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MANAGEMENT PLAN FOR OCEAN ENVIRONMENTAL ACOUSTICS PROGRAMS IN S--ETC(U)
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MANAGEMENT PLAN
FOR
OCEAN ENVIRONMENTAL ACOUSTICS PROGRAMS
IN SUPPORT OF
MOBILE SONAR TECHNOLOGY DEVELOPMENT

by
C. D. SMITH and J. L. BARDIN

NAVAL SEA SYSTEMS COMMAND
DEPARTMENT OF THE NAVY
WASHINGTON, D.C. 20362

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FOREWORD

Maximum effectiveness in mobile sonar development and operation dictates the closest sort of relationship and interchange between environmental acousticians and systems developers. The complexity and diversity of both the environmental acoustics (EVA) programs and users make it difficult to develop EVA program objectives which assure full EVA contributions to the Fleet.

The EVA community is aware of this situation and has taken many steps to improve it. The management plan contained herein is the latest step in improving EVA support of mobile sonar and attempts to put the entire effort into perspective. The plan has already been partially applied. Further implementation is intended in a straightforward manner.

Comments and suggestions concerning this plan are invited.

C.D. Smith, Director
Sonar Technology Office,
06H1/036

APPROVED:

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ABSTRACT

The role of the U. S. Navy as a credible world sea power is placing increasing demands on sonar systems development for ASW. The management of the Navy's Ocean Environmental Acoustics Program (EVA) is of great concern because of the critical nature of this support service to systems development. At present, sonar developers and operators do not have sufficient EVA data and models available for optimum systems design and use. The deficiency is primarily due to a technological gap between EVA program outputs and the system developers requirements. The most effective and efficient management and implementation of the EVA program is therefore required. A detailed plan for a program management structure in NAVSEA (Sonar Technology Division) is presented; it calls for the establishment of a technical group assigned the responsibility for developing and maintaining a working relationship between environmental acousticians and systems developers. The group members are modelers, acousticians, analysts, and developers who are responsible for (1) supervising the inventorying, evaluation, and certification of all EVA data on hand, (2) specification of developer's requirements for EVA data collection, (3) specification of acoustician's required input information from the systems developer, (4) supervising the development and operation of sonar data storage and retrieval systems, (5) supervising the development, certification, and documentation of all general EVA models and sonar systems models, (6) conducting or supporting all sonar technology requirements analyses, sonar systems performance predictions, and sonar systems performance evaluations, and (7) interfacing with other commands, offices, and activities to assist in the accomplishment of the necessary coordination of ocean science programs and systems development. The technical group will operate under the auspices of the MOST technical advisory committee structure which is maintained by the NAVSEA Sonar Technology Office.

SUMMARY

The purpose of this report is threefold: (1) to present a description of the organizational and working interfaces involved in the development of sonar systems; (2) to identify the management structural problem which gives rise to the gap between environmental acoustic support program outputs and systems developers' requirements; and (3) to present details of an operating plan which will permit the implementation of an effective ocean environmental acoustics (EVA) program in support of the NAVSEA sonar program.

The organizational and working interfaces which will result in the most effective EVA support programs have not been sufficiently developed. Because of this, sonar systems developers are not getting required EVA data and acoustic process models to allow analysis and development of optimum systems. The most significant actions necessary to improve this situation are the following:

(1) Clarify and assign responsibility within NAVSEA for the development and maintenance of a working relationship between environmental acousticians and sonar systems developers.

(2) Recognize that development of models, collection of data, and statement of development requirements are common to the needs of exploratory development (6.2), advanced development (6.3), and engineering development (6.4), and develop a closer alignment.

(3) Develop a more efficient and effective coordination among headquarters EVA program managers.

(4) Develop an EVA organization structure that will permit coordination among the diversified EVA performing activities (e.g., government labs, university labs, industrial groups) and permit coordination among diverse disciplines and the supporting EVA program (e.g., oceanography, physics, mathematics, and engineering; research, technology development, concept formulation, systems analysis, design, development; experimental, theoretical, engineering).

Effective communication between environmental acousticians and systems developers and an effective EVA program may be implemented by the establishment of a technical group of environmental acousticians and systems developers who would be responsible for:

(1) interfacing with acousticians and developers as interpreters of the EVA data collection requirements and capabilities;

(2) developing and selecting generalized standard EVA data banks and environmental acoustic model sets; and

(3) documenting appropriate data and models and presenting them to developers to be used in the various stages of sonar systems development; routine and special updating would be required.

The detailed plan put forth herein describes a management structure which would be appropriate in that it involves the formation of a technical group oriented toward modeling and analysis and supported for the specific task of alleviating the problems cited above.

I. INTRODUCTION

Ocean environmental acoustics (EVA) is that body of technical data and expertise comprising the oceanography, underwater acoustics, and EVA modeling which is required by systems development for use in undersea warfare programs. The efficient management of the Navy's EVA Program is a matter of great concern because of the importance of this support service to systems design and analysis and because of the increasing demands on U. S. sea power to ensure the freedom of movement on the seas along international trade routes (see Appendix).

Sonar developers and users do not have sufficient EVA data and models available for optimum systems design and use. We now have operational ASW forces which in some cases appear to be equal to the challenge of a potential aggressor. In other cases, we know that our forces are deficient. In most cases we cannot determine how well prepared we are to meet the demands on our ASW capability with respect to overall mission requirements. We are too often unable to state our preparedness level because we do not have the necessary environmental acoustic data and acoustic models. We have in hand the techniques to simulate all of our sonar systems, many conceptual systems, and our latest torpedoes and mines to an acceptable level of confidence. However, analyses of sonar performance in all ocean areas, at all times, and against all existing or postulated threat submarines cannot be conducted without the information that would be provided by EVA data and models. Clearly, then, optimum systems development with respect to overall effectiveness is at present impossible.

The challenge presented to managers of EVA programs is a particularly difficult one because of the diversity of the groups which are performing the environmental support and systems development effort. Several technical disciplines are involved, such as oceanography, physics, mathematics, and engineering; many different activities are involved--NUSC, NUC, NRL, NAVOCEANO, University labs, and industry. Also, it is difficult to trace the contributions of any support group through the chain of development; so the relationship of EVA to improved systems characteristics or operational capability is tenuous at best.

The discussion of management techniques in this document will be limited to analyzing the effectiveness of the NAVSEA management in providing sonar systems developers with the environmental acoustic data to meet the present requirements for the development of systems which meet the user's needs. In this discussion, systems developers should be interpreted to include Navy headquarters project managers and engineers, Navy laboratory managers and engineers, and selected contractor managers and engineers. The users of EVA data include all the developers and operators in the Fleet who are involved in systems utilization, evaluation, test, systems improvement, and analysis.

A noticeable deficiency has evolved in the management structure of EVA programs. Certain working relationships between environmental acousticians and systems developers are necessary to accomplish optimum systems design and development. As the ASW sonar requirements have increased, and the systems design and operation have become more complex, this working relationship has not progressively improved.

Stated simply, the systems developers are not getting the EVA support they require. This lack of support prevents comprehensive performance analyses of operational systems and conceptual systems, and the optimum design of any future systems. In general, we are lacking the necessary data and models because the proper working relationships between ASW systems developers and environmental acousticians are generally not well enough established.

The current EVA management permits the independent accomplishment of integral parts of the complete EVA Program. The accomplishment of individual goals makes it inevitable that there will be a mismatch between some of the program pieces. For example, basic goals are different. As for the acousticians, they are primarily interested in the pieces that go into making up the overall environmental effects of sound transmission in the oceans, such as ocean bottom types, acoustic reflection properties of the various bottom types, and sound transmission in the bottom. The systems developers are interested in the overall environmental effects on sound transmission, including, for example, the loss in acoustic energy over a known frequency range that results from the signal's interaction with the bottom.

The mismatch between acousticians and developers has characteristic results, as follows:

1. The environmentalist's acoustic data banks represent the ocean, but show little relation to the systems developer's needs.

2. To meet his needs, the systems developer must find out what is available, spend time and money to sift the data, and finally (when possible), reduce it to the parameters needed.

3. The developer must make his own data measurements in many cases that are not unique to a particular system.

The purpose of this document is threefold: (1) to present a detailed description of the complex organizational and working relationships between acousticians and developers which must exist in the development of systems, (2) to identify the management structural problem which gives rise to the gap between EVA support program outputs and the systems developer's requirements, and (3) to present the details of a plan to implement an effective EVA Program within the NAVSEA sonar program.

The management plan is based upon a small technical group that would have the responsibility (among other things) to ensure that the requirements of developers for EVA data and models and the requirements of environmental acousticians for systems oriented guidelines for data collection are communicated. Such development and utilization can be performed by a united technical group of acousticians and developers reporting to one program manager. The plan will provide management information for EVA program specification, control, and evaluation, as well as visible reporting to higher authority and to the wider technical community.

Section II of this document discusses the inadequacies of the existing structure for management of EVA programs and the new interfacing structure that is required to implement an efficient management plan.

Section III details the form of NAVSEA's sonar program management which will permit the bridging of the gap that now exists between systems development and environmental acoustics support.

II. DISCUSSION

A. Background

The developers and designers of sonar systems for use in ASW weapons systems must respond to requirements which are established somewhat independently of the technological state-of-the-art and of the environmental limitations.

With respect to a knowledge of the environmental limitations, there are two subject areas which are, in general, deficient. First, the EVA parameters of basic importance in systems development (propagation loss magnitude and interfering background level) are available only for selected ocean areas (and then not for all frequencies of interest). With the aid of some existing models, however, it is possible to predict reasonably well these parameters in some other areas. Of additional great significance in this first subject area is the fact that it is generally impossible to determine if the data are representative of a larger class of data. For example, if an acoustic process is nonstationary, the representativeness of any sample is limited to the specific conditions under which the sample was collected (viz, time, depth, frequency, location, observation time, etc.). This presents a problem if available data are assumed to completely describe the process of interest and the process is indeed nonstationary and the systems design parameters of interest are sensitive to the nonstationarities.

The second area of deficiency is that of the insensitivity of existing EVA data or models to systems development parameters which are to be traded off. For example, if a developer is attempting to trade off array shapes, then noise field data which do not include a demonstration of the spatial coherence cannot necessarily fulfill the developer's needs.

In general practice, the systems developer must generate his own EVA models and use whatever relevant EVA data he can find. This is true in every identifiable stage of systems development. Therefore EVA modeling currently used by most systems developers has evolved from meeting special case needs rather than from the design of general EVA modeling. Worse than that, however, is the fact that systems have reached a level of sophistication such that a necessary part of any future development program must be a data collection program to provide a useful base of EVA data.

The trend is definitely not toward bridging the gap between environmental acoustics support and sonar systems development requirements by an iterative interaction between the acousticians and the developers; it is widening. The Navy's job demands that someone bridge the gap. The conclusion must be that systems designers are not getting EVA data support and this is not in the national interest. It follows that the existing management structure is inadequate to promote the EVA support that is required because areas of responsibility have not been assigned.

