A Summary of

1968 DEVELOPMENT PLANNING SUPPORT STUDIES

FOR THE UNITED STATES COAST GUARD

NATIONAL DATA BUOY DEVELOPMENT PROJECT

by

Eugene J. Aubert, Gaylord M. Northrop
Principal Investigators

and

LeRoy H. Clem   Clifford A. Jacobs
Earl L. Davis   Carl F. Jenkins
              Joseph P. Pandolfo

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THE TRAVELERS RESEARCH CORPORATION

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1968 DEVELOPMENT PLANNING SUPPORT STUDIES

FOR THE

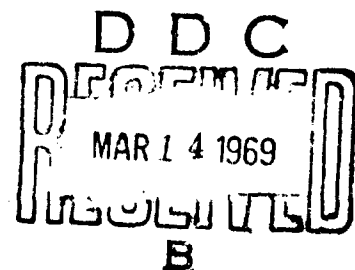UNITED STATES COAST GUARD

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FOREWORD

Contract Number DOT-CG-82504-A between the U. S. Coast Guard and The Travelers Research Corporation (TRC) consisted of five parallel activities. The five final reports stemming from these activities are entitled:

(1) Applicability of National Data Buoy Systems to Refined National Requirements for Marine Meteorological and Oceanographic Data (two volumes).

(2) Characteristics of National Data Buoy Systems: Their Impact on Data Use and Measurement of Natural Phenomena

(3) Cost Effectiveness Sensitivity of National Data Buoy Systems: An Essay

(4) Computer Programs for National Data Buoy Systems Simulation and Cost Models

(5) An Analysis of Cruise Strategies and Costs for Deployment of National Data Buoy Systems.

Each of these five reports is complete in itself, but it must be recognized that in all instances the other four activities both influenced and contributed to the results presented in each individual report.

The present USCG/TRC contract is an outgrowth of a study of the feasibility of national data buoy systems performed by TRC and Alpine Geophysical Associates for the USCG during 1967. Need was evident for investigation, research, and analysis in greater depth in several areas to support the concept formulation and deployment planning efforts of the Designated Project Office (DPO). This report summarizes the five reports cited above.

All five TRC reports have benefited from the close cooperation and guidance afforded by the DPO. Contributions have been made by Capt. J. Hodgman (Project Manager), Cmdrs. V. Rinehart, J. Wesler, E. Parker, and P. Morrill, and Lt. Cmdr. W. Merlin (Contract Monitor).

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1.0   INTRODUCTION

This summary report gives an overview of the 1968 activities and accomplishments of Contract DOT-CG-82504-A, between the U. S. Coast Guard and The Travelers Research Corporation (TRC), for development planning studies in support of the USCG National Data Buoy Development Project (NDBDP).

The five studies summarized herein fulfill in part the need for detailed research and analytical results for selected topics to expand the 1967 National Data Buoy Systems Feasibility Study performed by TRC for the USCG. [1, 2, 3, 4, 5, 6] The 1967 Feasibility Study provided a basis for preliminary concept formulation for National Data Buoy Systems (NDBS). [7]

It is anticipated that actual development of hardware for the NDBS will be initiated with FY-70 funds. The five reports summarized here are intended to provide background for undertaking contract definition, testing of off-the-shelf hardware, and other system development efforts. The five 1968 TRC studies were conducted in parallel and each has benefited from the close interaction among the principal scientists conducting the work. The specific areas of research undertaken by TRC during 1968 are:*

(1) Determination of the applicability of NDBS to refined national requirements for marine meteorological and oceanographic data,

(2) Establishment of the characteristics of NDBS and their impact on the use of collected data and the observation of natural phenomena,

(3) Preparation of an essay on the cost effectiveness sensitivity of NDBS,

(4) Development of computer programs for National Data Buoy Systems simulation and cost models, and

(5) Analysis of deployment ship cruise strategies and costs for deployment of NDBS for various numbers of buoys and locations throughout the northern hemisphere.

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*Publication titles, etc. are listed in Section 7.0.

Abstracts of each of these five parallel studies are presented in the remainder of this section. The remaining sections of this document present in turn detailed summaries of the five reports. The reader interested in even greater detail is referred to the reports themselves.

1.1 NDBS Applicability to Refined Requirements

All operational and research data requirements collected during the 1967 Feasibility Study were carefully assessed and compared with a hypothetical NDBS similar to that postulated in the feasibility study technical development plan. From this assessment a preliminary estimate of the applicability of the NDBS to meet each set of data requirements was made, and questions were framed to be answered by the U. S. Government agencies and supported organizations that had stated requirements. At a meeting of agencies, organizations, and observers held in Washington, D. C., on 19 March 1968, the preliminary assessments, the hypothetical data buoy "system," and the questions were presented and a refinement of data requirements and written answers to the prepared questions were requested.

From the refined national requirements for marine meteorological and oceanographic data, a revised hypothetical "system" evolved and a worldwide NDBS was structured to satisfy operational data requirements. The "system" comprised 279 data buoys spaced 100 to 150 n mi apart in a 400 n mi band around Coastal North America (CNA), south of 60°N, and 261 data buoys worldwide, approximately 600 n mi apart in the Deep Oceans (DO) between 60°N and 60°S. By combining all agency operational and research requirements, it was found that in the DO region each buoy would support an average of seven stated requirements for data, and in the CNA region an average of five stated requirements would be supported. This illustrates the advantage of using a common NDBS, rather than several data buoy systems supporting individual agency requirements.

1.2 NDBS Characteristics, Data Use, and Measurement of Natural Phenomena

The horizontal spacing of data buoys, the time period for averaging data, the time period between reports, and the response time of instruments are all character- istics of NDBS that influence the scales of natural variability that are resolvable by the NDBS and have impact on the use of the collected data. The purpose of the data

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use study was to provide means for assessing the compatibility of NDBS character-istics. natural variability, and certain data use techniques. In the course of the study, the interrelations between each of 15 parameters to be measured by a typical NDBS and certain atmospheric and oceanographic phenomena that influence the parameter were investigated. By using a spectral analysis approach, graphs of frequency (f) and wave number (k) were prepared for each NDBS-observed parameter, using present state of knowledge of natural variability. NDBS network spacing, reporting period, averaging period, and instrument response times were also plotted on the f-k graphs, along with approximate f-k regions of occurrence for a number of important natural phenomena. From these graphs, the ability of an NDBS to resolve the natural phenomena, and the suitability of the data as input for physical, empirical and statistical prediction models was then inferred. Very little is presently known about the intensity of natural variability in and above the oceans as a function of scale, sea-son, and location, and it is expected that this study will provide an initial framework for specifying tests and system configurations during the evolutionary growth phases of the NDBS.

1.3   NDBS Cost Effectiveness Sensitivity

The cost effectiveness analysis prepared for the 1967 feasibility study was expanded in this study to cover all operational requirements, with consideration given to eight competing and complementary data collection platforms: unmanned data-buoys, manned data buoys, oceanographic vessels, satellites, horizontal sounding balloons, ships-of-opportunity, aircraft-of-opportunity, and reconnaissance aircraft. It was found in this study that unmanned data buoys were the most effective single data collection platform for satisfying operational requirements for marine atmos-pheric and oceanographic data. Unmanned data buoys and horizontal sounding balloons, or buoys and satellites, or buoys and ships-of-opportunity represent combinations of complementary data collection platforms, because buoys are highly capable in the collection of oceanographic and surface meteorological data, and the other platforms can collect upper air data. Manned buoys are highly effective, but they are approximately 7.5 times more costly than equal numbers of unmanned buoys.

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1.4 NDBS Simulation and Cost Models

Many of the system simulation and cost models developed during the 1967 feasibility study were expanded and improved in the course of preparing computer programs for the fourth area of research. This effort produced computer programs for (1) an integrated Buoy Deployment Simulation and Cost Model, (2) a Procurement, Maintenance, and Replacement Cost Model, (3) a 10-year Technical Development Plan Financial Model, (4) maintaining a Buoy Component Characteristics Data File, and (5) a rapid access listing of Ocean Depth Data extracted from magnetic tapes supplied by the U. S. Navy Fleet Numerical Weather Central. During the course of TRC's 1968 efforts, these programs were used to support NDBS development planning as directed by the DPO.

1.5 NDBS Deployment Analysis

The fifth study undertaken in support of the DPO provided an analysis of cruise strategies and costs for initial deployment of NDBS. Seven northern hemisphere buoy system configurations, ranging from 60 to 500 buoys were considered. Ship average speed, ship buoy-carrying capacity, time-to-plant each buoy, number of deployment ports, number of days in port per cruise, ship operating base cost per sea-day, ship maintenance cost per day, fuel cost per n mi are all typical system characteristics that were treated as parameters in this study. All ship costs and other ship operating characteristics were provided by the DPO. The study showed that a ship with an average speed of 18 kt and capable of carrying 12 buoys was the best for the parameters investigated. Such a ship could deploy about 100 buoys per ship-year in the CNA region, and about 65 buoys per ship-year in the DO region. At least four deployment ports would be required, if deployment is to cover the entire northern hemisphere. However, if buoys are not deployed in the western North Pacific, three ports are adequate: Honolulu, San Francisco, and Portsmouth, Virginia. For a ship operating base cost of $5000 per sea-day and 10 days in port per cruise, buoy deployment costs for the 18 kt, 12-buoy ship averaged about $16,000 per buoy in the CNA region and about $26,000 per buoy in the DO region. Buoy deployment cost could be used as a major element of the maintenance cost for buoys, since maintenance procedures will also require visiting the buoy deployment sites periodically.

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2.0 APPLICABILITY OF NDBS TO REFINED NATIONAL REQUIREMENTS FOR MARINE METEOROLOGICAL AND OCEANOGRAPHIC DATA

This report documents the 1968 refinement of national requirements for marine meteorological and oceanographic data—initially compiled during the 1967 Study of the Feasibility of National Data Buoy Systems—and shows the applicability of certain postulated NDBS sensing characteristics to a subset of the refined data requirements. National data requirements to support operational and research activities are presented; they include physical, biological, chemical, geological, and radiological parameters which are to be measured throughout the world's oceans from the ocean bottom to 100,000 feet in the atmosphere. The data requirements are projected from the present to as far as 15 years into the future. The applicability of possible future National Data Buoy Systems to 1968 refined national data requirements is illustrated by the use, for reference purposes only, of the potential sensing capabilities (parameters and measurement characteristics) of a hypothetical data buoy "system."

The comprehensiveness and accuracy of the 1967 statements of data requirements were constrained by a lack of requirements collection precedence and by the usual difficulties encountered in collecting environmental data requirements from a wide variety of government agencies. The 1967 data requirements were collected without benefit of complete standardization or reference to the sensing characteristics shown to be economically and technically feasible in the 1967 TRC study. The U. S. Coast Guard was assigned development responsibility for the NDBS in November 1967. For the National Data Buoy Development Project, the USCG established a data requirements refinement effort as one activity of Contract DOT-CG-82504-A, to obtain more up-to-date, accurate, complete, and clearly-defined statements of data requirements, suitable for the initial phases of system development planning. Standardization of terms and units was sought and refinement of data requirements in the Deep Ocean* and Coastal North American†regions were solicited from the U.S. Government agencies that had provided data requirements for the 1967 feasibility study. Throughout this work, operational data requirements have been emphasized somewhat more than

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*Beyond 400 n mi of North American Coast.
†Within 400 n mi of North American Coast.

research requirements because of their more stable, long-term nature and because of the potential economic benefits that might be realized by implementation of an NDBS capable of satisfying operational requirements at the earliest possible time. (Additional emphasis on collection and assessment of research requirements and requirements for the near-shore, estuaries, and the Great Lakes is expected in 1969).

