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PROCEEDINGS

Santa Barbara, California
December 11, 1962

OF 2ND

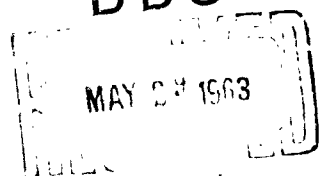
INTERINDUSTRIAL OCEANOGRAPHIC SYMPOSIUM

AD No



"The sea drowns out humanity and time: it has no sympathy with either, for it belongs to eternity."

—O. W. HOLMES, Autocrat of the Breakfast Table



PROCEEDINGS OF



SECOND
INTERINDUSTRIAL
OCEANOGRAPHIC
SYMPOSIUM

THE COVER—This fine marine is by Bennett Bradbury, probably the top American marine painter of the day. The title, "The Forerunner," refers to the approaching storm. It was painted in the vicinity of Laguna Beach. The original is the property of Henry R. Davis, owner of Rapid Blue Print Company, printer of the Proceedings. We are grateful to him for his permission to reproduce this masterpiece on our cover.

This publication was prepared from material submitted for this purpose by the authors. Tape recordings of the discussion periods provided the source for this information. The meeting was held at General Motors Defense Research Laboratories, Santa Barbara, California on 11 December 1962.

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IOS OBJECTIVES

To improve the application of oceanographic information.

To disseminate oceanographic information in industry.

To encourage cooperative research programs.

To encourage assistance to national planning groups.

To encourage research in oceanography.

THE INTERINDUSTRIAL OCEANOGRAPHIC SYMPOSIA

by Gordon G. Lill

Corporate Research Advisor
Lockheed Aircraft Corporation

A Word of Introduction

The Second Symposium was held on December 11, 1962 at the General Motors Defense Research Laboratories, Santa Barbara, California. The group was welcomed by Dr. H. A. Wilcox, Director of Research and Engineering. Dr. Robert G. Paquette acted as chairman for the technical sessions.

The Northrop Corporation, Ventura Division, will host the Third Symposium which will be held on June 5, 1963. The address is

Northrop Ventura
1515 Rancho Conejo Blvd.,
Newbury Park (Ventura), Calif.

The consensus was that the second meeting was an improvement over the first. It is anticipated that the Third Symposium will continue this trend.

Like all new publications, the first issue of *Proceedings* contained a few errors — both of omission and commission — which should be noted.

Page 2—Mr. Sidney Frank's affiliation should read "Autometric Research, Inc."

Page 7—Fig. 1, as corrected by the author, is reproduced below.

Page 9—Fig. 4 has also been corrected by the author and is reproduced below.

—The List of Attendees of the First Symposium was inadvertently omitted. It is included at the back of this issue.

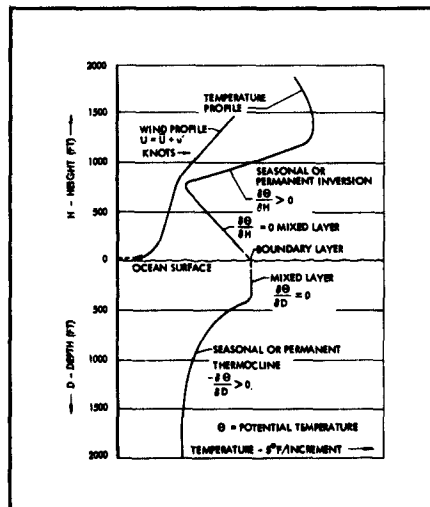


Figure 1

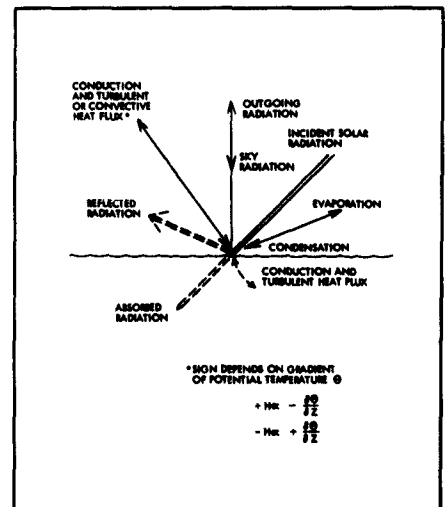


Figure 4

AN UNTENDED DIGITAL DATA ACQUISITION SYSTEM

by A. R. Metzler
Marine Advisors, Inc.
La Jolla, California

Abstract — An oceanographic buoy, with included instrument recording system, has been produced and tested which uniquely utilizes a variety of oceanographic sensors. The uniqueness of this system depends on the manner in which several types of sensor inputs can be handled by the data recording package. The present system utilizes the following type sensors: anemometer, wind-direction sensor, water temperature, Savonius Rotor Current Meters, and water current-direction sensors.

Data storage is performed by a digital magnetic tape recorder with direct application to telemetry methods. The buoy philosophy used dictates the transducer method employed in each sensor and is pointed toward handling large amounts of oceanographic data from a single station.

Due to unforeseen circumstances, the author was unable to be present at the Symposium. The foregoing paper was ably presented by Mr. Duane Maddux of Marine Advisers, Inc.

— EDIT.

Data gathering in the ocean as well as in the air-land interfaces of the ocean has been approached in many ways in the past several years. The prime method has been to take the scientist to the scene of his problem via surface vessels and collect data in this manner. It is certain that this philosophy will never be replaced, but the advent of new tools based on later developments is slowly coming to the aid of this thinly spread scientist. It is a natural development, therefore, for the oceanographic community to think in terms of untended data-gathering systems placed in the areas of interest for the particular problem concerned. This approach will give the scientist more time back at his institution, government lab or commercial enterprise to evaluate more adequately the information collected and form conclusions that are the primary interest in and reason for the data gathering.

Aside from having the scientist in the field working on leaky plugs and connectors related to his oftentimes faulty and frustrating instrumentation which consumes his valuable time, there is the very important economic factor concerning the logistics support that has to be given the scientist while he is in the field. Another factor of concern is the speed with which present-day oceanography would like to move ahead in the methods by which data are collected and the processes required merely to properly list the parameters measured.

It is from these three general problem areas connected with past oceanography that the field is naturally turning toward the systems approach to the collection of oceanographic data.

The systems approach outlined here is merely the combining of several different talents and techniques to perform the aims of satisfying what we might consider as the latest methods of data collection. This tendency toward automation in gathering data from the ocean is a natural development after considering the cost involved in utilizing ships and scientists in the field to perform the data-gathering function. As mentioned, this is not only time-consuming, but very costly, and results in many frustrations for the man who feels that he needs these data to form some general conclusion.

Marine Advisers, Inc., in association with Ocean Research Equipment, Inc., has considered many of the problems in the design philosophy of the untended data-gathering buoy. This system has been designed and built from the standpoint of the data assessment problem, assuming that such a device would be moored in an untended state for periods up to four months and be capable of recording up to one-third of a million complete samples of data from various individual sensors.

The present state of the art of oceanographic and meteorological sensors has not met the rate of expansion of the methods of transmitting or

transforming the energy from the oceanographic sensor to the data-logging system. Of much greater concern, however, in an oceanographic data-gathering buoy are the mooring problems of the platforms involved. Comparatively speaking, the methods of collecting and logging these data are much better defined than the methods of establishing or mooring such an instrument platform in the open ocean. We, at Marine Advisers, feel we have gone a long way in solving the sensor and data-gathering portion of the problem, but have only partially solved the problems of mooring the instrument platform. One can speak in very general terms about data gathering, sensors and tape recorders that can be applied to a variety of tasks, but when it comes to mooring systems, one has to be specific and talk about particular applications, especially water depths, currents, and the endless and unpredictable dynamics of the mooring lines and buoy shapes.

Beginning with the general configuration of the entire system, in particular the mooring system and the buoys, Figure 1 shows a cross-section of system such as we have developed. This is a two-buoy, taut-wire mooring system.

Below the surface buoy, with its meteorological sensors, is a slack painter leading to the subsurface buoy. The subsurface buoy contains the data-logging system and is moored between 30 and 60 feet from the surface. Below the subsurface buoy is the sensor chain down to the anchoring arrangement. In addition to the entire data-logging system, the power supply is located in the subsurface buoy. The mooring line and electrical cable are one and the same. The strain members exist within the electrical cable as far down as the last sensor. There is a similar electric cable with strain member for the slack painter. On the first mooring attempt, we worked in 150 feet of water with the subsurface buoy 30 feet below the surface.

Each underwater sensor unit in the diagram consists of a Savonius rotor current meter, a direction vane (referenced to a magnetic compass in each sensor) and a temperature probe. Each sensor is "hard-wire" connected to the data-gathering package in the subsurface buoy. On the surface in our present system, there is an anemometer and a wind-direction sensor, which is also referenced to a magnetic compass. This information also is sent by "hard wires" down to the subsurface data package.

The buoys are foam-filled fiberglass with an outer gel-coat. There is a polyvinyl-chloride central tube in the surface unit and aluminum tube in

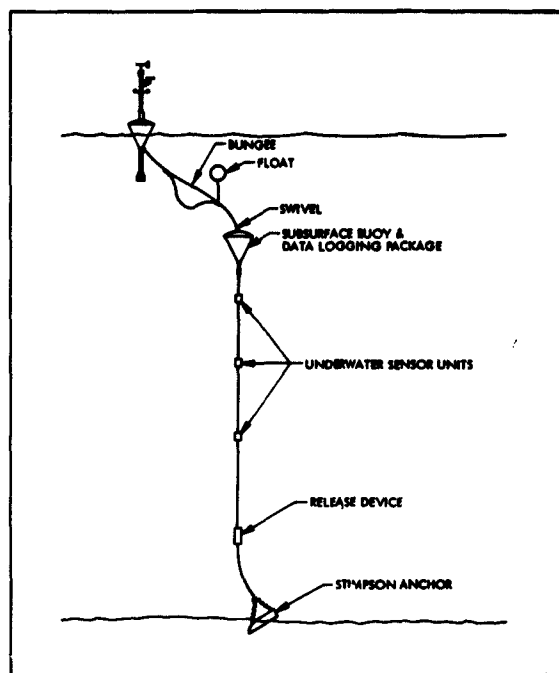


Fig. 1 — System Diagram Showing Subsurface Components

the subsurface unit. Internally the surface buoy contains only the batteries and flashing unit for the navigation lights. This buoy also serves as a junction box for the meteorological sensor wires going down to the subsurface package, as well as for a series of twelve data lines that come to the surface buoy from the subsurface buoy. One can plug a small readout box into the surface buoy from a small boat and read the data as it is occurring in real time to the same accuracy at which it is put onto the magnetic tape.

Three such underwater sensor units were used for the first series of tests. The system as presently designed may include at least 10 such sensor units in the chain. Leading to the anchoring system in Figure 1, there is a length of polypropylene line between the last sensor and the anchor, with a release mechanism at the area of the last sensor. The present release mechanism is a clock-operated, electrical firing squib. It releases the anchor on a short stay of line to let the buoy system come to the surface. In the present system, the subsurface buoy has approximately 500 pounds of positive buoyancy. The anchor weight is approximately 1,800 pounds.

this application, we have used two modes of operation: 2 minutes and 20 minutes. The transistorized motor is driven from a 120 standard frequency which we have developed at Marine Advisers. It consists of a 120 kc crystal and counts down through tunnel diode stages to 120 cycles to be used as the synchronizing source for the DC Brailsford motor. The 120-cycle frequency standard draws 3 mw of power, and the Brailsford motor draws approximately 300 mw; these are the only components in the system which have a 100% duty cycle. Everything else in the system is a sequence-operated device powered by the digital logic.

The digital clock in the system starts with a 100-kc crystal and counts down by divisions of 2 to, finally, 2.63 seconds. Referring again to the block diagram, (Fig. 2), if we take as an example a speed pulse input, arriving from a Savonius rotor, the input first goes into the stepping switch. When this is in the proper position to accept this signal, as determined by the digital clock, it will pass through the stepping switch into a wave-shaping circuit, where the shape of the wave-form is altered so that it will operate the digital logic more reliably. From there, the signal proceeds into an interval detector which makes a square wave out of the time interval occurring between switch pulses.

The square wave, as generated by the interval detector, is mixed with a standard frequency of 3125 cycles. The frequency burst from the interval detector passes through other portions of the stepping switch in the sequence of events and through the proper gating circuits and is impressed upon the count accumulator from which is formed the 12-bit binary. At the proper time, as determined by the logic, the information is transferred from the count accumulator into the tape heads. The 12-bit lines are fed into each tape head through gates to produce the presence or absence of a signal on a particular head. At this time, the tape is standing still when a current passes through the tape heads.

After the information is sent to the tape recorder, another step function is sent to the stepping motor of the tape drive and the tape latches over (in our case, about 36/1000 of an inch) ready to accept the next data cycle. During the cycling time that the tape is transferring, a pulse is sent to the interval detector and the count accumulator to completely reset these to their original state, ready to accept the next sample of information that will come through on a different signal line.

Since the method of measuring resistance differs slightly from the foregoing, it appears appropriate to follow the signal path through the system by the following example.

A vane for measuring water direction (Marine Advisers Model B-5a) moves a microtorque resistance element which is referenced to a magnetic compass device, thereby producing a value of resistance equivalent to the angle between magnetic north and the direction (clockwise) to which the vane is oriented. In this case, auxiliary resistance isolates the sensor and also establishes the proper voltage range to operate the analog-to-frequency converter located in the buoy system.

The analog-to-frequency converter is simply a printed card that performs the function of sending a DC signal into the input of the converter and the resulting frequency or pulses per second occur in the output. As an example, zero-volt input produces zero pulses per second output; $\frac{1}{2}$ -volt DC input produces 4,000 pulses per second on the output at full span. Since the range is 12-bit binary, which is a range of 4,095, a $\frac{1}{2}$ -volt swing in voltage will completely fill our register on the count accumulator.

From there, the signal passes through portions of the stepping switch and through the proper gates and logic and is impressed on the count accumulator. Again, the reset functions and the stepping functions of the tape motor take place in a manner similar to that discussed previously. One further thing that might be said with respect to resistance measurements is that there is a platinum electrode temperature element in the underwater sensor. This particular device is placed in a bridge circuit with bridge output and is put into the analog-to-frequency converter and, hence, passes through in the same manner as described before. The stepping switch turns the system off on its last position (25 sensor steps in present system) and waits for the master timer to activate the circuit again. In this manner, 25 points are sampled for approximately $2\frac{1}{2}$ seconds each. This is equivalent to less than one minute for the full data cycling to occur on the 25 separate sensor channels.

These are not all sensor channels, as there is a 3-point calibration function for the direction measuring devices and a 5-point calibration function placed in the unit for the temperature devices. This internal calibration is to determine the stability calibration of the device over a long period of time when voltage variations are liable to affect

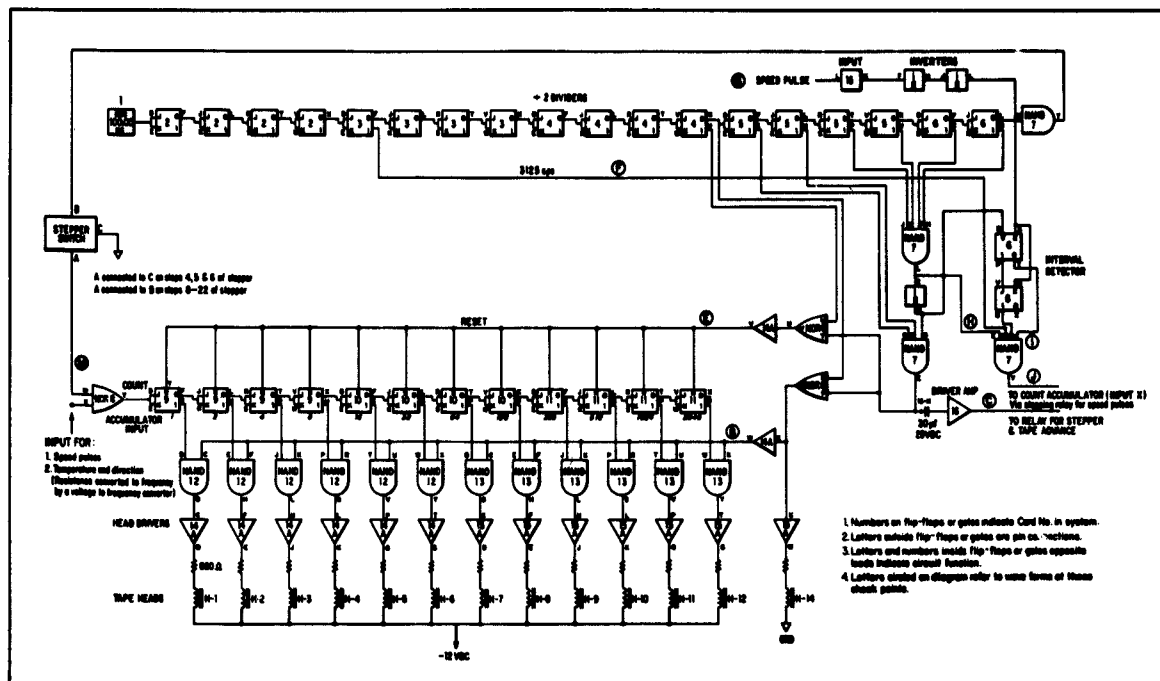


Fig. 3 — Schematic of Digital Logic System and Signal Recording

the accuracy of the data. On the tape machine (which was produced locally to our particular specifications) for this system, we are performing digital recording in a static or stationary mode—that is to say, the tape is standing still as the heads are magnetized.

There are several precautions to be taken in this type of recording to ensure good reliable, noise-free data. These have all been observed. Extremely clean signals are produced that are easily programmed into computer format. Eventually we have decimal units that are completely calibrated and in engineering units such as centigrade and knots, which can be used and properly put in tabular form so that one can look at and compare the various phenomena.

In our present configuration, we have stayed with the tape format that is compatible with equipment presently used at the Scripps Institution of Oceanography. From this tape, a new tape is made that expands the spacing between frames by about three times and then plays back at a constant speed. From this, a scanning process is used to produce punched paper tape. There are many ways one could go from the magnetic tape to punched

paper tape, but we use this method because it is available to us through the cooperation of the University of California.

After the punched paper tape is produced, it is programmed for the 1604 computer with calibrations in IBM format. Thus we obtain a calibrated decimal engineering output in the proper format. The entire data-transcription system has since been incorporated in approximately 48 inches of rack space which includes all the components necessary to produce a punched paper tape.

Of possible interest are Figures 3 and 4. Figure 3 is a schematic diagram of the Digital Logic and Signal Recording Systems. Figure 4 is a Logic/Data Time Diagram. Figure 5 is a composite of photographs showing the installation process as performed in Lake Michigan with the cooperation of the Public Health Service.

In summary, while untended data-gathering systems will never replace the oceanographic vessel or scientist, we feel that we have demonstrated the state of the art sufficiently to show that general ocean data gathering can be performed at one tenth or less of the cost of conventional methods utilizing a variety of different sensor inputs.



