NRL Report 7403

Initial Construction and Deployments of the Long-Term Ambient-Noise Buoy

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May 16, 1972

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Washington, D.C.

UNCLASSIFIED

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ABSTRACT

The Systems Engineering Staff of the NRL Acoustics Division has the requirement to build a long-term, unattended, bottom-anchored buoy for collecting acoustic ambient noise in the deep ocean. With a nucleus of surplus equipment from two buoy projects of the 1960's plus additional equipment designed and built at NRL, seven Ambient Noise Buoys were fabricated. One was designed for investigation in the frequency range of 1 to 10 Hz with four hydrophones, three were designed for the band from 20 to 400 Hz with two hydrophones, and three were designed for the band from 20 to 400 Hz with one hydrophone. The first 12 deployments using these buoys yielded recordings of over 1200 hours of acoustic ambient noise in the sea. This initial report was written as of July 1, 1971. It is a summary of the system, method of deployment and recovery, and the results of the first 12 deployments, involving continuous recording for up to 18 days. Future improvements and experiments to be more fully described in later reports involve data sampling and permit operation up to a year. A future second-generation buoy will include a miniature computer for some signal conditioning and conversion to a digital form.

PROBLEM STATUS

This is a status report on the first phase of the problem which is continuing.

AUTHORIZATION

NRL Problem K03-17
Project R2408

Manuscript submitted February 17, 1972.

INITIAL CONSTRUCTION AND DEPLOYMENTS OF THE LONG-TERM AMBIENT-NOISE BUOY

BACKGROUND

Interest has been increasing in the study of ambient noise in the sea. Due to the expense of ship time and ship availability, designs for long-term ambient-noise buoys have been studied and in some cases carried into construction.* Most of the early buoys were anchored systems with surface and subsurface floats. When NRL became actively interested in an ambient-noise-buoy system, in early 1969, studies were conducted of existing systems, and some general design concepts were thought out. In May 1970 a seismic buoy system built for Project Vela Uniform by Texas Instruments, Inc., became available, as the project had been terminated. NRL requested and was later given all of the equipment from this project. The buoy shell is an aluminum sphere 40 inches in diameter with a wall 1-3/4 inches thick. It weighs approximately 1500 pounds in air, and, before launching, it rests on its 350-pound anchor. The sphere has 100 pounds positive buoyancy in water when separated from the anchor. The entire unit is launched as a single package and ultimately rests on the ocean floor in any depth up to 25,000 feet. Fourteen of these units were available.

By July 1, 1970, all of the equipment had arrived at NRL. Work commenced immediately to produce the first NRL Ambient Noise Buoy. The basic shell, recall system, clocks, and other support equipment were used as a nucleus. In prior studies the United States and Canada had jointly developed a buoy system called Nutmeg. This project had also been terminated, and NRL had received many of its components. Among these were a number of the Nutmeg tape recorders. This recorder was designed to record the last 25 hours of data and could, by command, be made to play back at a speeded rate of 50 to 1. The frequency response of this machine was 20 to 300 Hz. The plans by NRL were to build a 30-day buoy capable of recording frequencies in the band from 20 to 600 Hz. After study and tests, work on the Nutmeg recorder was begun in an attempt to meet the needs of the NRL projected buoy.

The first attempt at achieving tape recorder longevity was to move the tape supply and takeup reels outside the main recorder and to increase their size and thereby the

*NRL letter report 8108-36:ATM:hap of March 14, 1969, Subject: Buoy Study for Noise Measurement Program; Defense Research Establishment Pacific, Recording Instrument Package (RIP); Naval Underwater Systems Center, Autobuoy; Naval Underwater Systems Center, Moored Acoustic Buoy System (MABS); Naval Undersea Research and Development Center, Sonodiver; Texas Instruments Incorporated, letter of March 3, 1969, to ONR and presentation of March 5, 1969, at the Navy Department; Woods Hole Oceanographic Institution, ACODAC Buoy.

amount of tape. This plus the use of thinner tape allowed recording time up to 9 days. The tape recorder is a two-track machine, and the 9 days of recording takes into account both tracks by use of automatic switching at the end of the first track to the second track. The machine automatically stops at the end of the second track. The frequency response was increased in two ways. First, the playback head in the original machine has been removed, and all tapes are played back on a laboratory machine which has a better reproduce head with a smaller gap. Second, the record-head current has been optimized for the frequency band of interest. The band itself cannot be expanded appreciably, but its center can be shifted enough to allow recording up to 600 Hz with only a small degradation of response at the low end of the frequency band.

The modified recorder plus a noise hydrophone and amplifier were integrated into the completely rewired Texas Instruments seismic-buoy package. In October 1970 an engineering trial was conducted in the harbor at Bermuda. After the buoy was deployed for 3 hours, it was acoustically recalled and the tape removed for analysis. This test was considered a success, although several minor problem areas were found.

As a result of the confidence gained by the engineering test, it was decided to make several copies of the original unit with minor changes for future deployments. In addition an engineering test model with a frequency response of 1 to 10 Hz was built which used the original Texas Instruments tape recorder. These units (Fig. 1) have been deployed one or more times between October 1970 and March 1971 and have proved their worth as well as demonstrating areas of needed improvement. The equipment, method of deployment and recovery, results, and future plans are discussed in this report, which was written as of July 1, 1971.

COMPONENTS OF THE INITIAL AMBIENT NOISE BUOY SYSTEM

The Ambient Noise Buoy comprises two major electronic systems. One is the noise monitoring and recording system, and the second is the support system including items such as the acoustic recall receiver, the clocks, and the batteries (Fig. 2). Also part of the total equipment required are the shipboard items used in recovery.

The principal electronic components of these initial buoys are: batteries, tape recorder (Nutmeg and Texas Instruments), hydrophones (General Electric and NRL Underwater Sound Reference Division), ambient-noise amplifiers (Mark I and Mark II), sonar-recall receiver, digital clock, backup clock, calibration and control, beacon transmitter, and beacon light. The shipboard recovery components are: the shipboard sonar-recall system, the sonar-recall transducer (fish), and the radio beacon direction finder.

