NOAA Technical Report OOE2

Data Flow and Applications of United States Deep-Ocean Moored and Drifting Data Buoys

Washington, D.C.
September 1979

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Ocean Engineering

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ABSTRACT. The National Data Buoy Office (NDBO) has deployed environmental data buoys to provide synoptic data for weather reports and for scientific data archives since 1972. The present data acquisition and telemetry electronics has evolved from a quest for the most accurate and reliable equipment that could be obtained at realistic costs. This report describes the 4 types of moored buoy payloads, 3 types of drifting buoy payloads, the 4 custom-designed buoy payloads, and the sensor requirements for the meteorological and oceanographic sensors. Data flow, including data requirements and system implementation, for these systems is also described.

BACKGROUND

Since June 1972, The National Data Buoy Office (NDBO) has deployed environmental reporting data buoys in various gulf and ocean regions to provide synoptic data for weather reports and for scientific data archives. As of April 1, 1979, 21 moored buoys were reporting environmental data routinely. In addition, NDBO has 50 drifting buoys being deployed by both ships and aircraft for the U.S. commitment to the buoy portion of the Global Weather Experiment Program. The first of two special observing periods during this worldwide experiment was completed during January-February 1979. A large complement of about 200 free drifters was deployed during the 1975-76 period in support of various global atmospheric research programs. Finally, NDBO has developed and deployed several special classes of buoys which will be addressed in more detail further on.

The present complement of buoy data acquisition and telemetry electronics was determined by a series of hardware evolutions, which in turn were brought about by continued quest for the most accurate and reliable equipment that technology could offer at realistic costs. The evolution of the data buoy hardware, together with the availability of microprocessor technology and suitable communication satellites, has permitted a fully automated, reliable approach for the acquisition of remote marine environmental data on a synoptic basis in all weather conditions, which encompass a wide range of sea states, from smooth seas to severe disturbances. In addition, the measurement and reporting of environmental data are accomplished on remote ocean platforms, which are relatively inaccessible for maintenance and therefore require a high degree of equipment and data link reliability.

SOURCES OF DATA

The environmental data acquired by NDBO are derived from both moored and drifting buoys. NDBO is currently maintaining and operating several types of payloads and buoy hulls. Fig. 1 shows the moored buoy deployment locations as of April 1979. The buoys continuously acquire and telemeter synoptic environmental data in near real time to the weather forecasting community, including the National Weather Service (NWS). These data, along with other environmental data, are used for engineering evaluation and analysis, and are provided monthly to the National Oceanographic Data Center (NODC) and the National Climatic Center (NCC) to be archived.

MOORED BUOY PAYLOADS

Background

The first-generation NDBO payloads were developed to meet both R&D and data product delivery requirements. These payloads were designated the Engineering Evaluation Phase (EEP) payloads and were placed on 12-m discus hull buoys with 100-ton displacement for evaluation of advanced state-of-the-art sensors and buoy components. Deployment of six of the EEP buoys began in June 1972. The term "payload" refers to the buoy instrumenta-

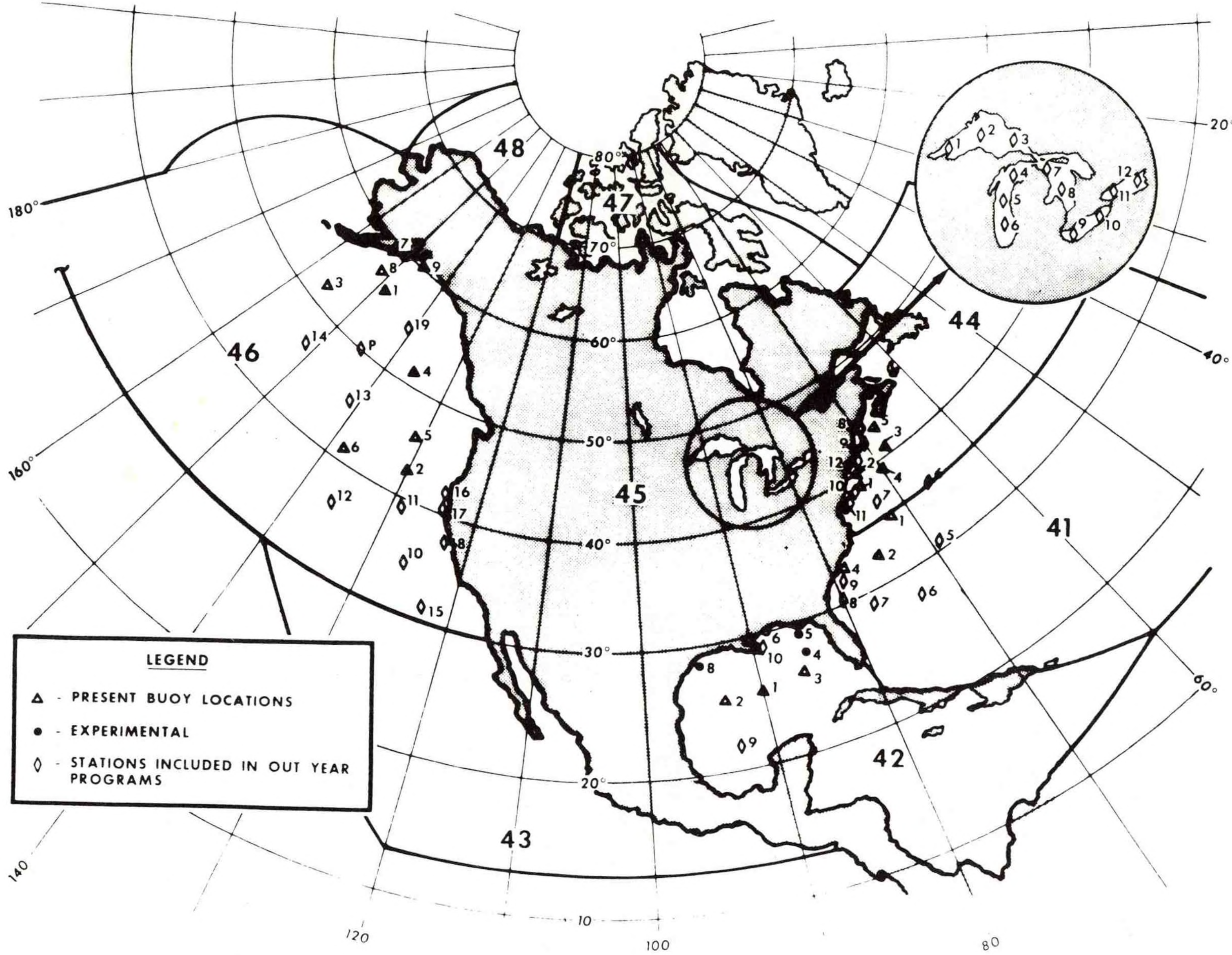


Figure 1.--Moored buoy deployment locations

tion, which includes onboard sensors, data processing, communications, and the power source.

A companion development to the EEP units were the Phase I payloads, which were designated for simple, less flexible data acquisition requirements and which were originally placed on small 1.7-m diameter drifting buoys. Deployment of Phase I payloads began in January 1973.

Current Deployment Scenario

NDBO is currently maintaining and operating four types of moored buoy payloads: the Prototype Environmental Buoy (PEB) payload, the Phase I and Phase II payloads, and a newly developed General Service Buoy Payload (GSBP). Of the payloads currently deployed, eight are PEB's, two are Phase I payloads, five are Phase II payloads, and six are GSBP's.

Prototype Environmental Buoy (PEB) Payload

The PEB design was based on concepts proved during initial NDBO programs. Although originally tailored to meet the needs of the weather community, its measurement capability was expanded to include surface wave data and subsurface water temperatures down to 300 m.

Figs. 2 and 3 display 10- and 12-m diameter hulls, respectively. Both types of hull support PEB payloads. The mast has meteorological sensors at the 10-m level. Measured values are telemetered via satellite link to shore every 3 hours in a self-initiated, internally programed mode. For special needs (e.g., during abnormal weather), the onboard weather data acquisition and reporting sequence changes to hourly operation by command from shore. Present and previous data frames can also be acquired on demand via radio link. The onboard data acquisition and timing is controlled by a special-purpose, stored-program computer. Batteries provide the power required for up to 3 years of continuous buoy operation.

This payload is equipped with a dual HF/UHF communications system. Redundant RF links were implemented to ensure a reliable and orderly transition from HF to UHF satellite communications. Conversion to UHF communications is nearly complete and will permit the use of this more reliable mode of communications. Eight 10- and 12-m diameter hulls equipped with PEB payloads are currently in service in deep-ocean areas, including the Gulf of Alaska and North Pacific and Atlantic Oceans. All PEB's are being modified to incorporate a microprocessor system to replace the stored-program minicomputer. The PEB microprocessor system comprises two RCA 1802 microprocessors. A 2K memory microprocessor provides the communications and timing function; a 1K memory microprocessor provides the data processor function.

Phase I and Phase II Payloads

The Phase II payload program is an outgrowth of the Phase I payloads for small buoy systems that were developed in 1972-73. These earlier buoys were spheres and horizontal and vertical cylinders, with typical diameters ranging