The 1968 data requirements refinement and the analysis of the applicability of hypothetical NDBS sensing characteristics were conducted in several phases. First, from the results of review of (1) the 1967 statements of data requirements, (2) the 1967 projected estimates of 5-year buoy state-of-the-art (SOA), and (3) the results of the 1967 feasibility study, a hypothetical data-buoy "system" was conceptualized for reference purposes (with a few important exceptions, this "strawman system" was comparable to those postulated in the 1967 feasibility study). Second, an assessment was made of how well each set of the 1967 data requirements would be met by this hypothetical "system." Third, the results of this assessment together with questions that arose during the analysis and assessment, were forwarded to the pertinent agencies for refinement action. Fourth, responses (including answers to specific questions submitted to the agencies) were analyzed, assessed, and translated into tentative NDBS sensing characteristics needed to meet data requirements in various marine regions. Finally, the refined data requirements were interpreted in terms of tentative observation sites in hypothetical DO and CNA "system" networks in 13 geographical regions called Modular Deployment Zones (MDZ), as shown in Fig. 2-1.

After receiving the TRC review and assessment of their statements of data requirements, the agencies made refinements to their data requirements in light of the potential sensing characteristics of the hypothetical technologically feasible NDBS. When the refined data requirements were returned to TRC, they were again assessed and tallied in the following manner: Total operational data requirements for observations of data at sites were sorted by agency-mission-operations (AMO), by agency, by DO and CNA regions, and by the 13 geographical regions called Modular Deployment Zones. In each category, where applicable, the distribution of requirements to collect data at observation sites, where possible, was analyzed to determine the minimum number of non-redundant required sites. For example, various operations within an agency (or among agencies) might have requirements for data

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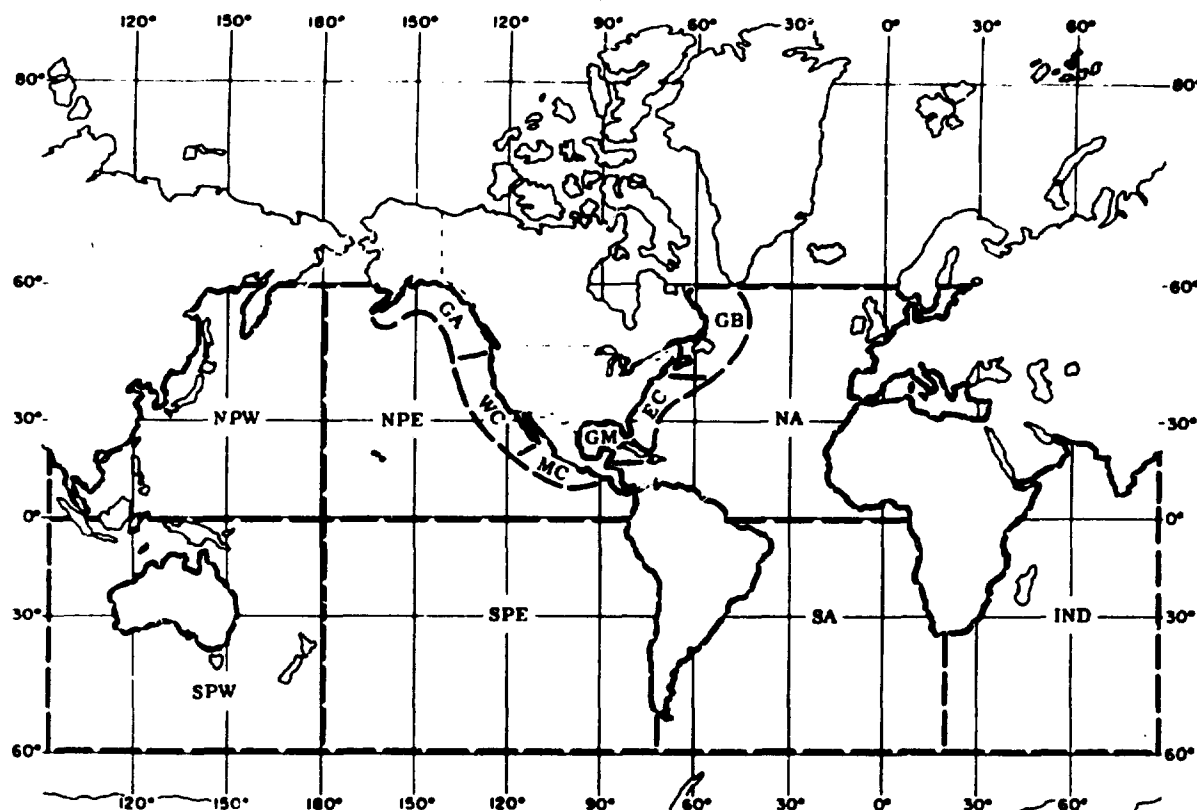
Definitions		
Region	Modular Deployment Zones	Symbol
Coastal North America (CNA)	Grand Banks	GB
	East Coast	EC
	Gulf of Mexico	GM
	Mexican Coast	MC
	West Coast	WC
	Gulf of Alaska	GA
Deep Ocean (DO)	North Atlantic	NA
	South Atlantic	SA
	North Pacific East	NPE
	North Pacific West	NPW
	South Pacific East	SPE
	South Pacific West	SPW
	Indian Ocean	IND

Fig. 2-1. National Data Buoy System Modular Deployment Zones.

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(the same or different parameters) from the same type of observational network in a given geographical area. The total number of requirements for observations would thus be larger than the number of observation sites required to meet them. The required observation sites were then related to those that conformed to the network sites of the reference "system." Required observation sites were then classified as "system" or non-"system." A similar analysis of the numerical distribution of specific parameter requirements was performed for "system" and non-"system" sites within each MDZ. For each of the 13 MDZ s, the total number of requirements for specific parameters has been established, thus demonstrating the degree of utility for each "system" observation site. The complete analysis also covers non-"system" sites in the same manner and illustrates the low operational utility of these sites. A similar, but less extensive, analysis was made of research requirements that were either met or partially met by the hypothetical reference "system."

Finally, all operational requirements and selected research requirements (those research requirements for which the hypothetical "system" had considerable applicability) were combined into national data requirements and assessed for numerical distribution of requirements for observations at sites that could be assumed to be those of the hypothetical reference "system." This indicated the degree of potential utility of the hypothetical reference "system."

In total, there are 1,893 DO and 1,353 CNA operational and selected research requirements for data collection at sites for combined national interests that could be met by hypothetical "system" observation sites. When the potential reduction of observation sites possible through the common use of a site is taken into account, the net number of required hypothetical "system" observation sites is 261 for the DO region and 279 for the CNA region, as shown in Fig. 2-2. Thus, a 7:1 average ratio of combined requirements-for-data-collection-at-observation-sites to "system" observation sites is achieved in the Deep Ocean MDZs, and approximately a 5:1 ratio of requirements to "system" sites is established in the Coastal North American MDZs.

Of course, these findings are based upon the assumption that the 1968 statements of refined data requirements are the best presently available and collectively represent the national interests. About mid-1968, estimates of the relative values of
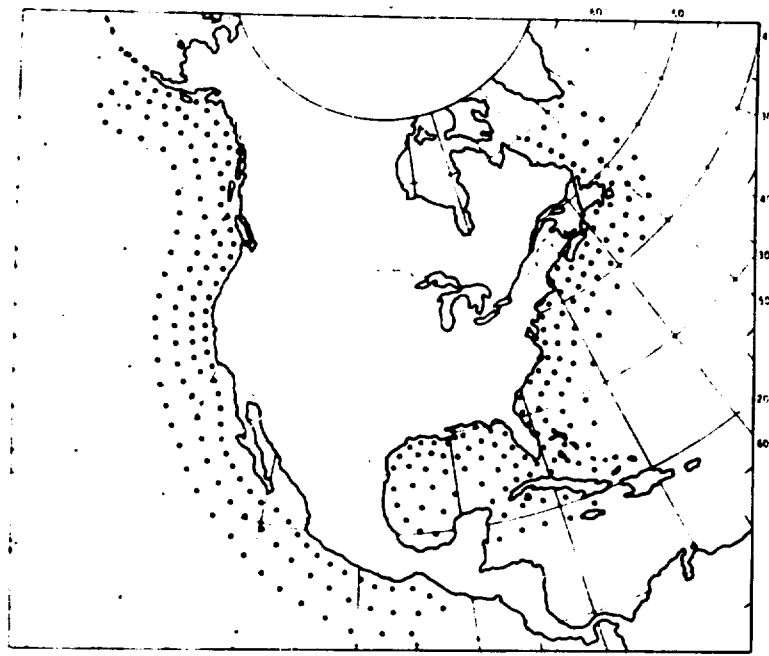
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Fig. 2-2(a). A hypothetical "system" network of observation sites (279 buoys) for the Coastal North America region.
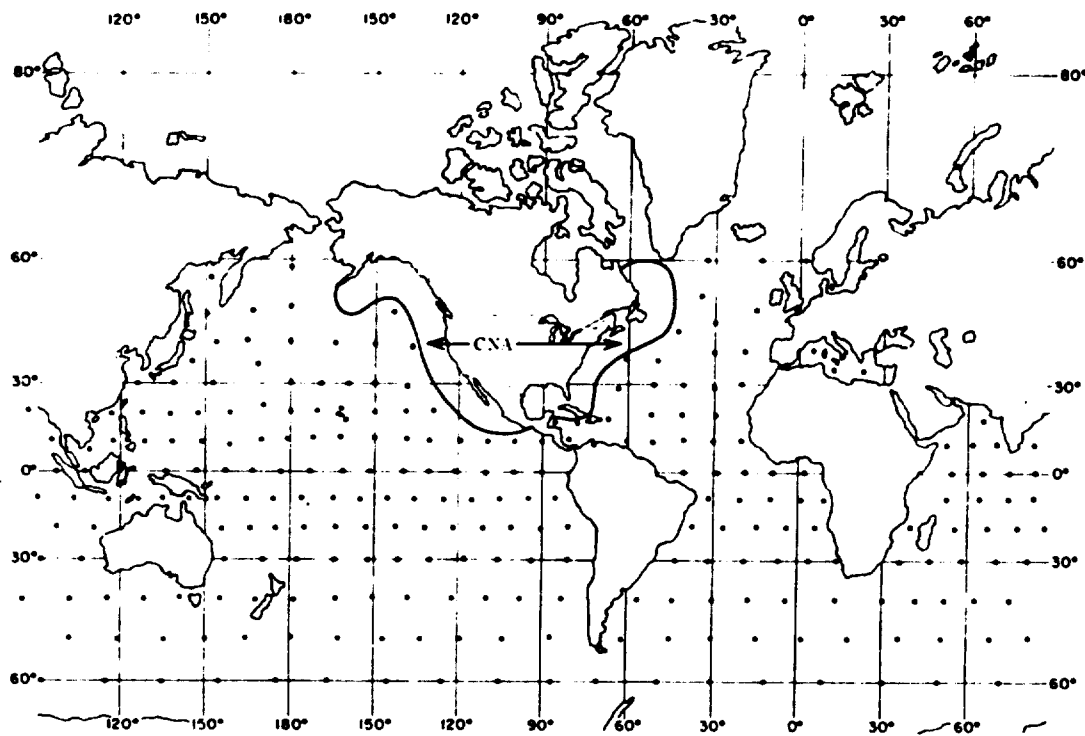

Fig. 2-2(b). A hypothetical "system" network of observation sites (261 buoys) for the Deep Ocean region.

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parameters and observing layers were solicited from four agencies with operational missions. The agency responses indicated that additional information related to data requirements and useful for NDBS development planning, can be obtained. This initial effort has made clear that further work of this kind should be undertaken in the future.

The ultimate sensing characteristics of various National Data Buoy Systems have not yet been finalized. The statements of data requirements presented in this report provide a base for assessment of hypothetical, technically feasible sensing characteristics,* thus adding another dimension to preliminary system development planning. Among other important features of evolving NDBS system development planning that will doubtless influence the NDBS sensing characteristics ultimately implemented are cost-effectiveness studies, trade-offs of potential development vs. off-the-shelf equipment acquisition, relative values of data from contiguous geographical regions, research, economic, social, and military benefits, and national and international relative worth of the NDBS (or, the data collected by the NDBS). Within this context, the conclusions of the refinement of data requirements study are as follows:

- The continuing evolutionary nature of requirements for marine environmental data must be recognized. It is the result of numerous factors. Annual review and refinement of requirements will probably be necessary throughout the foreseeable future.

