The MIT Marine Industry Collegium

OCEANOGRAPHIC INSTRUMENTATION AT WOODS HOLE OCEANOGRAPHIC INSTITUTION

Opportunity Brief #45

Revised Edition
July 7, 1986

Marine Industry Advisory Services
MIT Sea Grant Program

Cambridge, Massachusetts 02139

Report No. MITSG 86-15
Grant No. NA84AA-D-00046
Project No. A/M-2

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1.0 INTRODUCTION AND BUSINESS PERSPECTIVE

On June 18, 1986, the MIT Marine Industry Collegium and the Woods Hole Oceanographic Institution Ocean Industry Program sponsored a workshop, "Oceanographic Instrumentation at WHOI." The speakers were drawn from the WHOI Department of Ocean Engineering, which has 64 professionals, 53 technical staff and nine support staff divided into eight laboratories:

Applied Engineering
Deep Submergence
Moorings and Structures
Ocean Engineering Research
Coastal and Ocean Fluid Dynamics
Information Processing and Communication
Ocean Acoustics
Submersible Engineering and Operation

Last year grant and contract support for departmental programs totalled approximately $8.3 million. There are collaborative projects with each of WHOI's four scientific departments (Biology, Chemistry, Geology and Geophysics, and Physical Oceanography). In addition, WHOI and MIT engage in cooperative research efforts, and sponsor a joint degree program in several scientific and engineering disciplines.

The projects featured at the June meeting included:

- the POPUP profiler, a bottom deployed apparatus which releases a series of floating probes at programmed intervals to track vertical current profiles over prolonged intervals;
- the Fast Profiler, an autonomous, gravity driven fish programmed to take and store CTD data and return to its support vessel via a homing beacon;
- a one-cubic-inch digital recording voltmeter designed to measure sediment temperature from within the walls of a hydraulic piston corer;
- SEA DUCT, an inverted, recirculating ocean bottom flume designed to perform _in situ_ sediment transport studies;
- a custom data acquisition system for monitoring fixed and drifting hydrophone arrays in the high Arctic and the Marginal Ice Zone'
- an Arctic Remote Autonomous Measurement Platform (ARAMP), designed to serve as an easily installed, semi-permanent Arctic data station, logging data from a variety of on-board instruments and either transmitting the information via satellite or storing it on board for subsequent recovery.

Produced singly or in groups, as prototypes, production models or as unique research tools, each instrument has been developed to answer a pressing need. Most of the devices have recently undergone field trials, and the results have been positive and promising. Already the benefit to the research community has been substantial, whether measured by the increased quality and availability of data or by the wealth of experience gained in the actual development and deployment processes.

WHOI and MIT share a strong commitment to technology transfer, and welcome the opportunity to suport open and informal discussion between academic researchers and their industrial counterparts. The prominent oceanographic companies founded by WHOI and MIT staff and alumni bear witness to the advantages of this close working partnership.

2.0 THE POPUP PROFILER

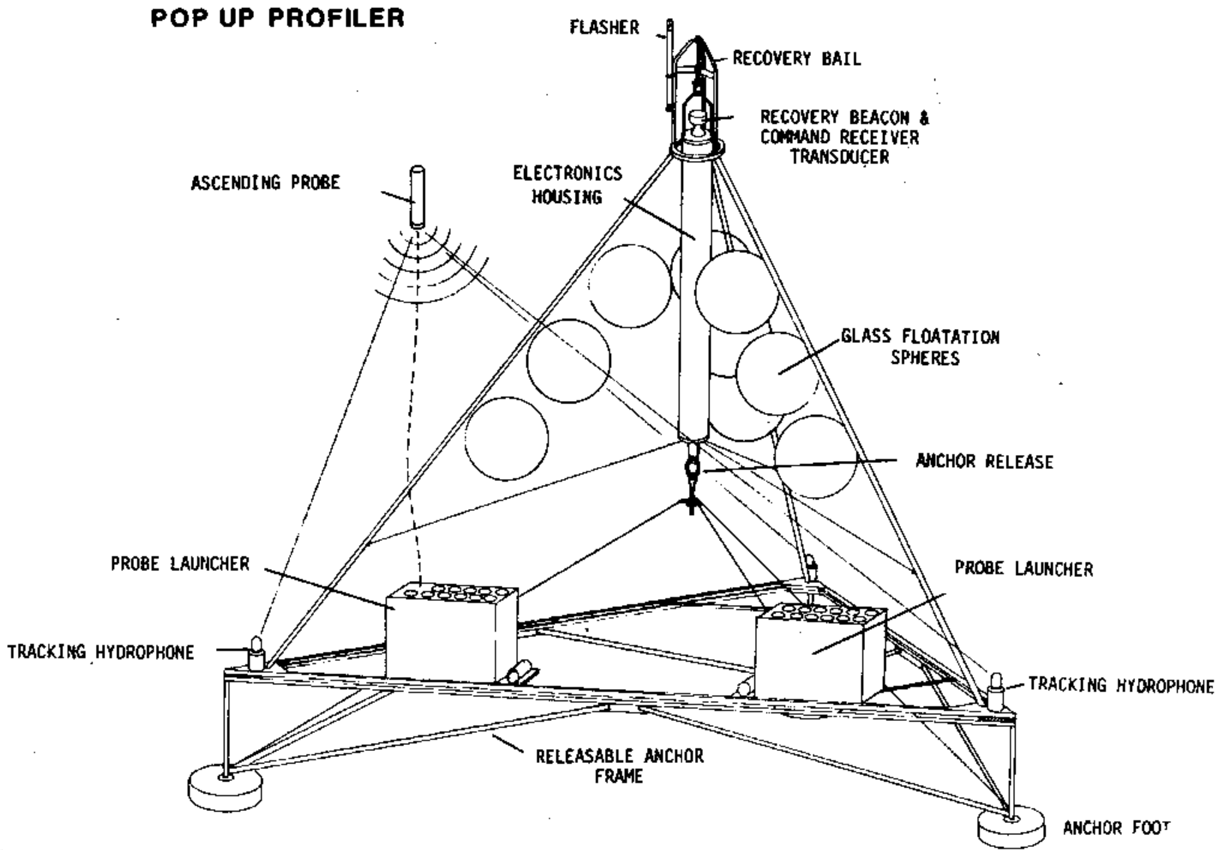
To investigate certain types of oceanic circulation, particularly in equatorial regions and along eastern and western temperature boundaries, an instrument is needed which can measure current from sea surface to bottom with high vertical resolution and over time periods of up to a year. Dr. Albert Bradley of WHOI says that the instrument would need vertical resolution of at least 10 m, and measurement accuracy of at least one cm per second. Additional constraints are that the instrument be readily launched and recovered from a ship, and that it be cost effective. Present free-fall profilers have mobility and excellent vertical resolution but require the presence of a support ship, while moored profilers are generally limited to 200 to 500 m depths.