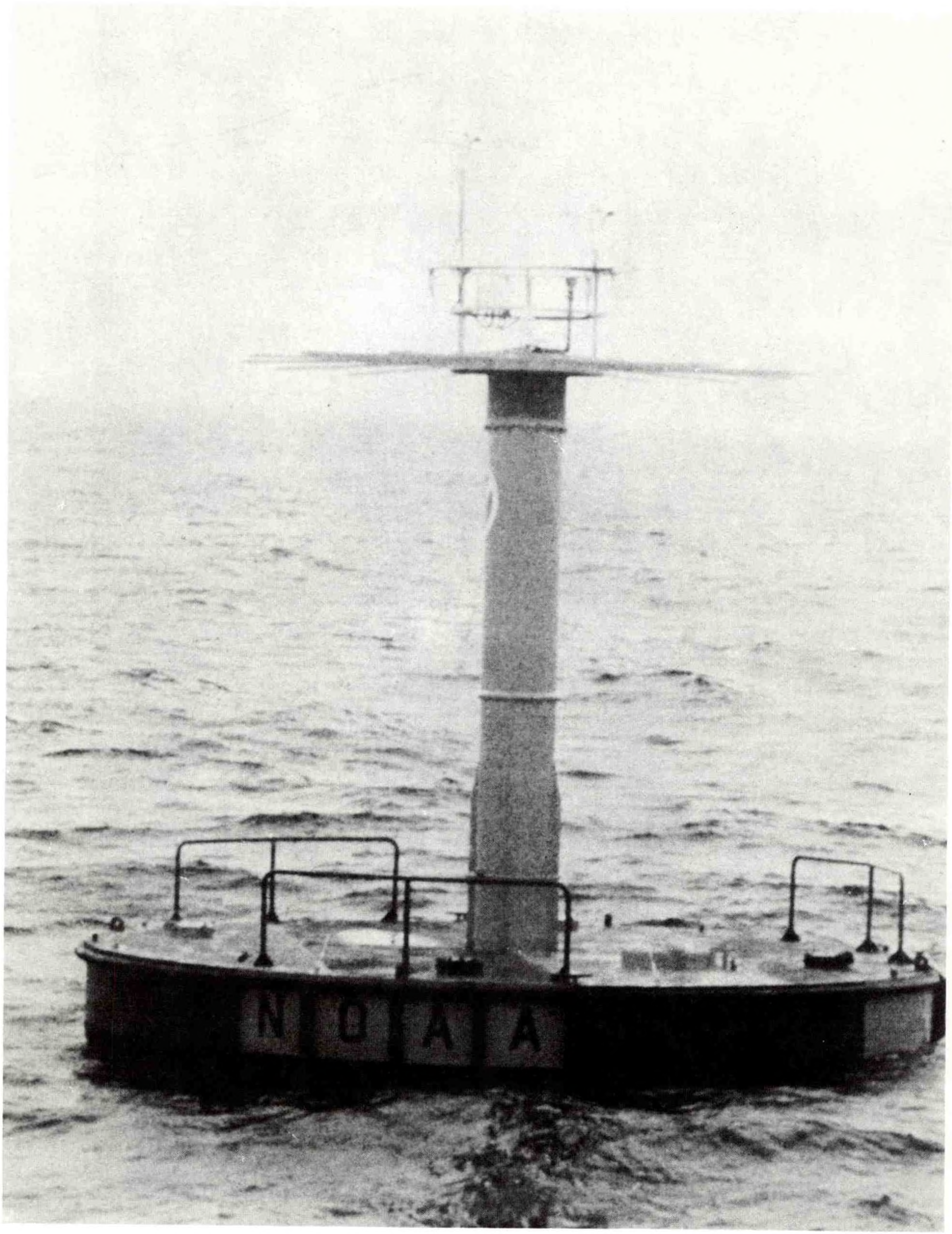


Figure 2.--10-meter discus hull buoy

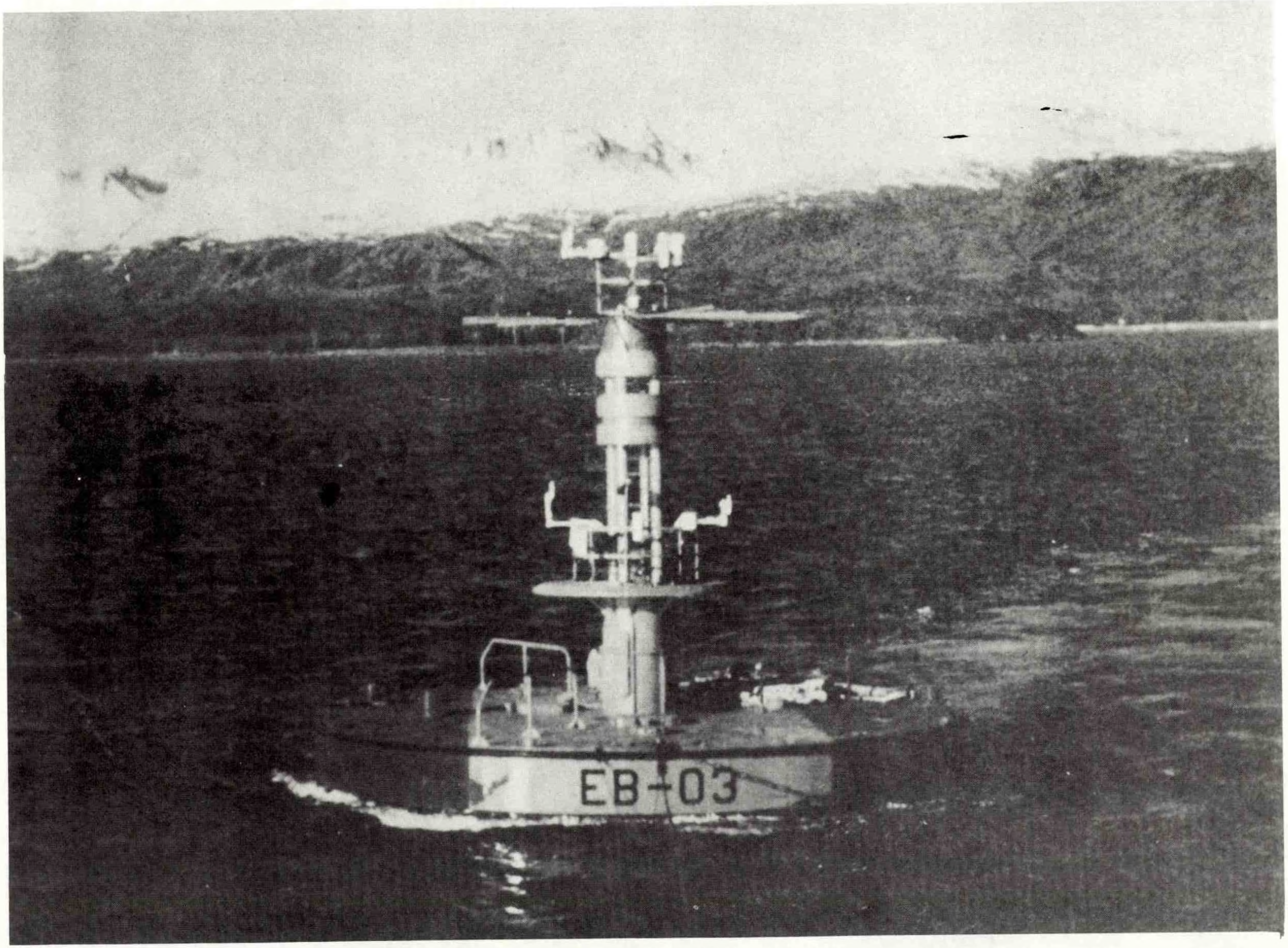


Figure 3.--12-meter discus hull buoy

between 1.4 and 1.7 m. None of the small buoy systems achieved significant success with regard to survivability and operability in the open sea; however, the data acquisition payloads were quite reliable.

The Phase II payloads are second-generation payloads that are now integrated in existing 6-m, boat-shaped hull, NOMAD's (fig.4). (The NOMAD hulls were developed in earlier U.S. Navy programs.) Phase II payloads are also installed on the larger discus hulls. The Phase II payload provides data on the meteorological environment and surface waves. The onboard data processing and RF data link are very similar to that of the PEB payload, using nonprogramable hardware and both hf and uhf satellite communications. However, the Phase II payloads are being upgraded to an all-uhf configuration. Five Phase II payloads are in service in both deep-ocean and continental shelf areas. Two buoys are still using the earlier Phase I payloads; however within 6 months, the buoys will be replaced with the General Service Buoy Payload described below.

General Service Buoy Payload (GSBP's)

The first 15-unit production run of this advanced payload class has just been completed. Six GSBP's are now in service onboard one 5-m discus, three NOMAD's, and two 10-m hulls. Ten additional payloads will be in service by the spring of 1979, along the continental shelf, in the Great Lakes, and in the deep-ocean areas.

The GSBP system design draws extensively upon proven hardware and systems. For example, the entire meteorological sensor suite is identical to that used in the Phase II payload. In addition, data input ports are provided for future sensor additions, including a wave measurement system and a multi-element temperature measurement system. Buoy communications consist of a uhf-satellite transceiver with 40-watt output power, and associated electronics similar to that used on Phase II and PEB payloads.

GSBP relies entirely on a ufh-satellite communications relay link, which eliminates the need for the large antennas required for previous hf systems. GSBP features a program-controlled microprocessor instead of the nonprogramable special-purpose computers used on earlier payloads. This element, the Intel 8080 microprocessor, acquires sensor data and digitally processes and formats the data. This microprocessor has a 3K core memory.

Future Moored Buoy Activities

A new program is being initiated in the Great Lakes. The loss of the Great Lakes ore carrier Edmond Fitzgerald in November 1975 prompted an intensive investigation of weather forecasting in this area. The finding of several deficiencies in the program led to the decision to deploy and operate a series of data buoys in this area. Two buoys are planned for 1979, and the remainder in 1980 and 1981. Each buoy will have a meteorological sensor suite and a wave measurement system.

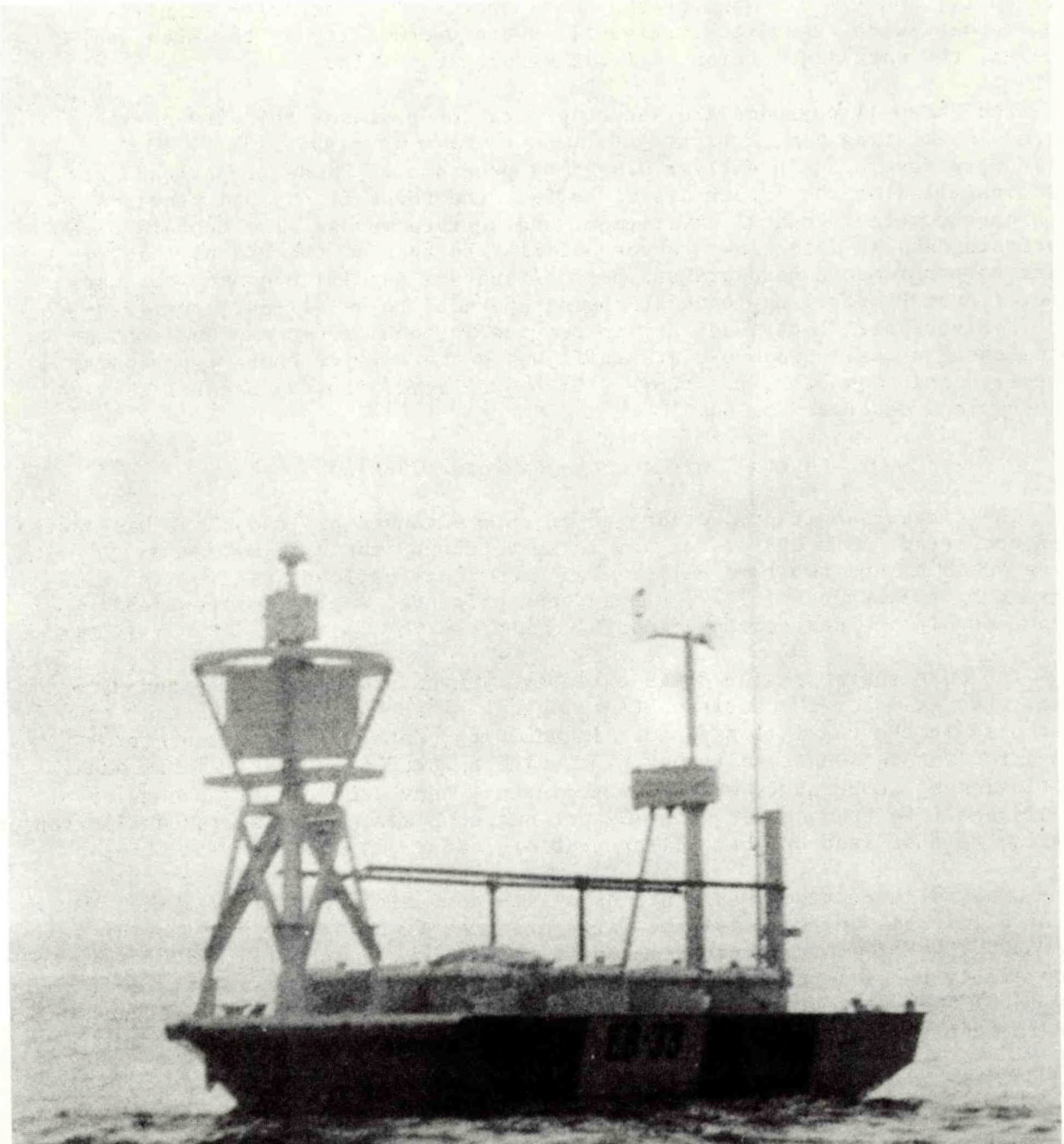


Figure 4.--NOMAD buoy

DRIFTING BUOYS

Unlike moored buoys, whose primary purpose is to report synoptic data to weather forecasting groups, drifting buoys provide information to the scientific community, usually for nonsynoptic purposes. Occasionally, there is a need for near-real-time receipt of data (e.g., the use of a buoy to track oil spills, as was done in the case of the Argo Merchant, which broke up on Nantucket Shoals off New England in December 1977). Generally, drifting buoys are used for various scientific investigations, including such projects as arctic ice dynamics, Lagrangian ocean current measurements, and large-scale experiments such as the Global Weather Experiment. These buoys are deployed worldwide.

Ice Drifting Buoys

The ice drifting buoys monitor environmental conditions in the deep polar regions to further the understanding of the dynamics and the thermodynamic interaction between arctic ice and the environment. These buoys usually have pressure and temperature sensors, and use a uhf orbiting satellite relay data link for telemetry and position fixing. The daily changes in position provide the measurement of ice movements needed to assess the ice dynamics. Fig. 5 shows an air-deployable ice buoy.

Lagrangian Drifting Buoys

The primary purpose of this buoy type is to achieve Lagrangian tracking of water parcels, while simultaneously measuring basic meteorological conditions. Tracking is enhanced by the use of a drogue which couples the surface buoy to a particular water layer depth. The drogue also reduces the wind drift of the buoy. The meteorological sensor suite generally measures air pressure and sea-surface temperature. Future instrumentation may include wind speed and air temperature.

Communications and position fixing depend upon the operation of a uhf transmitter on the buoy, which sends data to a specialized electronics package on board a polar-orbiting satellite. The satellite in turn relays the data to a ground station. Relative motion between the satellite and buoy produces a Doppler effect on the frequency of the RF link. This frequency shift is processed along with the satellite orbital track to derive buoy position. Our experience with position-fixing accuracy has been found to be well within 5 km rms.

Global Weather Experiment Participation

NDBO is currently participating in the Global Weather Experiment, which is being conducted from December 1, 1978, through November 30, 1979. We have developed a TIROS Meteorological Drifting (TMD) buoy for this application.