- Agency representatives have demonstrated a willingness and ability to estimate the relative importance of parameters and observing layers as part of the continued refinement of data requirements. A more intensive program to develop and exploit quantified ratings of this type should be undertaken.

- Horizontal spacings for Deep Ocean buoy networks of 600 n mi and Coastal North American network spacings of 100 to 150 n mi appear to be generally acceptable for an initial NDBS and appear to serve the stated needs of many activities. A total of 261 DO and 279 CNA data buoys would be needed to satisfy these horizontal spacing requirements in the ocean areas.

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*Technically feasible sensing characteristics are defined as those estimated to be achievable within 5 years by conventional development effort.

- Twenty parameters and their measurement characteristics (Table 2-1) are suggested as representative of the basic sensing characteristics of a future DO or CNA NDBS. They are the result of the assessment of refined 1968 data requirements and appear to be generally acceptable to the U.S. Government agencies involved at this time. Inclusion of additional parameters of high common need or importance in specific geographic regions appears indicated. Development of new sensing capabilities for some of the additional parameters (e.g., upper air parameters) appears worthy of further consideration.

In preparing the report on the refinement and assessment of data requirements, it has been the intent to document as clearly as possible the steps involved in the collection and assessment of data requirements, and the analysis leading to further delineation of the basic sensing characteristics of future National Data Buoy Systems. There is much yet to be learned about the marine environment; data requirements will likely change in the future in an evolutionary fashion. The NDBS will be but one data collection system operating ultimately within the context of a total national marine environmental data collection system. Thus, this report may be of use or guidance, not only in support of NDBS development planning, but also to the agencies having requirements now or in the future for data from the marine environment and agencies having present or future responsibilities for developing and/or operating the other data collection systems that will comprise the rest of the national marine environmental data collection system. Therefore, the refinement and assessment of data requirements has, to the extent possible, been structured to keep this larger task in view, while at the same time concentrating on details most relevant to NDBS development.

Many of the results and conclusions discussed in the report are based on interpretations by the authors of data requirements collected from U.S. Government Agencies. Often, interpretations were made in areas that are recognized to be controversial. The cooperating agencies have been encouraged to "set the record straight" on any point where these interpretations may not have hit the mark. Ultimately, it is hoped that through interactive efforts, such as described in the report, data requirements collection and assessment procedures that are both useful and acceptable to all concerned will evolve and the major task of developing an effective national marine environmental data collection system will be accomplished.

TABLE 2-1

TENTATIVELY PROPOSED NDBS SENSING CHARACTERISTICS

Parameter	Range (5-yr SOA)	Accuracy (5-yr SOA)	Vertical layer	Number of sampling levels
Oceanographic				
1. Current direction	0—360 deg	5 deg	0—5000 m	20
2. Current speed	0.05—10 kt	0.03 kt or 1%	0—5000 m	20
3. Salinity	0—42 ‰	0.01 ‰	0—5000 m	20
4. Sound speed	4500—5800 fps	1 fps	0—5000 m	20
5. Water pressure	0—10K psi	0.1 %	0—5000 m	20
6. Water Temperature	-5 to 40 deg C	0.01 deg C	0—5000 m	20
7. Ambient light	0—2 ly/m	1.0%	0—500 m	2
8. Ambient noise	-80 to -20 db	3 db	0—5000 m	2
9. Transparency	0—70%/m	2%	0—5000 m	2
10. Wave direction	0—360 deg	5 deg	surface	1
12. Wave period	1—40 sec	0.1 sec or 1%	surface	1
Meteorological				
13. Air temperature	-25 to 60 deg C	0.1 deg C	0—10 m	1
14. Atmos. electric.	0—10 kv	0.1 kv	0—10 m	1
15. Atmos. pressure	800—1099 mb	0.1 mb	0—10 m	1
16. Dew point	-25 to 40 deg C	0.2 deg C	0—10 m	1
17. Insolation	0.01—2 ly/min	1%	0—10 m	1
18. Precip. rate	0—12 in/hr	0.01 in/hr	0—10 m	1
19. Wind direction	0—360 deg	2 deg	0—10 m	1
20. Wind speed	0—160 kt	0.5 kt or 3%	0—10 m	1

Additional Notes:

(1) Buoy Locations: Deep Oceans (DO) and Coastal North America (CNA).

(2) Horizontal Sampling Intensity: 600 n mi in DO and 100 to 150 n mi CNA.

(3) Duration of Observation: Instantaneous or Representative short-period average up to 10 min.

(4) Time Sampling Intensity: 6 hr in DO and 3 hr in CNA.

(5) Synchronization of Observations: 10 min in Horizontal and 1 min in Vertical.

3.0 CHARACTERISTICS OF NATIONAL DATA BUOY SYSTEMS: THEIR IMPACT ON DATA USE AND MEASUREMENT OF NATURAL PHENOMENA

The ultimate goals for this area of research were twofold: (1) to provide sufficient information to National Data Buoy Systems designers to assist in making decisions pertinent to the design of the operational system; and (2) to provide a "users' manual" to inform data users of some of the properties of data that might be provided by the NDBS. At this time, these goals cannot be completely attained because of lack of basic information and understanding related to three problem elements: viz., system characteristics, natural variability, and data use techniques. It is recognized, however, that successively better approximate solutions to satisfy these goals can be made available to the DPO in an evolutionaly, iterative fashion. A structured approach and an initial effort to attain the outlined goals is presented in the report. It is not suggested that the concepts applied, the method of application, or the method of presentation developed in this report are definitive, but the framework developed therein for comparing NDBS characteristics, natural variability, and data use techniques is believed to be adequate for its purpose within our present state of knowledge of the marine environment.

The fundamental objective of the NDBS is to collect systematic measurements of information that will be useful for a variety of national purposes. As a "window" through which the natural marine environment can be observed, the National Data Buoy System must be designed with care. It is not feasible to attempt to observe all the natural processes occurring in the marine environment through the medium of NDBS data collection. Rather, economic factors dictate that a carefully selected set of phenomena be chosen for observation. It is important that the NDBS be designed to match the national marine data requirements and the natural environment. It is important, too, that users of this system be clearly aware of the limitations of the NDBS.

The NDBS is expected to route the data collected from the ocean and marine atmosphere to many different users as indicated in Fig. 3-1. For example, from the buoy system, the data will go to government agencies, industrial organizations, scientific institutions and to the general public. In some cases the dissemination of data will be direct; in other instances an important intermediate role will be played by data

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                    NATURAL ENVIRONMENT

                          │ Sensed data
                          ▼
                 ┌─────────────────────┐
    ┌ ─ ─ ─ ─ ─ ─►     NATIONAL DATA    │
    │            │                       │
    │            │     BUOY SYSTEMS      │
    │            └─────────────────────┘
    │                      │ Data
┌───────────────┐         │
│ New or revised │         ▼
│               │ ┌─────────────────────┐
│ requirements   │ │   DATA PROCESSING    │
└───────────────┘►│                      │
    └ ─ ─ ─ ─ ─ ─ ─│ CENTERS: "THE USERS" │
         ┌ ─ ─ ─ ─►│                      │
         │         └─────────────────────┘
┌───────────────┐            │ Data products
│ New user needs │            ▼
│               │  ┌─────────────────────┐
└───────────────┘  │    ULTIMATE USERS    │
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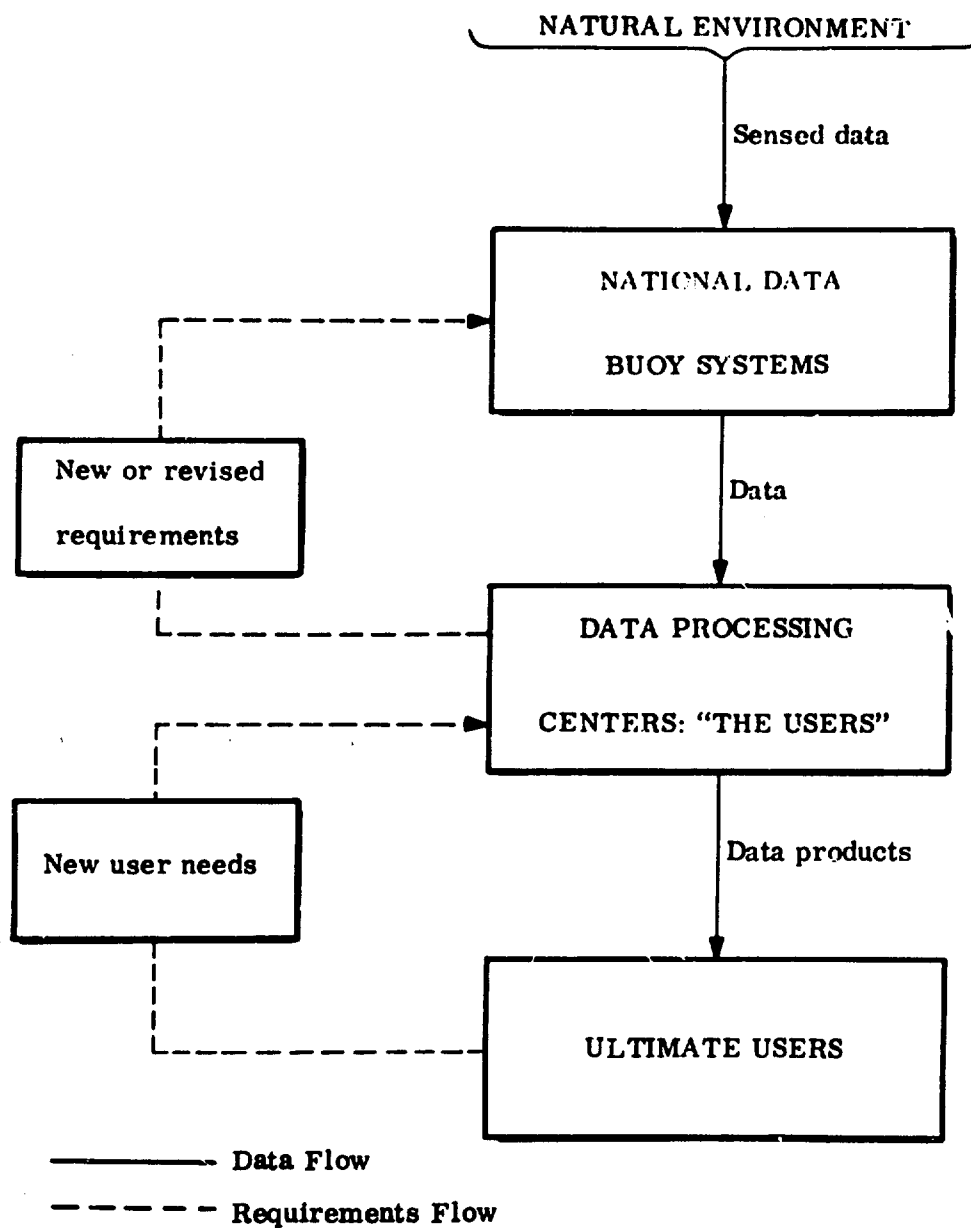——————► Data Flow

– – – – – Requirements Flow

Fig. 3-1. Relationship between Data Users and NDBS.

processing centers. At these centers, state-of-the-art data use techniques will be employed to convert the information into a form for maximum utility to the ultimate users.

An important function of the data processors will be their feedback to the design and operation of the NDBS. Feedback from the ultimate users to the data processing centers will likely lead to a sharper definition of the data buoy system requirements.

The NDBS will collect measurements over a three-dimensional spatial array of points in the ocean at regular intervals in time. At each array point, a time series of discrete values of a set of oceanic parameters will be obtained. These parameters might be. for example, temperature, salinity, current velocity, surface wind veolocity, etc. The time series for each parameter will represent the combined influence of a broad spectrum of physical processes. Typically, such processes might be tides, waves. hurricanes, diurnal heating, etc. The NDBS must provide information about selected natural processes, as required by a set of users.