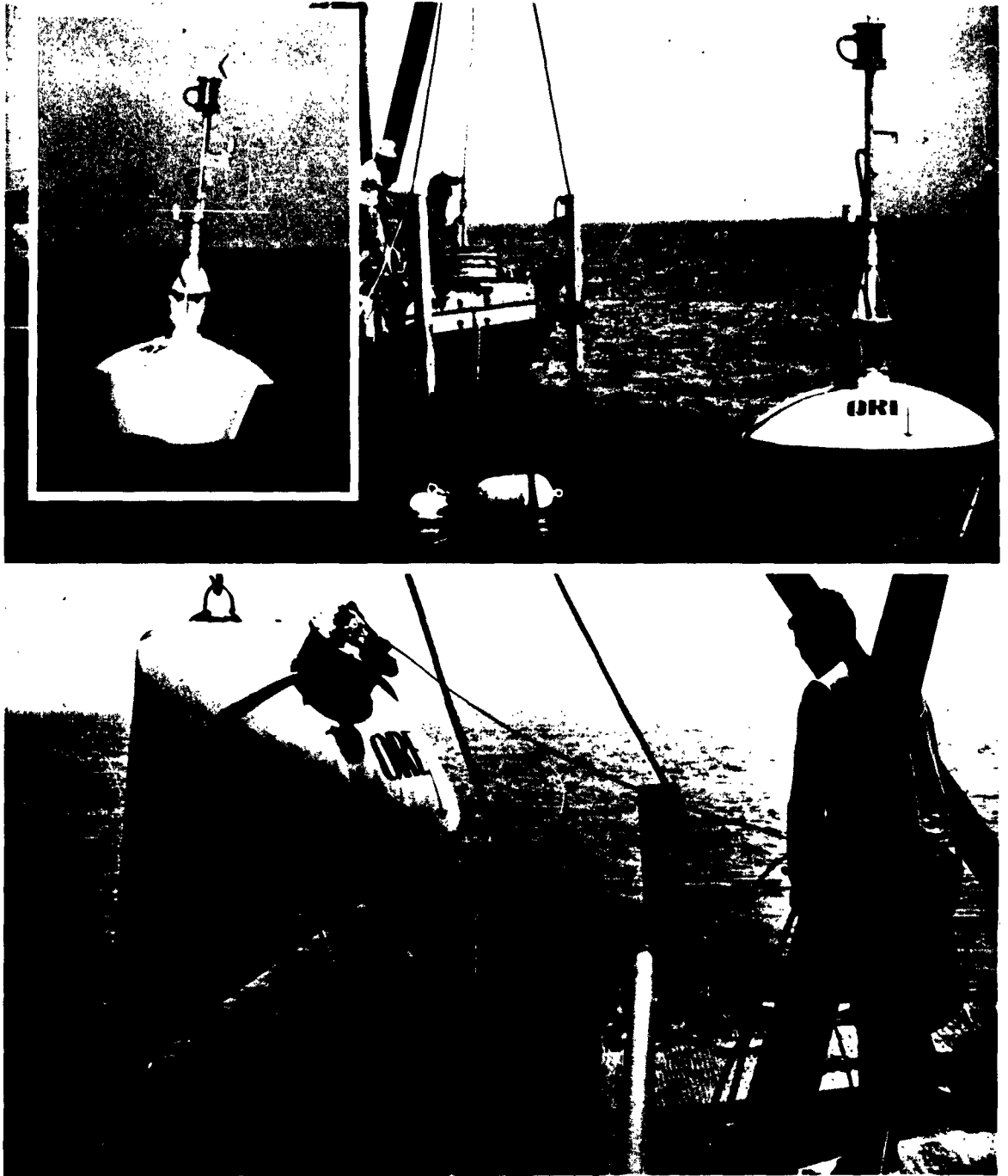


Fig. 5 — Photos Taken During Installation

DISCUSSION

HILDRETH: How is north determined?

Maddux: By referral to a magnetic compass.

BAER: How do the buoys behave with respect to the waves?

Maddux: We don't have much information on this, except that we know the surface buoy swings.

DAUBIN: How many kilowatt hours is the system designed for?

Maddux: It is designed to last four months. I don't have the figures in kilowatt hours.

SNODGRASS: I would like to call to your attention that Bill Richardson uses a flexible three-conductor, electric cable made by the Plymouth Cordage Company on his buoys installed south of Bermuda.

KIDD: What is the new anchor that you referred to?

Maddux: You will find a picture of it in the last issue of *Undersea Technology*. It is manufactured by Ocean Research Equipment, Inc.

Question: Were the sensors of an analog type?

Maddux: Yes.

NUMERICAL WIND-WAVE FORECASTING

by *Ledolph Baer*

Antisubmarine Warfare & Ocean Systems

Lockheed-California Company

Burbank, California

Abstract — The concentration on forecasting wind waves has been more intensive than that on the forecasting of other oceanographic parameters. Therefore, it is appropriate to use some of the problems and solutions that were developed in ocean wave studies, to point the way toward the forecasting of other parameters and the design of ocean systems. The innate variability of the various parameters must be recognized and defined before sensors are developed and before ocean systems can be planned. In many cases, forecasting or hindcasting techniques can be used to increase the efficiency of ocean systems.

A recent model for the numerical forecasting of the complete spectrum of wind waves is described briefly. In this model, the concept of "fetch" is replaced by an equivalent Lagrangian duration. Discussion of the verification of the model leads to the conclusion that the spectrum must be corrected and a dissipation function added. Consideration of the accuracy of the model would allow optimization of buoy spacing and use of the results for an optimum system.

My major field of research for the past several years has been the numerical forecasting of ocean waves. This is sometimes classed as meteorology; other times, it is called oceanography. Today, however, I do not want to apply either of these names because I want to stress the importance of this type of study to what we like to call ocean systems. I suggest that the study of wave forecasting is a reasonable example of the much larger problem.

Sailors have long known that the wind caused the waves, and they had rules of thumb to help them in navigation. They knew, for example, that a point on the coastline "drew the waves," but it was only in World War II that a real start was made in the scientific study of wave phenomena. At that time, basic hydrodynamic theory was combined with the empirical evaluation of nondimensional parameters to make a reasonably accurate forecast.

The war was the general impetus that forced the development of wave forecasting. However, there were and are a great many other needs for wave forecasting. High seas can damage large ships and be a real danger to smaller ones. Sea planes can land safely only in relatively low seas. Hydrofoils and surface-effect machines cannot operate in rough seas. In these applications, wave forecasting is not usually considered part of the system, but in the true sense, it is. The total system of transportation, or ASW, or whatever, is truly an ocean system.

For advanced concepts, we usually start by considering the mission and the environment, then combine all of this into a system. However, in the case of conventional ships, shore facilities like sea walls, docks, and so forth, much of this consideration is implicitly considered through many years of experience. The Navy and several private consultants provide wave-forecasting or ship-routing services to increase the efficiency of ships or vehicles. Waves are of critical importance to aircraft carrier operations because high seas cause large ship motions that make deck landings difficult. Therefore, efforts are devoted today toward ship stabilization, construction of more complete automatic landing controls, and the solution of similar problems. Thus, the environment is truly a consideration of the system although it has not always been thought of as such. Previously, this environment was left purely to the scientist, while the engineer used what was in his handbook.

Many of us here are associated with ASW problems. However, we do not even know the spectrum of ambient noise generated from a surface-wave spectrum. Some of us are beginning to work on it, but basic limits of the environment such as this have not been properly established for the system. These problems are not alone those of the wave researcher; they are, perhaps, of even more concern in other areas. For example, work is progressing rapidly on the development of unmanned instrument systems for gaining synoptic informa-

tion in the oceans. The papers preceding and following this one describe such systems. However, there is as yet almost no work since that of Defant in 1950¹ on the proper spacing of the systems to obtain optimum results at the least possible cost. To be certain, several people have guessed the spacing for buoys to show the particular factors in which they were most interested. However, in a large system such as this, where the buoys will be used to gather data which would then be fed into a computing machine and which, in turn, would be used to describe the complete environment, almost nothing is known about the basic limits of the environment.

Industry has put forth a great deal of effort to develop sensors, to develop buoys, to develop communications; but it may be useless to measure the velocity of sound so accurately that two minutes later it will have changed more than the instrument error claimed for the sensor, unless this change can be forecast accurately. We have been involved in the design of several acoustic ranges in which this has been shown to be extremely important.

I said that a good method of forecasting waves was developed during the war, but of course, it was not perfect. It was afflicted with troubles to be expected from any first study. The original definitions of wave height and wave length or period were so simplified that ambiguities and limits of applicability developed later. The original definitions referred to the average of the larger, well-defined waves. Today, we have redefined the study of waves in terms of spectra. Thus, today, we recognize the innate variability of the waves. Most of us still speak of a sea with "10-foot significant height," although we frown on saying "Sea State 5." When we say 10-foot significant height, we implicitly recognize that 10% of the waves will probably be above about 11-feet and 1% above 16-feet. There are still many problems to be solved, but the recognition that there is a lack of absolutes and the study of this variability by statistics and probability theory have allowed another step forward. The same recognition is not yet general among the researchers in other areas of ocean systems.

Large computing machines are not needed to forecast the significant height of the sea nor to estimate the cutoff frequency or other parameters for a particular location in time. However, to use the standard graphical methods for preparing a good synoptic forecast map or to forecast the entire spectrum, would be quite time consuming. For this reason and to provide more objectivity in re-

search, some of us have been experimenting with numerical models that can be put directly on a machine for a complete solution. Most wave-forecasting methods, today, use three basic parameters to forecast the sea conditions. These are (1) wind speed, (2) area over which the high winds are fairly constant, called "fetch," and (3) the time duration that the wind blows over that area. Some methods consider both the length and the width of the fetch. It is quite difficult to delineate such an area; no two people would choose the same fetch. Dr. Basil Wilson² and others have established methods for the objective consideration of an effective fetch length, but the basic problem is that the wind blows over the water, transfers energy to the water and continues this transfer until the energy in the water reaches a certain level which, of course, is a function of the wind speed. Thus, the concept of fetch itself is quite artificial and can only lead to complications. The model developed eliminates this fetch problem. Instead, we worked with an equivalent Lagrangian duration. The model used is described in more detail elsewhere³.

This model is based in the spectrum and the general conditions defined by Pierson, Neumann and James⁴. Thus, one should expect an answer that approximates what would be forecast using the Pierson, Neumann and James methods as defined in HO 603. The coordinates that were used are shown in Figure 1. In this figure, the grid points are shown to be approximately 120 miles apart and square, they are not oriented along latitude and longitude lines. In this first approach, we have not considered many small errors such as the curvature of the earth and the fact that a straight line on a Lambert conformal projection chart is not quite a great circle in mid-latitudes. If we can optimize the grid spacing by machine studies, then it should be quite simple to decide upon the spacing of a buoy system to provide us with the basic information.

Figure 2 outlines the major steps in the wave-forecasting procedure. Starting with an initial condition at every grid point in the machine's memory, a new spectrum is computed at every grid point, in turn, using the winds appropriate to that grid point and assuming that they blow for two hours. The two-hour period is somewhat arbitrary, but it is consistent with the spacing of the grid shown in Figure 1. The next basic step is to allow each component of the spectrum to move for two hours in its own direction at a speed computed from its frequency. This is accomplished essentially by plotting a map of one

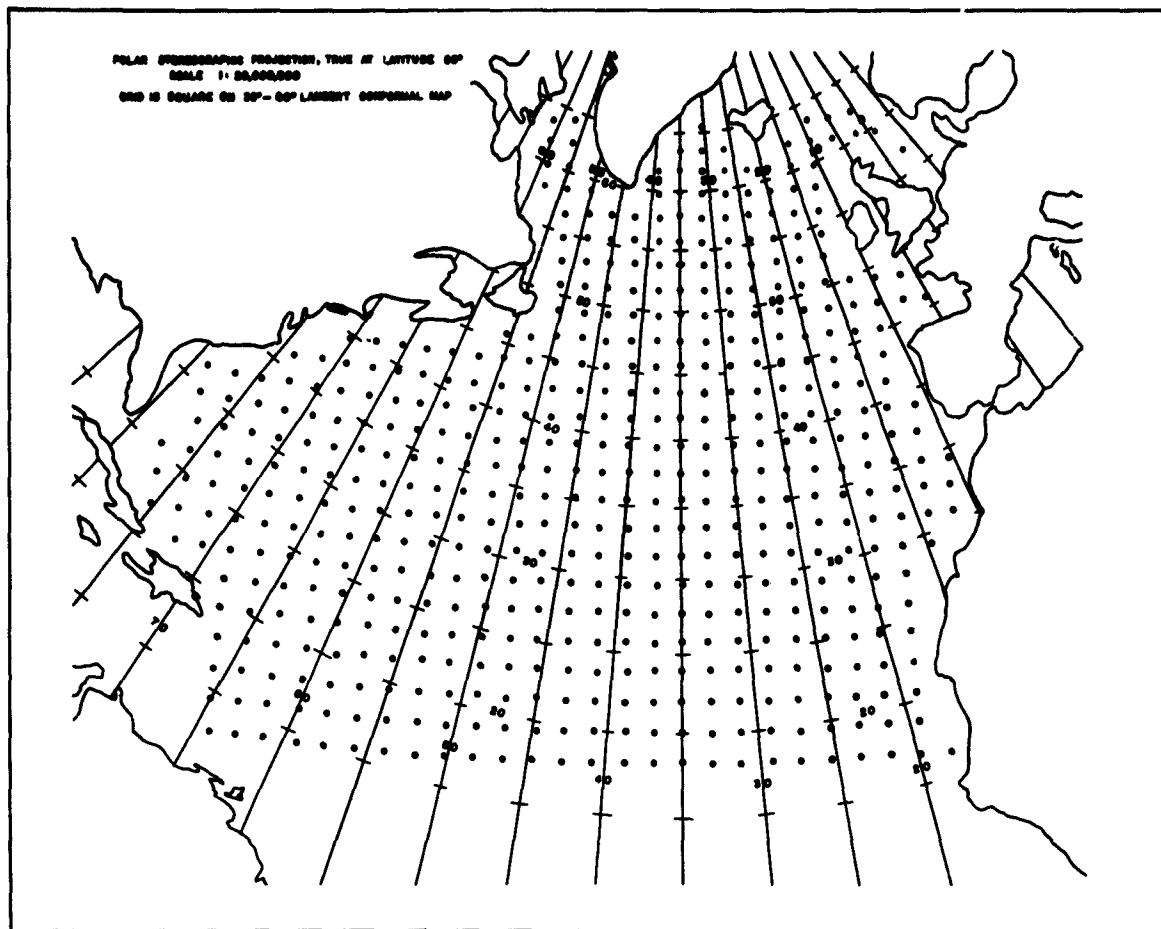


Fig. 1 — Grid Used to Specify Wind and Wave Fields

component and shifting the entire map. Then, in turn, each component is taken until all components are finished. Components of the spectrum are discussed here because the spectrum was specified in 120 discrete increments, 12 directional increments and 10 frequency intervals. By continuing this process, and repeating every two hours, we get the answers summarized in the next two figures.

Figure 3 is an example of forecasted directional spectrum for one grid point at one time. Although this detail is needed for some purposes, we are unable to show the important spatial variations and still keep the detail. For this purpose, the machine has plotted a map of the North Atlantic

Ocean showing the forecasted significant heights at each time increment desired. An example of this is shown in Figure 4. Figure 5 is a copy of sea condition chart prepared by the U.S. Naval Oceanographic Office for the same time. The verification does not look as good as could be hoped; note especially the area off Spain. However, when we consider the poor data used to prepare the verification chart, it is almost as suspect as the forecast itself.

As a further test, we compare the time histories of the significant wave height at all available weather ships throughout the period with the forecast for nearby grid points. This is shown in Figure 6. Note that weather ship "K" was

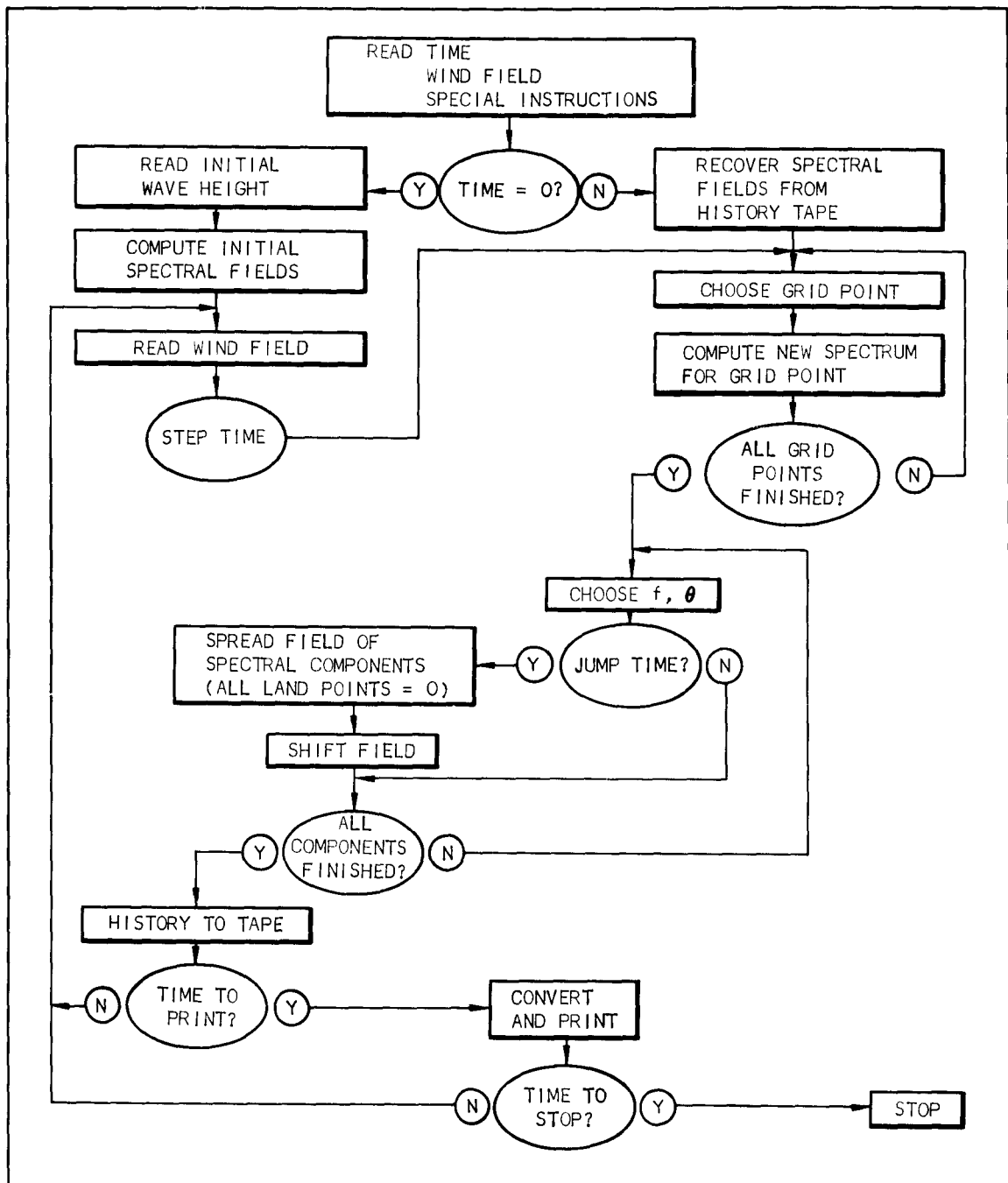


Fig. 2 — Master Flow Diagram

observing approximately 20-foot waves, while the Oceanographic Office chart never showed greater than 11 feet. Our forecast got into the low thirty's, only about 50% above the estimate. This overestimate seems fairly general through all of the plots. We also ran another test that could be verified at one point as a non-directional spectrum.