Batteries

Twelve battery packs are used in the Ambient Noise Buoy. During the evolution of the models the battery configurations have changed slightly but are basically eight packs of silver cells, three packs of mercury cells, and one pack of carbon zinc cells (Table 1). The silver cells were selected since they have the highest energy per unit volume and weight and work well at low temperature. They are rechargeable over a limited number of charges depending on their discharge rate, age, and care in handling both electrically and physically. The other four batteries are one-time packs and have to be replaced after each

Fig. 1—Ambient Noise Buoy about to be launched

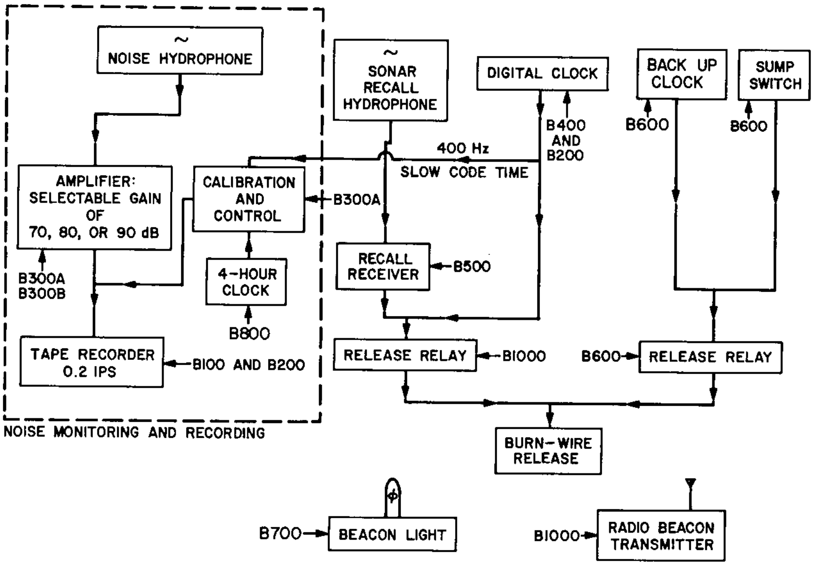

Fig. 2—An Ambient Noise Buoy. (B100, B200, etc. denote battery supplies.)

Table 1
Battery Packs Typical of One of the Initial Ambient Noise Buoys

Pack No.	Number of Cells	Type of Cell	Voltage (volts)	Power Use
B100	7	Silver LR-40	13.0	Tape recorder—in series with B200
B200	10	Silver LR-40	18.5	Tape recorder and digital clock
B300A	11	Silver LR-21	20.4	Calibrator and Control plus Noise Amplifier
B300B	9	Silver LR-21	16.7	Noise amplifier
B400	2	Silver LR-85	3.7	Digital clock
B500	2	Silver LR-70	3.7	Sonar recall receiver
B600	10	Silver HR-5	18.5	Backup clock and release relay
B700	1	Eveready Type 497	510.0	Beacon light (external to sphere)
B800	8	D size Duracells	12.0	Clock for calibration and control
B900	1	Mallory TR-234R	5.4	Current pump for noise amplifier (one amplifier when more than one hydrophone is used)
B1000	10	Silver LR-40	18.5	Beacon transmitter and release relay
B1100	18	Mallory RM828	25.0	Hydrophone preamplifier

deployment. All of the batteries with the exception of B700 and B1100 are in compartments mounted around the center ring of the buoy (Fig. 3). They have been so spaced so as to maintain weight distribution as evenly as possible and insure that the buoy will float upright when it surfaces.

Tape Recorder

Two types of tape recorders are used in the Ambient Noise Buoys. The first six buoys built were designed for frequency-band operation from 20 to 400 Hz and used a

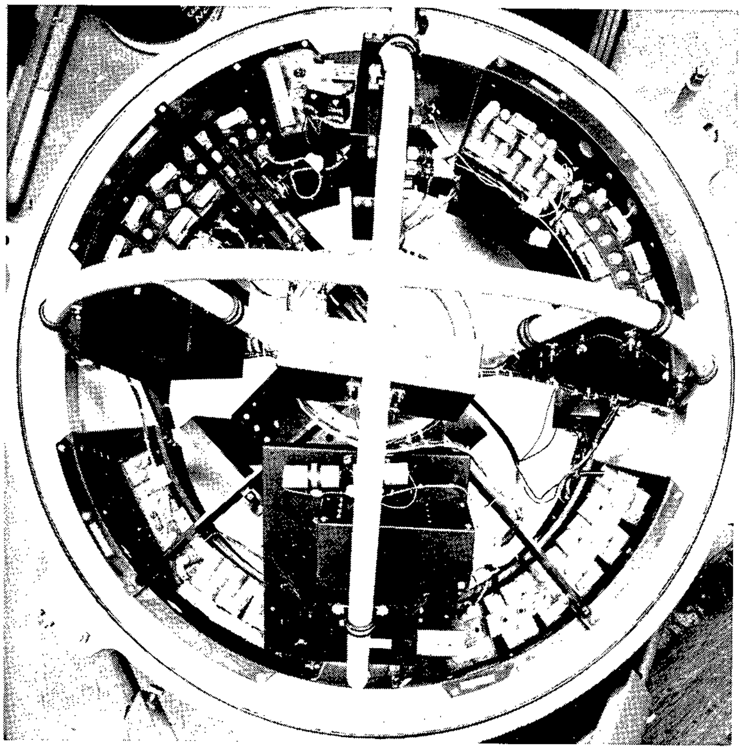

Fig. 3—Overhead view of an opened buoy showing the battery placement

modified version of the Nutmeg recorder. The seventh buoy operates from 1 to 10 Hz and uses the Texas Instruments seismic tape recorder.

Nutmeg Tape Recorder

The Nutmeg tape recorder, before being modified for the Ambient Noise Buoy, was designed to directly record low-frequency signals in the band from 20 to 300 Hz for long periods of time governed only by battery life, continuously storing the most recent 25 hours of input data, while erasing earlier information. This recording process employs 1/4-inch two-track instrumentation tape at a speed of 0.20 inch per second. The reservoir for this tape is a twin-spool contrarotating dispenser, with tape tension maintained by a tensator-spring/differential mechanism. Stored information plays back on command and at a time compression factor of 50 or, in other words, at 10 inches per second.

The power consumption is less than 2 watts during record. The drive motors are 30-volt synchronous motors. However, they will perform satisfactorily between 24 and 32 volts. The dynamic range is in excess of 30 dB. Maximum signal input level is 1 volt rms. The recorder requires less than 1 cubic foot and weighs approximately 30 pounds.

Since the NRL Ambient Noise Buoy was for a long-term application—with a goal of 30 days of continuous recording—methods were sought which would increase the 25 hours of stored data capacity of the original recorder. The resulting methods are use of thinner tape (1/2 mil instead of 1 mil), an increase in the amount of available tape, and replacement of the two-track head with a four-track head.