The management plan described in this document is a plan actually in the initial stages of implementation in NAVSEA sonar. The purpose of the NAVSEA EVA Program is to develop, identify, and utilize commonly validated models and data banks through the efforts of a technical group of acousticians and systems analysts who report to a Washington-based manager. The EVA models will be documented and will be used in sonar systems performance studies for various systems configurations. The documents will also provide management information for EVA Program specifications, control, evaluation, and visible reporting.

But, before the plan is presented in detail, we will describe the environmental acoustics input needed by the systems developers by looking at some relationships which in fact exist whether they are recognized or not.

B. The Problem and Its Status

In this section, an attempt is made to describe the EVA information which systems developers need and to describe in some detail the relationship between ocean environmental acoustics support and sonar systems development. We will then perhaps be able to show conclusively why the previous management structure could not ensure that there would be effective ocean environmental acoustics program management.

Sonar systems development is divided into and administered by three recognizable groups: exploratory development, advanced development, and engineering development. Within and around each of these groups is an establishment of managers and engineers for Navy headquarters, Navy laboratories, the selected contractors, and the Fleet operators. Collectively, they are "the systems developers" and, naturally, each speaks his own language. In this document, all of the groups are loosely referred to as systems developers; however, this grouping cannot be pressed very hard in the specifics of actual systems development and related environmental acoustics support. The type of development which is performed by each is different. Subsystem technology area development or perhaps experiment is done in exploratory develpment; conceptual systems design is accomplished in advanced development; prototypes and test models are built in engineering development.

The role for environmental acoustics support, then, quite obviously is different for each phase of the development cycle. Clearly, general EVA support could not meet the needs of all. For example, exploratory development is required to answer the question of what subsystems areas we are limited in, and subsequently to determine the technological development that is needed. Consequently, the exploratory development needs for basic EVA data could be met by standard or representative data by propagation mode type, for instance. However, the need for acoustic models is great. The models needed are those which represent the limiting physical properties of underwater acoustics that would have impact on sonar subsystems technology area development.

Advanced development is concerned with the selection of a systems configuration which maximizes systems performance within the limited number of years allowed for development. The needs for EVA data, then, are quite specific, although the areas may be large because the CNO requirements document specifies the ocean areas in which the system is required to operate. The EVA model needs are also quite specific. The models are those which are most sensitive to systems parameters, since the main problem is performance estimation as a function of systems configuration. Further, the systems parameters to which the EVA models must be sensitive are not general systems parameters. Rather, they are specific and, though they will vary, the range of variability will be limited. In some cases, it is conceivable that the system of interest will be included for a tradeoff study and the basis for performance comparison will not have a direct association with any acoustic parameters. Consider, for example, the operator's display format. Signal and noise levels could be represented by computer generated symbols or intensity markings on different types of recorder paper. It can be reasonably assumed that the signal-to-noise ratio required for the threshold of detection would not be the same for both types. The point of interest here, though, is that a model of the EVA noise is required that would permit calculation of the probability of marking either display for a fixed threshold, though marking density is not the tradeoff parameter. However, the probability of false alarm could be calculated for each display format as a function of threshold setting and this could be the tradeoff parameter.

Finally, in engineering development, a system is built as a test model and then as a prototype for production and installation. The tradeoffs made are in engineering design to meet stated, firm performance specifications. The requirements for additional unique EVA data and models are almost nonexistent. Certainly, it is intended that the "standard" EVA models could be used to ensure performance acceptability and optimum test design. However, this design group would never have a strong interface with environmental acousticians in the systems design stage but only in the design of standard acceptance tests (e.g., sonar certification tests).

It can be seen, then, that there is a key to effective EVA programs and to efficient utilization of EVA data and models which is missing. That key is the strong participation in the systems development cycle by a group whose responsibility is twofold: (1) the documentation and dissemination of EVA models in a standard format that is directly useful to systems developers, and (2) determining what is useful to systems developers and getting their needs (short and long term) for EVA data into the data collection programs and periodically publishing up-to-date information on the data residing in various data banks.

Such a group must be made up of environmental acousticians and systems developers who can build and use EVA models. They must have experience in designing and conducting experiments and utilizing experimental data. They are the ones who would be able to identify a general model set, specify the necessary maintenance, serve as interpreter between acousticians and developers, and generally bridge the gap between environmental acoustics and systems development.

The basis for understanding the real need for a group like that described may perhaps be indicated with the aid of diagrams showing the complexities, diversity, intricacies, and subtleties of the relationships between ocean environmental acoustics and sonar systems development. The diagrammatic descriptions are intended primarily for the use of program sponsors to trace technological concept development through to the systems development stage through use of EVA models and other support. However, technical integrity is not sacrificed for the sake of omitting tedious detail. The conclusion of the matter will be the use of the graphic descriptions to treat the problem under discussion in this document.

Figure 1 shows a block diagram of the top level relationships between the primary basic sciences that comprise ocean environmental acoustics

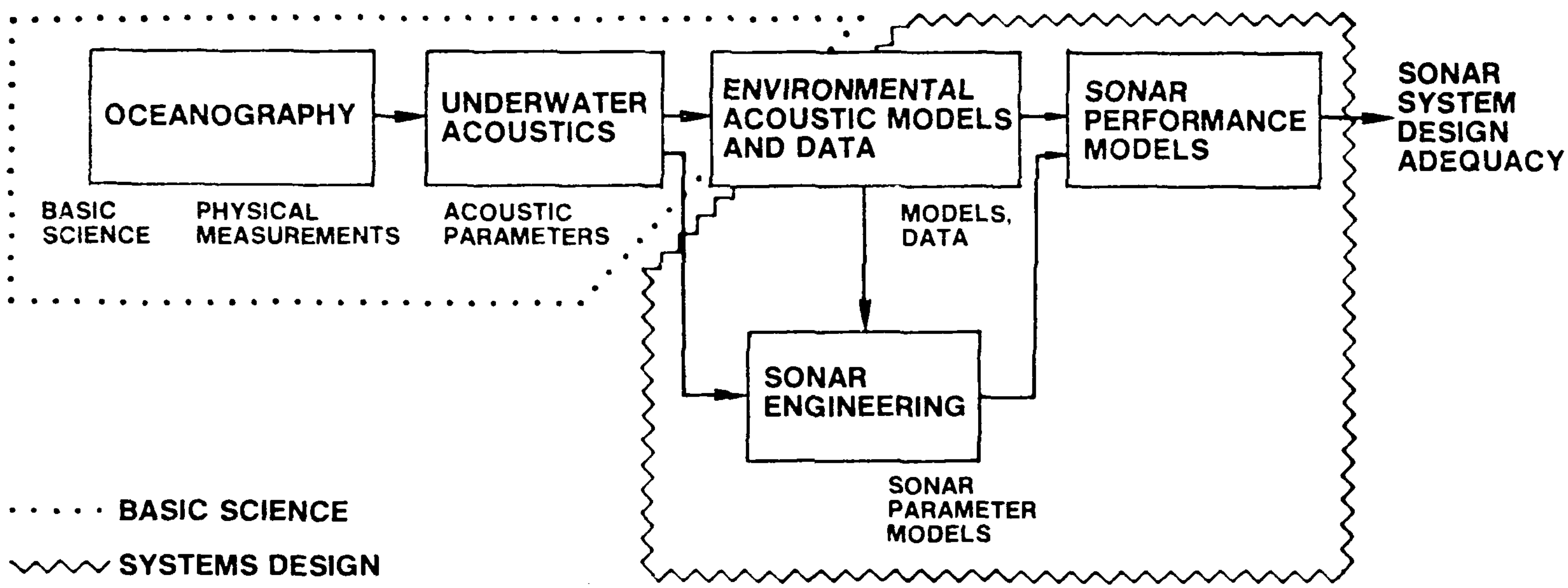

FIGURE 1
BASIC SCIENCE TO SONAR SYSTEMS DESIGN

and the final inputs to sonar systems design. Perhaps the best way to describe the generalized output of each element in the diagram is to use an example consisting of a familiar term and to track how it shows up in each elemental area of the total process depicted in Fig. 1. The term for the example is biological ambient noise.

It is sufficient for our purposes to say that oceanography is that endeavor which includes all of the physical measurements in all of the basic science areas of physical, chemical, biological, and geological oceanography for the descriptions of those ocean processes required in sonar systems design. For example, to produce the description of ocean processes involved in biological ambient noise, measurements must be made in the water column of interest to obtain a biomass assessment of the water. The biological measurement is necessary to understand and explain the behavior of the acoustic source. These measurements would be carried out in the basic science area of biological oceanography.

Moving through the diagram in Fig. 1, the physical measurements must be translated into acoustic parameters. These parameters then serve as requirements for data collection and model development by environmental acousticians. The block labeled Underwater Acoustics includes such effort. In our example, the biomass assessment would be translated to acoustic noise source, which would entail the delineation of biological life and the physical description of acoustic noise generated by that life in the water.

In the effort labeled EVA Models and Data in Fig. 1, the acoustic parameters such as spreading loss, absorption, noises, etc., are used as the parameters upon which environmental acousticians base their programs of data collection and model development for use by sonar systems developers. The outputs of the effort are, obviously, acoustic parameter models (such as for biological ambient noise) and acoustic data (such as recorded ambient noise levels).

There is an important output of Underwater Acoustics which is shown in Fig. 1 as an input to Sonar Engineering. This engineering is that effort required by systems developers which involves the effects of operating a system in the ocean (commonly called underwater acoustics systems engineering). The output of this branch of engineering is sonar parameter description with an inclusion of the effects of the relevant acoustic parameters. In our example, the output is a sonar model of the array gain in the presence of biological noises.

Finally, Fig. 1 shows that the EVA Models and Data in the form of EVA parameters and the sonar parameter models are used as inputs by systems developers to calculate sonar systems performance using performance models. The output of such activity can be equated to the specification of sonar systems design adequacy, performance prediction, or performance evaluation. The biological ambient noise is included in this area as a part of the ambient noise field EVA input, and the array noise gain equation as a sonar parameter input. The output could be any of a number of calculations such as the probability of sonar success as a function of biological noise. Obviously, there is a hierarchy of models within the area labeled Sonar Performance Models.

By reviewing the whole process depicted in Fig. 1 with respect to highlighting the relationships between environmental acoustics and systems development, it is possible now to become more specific in the identification of the relationships without being impeded by general organizational problems. Each block of Fig. 1 is used as the basis for the following diagrams.

Figure 2 is a modestly detailed list of basic areas of oceanography and the physical measurements that must be made in each area (represented by the separate grouping) to provide ultimately the EVA support and, to some degree the sonar engineering support, required in the development of sonar systems.