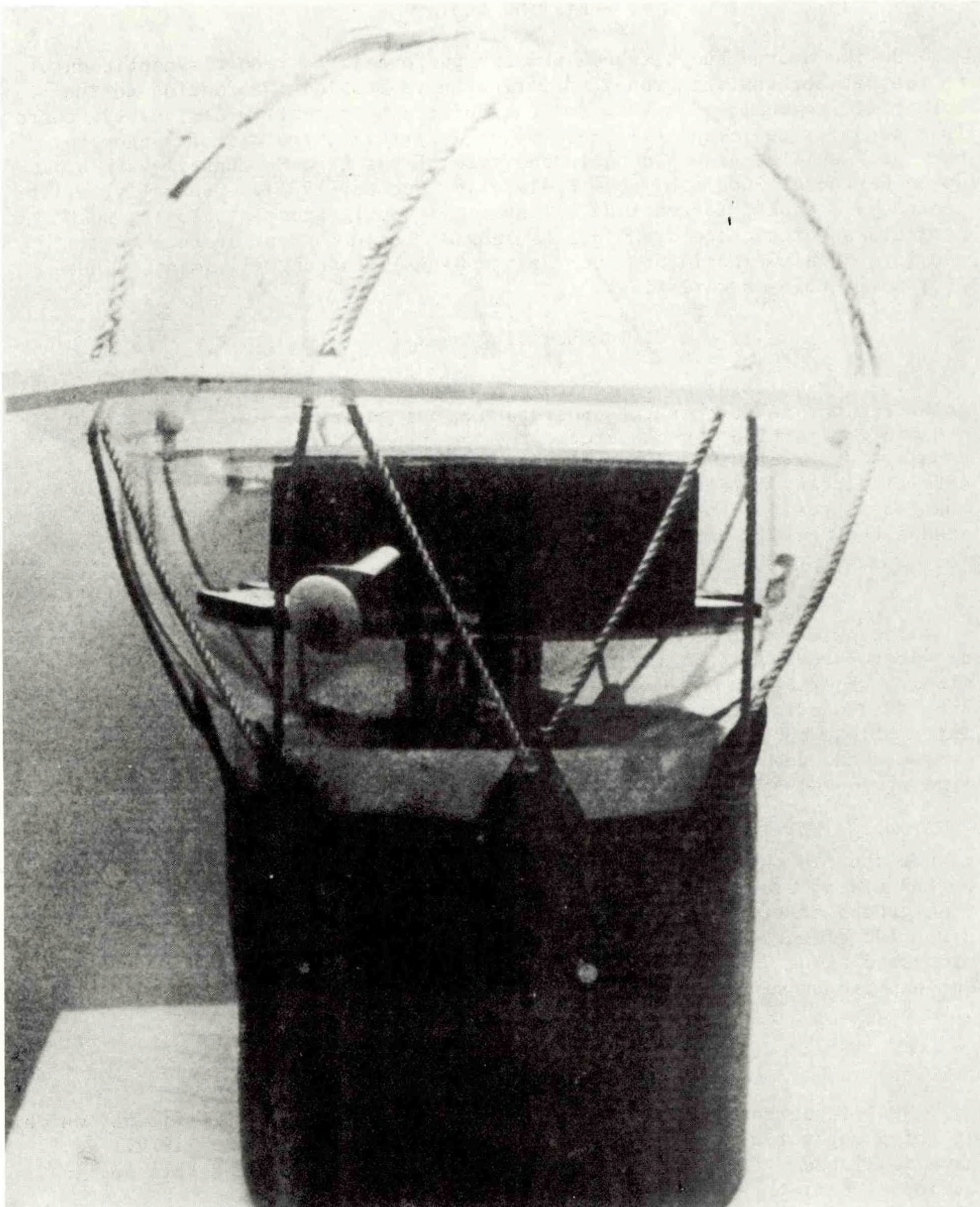


Figure 5.--Ice buoy

The TMD buoy is a small, free-drifting buoy which measures barometric pressure and sea-surface temperature in the open-ocean environment. The buoy also monitors its internal temperature and battery voltage. In operational use during the Global Weather Experiment, the TMD's are acquiring data continuously and transmitting via a radio-frequency up-link to the TIROS-N satellite. About two up-link transmission sequences of 10-min duration can be expected to reach the satellite with high accuracy each day.

Fig. 6 shows the design configuration of the TMD buoys. The mechanical characteristics are as follows:

Overall length	3.05 m (10 ft)
Maximum diameter	68.6 cm (27 in)
Spar diameter	20.3 cm (8 in)
Deployed weight	92.7 kg (294 lb)
Total buoyancy	228.6 kg (503 lb)

Ships will deploy 50 TMD buoys in remote areas of the Southern Ocean from Peru to New Zealand during the Global Weather Experiment. Since reseeding of the buoy network by ship would be difficult, NDBO has developed the capability to make deployments from long-range, high altitude aircraft. In this effort, air-drop tests were made at the National Parachute Test Range at El Centro, Calif. Four buoys were made available for the test, and the U.S. Air Force provided C-141 aircraft support. The buoys were mounted on wooden pallets and gravity launched from an altitude of 610 m into the Salton Sea, Calif. This altitude was chosen because of precision navigation problems with high-altitude, low-speed drops, but it was sufficient for air-drop certification purposes at higher altitudes. A 6.7-m cruciform parachute was attached to each buoy and opened by static line. The water entry speed with this parachute was about 9 mps. The TMD buoys had previously undergone free-fall tests from 12.2 m, which corresponds to a water entry speed of about 15 mps. Both test series were successful, and the buoys were certified by the Air Force for deployment by both C-130 and C-141 aircraft from altitudes of 150 to 6,100 m and maximum drop speeds of 155 knots.

Another series of drops from 610 m was made 50 miles at sea off Norfolk, Va. Both the buoys and buoy instrumentation performed flawlessly during and after all testing. Fig. 7 shows a TMD buoy dropping into the water with an open parachute.

Future Activity for Drifting Buoys

New missions for drifting buoys are in the research and development process, and will include the following:

- Fully develop the air-drop capability for meteorological and oceanographic buoys to include subsurface temperature and Lagrangian measurements.

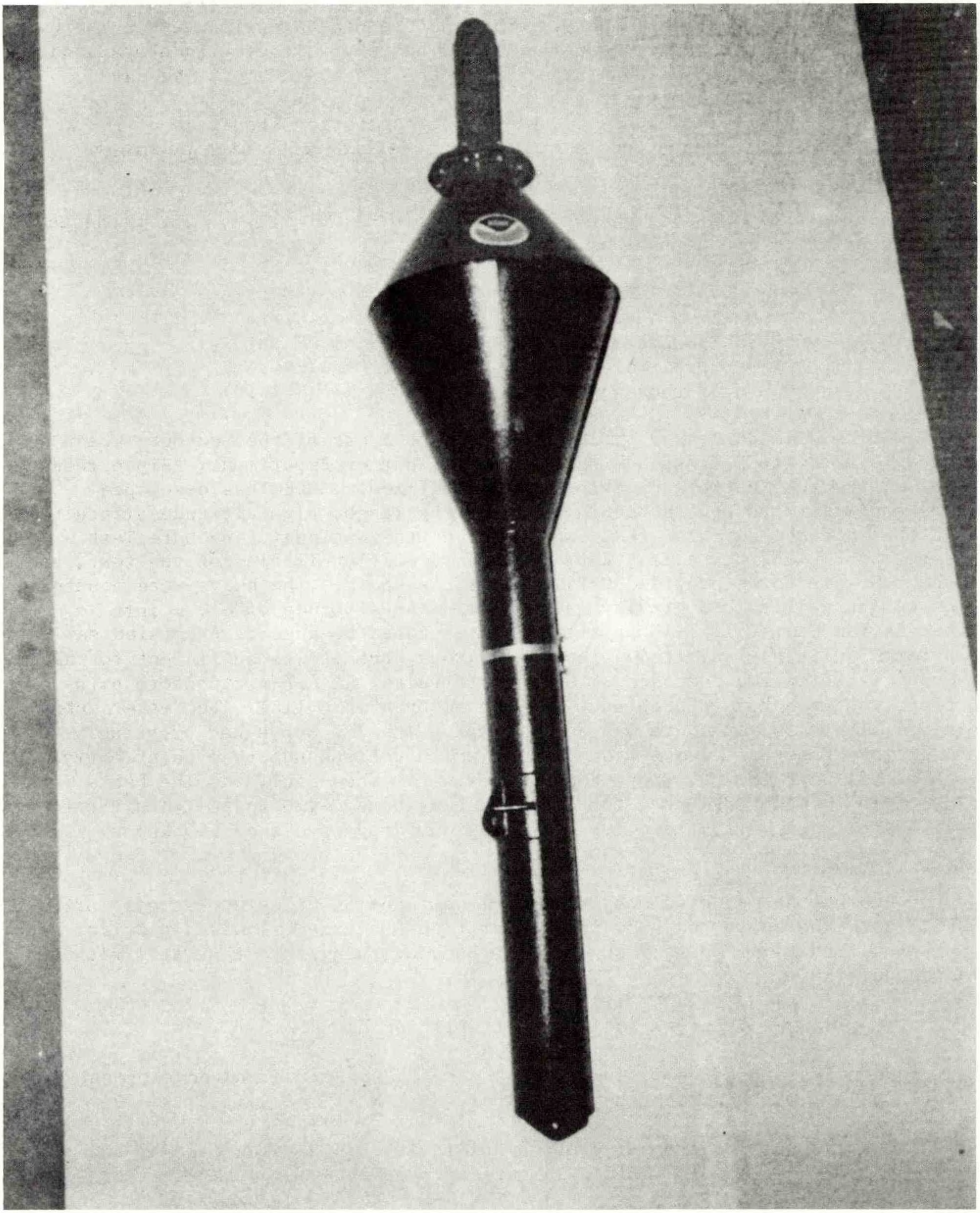


Figure 6.--TMD buoy

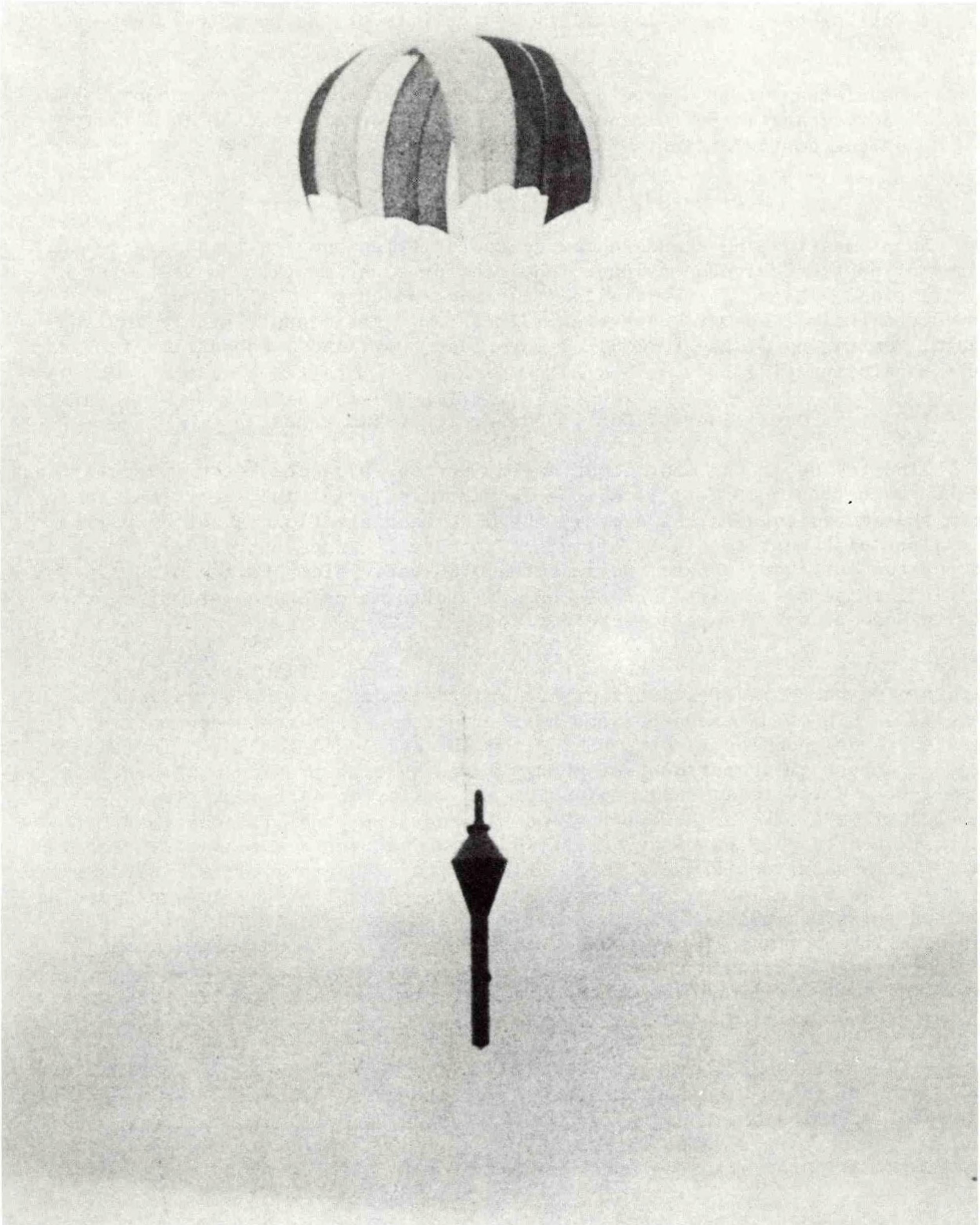


Figure 7.--TMD dropping via parachute

- o Further develop the capability and utility of the numerical buoy model.

- o Develop and test drogue configurations designed to improve buoy dynamics and Lagrangian performance, including the development of an air-dropped drogue configuration.

CUSTOM-DESIGNED BUOY PAYLOADS

Supplementing the standard moored and drifting buoy payloads are several types of custom-designed payloads required for experimental and dedicated applications. Major custom-designed payloads which will be addressed are the Ocean Thermal Energy Conversion (OTEC) buoy, the Ocean Platform Environmental Monitoring System (OPEMS), a Waveridge buoy, and a Subsurface Temperature Monitoring (Tz) buoy.

Ocean Thermal Energy Conversion (OTEC) Buoy

OTEC is one of the many ocean energy sources projects being investigated. Although the basic concept is simple enough (i.e., deriving electrical energy from thermogradients in the ocean), the OTEC mechanization is not only complex, but also must be highly efficient to make the concept viable. It should be pointed out that, unless the selected OTEC basic elements lie within a critical range of physical and biochemical performance characteristics, the entire concept cannot operate productively.