Due to the design of the tape supply and takeup reels and the required tension, the entire 7-inch reel cannot be used. Only the outside 3/4 inch or so has tape. Thus the ratio of diameters on the two reels is kept almost equal, and a spring can control the tension in conjunction with the differential. To increase the amount of available tape, this spring was increased in size and strength, and new supply and tapeup reels were built. The new reels are 14 inches in diameter instead of the original 7 inches. This required moving the spring and differential out of the main frame and supporting it on rails fastened to the sides of the recorder. (Fig. 4).

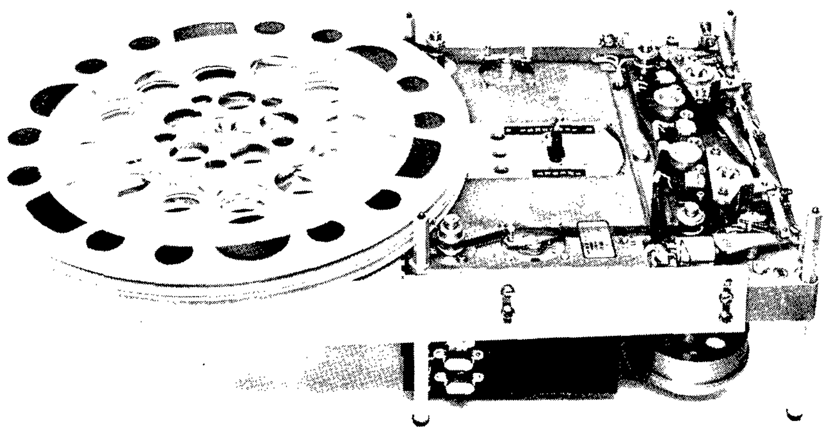

Fig. 4—Modified Nutmeg tape recorder

To use the four heads in increasing the time capacity, control circuits were built that allow one-track operation down and back twice with automatic reversing and head switching. There is an option for two hydrophone inputs, which would use two tracks down and back with 1/2 the recording time. Also, the four tracks can be used simultaneously for four hydrophones with one pass down the tape. The result yielded 18 days of recording time for one hydrophone, 9 days for two, and 4-1/2 days for four.

The input circuits have been modified with a buffer amplifier and the addition of a gain stage. This gain is 20 dB but can be adjusted downward to o dB if desired. The bandwidth has been increased to 400 Hz by optimizing the head current to record the higher frequency with a slight degradation in the lower end of the band. The upper frequency has been increased as high as 600 Hz in the laboratory and was used on the engineering tests. All other deployments have had a recorder bandwidth of 20 to 400 Hz. A typical response curve would show a maximum at approximately 100 Hz, 2 dB down at 400 Hz, and 5 dB down at 20 Hz. The minimum dynamic range over the band is in excess of 30 dB. Another factor in increasing the bandwidth is playback on a laboratory machine which has a smaller head gap and is of a higher quality than the original playback head of the Nutmeg recorder. The playback capability and erase head of the Nutmeg recorder have been removed to conserve on power and weight. Playback in the laboratory is at a speeded up rate selected to give as short a data retrieval time as possible while keeping the data within a frequency band which is compatible with existing filters.

The Nutmeg recorder is mounted on a tray (Fig. 5) which is suspended from the center ring and rests at an 11-degree angle with the front end, the highest point, just about even with the top of the lower hemisphere.

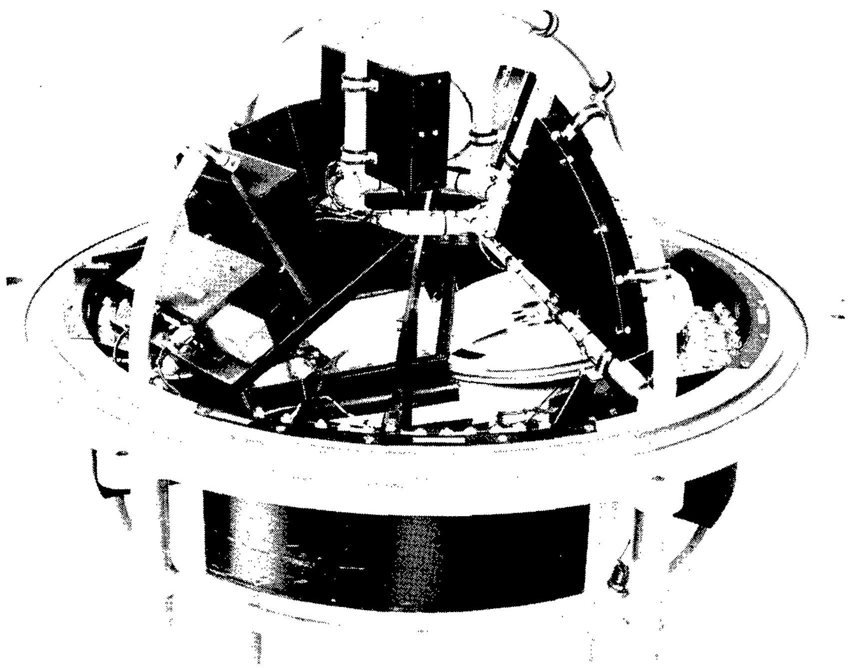

Fig. 5—Electronics and modified Nutmeg tape recorder in an Ambient Noise Buoy

Texas Instruments Tape Recorder

The Texas Instruments seismic tape recorder is a slow-speed (0.0075 ips), 14-channel, direct-record machine with a frequency response of 1 to 12 Hz. Up to 30 days of continuously recorded data can be put on an 8-inch reel containing 1800 feet of 1-inch magnetic tape. A sensor arm turns the tape recorder off when the supply reel nears the end of the tape. The transport is driven by a 12-volt dc motor powered through a regulator. The input signal required to the bias oscillator is 5 volts peak to peak into a 10,000-ohm resistive load for maximum recording level. The machine is at the top center of the arch support in a vertical position.

This tape recorder was used in only one buoy, which was an engineering model. It was a four-hydrophone system and was deployed only once. Prior to the deployment, tests were run on the tape recorder, and numerous deficiencies such as wow and flutter were encountered. Although an attempt to improve the machine had little success, it was used on this one deployment. The handling lessons of a four-hydrophone deployment were of value, but the recorder rendered the data of little value. There are no future plans for this recorder.