The POPUP profiler developed at WHOI consists of a tripod carrying several dozen expendable acoustic probes. Once the tripod has been lowered to the sea floor, it periodically releases a probe and measures and records the buoyant probe's trajectory to, and possibly along, the sea surface. As each probe rises, it is accelerated by the horizontal drag forces arising from the difference between the local fluid velocity and that of the probe. If the probe quickly matches local fluid velocity, successive determinations of position can be used to estimate the current field. At the end of the deployment as much as a year later, the tripod is recovered and the probe trajectories analyzed. (See Figure 1.)

The POPUP profiler was developed especially for measuring high vertical mode number current structures. "Think of the wind reversing seasonally, first pushing the water one way, then the other way," says Dr. Albert Bradley. To delimit the resulting vertical structure, a standard mooring would need perhaps 50 current meters on a string, which is not economically feasible, to spot the vertical structure. An alternative way to measure current uses a free-falling Lagrangian drifter dropped from a ship. It records the response from three transponders arranged on the bottom, making it easy to calculate its trajectory in three-dimensional space. Eventually it releases its weight and returns to the surface. One major drawback, however, is that it requires the research ship to hover in the area.

"My goal was to make an instrument which could be dropped from the surface, left on the bottom for at least a year, and take a useful number of full profiles from the bottom to the surface," says Dr. Bradley. This type of data gathering would be useful particularly in equatorial research, where the high mode number current structure is present. It also would be helpful to quickly determine the current during bad weather, such as in deep water near Cape Hatteras. While moorings might not survive in that rough environment, the POPUP could be dropped to the bottom to release its beacons. On a calm day suitable for sailing, the researcher would return to the site and command the bottom unit to release its anchor frame and float back up to the surface.

Figure 1. Schematic configuration of POPUP.



The present version takes to the bottom 40 beacons with acoustic transmitters, although that number does not represent a fundamental limit of how many it could carry. Rather than set up three transponders, Dr. Bradley uses an acoustic interferometer, which saves space on the bottom tripod. As the beacon floats to the surface, three receiving hydrophones forming an equilateral triangle five meters apart listen to the signal and give the bearing information by comparing the phase of the signals. Initial tests from 3000 meters indicate that the resulting velocity estimates averaged over 10 m horizontal bands are accurate to approximately 2 cm/sec at the surface, and considerably better at deeper levels.

"Suppose a designer is planning a deep water offshore platform and needs to know the current profiles at the site very quickly. POPUP could be dropped to the bottom and could give the current profile," suggests Dr. Bradley. "If the designer is interested in the loading of a hypothetical deep ocean work station, the full profile would be very valuable. If he is trying to integrate flow past a certain spot, then the Weller current meter would be more useful. Someone who designs riser legs wants to see both the full profile and the time history of every point. Taking some profiles of the vertical structure with POPUP and then putting in some current meters at specific levels will give that desirable combination of numbers."

The instrument is aimed at applications where a vertical mooring is either impractical or cannot adequately sample the target water columns. "Now we're looking around for someone who needs the instrument. A forthcoming research cruise to the Gulf Stream may provide the opportunity," Dr. Bradley says. "It's very difficult to make a mooring survive in the Gulf Stream."

3.0 The FAST PROFILER

Most sections of the world ocean remain undersampled because of the prohibitive cost of mounting a large scale ocean monitoring program. Despite recent advances in sensor technology, only one complete study of an entire oceanic basin has ever been made (IGY 1957-58), says Joshua Hoyt, a recent graduate of the Woods Hole/MIT joint doctoral program. A basic limitation of the models now used to predict weather is the paucity of oceanic data to cover the model's spatial and temporal scales. The Fast Profiler that Hoyt is developing is intended to break this cost bottleneck by radically increasing sampling speeds and making the data-gathering process much cheaper and easier.

