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Woods Hole Oceanographic Institution

Arctic Remote Autonomous Measurement Platform Post CEAREX Engineering Report

by

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Technical Report

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Approved for Distribution:

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1. Summary

The Arctic Remote Autonomous Measurement Platform (ARAMP) is a buoy design by engineers at the Woods Hole Oceanographic Institution to meet the need for a flexible, general-purpose self-recording instrument for use in the high Arctic (reference 1). It takes the form of cylindrical housing which is deployed vertically in the surface of pack ice. Its sensor complement consists of sensors inside the housing and on a tower above as well as instruments in the ocean below. The cylindrical housing also contains control and sensor signal conditioning electronics and an optical disk recorder which is used for mass storage. In addition, data telemetry is provided by a platform transmitter terminal to the ARGOS satellite system and a custom two-way VHF radio system for offloading larger quantities of data over line-of-sight distances.

The development chronology of these systems is as follows:

- one prototype system tested during Prudhoe Bay operations in 1987;
- five redesigned buoys were prepared for the Coordinated Eastern Arctic Experiment (CEAREX, reference 2) in 1989;
- engineering development and testing was performed on the five units during 1989/90 to resolve the problems encountered during CEAREX.

This emphasis in this report is on the engineering which was performed on the ARAMP's after CEAREX for two purposes:

1. to solve problems encountered during CEAREX;
2. to evaluate all aspects of the buoy's performance and make changes as necessary to achieve an operational system.

The biggest known problem was that the optical disks did not operate reliably. The other problems were a host of minor hardware and software details which prevented the expected acquisition sequence from occurring as desired.

The work consisted of a sequence of test, evaluate, redesign and retest until successful operation was achieved. Initially the tests were designed to answer the question "does it run and record data?" As fewer problems remained, the tests progressed to simulate more and more realistic conditions and the data recorded during the test was evaluated to answer the question "does it record useful information?" The final step in this procedure was a planned field deployment which was cancelled due to lack of funds.

The status of the systems is that all five now operate and record useful data. Two of the systems have been modified to ensure good optical disk operation at temperatures to -40C.

2. Description of ARAMP

The Arctic Remote Autonomous Platform (ARAMP) was designed specifically for deployment in pack ice to make environmental measurements unattended for extended periods. The sensor complement includes:

- a hydrophone and instruments in the upper ocean which are connected via an electromechanical cable for support, power, and communication;
- internal sensors to measure ice movement and engineering parameters;
- meteorological sensors on a tower above the instrument.

Table 1 gives detailed specifications for each sensor and subsystem. Figure 1 shows the complete system as deployed during CEAREX.

The instrument is self contained, powered from batteries contained in the pressure case and includes a high capacity mass store device for recording data. It provides several types of radio telemetry to allow its performance to be monitored and recorded data evaluated during deployment.

The system architecture is based on a low power version of the IBM-PC. This provides access to many software packages for program development and allows testing of hardware and programs on readily available PC's. The instrument runs a slightly modified form of MSDOS and the acquisition software uses standard programming languages (primarily C). Figure 2 is a block diagram of the system showing how the various elements are interconnected.

A more complete description of the system and its operation is presented in reference 4. Also of interest is the system's use of a write-once-read-many optical disk recorder. Testing and development of this portion of the instrument is described in reference 5.

Table 1. Sensor Suite and Specifications

Hydrophone

- low band, 2 to 250 Hz, 1,000 samples/second
- medium band, 125 to 1,250 Hz, 5,000 samples/second
- high band, 1,000 to 10,000 Hz, 25,000 samples/second
- all bands, computer variable gain 0 to 42 dB in 6 dB steps

Accelerometer

- VLF band (X,Y,Z), 0.025 to 0.66 Hz, 2.5 samples/second
- low band (X,Y,Z), 2 to 250 Hz, 1,000 samples/second
- all bands, hardware variable gain 0 to 42 dB in 6 dB steps