Hydrophones

Two types of hydrophones have been used with the Ambient Noise Buoy. In the first three buoys built, which were single-hydrophone types, a General Electric type DCH-2 hydrophone (Fig. 6) was incorporated. In all subsequent units a hydrophone fabricated by NRL's Underwater Sound Reference Division (USRD) in Orlando, Florida, was used (Fig. 7). The reason for switching to the USRD hydrophone was primarily the need

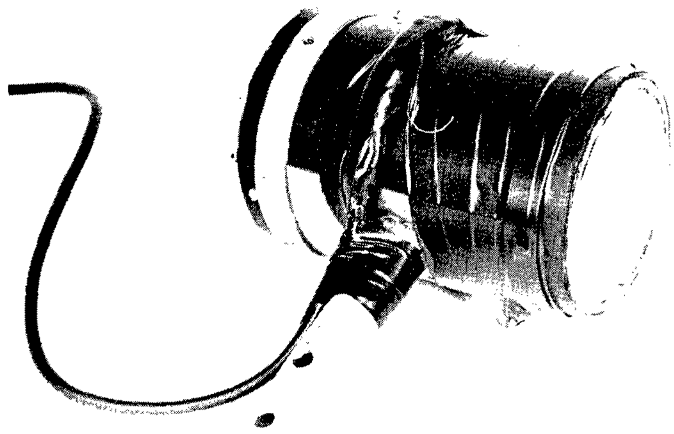

Fig. 6—General Electric DCH-2 hydrophone

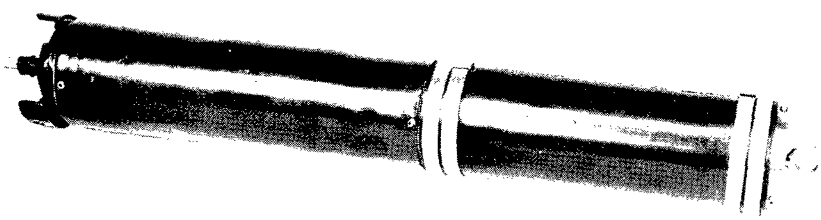

Fig. 7—USRD H-58 Hydrophone

of having a preamplifier at the hydrophone to drive long lines required of the later Ambient Noise Buoys using two- and four-hydrophone configurations. The USRD hydrophone is one complete package which houses the hydrophone, preamplifier, and battery supply.

The General Electric units have a receiving sensitivity of approximately −96 dB re 1 volt per μbar. This response is flat from 10 Hz to 2.5 kHz, and the calibrations were made at deep-ocean temperatures and pressures as well as under normal laboratory conditions.* They weigh about 3 pounds in air and are 9 inches long and 3 inches in diameter.

*Naval Research Laboratory, USRD Calibration Report 3143, Sept. 3, 1970.

The USRD hydrophones and preamplifiers shown in Fig. 7 weigh 10 pounds in air, weigh 7 pounds in water, and are approximately 2-1/2 inches in diameter and 24 inches long. Their sensitivity is about −94 dB re 1 volt per μbar over the band from 10 Hz to 4 kHz.* The crystal and housing were designed and built at USRD. The preamplifier was designed by the Systems Engineering Staff of NRL and constructed by the Engineering Services Division. The preamplifier has a unique characteristic in that its output impedance is 1 ohm. This circuit has been tested driving 30,000 feet of RG-58A/U cable without any amplitude loss, which is an important asset to a system of this design.

Ambient-Noise Amplifiers

Two noise amplifiers have been used in this program. The first was designed to be used with the General Electric DCH-2 hydrophones. It has a commercial NUS 2200 20-dB fixed-gain preamplifier followed by a five-stage transistor amplifier designed by NRL. The overall gain was selected by a switch and could be 52, 62, 72, 82, or 92 dB. For low-frequency equalization the frequency response of the amplifier was designed to roll off about 3 dB per octave below 150 Hz.

The second preamplifier and amplifier, and the one used in all buoys now being deployed, was designed at NRL, with the main design criteria being to drive long runs of RG-58A/U cable (up to 5 miles). The system features a voltage gain and frequency response that is virtually unaffected by the length of the cable. In addition the low effective cable-termination impedance (1 ohm) reduces the effects of mechanically induced cable noise. The hydrophone preamplifier is battery powered and is designed to have low power drain and low self-noise. The system can be adjusted by switches in the post-amplifier to have a gain of 70, 80, or 90 dB. Additional settings are easily changed by the proper selection of a feedback resistor for the operational amplifier in the post-amplifier.

Sonar-Recall Receiver

The sonar-recall receiver amplifies the sonar commands from the recovery ship's sonar transmitter to activate the release system when sonar recall of the unit is desired. The recall hydrophone acts as the sensor for the sonar signals. The hydrophone output signals pass through a filter to limiting amplifiers. The filter is broadband-tuned to the two interrogation frequencies. These output signals are then further amplified. At least 1 volt from the filter is required for limiting. The output of the limiting amplifier drives a discriminator which provides a maximum output at one frequency with a minimum at the other or vice versa depending upon the connection of the code selectors. The end result is either a digital 1 or 0. Each unit has its own prewired code. When the proper code has been received, the receiver activates a relay that applies current to burn the release wire.

*Naval Research Laboratory, USRD Calibration Report 3198, Feb. 11, 1971.

Digital Clock and Backup Clock

There are four means of commanding release of the buoy from its anchor and having it come to the surface. They are the acoustic recall just discussed, the digital clock, the backup clock, and a leak detector or sump switch. The leak detector will not be dealt with as a major component, since it is simply two contacts that sense salt water and activate a release relay. The digital and backup clocks, however, are major items within the buoy system.

The digital clock is a solid-state countdown circuit from a crystal-controlled oscillator. It has outputs of 400 Hz, 12.5 Hz, and a slow time code. In the original Ocean-Bottom Seismograph buoy built by Texas Instruments, Inc., for Project Vela Uniform, these signals were applied to the 14-channel tape recorder along with the seismic data. The clock also has connections which may be strapped or tied-across with different configurations of diodes or straps to select a release day. The clock runs for 40 days before recycling. Most days between 1 and 40 can be selected for buoy release by the digital clock. In the Ambient Noise Buoy the limited number of tracks on the tape recorder are dedicated to data. It is important, however, to have some time marks and a calibration signal on the tape. The use of these will be covered in the next subsection, on the calibration and control unit. The major function of the digital clock in the Ambient Noise Buoy is to provide a release command at the end of a number of days preselected by strapping or tying between outputs with one or more diodes or wires as prescribed for the selected day.