As has been mentioned, economic considerations dictate that the NDBS can return information on only a selected class of natural procedures occurring in the marine invionment. To attempt to monitor all oceanic processes in the wide sense cannot be economically justified. It is, therefore, necessary to develop criteria by which the information-collecting ability of the NDBS can be evaluated. These criteria must be clearly understood by both the system designers and by the data users.

The concept used in this report to describe the NDBS system resolution is that of the spectrum. Any time series can be decomposed into a set of spectral components, each contributing to the variability of the parameter being measured. This decomposition can be a powerful tool for resolving physical processes that are superposed in the data record. The design of a buoy data-collecting system can be conveniently formulated in terms of matching the spectral content of the natural environment as seen through the spectral "window" of the buoy system to the spectral content required by the set of data users.

The quantities used to classify oceanic and atmospheric processes in the spectral sense are frequency (for time variability) and wave number (for space variability). By specifying both frequency and wave number, it is possible to uniquely categorize all marine processes. In the report, this categorization is referred to as an f-k representation,

following the usual abbreviations for frequency (f) and wave number (k). Graphs with frequency as one ordinate and wave number as the other are used heavily in this study. For example, in the report will be found f-k graphs representing classes of natural phenomena in the ocean and atmosphere, and the window characteristics of various buoy system designs. Examples of f-k diagrams are shown in Fig. 3-2 and 3-3.

Often many different natural phenomena influence the measured values of parameters; some of the f-k graphs prepared for this report show the natural processes affecting the variability of specific parameters. A presentation in graphical and tabular form of known major oceanic and atmospheric phenomena which could be sensed by the NDBS has been undertaken. For each of a certain class of parameters to be measured by the NDBS, a f-k graph has been prepared showing the natural processes affecting that parameter. Also shown on each f-k graph are the windows implied by hypothetical sets of buoy system characteristics.

Some of the system characteristics under control of the NDBS designer have been studied with regard to the data requirements of the user and the natural variability of the environment. The study has considered alternatives for NDBS design. Unfortunately, knowledge and theory of processes in the marine environment are not yet sufficient to permit definitive design criteria to be established. The NDBS in its several evolutionary stages will be a vital instrument in the collection of knowledge that will aid in its own development and growth. Until further critical knowledge is obtained, there must be a degree of arbitrariness in the choice of some system design factors.

Guidelines have been provided in the report for the feedback of data use techniques to the data requirements. Somewhat greater detail is provided in an illustrative example where a particular data user—the Public Weather Service—is discussed. There is a potentially large number of data users each of whose needs and modes of operation should be investigated in detail, in order to derive maximum benefits from the NDBS and to ensure that the output of the data use techniques have the most favorable possible performance cost characteristics. This problem is broader than (not not independent of) NDBS design.
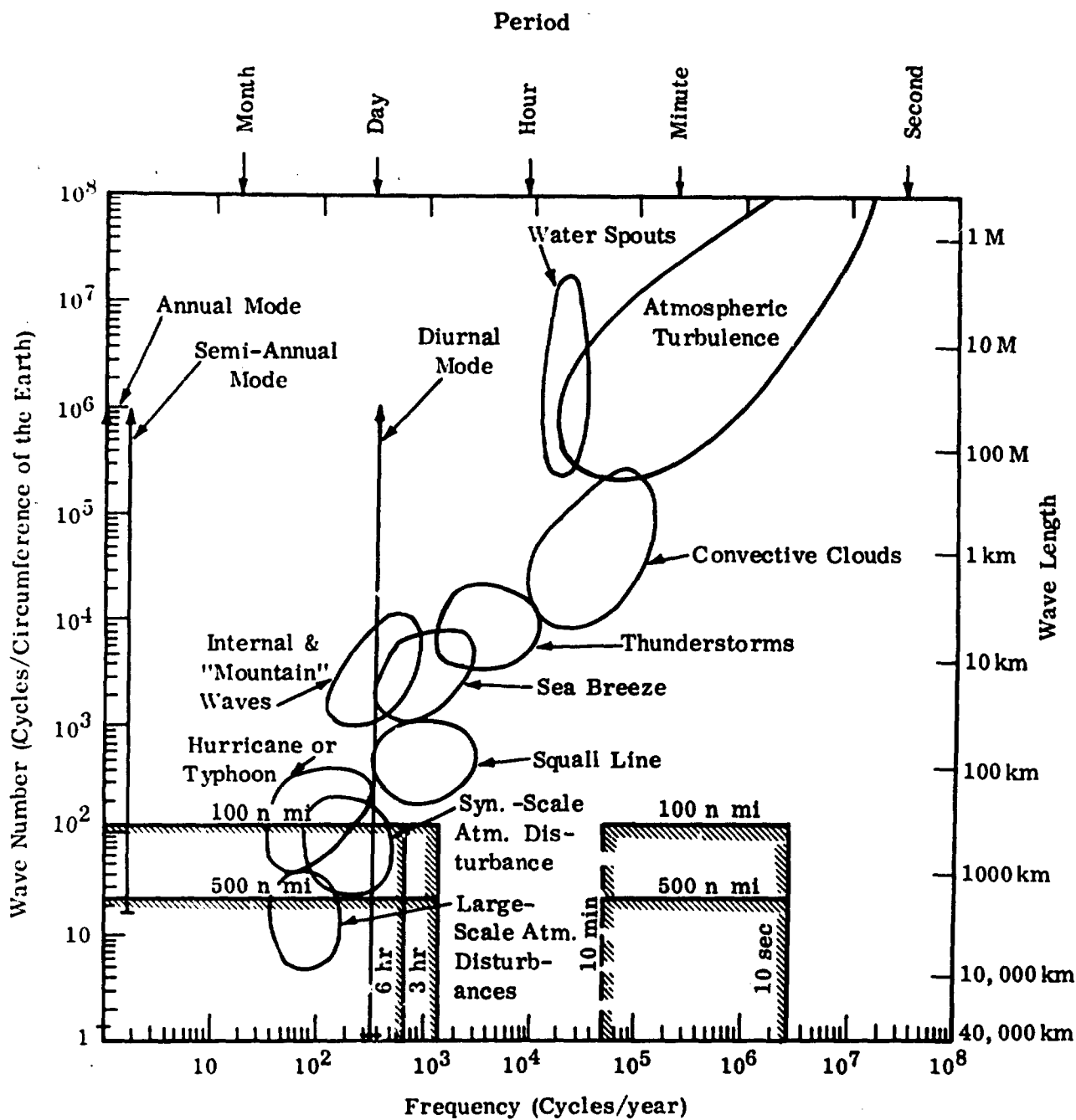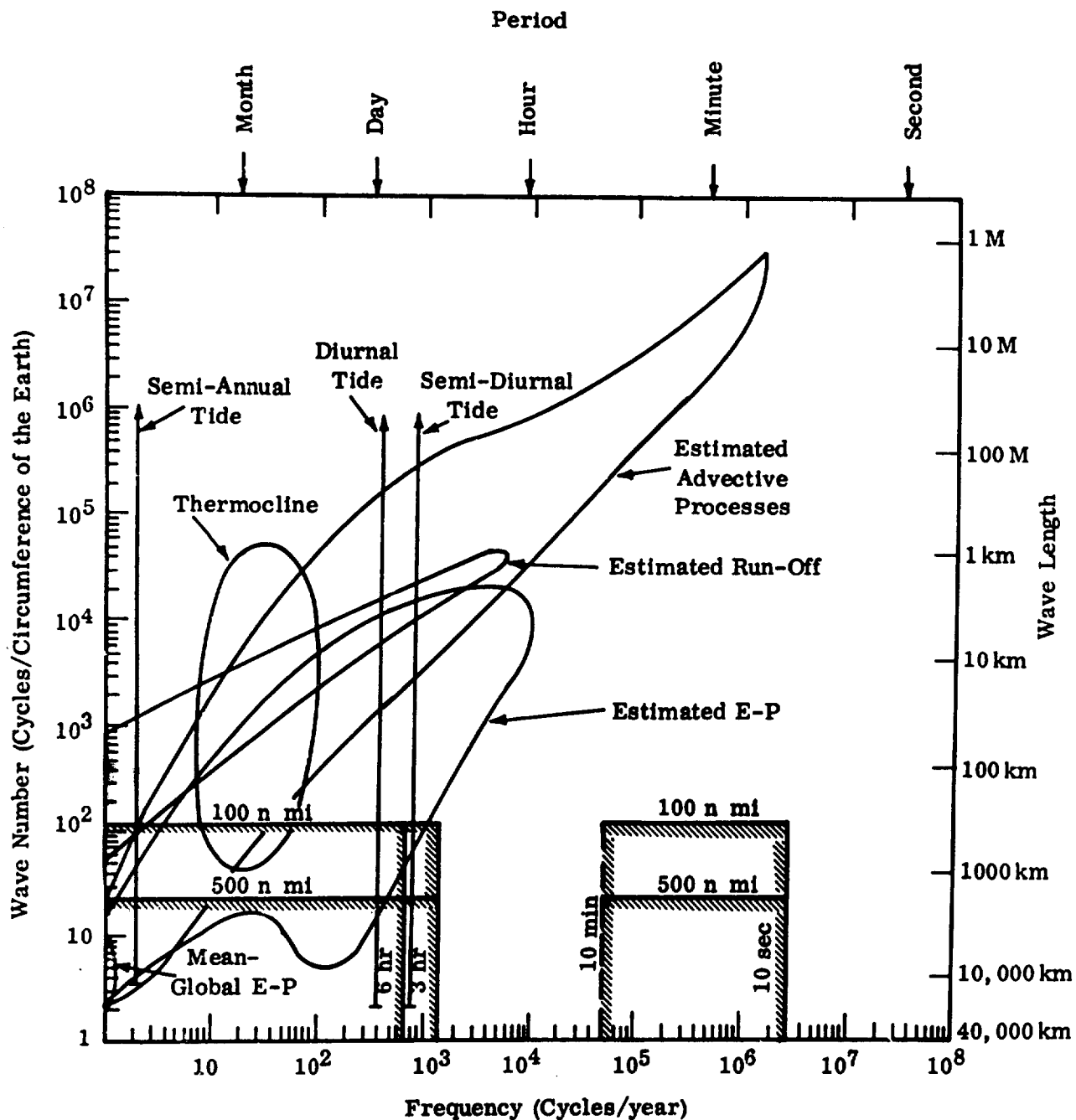
Fig. 3-2. Major atmospheric phenomena.

Fig. 3-3. Phenomena and processes affecting the variability of salinity.

The following are recommendations for further study and experimentation:

(1) It is recommended that the DPO sponsor a continuing study of the interface between the needs of data users and the design and operation of the NDBS. This study should establish priorities for parameters to be measured and the design requirements of the system.

(2) The DPO should support the early deployment of single buoys and small networks to obtain more information about natural variability. Requirements and priorities should be defined by a scientific organization that will also be responsible for analysis of the data, thus assuring continuity throughout the entire scope of the investigation.

(3) Similar experimental programs should be conducted in both natural and laboratory test environments to determine the performance and effectiveness of various hardware combinations being considered for use in the NDBS.

(4) The present study should be extended to examine the effects of instrument sensitivity on system design. This study should also consider the data quality requirements of NDBS users.

(5) The present study should be extended to examine the system design requirements in the vertical dimension. Such a study can only be effective in conjunction with additional studies of natural variability.

(6) A survey of available information in terms of specific regional and seasonal segments of the marine environment should be compiled into an easily used form, such as a handbook.