The object of the OTEC buoy is to provide an in situ platform for determining heat transfer coefficients and their derivatives on various samples of OTEC heat exchanger ocean-flow tubing. Heat transfer coefficients are degraded by in situ biofouling corrosion and scaling. To measure these changes, the Department of Energy asked NDBO to provide a 12-m discus buoy instrumented to acquire biofouling and corrosion data on various samples of OTEC heat exchanger tubing. In addition, the OTEC buoy was instrumented to acquire water quality data on near-surface seawater. To satisfy the data requirements applicable to the OTEC experiments, instrumented hardware was installed on the buoy. For OTEC, control of the data processing and control systems is through a modified Phase II payload. Hf rather than uhf satellite communications is used to enable virtually unlimited command control directly between the OTEC buoy and the NSTL base station. Uhf satellite communications was not deemed suitable for this application, because of the high-capacity RF traffic required.

NDBO's first OTEC buoy was deployed in the Gulf of Mexico in mid-March 1978. The platform was instrumented to perform three heat-transfer experiments to determine the fouling factor in aluminum and titanium samples. The fouling factor target value was specified at 0.0005 over a 90-day period. The achieved factor after a 7-week period was 0.0002.

By early June, the OTEC platform had had a number of problems that required retrieval of the buoy for refurbishment. The refurbishment effort incorporated features to enhance buoy reliability and to increase the scope of the experiments. The pumping system was modified to operate the experiments on the pressure side rather than the suction side of the pumps. Redundant pumps were incorporated to increase reliability. In addition, an improved 23-m suction hose system incorporating separators was available to help reduce interference with the buoy mooring chain.

The scope of the experiments was increased by the addition of a fourth heat-transfer monitor, which now enables monitoring to be performed on sample tubes of aluminum, copper/nickel, stainless steel, and titanium. An experiment to test the effect of flow on the aluminum tube exterior surface was also added. Finally, a corrosion and biofouling sampling system for each sample under test was incorporated. In the previous OTEC deployment, many varieties of living organisms were recovered and sent to marine laboratories for analysis. To keep up with the increased power demands brought about by the additional scope of experimentation, more powerful diesel engines were substituted for the original ones.

On December 2, 1978, the refurbished buoy was redeployed in the Gulf of Mexico. About 16 frames of experimental data of the heat-transfer monitor are being acquired weekly by the hf data transmission system. This is in addition to biofouling, corrosion, meteorological, and status data that are being acquired routinely each day.

Fig. 8 shows the OTEC buoy configuration.

Waverider Buoy

NDBO has successfully instrumented a small Waverider buoy capable of transmitting wave covariance data via uhf satellite communications. The Waverider hull is about 1 m in diameter and was selected because of its proven record for obtaining wave measurements. Existing Waverider inertial sensors and a double integrator are used to sense vertical acceleration and resultant displacement. A wave data analyzer generates a covariance function from the inertially derived time series displacements. The covariances are formatted into a number of discrete computer words (about 150) and transmitted to shoreside processing facilities via uhf satellite self-initiated transmissions. At the shoreside processing site, the covariances are converted to displacement spectral densities by Fourier transformations. Integration of the spectra produces the moments from which the wave height and period are calculated. This system has produced spectra in the range of 0.5 Hz, with a 0.01-Hz resolution; significant wave heights beyond 3 m were also computed from the spectra.

Two improved versions of the Waverider buoy are now under procurement, with the possibility of additional buoys being procured for deployment in support of other projects such as the Wave Climate Program. In summary, by providing a capability for accurate buoy-based measurement of ocean waves, users such as the National Weather Service, the U.S. Navy, marine shipping interests, and offshore operators can receive near-real-time wave spectral data.

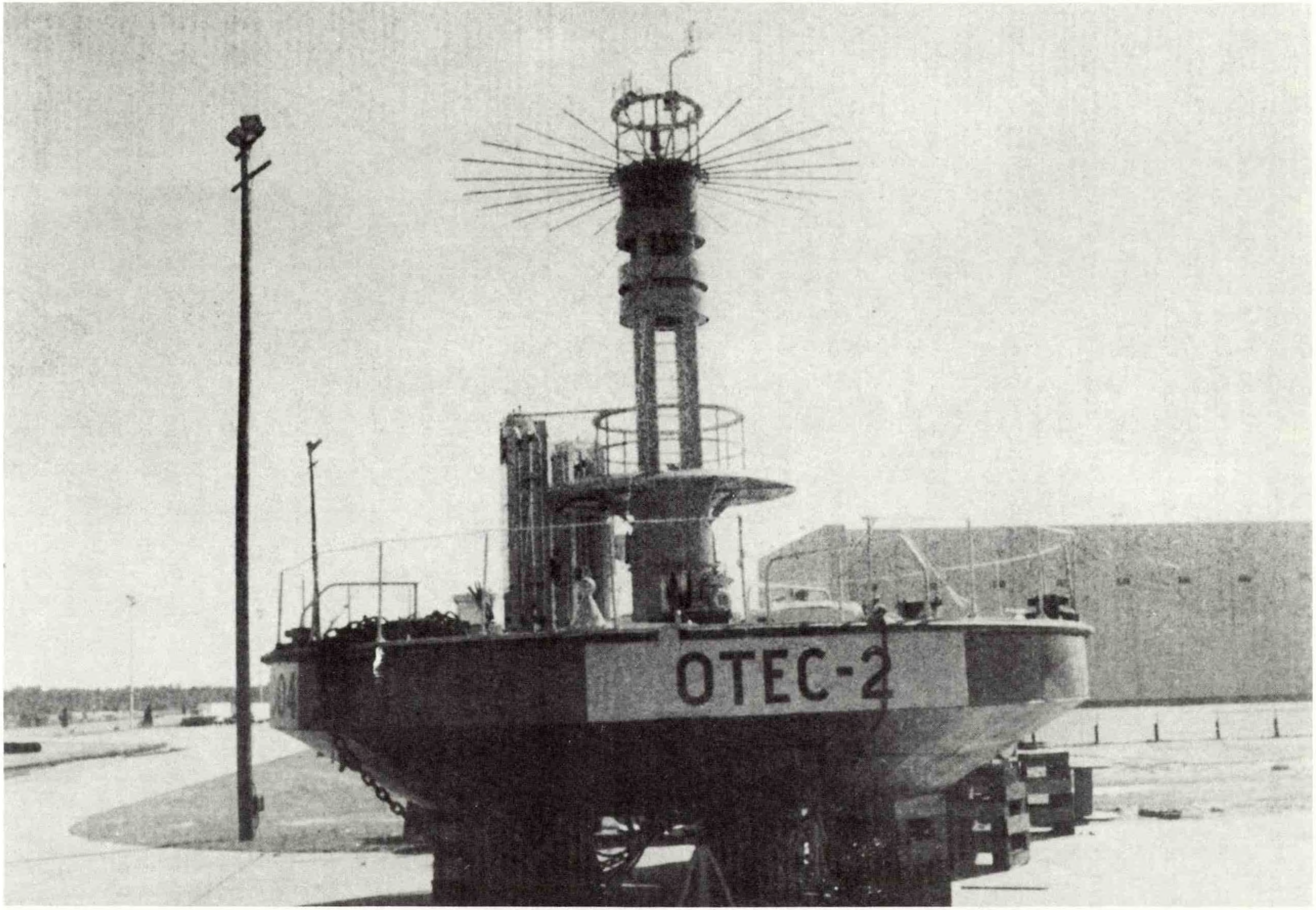


Figure 8.--OTEC buoy

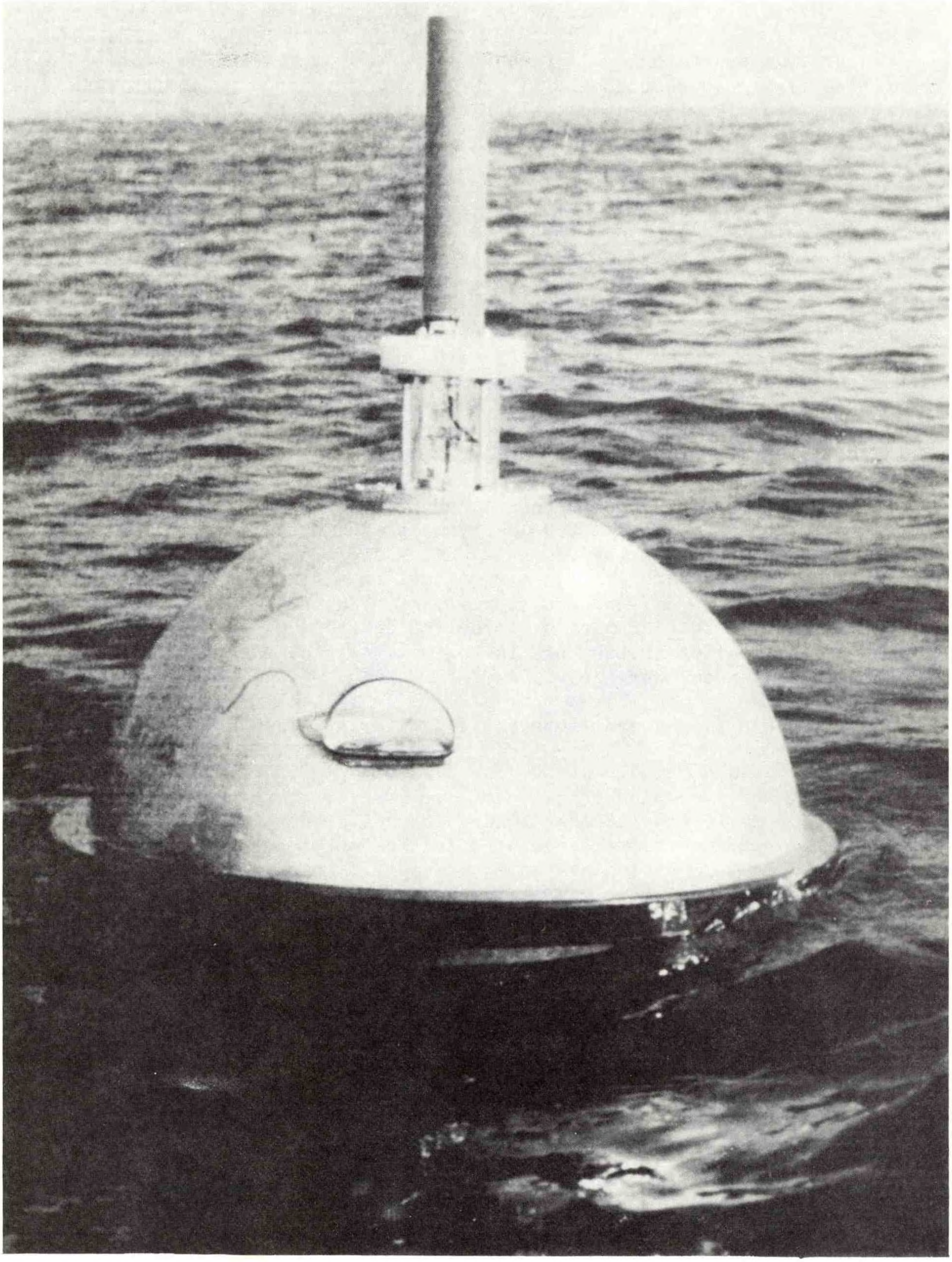


Figure 9.--Waverider hull

Ocean Platform Environmental Monitoring System (OPEMS)

To provide a strategic oil reserve, the Government will be storing large quantities of oil in salt domes. The OPEMS was developed to monitor and control the orderly displacement of brine from major salt domes while these domes are being filled with oil.

The OPEMS sensors and satellite communications systems were essentially in hand prior to development; however, the OPEMS electronics package is a new design. This design incorporates a solar cell and battery for virtually unlimited power supply life. The design also features a solid-state recording device for elimination of risks associated with tape transport units. Finally, the OPEMS has a built-in test-readout printer for onsite verification of performance. The OPEMS has been deployed on an oil rig off the Texas coast since September 1977. To date, the system has performed well with a report success rate of about 90 percent.

A second-generation OPEMS has recently been designed and installed, replacing the previous system at the site off the Texas coast. This system incorporates several enhancement features including redundant wind sensors, an improved barometric pressure sensor, addition of a conductivity sensor, increased solid-state storage from 8K bytes to 30K bytes, and an improved Geostationary Operational Environmental Satellite (GOES) transmit terminal. Fig. 10 shows the OPEMS operating off the existing platform in Texas. Future effort will be directed to improvement of materials and instruments, to reduce the high rate of marine biofouling and to seek materials and devices for implanting instruments in the warm coastal waters which will allow longer periods between service visits.

Subsurface Ocean Temperature Monitoring (Tz) Buoy

NDBO equipped a 5-m discus buoy with a multiple thermistor transducer sensor system and a mooring attachment loop system. This buoy was deployed in the Gulf of Mexico in December 1978 as an R&D effort, to measure and transmit gradients of ocean temperature at specific depths between 2 and about 300 m. The data acquisition system consists of a thermistor string connnected to an electronics package which converts each analog thermistor voltage into a digital word. The array of digital words, representing temperatures at each discrete depth, is then periodically transmitted via the GOES satellite to a shore-based data collection receiver. The Tz buoy is required to operate unattended for 12 months of continuous service.