The backup clock consists of a Bulova Accutron time generator with an output signal of 360 Hz. Contacts on the back of the clock give a closure for 23-3/4 hours before moving to the next of 60 sets of contacts. (It takes about 15 minutes to move from one day to the next.) Therefore, one can select a contact for relay closure and buoy release from 1 to 60 days. The 360 Hz is counted down into a time code like the digital clock for recording on the tape in the original configuration. In the Ambient Noise Buoy the countdown circuits are disconnected; the only parts of this system used are the mechanical contacts on a day-to-day basis.

The only hand on the backup clock is a sweep-second hand, so it is not possible to know what hour and minute the clock reads at any given time. To set the clock, one finds with an ohmmeter the contact which the clock has previously closed. Then by turning the setting handle on the back, the clock is advanced until the contact is just broken. The next contact in the series should now be closed. A count from this contact up to the number of days desired selects the point for connection of the release relay. This is crude but adequate, considering that this is a backup system.

Calibration and Control

The need of time marks and a calibration signal was recognized at the beginning of the planning of the Ambient Noise Buoy. Due to some problems with the circuit and changes in noise amplifiers, there have been several models. All of the models have had as their major control an electrically wound mechanical 12-hour-per-revolution clock. A cam attached to the shaft has detents every 1/12 of the circumference. A microswitch with a roller on this cam is adjusted to give approximately a 5-minute closure at the beginning of every hour after the initial setting. This switch closure applies voltage to the calibration and control circuits.

In the original design the unit, upon application of power, disconnects the output of the noise amplifier from the tape recorder and applies the slow code from the digital clock to the recorder for at least 1 minute. (The slow code is made up of 60 pulses, a second apart, for one time-code reading.) At the end of the time code the output of the noise amplifier is again connected to the tape recorder, and a 400-Hz calibration signal is inserted at the input to the amplifier. This 400-Hz signal is taken from the 400-Hz square-wave output of the digital clock. It is filtered to shape it into a sine wave and passes through a voltage divider so adjustment can be made to set it for the proper recording level. The calibration signal is applied for approximately 1-1/2 minutes. Then the noise amplifier is returned to its normal state. The main problem of this system, found after the first deployment, is the inability of the tape recorder to record the slow pulses of the clock. As a result the basic control system was kept the same but the time code was used to key the 400 Hz output from the digital clock. The time code now is made up of variable-width bursts of the 400-Hz signal, whose amplitude is the system gain calibration.

In the latest buoys the noise amplifier is the Mark II model, which has the preamplifier incorporated with the hydrophone and has the 1-ohm cable drive by means of the current pump. A calibration should be inserted at the hydrophone input, but this is not practical when the hydrophone might be 7000 or 8000 feet from the instrument package. It was therefore decided that the on-deck calibration before deployment and after recovery would have to suffice as far as the amplifier was concerned. There is a high confidence in the amplifier, since it is independent of voltage over a wide range. The time-keyed 400-Hz pulses are applied, however, to the tape recorder for time and as a recorder calibration.

Radio Beacon Transmitter

The radio beacon transmitter to aid in recovery is fastened to the top inside of the upper hemisphere. A Mecca type connector in the side of the recall hydrophone housing allows for the connection to the antenna, which is mechanically fastened to the beacon-light pressure case. The primary power relay in the transmitter is connected with its coil between the transmitting power supply and the antenna, with a decoupling network at the antenna. When a resistance of 1500 ohms or less is connected from the antenna tip and the release mechanism, the relay operates and removes electric power from the transmitter. For redundance in the system, a normally closed pressure switch is incorporated. This is mounted in the center ring and turns off the transmitter at approximately 275 feet during descent and turns it on at approximately 200 feet during ascent. Either system turns on the power to the radio beacon, but both must operate to turn off the power. The frequency of the beacon is 26.669 MHz. The AM pulsed carrier is modulated with a 400-Hz tone having an on time of approximately 15%.

Beacon Light

The beacon light uses an EG&G FX-6A flash tube which is a high-intensity tube widely used in other buoy-light applications. This tube and the associated triggering circuitry are housed in a Pyrex glass dome attached to an aluminum housing containing the battery power supply. A pressure switch is wired in series with the battery and is in a closed position until opened by a pressure of approximately 270 psi. Therefore the light flashes until it has submerged in water to a depth of 600 feet, when the pressure switch activates and the circuit opens. This process is reversed when surfacing, causing the circuit to close and the tube to begin flashing.

Shipboard Sonar-Recall System

The shipboard sonar-recall electronic system is mounted in a 19-inch relay rack 6 feet high. The electronics are crystal oscillators, timers and motor-driven cams and micro-switches, a solid-state power amplifier, and power supplies. Any one of the release codes can be dialed in by a combination of switches. The unit can be manually operated such that just one code is sent or switched into automatic so that it will continuously repeat the set-in code at a repetition rate set by a timer pointer on the control panel. The power-supply voltage controls the output power, and the maximum safe power is red-lined on the meters. The maximum electrical power for driving the transducer is 400 watts.

Sonar-Recall Transducer (Fish)

The sonar-recall transducer (Fig. 8) is towed behind the recovery ship. It is a cylindrical assembly of rectangular crystals of barium titanate mounted like staves in a barrel. Eight of these barrels are assembled end to end to form a transducer approximately 3.5 feet long and 3/4 feet in diameter. A watertight boot covers the crystals. Streamlining, fairings, and tail fins increase the length to approximately 7 feet. Rails are mounted on each side to provide attachment points for the towing harness. The transmitting transducer has a resistance of 30 to 50 ohms and a capacitive reactance of approximately 40 ohms at the operating frequencies. Energy is radiated radially from the cylinder, with an output minimum to the front and rear. The energy beam is approximately 17 degrees wide, measured at the points 6 dB down from maximum.