Figure 7 shows the spectrum estimated from the observations of the British OWS *Weather Reporter*, along with its 5 and 95% confidence levels. The stippled area is the forecast. Again this is slightly high, and the interesting point here is that the frequencies are also too high.

Figure 8 shows the observed and forecasted significant heights for this case. There are three

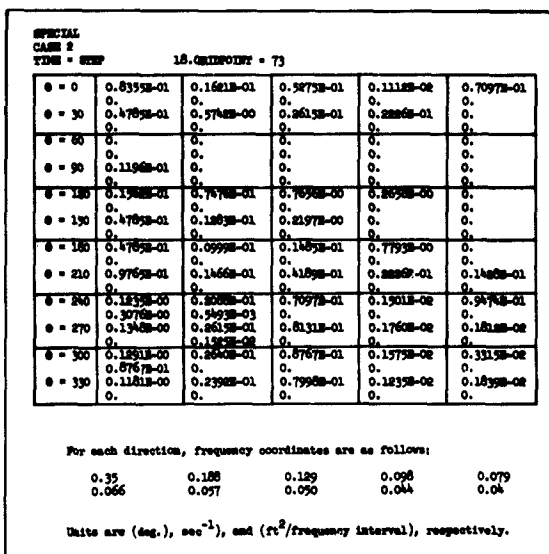


Fig. 3 — Example Forecast Directional Spectrum

basic problems with this forecast, as you can see. First, the waves get too high; second, the initial conditions are poor; third, the spectrum is too rich in high frequencies. These same errors would have occurred using the standard methods of HO 603. The problems of the initial conditions could be handled easily with observations instead of guesses. The wrong frequencies obviously are due to an incorrect spectrum, leaving the problem of the extra height, which could be due to many things. In this case, it seems due to the lack of a dissipation function when the wind changed direction radically.

With all of our problems, waves are still easier

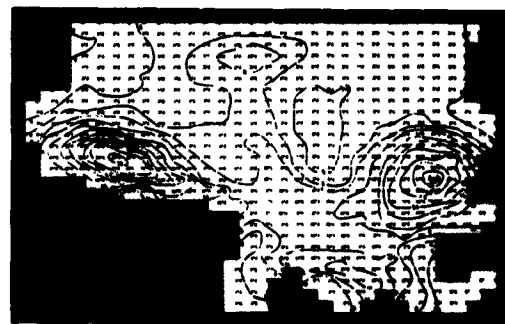


Fig. 4 — Forecast Map at the End of Time Step 24

to study perhaps, than other parameters that affect acoustic tracking and other important systems. At least, we can see the waves. However, without using forecasting techniques, we must take a great many more observations than are required when we use our present techniques of forecasting. The forecasts are only valid for short lengths of time and over reasonably small areas. However, the basic fact remains that forecasting, hindcasting, scientific interpolation, or whatever you please to call it, can materially decrease the number of observations of the environment required. It cannot, however, decrease the number of observations or increase the accuracy past some physical limit. In general, this limit has not been defined. In the case of waves, it is defined through the use of a spectrum where we recognize sampling variability.

In conclusion, may I suggest that we, as scientists, must define these limits, then develop forecasting techniques to try to attain these, or some lesser required limits, in an optimum fashion as our part in the ocean system programs of today and tomorrow.



Fig. 5 — Sea Condition Chart, 1230Z, 10 September 1956

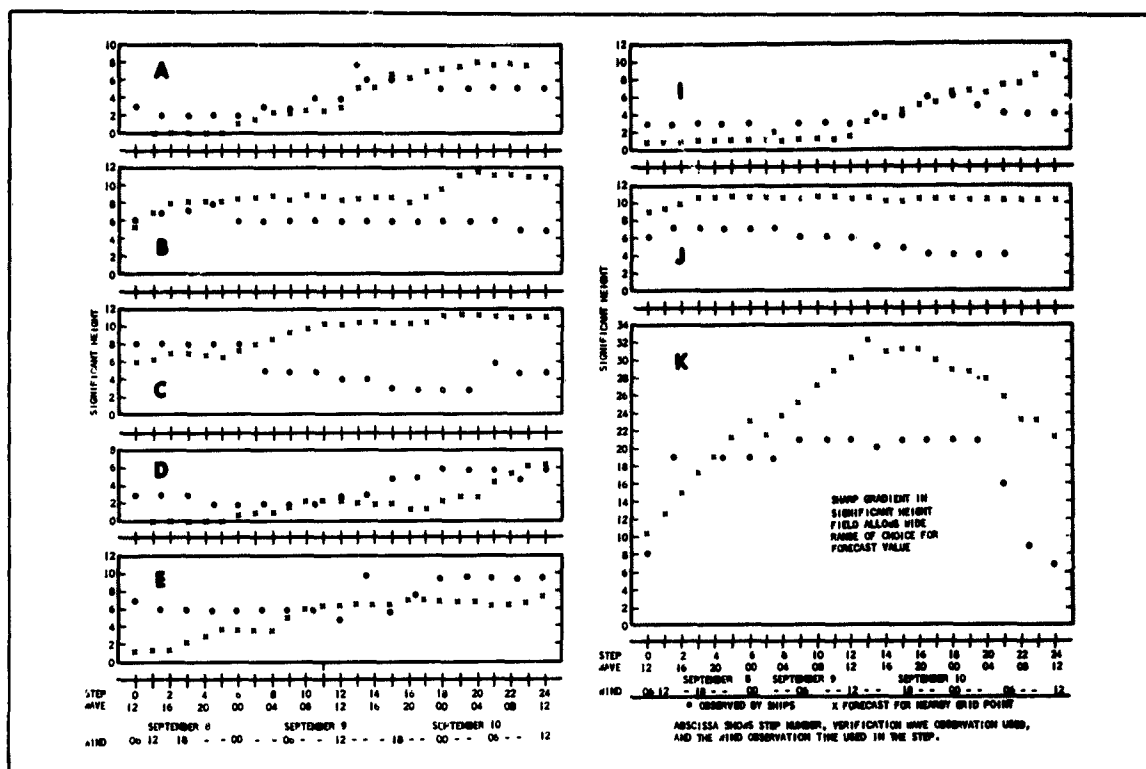


Fig. 6 — Case I, Verification Graphs for Various Weather Ships

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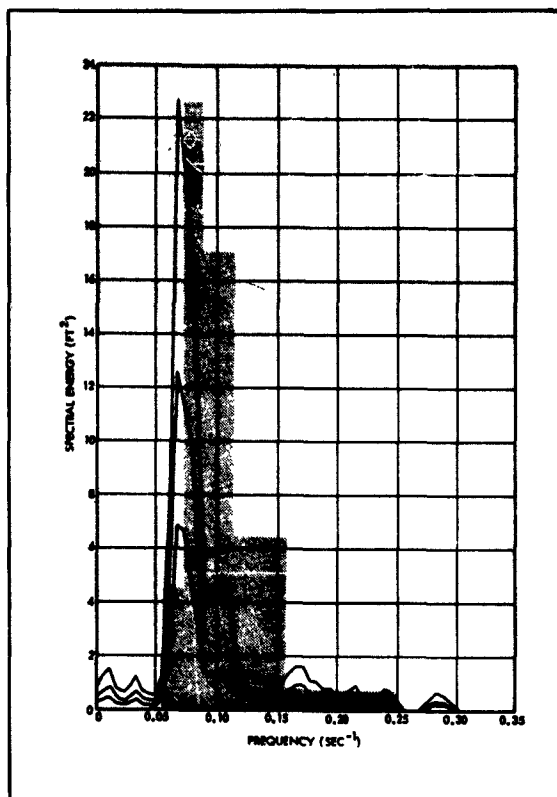


Fig. 7 — Comparison of Observed and Forecast Spectra, 0000Z, 18 December 1959

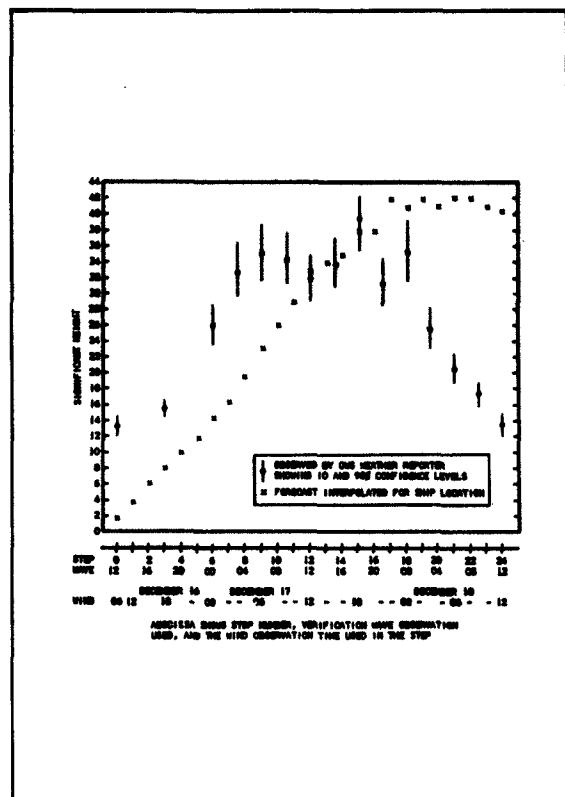


Fig. 8 — Case II, 18 December 1959

DISCUSSION

WILSON: In what form was the wind data supplied?

Baer: On punched cards which gave wind velocity values for every six hours at each grid point. Interpolations were needed for intervening times, but we decided to consider the wind constant instead because the errors were not too large.

Question: Is your work based on the forecasted wind?

Baer: Yes, for operational use, forecast wind is required. Of course, this test used the best available observations.

ASHBURN: How do you take into account the shifting of winds between grid points?

Baer: So far, we have not been able to handle them.

ASHBURN: Don't you also have to forecast winds to make wave forecasts?

Baer: Yes, but we're still in the method-testing stage. We're using hindcasting techniques at present.

Question: Can you estimate changes that may be required in the spacing of your grid points?

Baer: We are just beginning to try. The present spacing is used because that is as accurately as we know the winds.

PAQUETTE: Will "Pierson, Neumann and James" be found inadequate as a result of your work?

Baer: All of the present systems are likely to be inadequate.

PAQUETTE: It seems to me that Sverdrup and Munk were more nearly correct.

Baer: Sverdrup and Munk didn't try to give a spectrum.

DAUBIN: Was wave refraction near coasts considered?

Baer: No, but it would be a nice extension. The present model is applicable only to deep water.

SNODGRASS: A word of caution about the data point from that single British weather ship. I wouldn't worry about its not agreeing too closely with your forecast.

Baer: We're not really worried since we know of the inadequacies of making wave observations at sea.

POTTER: The size of the waves observed is always inversely proportional to the size of the ship.

SULLIVAN: I assume your eventual goal is to operate somewhere near real time. How long does the computation take?

Baer: Yes. At present the computation takes about two minutes per time step but the data gathering is quite slow.

SULLIVAN: What type of computer do you use?

Baer: We started on the 704 and ended on the 7090. The 1604 has also been used.

SULLIVAN: How much computer time is required for a complete run? That is, for one set of forecasts for the Atlantic?

Baer: About two and one-half minutes per time step. Each time step lasts two hours. On the 7090 computer a 24-hour forecast requires one hour.

THE GENERAL MOTORS DEEP-SEA OCEANOGRAPHIC BUOY SYSTEM

by Scott C. Daubin
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Abstract—The nature of certain oceanographic observables is related to the time required for data recovery. The implications of observation time on the method of data recovery are developed in an elementary economic analysis which compares the shipboard method with the automatic buoy system. Some conditions under which the buoy system becomes the preferred approach are developed.

The General Motors developmental buoy system is outlined and the arguments underlying a few of the basic design decisions are described. Some features of the buoy system are discussed in detail.

INTRODUCTION

The General Motors deep-sea oceanographic buoy system is intended to provide an untended data-collection station which is reliable, versatile, and adaptable to a variety of measurement situations. Prior to a description of the buoy system, a few words will be said concerning the underlying philosophy of untended data stations in general. Using a basic and simplified approach, the conditions appropriate to the use of the buoy system will be outlined. The arguments concern two aspects of the overall data acquisition problem: (1) the *technical*, based on the nature of the observables and the requirements of the measurement process, and (2) the *economic*, based on relative costs.

TECHNICAL

Information theory has some things to say regarding the time we must sample a function of bandwidth $\Delta\omega$ in order to extract significant information from the signal. If we consider a signal as a function of time or as a sum of different frequencies, that is, as a direct function or its Fourier transform, we will find that the *minimum* time duration of the function varies inversely with the bandwidth (Fig. 1). Oceanographic data of many types are of extremely small bandwidth. Consider,

for example, currents. If we were to plot a power spectrum from the measured time function of current magnitude as seen in the figure, we would find most of the energy to be contained in the band between DC and the tidal frequency of about a 12-hour period.

The relationship expressed in the figure states that at the very minimum we must sample for six hours, and if we wish to extract most of the information, we sample for a longer period, say ten complete cycles of the upper limiting frequency, i.e., for $k = 20$ in our relationship. Thus, to describe adequately a current where there is significant energy in the tidal frequencies, we should sample for at least five days. Essentially, this is to produce one good "reading." If I am interested in certain statistical aspects of currents, such as the perturbations due to storms, or need to know seasonal variations, then I must take many of these five-day samples. It is not difficult to see that in the measurement of currents the requirement for long time-series data collection is quite common.

ECONOMIC

An important consideration in any oceanographic program is the cost of data collection. When large-scale synoptic studies or long time-series measurement programs are contemplated, the economic question may be of overriding im-

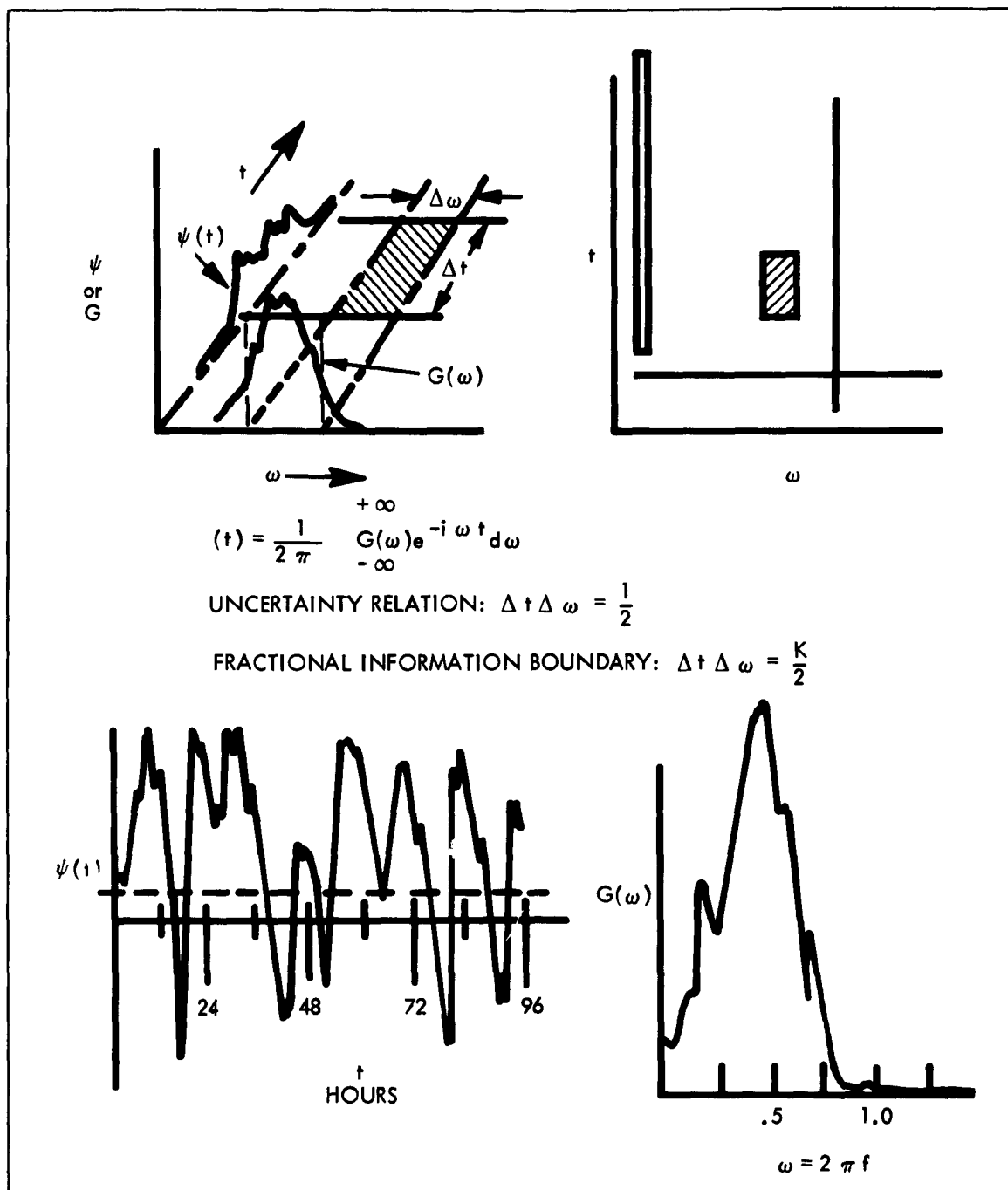


Fig. 1 — Information Theory Aspects of Observables

portance. We shall sketch the outline of analytical approach to a comparison of a shipboard system with a buoy system. Obviously, there are many ramifications which such an elementary approach will omit. Certain simplifying assumptions will be made at the outset. First, we will assume that whatever measurement we desire may be made with equal technical validity from either platform. Second, we assume that the ship is on hand, and that the buoy system is purchasable at some outlay of capital. It is to be noted that the ship is used in both systems; in the case of the automatic station, the ship is used to transport the system to the measurement site, and is used in laying and recovery. In the shipboard data recovery system, the ship is used also as a vehicle to carry the measurement equipment and personnel, and in addition, remains on station during the measurement operation.