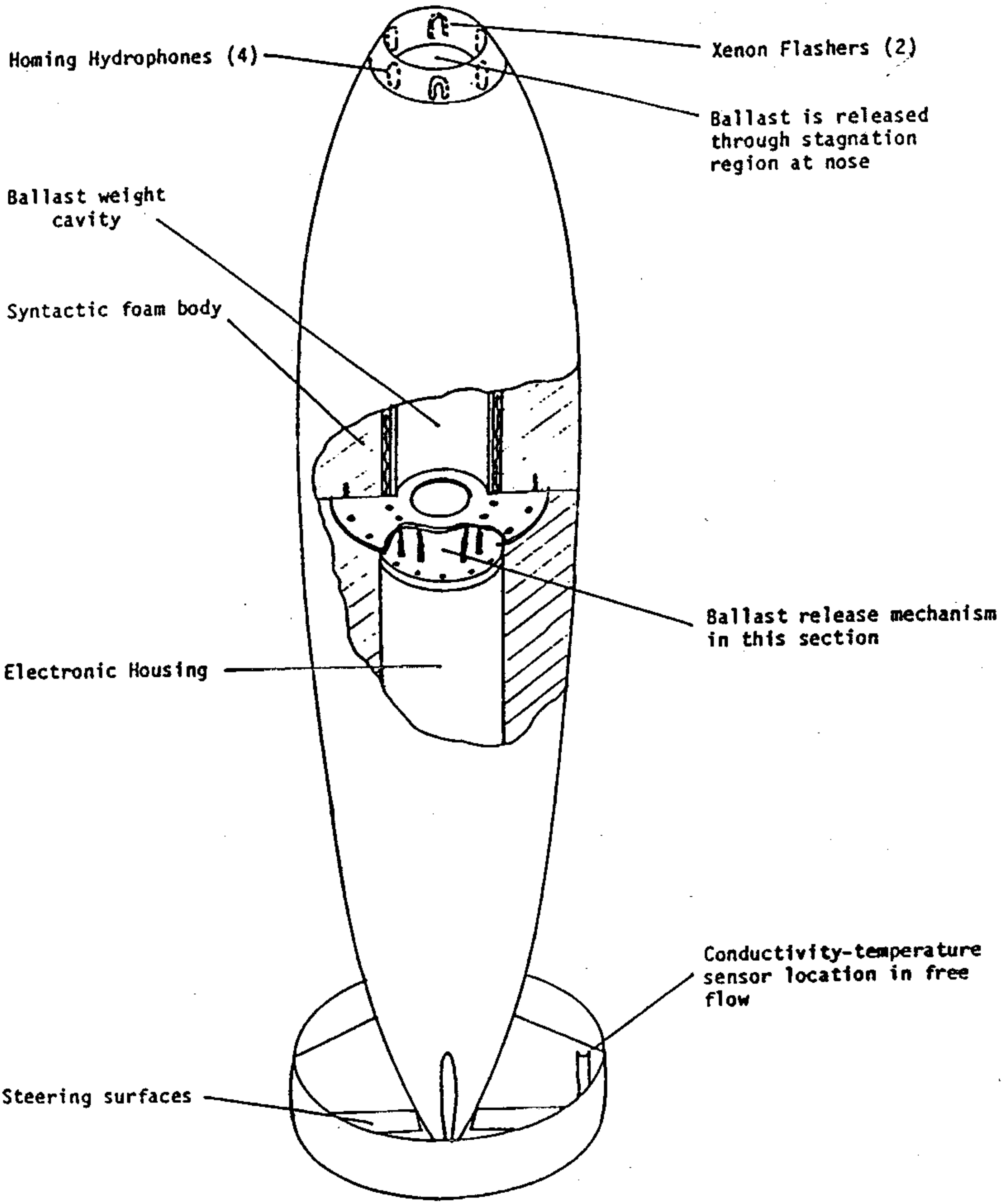
The Fast Profiler is an autonomous, streamlined, gravity driven vehicle capable of high speed (14 knots) vertical excursions to depths of 6000 m. (See Figure 2.) This torpedo shaped instrument can guide itself back to an acoustic beacon at the surface. Phase difference measurements made at four hydrophones mounted in the nose of the body are used to actuate control surfaces to correct vehicle attitude and steer the vehicle toward the surface beacon. The oceanographic sensor package is initially intended to measure conductivity and temperature as a function of depth. From these data one can derive a density field, which can then be used to reconstruct the relative motion of the ocean's currents.

The tried-and-true method of measuring temperature and conductivity consists of lowering small collection bottles to samplee the water column at specific locations. Even though the electronics revolution has spawned a wide range of instruments to measure and transmit or record data continuously and rapidly, cost and logistics continue to discourage people from doing large ocean-basin scale hydrography. Research ships alone can cost $10,000 per day.