Following the preceding example for ambient noise, we might expect that the measurements of the pressure field (or surface heights) and the biomass assessment would provide us with ambient noise with respect to physical and biological oceanography. For this case, however, geological oceanographers produce energy level data describing the seismic sources of ambient noise as well.

Figure 3 shows the relatively small list of acoustic parameters that are of ultimate interest to sonar systems developers. From the measurements given by oceanographers, underwater acousticians (environmental acousticians) produce the necessary descriptions of the acoustic parameters. Our example points out that at least for ambient noise, included in NOISES, measurements other than those derived in oceanography must be considered; viz, manmade sources of noise such as shipping, ocean engineering, oil exploration, and well drilling and pumping.

The EVA Models and Data covered in Fig. 4 are not necessarily intended to be complete. However, the lists should be complete enough to indicate the type of effort included at this point. It is particularly important to notice that it is at this point that the distinction between environmental acousticians and systems analysts/developers becomes somewhat less clear. That is to say, the generation of the EVA models and/or data may be accomplished largely by acousticians or developers. The relationship between the two should be strongest here, where it is most critical; however, it is virtually nonexistent. An ambient noise field model may be developed by an acoustician or a systems developer; the data representing environmental ambient noise, however, most likely would be collected by an acoustician.

Clearly, this is the relationship between acousticians and developers which could best be, and must be, developed by the technical group referred to earlier. The gap indeed exists because of the fact that no one in

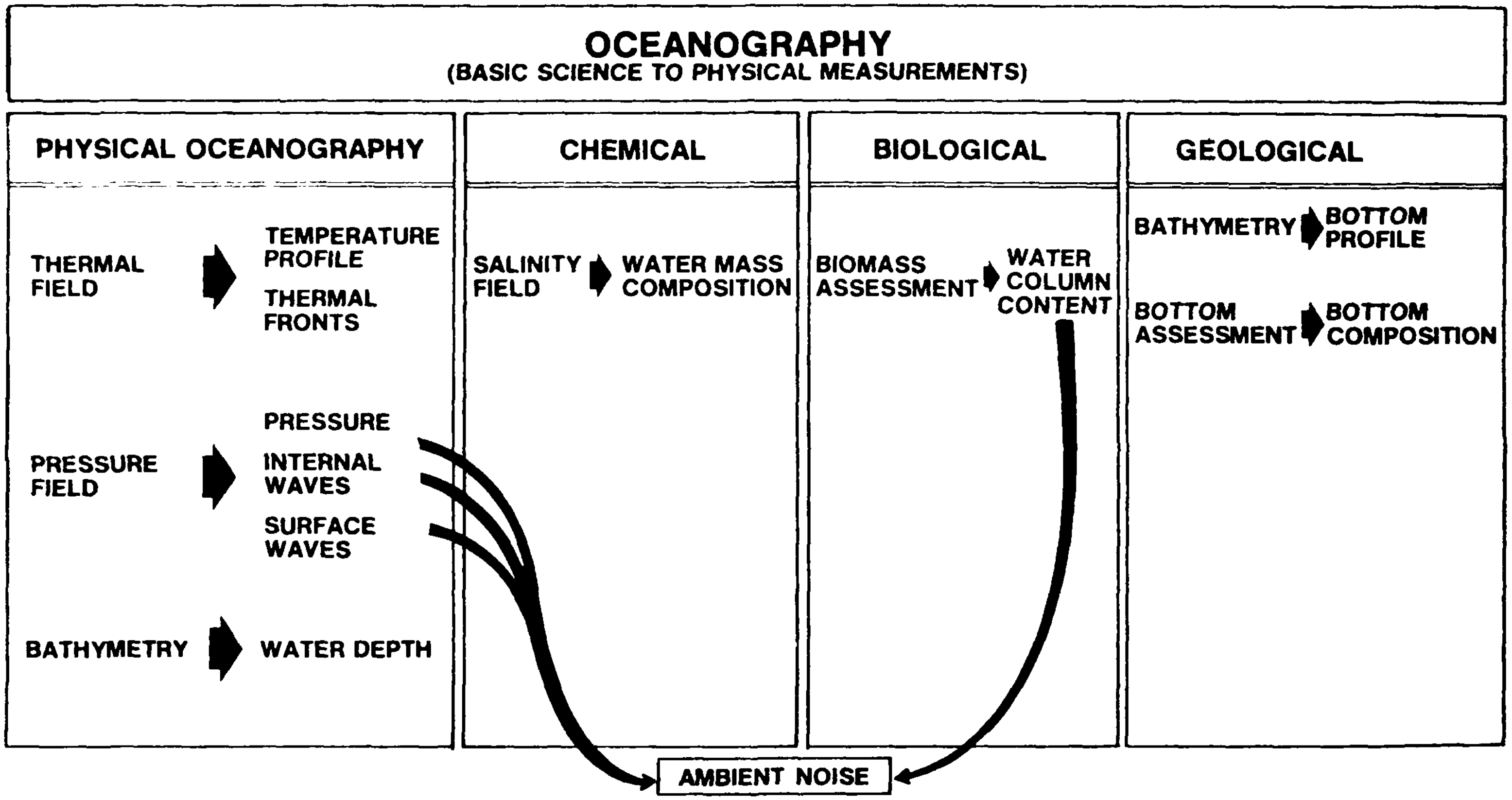

FIGURE 2
SONAR SYSTEMS DESIGN OCEANOGRAPHY

UNDERWATER ACOUSTICS
(PHYSICAL MEASUREMENTS TO ACOUSTIC PARAMETERS)

MEASUREMENT		ACOUSTIC PARAMETER
DISTRIBUTION OF SOUND VELOCITY (THERMAL OR PRESSURE FIELD) SALINITY	→	PROPAGATION AND SPREADING LOSS
WATER MASS ASSESSMENT	→	ABSORPTION
PRESSURE FIELD OR SURFACE HEIGHT DISTRIBUTION	→	SURFACE REFLECTION LOSS AND SURFACE REVERBERATION
BOTTOM ASSESSMENT (BATHYMETRY)	→	BOTTOM REFLECTION LOSS AND BOTTOM REVERBERATION
BIOMASS ASSESSMENT (SUSPENDED MATTER ASSESSMENT)	→	VOLUME REVERBERATION
BIOMASS ASSESSMENT PRESSURE FIELD OR SURFACE HEIGHTS ENERGY LEVEL SEISMIC MAN-MADE	→	NOISES

FIGURE 3
PROPERTIES OF ACOUSTIC PROCESSES

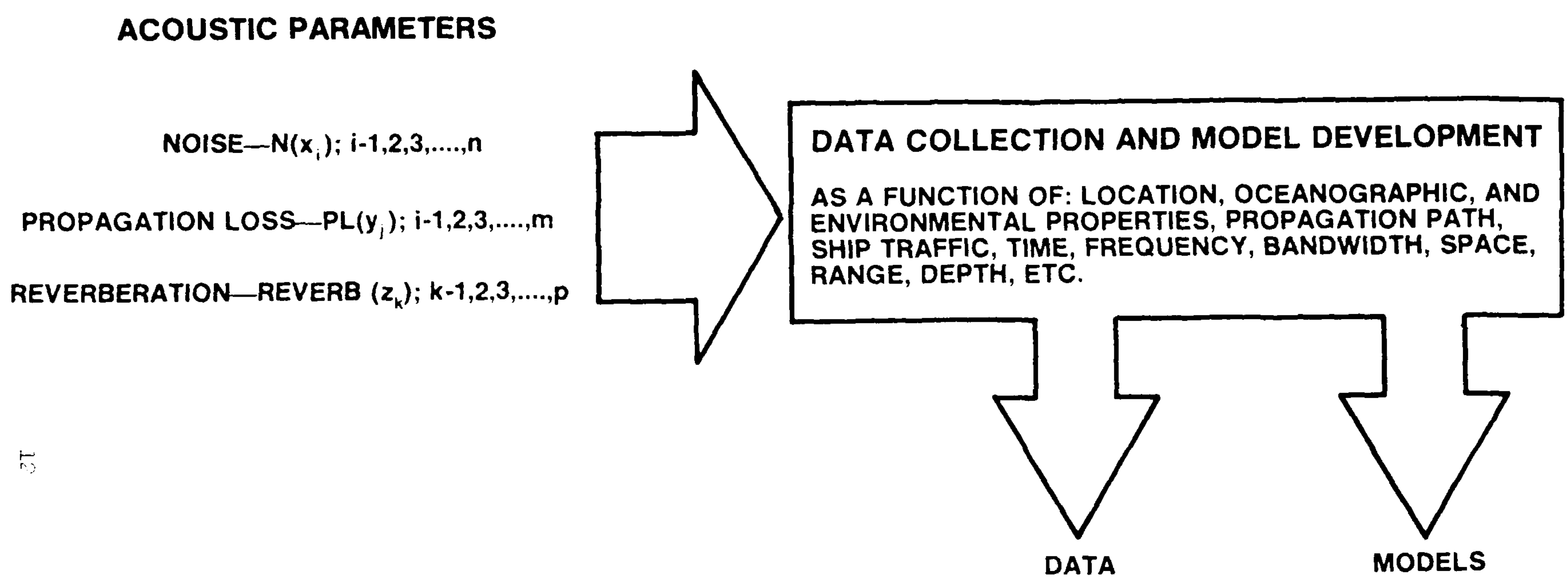

FIGURE 4
EVA MODELS AND DATA
(ACOUSTIC PARAMETERS TO DATA AND MODELS)

the management structure is specifically chartered to ensure that this critical role is carried out. This is the management structural problem.

Dropping down now to the first clearcut systems developer function, we see that Fig. 5 shows sonar models are the output that is required to relate the sonar systems behavior to the acoustics of the underwater environment in which the system operates. While this area includes specification of the intermediate equipment parameters, it is best known as that area which produces the "sonar equation" of interest.

Ambient noise in general is considered in this effort as input information in underwater acoustics for the determination of the environmental noise array gain equation.

Figure 6 represents a hierarchy of performance models which are constructed to give the desired quantity: an estimate of systems performance. The basic inputs and outputs are listed in this figure along with an indication of the modeling architecture. Ambient noise, for purposes of our example, is seen to appear as an input and as a factor within the set of performance models.

For clarity, Fig. 7 shows some detail in the performance model set.

The figures (1 through 7) give a reasonably detailed view of how basic science is related to systems development. The figures are intended to show the relationships between environmental acousticians and systems developers from the viewpoint of an objective observer.

The foregoing description of how basic science is related to systems development can now be used as a guide in evaluating the structuring of a management rationale for systems development. The Navy, for reasons quite justifiable, has established the present management structure based upon the recognizable stages of development of a system, as was pointed out earlier. The structure associates efforts under research, exploratory development, advanced development, and engineering development. Consequently, the following paragraphs contain a view of systems development from a manager's view and are presented so that it may be seen whether or not the necessary relationships are indeed accounted for in a form appropriate to the management structure.