Meteorological Package

- vane direction, relative to lubber line, instantaneous
- wind speed, meters/second, instantaneous
- compass, relative to north
- air temperature, degrees C
- relative humidity, percent
- barometric pressure, millibars, 1 second average

Temperature Pressure Module

- temperature, degrees C, 1 sample/10 seconds, 1 minute avg.
- pressure, decibars

Acoustic Current Meter

- current velocity two axis, 0 to 360 cm/sec, 10 min avg, 3%
- water temperature, -2 to +35C, +- 0.05
- tilt, 0 to 30 degrees, 10%
- pressure, 0 to 1000 decibars, 0.5%
- conductivity, 1 to 79 ms, 0.05 ms

Note: Sea cable instruments use SAIL protocol (ref 3). The system can be configured for any SAIL instrument.

Figure 1. The ARAMP buoy with meteorological tower deployed in pack ice during CEAREX. Helicopter used to transport equipment to remote site.

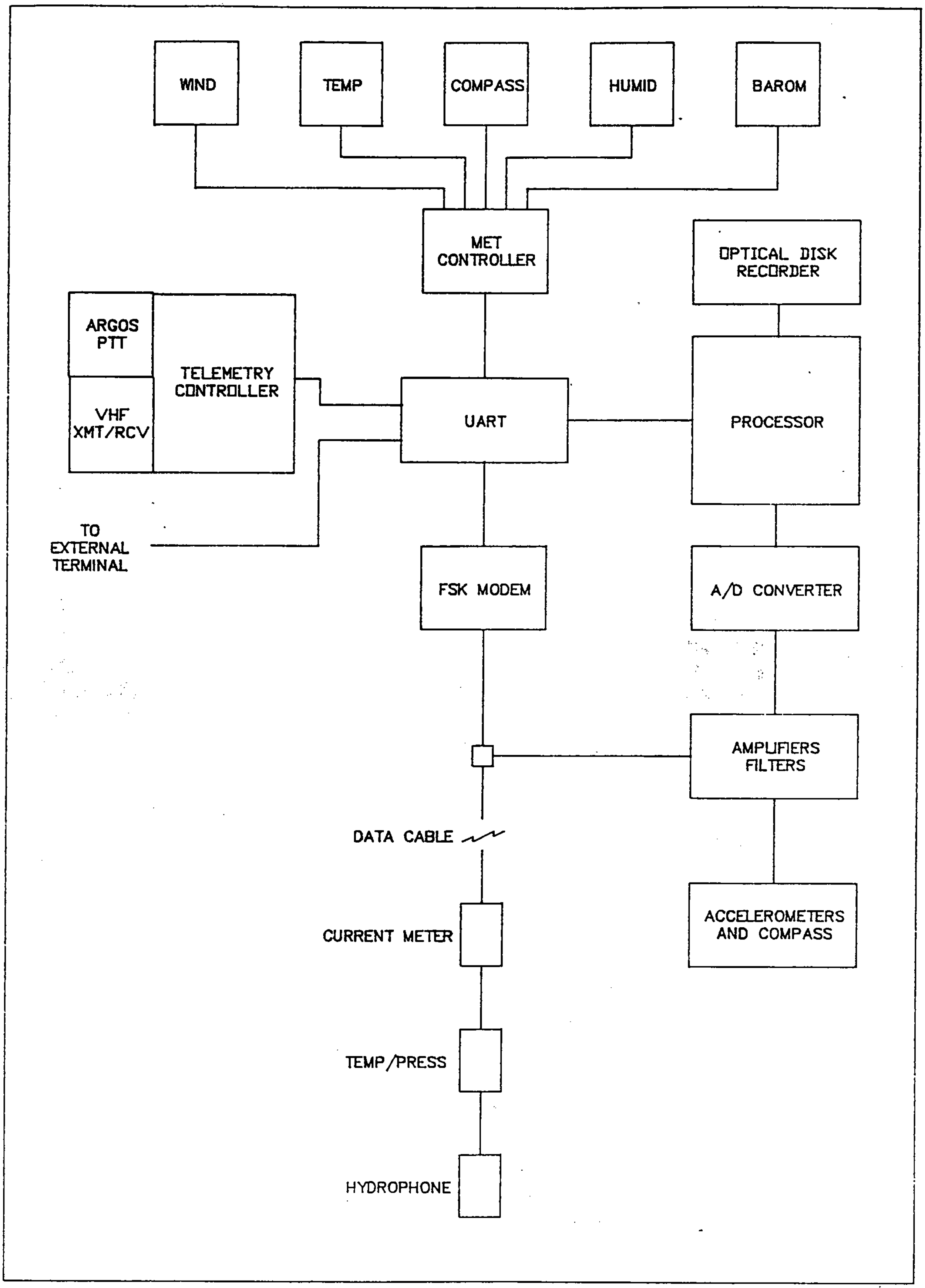

Figure 2. Block diagram of the system. The meteorological sensors are on the tower above the ARAMP pressure case, the current meter, hydrophone, and temperature/pressure module are connected to a sea cable.

3. CEAREX Problems

After the prototype system's deployment at Prudhoe Bay in 1987, a series of five units was manufactured for use during CEAREX in 1989. However, experiences during the prototype testing and subsequent requirements changes necessitated engineering changes and redesigns to the original instrument. As a result, the five units manufactured were quite different from the prototype and insufficient testing was performed which lead to problems during the CEAREX operations.

Details of the problems are outlined in appendix 1 which was written at the conclusion of CEAREX. A brief list of the problems follows:

- the optical disk recorder performed erratically due to problems related to temperature, power supply, and turn on/off protocol;
- FSK board power control was inoperative;
- incorrect RS-232 levels were used;
- incorrect capacitor type was installed;
- one solder bridge was found;
- the V20 CPU operates incorrectly at cold;
- wrong connector type was used on sea cable;
- sea cable rigging method was not suitable;
- no checkout procedures were provided;
- provision for keyboard input caused program to stop;
- incorrect interface was used between program modules;
- incorrect data format was recorded;
- inadequate support programs were provided.