This buoy is outfitted with 12 thermistors and 2 pressure transducers in accordance with the drawing shown in fig. 11. Six mooring attachment loops were incorporated to minimize adverse effects of buoy rotation and other buoy motions. This is the latest in a series of attempts to attach a Tz line to the mooring line of a large buoy. A combination mooring line/Tz line has had modest success on small buoys, but has not yet been demonstrated on a large buoy. This remains a problem area.

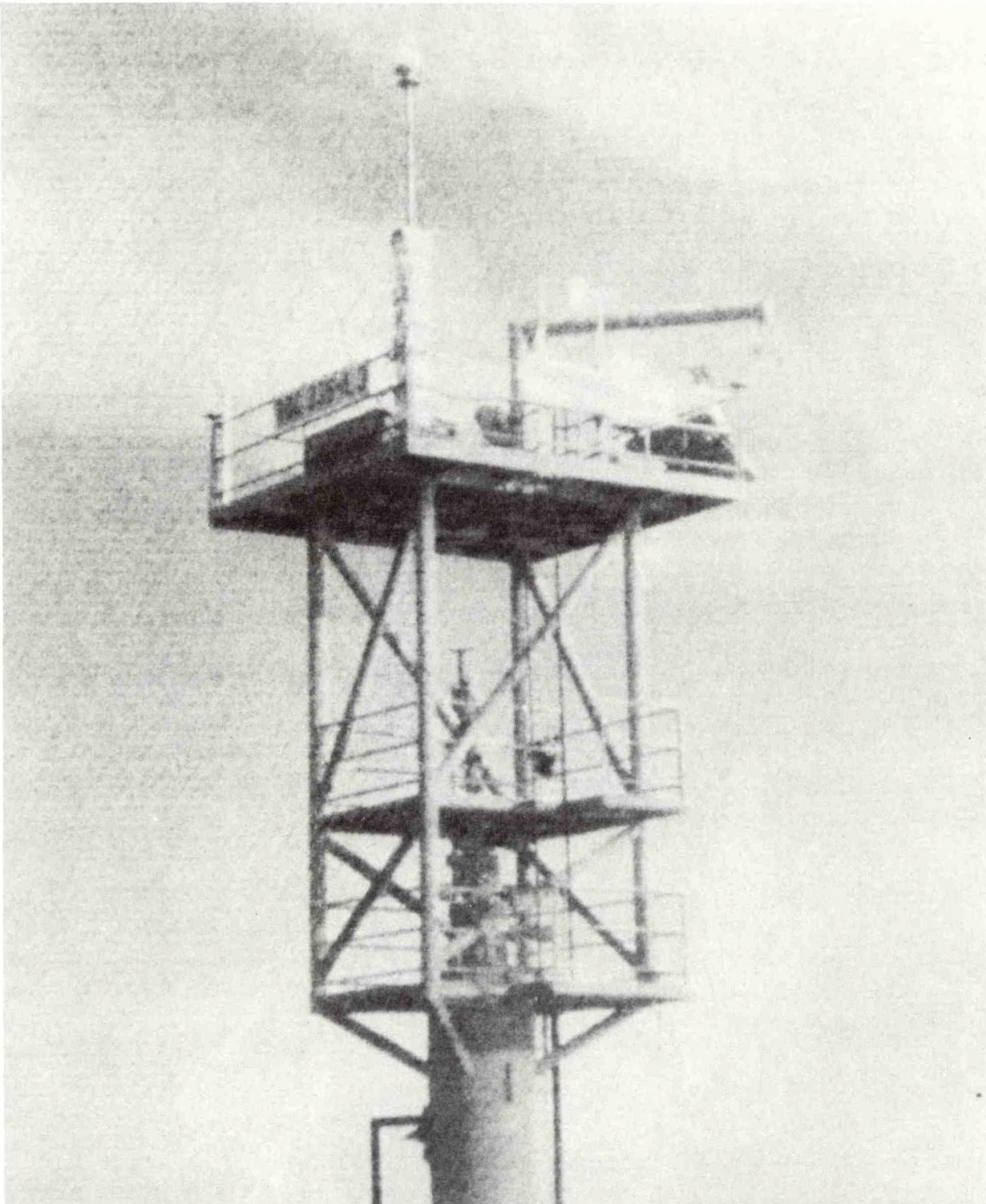


Figure 10.--OPEMS platform

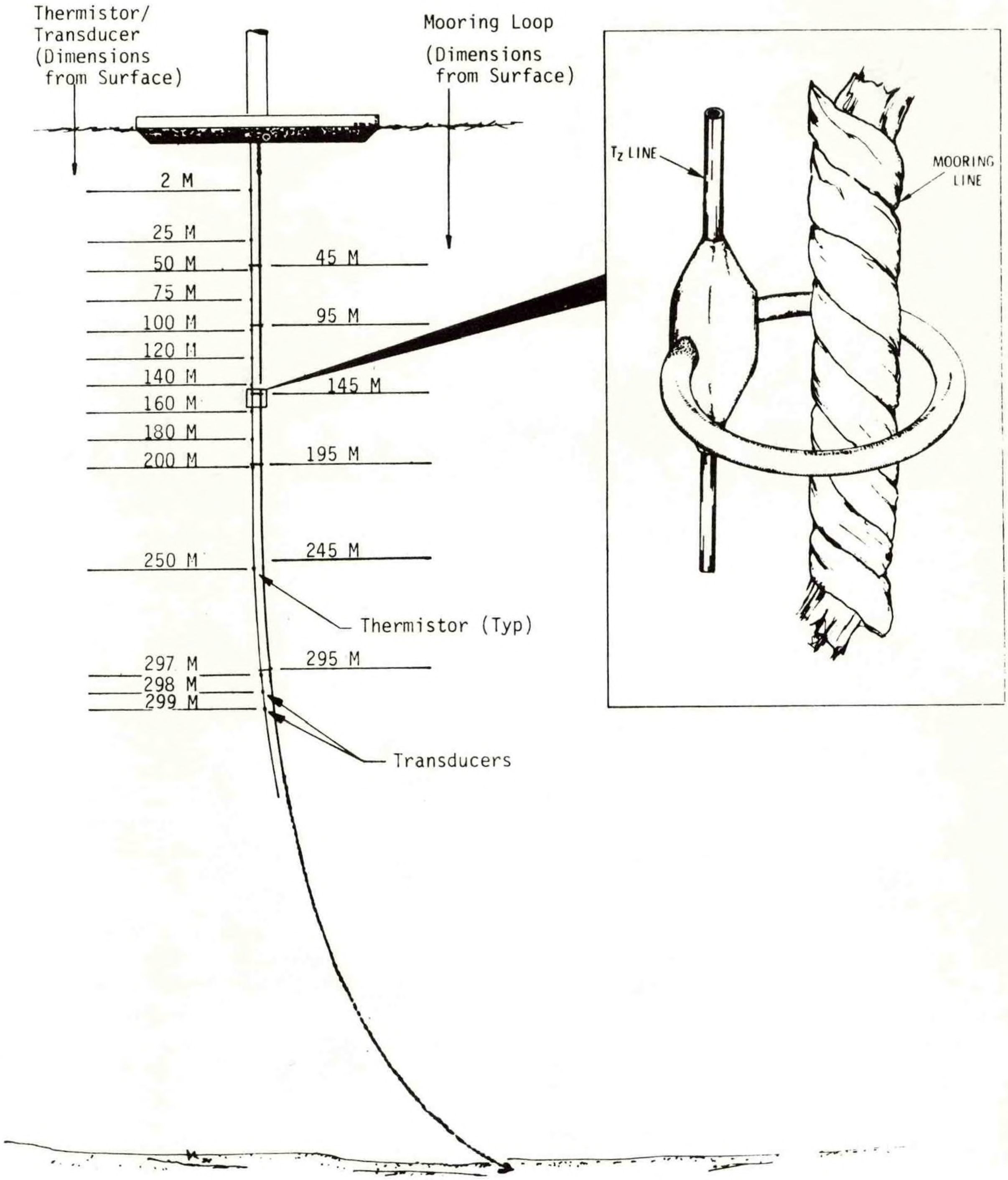


Figure 11.--Tz buoy

BUOY HARDWARE

Sensors

Fig. 12 presents an overview of the sensor requirements of the three different NDBO payloads — moored, drifting, and custom-designed. These sensors can conveniently be grouped into two major categories: meteorological and oceanographic.

Meteorological Sensors

The subject of meteorological sensors will be treated briefly via the meteorological sensor matrix shown in fig. 13. From these sensors, a standard meteorological data message is prepared, coded into the conventional World Meteorological Organization format WMO FM-24V.

Subsurface Ocean Sensors

The development of subsurface ocean sensors was an ambitious and difficult undertaking. An early result of this effort was the delivery of several inductively coupled ocean sensors capable of being attached to a combination mooring line/data line. Each sensor was packaged within a cylindrical pressure housing with hemispherical end caps, and each contained individual oceanographic transducers and secondary power cells. The total package was 52 centimeters long and 32 centimeters in diameter.

In June 1975, NDBO deployed a 12-m discus hull buoy in the Gulf of Mexico. This buoy had the standard meteorological instrumentation plus five inductively coupled ocean sensors attached to a mooring line/data line. The ocean sensor packages were installed at depths of 50, 100, 200, 350, and 500 meters, to measure conductivity, current direction, pressure, and temperature. The 50- and 100-m packages were additionally equipped with transducers to measure current velocity.

The buoy was retrieved in late January 1976. Extensive damage was noted on the mooring line/data line at the oceanographic sensor package attachment points. The extent of the damage was such that the packages would have separated completely in a matter of weeks. It was also found that the internal batteries of the ocean sensor packages would neither accept nor retain a charge. In reviewing the results of this experiment, the following conclusions were drawn:

- The inductive coupling concept appears to be a valid technique for transmission of information.
- The NDBO-configured ocean sensor system is not operationally feasible, owing to its high degree of complexity.
- Reliable measurements of current velocity and direction cannot be obtained from a surface moored buoy, because of motion of the mooring line and the blockage from both the sensor and mooring line.

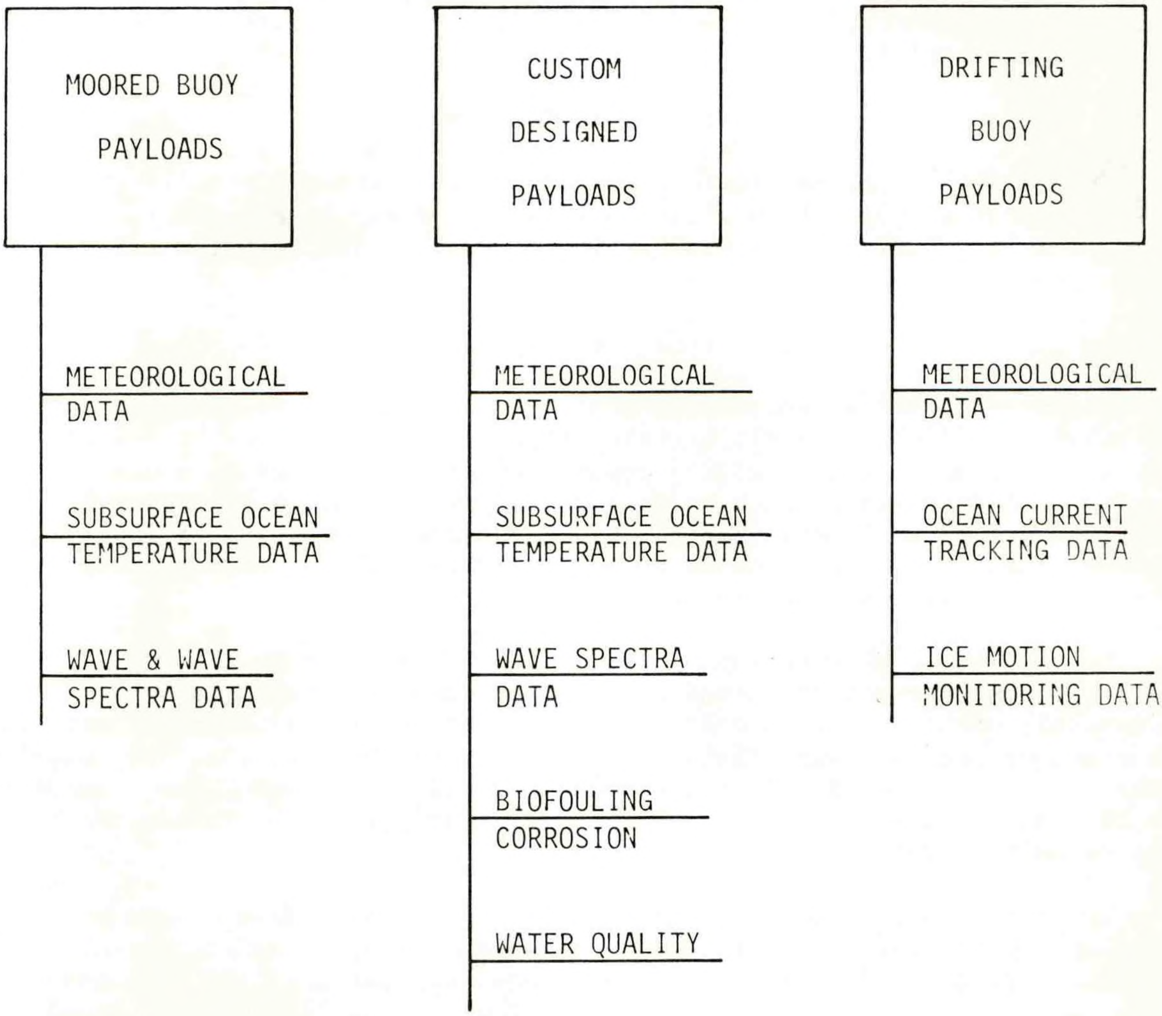


Figure 12.--Payloads versus sensor requirements

STATUS

STATE-OF-THE-ART SENSORS IN USE:

BENDIX PROPELLER-VANE ANEMOMETER MAURO MARINE ROTATING COMPASS	WIND SPEED & DIRECTION
J-TEC VA-300/VA-320 ANEMOMETER MAGNAVOX FLUX-GATE COMPASS	WIND SPEED & DIRECTION
ROSEMOUNT 1201 BAROMETER	AIR PRESSURE
ROSEMOUNT PLATINUM WIRE YELLOW SPRING INSTRUMENT THERMISTOR	AIR TEMPERATURE OCEAN SURFACE TEMPERATURE

ACTIVITY

- EXTEND OPERATIONAL LIFE OF PRESENT SENSORS
- IMPROVE MEASUREMENT ACCURACY OF PRESENT SENSORS
- IMPROVE AT-SEA SENSOR REPLACEMENT TECHNIQUES
- TEST RUGGED SENSORS FOR EXTREME ENVIRONMENT
- TEST SENSORS FOR NEW MEASUREMENT REQUIREMENTS (HUMIDITY, PRECIPITATION. SOLAR RADIATION)

Figure 13.--Meteorological sensors

In view of the limitations associated with the ocean sensor package, NDBO sought alternative solutions. During the past 3 years, systems capable of providing oceanographic current velocity data have been under development. This effort has in turn led to the development of improved current meters able to operate for reasonable lengths of time up to 1 year. Based on previous experience that current meters with moving parts were inherently incapable of long-term reliability in the ocean, further development of electromagnetic and accoustic current meters has been undertaken.

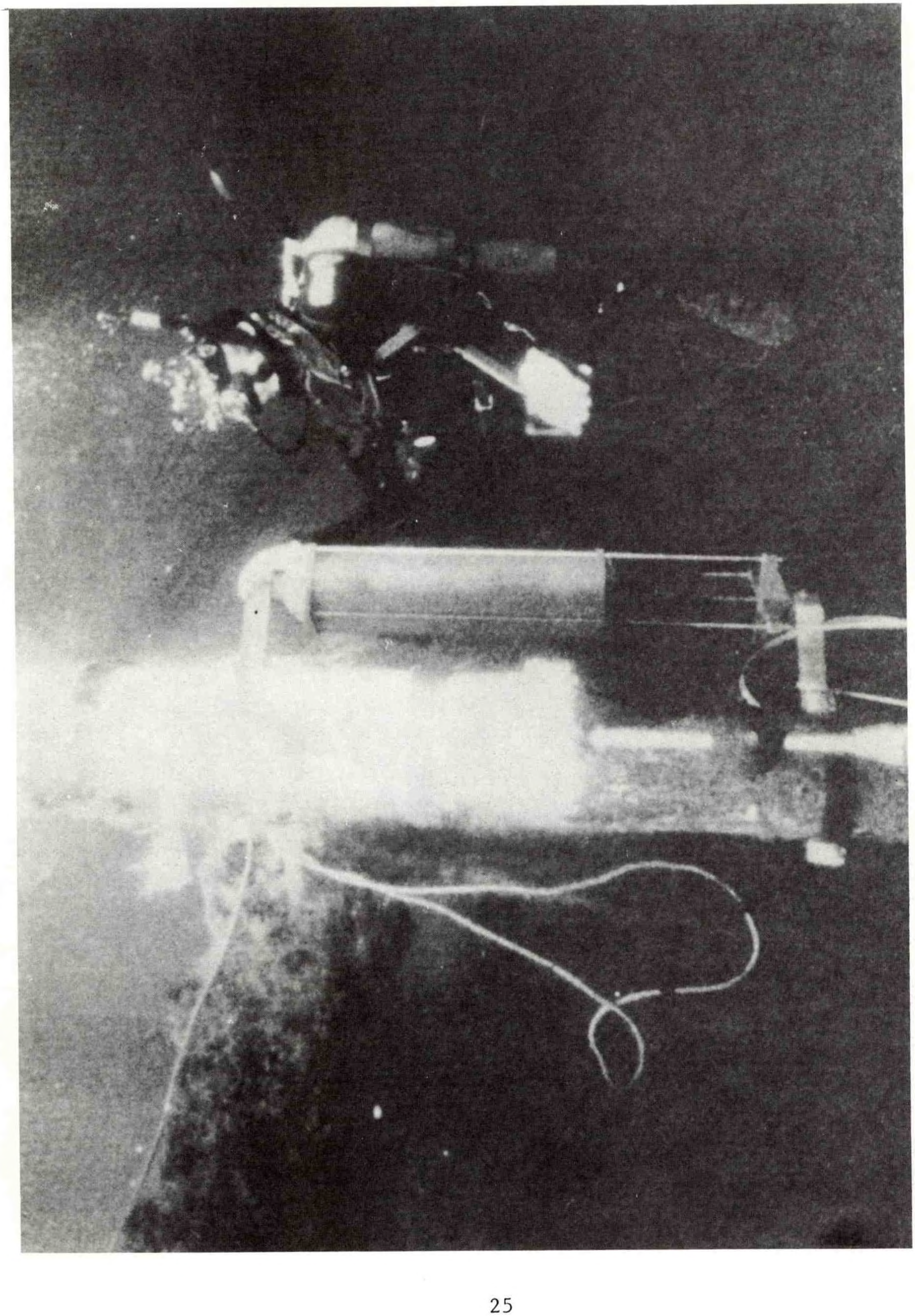
Fig. 14 shows a Marsh-McBirney electromagnetic probe current meter during installation for preliminary at-sea testing on an offshore tower. Two of these units operated satisfactorily during a short deployment period. Following close-in at-sea testing on the tower, the current meter will be deployed on a subsurface mooring array and coupled to an acoustic telemetry unit to transmit data and status to the surface in real time for relay through a geostationary satellite link to shore. The current meter contains a microprocessor integral to the unit housing to preprocess the current data before transfer to the acoustic telemetry unit for transmission to the surface.

Fig. 15 shows a Neil Brown acoustic probe current meter being installed for preliminary testing. Two such meters were recently retrieved from an offshore tower following 4 months of operation in 20 m of water. Although satisfactory performance is indicated from analyses performed to date on the current meter data records, insufficient analysis precludes judgment at this time on the degree of technical performance.

The Neil Brown design also includes an interface to an acoustic telemetry link for real-time reporting of data and hardware status. These units also record the data and status on an internal tape cassette. Pending verification of good performance, each unit will be attached on a subsurface mooring array and will be interfaced with an acoustic telemetry system for long-term at-sea testing. A test period of about 1 year is planned to evaluate the reliability of the current meters under operational conditions.

A major development paralleling the current meter activity is the acoustic telemetry link. The first system has been designed with variable design features to aid in system refinement. The telemetry system can vary key parameters such as bit rate and symbol duration to determine the correct combination required to combat channel fading and multipath. The system is designed to operate in the 15 to 25 kHz frequency band, using frequency hopping techniques and frequency shift keying modulation (FSK) with single and a multitone capability. The acoustic telemetry system is designed for a range of 1 nautical mile.

During 1979, a complete system test will be run for 1 year. It will consist of up to four current meters mounted in a subsurface buoy array, a surface buoy reporting data to shore, and the acoustic telemetry link relaying data from the current meters to the surface buoy. This test will be made on the Continental Shelf in the Gulf of Mexico at a depth of about 200 m. In addition, the acoustic telemetry link will be tested separately in deep water for other oceanographic research applications.



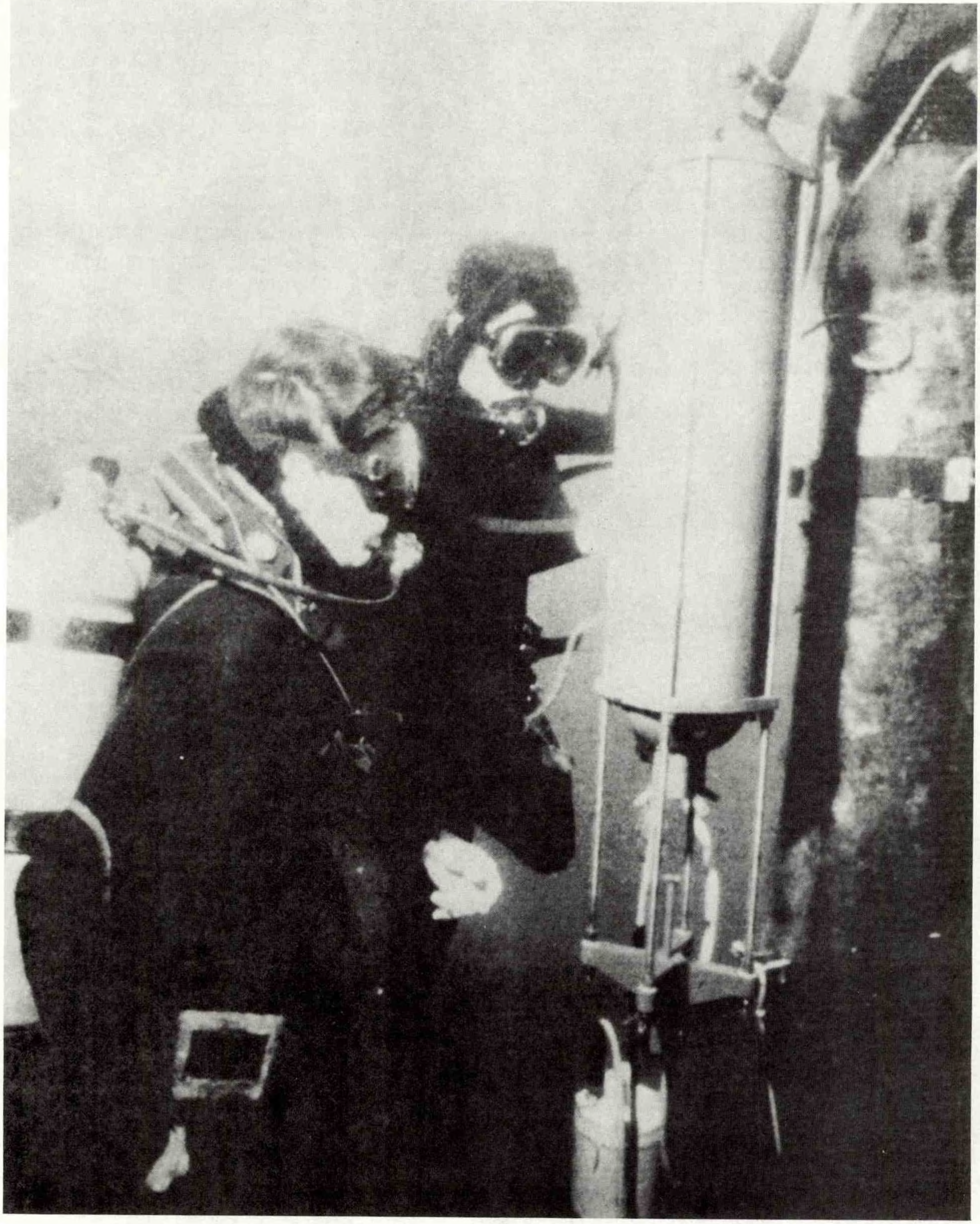


Figure 15.--NEIL BROWN acoustic probe

Wave and Wave Spectra Data Sensors

In the area of wave data, NDBO systems have evolved from simple systems providing only wave height and period to microprocessor systems providing wave spectral outputs. The first wave measurement system was essentially a buoy motion measurement system mounted within the buoy hull. The measurement device was enclosed in a gyrostabilized platform from which acceleration and pitch and roll angles were derived. Problems with the stabilized platform led to a strapped-down system, which consumed considerably less power and was quite reliable, but faltered when it came to producing high-quality data.

Although an improved version of the strapped-down system was under development, the requirement for spectral data as well as wave height and period led to the parallel development of two other systems. One of these systems, the digital wave data analyzer, produces spectra using time series inputs to generate a covariance function onboard a buoy microprocessor. At the shore processing site, the covariances are converted to displacement spectral density by performing the Fourier transform on the covariance function. Integration of the spectra produces the moments from which the wave height and period are calculated. This system produces data of excellent quality. The other wave measurement system resulted from a requirement for a system that could generate coarse spectral density and reasonable wave height and period data onboard a platform without a sophisticated processor. In this system, time series inputs are derived from a strapped-down single-axis accelerometer. Twelve frequency-sensitive analog filter circuits receive the time series inputs, after which each output is squared and smoothed. At the shore station, the data are processed with a matrix to generate a spectrum for acceleration, displacement, velocity, and estimates of the average value of the displacement spectral density in the bandpass of each of the 12 analog channels.