A feeling for the complexity of the management interaction which must take place in the working relationships can be gained perhaps through discussing the role of performance modeling in systems development in more detail. For example, consider the systems development problem of the generation of submarine sonars following the AN/BQQ-5 and 6. Theoretically, according to its charter, exploratory-development has work going which is applicable to various systems techniques should the decision be made to develop the next generation system (viz, advanced development).

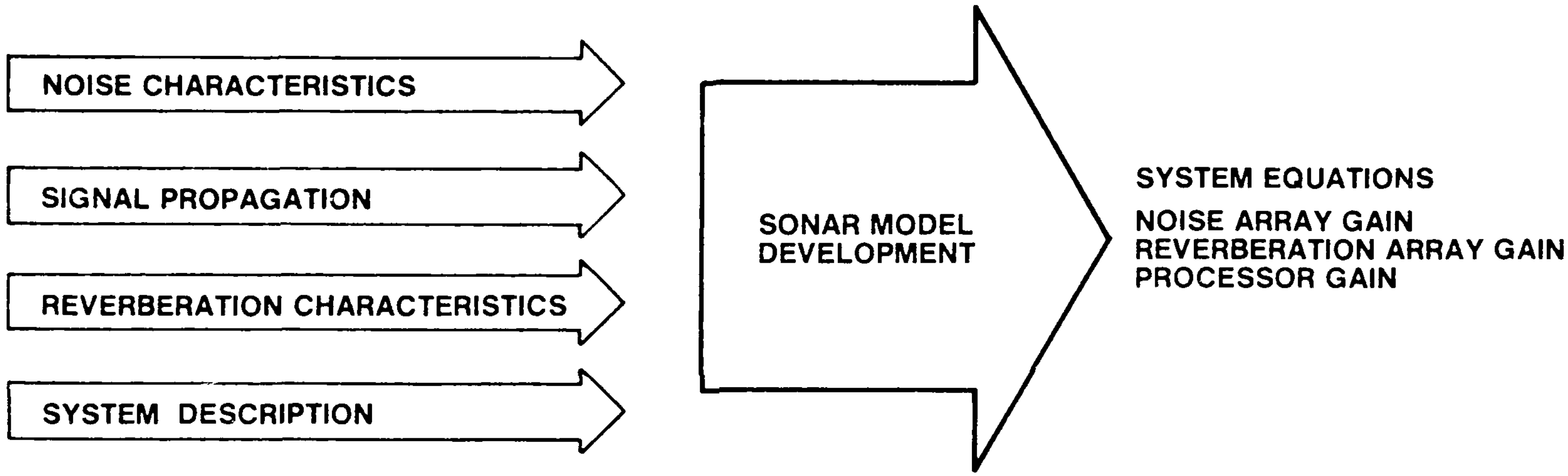

FIGURE 5
SONAR ENGINEERING
(ACOUSTIC PARAMETERS TO SONAR MODELS)

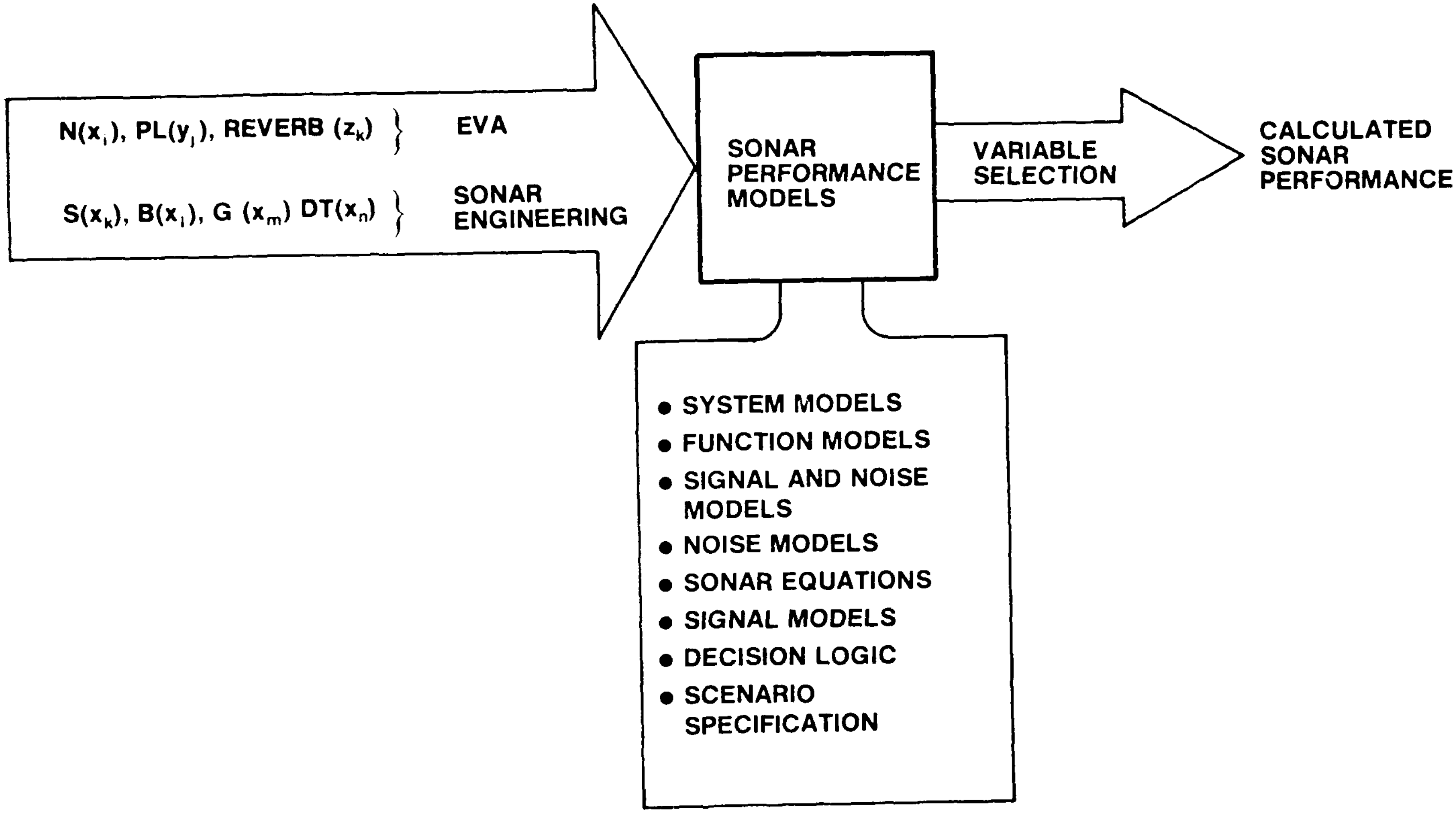

FIGURE 6
SONAR
(SONAR AND EVA DATA AND MODELS TO SONAR SYSTEM PERFORMANCE)

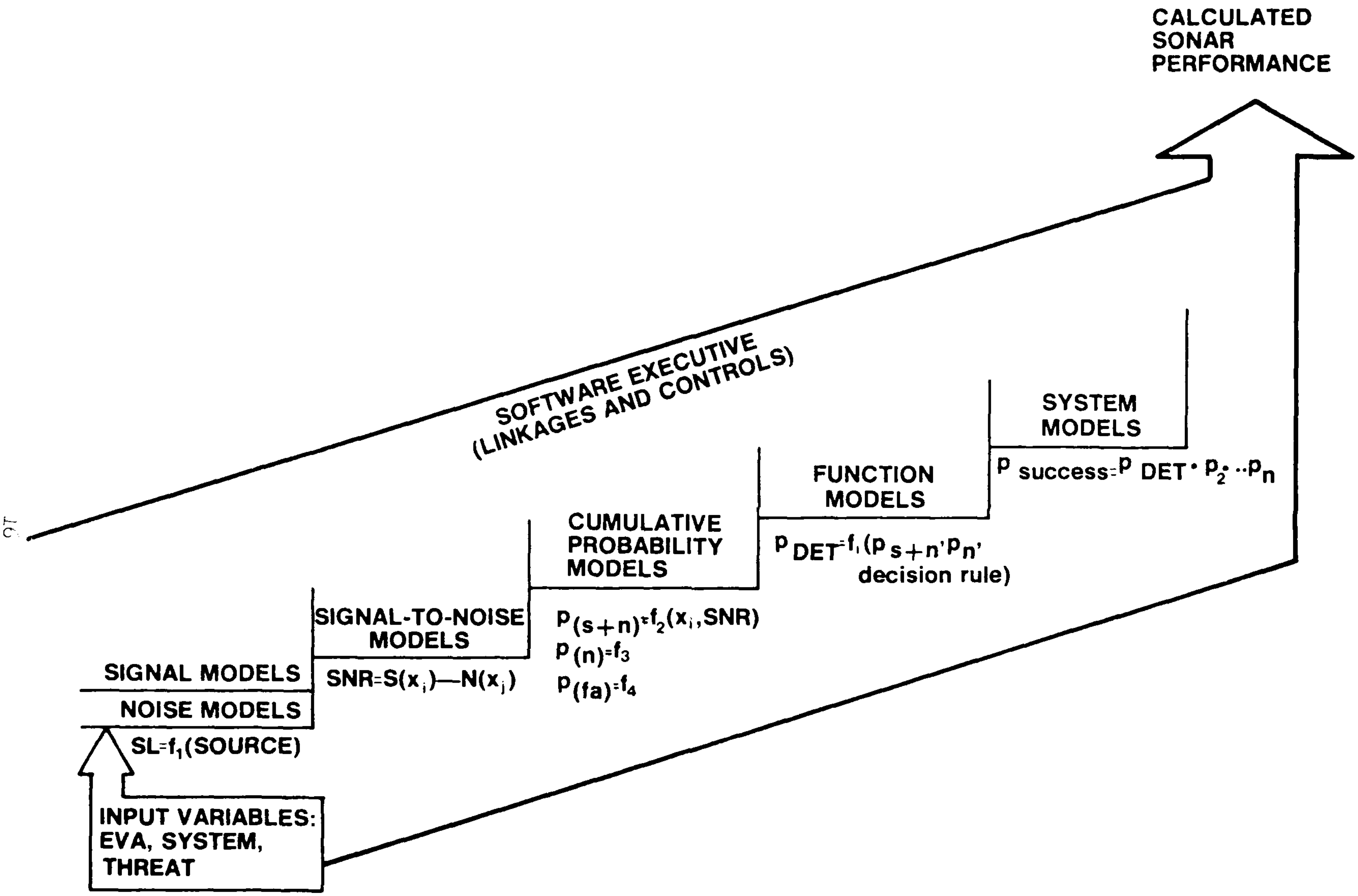

FIGURE 7
SONAR PERFORMANCE MODEL SET

Performance modeling has also been done to some extent already, in that it is generally accepted that a major operating mode should be passive and that performance in all missions is required against a submarine threat at longer ranges and for other frequencies than previously of interest.[1]

As has already been pointed out, exploratory development is engaged in evaluating the feasibility of conceptual subsystems with respect to environmental and systems technology limitations. These limitations are investigated within general guidelines from OPNAV operational requirements. Exploratory development's job is to extend the variation in subsystems parameters to the point which is permitted technologically or environmentally and to examine the variation with respect to impact on performance. Performance is considered both in the engineering sense and in the environmental sense. By implementing such a process, exploratory development can directly produce systems techniques for use in advanced systems conceptual design and operational systems maintenance and upgrading. Where technological limitations are identified, development can proceed at a pace consistent with the needs and resources of the total program. Any isolated environmental limitations could be documented and pursued. However, environmental limitations are not likely to come from the developer, but would more likely come from the EVA research providing support to the developer.