Figure 2 presents some of the economic considerations. This analysis is presented to induce an insight into situations in which an automatic data-collection system would be useful and competitive economically with the more traditional means. The analysis clearly shows that the buoy comes into

its own on a large-scale program, i.e., one which would require the ship to spend many days on station. The *derived criterion of comparison is the initial cost of the automatic system versus the operating costs of the ship*. The precise numbers in the curves shown are not to be taken too literally; for example, we have looked at just one type of program—one where a single buoy is compared with a single ship. We have not compared the N-buoy program with the single ship, or the N-buoy with the M-ship program. In addition, we have assumed that ship operating costs are fixed and independent of the type or duration of program, an assumption we know to be only approximately correct. However, we may still extract a little more insight from these curves. The interpretation of t_a is to include the *total usage* of the buoy in a data-collection program, and not limit it to any single experiment. Thus, we compare the useful life of the buoy with the relative costs, and our figure tells us that unless we can make a buoy of useful life, t_a , then the buoy is economically uncompetitive, other factors being equal. The figure also suggests the tremendous economic potential of an inexpensive, long-duration buoy system.

BASIC DESIGN

The basic design of the buoy system comprises a submerged buoy, moored below the zone of turbulence by a taut-line cable to the bottom, and attached to a surface float above. Instruments are mounted on the mooring cable which is a combination electrical and load-bearing cable. The surface float may also carry instruments. The arrangement of the system on station is shown in Figure 3.

Adaptability is provided by a frequency multiplex system of data transmission from instrument to buoy. Each instrument is to be made compatible with a voltage-controlled oscillator which generates a frequency-modulated signal in accordance with the output of the instrument. From the data-handling viewpoint within the buoy, except for bandwidth and dynamic range variations, all transducers are handled in a similar fashion.

The submerged buoy vessel has been chosen in lieu of the single surface buoy, primarily to provide a stable taut-line instrument cable. This is an absolute necessity in certain types of measurement. It is expected that the submerged buoy will have more endurance on station than the surface-buoy system; this is due to the reduction of fatigue in the mooring. The submerged buoy also

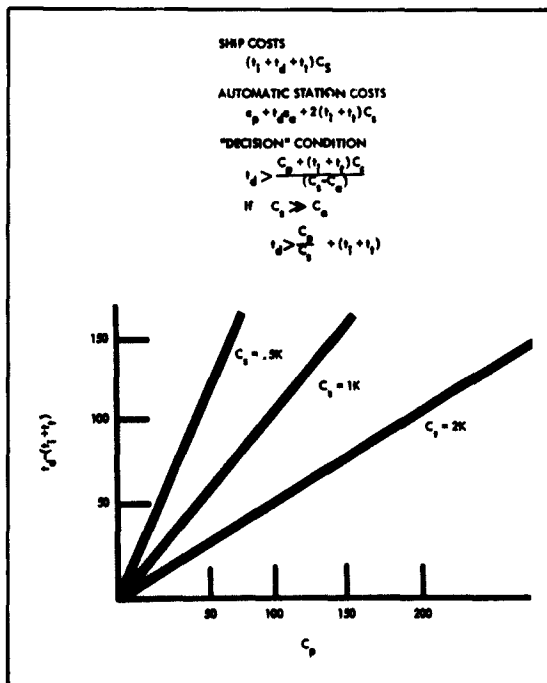


Fig. 2 — Economic Comparison

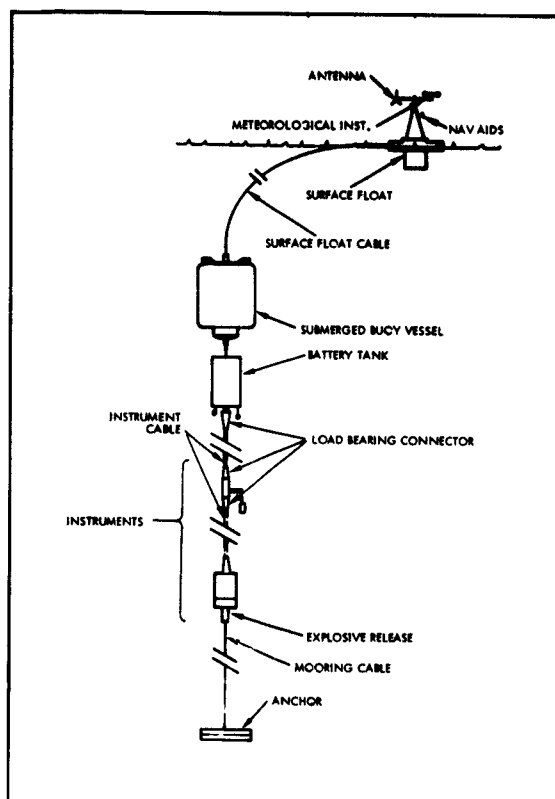


Fig. 3 — System Diagram

provides a less pilferable container for expensive equipment than the surface float.

Special instrument cable has been developed which is capable of three functions: (1) transmit information from the sensors to the submerged buoy; (2) transmit power and control signals from the buoy to the sensors; and (3) bear the load of the mooring. This cable consists of a central coaxial cable, RG-58C/U, surrounded by 12 No. 22 single conductors. Load is borne through a double helical armor; breaking strength is of the order of 25,000 pounds.

The importance of the magnitude of the buoyancy of the submerged buoy vessel is illustrated in Figure 4, which plots the total depth of water possible for installation of this type of buoy system versus the length of instrument cable. The plot is based upon $\frac{3}{8}$ -inch wire rope for the remaining mooring cable and an instrument cable of 630 pounds per 1000-foot weight in water. It is

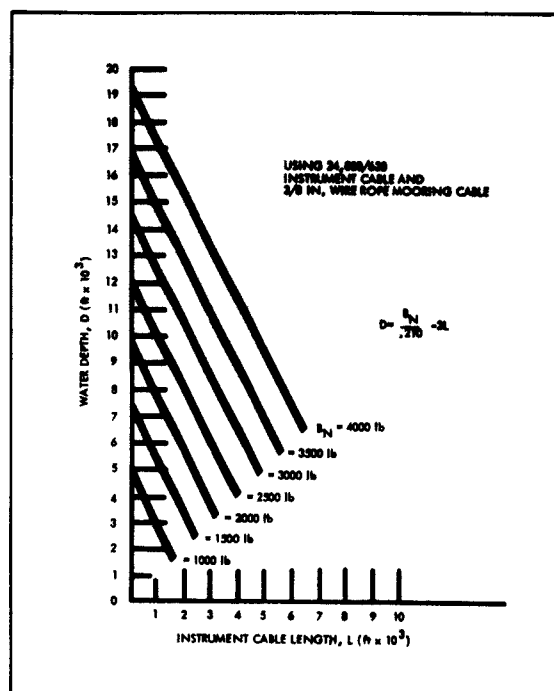


Fig. 4 — Depth-Buoyancy Characteristics

seen that for a deep-sea capability, net buoyancies of the order of 3000 to 5000 pounds are demanded. The submerged buoy vessel, shown in Figures 5 and 6, has a displacement of 5200 pounds.

Power supply consists of a storage battery of about 61½-kwhr capacity, placed in the pressure field under the submerged buoy. Figure 7 shows the battery box with cover removed. Figure 8 shows a close-up of the battery box arrangement. The fuse cavity, electrical terminal and cable harness are clearly visible. It should be noted that the batteries require protection from the dissolution of the pitch sealant around the terminals by the kerosene pressure fluid. The white tops of the cells are from an epoxy coating to protect the pitch.

The data handling and communications systems are shown in Figure 9. The block diagram indicates the essential features of the system. First, the state of the system may be controlled from the outside via radio or directly through an umbilical attachment, or it may be programmed through an automatic internal program unit. Information from the transducers, which is multiplexed up the instrument cable, as previously discussed, may be

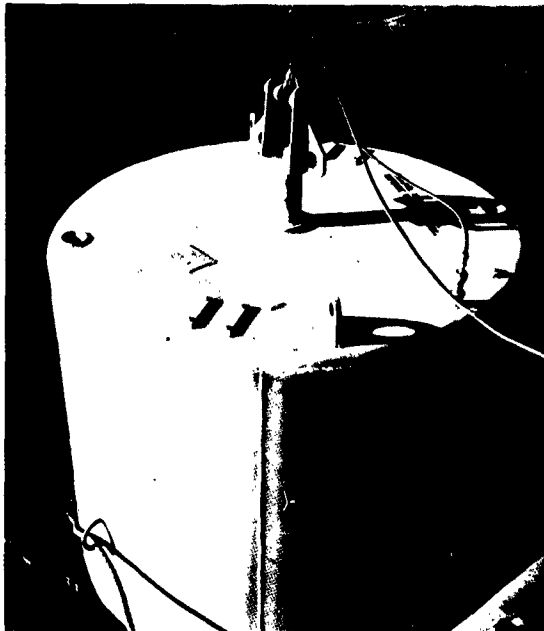


Fig. 5 — Submerged Buoy Vessel (Top)

recorded, or sent directly up to the surface float through the five twisted pairs of the surface float cable.

SPECIAL FEATURES

A special feature of the buoy vessel is its pressure compensation. The internal pressure of the buoy vessel is maintained at or above ambient hydrostatic pressure, and thus permits a much lighter and more simply constructed (and hence,



Fig. 6 — Submerged Buoy Vessel (Bottom)



Fig. 7 — Battery Tank (Side)

cheaper) container than if it were a pressure vessel.

When the buoy is at its operating depth, the current may lay it over and its depth will increase. In 4000 feet of water, an increase in depth of about 100 feet would be expected with a current of the order of one knot. As the buoy increases

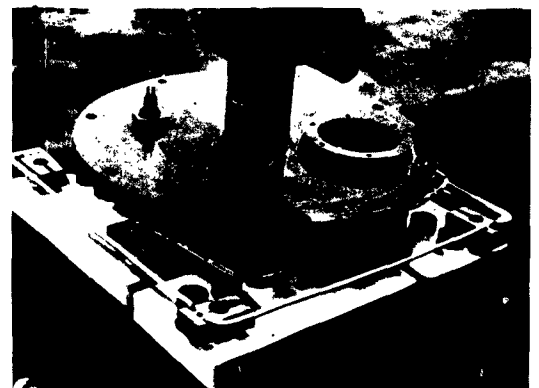


Fig. 8 — Battery Tank (Top)

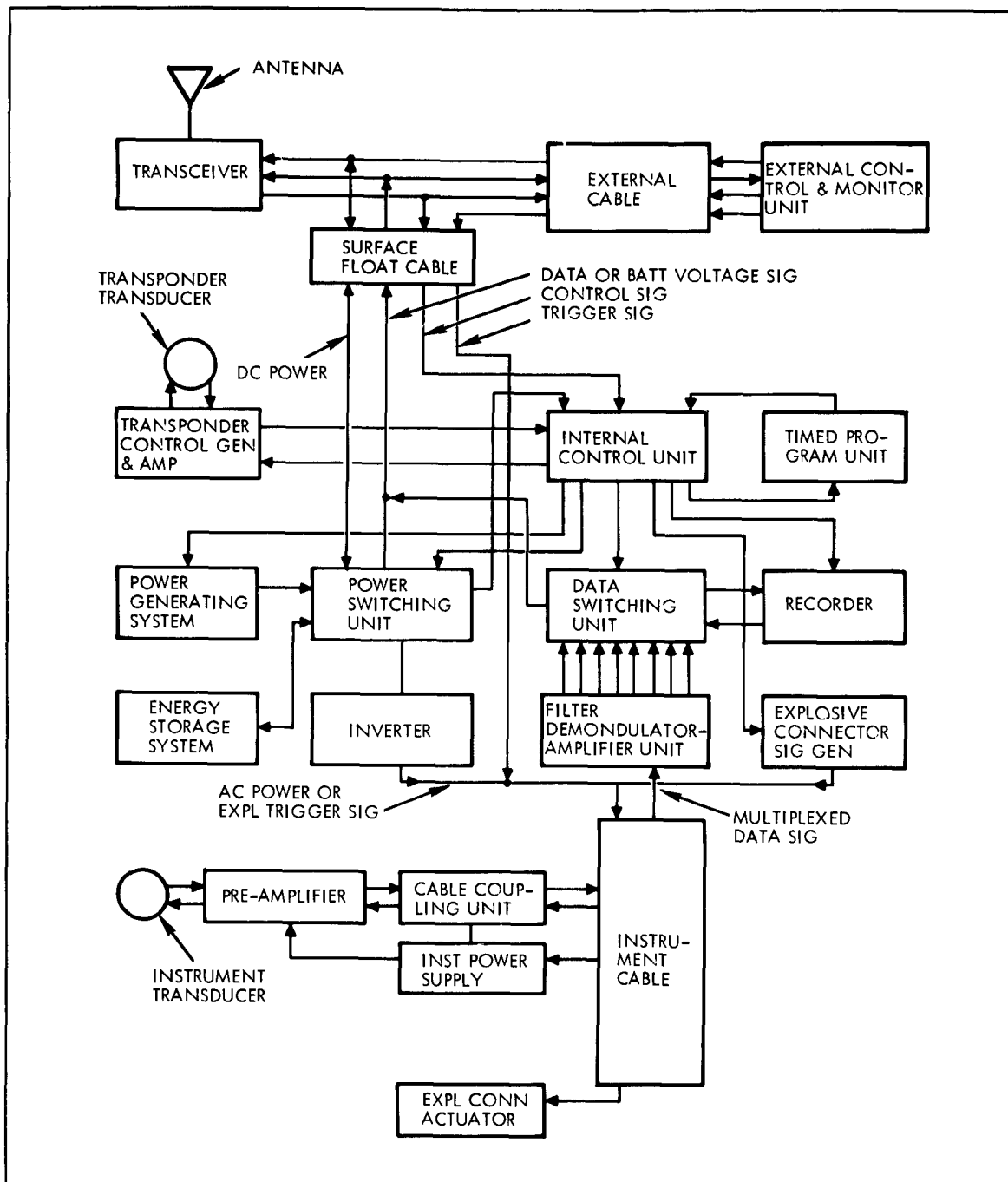


Fig. 9 — Electronic Systems Block Diagram

depth, it requires more air to equalize pressure. A periodic change in current is to be expected which allows the buoy to return to its original depth. The buoy internal pressure now exceeds that of the hydrostatic head. If there were a direct check-relief valve, this overpressure would bleed out as the buoy loses depth. It would seem desirable to have a spring-loaded check valve which would permit an overpressure in the buoy (within design limits) as the buoy returns to a shallower depth on change of current. However, such an overpressure would be completely unacceptable at the surface from considerations of personnel safety.

This dilemma is resolved by a valve which can relieve with an overpressure which is a function of depth (Fig. 10). The valve operates on a differential area principle, with sea pressure acting over the entire piston area and the buoy internal pressure operating only on the annular space outside of the bellows. The figure shows both actuating pressure and hydrostatic head as a function of depth. It is seen that the actuating pressure increases linearly with depth at a greater rate than hydrostatic pressure. At the surface the two are equal, but at 150 feet the actuating pressure exceeds hydrostatic head by about 44 psi.

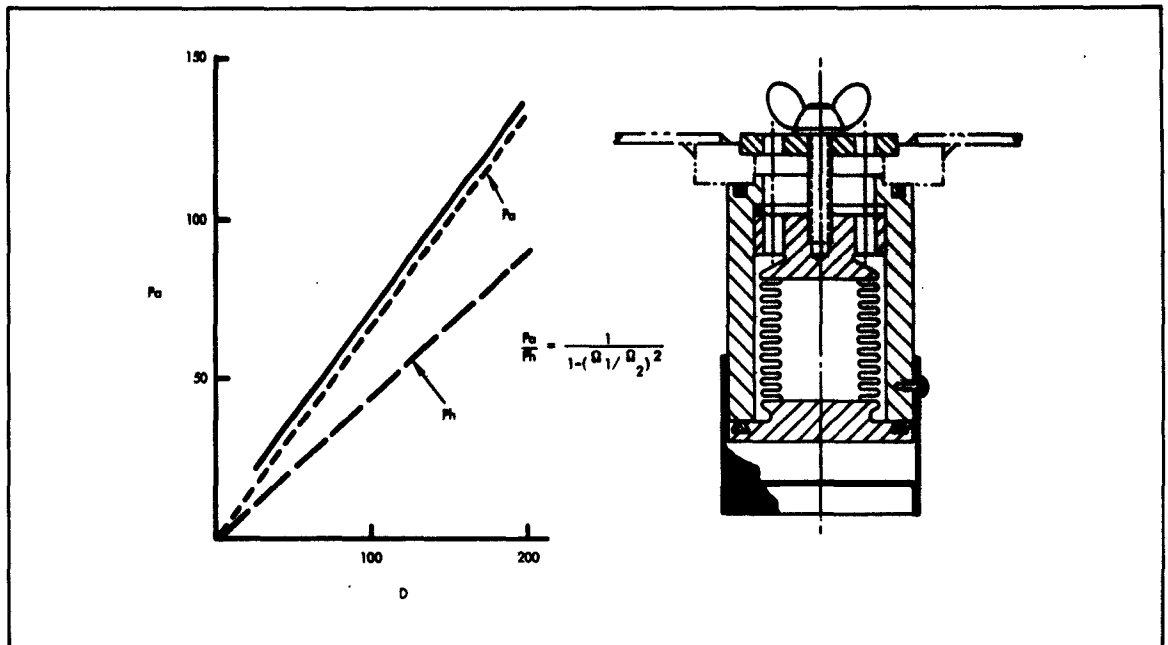


Fig. 10 — Variable Pressure Relief Valve

DISCUSSION

Question: How do you pressurize the buoy?

Daubin: The pressure valve responds to sea pressure. If the sea pressure is greater than ambient then air comes in. If less than ambient the valve closes. The buoy will take up to 44-lb overpressure.

BAER: Is there any motion to the buoy that is submerged at 150 ft?

Daubin: The wave action is attenuated to .04 of that at the surface.

BAER: What happens if a 1,000-ft wave arrives?

Daubin: It would have to be a small 1,000-ft wave.

C. WILCOX: What is your schedule for placing the buoy system (shown in your last figures) in operation?

Daubin: We plan to install it next week.

SULLIVAN: Do you use telemeter frequencies?

Daubin: We are licensed for 250.7 mc. We have a 2.5-w transmitter and are reading the signal at the laboratory 65 miles away. Our license requires us to check with the Pacific Missile Range before operating.

SULLIVAN: Do you interrogate the buoy?

Daubin: Yes.

Question: Did you give any consideration to the use of a spar buoy as the submerged buoy?

Daubin: A spar buoy would just add to the drag so we gave it no consideration.

ACOUSTIC SCATTERING MEASUREMENTS AS INDICATORS OF WATER INHOMOGENEITIES

by *D. S. Potter*

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Abstract—This paper will first consider the interaction of acoustic waves in an inhomogeneous medium. The gross effects of the general depth dependence of the index of refraction in the open ocean situation are not of particular importance in this problem; thus the main concern will be the microstructure of the water medium. The consequences of scattering theory will be examined and compared with applicable experimental evidence. The two most prominent problems, first, short correlation distance phenomenon, and second, the quasi-determined large-scale phenomenon, will be discussed from the point of view of the fundamental limits on acoustic information transmission thus imposed.

