atmospheric Radiation and Cloud Station. The instrument installations that will be deployed at five island sites in the TWP. Each ARCS will have radiometers for up and down irradiances, diffuse irradiance, radars, lidars, whole-sky imagers, and microwave radiometers.

ARM: Atmospheric Radiation Measurement (program).

CART: Cloud and Radiation Testbed. The name given to the instrumented field deployments by ARM. Presently, the CART sites are the Southern Great Plains (SGP), the Tropical Western Pacific (TWP), and the North Alaskan Slope (NAS).

COARE: Combined Ocean Atmosphere Response Experiment, a four-month observation study of the western tropical Pacific Ocean.

IRT: Infrared Thermometer. A device that measures radiation in a set bandwidth and converts the measurement to a brightness temperature equivalent to a black body.

ISS: Integrated Sounding System. A combined doppler, RASS, and balloon sounding system.

NCAR: National Center for Atmospheric Research.

NOAA: National Oceanic and Atmospheric Administration.

PCMCIA: The removable card standard for personal computer interface to memory, and peripherals.

PIR: Precision Infrared Radiometer. The name used by Eppley for their long-wave radiometer commonly used in the ARM program.

PMEL: Pacific Marine Environmental Laboratory. One of the NOAA Environmental Research Laboratories

PROBE: Pilot Radiation Observation Experiment. This was an experimental radiation deployment on the island of Kavieng during the TOGA-COARE experiment.

PRP: Portable Radiation Platform

PSP: Precision Short-wave Pyronometer. A name given to the Eppley short-wave radiometer commonly used in the ARM program.

RASS: Radio Acoustic Sounding System. A means of using acoustic waves and radar to discern the virtual temperature profile in the lower atmosphere.

RSR: Rotating Shadowband Radiometer. An instrument for measuring the diffuse radiation from the sky by placing an arm in front of the sun.

SGP: Souther Great Plains. The first and largest ARM CART site located in northern Oklahoma and southern Kansas.

SUNY: State University of New York.

TAO Buoy: Tropical Atmospheric Ocean buoy. See figure ???. A basic meteorological and ocean mixed-layer observation buoy deployed in the TWP by NOAA/PMEL. Approximately 65 buoys are maintained in a permanent array across the Pacific Ocean between $\pm 10^\circ$ latitude.

TOGA: Tropical Ocean Global Atmospheres.

TWP: Tropical Western Pacific. The name given to the ARM CART site in the western Pacific Ocean.

A Daily Data Plots

The daily plots in this section were derived on a day-by-day basis using the Macintosh powerbook and Excel v5.0.

Three plots are shown on each page:

PSP and PIR Global Radiation. The top graph shows the one-minute averaged (one-sec samples) of global downward irradiance from the Eppley instruments. These are used as standards for comparisons to the Li-Cor sensor on the RSR. These sensors have been calibrated against standards at NREL. In addition they were compared to the same sensors during the Penn State intercomparisons and were within 5 W m^{-2} in all cases.

RSR Global and Shaded Irradiance. The middle curve is a plot of one-minute averages (10 samples at 5-sec period) of the downward global irradiance and the shaded irradiance derived from the Li-Cor sensor on the RSR. The short-wave global curves on the PSP and RSR agree quite well. The calibration equation on the RSR was taken from the sensor as delivered from the factory. It is the intent to use the PSP to provide a cross-calibration for the Li-Cor in final analysis.

PIR Global and IRT Temperature. The bottom curve is the long-wave downward irradiance measured from the Eppley PSP sensor and the radiance temperature measured by the infrared thermometer. The vertical scales are expanded to provide maximum resolution.

Figure 12: Excel data plots for Day 96/075. (prp96075)

Figure 13: Excel data plots for Day 96/076. (prp96076)

Figure 14: Excel data plots for Day 96/077. (prp96077)

Figure 15: Excel data plots for Day 96/078. (prp96078)

Figure 16: Excel data plots for Day 96/079. (prp96079)

Figure 17: Excel data plots for Day 96/080. (prp96080)

Figure 18: Excel data plots for Day 96/081. (prp96081)

Figure 19: Excel data plots for Day 96/082. (prp96082)

Figure 20: Excel data plots for Day 96/083. (prp96083)

Figure 21: Excel data plots for Day 96/084. (prp96084)

Figure 22: Excel data plots for Day 96/085. (prp96085)

Figure 23: Excel data plots for Day 96/086. (prp96086)

Figure 24: Excel data plots for Day 96/087. (prp96087)

Figure 25: Excel data plots for Day 96/090. (prp96090)

Figure 26: Excel data plots for Day 96/091. (prp96091)

Figure 27: Excel data plots for Day 96/093. (prp96093)

Figure 28: Excel data plots for Day 96/094. (prp96094)

Figure 29: Excel data plots for Day 96/095. (prp96095)