Figure 8 depicts the subsystems technology areas of sensors, electronics package, and sonar decision making which are the areas currently being investigated in NAVSEA sonar exploratory development. The process of extending the parameters is implemented in each area; that is, parameter values are ranged to the extent of technological and environmental limitations.

Let us return to the example of the next generation submarine sonar and performance modeling. The systems developer will always be interested in calculating levels and characteristics of signals and noises to conduct his performance analysis. So, the noise field $N(x_i)$, where $i = 1,2, \ldots, n$, and propagation loss (PL as a function of each specified propagation path and boundary condition) for specified signal types are the first level EVA models which are required.

Common terms for specifying the ocean areas of interest are, for example, the Norwegian Sea in the summer; or, the Ionian Basin in the Mediterranean Sea during the winter; or, the Harmuz Passage between the Arabian Gulf and the Indian Ocean. Probably the scope and structure of the EVA models can be determined by looking at the objective of the systems analyst. That is, if one is looking for an optimum sonar design in an ocean area, he must have complete statistics on the $N(x_i)$ and $PL(y_j)$ with respect to time and transient phenomena for the entire area. However, if one is interested in the average performance of one type sonar versus that of another type for various ocean areas, the data required

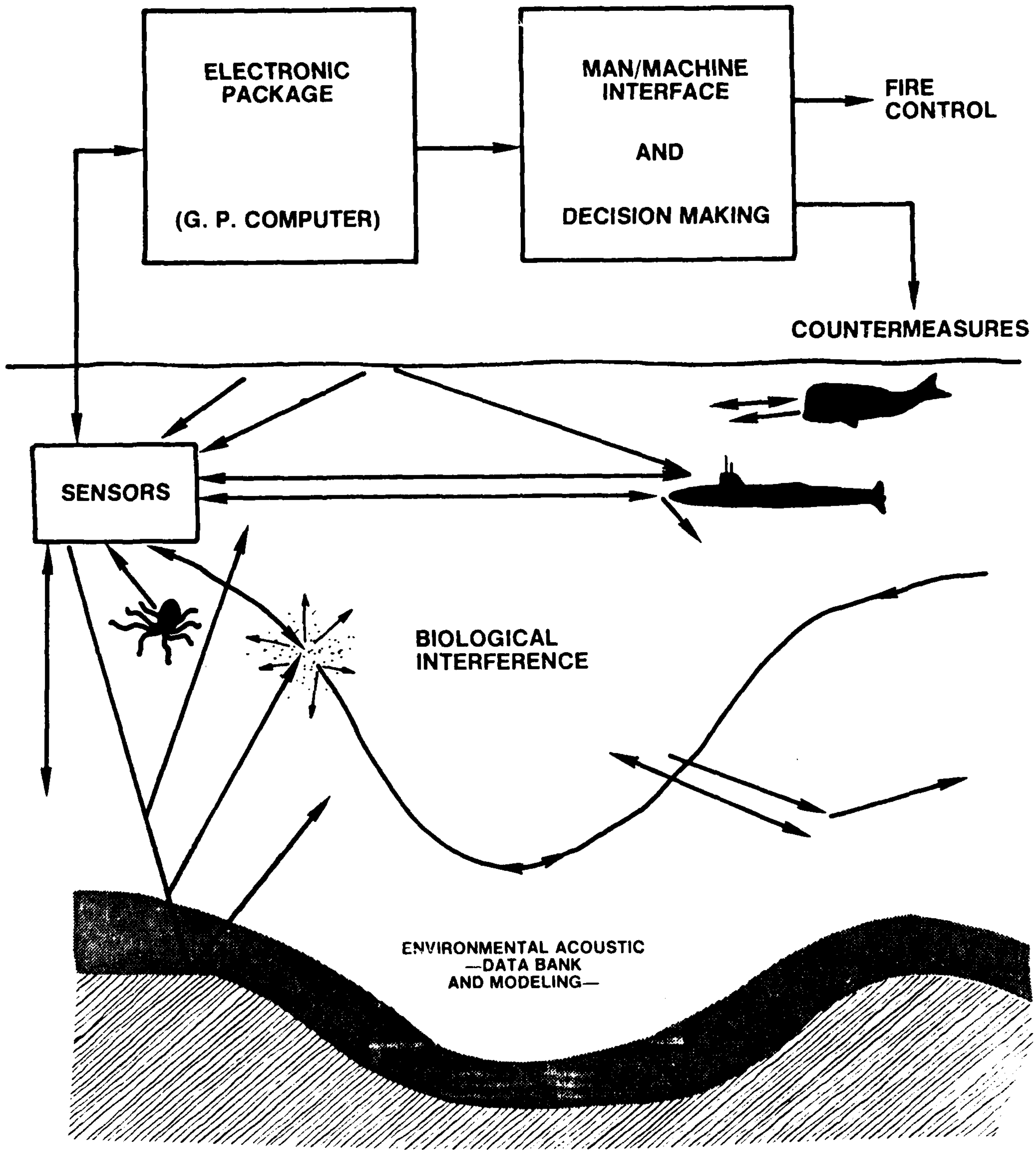

FIGURE 8
MOBILE SONAR TECHNOLOGY
FOR
SUBS, SURFACE SHIPS (CONV. & UNCONV.) & MULTIPLATFORM

probably would be only the average, or typical, characteristics of NL and PL with perhaps the variances thrown in if they are known. The EVA models must include provisions for parametric analysis of those acoustic parameters that influence systems performance at the level of detail of the systems models. Figure 9 shows a block diagram of the elemental relationships which are involved in the problem at hand. Modeling emphasis is indicated to be heavily oriented toward EVA models. Management must recognize this bias and its management implications.

For the sake of completeness in discussing our example, let us assume that the CNO decides to exercise the option of building this next generation system and an Operational Requirement is issued. From analysis of the data available from exploratory development and other sources, the advanced development office puts together a program containing plans for analysis of alternative systems configurations and the estimated development risk associated in meeting the specified systems performance goals.

The major work objective is to evaluate candidate systems techniques and to come up with a satisfactory systems configuration on schedule. This set of activities is outlined in Fig. 10. The differences in systems analysis should now be seen in advanced development shown in Fig. 10 and in exploratory development in Fig. 9. The EVA support is different also. The modeling emphasis is on the systems model, as indicated in Fig. 10. Again, management must recognize this emphasis and supply support as may be required.

For purposes of this document we will assume that the EVA models which are generated and collected in advanced development will meet the needs of engineering development. No additional effort before sea testing is anticipated.

Now, the summary of the development cycle from this practical viewpoint is shown in Fig. 11. It is noted that the subtle interfaces are clearly brought to light. Finally, Figs. 12 and 13 show in the lowest level of detail, for our purposes, the relationships which must exist if design and development of an effective next generation submarine sonar system is to proceed efficiently. Figure 12 is of the general relationship between basic science and systems development. Figure 13 shows the specific case, for example, of the next submarine sonar development. The differences show up in the systems description and the EVA models of interest.

It is possible now to use Fig. 12 to point out where the EVA support is lacking and to identify precisely where the gaps are located between environmental acoustics and systems development. The general relationships may be readily deduced. Figure 12 shows that the following EVA support is required but is not now being provided. (These make up the technical gaps.)