INTRODUCTION

By way of introduction, let me present a thumbnail discussion of the mathematical treatment of acoustic propagation in sea water. Ordinarily, one begins by assuming that the sea is an idealized medium with constant sound velocity throughout — without attenuation, without boundaries, without volume scatterers, and as a result, without problems. This, of course, is far removed from reality, but within such an ideal framework, one can estimate the effect of the non-ideal properties just mentioned.

The approach is to consider them singly, with the hope that they represent corrections which can be added in a linear fashion. By so doing, one avoids the monumental problem of confronting the physical realities of acoustic propagation in sea water all at once: a sound wave leaving a less-than-perfect transducer; being bent according to the vagaries of a medium with changing sound velocity; being attenuated with a varying attenuation constant; being scattered by temperature inhomogeneities, shrimp, air bubbles, etc.; and finally being received by a non-ideal receiver. This single-problem-at-a-time approach can be justified on the basis of the good results achieved. Occasionally, it is necessary to include several effects simultaneously, but if they can be considered to be additive, the problem is still not too difficult.

From a theoretical point of view, of course, the grand, all-inclusive problem can be solved. Given the complete specification of the water — its

boundaries, its inhabitants, and so on — one can answer, at least in a symbolic manner, any particular acoustic propagation problem. There are two difficulties with this theoretical approach: (1) the exact specification of the water and its boundaries are not known; (2) it is increasingly evident that even if they were known, they are too complex to be calculable by means presently available.

This, in turn, brings me to a fairly important digression. You will sometimes hear that the theoretical predictions of a particular case are not borne out by experiment. If this is the case, then (1) the ocean model used was wrong; (2) the approximations to the theory necessary to give a calculable answer were too coarse; or (3) as is often the case, they were improperly applied. In summary, then, it is not a theory of propagation that is required, but an adequate model of the ocean, and simplified calculation schemes which will give data of engineering accuracy in a reasonable time at a reasonable cost.

It is the purpose of this paper to give a quick summary of the present state of the art in the knowledge of the effect of local velocity inhomogeneities in the water.

Horizontal and Vertical Velocity Variation

For this discussion, I will not consider the normal depth dependence of the sound velocity. The problem of the simple depth dependence, uncluttered with a horizontal variation, has been treated many times. There are numerous computer programs available for the calculations of ray

paths, transit times and intensity anomalies. This paper will consider the propagation situation when the velocity variation is not confined to the vertical but also includes the horizontal direction.

THREE OCEAN MODELS

The horizontal variations or "ocean models" which could be considered are probably innumerable but, from the acoustician's point of view, it is necessary to recognize at least three distinct cases. These cases have been observed both by physical oceanographers and by acousticians; they do not necessarily occur simultaneously, and their magnitudes seem to vary in time as well as space.

Small-Scale Thermal Microstructure

The first of these is the small-scale thermal microstructure. Well before it was definitely observed experimentally, Professor Bergman calculated the effect of small-scale velocity inhomogeneities for those cases where ray theory can be assumed to hold. In his approximation, the wavelength of the sound energy must be much shorter than the physical size of the velocity inhomogeneities; on the other hand, because of the statistical nature of the calculation, it is necessary that the total path length be long. The inhomogeneities were considered relative to their statistical properties; spherical symmetry, and the notion of the correlation distance were invoked. This gave rise to a so-called "patch size," a semantic distortion which is meant to be a kind of measure of the correlation distance.

The physical situation according to this model is roughly as follows. If one moves a temperature probe either vertically or horizontally through the water, small-scale temperature fluctuations of the order of a few hundredths to a few tenths of a degree Centigrade, may be observed. These variations occur in a relatively short distance — of the order of a meter. The statistics are assumed to be spherically symmetric; that is, the results of motion vertically or horizontally are indistinguishable.

About ten years ago, Dr. Liebermann of Scripps made a series of measurements of the horizontal fluctuations of water temperature from the bottom of a submarine. Although the cruise was in deep water, the submarine remained in relatively shallow depths, of the order of 150 to 300 feet. He found a correlation distance for the fluctuations of the order of 60 cm and an rms magnitude of 0.04°C . At about this time, several theoretical papers were produced both in this country and

in Russia. (An up-to-date list of references may be found in a recent paper by Mintzer and Stone in the May 1962 *Journal of the Acoustical Society* which, incidentally, gives the first laboratory result on the study of acoustic interaction in an artificially produced thermal microstructure.) Acousticians regarded this particular model of the thermal microstructure as an interesting oddity for several years. Acoustic scattering measurements conducted in the Pacific Northwest and in the Atlantic off the coast of Florida gave results very different from those predicted by this model.

Recently, however, a series of acoustic measurements made by our group in the Santa Barbara Channel, in essentially the same kind of water measured by Liebermann, gives results which are in consonance with the model. This experiment was reported in the Acoustical Society Meetings in Seattle, November 8, 1962 and, so far as I know, constituted the first direct ocean measurements of this kind of acoustic scattering. In general, our findings were that, depending on path length, the sonic transit times between projector and receiver sustain fluctuations of a few tenths of a per cent in the disturbed region. The experimental evidence pointed strongly towards the upper half of the well-mixed layer as the zone of the scattering centers. We know of no other direct *in situ* measurements of acoustic scattering from this type of thermal microstructure. However, it is clear that a great deal of existing data must be contaminated with these small-scale fluctuations.

Lenticular Structure

The second acoustic model from the historic point of view is that of a lenticular structure. It differs from the first model in two respects: (1) the thermal variations, rather than having spherical statistical symmetry, are considered to be lenticular with depth-to-length ratios of the order of 1 to 100, or greater; (2) the horizontal extent of one of these structures is in hundreds or thousands of meters. These structures have been measured adequately in the Dabob Bay region of Puget Sound, where it is found that at certain times of the year temperature variations from a few hundredths of a degree Centigrade to as much as 1°C are found in the vertical temperature profile.

One can follow any particular vertical temperature variation by making succeeding temperature profiles at increasing horizontal distances from the first point. It is found that, although a particular variation might oscillate slightly in depth,

the general structure is maintained. Hence, a particular temperature fluctuation can be identified over fairly long horizontal distances of hundreds and even thousands of meters. The mechanism for the production of these structures is now fairly clear, the major requirement being a boundary between two water masses of essentially different histories. In Dabob Bay, this effect is achieved because the bay, protected by a sill at its entrance, has little mixing from either wind or tidal action and, hence, only the near-surface water is affected by seasonal temperature changes. On the other hand, the bay joins Hood Canal, which is a long, narrow stretch of water with fairly high tidal currents, producing virtually complete vertical mixing. One of the interesting aspects concerning these lenticular structures is their extreme time stability: once formed, they last for many months.

Acoustic experiments with lenticular perturbations have all been of relatively short range, less than 1,000 meters. For this reason, it was necessary to abandon the statistical approach and to consider the interaction of acoustic propagation with this well-defined, layered medium. The calculations were successful in predicting the amplitude fluctuations actually observed. (All of this work has been reported from time to time in papers originating at the Applied Physics Laboratory, University of Washington.) Evidences of layered structures have been found in several other areas of the ocean. These evidences are usually indirect, however, and consist of a rather large "bump" on the BT record at depths well below the well-mixed layer. In a few cases, the sea conditions permitted a quick repeat of the BT measurement at a short distance from the original point, and the "bump," in essentially unchanged form, was found at the new point. Some recent propagation-time fluctuation data have been obtained, again in Dabob Bay, with essentially a layered medium, and recently reported at the Seattle Acoustical meetings by S. R. Murphy, T. E. Ewart, and G. R. Garrison. One can conclude that the model is well documented and has an adequate theoretical treatment borne out by experiment. The main shortcoming of the model is that there are no direct measurements of its existence in other ocean areas.

Internal Waves

The third ocean model necessary to explain certain acoustic effects supposes a series of long-wavelength internal waves. These are much akin to the seiches that have been observed for about

200 years, which are really only the allowed oscillations of a bounded water surface. The same kind of thing happens in the interior of a water mass in the presence of a density gradient, but in this case, the time associated with the wave is much longer than with the surface wave. The physical oceanographer measures these internal waves as a series of vertical undulations in the isotherms. Internal waves have been well documented, particularly by the Navy Electronics Laboratory and Scripps Institution of Oceanography in the San Diego area. There have been a few papers which attempt to estimate the effects of such waves on acoustic propagation. However, the subject has not received much attention, and the theoretical arguments are not so well developed as in the first two models.

Direct acoustic measurements have given strong indications of both intensity and time fluctuations in acoustic propagation arising from internal waves. Time fluctuations of the order of a few tenths of 1% have been observed in the Caribbean. Amplitude fluctuations were studied off the San Diego coast and were found in some extreme cases to amount to several orders of magnitude changes in acoustic intensity. Of the three models which we have thus far considered, the internal wave model has received the least theoretical and experimental effort; yet it now seems that in some of the acoustic test areas under consideration, it will be the most important perturbation.

SUMMARY

The three ocean models which have thus far been used to explain certain acoustical results are: (1) small-scale fluctuations, which must be treated on a statistical basis and to date have been observed only in the upper water layers (probably the upper half of the well-mixed layer); (2) "layered" structures, arising from the interaction of two water masses of different past histories, probably distributed through the depths of the ocean; and (3) internal waves, which are probably confined to those depths exhibiting a high temperature gradient. In all three cases, amplitude fluctuations have been found. These amplitude fluctuations are most prominent in cases (2) and (3), and can be several orders of magnitude. Time fluctuations have been observed in all three cases with a magnitude of between 10^{-4} and 10^{-3} . As acoustic instrumentation becomes more sophisticated, these microstructure effects are likely to have a greater influence on the design and operability of sonic equipment.

DISCUSSION

SNODGRASS: Did you take your temperature measurements at the same time of year as Liebermann?

Potter: Liebermann made his measurements 10 years ago during June and July. We made ours during August and September, 1962.

C. WILCOX: At what frequencies were you working?

Potter: At 20 and 40 kc, in the Santa Barbara Channel (wavelength, 2 in.).

SULLIVAN: Did you use several hydrophones placed equidistantly along an arc so that you were measuring the arrival of a plane or coherent wave front?

Potter: Some were at the same radius. The experiment was designed to tell us if the wave front was coherent. The answer is: it was not. It was a scattered wave front.

SULLIVAN: At these wavelengths, constant radius arrival times should be measured. Can you measure the face of the wave front?

Potter: No. The velocity over the path was the quantity that was asked for.

SULLIVAN: You were measuring the variation in arrival times?

Potter: Yes.

C. WILCOX: Why didn't you make the same temperature measurements as Liebermann?

Potter: We can do that now although we could not at that time. However it is a very difficult meas-

urement to make. Also, we do not wish to operate a submarine.

MCNEIL: Do you plan to perform the experiment again in the spring?

Potter: If we have the opportunity, yes.

KIDD: Jim 'nodgrass' early work with the thermistor leads off San Diego, in which he made repeated high-speed casts for checking repeatability and response, showed a similar lenticular structure. If one makes some assumptions about ship drift rate and spreads out the individual temperature traces, the record looks suspiciously like the ship is moving over a thin, comparatively extensive, temperature lens, such as you encountered in Dabob Bay.

Potter: The evidence for the existence of lenses has begun to mount.

SNODGRASS: Lew (Kidd) has a good memory. Later measurements have shown layers of only a few centimeters in thickness that are also very persistent.

HILDRETH: Does the patchiness you describe occur mainly in the well-mixed layer?

Potter: Yes.

CHEW: You mentioned that one of the lenses could maintain itself for 100 years. What effect would turbulence have?

Potter: 100 years with no turbulence and heat diffusion only at work; in the real case this is shortened considerably.

AN OCEANOGRAPHIC DATA AND COMMUNICATIONS SYSTEM

by James M. Snodgrass

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Abstract — Of major interest to oceanographers and industrial organizations interested in oceanographic data acquisition problems is the formal approval by the Intergovernmental Oceanographic Commission (IOC), September 1962, of standards and proposals relating to the use of radio frequencies for telemetering of oceanographic data, facsimile, CW, and telephony for all oceanographic activities including Federal agencies and scientific research groups. A systems engineering approach to the communications problem has been productive and made possible major advances for all oceanographic activities.

Major emphasis is given to aspects of telemetry involving the high-frequency (HF) portion of the radio spectrum. Specific limitations which apply to this portion of the spectrum will be discussed, as well as measures incorporated in the system to obviate, insofar as possible, known problems. Inherent in the system proposed is a new method of using the radio spectrum from the administrative and operational standpoint. A major advantage of the system is that more stations can be accommodated within the same portion of the radio spectrum.

Specific requirements of the system as related to certain hardware considerations will be presented. As a corollary to the system, it will be pointed out that there will be opportunities for certain types of contract operations to take over some of the more troublesome aspects of logistics operations.

I wish to begin in a somewhat unusual fashion, partly because it will save a lot of digression later. What I propose to do is fill you in on some of the national and international alphabet combinations that I will be referring to. First, one that's referred to in the abstract, is the IOC, the Intergovernmental Oceanographic Commission. One that is often confused with IOC but is distinctly different is ICO, the Interagency Committee on Oceanography. Then there is the National Academy of Sciences Committee on Oceanography which is abbreviated NASCO; and one which we cannot abbreviate phonetically is another National Academy Committee — the National Academy of Sciences Committee on Radio Frequency Requirements for Scientific Research.

Another group is the IFRB, the International Frequency Registration Board, an advisory agency under the ITU, the International Telecommunications Union. Incidentally, the ITU is the highest body having to do with frequency allocations on a world-wide basis, and the IFRB is an engineering technical advisory body to the ITU. Then, we get down to some at home that most of you know about: FCC, Federal Communications Commission, and IRAC, Interagency Radio Allocations Commission. What many of you may not know is that the FCC and IRAC are direct connections

to the President's office and are under the Office of Emergency Planning; they're coequals more or less at that level.

I wish to present something in the nature of a progress report on work that has been going on regarding oceanographic communications. Those of you who have attempted to use radio frequencies for communications, particularly from buoys, are aware that we have many problems. Short ranges involving line of sight, though troublesome, do not involve a serious frequency problem. However, if we are concerned with long ranges over water, we find ourselves facing a currently insolvable problem. It was not until the National Academy of Sciences Committee on Radio Frequency Requirements for Scientific Research accepted responsibility for the oceanographic problem that rapid progress began to be made.

Perhaps you may be interested in learning why the scientific research community has encountered so much difficulty in obtaining radio frequency assignments in the past. I was fortunate to learn of some of the difficulties quite by accident. In the course of a conversation with the chief of IRAC, it was pointed out to me that research laboratories, in attempting to justify their need of radio frequencies, had claimed too many, and by so doing had torpedoed their chances of obtain-

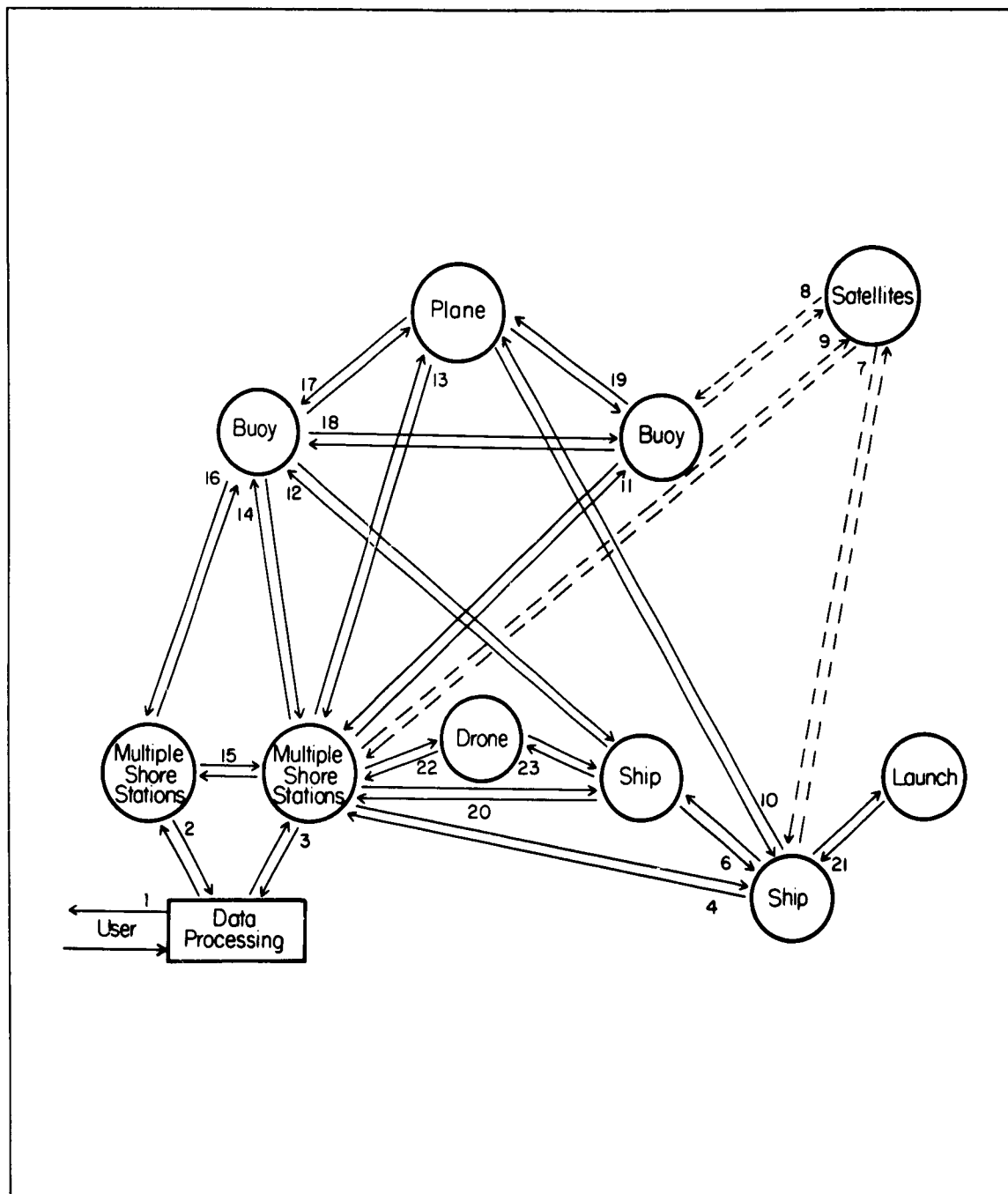


Fig. 1 — Systems Engineering Block Diagram for Oceanographic Communications

ing frequencies. The difficulties were due to the fact that both civil and Department of Defense requirements were included in the same application. In the Washington atmosphere, this meant that the application did not fall in either the domain of IRAC, which is a government agency for Department of Defense frequencies, or of FCC, which concerns itself with the civil assignments. It is thus apparent that no particular office in Washington was going to be much concerned about our applications.