4.0 COST EFFECTIVENESS SENSITIVITY OF NATIONAL DATA BUOY SYSTEMS

The National Data Buoy Systems being planned by the U.S. Coast Guard will be a part of a larger future national marine data acquisition system. NDBS planning and development must be cognizant of the fact that a national marine data acquisition system doubtless will include a mix of observation platforms to meet the many user data requirements. The characteristics of non-buoy systems to be included in a future marine data acquistion system will probably provide a planned overlap in data acquisition capabilities. NDBS design should maximize the non-redundant NDBS data acquisition capability with regard to the total capability required for the national marine data acquisition system. The sensitivity analysis was carried out to assess the potential role of the NDBS in the national marine data acquisition system of the future and to determine the sensitivity of the NDBS design to complementary and competitive characteristics of other data collection platforms that may be part of the national marine data acquisition system.

For this study a cost effectiveness model was designed to evaluate alternative mixes of buoy and non-buoy platforms against certain categories of stated user requirements. The user requirements were categorized by type (research or operational), by geographical regions such as the Deep Ocean areas, Coastal North America regions, and Great Lakes and U.S. estuarine regions,and by vertical layers in the ocean and atmosphere. The analysis was performed using the Deep Ocean and Coastal North America operational requirements as the basis for evaluation of alternative system mixes of platform types. Parameters required by the users surveyed in the 1968 refinement of data requirements carried out by TRC in parallel with this study were selected by the DPO for inclusion in the cost-effectiveness evaluation (see page 5).

Factors used in the effectiveness model include system capability, reliability, survivability and areal coverage as a function of number of observation platform units employed. Capability is determined as the fraction of the user requirements that can be met at a given location using a given platform type. Reliability is defined as the probability of performance of an intended function for a specified time under specified environmental conditions. Survivability is defined as the probability that a platform type will continue to exist in maintainable or repairable form for a specified time period under specified environmental conditions. Based on results from the 1967

feasibility study, it was decided that in this study all platform types would be assumed to have a survivability of 1.0. Areal coverage relates the number of platform units employed to the ability to acquire data over the entire geographical area of interest for the temporal intensity and spatial intensity (number of observation locations) required. Effectiveness is given by the product of these four terms.

Cost information was gathered for initial investment required and yearly operating costs including replacements and support activities for each of the platform types considered.

The eight platforms considered for the future national marine data acquisition system were:

- Aircraft of opportunity
- Buoys
- Horizontal sounding balloons
- Manned buoys

- Oceanographic vessels
- Reconnaissance aircraft
- Satellites
- Ships of opportunity

A limited number of systems comprising alternative mixes of platforms were evaluated using the Deep Ocean and Coastal North America operational requirements. These regional requirements were stratified into six layers in the vertical to permit evaluation of the mixes in each of the layers, as well as an overall evaluation.

The evaluation showed that a system comprised solely of unmanned buoys was the most cost effective system for meeting either DO or CNA requirements. However, the unmanned buoy system was relatively ineffective in meeting the data requirements for the atmosphere above the surface interface layer, because the unmanned buoys were assumed to have no upper air sounding capability* Systems of buoys mixed alternatively with satellites, horizontal sounding balloons, ships of opportunity, and manned buoys were evaluated to examine the cost effectiveness of these pairings of systems; in all cases, buoy performance in meeting both atmospheric and oceanographic

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*Rockets, capable of carrying parachute-supported radiosondes, were fired automatically from a buoy in 1968, thus demonstrating the feasibility of this concept.

data requirements was found to be high, as shown in Figs. 4-1 and 4-2. Several alternative assumptions that influence the effectiveness of systems other than unmanned buoys (e.g., changing the areal coverage term) were considered in order to determine the boundaries of resultant system mix cost and effectiveness. Figure 4-3 shows a bounded region in which is found the ratio of cost and effectiveness for various mixes of unmanned buoys and manned buoys in the Coastal North America region and alternative assumptions for the number of upper air measurement locations.

Some of the conclusions reached from the analysis were:

(1) A system comprised solely of unmanned buoys is potentially capable of providing a high percentage of the stated marine atmospheric and oceanographic data requirements of several major government agencies in both the Deep Ocean and Coastal North America regions.

(2) The cost of providing the marine data is relatively low for a system of unmanned buoys when compared with any system comprising other platform types. Buoys are the most cost-effective platform types when all parameters and all layers are jointly considered using the assumptions outlined in this report.

(3) An unmanned buoy system is ineffective in providing data for the atmosphere above the atmosphere-ocean interface layer, unless upper air sounding capabilities not considered in this report are provided.

(4) Several other platform types can be used with unmanned buoys as complementary systems to provide observational data for the atmosphere with essentially no redundancy between the buoy system and the non-buoy system employed.

(5) Any non-buoy platform that provides a capability for measuring atmospheric parameters above the ocean-atmosphere interface, when combined with buoys, will improve the overall system effectiveness, but those non-buoy platforms investigated will be relatively expensive and will, therefore, cause an increase in the combined system cost effectiveness ratio.

(6) The design of a buoy system as a part of a national marine data acquisition system is sensitive only to a relatively minor degree to the existence of other platform types.

The summary recommendation made as a result of this study is that planning for a National Data Buoy System should be carried forward considering the NDBS to be a major component of any future national marine data acquistion system.

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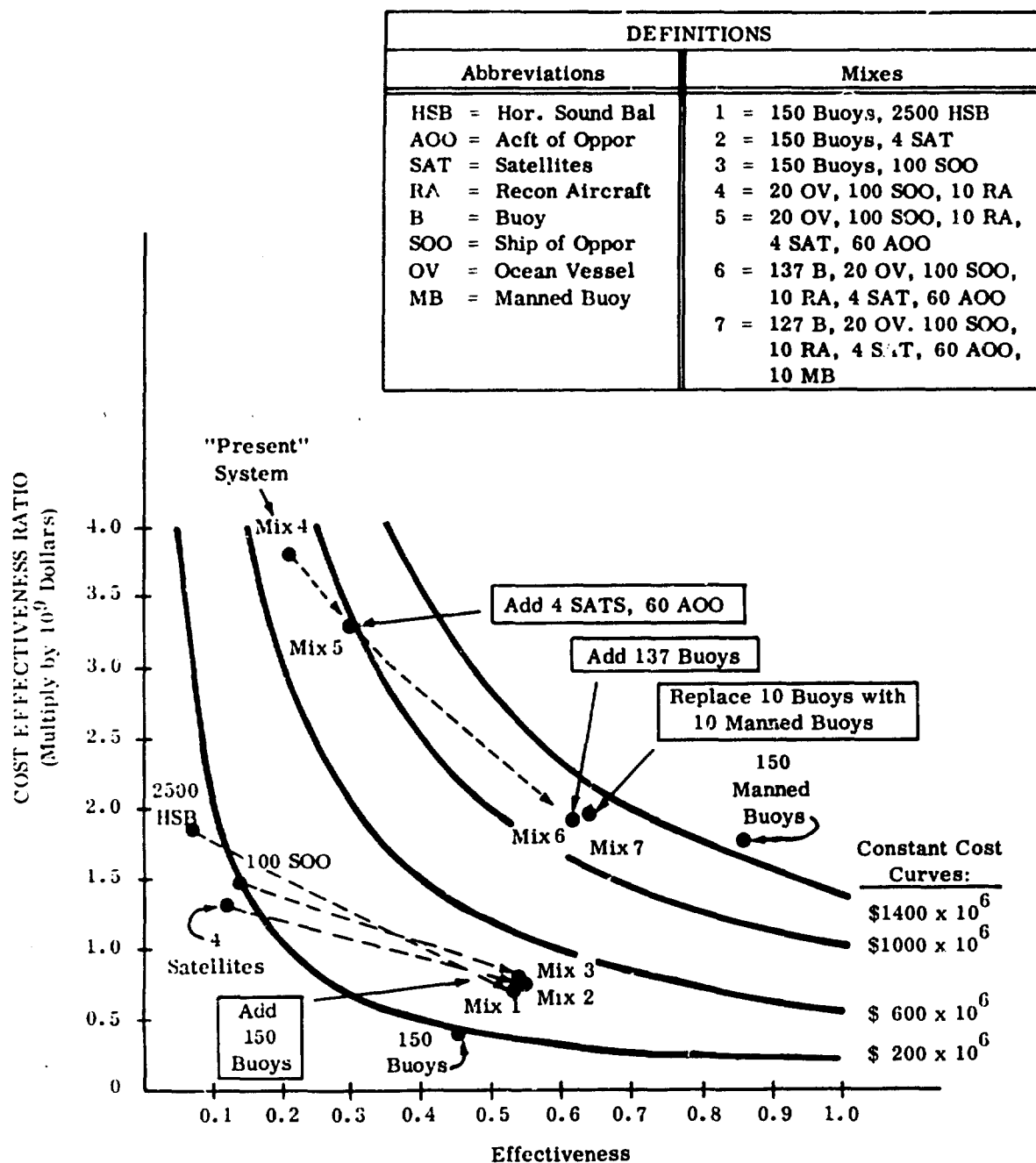| DEFINITIONS	
Abbreviations	**Mixes**

HSB = Hor. Sound Bal
AOO = Acft of Oppor
SAT = Satellites
RA = Recon Aircraft
B = Buoy
SOO = Ship of Oppor
OV = Ocean Vessel
MB = Manned Buoy
	1 = 150 Buoys, 2500 HSB
	2 = 150 Buoys, 4 SAT
	3 = 150 Buoys, 100 SOO
	4 = 20 OV, 100 SOO, 10 RA
	5 = 20 OV, 100 SOO, 10 RA,
	    4 SAT, 60 AOO
	6 = 137 B, 20 OV, 100 SOO,
	    10 RA, 4 SAT, 60 AOO
	7 = 127 B, 20 OV. 100 SOO,
	    10 RA, 4 S:T, 60 AOO,
	    10 MB

Fig. 4-1. Comparison of cost effectiveness ratios for platforms and platform mixes in the Deep Ocean area.
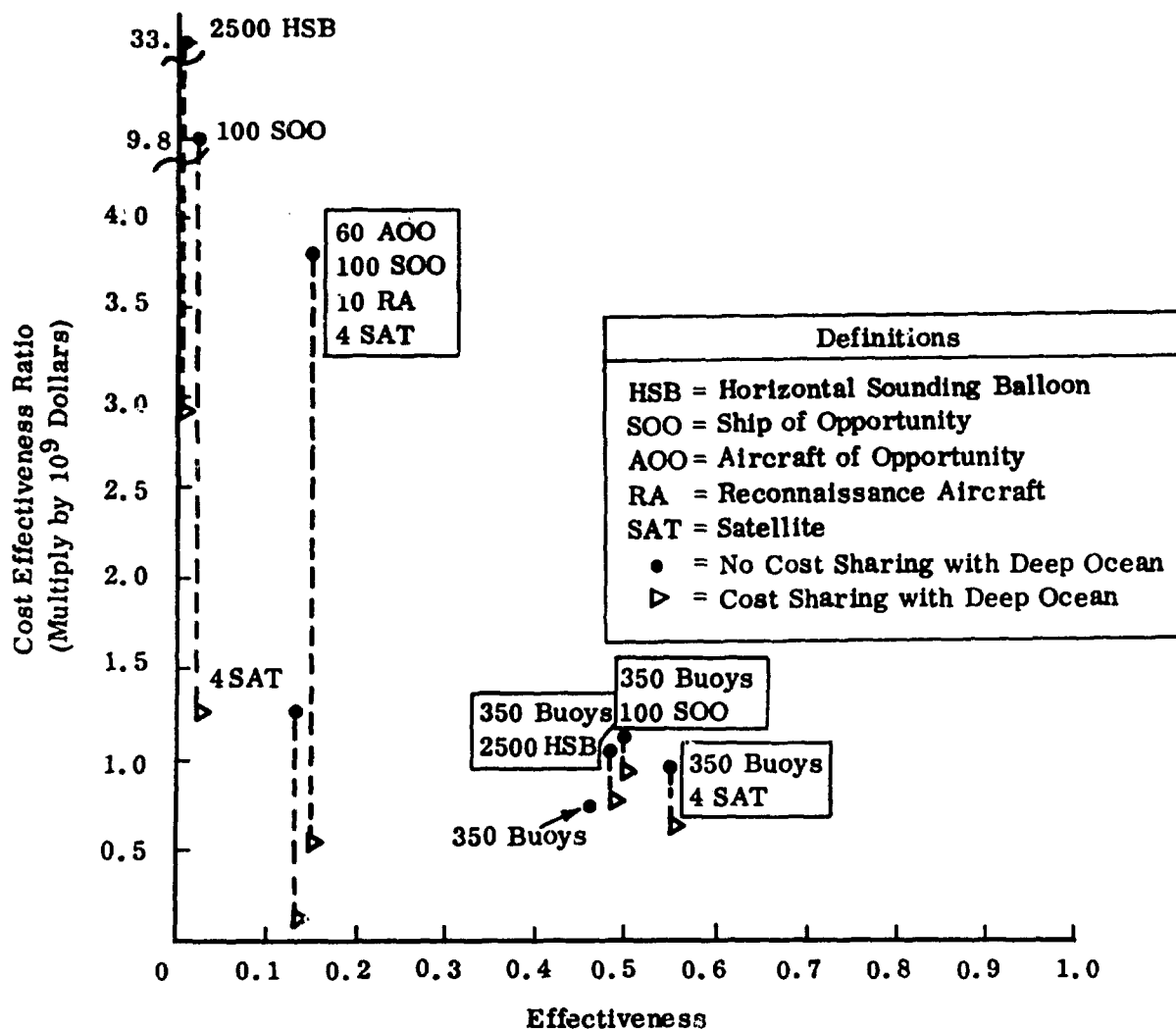
Fig. 4-2. Variations in cost effectiveness ratios for platform mixes in the Coastal North America area due to cost sharing.