As a result of the above, the author undertook to

- solve problems encountered during CEAREX;
- evaluate all aspects of the buoy's performance and make changes as necessary to achieve an operational system.

Described below are the tests performed and an outline of the problems identified and repaired followed by some improvements that were designed and implemented as part of the process of bringing the instrument to operational status.

4. Tests Performed

Bench

The system was set up on a laboratory bench so that it could be monitored during operation and many different tests were performed. Initially, only the digital portion was operated because the symptoms indicated that it would not run its normal acquisition program to completion.

In this mode, the causes of the basic operating problems were identified, design changes effected as necessary and the system retested.

As the digital problems were resolved, sensors or simulated inputs were added to allow analog portions of the system to be tested. This included for example connecting the hydrophone to the system with suitable audio signals air coupled from an amplified signal generator. Likewise, most of the stand-alone instruments that were used could be operated in the laboratory. Their outputs while different from that obtained in the Arctic served to verify that the system could control the instrument's operation and collect the data.

Freezer

A series of tests was performed using a low temperature freezer to evaluate the performance of the disk drives and the batteries at Arctic temperatures. The aim of these tests was to determine lowest temperature at which reliable disk operation could be obtained.

These tests were performed on two types of optical disk drive: a unit from NHance which is a commercial service drive, and a unit from Mountain Optech which is a variant of their ruggedized drive specified for operation to -20C. A summary of the tests performed is in appendix 2.

From these tests it was clear that it was necessary to reconfigure the internal framework of the ARAMP to take advantage of the warmth of the ocean water which surrounds it when deployed. To evaluate the success of this reconfiguration, internal temperature sensors were added and a series of tests was performed in a simulated Arctic environment at the army's Cold Regions Research and Engineering Laboratory (CRREL) in Hanover N.H.

