Technical Report on DUMAND's "Muon String"

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Introduction

The "Muon String", a ship-deployed 30m high string of five large area photodetectors plus programmable high-speed electronics, was built and tested as one step in the development of a deep ocean neutrino detector (DUMAND). (See Figure 1.) The instrument was built at the University of Hawaii during 1981 and was given a preliminary ocean test in December on two brief cruises of the *Kana Keoki* (HIG oceanographic vessel). The instrument was then brought to essentially full design performance in preparation for a longer term data-acquisition cruise in March 1982 aboard the DeSteiguer. After some initially successful operation at 1500 meters, the Muon String was lowered to greater depths...and lost at sea. The loss was due to not completely understood dynamic interaction of ship, cable and package resulting in the parting of the (20:1 static design safety factor) package harness.

Detector Construction

The funds provided by NOSC were utilized for the final development, assembly, and preliminary tests of the Muon String. Funds from the DOE High Energy Physics contract were utilized for most of the purchase of the optical sensors and circuits (electronics, photomultiplier tubes, and pressure housings). Each optical sensor consisted of a large area phototube (13" diameter EMI PMT), contained in a 17" diameter Benthos glass pressure housing, which also houses power supplies and light pulses. These were assembled at the Hawaii DUMAND Center. HIG Engineering Support provided the rectangular capture frames for the spheres, special light tight transport/test cases for them, and associated hardware. The spherical detectors in their frames were held between two parallel vertical cables (6' separation). The parallels had spreader bars at the top, just below the electronics package, and at the bottom, just above the anchor.

The electronics package consisted of an aluminum plate (about 6' x 2' x 4" thick) with three large holes (20" diameter). Hemispheres (22" diameter aluminum) were placed on either side of the holes. The resulting three nearly spherical cavities were connected by holes drilled in the aluminum plate. The plate also contained connectors for the main cable and for the many cables (24) hooked to the detectors and other devices (sensors and light pulser). This pressure housing, weighing about 1,000 pounds in air, was machined at the University of Wisconsin as part of this contribution to the project. The hemispheres, used previously for ocean bottom seismometry, were provided by Scripps Institution of Oceanography.

The electronics package contained two CAMAC (Computer Automated Measurement and Control system modular electronics, common in high-energy physics laboratories) crates and a power supply package. This CAMAC plus computer system was funded by DOE. The electronics were controlled by an onboard computer (LSI 11/2) which had the ability to individually turn on phototube power, control high voltages, monitor the high voltage and current to each module. There was a programmably two fold redundant fuse for each power supply. Other monitoring consisted of temperatures, fan flow, humidity, orientation, pressure, and various voltages. The fast electronics could remotely and selectively pulse each phototube with a nanosecond LED pulser. Another pulser was placed at the spreader just above the anchor to provide a common strobe pulse visible to all tubes. Special pick ups were recorded to tag the firing of these pulsers.

The fast logic had the ability to set the discriminator threshold for accepting phototube pulses, choose the logic combination desired for recording and simply counting (e.g., a coincident event in 4 out of 5 counters, etc.). Twenty different rates were counted including such things as "line time" and the high precision depth transducer (Digiquartz provided to us by NOAA-PMEL). When events were selected and detected, the signal pattern, fast times ($\frac{1}{4}$ nanosecond resolution), and amplitudes were recorded for all five photodetectors.

The phototube signals were also fed to a programmable module which integrated their outputs before supplying them to a multichannel programmable waveform digitizer. This was intended for a study of the temporal dependence of bioluminescent light pulses. Further plans to add acoustic detectors and a CCD TV camera had not yet been implemented when the Muon String was lost.

Testing

The detector was tested in pressure tanks at Pearl Harbor Naval Shipyard on two occasions (November 2 and November 10, 1981). The first test consisted of pressurizing the individual components to 3000 psi and checking for leaks. None were found. The second test, in a larger tank, permitted the first in water functional test of the nearly complete system, including remote computer reprogramming. This test was also successful with no leaks (1000 psi). The first at-sea test intended as a deployment and mechanical exercise took place west of Oahu on December 1, 1981, from the UH R/V Kana Keoki. The empty package was lowered to a depth of 1.5 km and recovered with no leaks in a deployment and recovery sequence that proved to work well on the first try (and with a fairly inexperienced crew of physicists).

The communications and power were carried by a cable loaned to us by MPL and normally used for a Deep-Tow vehicle. We were able to supply about 1 kw of power to the package (60 H_z, 480V at the package), and send data (at $\frac{1}{2}$ mbd with a computrol FSY Modem) over this cable. A winch capable of handling this cable was not available during the first two cruises (described below), and a makeshift cable (coax taped to the main cable) was used for the first functional test.

The second at-sea trial occurred during December 18-19, also from the Kana Keoki. Two winches were used--one for carrying the load and one for the signal/power cable. The signal/power cable was RG 223/U (50Ω video cable) obtained from federal surplus. It turned out that this cable (supplied on a large reel) had been cut into 170-foot lengths. We installed connectors and unions (ordinary UHF) with 3M waterproofing tape to form a 1 km cable. This cable worked well (no leaks), and the ability to disassemble it proved useful since several turns accumulated around the main cable during winching-in and we had only to disconnect, untwist, and reconnect, losing no cable upon recovery.