The Fast Profiler is intended to make large-scale hydrographic experiments more feasible. Because it is a small, free-fall vehicle driven by expendable weights, a large ship with a deep sea winch is not needed to send it off. Instead of the typical four hours to deploy a cable-lowered device, the streamlined Fast Profiler will make a round trip to 6000 m in a half hour for a time savings of a factor of eight. Software can be configured to include custom self-diagnostics and internal calibration routines to lower the maintenance costs. Data is downloaded and batteries recharged without having to open the pressure case, thereby shortening the turn-around time. It homes acoustically to a fixture near the ship, reducing recovery time. Because the various measurements are more closely spaced in time than a conventional CTD, the resulting picture is a better overview and more representative of what the ocean is doing, affirms Dr. Hoyt.

Extensive use of microprocessors within the instrument makes the obvious complexity transparent to the operator in the field. Programs within the instrument allow the user to ask the computer to do a self-test. If it responds, "I have a problem," another program isolates that problem, allowing the operator or field engineer to atempt repair on the spot.

Figure 2. Cross section view of Fast Profiler.



Even though it reaches speeds of 14 mph and shoots spectacularly out of the water, the Fast Profiler is completely gravity driven. A 100-lb weight drags it down to the bottom, and after dropping ballast it becomes 50 lbs buoyant. Once it reaches the surface the fish can no longer propel itself. "We have to work very hard to make it go so fast and still be a practical instrument. It's very easy to add more and more appendages until pretty soon it's a rather slow vehicle," says Hoyt. Batteries take and store the data, and run the servomotors which steer the fish toward the beacon on the surface. Since it will profile in scientific missions perhaps once every 50 miles, in between dives the operators have ample time to add a new weight and recharge the batteries.

The eight microprocessors on board are arranged in a hierarchy in which the lowest level microprocessors sense the direction to the beacon and move the control surfaces to the appropriate position to steer the vehicle. One level up is an autopilot, a mathematical model of the fish that deals with the instrument's dynamics to prevent it from sailing off wildly. The next step up is a master controller and an executive that asks, "Is everything healthy?" When something is wrong, it reverts to a number of fall-back positions. If it decides to abort the dive, the fish drops its weight and zooms up to the surface, trying to home in on a beacon. "In the field we had some problems initially with the acoustics and the instrument went perfectly to the fall-back position," recalls Dr. Hoyt.

During one deployment the fish missed the beacon by 6 inches out of a total trip of 700 ft. "That level of accuracy proves the concept that we can make a small-based interferometer to steer a vehicle toward an acoustic beacon," says Dr. Hoyt. The vehicle is designed to go up to 10 degrees off the vertical, so its glide angle is relatively small. "We know not ony where it's going to come up, which is near the beacon, but also when it will emerge. It emits a ping once a second so that we can get a slant range on from the ship."

From a cost and a reliability view, Hoyt finds a strong arguement for making the Fast Profiler as simple as possible. As it goes farther from the vertical, the body has to generate more lift. To produce more body lift a design usually calls for fins, which makes the instrument more fragile. "The fish bashed into the side of a ship once and knocked off a chunk of its skin, and we just patched it up and sent it off on the next trip. It went a little slower because it had lost some buoyancy, but it still worked," Dr. Hoyt remembers.

People who work on autonomous vehicles typically try to get around three crucial problems, says Dr. Hoyt. First, it is necessary to supply enough power to the instrument. Without a cable it needs an internal power source. Second is navigation: how does the vehicle know where it is? Third is communication, since there are severe bandwidth limitations in communicating acoustically through water.

Backing off from trying to solve those generic problems, Dr. Hoyt decided to try to mate the Fast Profiler to a mission which could use existing technology. "For example, we don't have a high power requirement because we use a weight instead of thrusters, and the vehicle's trajectory is largely vertical. If we wanted a large horizontal excursion we would need thrusters, and the power requirements would go up appreciably." The problem of communication through the water typically involves sidescan sonar and video pictures. For the Fast Profiler, communication has been reduced to one bit of information saying, "System's working" or "System's not working."

Dr. Hoyt solved the issue of navigation "because the fish neither knows nor cares where it is or where the beacon is in three-dimensional space. It just has two bearings that say, 'The beacon is over there somewhere, and as long as I'm still moving through the water, I'll try to go in that direction.' So we were able in some sense to circumvent here the three crucial problems that people are trying to solve in autonomous vehicles."

4.0 A ONE CUBIC INCH DIGITAL RECORDING VOLTMETER

With ship time for the Ocean Drilling Project running at about $35,000 per day, researchers have a strong incentive to gather data as efficiently as possible. To streamline the process of collecting marine geothermal measurements, Dr. Richard Koehler and colleagues at WHOI have built a miniature temperature recorder that fits into pressure-sealed slots in the wall of the hydraulic piston sediment (HPS) corer. Each time the corer is pushed below the drill bit into undisturbed sediments, the temperature recorder collects measurements at 2 to 10 meter intervals to depths as much as 2 km below the seabed.

Sending down a temperature instrument inside the drill stem and into the sediment below the bit gives researchers the opportunity to investigate how heat flow varies with depth. Although many results indicate relatively constant heat flow with depth, as expected for steady-state conductive thermal transfer, oceanographic studies suggest that some regions might have more complicated thermal structures.