The analog wave spectrum analyzer systems are currently installed on the PEB payloads. By the end of this year, they will be replaced by digital wave analyzers. Phase II payloads already have digital wave analyzers on board. The GSBP's will be augmented with digital wave analyzers by the end of this year.

The next area is the development of wave directional spectra. Recent demands by various government agencies for directional spectra have prompted NDBO to pursue this development vigorously. An experimental system has been developed and tested that will provide directional spectra in 15-degree directional increments. The experimental system calculates auto- and cross-covariances of heave acceleration and wave slope in two orthogonal directions for a number of time displacements. Similar to the routine for nondirectional spectra, these functions are transmitted to shore where the spectra are constructed via the Fourier transform. The output data are three-dimensional and include displacement spectral density, direction, and frequency.

In the future, NDBO plans to prepare specifications for an operational Directional Wave Data Analyzer (DWDA) to function with existing and future payloads. Continued development using the 12-m experimental buoy will take place during 1979, including upgrading the system software, calibrating its directional wave measurement system, and distributing directional data to selected users for evaluation on a trial basis.

DATA FLOW

Data Requirements

NDBO programs have two general categories of data requirements. The first requirement comes from various weather forecasting groups, including the National Weather Service (NWS), needing real-time or near-real-time data. The NDBO weather message is about 10 sec long when transmitted at a 75-bit-per-second rate and includes air pressure and temperature, seasurface temperature, wind speed and direction, and wave data. NDBO buoys are deployed in the Atlantic Ocean, Gulf of Mexico, North Pacific, Gulf of Alaska, and Great Lakes. These diverse geographic locations require overthe-horizon data links.

The second requirement is governed by the needs of the scientific community. These applications generally do not require the real-time feature of the first type, although processed data occasionally are desired in a matter of hours. An important example of users would be oceanographers, who have for many years mapped ocean currents through Lagrangian tracking techniques. The oceanographers are interested in obtaining position fixes from drifters that follow ocean currents. The length of the position-fixing message is about 1 sec. These messages contain about four to eight 8-bit words. Another example of scientific users would be investigators concerned with wave data. The U.S. Navy Fleet Numerical Weather Central (FNWC) currently uses NDBO wave spectral data from moored buoys as calibration points for their formulation of prediction models used to forecast sea states for the entire Northern Hemisphere. Shippers in the Great Lakes and North Pacific are keenly interested in wave data for safety and optimum ship routing. The length of the spectral wave data message is about 40 sec and contains about 150 16-bit words. There are other important applications of buoys for scientific uses, including oil spill tracking and the worldwide Global Weather Experiment discussed previously.

Data System Implementation

Since program inception, the long-range plans for accomplishing environmental data reporting called for the use of satellite telemetry links. Initially, these plans had to be held in abeyance, because suitable cooperative satellites did not exist in 1972, nor had international frequency allocations been assigned for the collection of environmental data on the ocean surface via satellite relay. Because of these limitations, initially and up to 1978, NDBO uses high-frequency over-the-horizon communications to satisfy the data link requirements. However, since the launch of the first two Geostationary Operational Environmental Satellites (GOES) in May 1974 and February 1975, respectively, NDBO has tested buoy-satellite link hardware on the ground and onboard ocean platforms. Simultaneously, coordination was achieved with allied U.S. Government agencies, including the National Environmental Satellite Service (NESS), the National Weather Service (NWS), and its

National Meteorological Center (NMC), to implement a timely, reliable system from data acquisition to data dissemination.

As indicated previously, data flow was initially carried out via hf telemetry links. Judicious implementation of equipment on board the data buoys and at the shore receiving sites has provided NDBO with a consistent delivery of synoptic data to NWS from all platforms on station (well above 90 percent). Since successful transition from hf to uhf satellite data link is virtually accomplished, the hf data flow will not be described; however, uhf satellite data flow for both moored and drifting buoys will be covered.

GOES System for Moored Buoys

The GOES satellite is operated by NESS and is the first of a series of international meteorological satellites. GOES satellites were launched in May 1974, February 1975, October 1975, June 1977, and the spring of 1978. The current operational configuration comprises the GOES satellites designated GOES-3 and GOES-2 and provides the coverage and elevation patterns shown in fig. 16. The elevation contours define the buoy-to-satellite pointing angles with respect to each satellite. With the current configuration, realistic coverage exists from approximately the Greenwich Meridian westward out to longitude 150°E, or better than one-half Earth coverage.

GOES contains the necessary communications hardware to serve as a stationary relay for environmental instrumentation on board ships and buoys and on land-based stations. It is this feature, together with the shared satellite concept, that makes GOES ideally suited for NDBO's remote onboard data acquisition and telemetry function. The data collection relay function is only one of several major functions associated with GOES. Other GOES capabilities include an Earth's surface and cloud cover camera, a weather facsimile for cloud cover picture transmission, and a space environmental monitoring system to measure particle trajectory and energy content near the satellite.

System Data Flow and Timing for Moored Buoys

Fig. 17 shows a comprehensive data flow and timing diagram for NDBO moored buoys. Data from moored buoys are transmitted, in sequence, to either the east or west GOES satellite, depending upon elevation angle geometry. In general, all satellite transmissions are aimed at achieving the highest buoy-to-satellite elevation angle, to minimize the effect of sea-multipath during periods of buoy motion. A secondary criterion in selecting either the east or west GOES is for achieving a balance of traffic load. These two criteria have resulted in an overall system wherein all buoys in the North Atlantic region use the east GOES and all buoys in the Pacific region and Gulf of Mexico use the west GOES.

Onboard data acquisition begins 20 min before the synoptic hours (i.e., 0000, 0300, 0600, ..., GMT). From 9 min before the synoptic hour, until nearly 20 min after the hour, all buoys transmit their environmental data, each buoy at a programed time slot to either the east

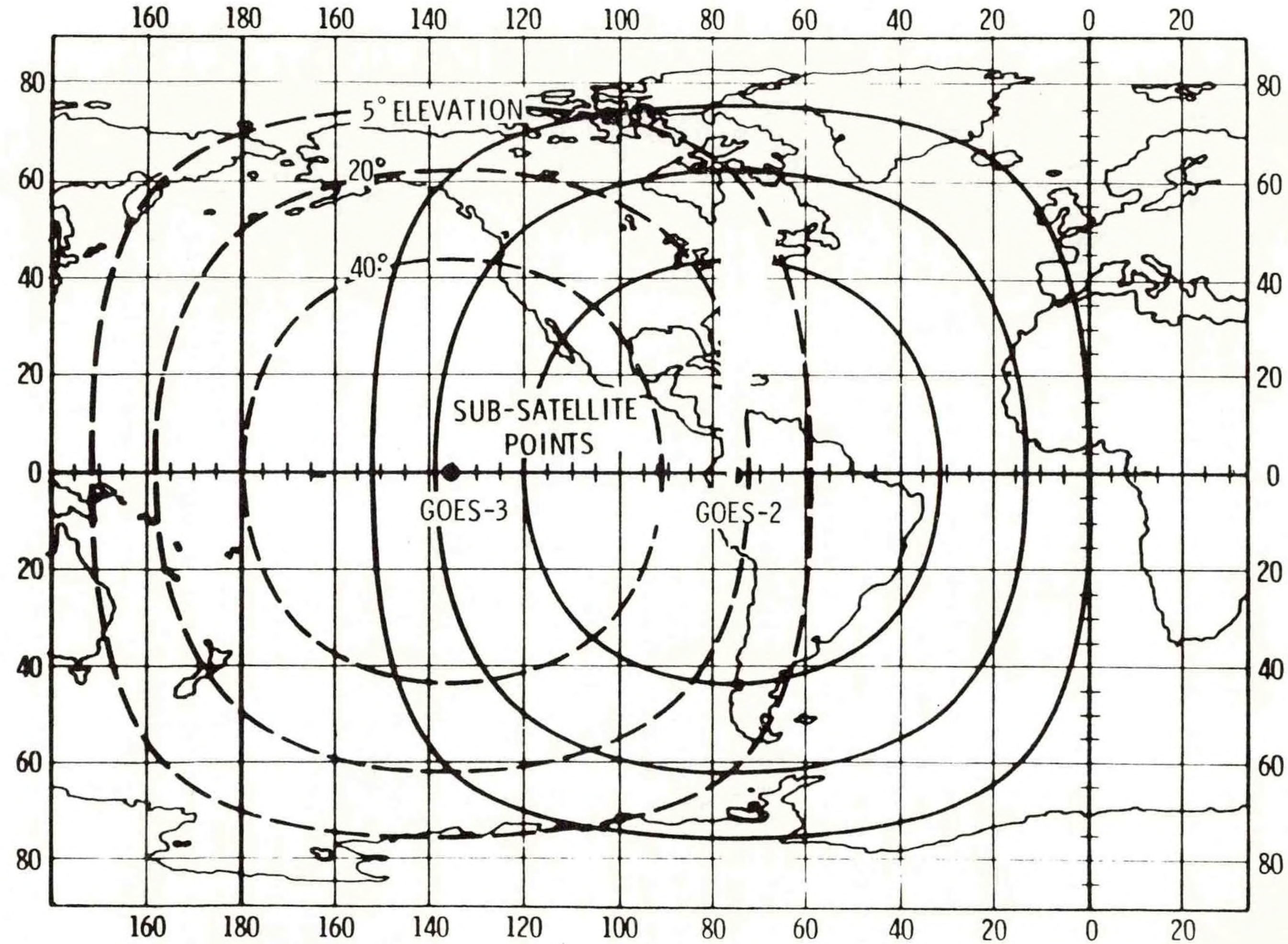


Figure 16.--GOES coverage and elevation pattern

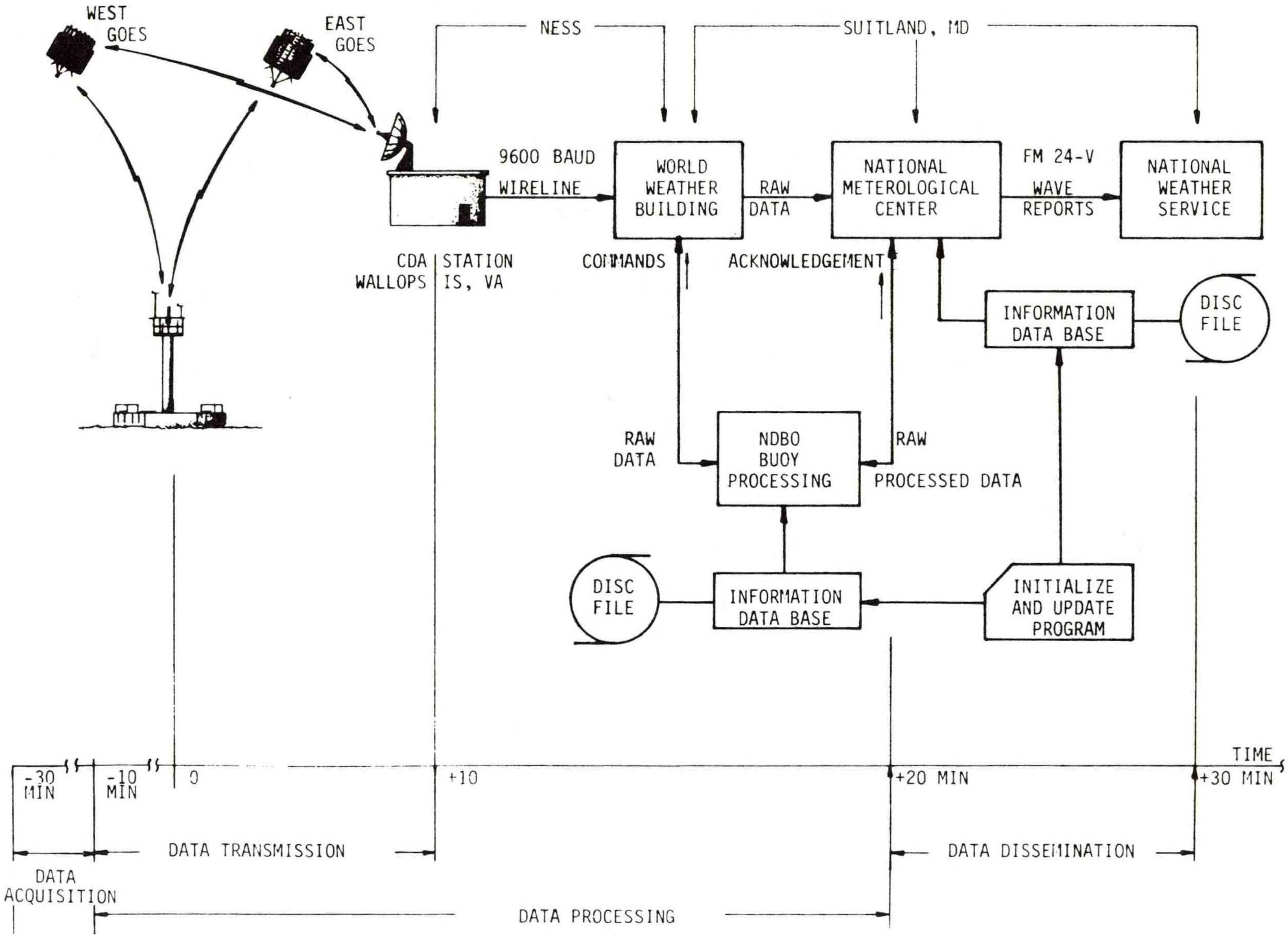


Figure 17.--Data flow and timing for moored buoys

or west GOES. Each buoy is provided an opportunity to report via a self-initiate, automatically pretimed mode. The primary objective at the NMC dissemination center is to place synoptic data on-line to NWS by 20 min after the synoptic hour. In the event the self-timed report is either missed or fails to meet minimum data quality criteria, the message is automatically requested again during the 20- to 40-min period following the synoptic hour. In general, three interrogations are programed in the attempt for a satisfactory message reply. If the message cannot be acquired by 40 min following the synoptic hour, the message is disseminated the following hour. During periods of environmental disturbances, buoys can be interrogated to provide data in either near real time or in the same sequence during the synoptic hour, while providing data hourly as opposed to every 3 hours.