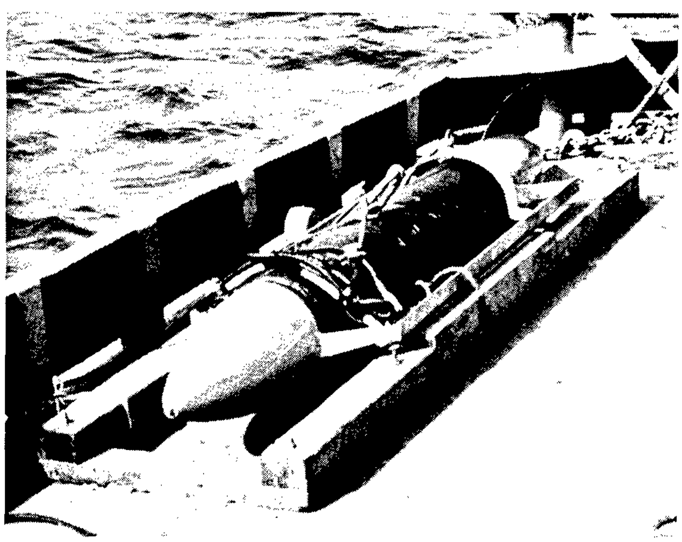

Fig. 8—Sonar-recall transducer (fish)

Radio Beacon Direction Finder

An Ocean Engineering Corporation hand-held loop has been used for radio direction finding. This direction finder is a completely self-contained radio-beacon locator. The loop is a bidirectional system, and sense orientation is obtained by switching in a vertical whip which unbalances the loop, with maximum signal obtained where one leg of the loop and the whip are in phase. This direction is indicated by a white band on the loop.

DEPLOYMENT AND RECOVERY OF THE AMBIENT NOISE BUOY

Eleven of the 12 buoy deployments and recoveries which had taken place as of July 1971 were from the USNS *Gibbs*. The other drop was the first and was an engineering trial from a small personnel boat in the Bermuda harbor. Any handling of an Ambient Noise Buoy is greatly dictated by the size of the ship and the equipment available. The description of a deployment and recovery which follows is predicated on the use of the USNS *Gibbs*.

Deployment

A typical configuration after deployment is shown in Fig. 9. Prelaunch duties include charging the batteries, setting the clocks, testing the amplifiers, and making a calibration run on the tape. (The calibration run is usually 10 minutes at 0 dBV with a 1-minute break and 10 minutes at −10 dBV for 25, 50, 100, 200, and 400 Hz.) The anchor is in place at the starboard U frame. The 3/8-inch polypropylene anchor line and strain member for the hydrophones has been transferred to the Almon Johnson winch which feeds the U frame. If this is a one-hydrophone deployment, then the 50 feet of RG-58A/U electrical cable is coiled, ready to be attached to the buoy, and then thrown overboard by hand. If this is a multihydrophone deployment, then the precut RG-58A/U cable is on separate reels ready to be married onto the support line.

The closed buoy with the electronics operating and a vacuum drawn down to 6 psi is brought down to the starboard U frame by the ship's crane. The anchor, which weighs 350 pounds in air and 300 pounds in water, is fastened to the anchor line. It is then lowered over the side into the water. Line is payed out from the winch to the desired length of the buoy package off of the ocean floor. At this point the 3/8-inch polypropylene line is tied off to the U-frame platform. It is then made fast to the buoy release mechanism. The hydrophone cable and the polypropylene line are made fast to the top of the buoy. The tie-off point on the platform is cut, and the buoy is lowered into the sea (Fig. 10). Both the RG-58A/U cable and the polypropylene line, are payed out to the desired lengths, the electrical cable being hand fed from the reels on a stand and the polypropylene line from the Almon Johnson winch. Ten-inch glass balls are attached 500 feet apart to provide adequate flotation and to keep the hydrophone string upright. The RG-58A/U cable and polypropylene line are taped together at 500-foot intervals. Whether the procedure be for a string of two, four, or more hydrophones, it is the same. An additional glass ball is added 50 feet above each hydrophone. At the end of a string and 50 feet above the last hydrophone a 16-inch glass ball is used and the line is tied off to the U-frame platform. The line is cut from the winch and then from the platform; the launch is complete.

Recovery

The recovery is started by arriving at the site and streaming the recall fish. On the *Gibbs* the fish is towed over the starboard side just forward of the stern. The fish must have enough cable to be at least 15 feet below the surface while being towed; the transducer can be damaged if it is operated above 15 feet. The sonar-recall rack is energized, the proper code having been set in previously. The buoy, after release, rises at a rate of not more than 6 feet per second. If the buoy had been 10,000 feet deep, then it would take 28 minutes to surface.