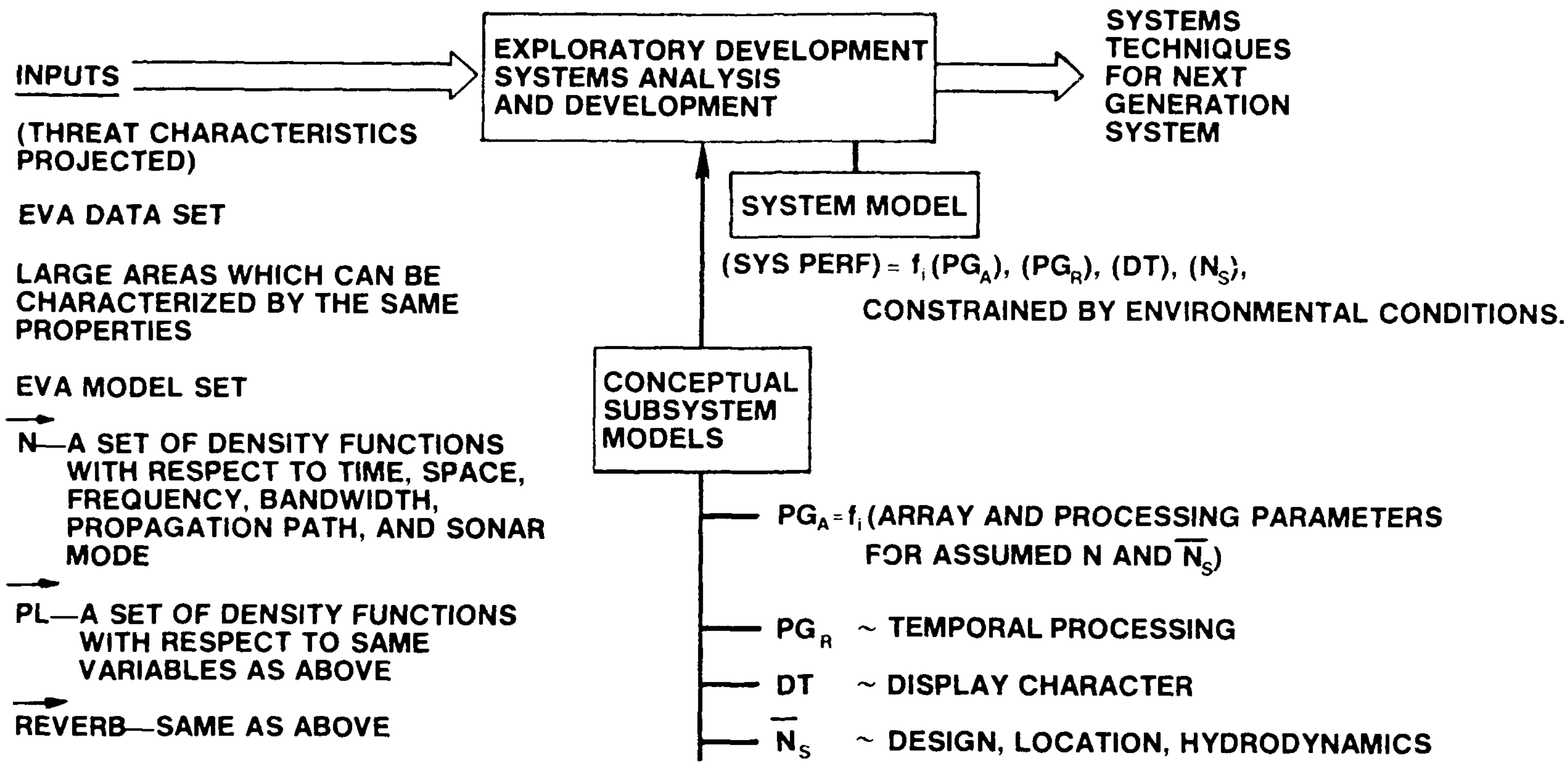

FIGURE 9
SYSTEMS ANALYSIS IN EXPLORATORY DEVELOPMENT

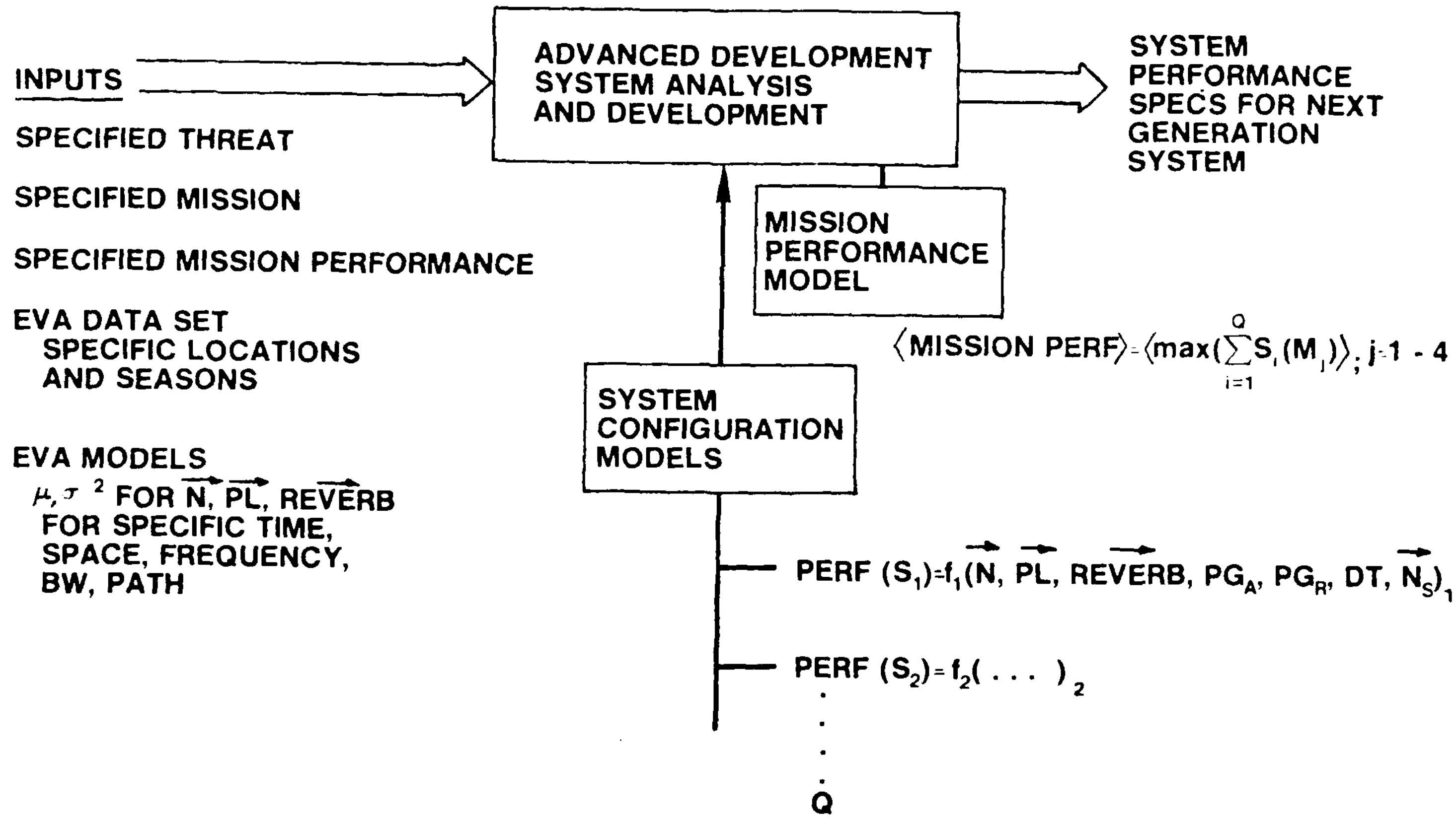

FIGURE 10
SYSTEMS ANALYSIS AND DESIGN IN ADVANCED DEVELOPMENT

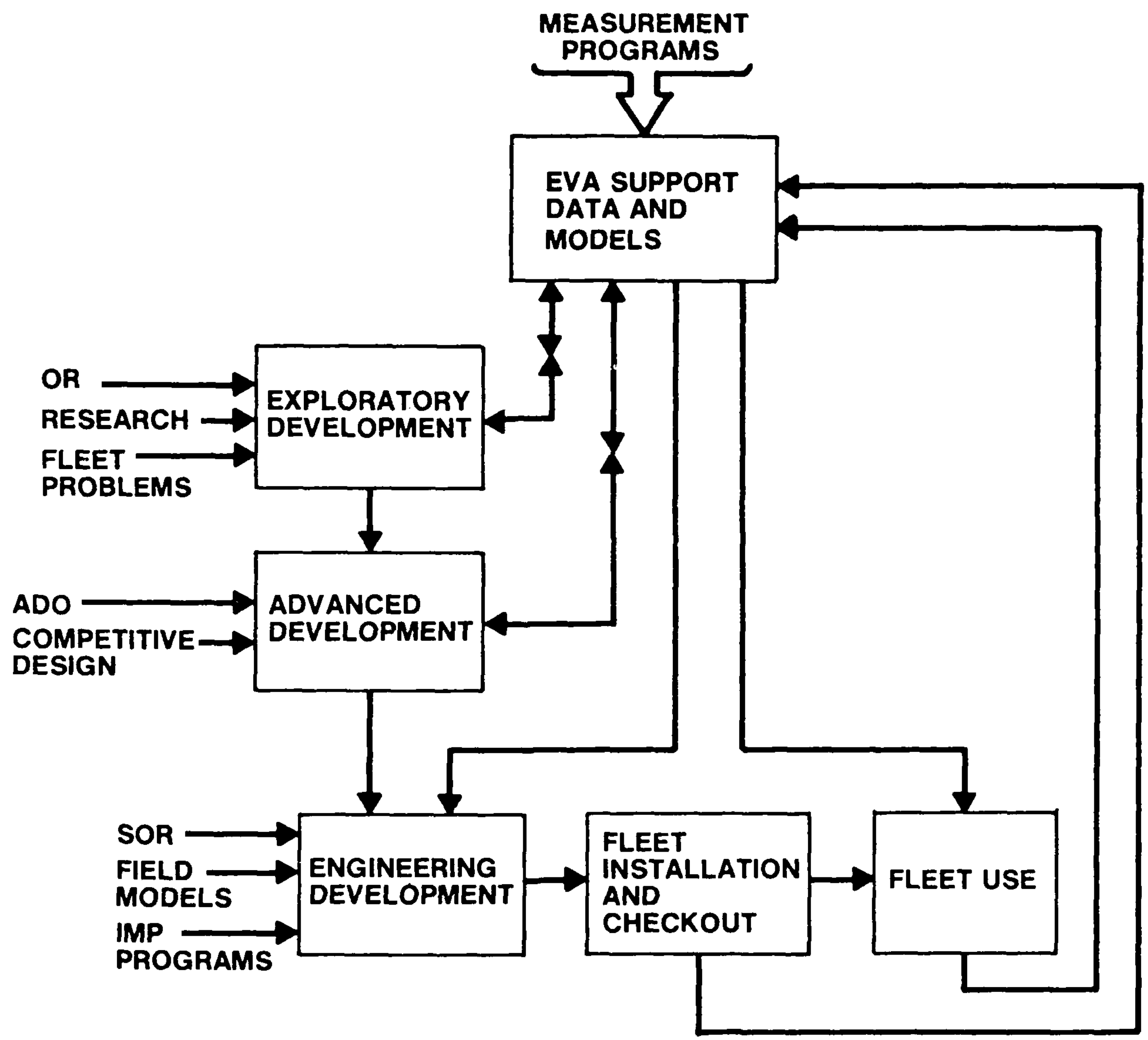

FIGURE 11
EVA SUPPORT IN SYSTEMS DEVELOPMENT

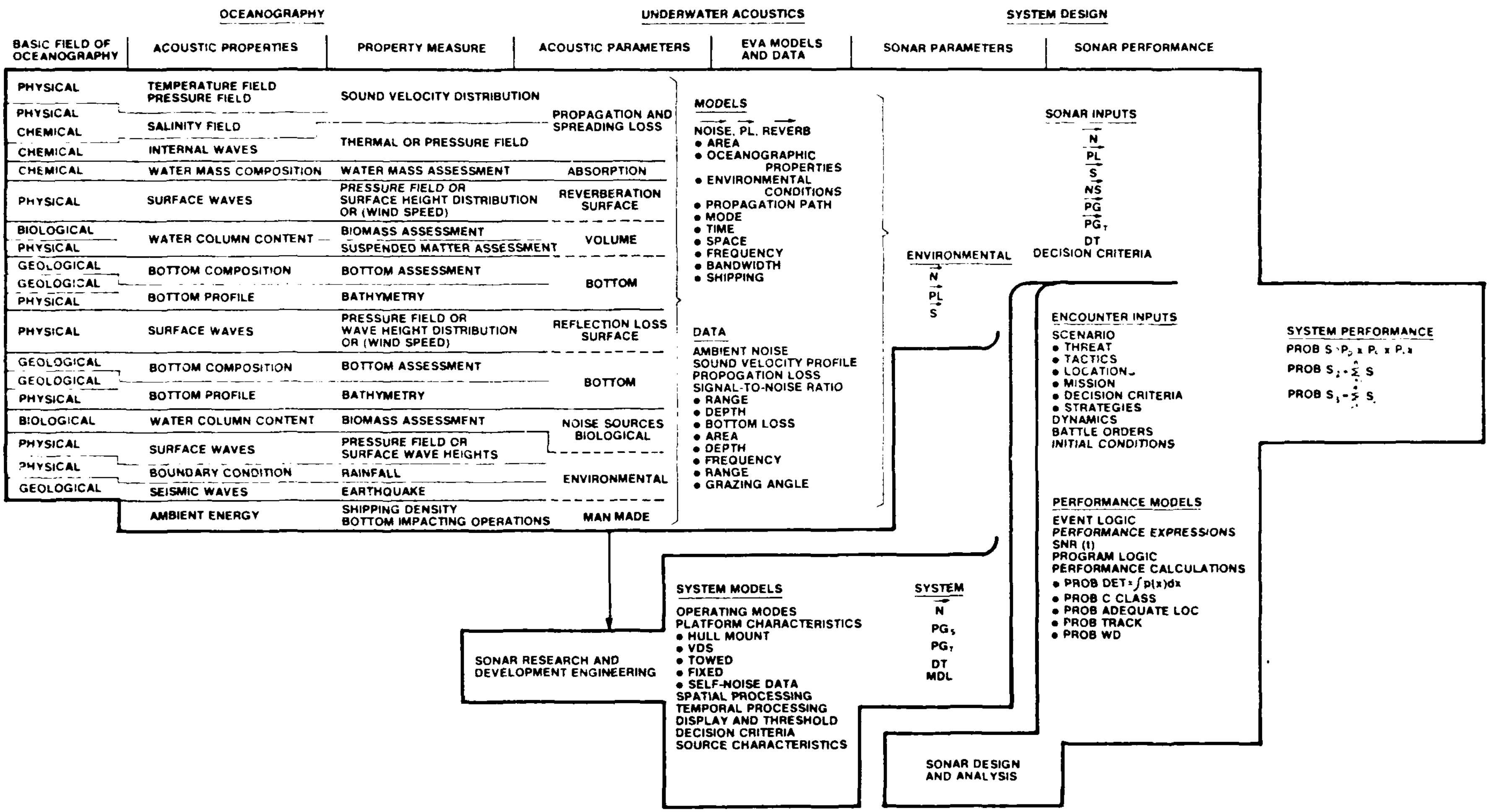

FIGURE 12
BASIC SCIENCES TO SYSTEMS DESIGNS

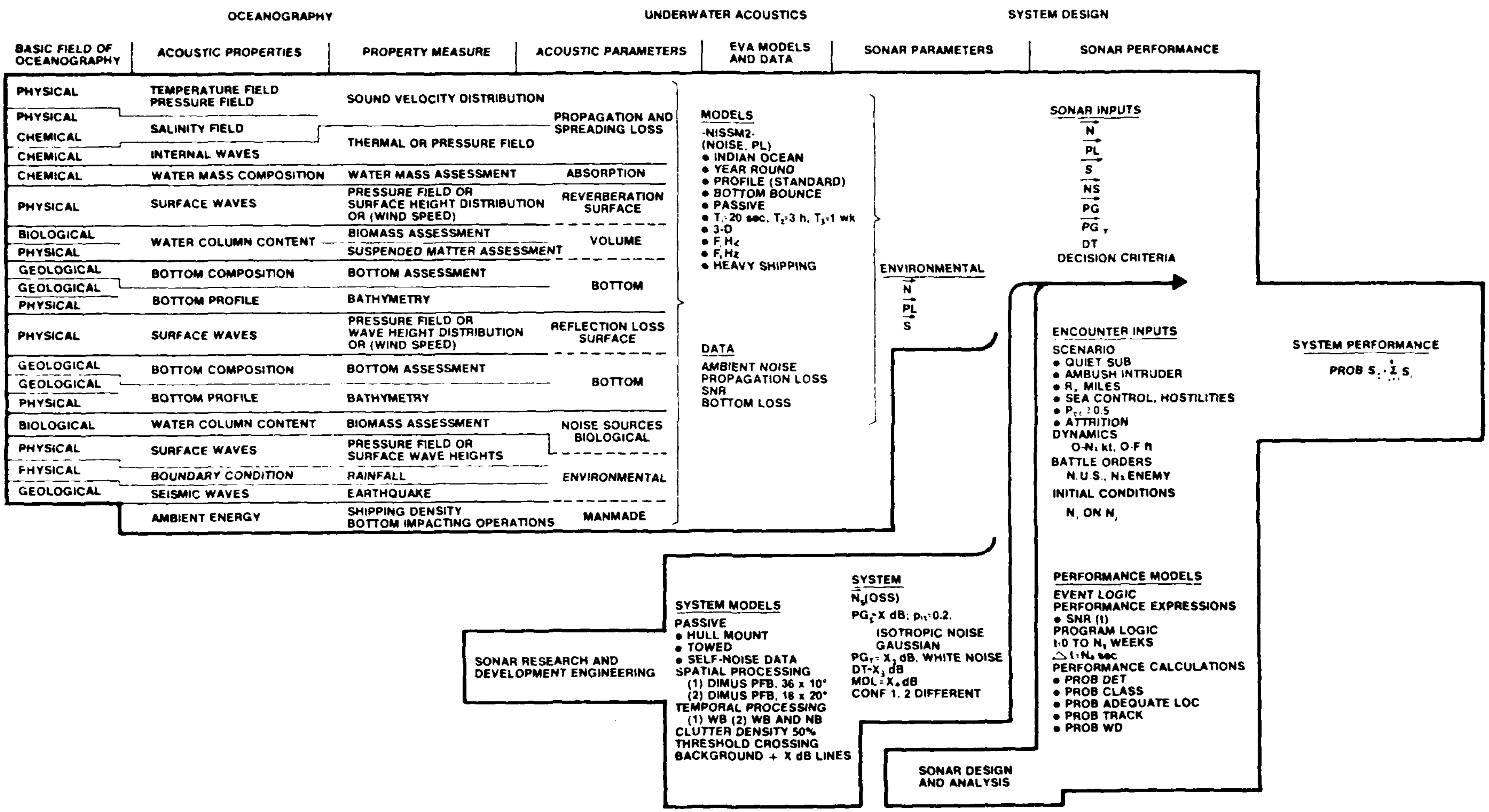

FIGURE 13
BASIC SCIENCES TO SYSTEMS DESIGN FOR NEXT GENERATION SUBMARINE SYSTEM

1. Long term data collection programs designed to statistically describe the acoustic parameters for direct translation to sonar performance parameters for all areas and frequency ranges of known priority interest (the statistics must include density functions for non-Gaussian variables, or knowledge that they have finite means, and means and variances for Gaussian functions all with respect to time, space, coherence, and stationarity).

2. Development of a spectrum of EVA models (perhaps in cooperation with developers) of the acoustic processes shown (Fig. 12 or Fig. 13) based on the sample space generated in 1 above.

3. Programs of measurement and model development which are specifically designed to determine physical limitations that have resulted from subsystems configuration.

4. Development of systems oriented EVA models using the sonar parameters in a generalized form.

5. Wide dissemination of descriptions of stored data which are adequately and appropriately annotated.

6. Generally, more documented information on stored data which results from reduction and analysis, such as

a) statistical significance of sample,

b) possibility of unknown signals in the data, and

c) uncertainty associated with each sample.

Clearly, a group which does not now exist must be formed if the requirements outlined are ever to be met. As stated earlier, the key to successfully managing an efficient development program is the technical group that has the responsibility of solving the root problem discussed in this document: bridging the gap between environmental acoustics support programs and systems development requirements. The group will in fact form the bridge. The management's inherent structural problem of the type just discussed, that permits the gap to exist with no directly assigned responsibility for bridging the gap, is solved by establishing the technical group.

The group will have the responsibility of appropriating those EVA models already in existence which are accepted as generally useful, of developing the models which are needed, and of specifying required characteristics for the data collection and its storage in acoustic data banks. This job will be a continuing one and the group should evolve into a group of new specialists in environmental acoustics/system development.

A most important requirement for individuals in the technical modeling group is that they must remain current in the fields of ocean acoustics, computer model development, and sonar systems analysis and development. They must also interface on a routine basis with the NAVSEA Program Manager and function as his staff in his duties of representing the EVA program. A further description of the group is presented below as a list of characteristics.

(1) Most of the members might be continually on assignment to both an oceanographic program and a sonar systems design/development.

(2) There should be an approximate balance in numbers between acousticians and designers, although this is not essential.