B Zeno Configuration Program

Input the zeno config file. See the manual for explanation of the software [6].

```
* Zeno 3200 System Setup File
* Program Version And Date: Zeno 3200 V1.60-768-4, Jun  3 1995
* Copyright (C) Coastal Environmental Systems, 1995.
* Setup File Date And Time: 96/02/16 12:14:07
PARAM1 60 0 60 2 110 4 102 0 9600 9600
PARAM2 9600 0 0 0 0 3 0 0 0 0
PARAM3 16777 1 60 18 600 20 0 0 2 2
PARAM4 2 2 0 0 0 3276800
PARAM5 NONE NONE
SENSOR 3 "PIR" 1 2 0 0 0 0 0 2 0 2 0 251256 0 0
SENSOR 3 "PSP" 3 2 2 0 0 0 0 1 0 2 0 115804 0.31 0
SENSOR 1 "IRT" 12 0 1 6 0 0 60 1 0 2 0 80 -60 0
SENSOR 1 "THER-GC" 8 0 0 0 2 1 0 1 0 2 0 -0.4 1 0
SENSOR 1 "THER-GD" 9 0 0 0 2 1 0 1 0 2 0 -0.4 1 0
SENSOR 1 "BATT_EXT" 1 0 2 0 0 0 0 2 1 3 0 10.27 0 0
SENSOR 1 "BATT_INT" 2 0 0 0 0 0 0 2 1 3 0 1 0 0
SENSOR 1 "INT_TEMP" 3 0 0 0 0 0 0 1 0 3 0 1 0 0
SENSOR 1 "THER_IRT" 10 0 0 0 2 1 0 1 0 2 0 -0.4 1 0
PROCESS 1 2 S2.1
PROCESS 5 9 S4.1
PROCESS 5 8 P2.1 0 0 0 0 0 10000 -10000
PROCESS 4 1 S4.1 0.00103085 0.000238918 1.57464e-07 9974
PROCESS 5 9 S5.1
PROCESS 5 8 P5.1 0 0 0 0 0 10000 -10000
PROCESS 4 1 S5.1 0.00103085 0.000238918 1.57464e-07 9972
PROCESS 4 5 P7.2 P4.2 S1.1 1 3.04
PROCESS 1 9 S1.1
PROCESS 1 9 P4.1
PROCESS 1 9 P7.1
PROCESS 1 2 P8.2
PROCESS 1 2 S3.1
PROCESS 4 4 S6.1 S7.1
PROCESS 1 1 S8.1
PROCESS 4 1 S9.1 0.00103085 0.000238918 1.57464e-07 9978
DATA 3 1,2 "" 1.1 0 0 1
DATA 6 1,2 "TWP-" 1.1 0 0 1
DATA 6 1,2 "OCEAN" 1.1 0 0 1
DATA 6 1,2 "PRPRAD," 1.1 0 0 1
DATA 8 1 "PSP_AVE" 1.1 2 0 8
DATA 8 1 "PSP_SD" 1.3 2 0 8
DATA 8 1 "PSP_MAX" 1.4 2 0 8
DATA 8 1 "PSP_MIN" 1.5 2 0 8
DATA 8 1 "PIR_E_1" 9.10 2 0 8
DATA 8 1 "PIR_E_2" 9.30 2 0 8
DATA 8 1 "PIR_E_3" 9.50 2 0 8
DATA 8 1 "RC_1" 10.10 2 0 8
DATA 8 1 "RC_2" 10.30 2 0 8
DATA 8 1 "RC_3" 10.50 2 0 8
DATA 8 1 "RD_1" 11.10 2 0 8
```

DATA 8 1 "RD_2" 11.30 2 0 8
DATA 8 1 "RD_3" 11.50 2 0 8
DATA 8 1 "PIR_AVE" 12.1 2 0 8
DATA 8 1 "PIR_SD" 12.3 2 0 8
DATA 8 1 "PIR_MAX" 12.4 2 0 8
DATA 8 1 "PIR_MIN" 12.5 2 0 8
DATA 8 1 "IRT_AVE" 13.1 2 0 8
DATA 8 1 "IRT_SD" 13.3 2 0 8
DATA 8 1 "IRT_MAX" 13.4 2 0 8
DATA 8 1 "IRT_MIN" 13.5 2 0 8
DATA 8 1 "IRT_TEMP" 16.1 2 0 8
DATA 8 1 "INT_TEMP" 15.1 2 0 8
DATA 8 1 "BATT_INT" 14.2 2 0 8
DATA 8 1 "BATT_EXT" 14.1 2 0 8
DATA 6 1,2 "<OD><OA>" 1.1 0 0 1
EOF

C RSR TxBasic Program

The RSR data logger was programmed in “TxBasic,” a special language for the Tattletale microprocessor modules [8].

The program name `rsr304b.bas` was used in the RSR during the cruise. It is not printed in this version of the report. See Dr. Reynolds if this is desired.