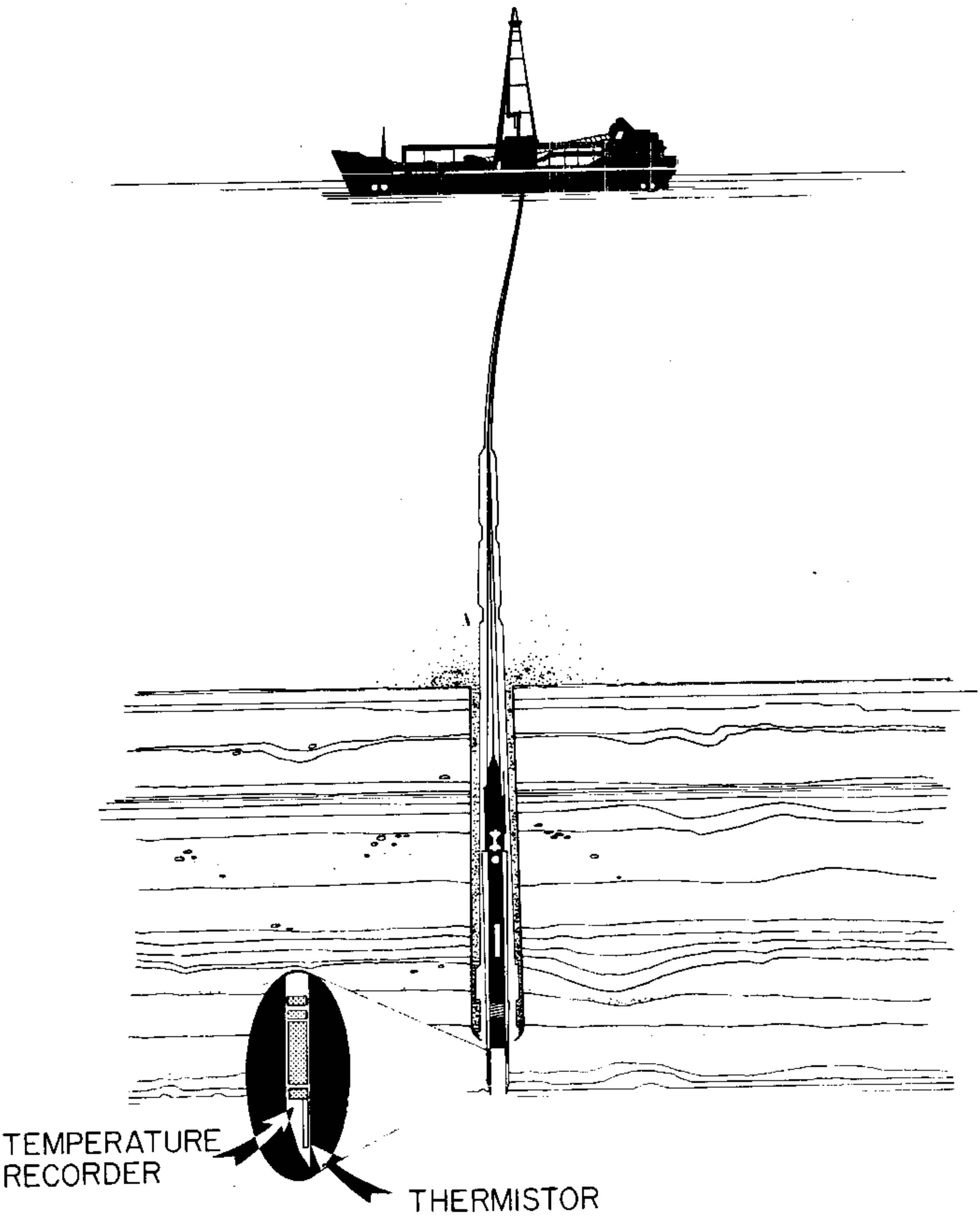
The wall of the coring tool is about 1.4 cm thick and about 9 cm in diameter. It is hollowed out to make room for the temperature recorder, which occupies 16 cubic cm (1 cubic in.), and 10 cubic cm of silver oxide hearing aid batteries. The voltmeter can record about 1300 measurements over a period of a few minutes to 20 hours of temperatures from -2^{o} to 70^{o} C, with a resolution of about 0.01^{o} C.

During a typical run, the HPC carrying the temperature recorder is dropped down the center of the drill string and then forced about 10 m into the ground below the string. "We can make heat measurements every five or 10 seconds, however often we decide. We can also command it to wait some minutes before beginning to record," says Dr. Koehler. After remaining in the mud for about 10 minutes to let the temperature equilibrate, the coring tool is pulled back up. The whole turn-around takes about two hours, during which time "they've done a coring and we've gotten a temperature measurement almost as a freebie." (See Figure 3.)

The most useful location for the temperature sensor is in the tip of the HPC, where it is farthest from the drilling disturbances of the drill bit. Since the tip is thinner than the rest of the core barrel, it takes less time to reach sediment temperature.

The recorder is coupled to a small computer and its program is loaded each time before use. Up to eight time delays and recording rates can be inserted, although only one is normally used. After the corer returns from the bottom, the instrument is removed and the data are read into the computer over an RS-232C (teletype) line. The raw data can be converted to actual temperatures and stored or plotted.

