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DEVELOPMENT OF A TELEMETERING OCEANOGRAPHIC BUOY. A SYSTEM CONC--ETC(U)

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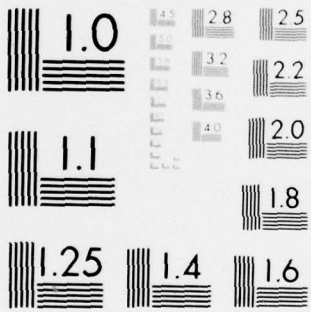
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**DEVELOPMENT OF A TELEMETERING
OCEANOGRAPHIC BUOY**

**A SYSTEM CONCEPT FOR
SYNOPTIC DATA COLLECTION**

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Prepared by
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INTRODUCTION

Basic knowledge of the world's oceans has been acquired using devices for the collection of oceanographic data such as the research vessel, the Nansen bottle, the inverting thermometer, the bathythermograph and the echo sounder.

Further understanding of the oceans involves synoptic study of oceanographic and meteorologic phenomena. Research vessels seldom remain long on one station and rarely operate with other ships occupying fixed stations. Thus, a long-time synoptic picture of the ocean is entirely lacking.

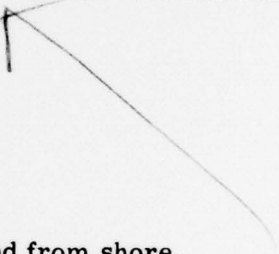
To remedy this situation, a general-purpose telemetering oceanographic buoy system is being developed at General Dynamics/Convair under ONR Contract Nonr-3062(00).

This effort, begun four years ago, was aimed first at assembling in one volume all the scattered information that would be necessary to investigate the feasibility of a system for oceanographic telemetry. After compiling this information, the procedures and mathematic models were converted so as to be mutually compatible regardless of source, and simple graphical methods were devised for their use. It remained to test the methods. Certain VHF telemetry systems then in routine use were evaluated using the new methods to test their accuracy. Successful performance was indicated when the theoretical evaluations agreed closely with actual observed system performance. The oceanographic telemetry volume, published in November 1960, is in its second printing and is widely used.



While investigating the feasibility of new uses of radio telemetry, it was found that: given 2 or 3 frequencies to choose from, it should be possible to telemeter data at useful rates with as little as 100 watts of transmitter power at any time of day, from a buoy located as far away as 2,500 miles.

A proposal then was submitted to the Office of Naval Research outlining a plan to develop a telemetering buoy. The proposal was reviewed by a technical panel of the Guidance Committee composed of representatives from the Navy Oceanographic Office and the Office of Naval Research. It was recommended that each buoy have the following capabilities.

- 
- a. 100 channels of scientific data.
 - b. Sample each channel once per hour.
 - c. Telemeter data four times per day on command from shore.
 - d. Store all data on board for one year.
 - e. Remain effective on station for one year.
 - f. Telemeter a distance of 2,500 miles or more.

System development has proceeded based on these typical requirements. The Principal Investigator also has established environment limits for successful buoy performance: wind velocity 150 knots, wave height 60 feet and breaking, and current velocity 10 knots. Flexibility of system concept, and buoy power and space accommodations permit an increase or decrease in system capability with minimum changes or costs. The buoy system should be capable of application to a wide variety of oceanographic and meteorological tasks. The same shore equipment will acquire data from a single buoy or a field of 999 buoys. Finally, the entire system is being developed using off-the-shelf components of known reliability, with standard rack-mounted electronics equipment used in the buoy.

1 | DATA ACQUISITION USING BUOYS

Except for specialized investigations with drifting buoys, most of those used to gather oceanographic and meteorological data will be moored. It is now possible to design reliable moorings for almost any depth of the ocean.

A moored buoy can obtain meteorological data in essentially the same way as is done automatically on shore. Oceanographic data will be obtained by placing sensor packages at intervals along a mooring line containing one or more electrical conductors (see Figure 1).

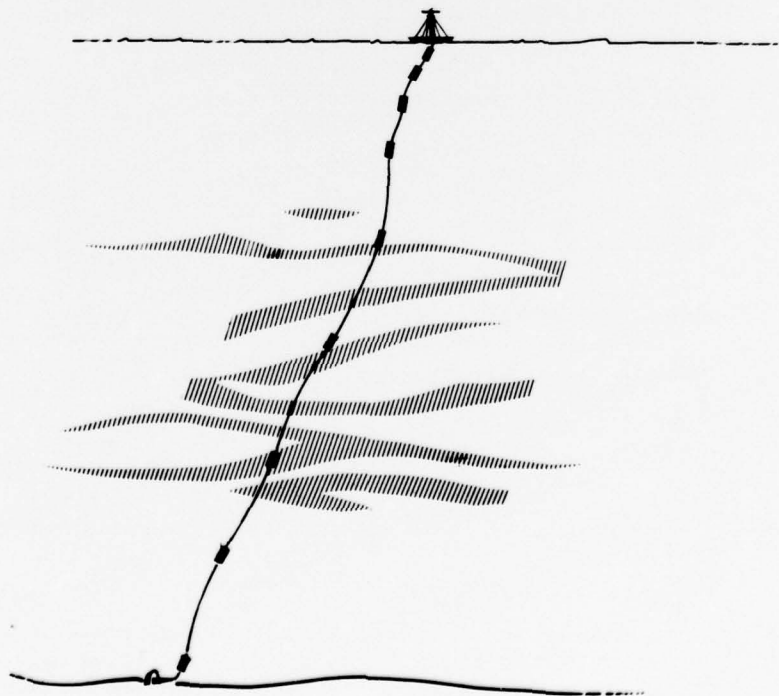


Figure 1. Telemetering Buoy with Sensor Packages in Mooring Line

Sensors now exist, or are being developed, that will give the following data:

a. Oceanographic:

1. Current direction and velocity.
2. Water temperature.
3. Salinity.
4. Oxygen dissolved.
5. CO₂ dissolved.
6. Sound velocity.