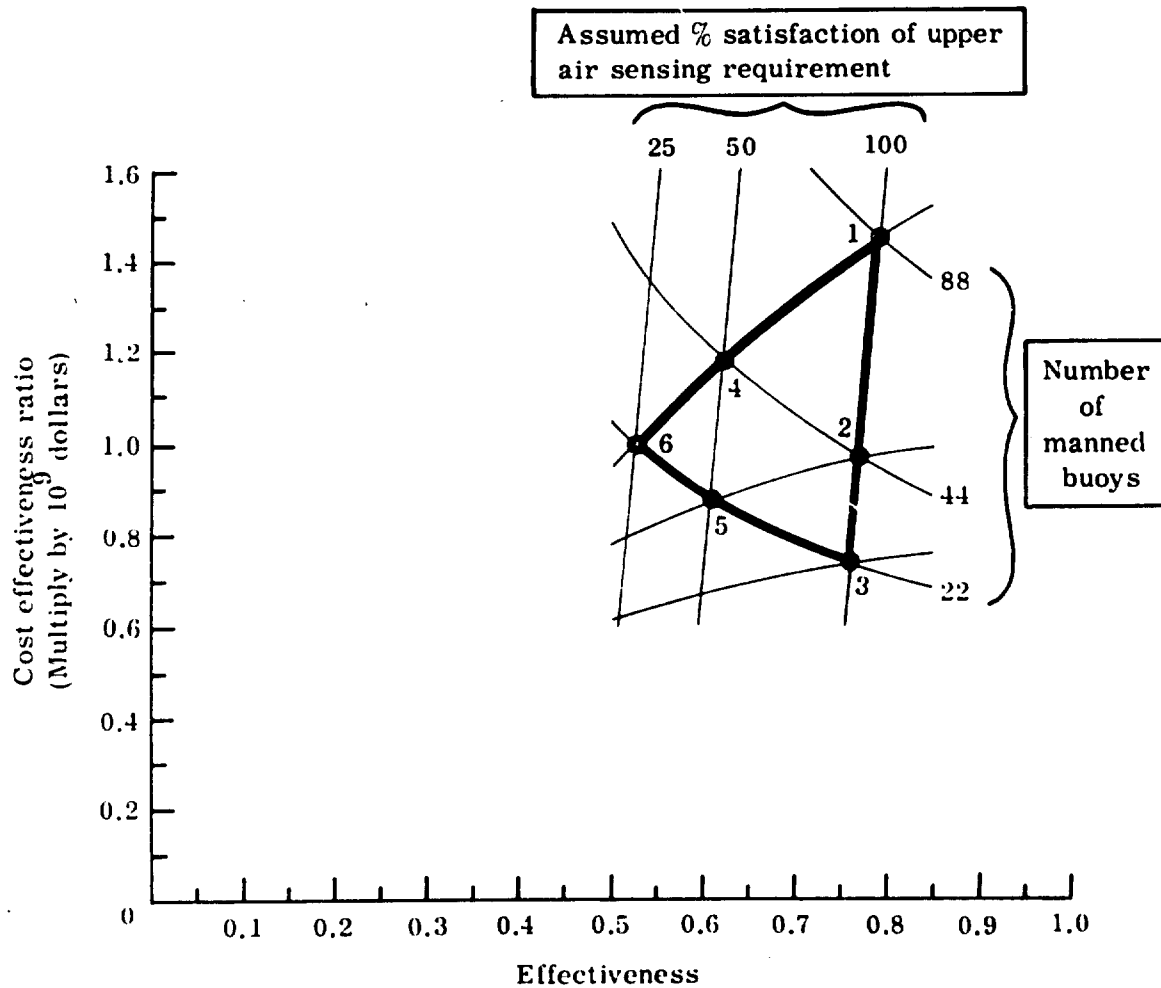| Definitions | | | | M. buoy grid spacing (n mi) | Cost ($ M) |
| Data point | Assumed % atmos. cover. | System mix | | | |
		M. buoys	Buoys		
1	100	88	262	200	1142
2	100	44	308	280	746
3	100	22	328	400	548
4	50	44	308	280	746
5	50	22	328	400	548
6	25	22	328	400	548

Fig. 4-3. Variations in cost effectiveness ratios of buoy - manned buoy mixes in the Coastal North America area with respect to variable atmospheric grid requirements.

5.0 COMPUTER PROGRAMS FOR NATIONAL DATA BUOY SYSTEMS SIMULATION AND COST MODELS

Part of the 1968 TRC contractual effort for the USCG was directed to developing and automating a selected set of simulation and cost models, some of which were investigated manually during the 1967 feasibility study. The models can be used to determine the deployment, maintenance, and replacement cost characteristics of alternative data buoy system configurations. A corollary objective under the task was the preparation of an automated data base file, using buoy components data collected during the 1967 feasibility study. In addition, a computer funding schedule model was developed to assist in analyses related to structuring a NDBS Technical Development Plan.

The TRC report covering the NDBS computer programs has been divided into three sections, each presenting a different level of detail for three categories of readers. The section titled, "General Descriptions of NDBS Data Buoy Systems Automated Models and Data," provides a comprehensive view of the computer programs and data files developed by TRC. The section primarily provides a management overview by presenting computer program objectives and capabilities and data file descriptions with a minimum of detail. Descriptions are given for computer programs for the

(1) Integrated Buoy Deployment Simulation and Cost Model,

(2) Procurement Maintenance and Replacements Cost Model,

(3) Ten-Year TDP Financial Plan Model,

(4) Buoy Component Characteristics Data File, and

(5) Fleet Numerical Weather Central Depth Data File.

A section title, "Computer Programs Operating Instructions," outlines the procedures for preparing input data card decks and operating the above computer programs.

There is also a section called, "Maintenance Programmer's Manual" for use by the experienced FORTRAN programmer who may be called upon to modify or improve these programs for other projects.

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6.0 AN ANALYSIS OF CRUISE STRATEGIES AND COSTS FOR DEPLOYMENT OF NATIONAL DATA BUOY SYSTEMS

A large fraction of the annual operating cost of a data buoy system consists of the cost of deploying the buoys and traveling to and from the buoys to provide maintenance. The details of carrying out this operation are at the core of a series of highly interrelated and important questions such as, "How many buoys should a buoy-tending ship be designed to carry? What is the optimum average cruise speed? How many deployment/maintenance ports should be used? What number of days in port should follow each cruise?" Answers to all of these questions and others of similar nature are needed to provide a firm basis for U.S. Coast Guard NDBS development planning. The analyses performed for this study include investigations of each of the questions noted and many more. The results of the investigations are presented as functions of many different parameters, including number of buoys in the system, ship buoy-carrying capacity, ship average speed, number of deployment ports, number of days in port per cruise, time-to-plant each buoy, ship operating base cost per sea day, ship maintenance cost per day, fuel cost per n mi, and others.

In this study, all system investigations have been carried out in the following manner. First, analyses were performed for each of nine non-overlapping geographical regions called Modular Deployment Zones (MDZs) covering the oceans of the northern hemisphere. Second, certain MDZ results were combined for six MDZs collectively referred to as the Coastal North America (CNA) region covering the waters from the North American coast to 400 n mi off-shore. Third, the results for the remaining three MDZs were combined for a region (outside CNA) collectively known as the northern hemisphere Deep Ocean (DO) region. Finally, results from all nine MDZs have been combined to give averages for each of the seven specific data buoy systems considered, ranging in size from the 500-buoy baseline system down to a 60-buoy system.

To make this multi-dimensional study possible, TRC developed and programmed for the computer a buoy deployment/maintenance simulation and cost model. The model accepts as inputs the geographical locations of data buoys and ports, costs, ranges of parameters to be investigated, ocean depth for each buoy location, and sequential schedules for deployment or maintenance of buoys. The simulation model computes

the distance traveled for each cruise using the great circle distance between points; it then generates cruise time as a function of speed and time-to-plant each buoy under both ideal conditions (safety factor of 1.0) and under the assumption that a safety factor such as 4/3 is needed to make allowance for bad weather and other uncertainties. In addition to computing distance, time, and costs associated with deployment/maintenance cruises, the model also accepts buoy hardware costs—both fixed and depth dependent, such as mooring line cost—and computes the individual and cumulative costs of all buoys deployed. Average values are calculated for distance traveled per buoy planted, ship operating cost per buoy planted, mooring depth per buoy, hardware cost per buoy, deployment time per buoy, buoys deployed per ship-year, etc.

The TRC buoy deployment/maintenance model has been structured to facilitate modifications and additions. In its present state the model is applicable to a comparable study of air-droppable data buoy systems, or for a study of the use of aircraft or ships-of-opportunity to obtain marine data, etc.

The results of studies such as this are recognized to be only as good as

- The model programmed.
- The ranges and values of parameters used, and
- Values of system constants used.