Figure 3. Schematic configuration of drill ship deploying hydraulic pressure core and temperature recorder during coring operations.



As the drill cuts through hundreds of meters of ocean bottom, it is possible to take a temperature sample every 10 m. Dr. Richard von Herzen at WHOI uses the data to measure the heat flow out of the earth. Knowing the thermal conductivity of the core and measuring the temperature at diverse points down into the earth provides researchers with an idea of how fast the heat flows out. Ki-iti Horai gave the recorder its first extensive field tests on Leg 86 of the Deep Sea Drilling Program, and developed the theory to extrapolate equilibrium temperatures from transient thermal decay of the corer.

If a recorder fails on a run, another recorder can easily be slipped in a subsequent HPC. "The scientists want about four measurements in a drill hole, and the instrument gives us many more opportunities than that," says Dr. Koehler.

In its current form, the temperature device measures from about -2° to 70° C. Since it has already encountered its maximum temperature in drill holes, Dr. Koehler has been asked to make a version which can record up to 200° C. "The limit right now is that the A/D stops working above 75° C and the A/D capacitor melts above 105°. If it gets really hot we have to worry about the batteries, since the electronics seem to withstand high temperatures better than the batteries."

The 500-byte program is downloaded into the instrument each time it is used. At the moment it only measures the voltage off the temperature bridge. When the instrument runs at higher temperatures, Koehler presumes that they would modify it to incorporate microprocessors designed for those conditions. A hollow annulus would be made in the coring tool to give more space for the electronics, and data would be transmitted acoustically through the wall of the seabed coring shoe.

"I think that the innovative part of the temperature recorder is that it makes quite a few measurements in a very tiny space," says Dr. Koehler. However, he mentions that "it is a real nuisance" getting the miniature hybrids made. He put the circuit together on a breadboard, and an outside firm put it into a much smaller hybrid form. Finding a hybrid manufacturer who was willing to make only five to 10 units was difficult. "It took a fairly large engineering effort in laying out the circuit, and sources for just a few of each type of integrated circuit had to be found." Larger hybrid companies preferred to use their engineering expertise on products with a larger production run. "Even the smaller company we found accepted the job with reluctance, but then was determined to do the job, even though it was more complicated with its five metalization layers than other companies thought prudent."

"Ultimately we solved all the manufacturing problems, but the hybrid was considerably more difficult than working with a printed circuit. The circuit should be designed so that faults can be isolated. The most difficult problem is designing a technique for determining which of the several ICs fastened to the same lead is at fault," says Dr. Koehler.

5.0 SEA DUCT--AN IN SITU FLUME FOR SEDIMENT TRANSPORT EXPERIMENTS ON THE OCEAN FLOOR

For many years the bottom of the ocean was considered to be a tranquil place, even though photos taken of the depths revealed ripples in the sand that did not suggest low energy conditions. During HEBBLE (High Energy Benthic Boundary Layer Experiment), an ongoing multi-institutional, multi-disciplinary program which began in 1978, experiments showed that the bottom turbidity was about 120 times greater than anticipated, and sediments were moving along the bottom much faster than had been postulated. Intense periodic storms lasting up to two weeks were also found to scour and redeposit materials as far as 1000 km down current.

To simulate these storms and carefully measure how the sediment interacts to known forces at the bottom boundary layer, a group of WHOI researchers built an *in situ* flume for sediment transport. Named Sea Duct, it is a computer-controlled "laboratory" ringed by an enclosed flume or duct. On command from a microprocessor, the 4x2 ft test section of the flume is lowered like a cookie cutter into the sea floor. As the system pumps water through the flume at various prescribed speeds, an onboard stereo camera, laser velocimeter and transmissometer mounted above the test section observe and measure how the seafloor responds.

"Sea Duct represents a new generation of oceanographic instrumentation. It will enable us for the first time to measure *in situ* the seafloor's response to currents," says William Terry of WHOI. Flumes have been used before in oceanographic research, but only in shallow water. Following its debut deployment in summer 1986, Sea Duct will operate at full ocean depths. It is the only deep ocean device that can simulate currents on the seafloor and directly measure the fluid forces that modify the ocean bottom. "This unique capability will allow us to refine our sediment transport models," says Terry.

Sea Duct was designed expressly to generate known bottom stresses and obtain accurate measurements of the effects of current forces on the seabed. Because it can directly measure the forces that erode and deposit material, it also offers the capability to predict when certain events might bury or destabilize any bottom-mounted devices such as structures or cables.

The entire Sea Duct apparatus is a triangular structure about 16 ft on a side that stands over 14 ft high. It weighs 12,500 lbs in air and 2,800 lbs in water. A specially designed pump recirculates water in the duct at velocities up to 50 cm/sec. At such speeds the boundary sheer stress will scour sands, soils and fine clays. The velocity is controlled and can be changed to simulate any sequence of storms and tides.

When Sea Duct lands on the bottom, its microprocessor first ascertains if the ground is level enough to carry out the experiment. If the ground is suitable, Sea Duct is programmed to rotate to a pre-selected orientation and sink the test section of the duct about 2-1/2 in. into the seabed. The device then runs through a series of velocities to simulate particular characteristics, such as a deep ocean storm or the tidal flow. In the meantime, the fluid stresses are measured by a two axis forward scatter laser Doppler velocimeter. The transmissometer measures the buildup of sediment in suspension caused by eroding the bed. Stereo cameras photograph the seafloor in the test section before and after a simulated storm. Various devices aboard can also collect sediment cores and water samples from the area of interest.