} Continuous from surface to bottom, or at standard depths.

7. Wave profile, surface.
8. Wind velocity and direction, surface.
9. Insolation.

b. Meteorological:

1. Wind direction and velocity.
2. Air temperature.
3. Relative humidity.
4. Incident vs. reflected radiation.
5. Barometric pressure, surface.
6. Precipitation.
7. Rocketsonde data.

} At standard height above surface.

Such data may be recorded or telemetered, continuously or at intervals.

Generally, it is considered best to telemeter data to shore upon command at

least 4 times each 24 hours, to afford an extra measure of redundancy in telemetry. It also appears desirable to record on board all data obtained during the time the buoy is on station.

It is not necessary to continuously measure the output of each sensor. Some parameters have long time constants; instantaneous sampling at hourly or daily intervals will give valid data. Other parameters have shorter time constants; sensors measuring these variables must have their outputs smoothed so that an hourly instantaneous sampling is a meaningful average value. In the case of surface waves, it is now feasible to measure directional spectra from a buoy, which involves special data treatment.

In many cases, the accuracy with which the data can be telemetered to shore approaches or equals that presently realized using classical collection methods. There is no fundamental limit that prevents over-all telemetering system accuracies exceeding those now possible in data collection aboard research vessels.

Telemetry of data over distances of 2,500 miles in the absence of satellites involves ionospheric radio propagation. But it is now feasible to use shortwave radio in more sophisticated ways than that represented by CW using Morse code. Scientific literature does not yet reflect the recent advances. However, the ONR-sponsored experiments have verified that binary encoding, pulse-code-modulation of a single-sideband transmitter by a frequency-shift keyed subcarrier oscillator gives significantly better results than other techniques. This is probably the best method for oceanographic telemetry.

Depending upon the time of day, the season, and the status of the 11-year sunspot cycle, certain radio frequencies will work well over a certain path when others will not. The National Bureau of Standards has developed a prediction technique involving the digital computer facility at its Boulder, Colorado Laboratory. Studies of actual radio path performance agree with NBS predictions. These recent experiments, carried out under this contract, also have verified that if a buoy can be interrogated on and transmit on one of at least two properly chosen frequencies, reliable telemetry should be possible at any time with low power over great distances. A report on these results is now in preparation.

Interrogation is vital in ionospheric telemetry. Accurate clocks are available that will initiate transmission satisfactorily at preset intervals. But the intervals chosen for January, for example, are no longer optimum in July.

Clock-controlled transmission is to be avoided, partly due to nature's unwillingness to perform according to a set schedule, and partly to the unwillingness of the FCC (or ITU) to permit "uncontrolled" operation of a transmitter operating in the 3 to 30 mcps range, capable of causing world-wide interference.

Using single-sideband, suppressed-carrier modulation for both telemetry and interrogation permits each to be done on the same radio frequency (see Figure 2). Under this system, several interrogations and telemeterings to and from different buoys and shore stations can be made simultaneously on the same frequency with no problem of heterodyning or other degradation. Although this capability requires crystal control of both receiver and transmitter, it does ensure maximum system reliability. Significant savings in radio-spectrum space can be realized if these techniques are used. Frequency allocations for the exclusive purpose of oceanographic telemetry are now a matter of international negotiation, and a favorable outcome is anticipated.

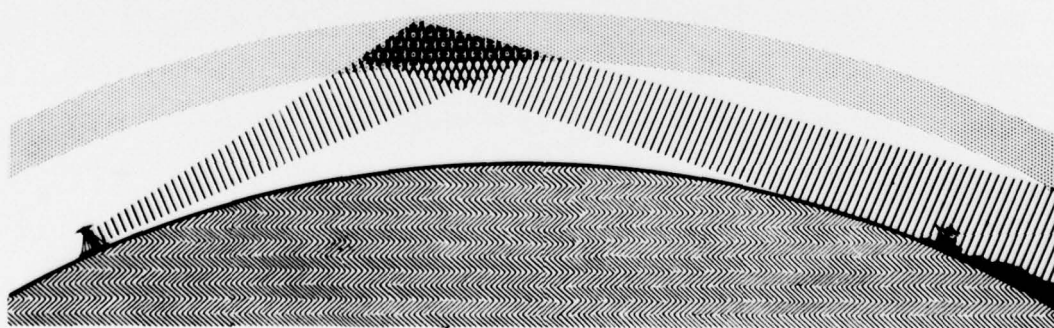


Figure 2. Ionospheric Radio Telemetry From an Oceanographic Buoy to Shore Station

A buoy system can be developed having sufficient flexibility to be applicable to research as well as to surveys. The system will be capable of a wide variety of tasks provided that:

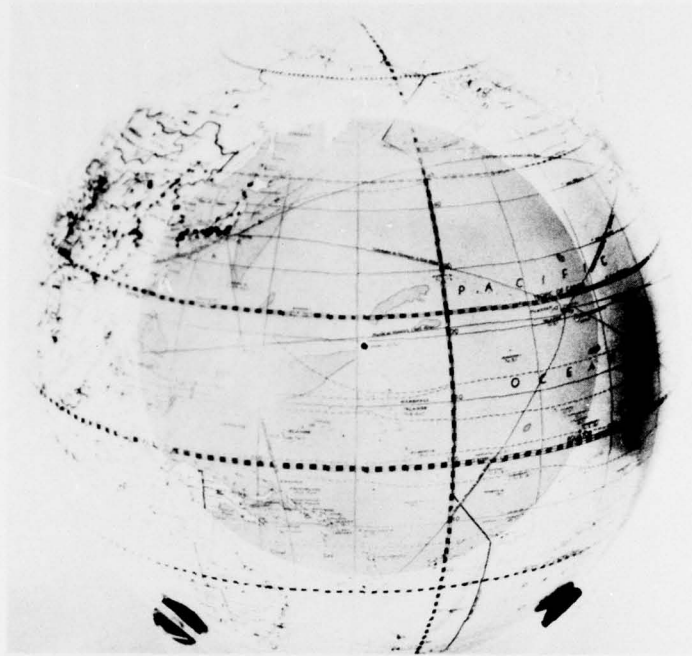
- a. Its data-acquisition system is not arbitrarily limited in capability.
- b. Different electronic packages can be plugged in.
- c. The buoy can operate in deep or shallow water, alone or in groups, and closely or loosely spaced.