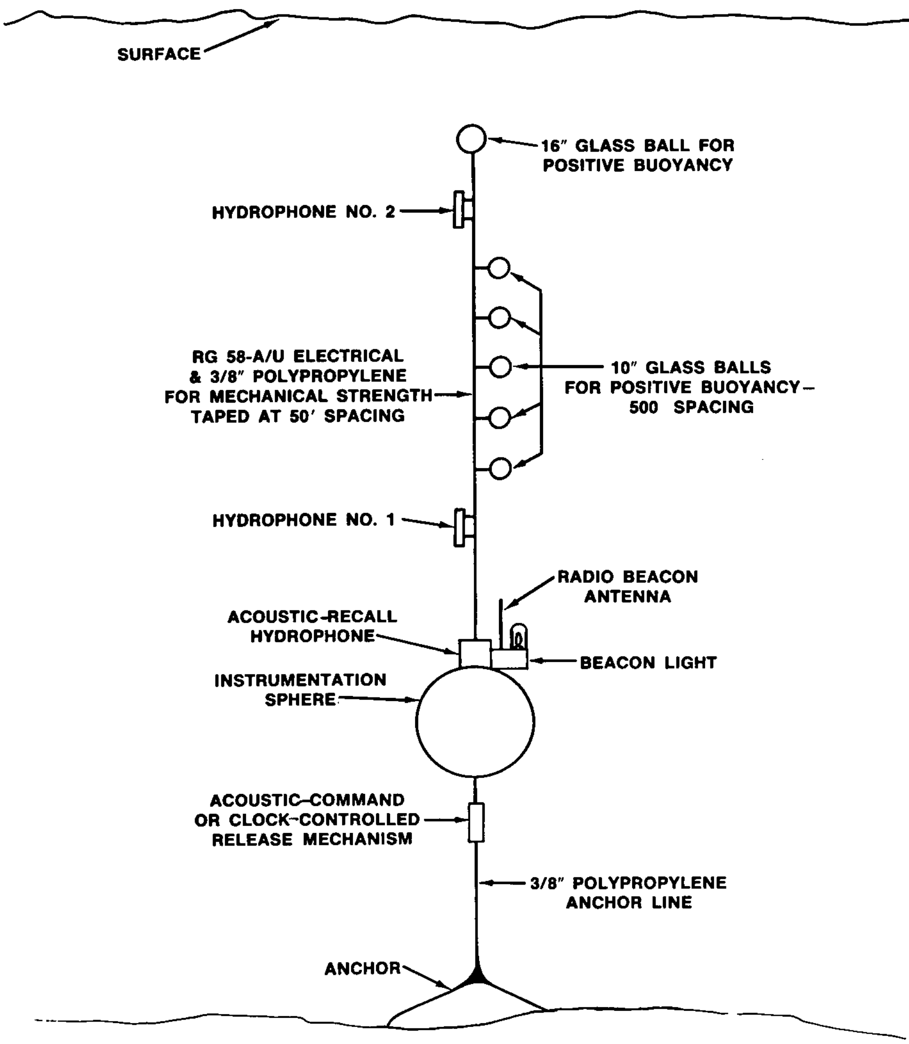

Fig. 9—Typical deployment configuration of an Ambient Noise Buoy

Since one has no way of knowing if the unit has released, the fish is towed during this time and the code transmitted. When the buoy surfaces, its radio beacon energizes, and this is picked up with the hand-held direction finder. Other communication equipment on the ship can be tuned to this frequency. If the unit is not heard from, after an appropriate length of time, then a search pattern is set up and the tow continued. If there is still no radio beacon heard or visual sighting, then it is a matter of waiting to see if one of the clocks will bring the buoy to the surface.

Once the buoy string is sighted in the water, the top float must be located. For a single-hydrophone buoy this is easy. For a multihydrophone buoy the weather and the currents will vary the pattern which the line and floats assume on the surface. Care must be taken not to foul the line under the ship. The ship has to approach the line and grapple for the top float. Once this is on board, the float is cut from the support line. The line is further pulled in, and the top hydrophone is cut free. From here on the polyproplene line is continued to be pulled in over the sheave on the starboard U frame to the Almon Johnson winch. The RG-58A/U electrical cable is cut from the support line

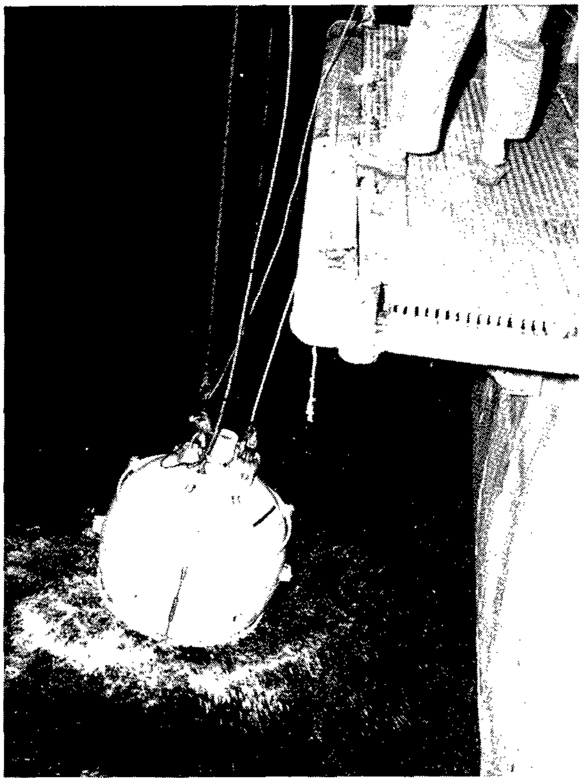

Fig. 10—An Ambient Noise Buoy being launched

and allowed to sink. The floats are removed and stored. When all the hydrophones and support line have been recovered, the buoy is pulled on board.

As soon as is practical the beacon antenna and the beacon light are removed. The buoy is opened, and a calibration is run on the tape as was done prior to deployment. All circuits are turned off, and the buoy is closed. It is then washed down with fresh water and the plastic cover put over the sphere. The hydrophones also need to be opened and their batteries disconnected from the preamplifiers.

RESULTS OF DEPLOYMENTS

As was mentioned, there have been 12 deployments of the Ambient Noise Buoy as of July 1971 (Table 2). The shortest duration other than the 3 hours on the engineering trial was 4 days and 20 hours. The longest deployment was 18 days and 4 hours. A total of 1218 hours of data has been obtained from these 12 deployments. Six of the buoys were acoustically recalled. In four more cases the ship was late getting on station, and the buoys were already on the surface, having been released by one of the clocks. One buoy was lost at sea. But it was later found and picked up by a passing merchantman and was being returned to NRL as of this writing.

Table 2
Summary of the First 12 Deployments of the Ambient Noise Buoy

Deployment		Buoy No.	Area	Water Depth (ft)	Sphere Depth (ft)	Hydrophones		Duration			Data on the Tape (hr)	Cause of Surfacing	Operation of the Beacon Light	Operation of the Radio Beacon
No.	Date					No.	Depths (ft)	Full Days	All Hours	Total Hours				
1	10-13-70	18	Bermuda	80	70	1	50	0	3	3	3	Recall	OK	OK
2	11-21-70	18	Bermuda	9,800	350	1	300	6	22	166	162	Recall	OK	OK
3	11-22-70	26	Bermuda	10,400	350	1	300	7	8	176	168	Backup clock*	OK	OK
4	3- 2-71	26	Exuma Sound	5,400	5,340	4	5,290; 3,790; 2,290; 690	5	11	131	131†	Recall	OK	OK
5	3- 2-71	26	Exuma Sound	4,440	540	1	490	5	12	132	0‡	Recall	OK	OK
6	3- 2-71	29	Exuma Sound	5,560	5,000	2	4,955; 555	4	20	116	232	Recall	OK	OK
7	3-15-71	29	Caribbean Sea	13,500	13,400	2	13,300; 3,500	18	4	436	204§	Backup clock¶	OK	OK
8	3-16-71	27	Caribbean Sea	13,500	1,300	2	1,200; 500	17	3	411	0**	Backup clock¶	OK	For 6 hr
9	3-17-71	18	Caribbean Sea	12,500	12,400	1	12,300	17	22	430	104††	Digital clock‡‡	NG	NG
10	3-17-71	26	Caribbean Sea	12,400	12,200	1	12,100	16	21	405	214	Digital clock‡‡	OK	OK
11	3-18-71	30	Caribbean Sea	12,100	12,000	1	11,900	16	11	395	0§§	Recall	OK	NG
12	3-19-71	16	Caribbean Sea	12,600	12,400	2¶¶	12,300¶¶	—	—	—	—	—***	—	—

*A wire was broken between the recall hydrophone and the receiver. The backup clock was set prior to the digital clock.
†Data from one hydrophone only. One hydrophone had wires reversed, causing its battery to explode; two hydrophones leaked.
‡The recall hydrophone leaked, shorting out the noise hydrophone at the Mecca connectors.
§The top hydrophone worked only the first few minutes; a leak is suspected.
¶Not on station to use acoustic recall. The backup clock was set prior to the digital clock.
**The recorder stopped before deployment due to a bad tuning fork.
††The recorder stopped after one pass due to an improperly adjusted pinch roller.
‡‡Not on station to use acoustic recall.
§§The recorder stopped before deployment due to metal chips in the drive gears.
¶¶The second hydrophone was not connected following discovery of a seawater ground in the RG-58 A/U cable.
***Lost at sea but later found by a passing ship and is being returned to NRL (July 1971).