The basic structures of the time-to-deploy and cost-to-deploy models are simple and straightforward and are believed to be acceptably close to real-world conditions. Best strategies for deployment cruise scheduling is a relatively complex question for which there is no exact general solution, although for any given set of port and buoy locations, there is always one set of deployment cruise schedules that is at least as good or better than any other set out of the total of all possible schedules. Because the variables in this problem include (1) ship buoy-carrying capacity, (2) number and locations of buoys in a given geographical region, and (3) port locations, it was elected not to attempt to optimize deployment cruise schedules, but to use schedule strategies that could at least be shown explicitly in specific instances to be better than other strategies that appear intuitively to be as good or better. Several such scheduling strategies have been investigated (an illustration is given in Fig. 6-1) and those shown to be best were used where applicable in this study. Thus, although the deployments

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a) Cruise schedule for deployment by 4-buoy ship
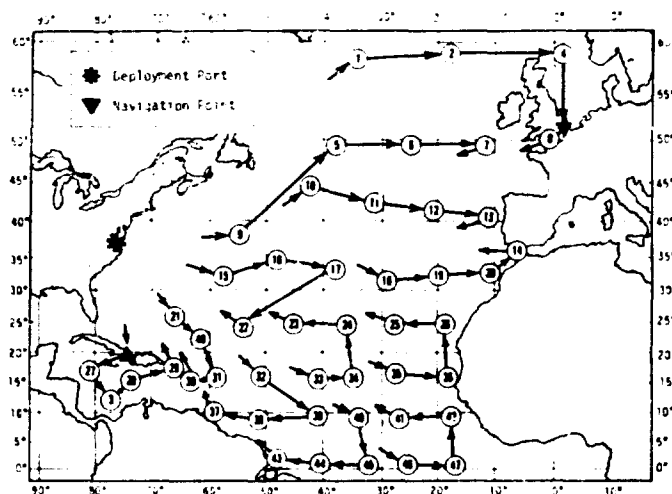
b) Cruise schedule for deployment by 8-buoy ship
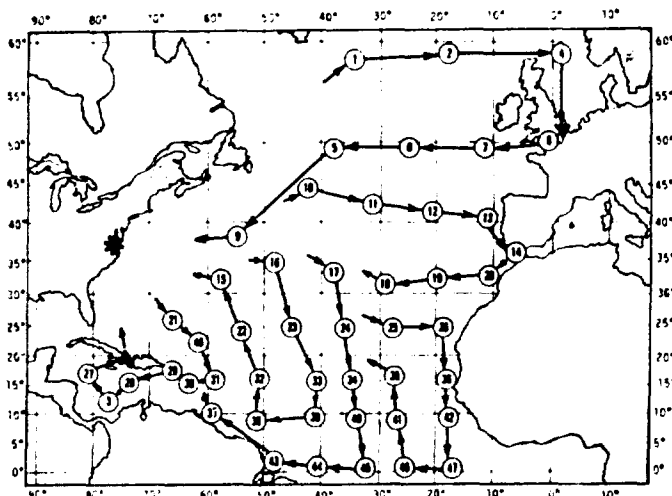
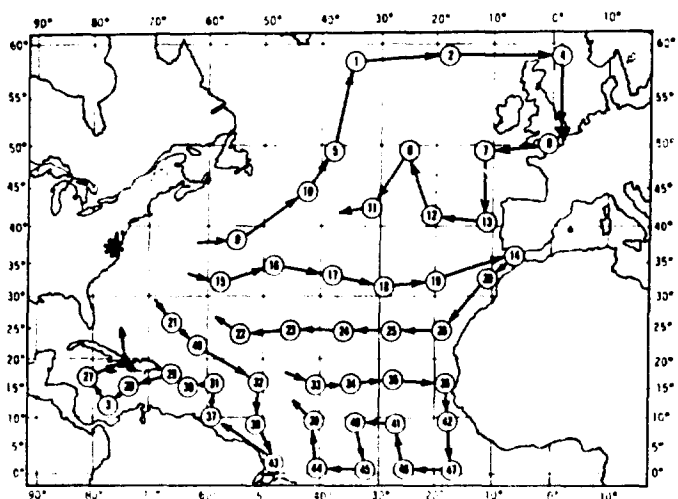c) Cruise schedule for deployment by 12-buoy ship

Fig. 6-1. Deployment cruises for the North Atlantic 500-buoy baseline system.

cruise schedules used herein are not suggested as optimum, it is considered that the schedules are probably very close to optimum. The ranges and values of parameters used in this study were specified by the DPO. Most of the study results summarized below are greatly dependent on the accuracy of the parameter values and are confined to the parameter ranges specified by the NDBS DPO.

One of the most significant results to emerge from this study applies to the buoy deployment/maintenance ship. For the cost values supplied and the range of parameters investigated, the 12-buoy, 18 kt ship was clearly superior, based on average ship operating cost per buoy planted; an example of a typical average cost characteristic is shown in Fig. 6-2. This conclusion has been shown to be independent of selected variations in ship operating base cost per sea-day, time-to-plant each buoy, number of deployment ports, relative proximity of buoy networks to deployment port, and incorporation of prorated ship construction costs. The alternative on either side of the 12-buoy, 18 kt ship (costing $16.4 million) are the 8-buoy, 15 kt ship (costing $11.6 million) and the 12-buoy, 21 kt ship (costing $20.8 million). Choice of the 12-buoy, 18 kt ship shows typical savings in average ship operating cost per buoy planted to be of the order of 15—17% when compared with the 8-buoy, 15 kt ship, and of the order of 6—10% when compared with the 12-buoy, 21 kt ship. Comparison with the other ships considered* shows even higher savings. As noted earlier, the validity of this result depends strongly on the accuracy of the cost factors provided by the DPO.

Another salient result from the same phase of the study that indicated best ship characteristics was the range of values that appeared to apply for an important planning factor: average ship operating cost per buoy planted. For the 12-buoy, 18 kt ship and a number of other "mid-range" parameter values,† the average ship operating cost per buoy planted is about $16,000 for CNA buoys and $26,000 for DO buoys, with between $18,000 and $19,000 representing the average over all buoys. These average cost values

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*The other ships were: 4-buoy, 15 kt at $7.9 million; 6-buoy, 18 kt at $10.7 million; 12-buoy, 24 kt at $25.6 million; 12-buoy, 27 kt at $31.5 million, and 12-buoy, 30 kt at $39 million.

† The results are for the basic ship operating cost per sea-day of $5000, time-to-plant each buoy of 24 hrs, 10 port days per cruise, a safety factor of 1.0 (i.e., ideal weather and other operating conditions), and deployment from 3 ports (Portsmouth, Virginia, San Francisco, and Honolulu).

Notes: 1. Time-to-Plant = 24 hr
       2. Base Cost/Sea Day = $5,000
       3. Safety Factor = 1.0
       4. Port Days/Cruise = 10
       5. Ship Speed = 15 or 18 kt

East Coast MDZ

49 Buoys

Ship Buoy-Carrying Capacity

Average Ship-Operating Cost Per Buoy Planted ($K)

North Atlantic MDZ

48 Buoys

Ship Buoy-Carrying Capacity
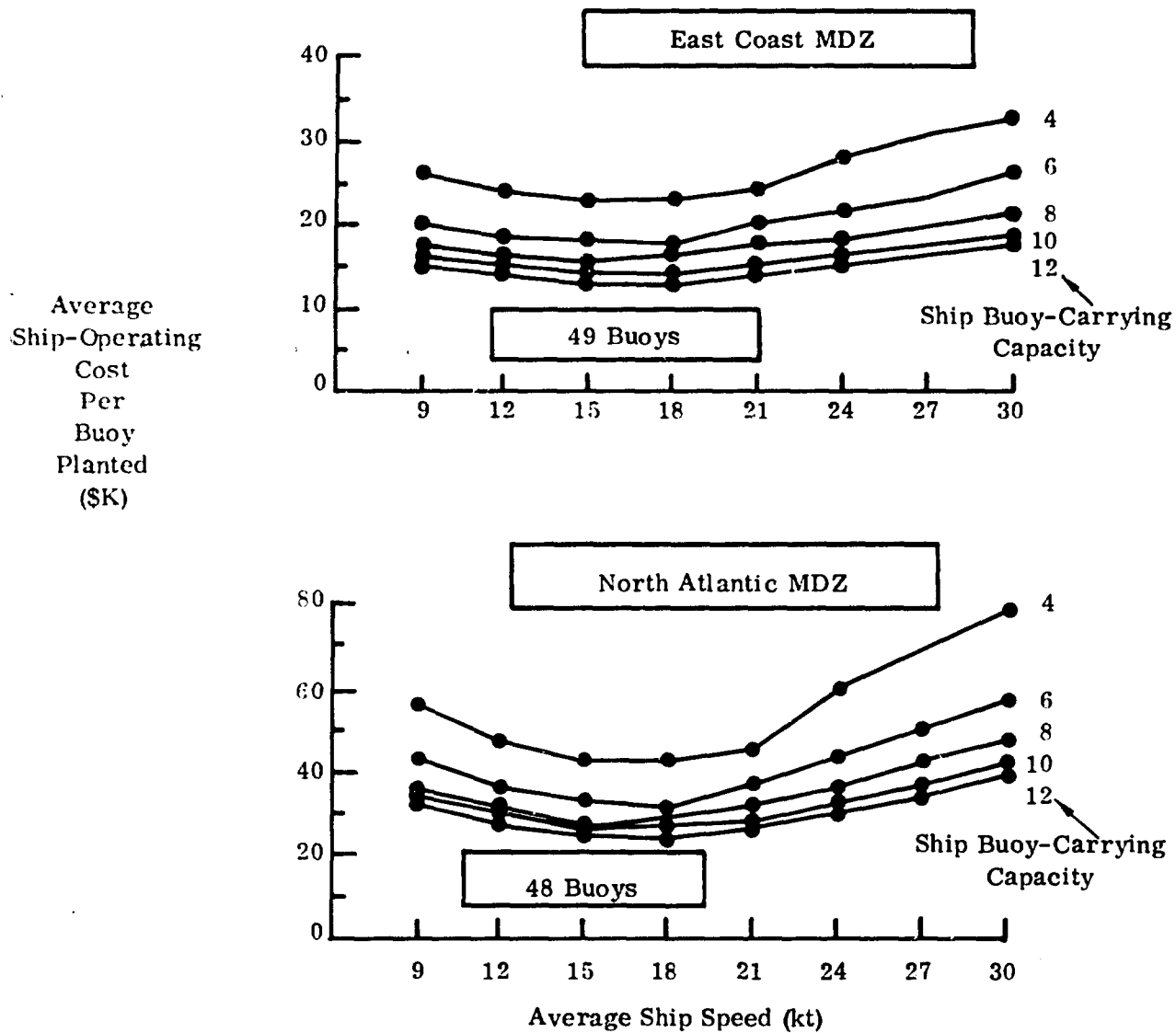
Average Ship Speed (kt)

Fig. 6-2. Typical average ship operating costs curves.

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are essentially independent of number of buoys in the system for the seven buoy systems considered, as seen in Fig. 6-3. (In Fig. 6-3, the "50%" system comprises 250 buoys and the "25%" system comprises 125 buoys, but the buoy locations are not the same as those in the "250" and "125" buoy systems.)

This important system development planning factor—average-ship-operating-cost-per-buoy-planted—is sensitive to variation in base ship operating cost per sea-day. For the 12-buoy, 18 kt ship (and the other conditions noted earlier), the average ship operating cost per buoy planted varies approximately $3.00 in proportion to every $1.00 change in base ship operating cost per sea-day. The variation is higher for other ship configurations.

There is also sensitivity of the average ship operating cost planning factor to variation in time-to-plant each buoy. For the 12-buoy, 18 kt vessel (and the other conditions noted earlier), the sensitivity is of the order of $230 saved per buoy planted for each hour reduction in time-to-plant.

Average ship operating cost per buoy planted is sensitive to the number of scheduled days in port per cruise, so factors of 5 port days and 20 port days were also investigated for both 3-port and 8-port deployment configurations. For the 12-buoy, 18 kt ship and 3-port deployment, use of 5 port days, in place of 10 port days, reduces average ship operating cost per buoy planted by 12%: using 20 port days per cruise increases the average cost per buoy planted by 25%. For the 8-port deployment, comparable changes are 13.6% reduction and 27% increase, respectively. Added costs such as those commensurate with a two-crew concept ("Blue" crew and "White" crew) needed to sustain the 5 port day condition have not been taken into account.

Use of 8 deployment ports, rather than 3 ports, indicates for the 12-buoy, 18 kt ship (and the other conditions noted earlier) the possibility of a 6% reduction in average ship operating cost per buoy planted in the CNA region, and 7% reduction in the DO region, and a reduction of slightly more than 6% for both regions combined. In selected MDZs the saving could run as high as 16%. None of these comments takes into account the additional expense of construction or maintenance at the additional 5 ports. In an overall sense, these additional costs would reduce the degree of saving noted.