In fact, research and survey tasks could be done at the same time on the same buoy.

The capability limits of a buoy system should be fixed in the same way as for a ship, aircraft, or missile system. The system capability will be between the upper limit, defined by such real limits as data rate and a certain lower limit set by the economy of logistics such as deployment costs. The system will not be economical if not operating continuously; however, if it can be kept busy, it may be false economy to set arbitrary limits on maximum capability. The cost of deployment alone indicates a certain minimum cost allowance for hardware. Such upper capability limits as the data rate that can be sent over an ionospheric radiotelemetry link are real, and it is proper to design hardware within these limits. But between these and the minimum capability set by the economy of logistics, the limit of actual hardware capability should be placed as high as possible.

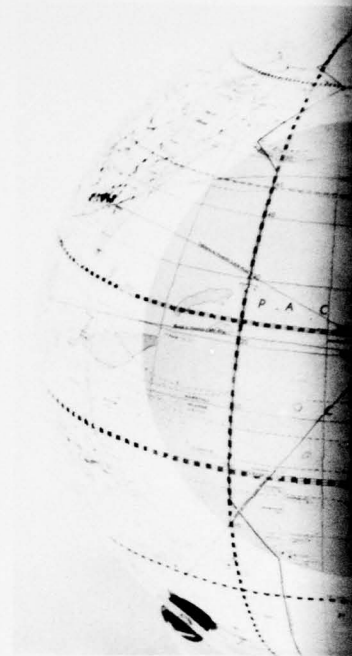
Although it is convenient to think in terms of a buoy, it must be considered a system. The Polaris missile, for example, is useless without its supporting system. Both are useless without an adversary. The same is true of a buoy system, and the same criteria may be used in the development of each. To be successful, both technically and economically, all possible purposes to which the buoy might be put must be carefully considered — the ocean areas to be covered, the shore stations required, number of buoys required, and philosophy of logistic support determined. Hardware development must proceed concurrently. Sea-going hardware must be carefully planned and conservatively built for high reliability. It must have been rigorously tested, ashore and afloat, before spending a year in the ocean environment.

The maps in Figure 3 illustrate the ocean areas that could be studied synoptically by this system. They show four typical locations for command/receiving stations — three with hard-line communications to Washington, D.C. The maps are polar projections over each location. The circles on each map indicate that synoptic data could be gathered routinely from any number of buoys in that area by the shore station at the center. A range of 2,600 miles has been demonstrated conclusively in the propagation experiments conducted in this program.



WAKE ISLAND

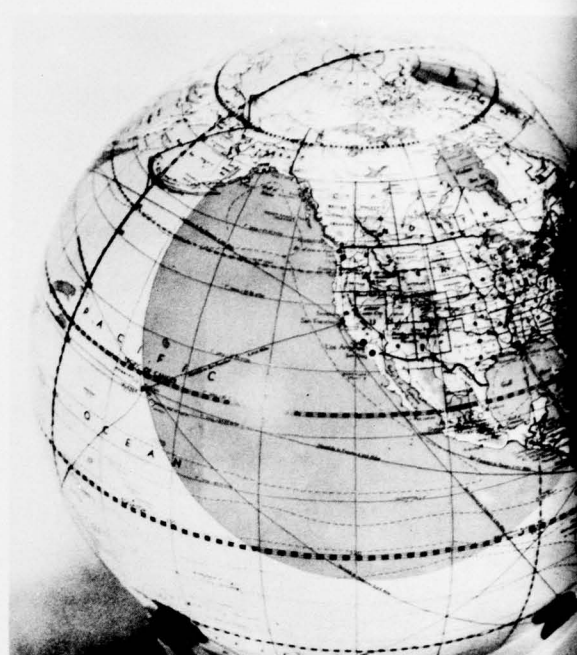
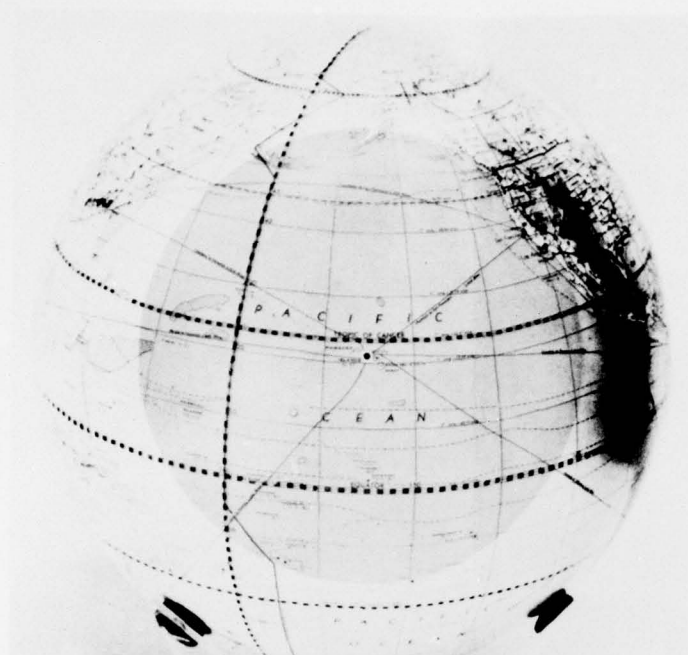
A 2,600-mile radius reaches Bismarck Archipelago, Rabaul, Bougainville, the Solomon Islands, and New Guinea southwesterly; Canton Island, southwesterly; Hawaii to the east; Kamchatka and the Aleutian chain to the north; reaches Tokyo, and Korea, northwesterly; easily passes Guam to reach Yap Island, westerly.