FUTURE USE AND IMPROVEMENTS TO THE AMBIENT NOISE BUOYS

Deployments Planned in the Near Future

In addition to the 12 deployments reported herein, 14 more drops are planned during the remainder of the calendar year 1971. It is planned to make three buoy deployments in the North Atlantic. One unit will be of the present type and will have a duration of 2 weeks. The other two units are being modified and will be deployed for a year. These units have a new electronic clock system that will control the tape recorder and allow sampling of data over this extended period; the present design turns the recorder on for 2 minutes each 4 hours. This sampling Ambient Noise Buoy will be described in a future report. Subsequent to the three deployments in the North Atlantic, seven deployments will be made in the eastern Atlantic, followed by four at an undetermined site.

Equipment Changes

An investigation is underway into other types of cable, both electrical and mechanical, as well as an integrated mechanical and electrical cable.

The lifting harness and vertical attachments to the sphere are being made stronger and simplified. These modifications will be completed in time for the remaining deployments in 1971.

A new automatic direction finder manufactured by the Ocean Applied Research Corporation has been purchased and is being made a permanent installation on the USNS *Gibbs*. This unit has a fixed antenna system which is electrically swept in bearing and whose output is displayed on a cathode-ray tube. This unit will be far superior to the hand-held model. A study is being made on the feasibility of adding an acoustic pinger or transponder to the buoy.

The possibility of using two separate acoustic release systems in parallel and removing the clocks is being studied, and two of the remaining buoy deployments of 1971 will be so outfitted.

A study is underway as how best to improve the system's dynamic range by such means as logarithmic amplifiers and automatic ranging amplifiers.

All of the tape recorders left from the Nutmeg buoy system are being modified to operate with one, two, or four hydrophones. The recorder circuitry controlling the starting, stopping, direction of tape movement, and end of tape stoppage is being redesigned to make the recorders more reliable and usable not only in the continuous mode but also in future sampling modes.

Digital Ambient Noise Buoy

A design concept has been completed and steps taken to purchase the major components to build an Ambient Noise Buoy which will use a mini-computer. The analog processor will provide certain signal conditioning prior to conversion to digital form. This may include filtering, integration, and squaring. The heart of this buoy will be its computer and digital tape recorder.

SUMMARY AND COMMENTS

The proposal to construct, deploy, and recover a long-term buoy system which can continuously direct record analog data on magnetic tape in the band from 20 to 400 Hz has been demonstrated to be feasible and practical. By starting with the shells and the housekeeping of surplus seismic buoys left from Project Vela Uniform and by the modification and integration of the tape recorder left from the buoy system called Nutmeg, NRL has been able to build seven Ambient Noise Buoys. Twelve deployments have been made as of July 1, 1971, with over 1200 hours of ambient noise data. This buoy system is unattended and bottom mounted and can be left in even the remotest areas of the ocean for up to 40 days. Fourteen deployments in addition to the 12 described herein are planned in 1971. Some of these will use buoy systems with modifications allowing deployment for a year.

The Ambient Noise Buoy can greatly increase the amount of data collected for a given amount of ship time. Since this buoy system is left unattended, the data is not contaminated by one's own ship. Also, because the system is bottom mounted and there are no surface floats or flags, the wind and waves do not effect the deployed string and thereby the data. There is sufficient tape at the speed of the tape recorder to record continuous data from one hydrophone for 18 days. Up to four hydrophones can be used with a subsequent loss in longevity by a factor of the number of hydrophones. The deployments can be made for extended periods up to a year by sampling and turning on and off the tape recorder as long as the total sample time does not exceed the 18 days or 432 hours.

Included in enlarged future programs will be buoys capable of an increased number of hydrophones, increased frequency band, increased dynamic range, and on-board data processing using a mini-computer.

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Naval Research Laboratory Washington, D.C. 20390	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

INITIAL CONSTRUCTION AND DEPLOYMENTS OF THE LONG-TERM AMBIENT-NOISE BUOY

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Status report on the first phase of the NRL Problem, which is continuing.

5. AUTHOR(S) (First name, middle initial, last name)

Walter C. Diehl

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
May 16, 1972	22	3

8a. CONTRACT OR GRANT NO. NRL Problem K03-17 b. PROJECT NO. R2408 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) NRL Report 7403 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Department of the Navy Office of Naval Research Arlington, Virginia 22217

13. ABSTRACT

The Systems Engineering Staff of the NRL Acoustics Division has the requirement to build a long-term, unattended, bottom-anchored buoy for collecting acoustic ambient noise in the deep ocean. With a nucleus of surplus equipment from two buoy projects of the 1960's plus additional equipment designed and built at NRL, seven Ambient Noise Buoys were fabricated. One was designed for investigation in the frequency range of 1 to 10 Hz with four hydrophones, three were designed for the band from 20 to 400 Hz with two hydrophones, and three were designed for the band from 20 to 400 Hz with one hydrophone. The first 12 deployments using these buoys yielded recordings of over 1200 hours of acoustic ambient noise in the sea. This initial report was written as of July 1, 1971. It is a summary of the system, method of deployment and recovery, and the results of the first 12 deployments, involving continuous recording for up to 18 days. Future improvements and experiments to be more fully described in later reports involve data sampling and permit operation up to a year. A future second-generation buoy will include a miniature computer for some signal conditioning and conversion to a digital form.

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Underwater acoustics						
Acoustics						
Unattended moored buoys						
Ambient noise						
Tape recorder						
Hydrophones						

DD FORM 1 NOV 65 1473 (BACK)
(PAGE 2)

Security Classification

☆ U.S. GOVERNMENT PRINTING OFFICE : 1972—483-540/V-770