Early in the spring of 1962 I was appointed a radio frequency consultant for the ICO and, at the same time, was selected to represent the National Academy of Sciences Committee on Oceanography on the National Academy of Sciences Committee on Radio Frequency Requirements for Scientific Research. Since groundwork had been laid in early 1962 under the auspices of the governmental oceanographic commission relating to a coordinated international effort toward oceanographic communications, I was appointed to be the representative of the United States government as a member of the Working Group on Communications under IOC. This group duly convened in August 1962 in Paris, France. In September 1962, the entire Intergovernmental Oceanographic Commission approved the recommendations of the Working Group on Communications and referred the matter to the member governments concerned for action.

The Working Group on Communications under IOC proposed some novel and distinctly new methods of using the radio frequency spectrum which essentially makes a more efficient use of a given working radio channel and institutes the concept of time sharing.

Figure 1 is a block diagram of the proposed general systems concept of communication as applied to the field of oceanography. The diagram portrays the essential links of any major oceanographic communications and telemetering network. The terrestrial long-haul radio circuits are all expected to be HF frequencies. However, those involving aircraft and satellites may well be VHF or UHF. It is also true that certain terrestrial applications involving line of sight may also use VHF or UHF, if applicable.

Our major concern today, however, is the use of radio frequencies in the HF region, since this is the location of the frequencies which are involved in long-haul communications and which are among some of the most restricted on a world-wide basis.

Due to the action of the Intergovernmental Oceanographic Commission last summer, the oceanographers in the United States now have a formal channel directly to the frequency allocation and regulatory agencies of the United States government which were not previously available to them. Due to the efforts of the National Academy of Sciences Committee on Radio Frequency Requirements for Scientific Research and the IOC, the oceanographers have achieved a status both nationally and internationally in the communications community which they lacked almost completely previously.

To develop a proposal for oceanographic communications, it was necessary to work out certain standards and recommendations. Fortunately, we were able to obtain the valued assistance of the Boulder Laboratories of the National Bureau of Standards with the assistance of the late Dr. J. Howard Dellinger, Chairman of the National Academy of Sciences Committee on Radio Frequency Requirements for Scientific Research. Much of the system detail I am going to present has been checked through with the assistance of computers at the Boulder Laboratories and represents a valid engineering approach to communications in the HF region. To actually operate a finite system, much hardware will have to be developed, and it is my hope that some of you may be sufficiently interested to begin thinking about how you would go about designing and manufacturing some of the required hardware.

To standardize where possible, it is proposed that we use 300-bit-capacity messages, and that the transmission rate be at a maximum of 100 bits per second. (In the event a longer message is required, it would be made of essentially 300-bit increments.) This bit rate, combined with oscillator stability requirements and engineering design problems, would require a 300-cps maximum bandwidth. It is further proposed that we limit the antenna input power to 100 watts. For the purposes mentioned, the IOC has requested the telecommunications authorities of the respective countries to consider allocating a minimum of one 3.5-kcps channel in each of six mobile maritime exclusive frequency bands. These bands are as follows, with the frequencies given in kilocycles: 4063-4438; 6200-6525; 8195-8815; 12330-13200; 16460-17360; 22000-22720. Certain regions of these bands are presently unassigned on a world-wide basis, though they are allocated to the use of maritime and mobile marine communications. There is reason to believe that it would be

expeditious to attempt to accommodate the oceanographers' needs within these bands rather than any other HF regions.

Within the last few weeks a rather interesting letter has been written by Dr. N. I. Krasnosselski, Chairman of the IFRB, to the Director General of ITU, with copies to the chiefs of the telecommunications authorities of the member nations within IOC. This letter essentially sets forth the needs of the oceanographers and makes a specific proposal for accommodating these needs in the referenced channels. Dr. Krasnosselski further suggested that the countries concerned begin planning how they propose to implement the allocations of the frequencies to the oceanographers.

simile, and data telemetry. Insofar as all mobile maritime services are scheduled to be converted to single sideband in 1965, Figure 3 illustrates the use of a single 3.5-kcps single sideband channel. The full channel width would be used for such things as voice transmission and facsimile. Further, on the multiple use and time-sharing concept mentioned earlier, it is proposed that the single 3.5-kcps channel be subdivided into ten 300-cps data subchannels with a 250-cps buffer subchannel on either edge of the band to reduce adjacent channel interference. As mentioned previously, considerable confusion has arisen because of the misinterpretation of the subchannel concept. Some radio communications people have inter-

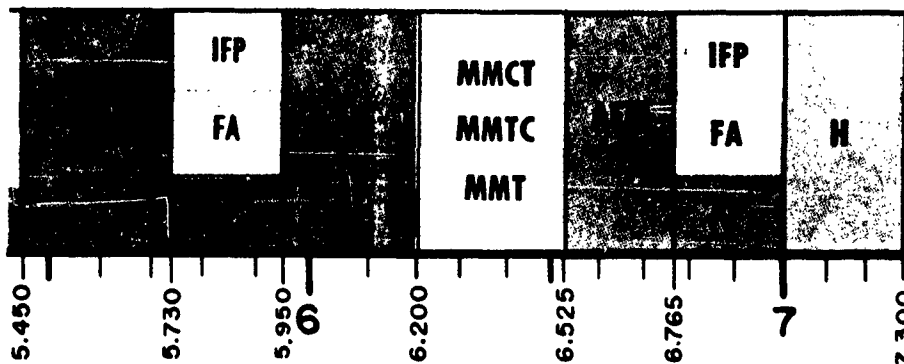


Fig. 2 — Section International Radio Frequency Allocations Showing Mobile Maritime Channel

Figure 2 represents a small sample of the currently allocated regions in the HF spectrum. You will note that the band shown as defined by 6.200 and 6.525 Mc is wholly occupied by mobile maritime services. It is to the point, perhaps, to emphasize that this band is allocated to this service on a world-wide basis and does not represent any particular nation. There are no frequencies used exclusively by land stations or aircraft or fixed maritime stations.

Earlier in our discussion we mentioned the use of 300-cps data channels. Figure 3 illustrates how these data channels would be used in relation to conventional radio channel allocations. The block at the bottom of Figure 3 is identical to that shown in Figure 2 with a single slice proposed for oceanographic telemetry and communications occupying the mobile maritime channel space. The oceanographers will require a variety of communications services such as speech, CW, fac-

interpreted this to mean subcarrier and not subchannel. However, this is not correct, and subchannel is the proper terminology. Each of the 300-cps data subchannels would also be of the single-sideband type.

A particularly pertinent question, but one extremely difficult to answer, is how many radio frequencies must be put in a buoy to make it possible for the buoy to perform its assignment. This is a thoroughly legitimate question, but until recently, one which has been extremely difficult to answer. The Boulder Laboratories of the National Bureau of Standards have now put into one of their computers the mathematical model of radio propagation as we presently understand it. Fortunately, it is now possible to program the computer to answer pertinent questions such as the one just referred to. Figure 4 illustrates the type of situation we have fed into the Boulder Laboratories computer. One buoy position is shown in the

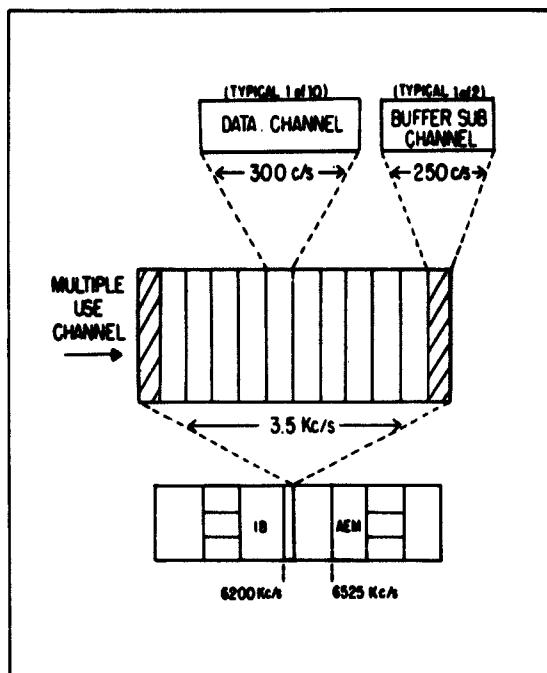


Fig. 3 — Proposed Use of Oceanographic Channel Within Maritime Mobile Band

North Pacific area, located in a region of interest to the U.S. Coast & Geodetic Survey for possible early seismic warning service. Two receiving positions have been selected, one at Adak, Alaska, and the other at San Francisco. Another buoy is shown in the Atlantic Ocean with receiving stations at Boston and Madison, Wisconsin. Another buoy is shown in the Gulf of Mexico with receiving stations at Washington, D.C., and Jacksonville, Florida. The multiple receiving stations have been selected with an idea of examining the advantages to be obtained by making use of skip distances in the HF region in order to improve over-all system reliability.

With an eye to certain political situations, we have also selected a buoy position in the Western Pacific, as shown in Figure 5. Here, receiving stations have been selected at Tokyo, Vladivostok, Glinka and Midway.

Figure 6 is an illustration of tabular data produced by the computer. Detailed explanation of the computer data is attached for your convenience.

We have spent a considerable amount of time discussing the details of the proposed oceanographic data communications system and I would like at this time to explain some of the aspects involving both frequency and time-sharing. We mentioned earlier that we would propose to use the full assigned channel width of 3.5 kc/s as a

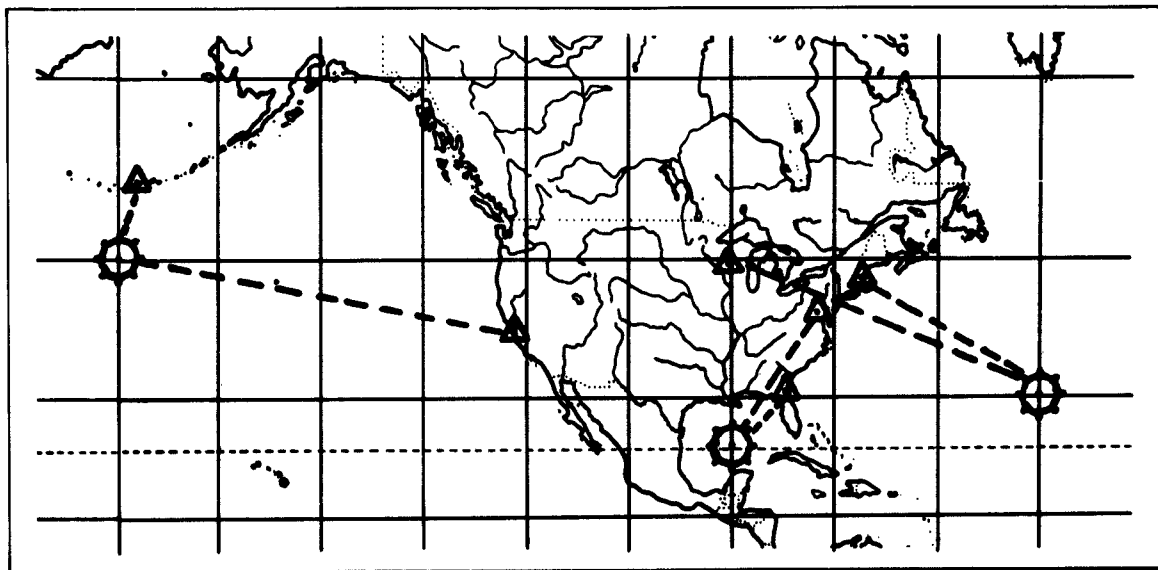


Fig. 4 — Buoy Positions and Receiving Stations

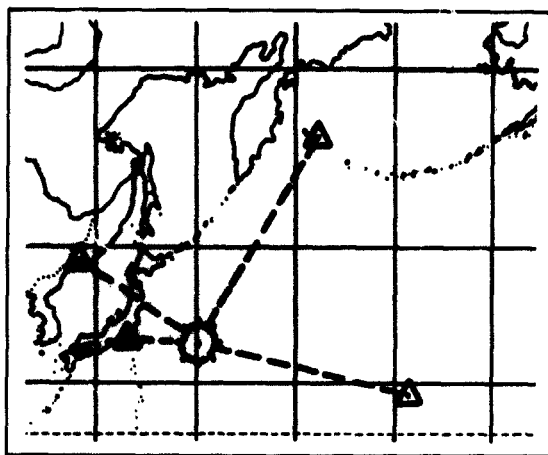


Fig. 5 — Western Pacific Buoy Location and Receiving Stations

voice channel for logistics operations, facsimile, and CW. This was to be used on a time-sharing basis with the data acquisition phase involving the 300-cps subchannels. It is suggested that the entire system operate on the basis of GMT and an example might be as follows: at 0000 GMT to 0005 all uses of the 3.5-kcps channel as a full channel would cease and the subchannel 300-cps data transmissions only would be operating. Incidentally, all of these data systems depend upon interrogation. Then again at 0005 GMT data transmissions would terminate and full channel operations would resume. Changes of this sort would be programmed throughout the 24-hour period. On a world-wide basis such a sharing of frequency and time would require a rather sophisticated control. It is suggested that a frequency pool be operated under the direct control of a suitable computer facility.

It is believed that each 300-cps subchannel can readily accommodate at least 100 buoys. Therefore, each channel which consists of ten subchannels can accommodate over 1000 buoys. It is evident, therefore, that on a world-wide basis a very large number of buoys can be accommodated. In fact, there is a great deal more elasticity than appears on the surface. With improvements in engineering capability and application of information theory to the data system, it is anticipated that the system could easily be doubled in effective capacity.

It is perhaps advantageous to point out that

the HF system involves some distinctly different techniques than are currently practiced with ease in the VHF and UHF regions. For instance, current techniques used for error-rate detection do not work well in the HF region. Some of the difficulties to be encountered are caused by the existence of the so-called "blackout pulses." These are similar to blackout situations referred to by Dr. Potter this morning in underwater sound. However, this is a different kind of blackout situation and is due to solar flares and activities of that sort which make it utterly impossible for the ionosphere to reflect radio signals. Wrapped up in the blackout pulse situation is the selection of the 100-bit-per-second data rate and the 300-bit message, since this requires three seconds for the transmission of the message. Since the duration of the solar blackout pulse is between 2.5 and 2.8 seconds, it is seen that if the message is automatically transmitted three times in sequence we can expect a high degree of reliability in receiving two relatively undisturbed messages, even though the third may be seriously or almost completely lacking.

One reason why I had hoped that all of this might be of interest to you as a group relates to some of the figures that Dr. Daubin mentioned this morning when he quoted the figures on the use of buoys and their amortization costs. I should like to propose a method of minimizing the cost of buoys to the consumer through the establishment of what might be called a contract facility which would own and operate buoys on a contract basis. This would mean that the buoys not be owned by the actual user, but rather the user would contract for the use of the buoy and the collection of data.

It is quite true that institutions such as the Scripps Institution of Oceanography do not wish to be involved in the logistics or detailed planning and operations which involve servicing and placement of buoys. We would much rather contract for this type of service. A contract facility would be able to make buoys available to a scientific project which might only require, for instance, three months for its completion. Unless buoys could be obtained on a contract basis such projects could probably never be undertaken since the buoy costs if they had to be borne completely by the contract would be quite prohibitive. Such a contract operation would also have the very material advantage of spreading the cost of the buoys over a broader base, which would materially assist in the amortization. It would also be anticipated that

the contract facility would be able to maintain the necessary technical know-how and skill to handle the buoys. Undoubtedly one or more ships would be required in a given region depending upon the total number of buoys involved. Obviously this would have to start from relatively small beginnings, but I would hope that it might appear to be an attractive future interest.

There is an additional interested group in the oceanographic field and that is WMO, or the World Meteorological Organization. They are presently greatly concerned over the lack of anything remotely resembling a data collection network over the world's oceans. Through the Intergovernmental Oceanographic Commission, WMO has signified an interest to work with the

oceanographic groups in establishing the network of unattended buoy stations. This is highly advantageous to the oceanographers, particularly since WMO already possesses a communications network. However, the existing WMO network is seriously overloaded. WMO has signified that they are now planning on expanding the capacity of their network and are considering the feasibility of enlarging it to accommodate the increased load which they would have to carry if as they expect they would be handling substantial amounts of oceanographic data. Quite possibly one reason that WMO is interested in going along with the oceanographers is that WMO does not now have any HF frequencies assigned to the weather-collection networks.

DISCUSSION

DAUBIN: The communication links were from buoy to shore only?

Snodgrass: No, there were other communications links such as were shown on the systems engineering diagram, such as from buoy-to-buoy, buoy-to-ship, buoy-to-plane, and even buoy-to-satellite.

Question: Were other frequencies than HF considered?

Snodgrass: Yes, that is also a part of the report of the IOC Working Group on Communications. In the case of satellites and aircraft overflight inter-

rogation of buoys, as well as line-of-sight, VHF and UHF would be used. Our primary reason for being somewhat preoccupied with the HF region is due to the fact that the HF frequencies are allocated on an international basis; whereas, VHF and UHF frequencies are normally handled on a national basis. However, since the advent of satellites these latter frequencies are now considered also on a world-wide basis and an extraordinary meeting of ITU is scheduled in 1963 in order to work out world-wide regulations for this new situation.

SUPPLEMENTAL NOTES

FOR FIGURE 6

- | | |
|--|--|
| <ol style="list-style-type: none"> 1. Computer Sequence No. 2. Month. 3. Sun spot level (activity)
10 = low; 100 = high. 4. Computer code for receiver location
(TK 8.005 = Tokyo). 5,6,7. Transmitter: latitude and longitude. 8. Receiver: latitude and longitude. 9. Bearing of transmitter from receiver
(computed). 10. Nautical miles between transmitter
and receiver (computed). 11. Transmitter antenna constants (as-
sumed vertical whip with top 8 meters
above water). 11A. Noise figure for latitude of receiver. 12. Transmitter antenna input power. 13. Receiving antenna: assumed 12 db
gain. Required signal/noise ratio of 45
db, i.e., ratio of total signal power-to-
noise in a one-cycle band. 14. GMT: Greenwich Mean Time. 15. MUF: Maximum Usable Frequencies. 16. FOT: Optimum Traffic Frequencies. 17. Operating frequencies 3-30 Mc for
which data are computed. 18. MODE: Propagation path. Layer of
ionosphere and number of reflections. 19. Angle of received signal above hori-
zontal. | <ol style="list-style-type: none"> 20. RELIABILITY: Percent of the days
of the month (2) that a signal will be
received with a signal-to-noise ratio of
45 db (13) or better, at a given hour
GMT (14) with a specified sun spot
level (3) and at selected operating fre-
quencies (17). <p><i>Note A:</i> The computer calculates the Maxi-
mum Usable Frequency (MUF) (15) and the
Optimum Traffic Frequency (FOT) (16) for
each hour GMT (14). Every two hours GMT
(14) the MODE (18), ANGLE (19) and
RELIABILITY or S/N (20) are calculated
for each of the Operating Frequencies (17)
and the Optimum Traffic Frequency. (Right
hand column of data.)</p> <p><i>Note B:</i> Zeros will automatically appear to
the right of the last printed RELIABILITY
or S/N value if the calculated received signal
level is below a signal-to-noise ratio of 45 db
(13), i.e., it would be zero if the S/N ratio
were 44 db—etc.</p> <p><i>Note C:</i> The left hand columnar data repre-
sents calculations of the S/N ratio of the re-
ceived signals. The values given represent the
monthly median of the hourly median signal-
to-noise ratios to be expected under condi-
tions set forth for RELIABILITY (20).</p> <p><i>Note D:</i> Values are calculated for all condi-
tions which yield reliability figures of 1 or
above. In addition S/N ratios are calculated
for any operating frequency (17) below a
frequency for which a reliability is given.
This explains some of the minus levels shown.</p> <p>Notes C & D above apply to another sheet of com-
puter data (not illustrated) which gives detailed
data on calculated signal to noise (S/N) ratios.</p> |
|--|--|

HUGHES RESEARCH PROGRAM IN MARINE GEOPHYSICS AND OCEANOGRAPHY

by J. C. Harrison and C. H. Wilcox
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Abstract — The Hughes Aircraft Company operates a 100-foot, 180-gross-ton, all-steel ocean work boat, the *Tilman-J*, which is mainly employed in ASW research projects. This vessel is available for a limited portion of its time, however, for general oceanographic research and the Hughes Research Laboratories are initiating a research program in oceanography.