HAWAII

A 2,600-mile radius reaches the Aleutian chain, the Equator, and includes Christmas Island easterly and easily reaches San Diego northeasterly; reaches the Hawaiian Islands and Gilberts to the west and the Aleutian chain is just over 2,000 miles.

Figure 3.



Archipelago,
lands, and New
southwesterly;
Aleutian chain
north-
Yap Island,

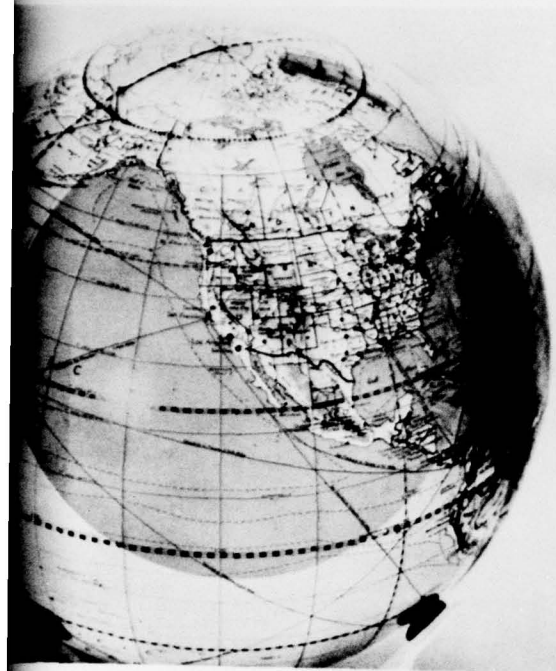
HAWAII

A 2,600-mile radius reaches Tahiti, south of the Equator, and includes Christmas Island; to the Marquesas easterly and easily to Canton Island westerly; San Diego northeasterly; Wake Island, the Marshalls, and Gilberts to the west and southwest; the Aleutian chain is just over 2,000 miles northerly.

SAN DIEGO

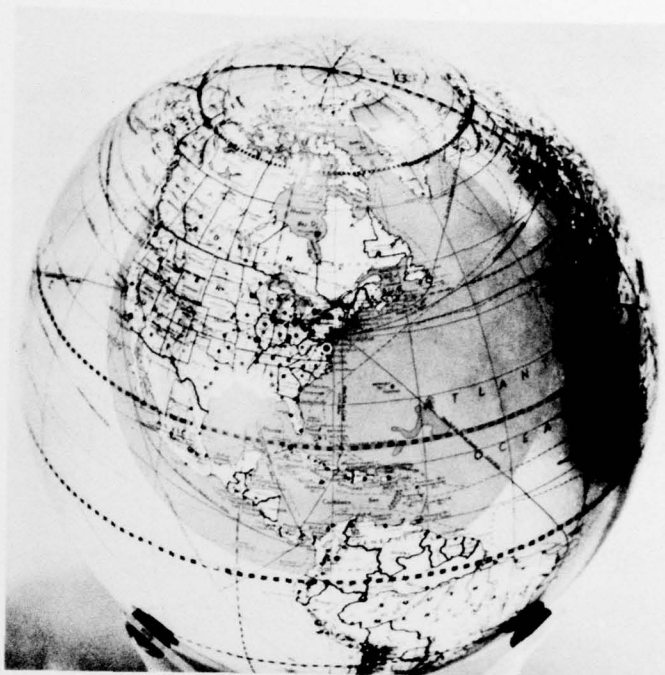
A 2,600-mile radius reaches the Alaska Peninsula, Hawaii; beyond the Equator; and to Costa Rica, eastern boundary of the central Pacific.

Figure 3. Area Coverage, Typical Deployment of Four Command/Receiving Stations



SAN DIEGO

The radius reaches the Alaska Peninsula;
beyond the Equator; and to Costa Rica, on the
southern boundary of the central Pacific.



WASHINGTON

A 2,600-mile radius touches Greenland; the Azores
to the east; the Isthmus of Panama, Colombia, Vene-
zuela and Ecuador are to the south; Puerto Rico,
Bermuda, Port of Spain, and the entire hurricane-
breeding area are less than 2,000 miles to the south-
east; the entire Gulf of Mexico lies less than 2,000
miles to the southwest.

Command/Receiving Stations

4 | ONR BUOY DEVELOPMENT PROGRAM

The ONR Telemetering Oceanographic Buoy is being developed under the system concept so that future expansion of capability may be easily accomplished. For example, the first operational buoys will be interrogated manually from a command and receiving station that will record data on magnetic tape for insertion into a computer. Eventually, without any change in basic hardware, data will be fed directly into the computer. Later still (again with no basic changes), the computer will be set up to interrogate each buoy, to decide if the response is error-free, and to acquire and process the data immediately. Operation will be entirely automatic. Also, the ONR Buoy System is being developed so that any number of buoys or command stations eventually can operate simultaneously, even on identical radio frequencies. All would be under direct control of a central data-acquisition facility responsible for an entire ocean or hemisphere, with no change in basic concept or existing hardware.

The building-block concept is the most economical way to achieve optimum system capability. It permits operational use of the system as it evolves and avoids obsolescence.