Overall ship operating cost was computed for deployment of each of the seven data buoy systems considered. When using the 12-buoy, 18 kt ship (and the other considerations
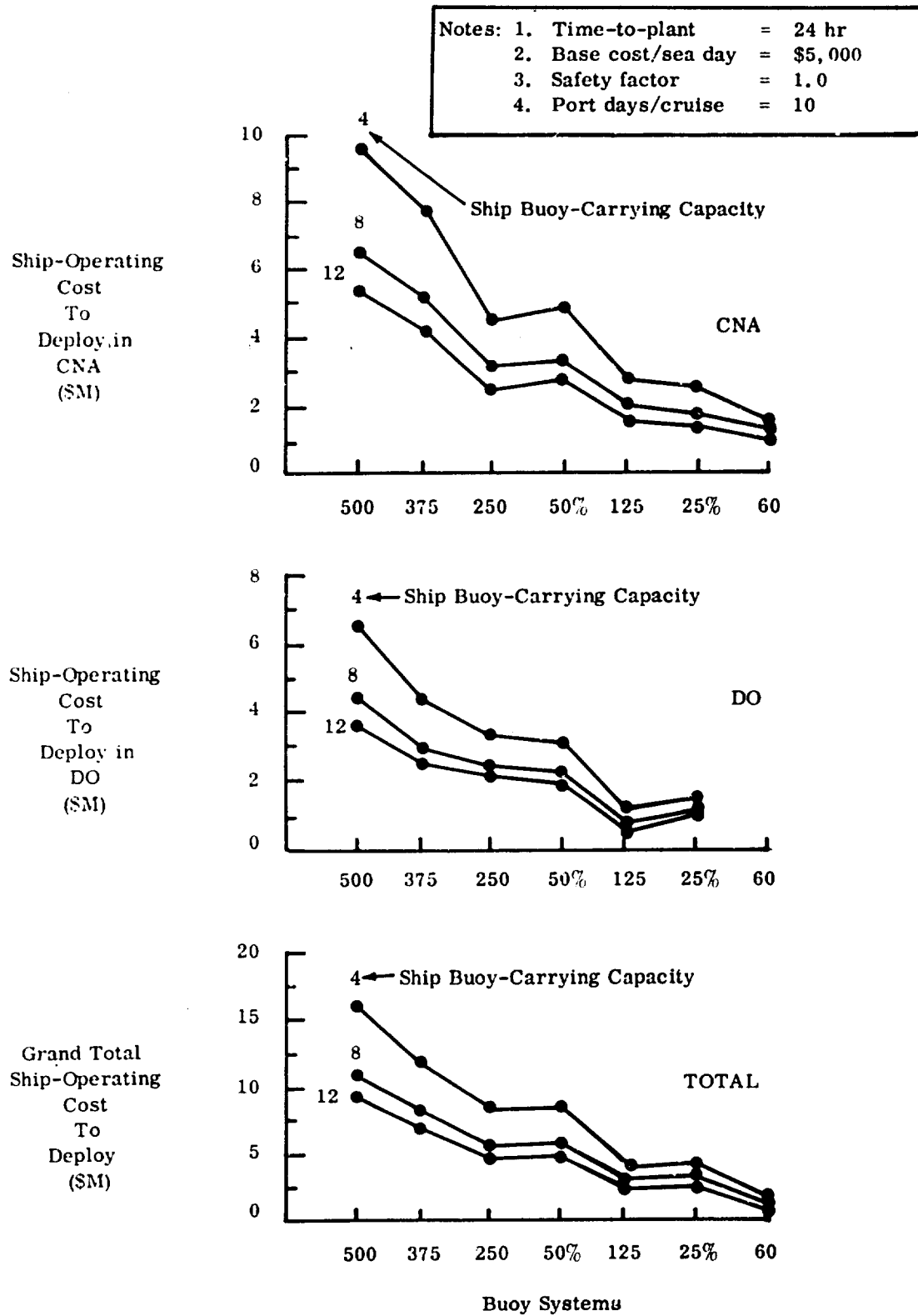
32

Fig. 6-3. Total ship operating cost for all systems.

noted earlier) total deployment cost ranges from $9.121 million for the 500-buoy baseline system to $0.944 million for the 60-buoy system. For systems of more than 125 buoys, CNA deployment cost represents about 60% of the total deployment cost, although the number of CNA buoys represents about 70% of the total. The DO buoys are farther apart and at greater distances from deployment ports and, therefore, cost more to deploy than CNA buoys. These total deployment costs are for ideal conditions (safety factor of 1.0).

Buoy hardware costs (considered to be conservatively high) for a data buoy comparable to the ONR 40-ft discus were used to illustrate the cost capabilities of the TRC buoy deployment/maintenance simulation and cost model. It was determined that the cost of hardware deployed in the 500-buoy system would be about $146 million and nearly 5 million ft of mooring line would be required, assuming one-point moo ing at a scope of 1.0. Under the assumption that oceanographic sensor packages would be mooring-mounted at up to 20 IAPSO levels through 5000 m depth, 8,386 packages would be required—an average of 16.8 sensor packages per buoy. Using hardware costs provided by the NDBS DPO, these sensor packages represent 40% of the total buoy hardware cost, and the mooring represents 6% of the cost. The buoy hull cost would be only 27% of the total. The buoy hardware costs cited in the report are not intended for use in financial planning.

Another useful planning factor that emerged from this investigation is the average maximum number of buoys deployed per ship-year.* For the 12-buoy, 18 kt ship and 3-port deployment (and the other conditions noted earlier), this planning factor for average maximum numbers of buoys planted per ship-year is 137 CNA buoys, or 90 DO buoys, or 120 buoys for the combined regions. If 8-port deployment is used, the planning factors are 141 CNA buoys, 96 DO buoys, or 125 combined DO and CNA buoys planted per ship-year. These factors apply for a safety factor of 1.0 (ideal conditions) and probably should be degraded by 10% to 30% to account for bad weather and other operational uncertainties.

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*There were assumed to be 335 ship-days per ship-year, leaving 60 days for over-haul every 2 years.

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One of the minor goals of this study was to consider briefly system relative effectiveness of the seven buoy system configurations. (The seven buoy systems varied both in numbers and locations of buoys). Some system relative effectiveness values have been obtained, but it is stressed that this was done more to illustrate some of the facets of a more comprehensive study of system relative effectiveness that should be undertaken. Such a study would concentrate on relating numbers and locations of buoys to the potential economic, research, social, and military benefits that might derive from the use of the collected data and/or data products (forecasts, etc.). The minor effort undertaken for this report indicates that marginal system relative effectiveness per buoy added would be greatest for the small 60-buoy system and would decrease almost linearly as the number of data buoys in the system increases. Beyond the 375-buoy point (nearly 95% system relative effectiveness) the marginal increase for each added buoy is quite small. In part, this conclusion is due to the <u>assumption</u> that the 500-buoy baseline system is 100% effective. The brief attention devoted to this subject suggests that system relative effectiveness is greatly enhanced by allowing the system designer considerable freedom to select buoy locations that are closely related to satisfying data requirements that have high benefits. An alternative to this policy—building up the number of deployed buoys with uniform emphasis in all Modular Deployment Zones—is shown to be much less effective, in general.

As noted at the outset of this section, the primary goal of this effort has been the provision of analyses and results to aid the development planning for National Data Buoy Systems. It is recognized that this study is not completely definitive in many of the subject areas addressed, but it is considered that the results, properly interpreted in their application, will suffice as an initial foundation for planning at this stage of development of National Data Buoy Systems. As buoy and port locations, costs, and other factors become more firmly established, the buoy deployment/maintenance simulation and cost model can be used to refine or develop as needed planning factors such as those presented in the report. An interest shifts from deployment of buoys to cyclic maintenance, the computer model can still be used. Addition of other features to the model, such as weather conditions and some decision rules relating weather and operations, can and should be undertaken. In this vein, then, this study offers an initial foundation for certain facets of NDBS development planning, and an invitation to use these results as a point of departure for further study efforts.

7.0 PUBLICATIONS FOR NDBS DEVELOPMENT PLANNING SUPPORT

Listed below are the five reports documenting the 1968 TRC studies in support of USCG NDBS DPO development planning efforts.

1. Clem, L. H., and G. M. Northrop, 1968: Applicability of National Data Buoy Systems to Refined National Requirements for Marine Meteorological and Oceanographic Data. TRC Report 7493-332. The Travelers Research Center, Inc., Hartford, Conn. USCG Contract DOT-CG-82504-A.

2. Jacobs, C. A., J. P. Pandolfo, and E. J. Aubert, 1968: Characteristics of National Data Buoy Systems: Their Impact on Data Use and Measurement of Natural Phenomena. TRC Report 7493-334. The Travelers Research Center, Inc., Hartford, Conn. USCG Contract DOT-CG-82504-A.

3. Jenkins, C. G., A. Thomasell, D. B. Spiegler, and G. M. Northrop, 1968: Cost Effectiveness Sensitivity of National Data Buoy Systems: An Essay. TRC Report 7493-33C. The Travelers Research Center, Inc., Hartford, Conn. USCG Contract DOT-CG-82504-A.

4. Davis, E. L., B. J. Erickson, and E. R. Sweeton, 1968: Computer Programs for National Data Buoy Systems Simulation and Cost Models. TRC Report 7493-333. The Travelers Research Center, Inc., Hartford, Conn. USCG Contract DOT-CG-82504-A.

5. Northrop, G. M., 1968: An Analysis of Cruise Strategies and Costs for Deployment of National Data Buoy Systems. TRC Report 7493-337. The Travelers Research Center, Inc., Hartford, Conn. USCG Contract DOT-CG-82504-A.

8.0 REFERENCES:

1. Aubert, E. J., L. H. Clem, C. F. Jenkins, and G. M. Northrop, 1968: A Summary of the Study of the Feasibility of National Data Buoy Systems. TRC Report 7485-286, USCG Contract TCG-16790-A (AD665 314), The Travelers Research Center, Inc., Hartford. Conn.

2. —. 1967: National Requirements for Marine Meteorological and Oceanographic Data. TRC Report 7485-253, USCG Contract TCG-16790-A (AD 664 617), The Travelers Research Center. Inc., Hartford, Conn.

3. Walden, R. G. (AGA) and E. J. Aubert, 1967: Buoy and Buoy Components Data Compilation and Analysis. TRC Report 7485-256, USCG Contract TCG-16790-A (AD 664 618), The Travelers Research Center. Inc., Hartford, Conn.

4. Jenkins, C. F., E. J. Aubert, W. R. B, Caruth, L. H. Clem, and R. G. Walden (AGA). 1967: A Cost Effectiveness Evaluation of Buoy and Non-Buoy Systems to Meet the National Requirements for Marine Data. TRC Report 7485-274, USCG Contract TCG-16790-A (AD 664 619, The Travelers Research Center, Inc., Hartford, Conn.

5. Northrop, G. M., W. R. B. Caruth, E. L. Davis, L. J. Reed, and J. A. Russo, 1967: Cost-Benefits for a National Data Buoy System: An Essay. TRC Report 7485-280, USCG Contract TCG-16790-A (AD 664 620), The Travelers Research Center, Inc., Hartford. Conn.

6. Aubert, E. J., A. W. Bostick, L. H. Clem, and R. G. Walden (AGA), 1967: Technical Development Plans for the National Data Buoy System. TRC Report 7485-270, USCG Contract TCG-16790-A (AD 664 621), The Travelers Research Center, Inc., Hartford, Conn.

7. Preliminary Concept Formulation Summary for National Data Buoy Systems, 1968. U.S. Coast Guard National Data Buoy Systems Designated Project Office, USCG Headquarters, Washington, D. C.

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	UNITED STATES COAST GUARD

13. ABSTRACT

This summary report gives an overview of the 1968 activities and accomplishments of Contract DOT-CG-82504-A, for development planning studies in support of the USCG National Data Buoy Development Project (NDBDP).

The five reports summarized here are intended to provide background for undertaking contract definition, testing of off-the-shelf hardware, and other system development efforts. The specific areas of research summarized in this volume are:

(1) Determination of the applicability of NDBS to refined national requirements for marine meteorological and oceanographic data;
(2) Establishment of the characteristics of NDBS and their impact on the use of collected data and the observation of natural phenomena,
(3) Preparation of an essay on the cost effectiveness sensitivity of NDBS;
(4) Development of computer programs for National Data Buoy Systems simulation and cost models; and
(5) Analysis of deployment ship cruise strategies and costs for deployment of NDBS for various numbers of buoys and locations throughout the northern hemisphere.

The reader interested in even greater detail is referred to the reports themselves.