Besides determining whether the seafloor is level enough to conduct experiments, the Sea Duct microprocessor also handles problems in rotation or insertion. "The machine is basically on its own, but if it runs into problems it tells us so we can make decisions such as 'try over, try again'," says Terry. "The programming is very flexible. At sea it's fairly easy to change the program so if the first experiment doesn't find what we want to examine more specifically, we can program it to do something else."

The experiments will typically run about six to eight hours. The deployment time depends on the depth of the water. Once Sea Duct finishes the experiment, it remains in place until it is ordered to release its weights and return to the surface. If it has trouble coming up, it can drop its three battery pods which weigh about 600 lbs each. If it stays stuck, it releases long floating lines so that the determined crew on the ship can grapple for it.

Testing sediment _in situ_ is far more reliable than trying to retrieve cores and work them over in the laboratory. Once a large sediment core is wrenched out of the bottom and lifted to the surface, its temperature and pressure change radically and the living creatures which constantly rework the sediment are all killed.

Terry expects Sea Duct to improve existing models of sediment transport. "We really have no data of this sort to make good models. Experiments done with large pieces of sediment brought back from the bottom have had too much scatter in the data. A sediment core retrieved one month is different from a core brought up the following month. Even the same piece of sediment changes with time because of the biology, so the premises for the model based on retrieved cores would not be right."

The work is funded by the Office of Naval Research. Cliff Winget of WHOI is the lead designer and engineer, and has been working on the project for five years. The co-principal investigator is Arthur Nowell of the University of Washington. Terry designed the microprocessor controls and onboard computer system, and Yogi Agrawal designed and built the laser Doppler velocimeter which measures velocity and stresses as the fluid moves.

Terry says, "I think Sea Duct is going to show that we can do other large autonomous _in situ_ experiments in the future. Sea Duct represents a scale of laboratory experiment in the ocean that has not been done before, and we hope it will encourage people to try other, bolder things."

6.0 ARCTIC ACOUSTIC ARRAY DATA ACQUISITION

Since Spring 1978, a group from WHOI and MIT has conducted five month-long acoustic and geophysical experiments in the western Arctic. Data have been acquired from refraction, reflection, reverberation, ambient noise, and long distance transmission experiments. This work has been done from high Arctic camps on the pack ice and from ships in the marginal ice zone (MIZ) between northeast Greenland and Svalbard.

The primary data source on these experiments has been a large geometry hydrophone array of 1 to 5 km aperture, usually consisting of 24 individual sensors. A data acquisition system developed at WHOI has been used to record digitized signals between 5 and 250 Hz from these arrays in the field. While high Arctic ice conditions permit the use of hard-wire linked sensors, conditions in the MIZ do not. For MIZ operations, the Woods Hole research team developed a wide dynamic range RF telemetry link. A companion sensor tracking system continuously tracks and records sensor positions with +/- one meter accuracy as the floe-deployed sensor drifts. The open array data acquisition system was first tested during the MIZEX '83 experiment series, and was fully operational for MIZEX '84.

The WHOI team is presently upgrading the system to improve its low frequency response and reduce signal distortion. The improved system will allow the operator to reallocate bandwidth between channels at run-time, within the constraints of a fixed channel-bandwidth product. An optical disk-based storage system will replace the current tape-based system to improve data bandwidth and storage density.

Dr. Keith von der Heydt of the WHOI Applied Engineering Laboratory has been involved with the Arctic experiments from their beginning. His experience with the equipment, both in the lab and through the ice, has made him acutely aware of the difficulties involved in deploying advanced scientific equipment in the harsh Arctic environment, where scientists sometimes carry guns to ward off polar bears and the most carefully planned experiment can quickly become a victim of unpredictable conditions.

7.0 AN ARCTIC REMOTE AUTONOMOUS MEASUREMENT PLATFORM

The perpetual Arctic ice cover has made it impossible to conduct a broad analysis of the Arctic Ocean's circulation and meteorology from ships. For over a hundred years scientists have established camps on the drifting pack ice and have collected valuable data in the vicinity. Research ships have ventured into a few areas to perform short term programs. However, the temporal and spatial coverage of all scientific disciplines is insufficient to provide a detailed analysis of important physical properties. Sensors on satellites have improved the general understanding of the area, but even there the resolution accuracy and depth of information is limited.

The Arctic research community has used a variety of ice- and water-borne platforms to collect data. While these data have added considerably to the knowledge of certain processes, they typically have been limited in type and scope. In recent years the participants in the FRAM and MIZEX programs in the east Arctic and marginal ice zones have asked for tools to provide extended coverage in a number of disciplines.