During the second cruise, we were able to operate nearly the full system, in particular controlling phototubes and detecting some muons. Because of the limited cable length, we were able to operate at 870 m maximum depth and thus experienced heavy bioluminescent background light. (Bioluminescent activity peaks near this depth.)

A third cruise was carried out from the USNS DeSteiguer on Marcy 1-10, 1982. Intended as an extended data-acquisition run it ended prematurely when the package was lost. We were in the "tune-up" stage and had not yet acquired significant data when the cable parted somewhere between 1500 and 2500 in depth.

Summary

The Muon String was constructed, laboratory and ocean tested during late

1981. The general results were that the DUMAND group learned how to solve the problems of fabricating large area light detectors for ocean use, and learned much about the electronics and hardware associated with them. While the detectors themselves have much development required as yet before use in a DUMAND arroy, we have demonstrated the feasibility of their operation and verified their sensitivity. While no cosmic-ray data was acquired, we have successfully manufactured and tested a very sophisticated instrument which, when built with improved technology (we hope to use fiber optics in the next version), will bring us a step closer to DUMAND and provide an unprecendential tool for deep-ocean research.

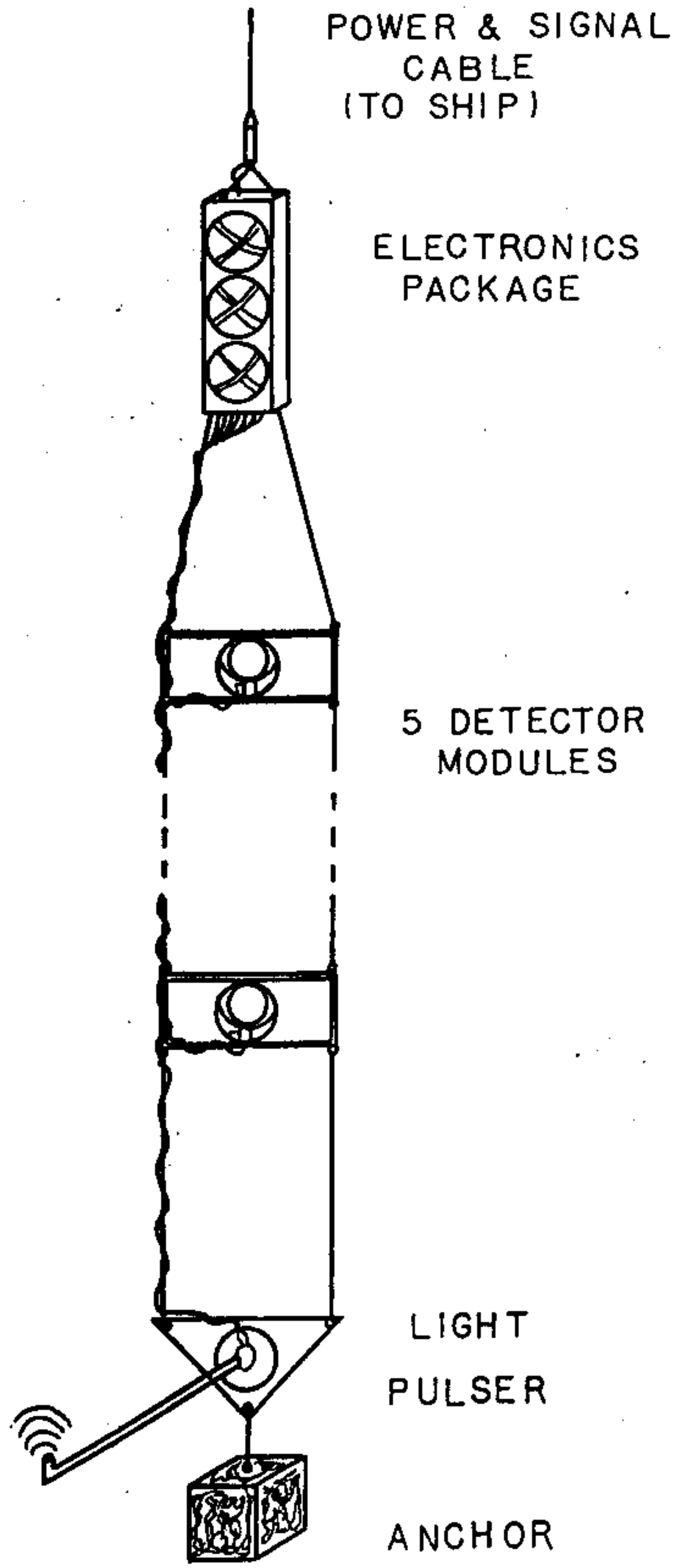
POWER & SIGNAL
CABLE
(TO SHIP)
ELECTRONICS
PACKAGE
5 DETECTOR
MODULES
LIGHT
PULSER
ANCHOR

FIGURE 1