System components are being chosen from available equipment wherever possible. All components are being tested both ashore and at sea to ensure high reliability. Logistics and system maintenance are also considered.

Figures 4 and 5 are block diagrams of the data acquisition system in each buoy and in the command/receiving station. These represent preliminary thinking; actual system design is now being done.

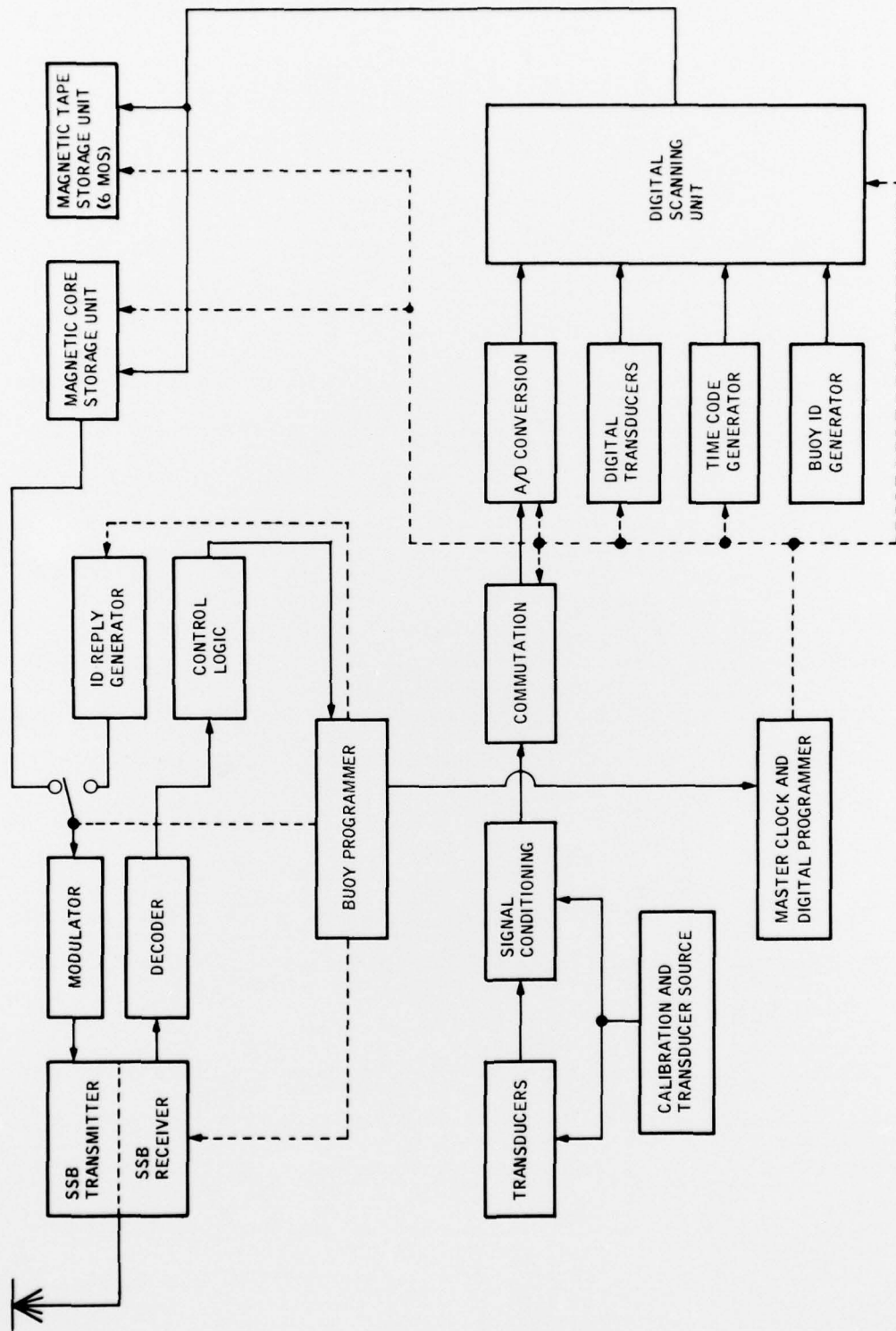


Figure 4. Data Acquisition System

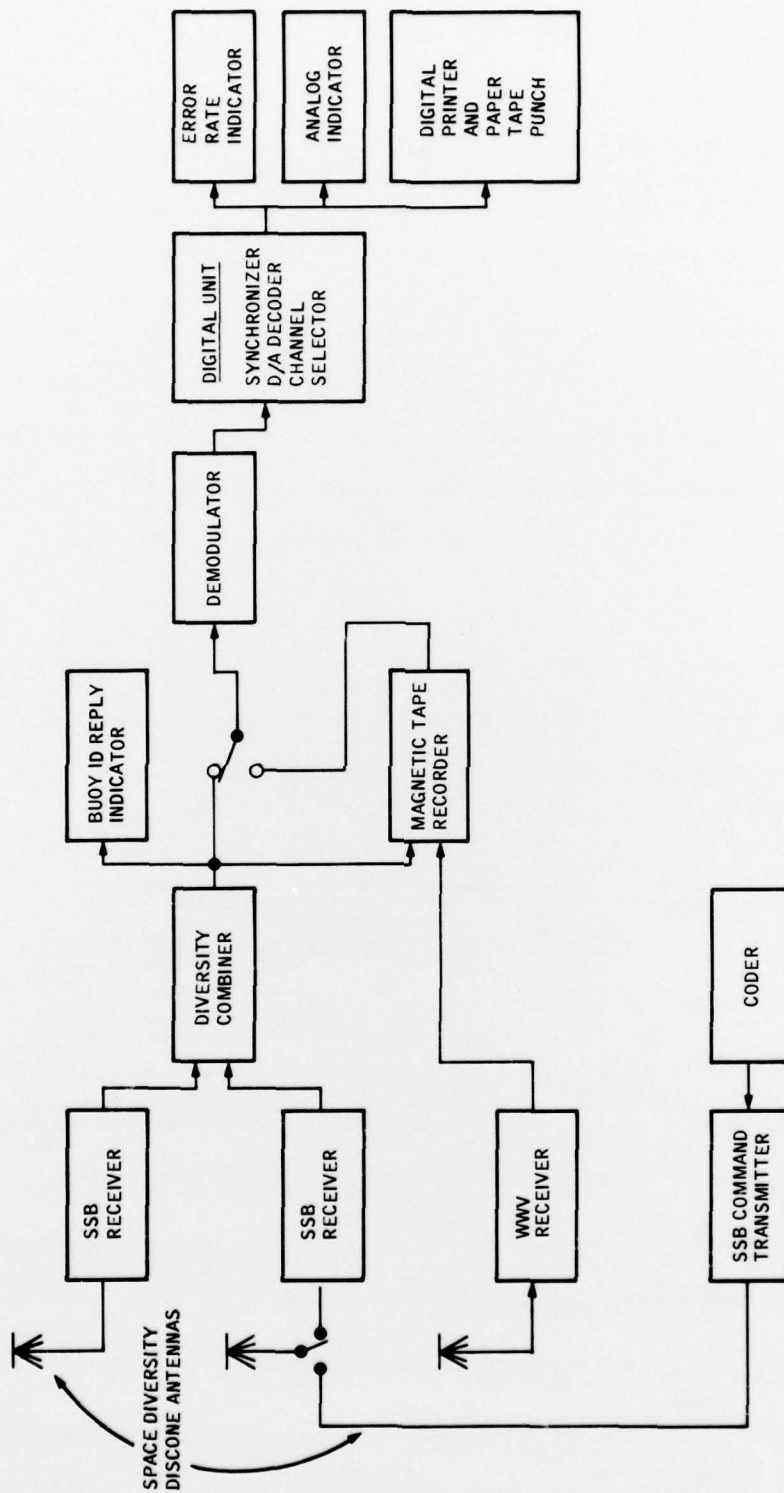


Figure 5. Mobile Command Receiving Station

4.1 SELECTION OF HULL SHAPE

A comparative evaluation has been conducted of the shapes that could be used as hulls for oceanographic buoys. Hundreds of test runs in a hydrodynamics towing basin have been analyzed. The disc shape (Figure 6) was chosen as the optimum for a telemetering oceanographic buoy for the following reasons:

- a. Being nonresonant, the disc precisely follows the contours of waves, whose slopes seldom exceed angles tolerable for efficient operation of a radio-transmitting antenna. The pronounced resonance typical of a rolling ship, or of spar buoys, which also degrades wind direction and velocity measurements even in moderate weather, is entirely absent.
- b. Because the disc closely follows wave contours, wave profile and even wave directional spectra may be measured from its motions. This is possible partly because the disc is symmetrical.
- c. Being symmetrical, the disc may easily adjust to forces of wind, waves, and current impinging upon it from conflicting directions. This is true also of spar and torus buoys, but their hydrodynamic drag is comparatively great.
- d. The hydrodynamic drag of the disc is small, less than that of most boats either in the displacement mode or the planing mode. It places minimum demands upon the mooring that holds it on station.
- e. The disc has the most favorable lift-to-drag ratio, and may be constructed to have the greatest freeboard buoyancy of any practical shape.

4.2 RELIABILITY AND STANDARD COMPONENTS

Reliability and economy can be achieved in complicated electronic systems if component circuits are selected from off-the-shelf equipment. Solid-state