To the present, the Research Laboratories' use of the *Tilman-J* for oceanography has been limited to participation in COW VI. In marine geophysics, Dr. Harrison has continued working on gravity-at-sea data taken while he was with the University of California and has conducted ship-towed magnetometer surveys from the *Tilman-J*. It is hoped in the future to greatly expand the relative effort in oceanography, while continuing a program in marine geophysics.

The Hughes Aircraft Company operates a 100-foot, 180-gross-ton, all-steel ocean work boat, the *Tilman J* which is mainly employed in ASW research and development projects. This vessel is available, however, for a limited portion of its time for general oceanographic research and the Hughes Research Laboratories are initiating a research program in oceanography.

To the present, the Research Laboratories' use of the *Tilman J* for oceanography has been limited to participation in COW VI. On the 22nd and 23rd of October, 1962, continuous surface water temperature measurements were made on a zig-zag track from Santa Barbara to San Miguel Island which involved three crossings of the Santa Barbara Channel, in both the outward and return directions. A total of 12 bathythermograph temperature profiles was taken on the outward journey and routine meteorological data recorded. This program was repeated on 25 and 26 October with the additional feature that a smoke generator was used to lay a smoke trail on the run into Gaviota on the afternoon of October 25 to study the wind pattern. Photographs of this trail were obtained from the *Tilman J*, from the shore and from an Air Force Cambridge Research Laboratories' U-2 airplane which was participating in the cooperative observations. A very strong wind shear was observed off Gaviota.

It is intended that the relative effort in oceanography will be greatly expanded in the future, although a large program is not envisioned.

Before joining Hughes, Dr. Harrison worked at UCLA in the field of measuring gravity at sea

and made extensive surveys off the coast of Southern and Baja California, in the Gulf of California and elsewhere. He has continued working on this data at Hughes and used the *Tilman J* for magnetometer surveys to assist in interpretation of the gravity anomalies. The remainder of this paper consists of a progress report on these geophysical surveys in the continental borderland off Southern California between the Channel Islands and the seaward extension of the Mexican border.

Gravity measurements were made in this area from submarines in 1954¹ and 1958. The first surface ship measurements, in October 1958 on the *R/V Horizon*, were more an evaluation of the instrument than a geophysical survey², but proved very successful. A systematic survey of the northern Borderland was undertaken in 1959 with the cooperation of NOTS, China Lake, on *USS Butternut* and further data added in 1961 and 1962 using the *USS Gear* and *USS Rexburg*. The data are published in the form of Interim Reports given limited circulation by the Institute of Geophysics at UCLA^{3, 4, 5}.

Cumulative error curves of the comparisons of these surveys at track intersections are shown in Figure 1. The discrepancy is equal to or less than 5 mgal at two thirds of the intersections and there is no evidence for systematic differences. The probable error of a single gravity measurement, therefore, is about 3 to 4 mgal — about the error expected from purely navigational uncertainties.

The Scripps Institution of Oceanography has made extensive magnetic measurements in the

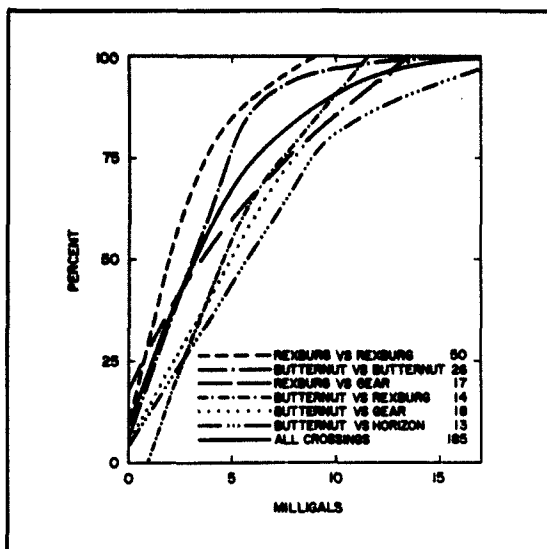


Fig. 1 — Cumulative Error Curves of Discrepancies at Track Intersections during Gravity Surveys off Southern California.

Pacific Ocean. Surveys by Scripps from the U.S. Coast and Geodetic Survey ship *Pioneer*⁶ stopped at an eastern limit of 122°W, and surveys by Dale C. Krause⁷ in the southern Borderland have a northern boundary at the latitude of San Diego. There are no available data, therefore, from the northern continental Borderland apart from the reconnaissance airborne survey by Bromery, Emery and Balsley⁸ which is rather misleading in its lack of detail. Our survey made from the *Tilman J* (Fig. 2) represents a start at filling this gap, using ship-towed magnetometers loaned by the Scripps Institution of Oceanography.

A preliminary examination of the map of Bouguer gravity anomalies (Fig. 3) shows a tendency for closed gravity lows over the inner, flat-bottomed basins (Santa Monica, Santa Catalina and Santa Cruz Basins, northern San Diego trough) and highs over the banks (Thirty-Mile, Forty-Mile, Tanner and Cortez Banks, San Clemente, Santa Catalina and San Nicholas Islands). This relation is consistent with a faulted structure in which the down-faulted basins have been partially filled with sediment, and the denser basement is shallower or actually reaches the surface on the island and banks. Three anomalous regions may be noted.

(1) The San Nicholas Basin evidently consists

of two sections. A northern east-west basin is marked by a considerable gravity low and, hence, presumably by thick sediments, while the southern part appears average with regard to gravity anomaly and hence sediment thickness.

(2) The normal situation of highs over banks and lows over basins is reversed along the Coronado Escarpment southwest of Point Loma. Here the shallow area between the Loma Sea Valley and Point Loma is characterized by a gravity low, there is a rapid rise in anomaly across this valley and very little significant change in crossing the Coronado scarp, the anomaly on Coronado Bank and in the San Diego trough being very much the same. It appears that the fault here runs along the line of the Coronado Islands-Loma Sea Valley and that the basin is on the landward side of the fault. The Coronado Escarpment is not the major tectonic feature and may merely represent the edge of sediments built out from the land which have completely covered the basin to the landward side of the Coronado Islands-Loma Sea Valley fault.

(3) A very prominent high runs from Santa Barbara Island in a southeasterly direction some 20 miles to the west of San Clemente Island, stopping at about the latitude of the southern tip of the island. This feature is also characterized by a large magnetic anomaly (Fig. 2). There is evidently a dense, magnetic body between the ridge on which San Clemente Island is situated and the deepest part of the San Nicholas Basin. One suspects a large basic or ultrabasic intrusion.

This has been a very sketchy outline of the interpretation of geophysical data in this very interesting Borderland area. Much remains to be done in extending these surveys to the western section of the Borderland, even some little way out into the deep Pacific, and in obtaining greater detail in some of the key areas. The interpretation can be greatly improved by incorporating the extensive seismic data obtained by Shor and Raitt at Scripps, and improved data reduction and fitting of specific models in the case of the gravity and magnetic surveys. The area is one of the few marine regions where one may hope to obtain a detailed geological interpretation as the neighboring land geology is well known, the islands may be studied in detail and a great deal of effort has already gone into obtaining geological samples from the sea floor and in geophysical studies. Such a detailed study is worthwhile as a means of sharpening the tools of marine geophysics and in gaining confidence in the results obtained from

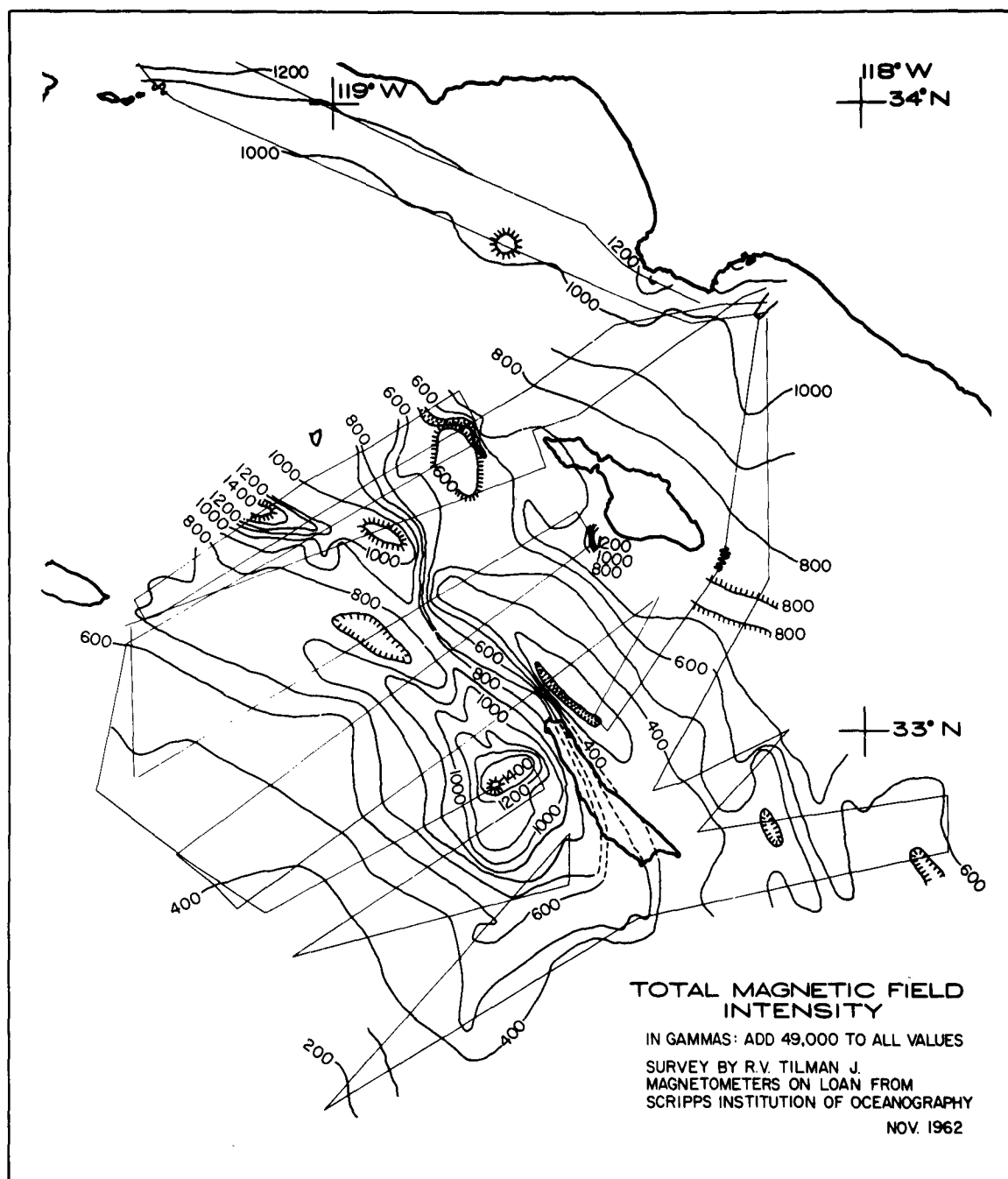


Fig. 2 — Total Magnetic Field Intensity in the Vicinity of San Clemente Island Surveyed by Hughes Research Laboratories using R. V. Tilman Jr.

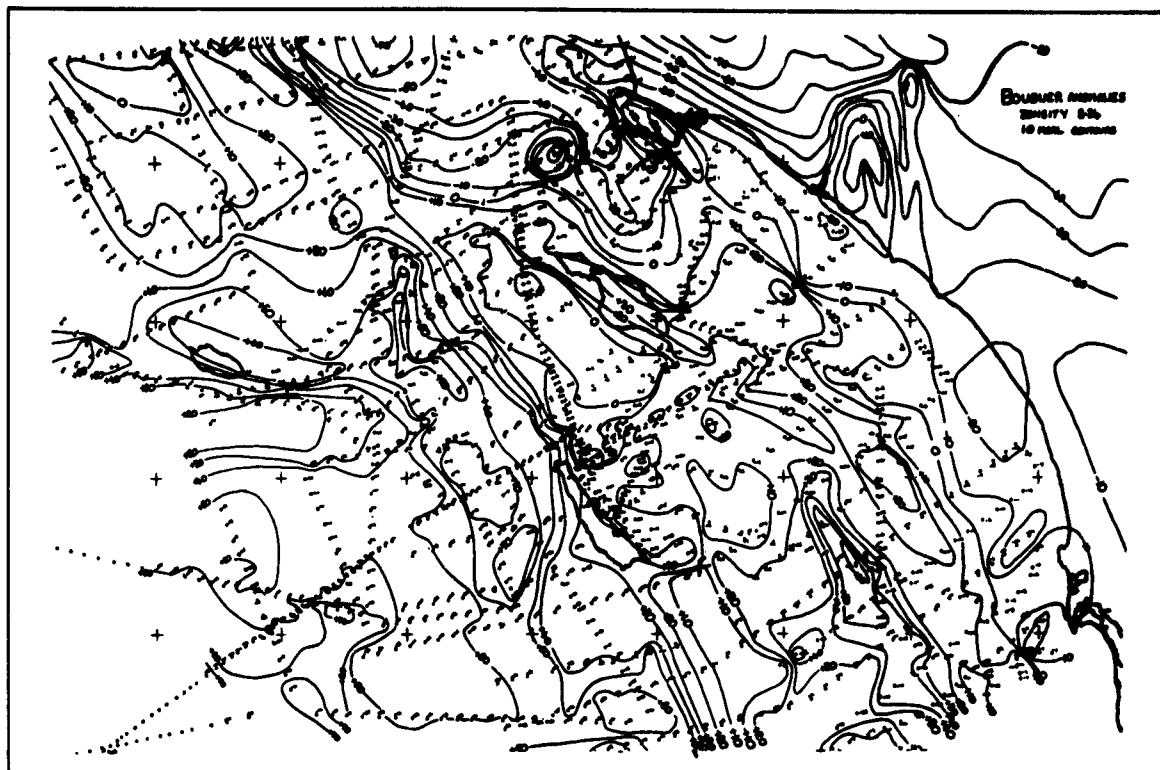


Fig. 3 — Bouguer Gravity Anomalies in the Northern Borderland Area off Southern California. (Surveys by Institute of Geophysics, UCLA).

these techniques. As a problem in itself the transition between the American continent and the Pacific Ocean is of major importance.

It is intended that these studies will be continued at Hughes Research Laboratories. The Office of Naval Research has agreed to loan the Laboratories a LaCoste and Romberg surface-ship gravity meter for the first quarter of 1963 for studies aimed at improving the instrumentation. It is ex-

pected that more gravity data will be obtained in the area during this work and it is hoped that, with the continuing assistance of the Scripps Institution of Oceanography, opportunities for extending the magnetometer coverage will arise from time to time. Perhaps most importantly of all, work will continue on the interpretation of the very extensive data already available and awaiting a more detailed analysis.

DISCUSSION

DAUBIN: Do you find a similar structure in the Santa Barbara Basin with a gravity low over the Basin?

Harrison: Yes.

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NARRATED FILM-COW OPERATIONS

by E. L. Hovind and S. R. Frank

Aerometric Research

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Abstract — The film shows the contributions of several participants to COW programs during 1961 and 1962. The activities illustrated include such atmospheric monitoring techniques as floating smoke pots at sea (positioned by both aircraft and ship) and tethered launchings (tracked by both optical means and radar). Not illustrated, but discussed, are the current contributions of all the participants and the methods by which the data are used to reconstruct the characteristics of the Marine Layer.

The *Proceedings* of the First Interindustrial Oceanographic Symposium contained a discussion of the Cooperative Observational Week field program as well as a list of the participating members. The film exhibited at the Second Symposium illustrated the area under investigation and the activities of these participants plus added information concerning new techniques.

To recapitulate, the basic problem under investigation by Aerometric Research under United States Public Health Service sponsorship, is to determine the transport and diffusion characteristics of the Marine Layer—that layer of the atmosphere along the Southern California coast, bounded by the surface and the height of the major temperature inversion. It had been previously determined that the Marine Layer was not a homogeneous air mass in terms of these parameters but rather exhibited distinct differences in both altitude and geographic extent. The approach toward documenting these characteristics was two-fold: (1) intensive localized observations, including a series of vertical soundings of temperature, humidity, and wind for examination of time variations; and (2) extensive network of surface observations for examination of synoptic space variations during the period of observation.

The localized observations were made mainly by Aerometric Research utilizing such specialized equipment as tethered radiosondes for detailed sensing of temperature and humidity in the lower 3000 feet, double theodolite slow-ascent pilot balloon observations for low-level wind determination, and time-lapse photography of incinerator smoke from the City of Santa Barbara during the time observations were being made within the city.

With the area of observation extending from the coastal areas of Santa Barbara and Ventura

counties across the Santa Barbara Channel to the Channel Islands, it was obvious that a large number of observers was necessary to cover the area on a synoptic basis. As the budget was much too limited to support such a group, the help of other organizations interested in geophysical problems of the area was solicited and gratefully received. Hence, we can state categorically that the synoptic picture was made possible only through the cooperation of the following participants in Operation COW:

U.S. Government Agencies

Weather Bureau
Navy
Air Force
Coast Guard
F.A.A.
Forest Service

Industrial

Lockheed Aircraft
General Motors
Rocketdyne
Hughes Aircraft
Southern California Edison Co.

California State Government

Beach Park Rangers

County Governments

Santa Barbara Beach Park Rangers
Los Angeles Air Pollution Control District

Universities

U.C.L.A.
U.S.C.

The participants not only contributed personnel to the program but the necessary equipment and vehicles as well. This included oceanographic

research vessels (Lockheed, General Motors, Hughes, U.S.C., Navy, Coast Guard), aircraft (Lockheed, U.C.L.A., Air Force—U-2), and radios (General Motors), radar (Navy, Air Force) and photographic coverage (General Motors, Lockheed).