Kenneth E. Prada of WHOI is working on an Arctic Remote Autonomous Measurement Platform (ARAMP), a development project to provide such a tool. ARAMP is a free drifting platform (buoy) implanted in the ice that will collect data from a wide variety of sensors, transmit selected data by Argos satellite, and internally store other large volume data sets for later physical recovery or off-loading by high speed RF telemetry. Its design objective is to measure physical parameters both above and below the ice. A typical suite of basic sensors includes:

vector wind
barometric pressure
air temperature
humidity
compass
sea surface temperature
ice motion and dynamics
broadband ambient noise
upper ocean currents, temperature and conductivity

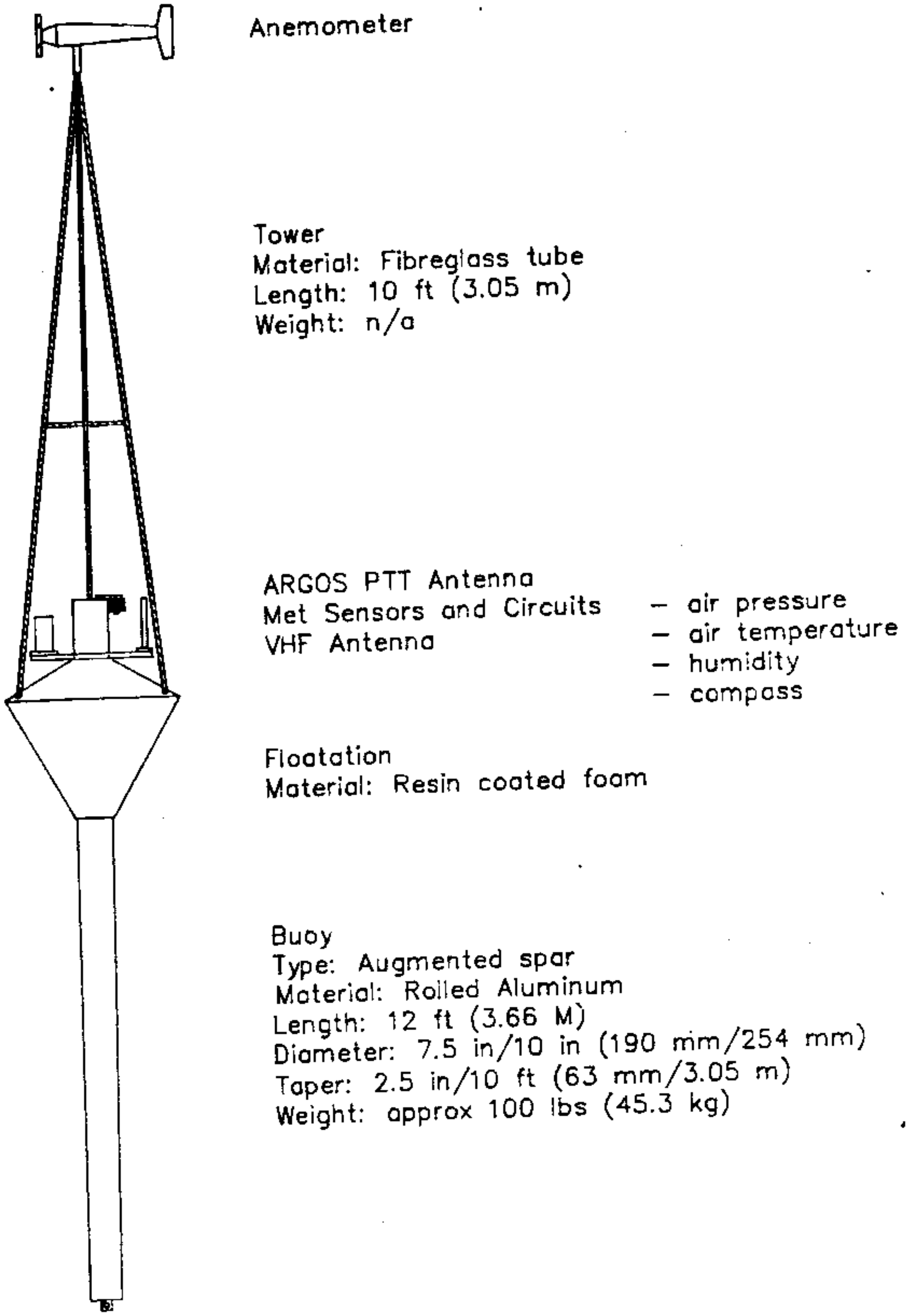
Optional sensors might include:

ice thickness
ice ablation
ice thermal conductivity profile
solar radiation

ARAMP consists of a four-meter segmented spar buoy, tapered for easy insertion and removal from a 10-in. ice hole. (See Figure 4.) A three-meter tripod tower mounted atop the spar supports an anemometer and telemetry antenna. Below the spar, a cable several hundred meters long is suspended to give mechanical and electrical support for temperature, current, conductivity and hydrophone sensors. The spar housing contains a three axis accelerometer for high resolution measurements of ice motion. The data collection system is controlled by a powerful microcomputer that performs intelligent data sampling, real-time spectral analysis of ambient noise data, data telemetry, and data compression and internal storage.

Prototype testing will take place during the MIZEX-87 field program in March 1987. At least 50 of these platforms are scheduled to be produced commercially for the winter MIZEX-89 field program.

Figure 4. Outline diagram of the Arctic Remote Autonomous Measurement Platform (ARAMP) buoy/tower.



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