Data Processing

Following the transmission of data from the buoy to the satellite, the data are immediately relayed from the satellite to a NESS Command and Data Acquisition (CDA) station at Wallops Island, Va. At the CDA, the data are received, detected, identified, and checked for quality with regard to parity and proper message heading and termination. From the CDA, the data are transmitted over a 9600-baud landline to the NESS World Weather Building at Suitland, Md. Here the data are placed in dissemination queues for simultaneous transmission to NMC and NDBO data processing facilities.

At NMC, the data are further processed and scaled into engineering units. Data quality refinements are implemented using boundary value limits and time rate-of-change limits. Similar analyses and processing are done at NDBO with a view toward changing onboard acquisition modes via interrogation commands. Landline communications between NDBO and NMC computers are maintained to ensure that final data dissemination is limited to valid data.

Data Base Systems

NDBO maintains both information and archival data base systems. The information data base serves to provide the necessary integrity for the buoy processing programs at both NMC and NDBO. The data base program is established at NDBO and maintains a disc storage file there. Via computerto-computer wireline transfer, NDBO maintains and updates the disc data base at NMC.

Archival data base systems are also maintained from which 7- and 9-track magnetic tapes are generated. Once a month, tapes are sent to the National Climatic Center (NCC) and the National Oceanographic Data Center (NODC) for archival and meteorological and oceanographic data base analyses.

Data Formatting and Dissemination

The United States, similar to other nations, has deployed environmental data buoys to provide reliable, periodic weather information from remote ocean areas. Buoy instrumentation provides measurement capabilities that exceed the accuracies achieved with shipboard observation systems. For this reason, NDBO has recently changed its meteorological dissemination format and is now using a new code which reflects the accuracy and resolution of the onboard instrumentation and shore processing.

The World Meteorological Organization (WMO) sponsors the new weather code. The code will be implemented by all cooperating nations for disseminating reports derived from automated marine weather stations of participating countries. The full name of the code as listed in the WMO Manual on Codes is "FM 24-V SHIP - Report of synoptic surface observation from a sea station."

A unique code has been generated for the dissemination of spectral wave data. Every 3 h, on the synoptic hour, and at accelerated intervals during abnormal disturbances, NMC disseminates values of power spectral density of vertical displacement at specified frequency intervals. NMC disseminates directly both the WMO Code FM 24-V message and the NDBO spectral wave data. The coded formats are generated by the NMC computer and placed into switching directories for dissemination to the NWS user community.

Data Flow for Drifting Buoys

Fig. 18 shows the data flow for the TIROS drifting buoys. The major acquisition, processing, and dissemination function parallels those described for our moored buoy systems. The main difference between the two systems is that the drifting buoys cannot provide synoptic data, but rather provide data about every 6 h depending upon buoy latitude. The TIROS-6 data orbiting satellite successfully launched in October 1978 collects drifting buoy sensor data and determines buoy position by measuring the frequency shift of the buoy transmission during the time the buoy is in view of the satellite. All the data are collected at the CDA stations in Gilmore, Alaska, and Wallops Island, Va. The received and detected data are then sent to the spacecraft operational control center in Suitland, Md., for preliminary processing. All the data are then transmitted to the Centre National d'Etudes Spatiales (CNES), an agency of the French Government in Toulouse, France, where it is processed and disseminated worldwide. Special formats for each class of drifting buoys have been prepared and are contained in this workshop manual.

CONCLUSION

In summary, environmental moored buoy data transmission, using GOES and NESS/NDBO data processing and dissemination facilities, has been refined. This achievement permitted the acquisition and dissemination of well over 2,500 synoptic weather messages per buoy in 1978 from a complement of about 15 buoys. In addition to weather messages, about 25,000 wave spectra reports were disseminated in 1978 from 10 buoys equipped with wave measurement systems.

The data quality requirements and achievements associated with the moored buoy program is shown in fig. 19. The ability to deliver high-quality data from various remote and often hostile ocean areas on a

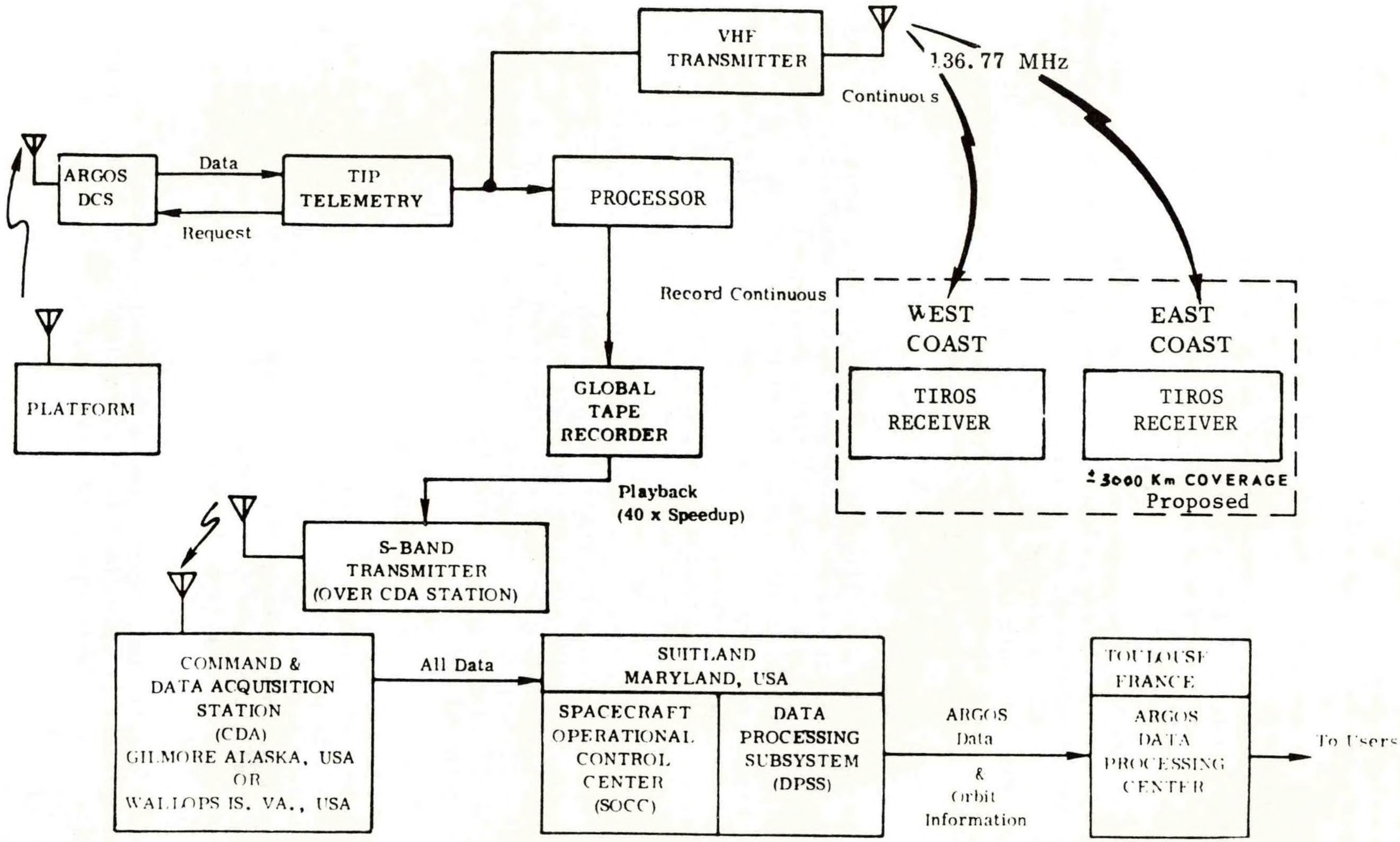


Figure 18.--Data flow for drifting buoys

.BUOY MTBF	
1972-75	1977
36 days	150 days
4 buoys	15 buoys

.DATA QUANTITY	
1972-75	1977
2200 MSG	2550 MSG
per buoy	per buoy

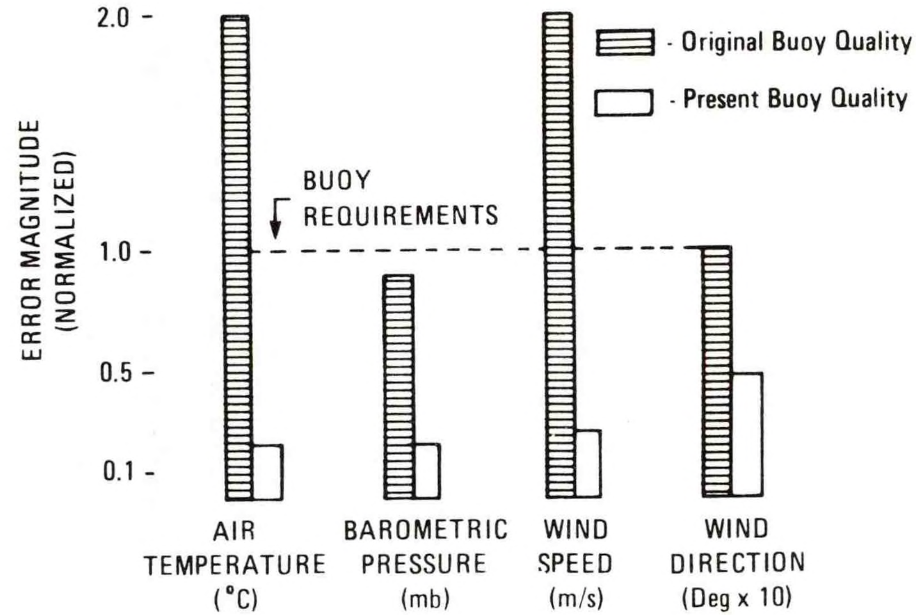


Figure 19.--Buoy data quality requirements

reliable basis has provided major impacts in the following areas of WMO activities:

- o Improved weather forecasting
- o Enhancement of climate monitoring program
- o Assistance to energy source assessment problems
- o Augmented ocean monitoring studies.

NDBO has furnished 50 buoys comprising the entire U.S. commitment to the buoy portion of the Global Weather Experiment. Each buoy has been designed to include an air-drop deployment capability and a sensor data link compatible with the TIROS satellite. Results from the Global Weather Experiment will increase understanding of the entire global ocean/atmosphere interaction system. Systematic knowledge about the behavior of this global system will enable numerical weather prediction for periods extending beyond just a few days, with increased reliability and accuracy.

Developments in advanced deployment areas have also flourished during the past year. These activities included development of directional wave spectra systems, buoy motion packages, subsurface current measurement instrumentation, acoustic data links, profiling and discrete level ocean temperature measurement systems, advanced meteorological sensors, and an onsite meteorological sensor test and evaluation facility.

Finally, remote data acquisition and telemetry operational systems for custom applications have been developed. Perhaps the major undertaking in this category was development and implementation of two unique laboratory-supported biofouling and corrosion field experiments in the Gulf of Mexico in support of our Department of Energy's Ocean Thermal Energy Conversion (OTEC) Project. Another custom system designed and established by NDBO was the Ocean Platform Environmental Monitoring System (OPEMS) for brine discharge activity for the Strategic Oil Reserve Program.

NOAA SCIENTIFIC AND TECHNICAL PUBLICATIONS

The National Oceanic and Atmospheric Administration was established as part of the Departme Commerce on October 3, 1970. The mission responsibilities of NOAA are to assess the socioeconomic ir of natural and technological changes in the environment and to monitor and predict the state of the solid E the oceans and their living resources, the atmosphere, and the space environment of the Earth.

The major components of NOAA regularly produce various types of scientific and technical infc tion in the following kinds of publications:

PROFESSIONAL PAPERS — Important definitive research results, major techniques, and special investigations.

CONTRACT AND GRANT REPORTS — Reports prepared by contractors or grantees under NOAA sponsorship.

ATLAS — Presentation of analyzed data generally in the form of maps showing distribution of rainfall, chemical and physical conditions of oceans and atmosphere, distribution of fishes and marine mammals, ionospheric conditions, etc.

TECHNICAL SERVICE PUBLICATIONS — Reports containing data, observations, instructions, etc. A partial listing includes data serials; prediction and outlook periodicals; technical manuals, training papers, planning reports, and information serials; and miscellaneous technical publications.

TECHNICAL REPORTS — Journal quality with extensive details, mathematical developments, or data listings.

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