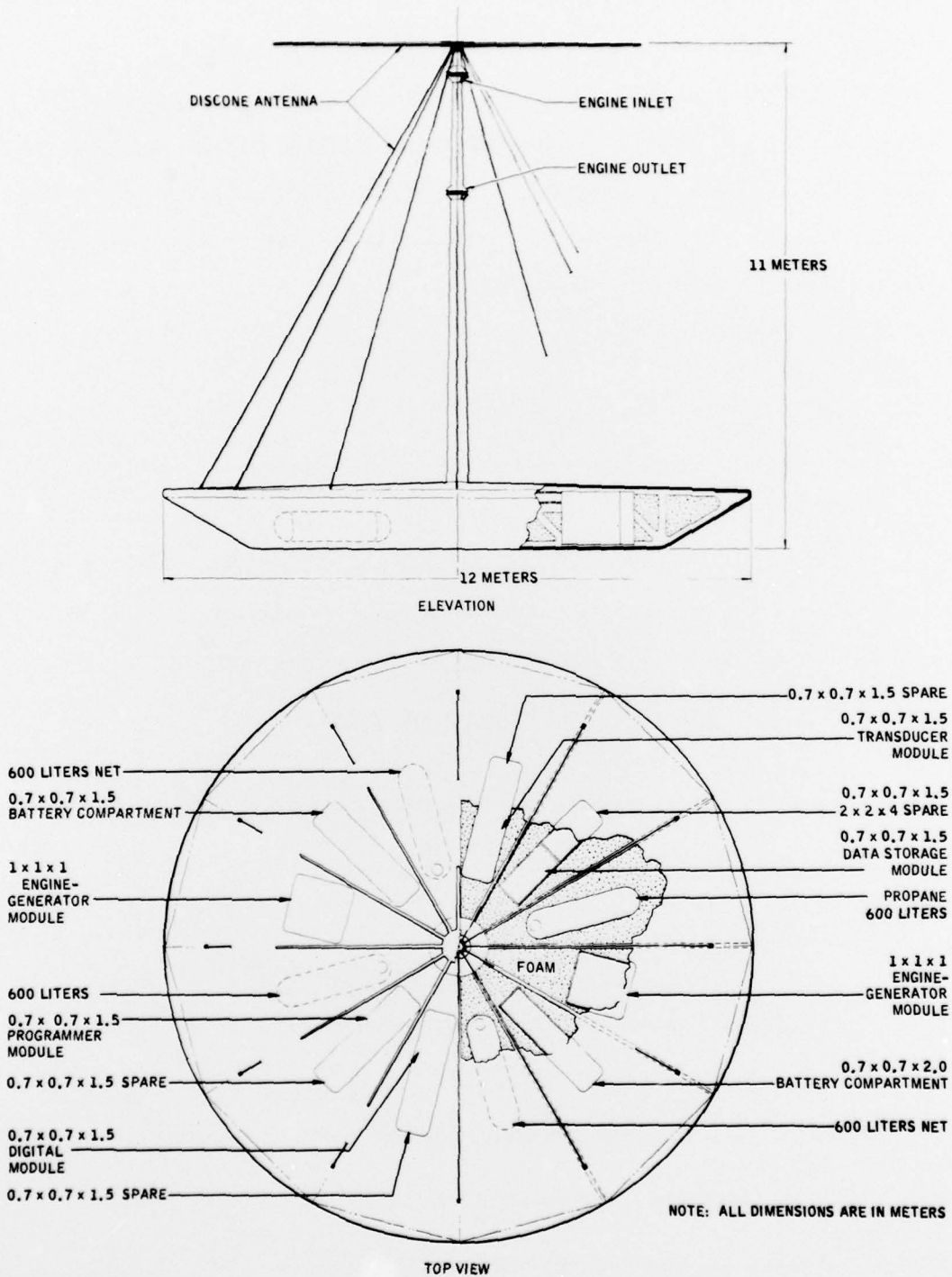


Figure 6. ONR Telemetry Buoy Configuration

circuitry, involving silicon transistors and diodes, welded connections, and plastic encapsulation, is commonly available in a standard 19-inch, rack-mounted configuration (see Figure 7). This combines the ruggedness of field equipment with the accuracy and reliability of laboratory equipment at mass-production prices. By eliminating miniaturized equipment except in the underwater packages, the ONR Telemetry Buoy is evolving as an economical, highly reliable, easily maintained system. Much of the equipment commercially available at reasonable cost has been given the NASA certification of reliability.

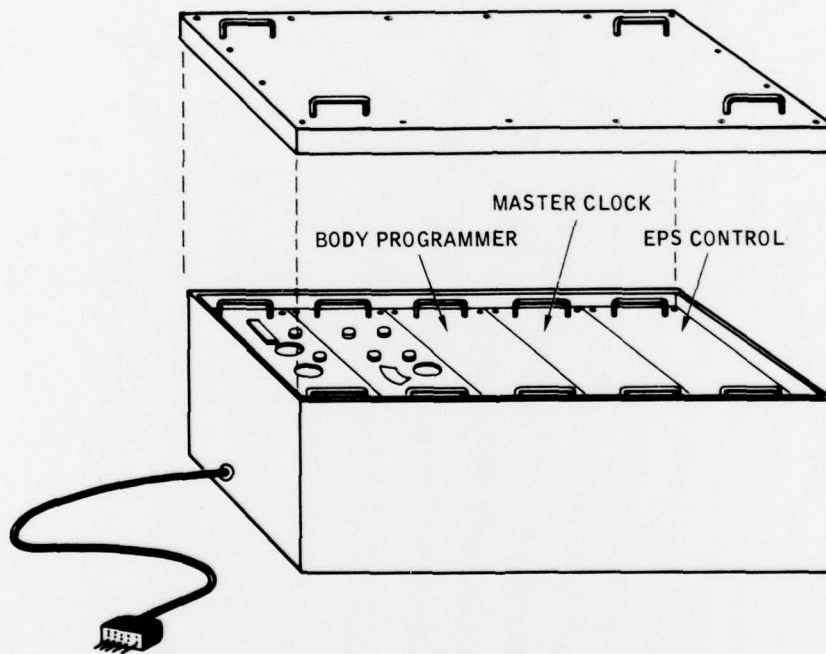


Figure 7. Sealed Module Showing Standard Rack-Mounted Equipment

4.3 INTERCHANGEABLE MODULES

All major subsystems of the ONR Telemetry Buoy will be packaged as sealed modules. Installing or replacing a module will require only the plug-in of a

waterproof electrical connector, placing the module in its compartment, and closing and sealing a hatch (see Figure 8). Maintenance will not involve exposing electronic circuitry at sea, either on the buoy or aboard the service vessel. This philosophy has proved both effective and economical in the Polaris program.

Changing the application of a buoy upon its return from sea can be accomplished simply by substituting standard-size sealed modules of different capability but compatible electrical connections. Routine maintenance will involve changing all modules. Total system checkout and calibration will require no more time than will cleaning and repainting the hull; both tasks could be done concurrently ashore, or aboard a service vessel at sea.

4.4 STATION ENDURANCE

Each buoy is intended to operate at sea for one year, unattended, without intolerable degradation of performance.

4.5 BUOY HARDWARE LIFE

The ONR Buoy System hardware is being designed to have a useful life of at least 10 years. Because the buoy hull is completely filled with closed-cell plastic foam, it will be virtually unsinkable.