(3) Each must have a working knowledge of model development and utilization of digital computers. The working knowledge means at least experience in directly interfacing with the software developer.

(4) The members must have or be able to develop an easy accessibility to the technical community at large.

(5) The members must be able to construct and accomplish an analysis and development program which will provide the basis for an EVA Program Plan which will be generally acceptable to and understandable to the workers in each systems development area.

The group of technical people that has been established to accomplish jobs such as the one described above is named the Sonar Analysis Committee (SAC), which is a part of the Mobile Sonar Technology (MOST) Committee structure retained as working technical advisory groups by the NAVSEA Sonar Technology Office.

In the following section of this paper, the details are presented which describe the NAVSEA sonar program management's use of the SAC to bridge the gap between environmental acousticians and systems developers.

III. MANAGEMENT PLAN

The approach to management of the NAVSEA Sonar EVA program which is now being implemented was selected because of the success which has been experienced in the past in utilizing a technical advisory committee structure. The structure is known as the Mobile Sonar Technology (MOST) Committee and it has been functioning since 1966 as an aid to the Sonar Technology Office in the evaluation and definition of the overall exploratory development program conducted. The MOST structure includes standing technical advisory committees in each major technology area of mobile sonar exploratory development and the principal MOST Committee. The committees in the technology areas review and evaluate the individual programs and make annual recommendations to the MOST Committee for the programs in their respective areas. The MOST Committee reviews and evaluates the recommendations within the perspective of overall requirements and guidance and annually composes a program of exploratory development which is recommended to the NAVSEA Sonar Technology Office.

The Sonar Analysis Committee (SAC) was established in 1972 to work with all of the technology development committees in MOST to provide the framework necessary to evaluate each of the various programs with respect to meeting systems developments needs for exploratory research and development. The job of overall requirements analysis and translation to goals for technology development has been performed by SAC.

The gap which exists between the environmental acoustic support program outputs and the systems developers' needs in all stages of development can be bridged by the SAC operating within the MOST advisory committee structure. Figure 14 shows the relationships that already exist and that will permit the SAC to overcome the problems discussed earlier by becoming the bridge between environmental acousticians and systems developers. The SAC is specifically tasked to meet the following set of responsibilities within an overall systems development framework:

(1) Supervise the inventorying, evaluation, and certification of all EVA data on hand.

(2) Specify the systems developers' requirements for EVA data collection to the ACME Committee (see Fig. 14) on a working level basis.

(3) Specify the environmental acousticians' need for inputs from systems developers to the technology committees (shown in Fig. 14) on a working level basis.

(4) Supervise the development and operation of sonar data storage and retrieval systems.