CRREL

At CRREL, a cold room complete with water tank was used to perform tests of the modified ARAMP internal framework which were designed to determine what temperatures the optical disks would be exposed to in Arctic conditions. Details of the tests performed are in appendix 3. A full description of the process is in reference 5.

Simulated Field Tests

These tests were designed to operate the ARAMP in configurations as near as possible to those in a field deployment. Two tests were performed both of which used battery power and had ARGOS telemetry operational.

The first was a dock test that had the full buoy hull assembled and deployed off the WHOI dock. Due to the water depth however, neither the sea cable nor the instruments were installed. Also, the necessary method of suspending the unit precluded the use of the met tower.

The second test used the complete system with tower and instruments on land. The main hull was suspended on deployment tower (quadrapod) with the meteorological tower attached. The sea cable and instruments were also connected and operating.

These two tests served to confirm that no problems exist relating to interference between modules or to wiring or packaging in its deployed form.

Telemetry

A stripped version of the digital electronics was assembled and installed in the top floor of our laboratory with the antenna on the roof. Communication and data transfers were performed initially from a laboratory separated by two floors of the building then from a truck at various ranges from the building. Finally a small plane was chartered to try to determine the maximum range for successful operation.

Although problems were identified and solved during these tests, the range question is unresolved due to a problem during the flight test. The end of the contract funds prevented the flight test from being repeated.

5. Problems and Solutions

Optical disk

The problems relating to the optical disk were identified as:

- regulator and battery
- controller reset
- turn-on sequence
- temperature.

Regulator and battery

A photograph of a problem media indicated that a series of pits had been burned that were too small causing the system to try to re-use the location in subsequent operations. This resulted in a corrupted media which could not be read. The cause of this problem was current starvation which was cured by using a higher capacity battery and regulator.

The original regulator was a 78M05 driven by a Mallory PC-915 (lantern battery). In the new design, the main battery stack (12 Gel Cells no. GC 1245 in parallel) was used to drive switching DC to DC converters with over-specified surge and steady state current drive.

This redesign also apparently solved erratic problems such as disk eject at power on which resulted from a dip in the logic supply caused by the underspecified regulator.

Controller reset

Since the disk controller being used drew about 1 watt of power, a special adapter board was designed to allow it to be turned off when not in use. The adapter board however, did not apply a reset when the power was turned on resulting in unpredictable operation at power on. This was solved by adding a power up reset circuit to the adapter board.

Turn-on sequence

Occasionally the optical disk system would indicate a not ready condition at power up which was solved by sequencing the power at turn-on: first the drive then the controller must be powered.

Temperature

Initial cold testing indicated that the drives would operate in arctic conditions in the ARAMP buoy. More extensive tests showed that operation below about -5C was undependable if a long soak occurred between uses. Extensive tests and some redesign were performed in this connection - reported in reference 5.

The solution to this problem was to use a different disk drive and to redesign the interior frame to take advantage of the relatively warm ocean water surrounding the lower end of the pressure case. This necessitated a new disk mount, changed system and applications software, different cable routing and thermal insulation designed to retain the heat generated by the drive's own 25 watt dissipation. In addition, the power system was changed as described above. System drawings have been updated to reflect these changes. Figure 3 is a photograph of the system after these modifications have been performed.

Other hardware problems

A collection of minor hardware problems were identified during laboratory testing of the system's operation. Although some are trivial problems, many would inhibit successful field operation. Where applicable, documentation changes have been made. The problems are briefly discussed below.

V20 chip

To achieve faster processing, the CPU chip (an 8088) was replaced with a NEC V20. Our philosophy of achieving cold operation has been to use commercial temperature (0 to 70C) range chips and select for cold operation through extensive cold testing. Our experience has been that few failures occur. In the case of the V20 chip, several samples failed to operate, so we deduce that the industrial range (-55 to 125C) must be used.