The project has now reached sufficiently large proportions to enable each cooperating participant to request and receive the types of data pertinent to his particular program. In effect, the "cost" of these data is the participation in the program. To enable each member to get the most for his effort, Aerometric Research undertook the job of collecting and disseminating all observations made during each COW operation.

Figure 1, showing observation stations and tracks, illustrates part of the pre-program planning conducted for each COW operation. The dashed lines indicate the tracks of the oceanographic vessels along which sea surface temperatures and BT's were to be taken. It was the purpose here to make comparisons of temperature at the same locations throughout the week as a check on the variability of this parameter with time. The solid dots represent stations where standard weather observations were to be made. (Personnel on the oceanographic vessels were also making standard weather observations.) The solid line shows the flight path to be taken by the Air Force U-2 during four days of COW VI—October 22-26, 1962.

Sketches made by the U-2 pilot of the stratus coverage and characteristics are shown in Fig-

ures 2, 3, 4, and 5. The film exhibited at the meeting consisted of clips taken by several participants—Aerometric, General Motors, Lockheed and Hughes. Each clip illustrated some phase of the program with some having the double purpose of being both illustrative and useful as actual data. The sequence was as follows: Lockheed's oceanographic vessel releasing smoke pots in the Channel, Lockheed's aircraft flying over coastal stratus and making smoke drops in the channel through a clear zone in the stratus, General Motors personnel releasing smoke pots in the Channel from their oceanographic vessel, General Motors personnel releasing tetroons from mid-channel, Aerometric personnel optically tracking the tetroon with shore-based theodolites and finally, the Hughes boat showing the dispersion of oil fog over the channel (the oil fog generator was carried by the boat and operated by Aerometric).

The above brief resume of the film is made for the purpose of acquainting those readers unfamiliar with the program with some of the activities of the participants. For more details concerning the project, the reader is invited to communicate with the author.

The data acquired from these Cooperative Observational Weeks are proving invaluable in the documentation of oceanographic and meteorological characteristics of the area. As a *modus operandi* for attacking geophysical problems, the cooperative approach has proved to be both scientifically and economically sound.

DISCUSSION

BAER: What other observations did you make besides tracking the smoke plumes?

Frank: Temperature and humidity up to 3,000 ft and winds up to 6,000 ft. Surface observations were made along the coast and on the islands. General Motors released 4 tetroons and tracked 3 of them with radar. One tetroon finally was found 50 miles south of Douglas, Arizona.

BAER: How continuous were the measurements that you made aloft?

Frank: We made a series of 1-hour piballs between

0800 and 1200. The U-2 flew the channel at 50,000 ft, Monday through Thursday, between the hours of 1000 and 1300. Lockheed made vertical temperature measurements at several points over the channel. Wind and temperature measurements were made all day long. We hope to get airborne radiometer readings the next time.

HILDRETH: If anyone has an infrared indicator for measuring sea surface temperatures that needs checking out, please speak up.

Frank: We'd be very happy to have any offers of instruments.

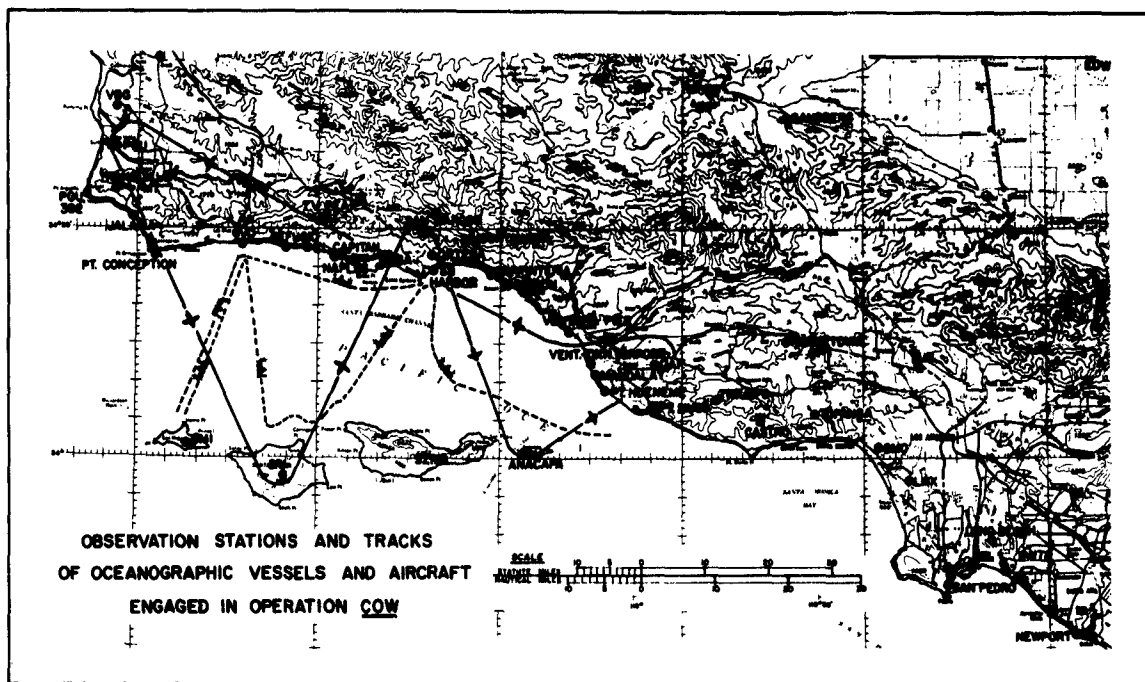


Figure 1

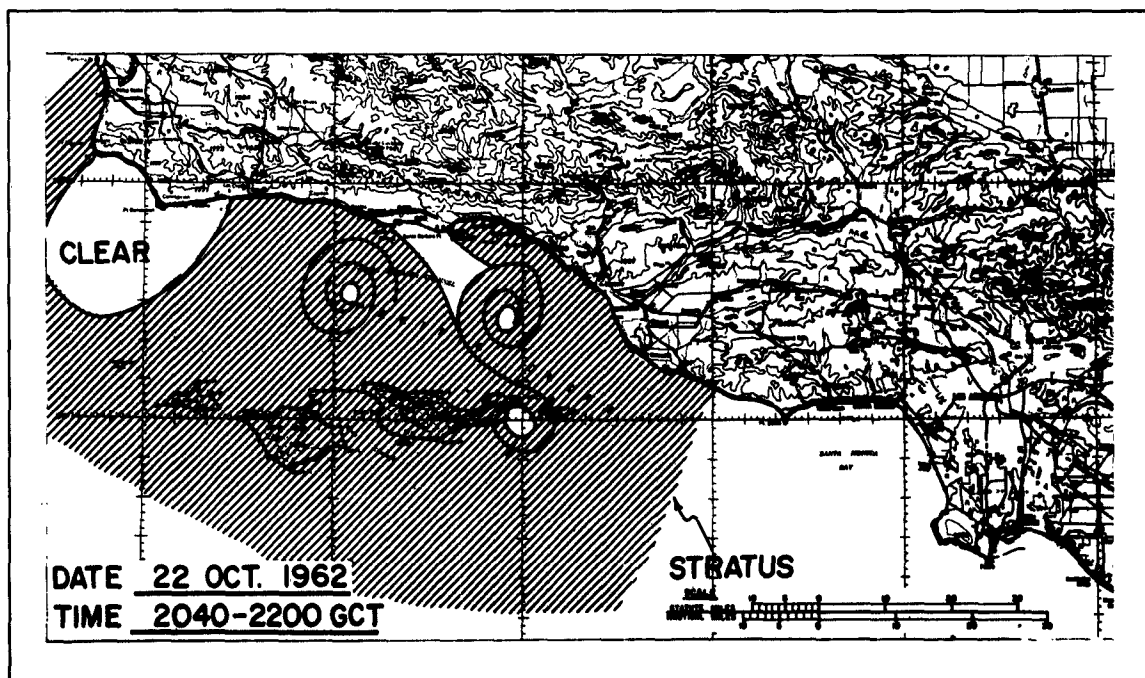


Figure 2

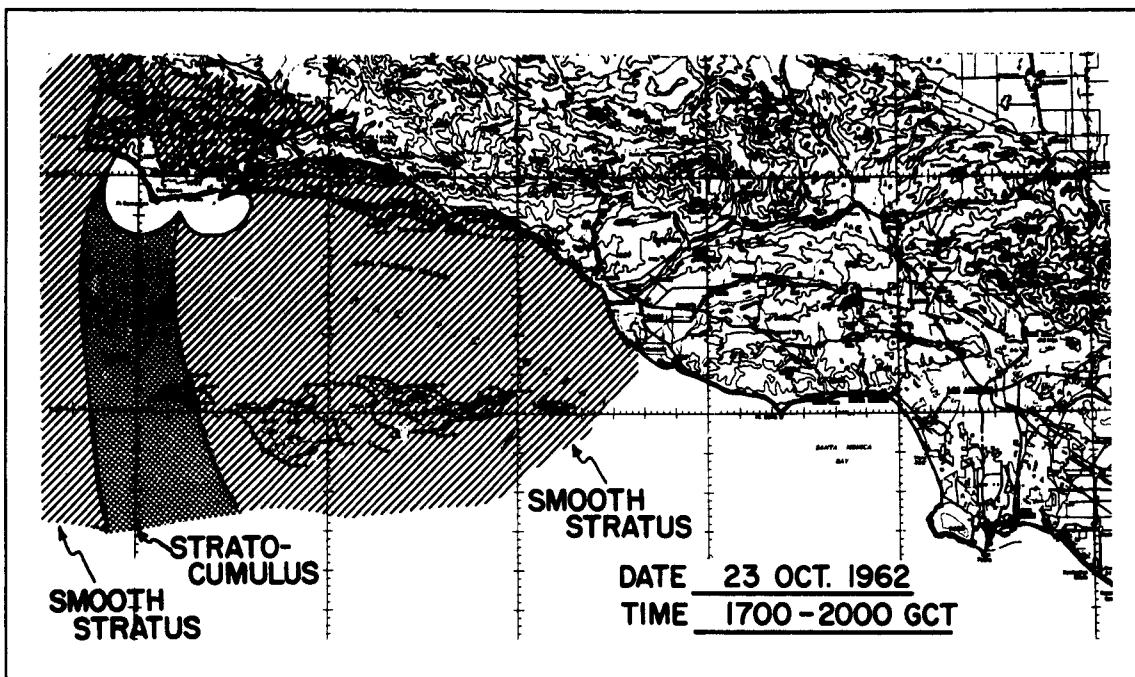


Figure 3

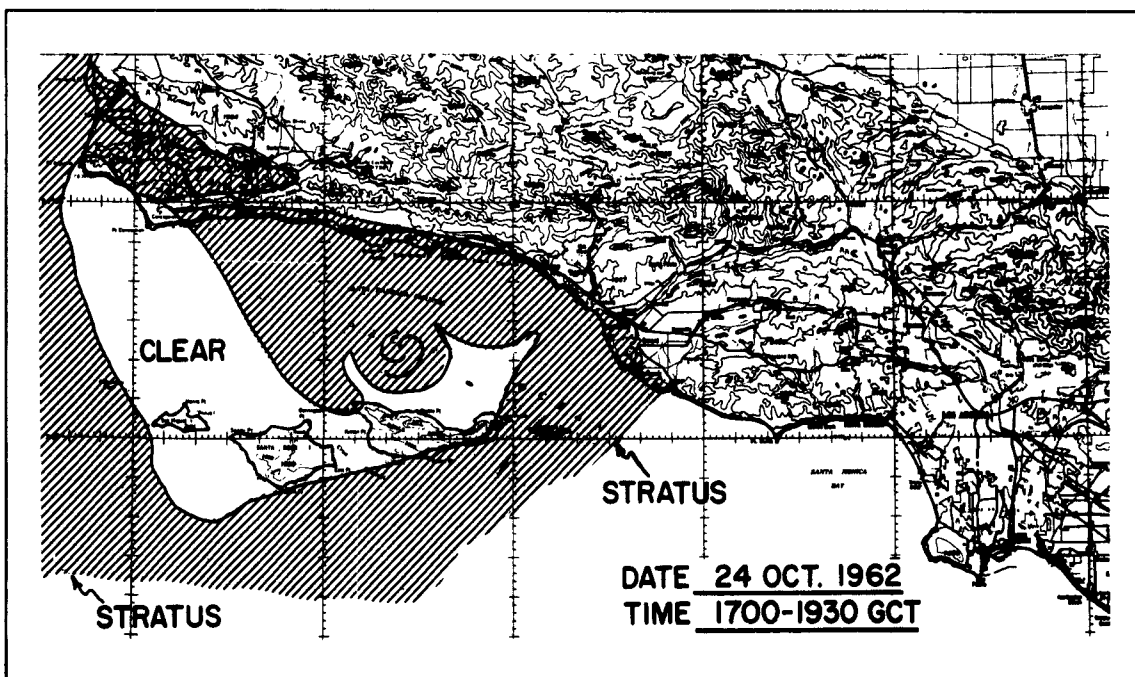


Figure 4

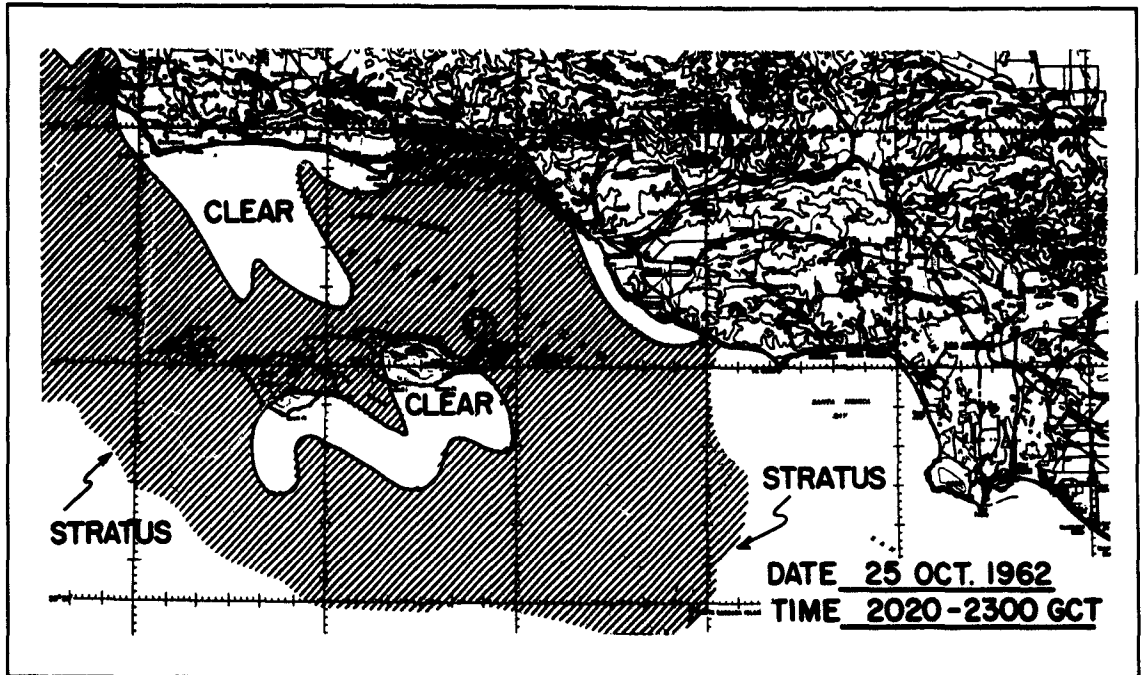


Figure 5

LIST OF ATTENDEES

FIRST INTERINDUSTRIAL OCEANOGRAPHIC SYMPOSIUM

ACOUSTICA ASSOCIATES, INC.

G. M. Bryan

AEROJET-GENERAL CORP.

Downey

L. W. Kidd

Azusa

W. K. Witthaus

AEROMETRIC RESEARCH, INC.

S. R. Frank

DOUGLAS AIRCRAFT COMPANY

Long Beach

A. W. Phillips

GENERAL ELECTRIC CORP. (TEMPO)

P. J. McDonough

GENERAL MOTORS CORP.

D. S. Potter

S. C. Daubin

HUGHES RESEARCH LABORATORIES

C. H. Wilcox

INTERSTATE ELECTRONICS CO.

R. Timme

LOCKHEED AIRCRAFT CORPORATION

G. G. Lill

LOCKHEED-CALIFORNIA COMPANY

L. Baer

E. A. Bartsch

A. J. Carsola

T. P. Higgins, Jr.

W. W. Hildreth, Jr.

W. V. Kielhorn

R. M. Lesser

D. W. Painter

W. G. Pitt

A. A. Sullo

LOCKHEED MISSILES & SPACE CO.

H. E. Wharton

MARINE ADVISERS, INC.

W. F. Brisch

NATIONAL ENGINEERING SCIENTIFIC CO.

B. W. Wilson

NORTHROP CORPORATION

Beverly Hills

M. A. Peterson

SPACE TECHNOLOGY LABORATORIES

C. T. Malloy

LIST OF ATTENDEES

SECOND INTERINDUSTRIAL OCEANOGRAPHIC SYMPOSIUM

AEROJET-GENERAL CORP.

Downey

L. W. Kidd

Azusa

R. G. Dean

T. L. Russell

AEROMETRIC RESEARCH, INC.

S. R. Frank

AMERICAN MACHINE & FOUNDRY CO.

W. Brock

B. Chambers

G. Hosmer

J. D. Phillips

BENDIX PACIFIC DIVISION

A. W. Phillips

GENERAL ELECTRIC — TEMPO

J. M. Sullivan

GENERAL MOTORS CORP.

W. I. Aron

J. S. Bucan

S. C. Daubin

V. Elliott

W. B. Moore

R. G. Paquette

D. S. Potter

W. G. Sherwood

D. E. Well

H. A. Wilcox

HAWAIIAN ELECTRIC COMPANY, LTD.

R. E. Bell

HUGHES RESEARCH LABORATORIES

J. C. Harrison

C. H. Wilcox

LOCKHEED AIRCRAFT CORPORATION

G. G. Lill

M. McNeil

LOCKHEED-CALIFORNIA COMPANY

E. Ashburn

L. Baer

F. Chew

W. W. Hildreth, Jr.

MARINE ADVISERS, INC.

D. Maddux

MINNEAPOLIS-HONEYWELL

Seattle Development Lab

J. Shaw

NATIONAL ENGINEERING SCIENTIFIC CO.

L. Skjelbreia

B. W. Wilson

NORTH AMERICAN AVIATION —

AUTONETICS DIV.

Anaheim

C. Fuller

Downey

J. M. Slater

D. E. Wilcox

NORTHROP CORPORATION

Beverly Hills

A. R. Farrell

M. Peterson

Ventura

H. Ritland

OCEANOGRAPHIC ENGINEERING CORP.

J. E. Kenny

J. Lasch

RICHFIELD PRODUCTS RESEARCH

M. J. Cruickshank

SCRIPPS INSTITUTION OF OCEANOGRAPHY

J. M. Snodgrass

WRIGHT ENGINEERING

P. Nooteboom