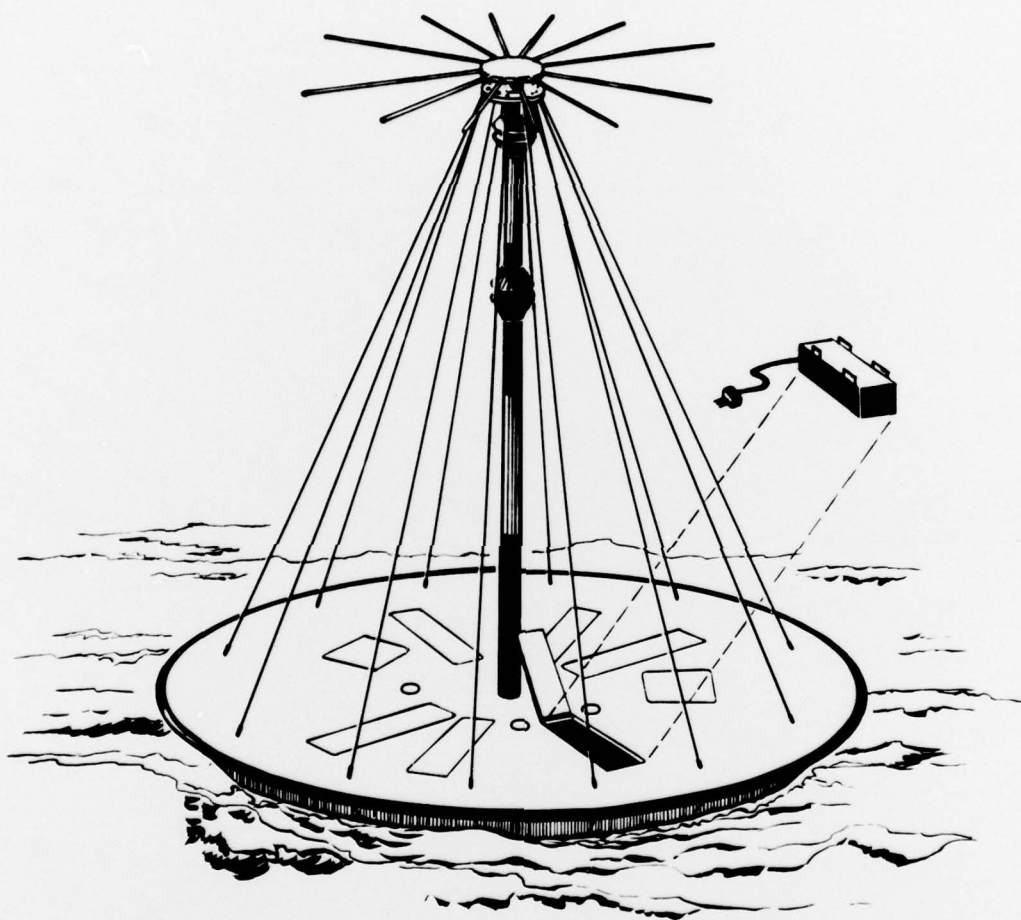


Figure 8. Modular Installation of Electronic Subsystems Within Buoy

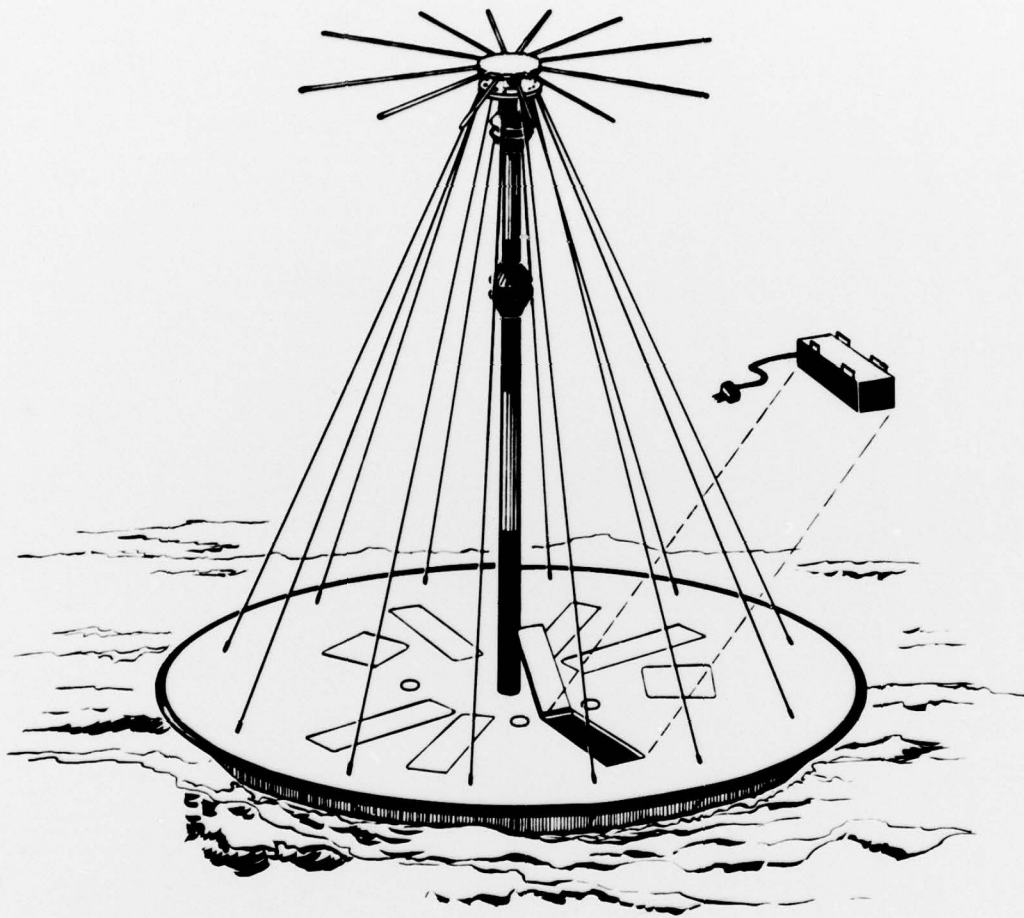


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