(5) Supervise and participate in the development, certification, and documentation of all general EVA models and sonar systems models.

(6) Conduct or support all sonar technology requirements analyses, sonar systems performance predictions, and evaluations.

(7) Assist in interfacing with commands other than NAVSEA, offices within NAVSEA other than the Sonar Technology Office, and all participating activities to aid in accomplishing the necessary coordination of ocean science programs and systems development.

By accomplishing these tasks, the SAC will provide guidance for the evaluation and definition of the EVA programs and for the systems technology development programs and input information to those who conduct higher level analyses such as MASWSPO, OP-95, and OP-96.

The SAC will perform its work in the EVA/Systems Development interfacing area by using EVA models and systems models as focusing tools. The SAC will be assisted by panels on model development for both EVA models and systems models. The panel memberships will comprise researchers who are properly rooted in real modeling aspects which are lacking in many current modeling

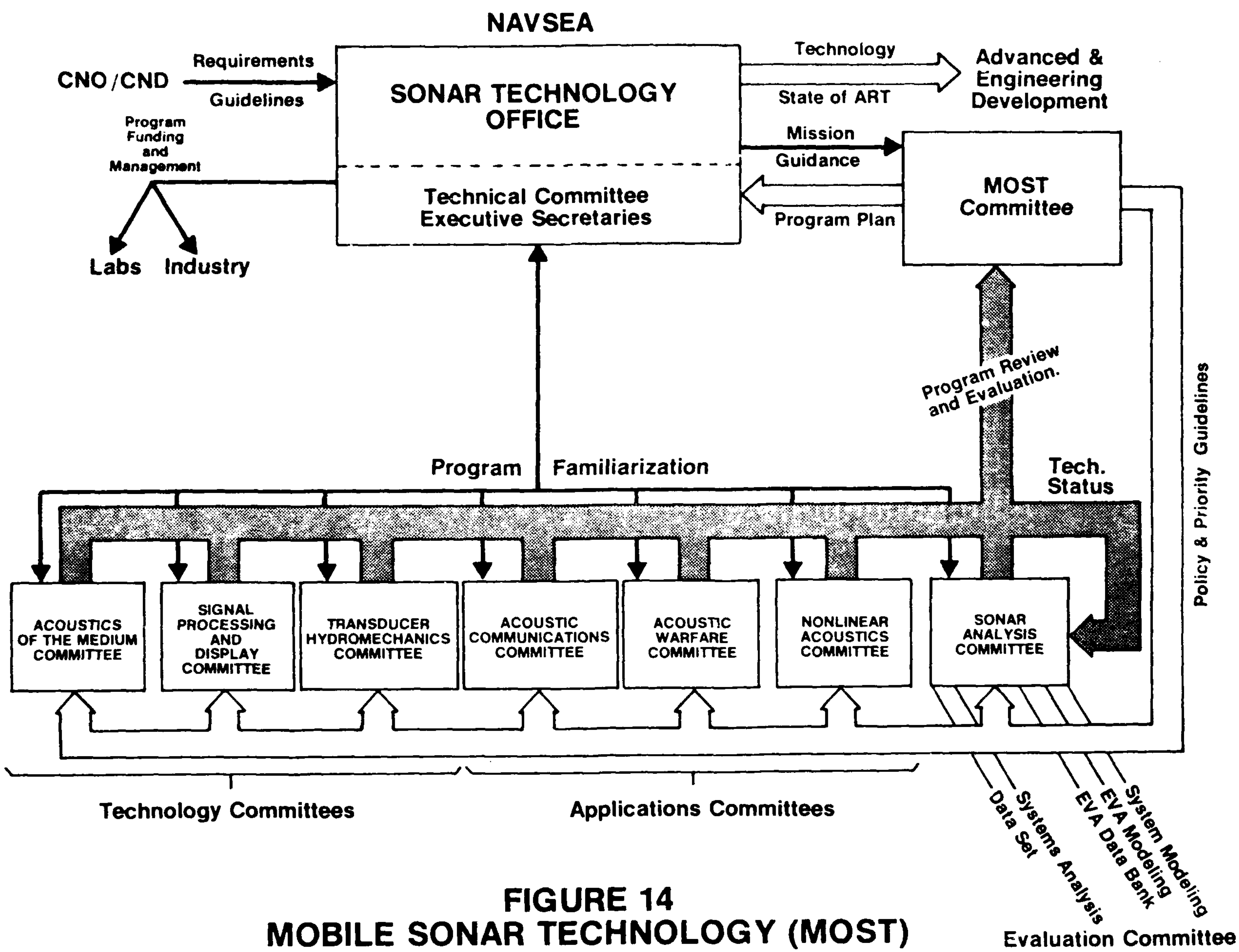

FIGURE 14
MOBILE SONAR TECHNOLOGY (MOST)
EXPLORATORY DEVELOPMENT PROGRAM

programs. The majority of the panel members will be those who are working full time in EVA and modeling and analysis development programs.

The SAC members are now identified and basically committed full time to the work herein described. They are systems modeling and analysis specialists with experience in detailed sonar systems analysis. Each has a working knowledge of model development and analysis with the utilization of digital computers. Experience includes analyses involving the environment, own ship's systems, threat systems, missions, and dynamic engagements.

Based on the successes of the past, and with objectivity strictly maintained, the SAC (supported by the modeling panels) will be able to conduct a significant certification of the EVA Program on a fiscal-year basis. However, one should not expect the operational procedure to reach full maturity until the second or third operating year. By that time, it is anticipated that the working relationships which are so necessary between environmental acousticians and systems developers will be vibrantly active and healthy. Then, only technological gaps will exist; and, even those will be the objects of program emphasis as appropriate.

APPENDIX

Background Developments in Environmental Acoustics Support for Systems Development and Analysis

The Navy's oceanic strategic and tactical policies have evolved from the late 19th century, primarily under the influence of economic interests in importation and successes at sea in two world wars, to the point where the U.S. Naval Forces are considered a generalized sea power to be used as instruments of national policy.[2] Such utilization has prompted recognition of four basic missions for the Navy that have impact on underwater acoustics systems development. The mission names are Sea Control, Projection of Power Ashore, Peacetime Presence, and Strategic Deterrence.

We have been able to perform these missions successfully in the past. However, the role of sea power and our nation's development are such that today we rely more on sea power to survive crucial issues than ever before. The crucial issues are both political and economic. Politically, to maintain the worldwide balance of military power that is the objective of the U.S. and its allies, we must maintain naval forces that are widely regarded as at least equal in capability to the naval forces of the USSR and its allies.[3] We must possess the ability to:

1. display a credible commitment within range of almost any area of the world;

2. protect or evacuate the U.S. Nationals in almost any world area;

3. provide a military presence without an automatic commitment of forces; and

4. clearly demonstrate U.S. interest and capability without disclosing precise intentions.

The primary economic issues have to do with the importation of raw materials into the U.S., and with the freedom of oil distribution to the international market by Mideast countries. Each of these are briefly discussed below.

The U.S. economic base is obviously dependent on the strategic raw materials which are used in the U.S. industry. At present, 68 of the 71 raw materials are imported, all or in part, by sea.[2] And the trend is toward more reliance on sea imports. Sea power must be adequate to protect the sea lanes for these critical imports.

The Mideast's oil distribution on the international market is having a considerable impact on the international financial structure. The monetary reserves of the oil producing countries have risen almost threefold from $13 billion to $38 billion in one year. Such rapid accumulation of wealth, and its concentration in the Mideast, threatens to create new pressures on the world's financial system.

U.S. sea power may well play a major role in the stability of the strategic straits of Hormuz and the Indian Ocean through which pass an average approaching 20 million barrels of oil per day, representing half of the world oil exports.[2]

Thus, the ever-increasing needs for adequate sea power place a heavy responsibility with the R&D community to design and develop systems capable of fending off an instigator of undersea warfare. Further, if we are to succeed in all the Navy's missions, at some point or another in each mission we must have ASW systems which are effective against the threat of submarines. The development of such systems requires a management structure which ensures that the necessary support programs are accomplished on a schedule consistent with the main development program's objectives.

The Navy's missions imply the potential for effective ASW all over the world against the primary potential adversary, the USSR. In January 1975, the USSR had 325 seagoing submarines compared to the U.S.'s 115.[3] These are mostly modern, high speed, heavily armed, versatile submarines which can remain on remote stations for long periods. It is believed that threat submarines are being made acoustically quieter in each succeeding generation. In all, the Russian submarine fleet appears to be the most formidable potential threat any nation has ever faced. These submarines appear as a threat in all our Navy's priority missions.

With regard to ASW systems development implications, many difficult questions need to be answered concerning existing systems if we are to do an efficient job of systems development. Such questions are as follows:

a. Why were the present systems built?

b. Are adequate operating and training procedures available?

c. Can systems performance be predicted?

d. Are we able to say by how much and in what environmental situations these systems are superior to other proposed systems which were not built?

e. When should these systems be replaced?

f. What mix of systems types is optimum for the most probable operations in the Mediterranean Sea, the Norwegian Sea, the Indian Ocean, the North Atlantic, or other strategic areas?

Unfortunately, we cannot answer these questions satisfactorily due primarily to the lack of information on the ocean environment. The systems developers, then, have a job which includes direct accounting for the interaction between underwater sound transmission and ocean environmental acoustics.

The information, or data, which is required by developers might be obtained in any of several different ways. For instance, a late model, flexible sonar system could be appropriated to an advanced development group and the system could be operationally tested to collect data on performance; and, to whatever degree practical, the design parameters of the system could be varied to conduct operational sensitivity tests. This approach could provide quite a lot of the data which systems developers need.

Another way in which some of the required information could be collected is through the exercise of models of the acoustic process involved in underwater sound propagation in the situations of interest. If there were a current catalog available of the many EVA models which have been developed, systems developers could either obtain a version of the model or they could obtain the model calculations for specified input parameters.

Finally, systems developers might acquire the required information by designing and conducting at-sea data collection programs. Such a method would be costly in time, money, and available equipment and manpower, as would the other methods, but this method would also be inefficient.

With at least these options, the Navy decided to rely upon support groups to see that the developers' needs are met in environmental acoustics. Such a decision seems to be wise. It is reasonable to expect that diverse needs can be met if many systems compete for development by a permanent, sustaining group operating outside the systems development offices.

Also, in the current world situation it is difficult to justify the commitment of a ship and system and then schedule frequent exercises on an indefinite basis so that exhaustive (consequently, meaningful) systems operational testing could be conducted by development engineers. The Navy is critically short of active duty warships now. Services for systems testing are limited to some feasibility and evaluation for acceptance tests. The sea tests are difficult to schedule and are highly susceptible to change. It appears that a well equipped ASW ship will not be available for research so long as we do not have enough ships to staff the operational fleet in the desired numbers.

Of course, lesser objectives could be met by using a research vessel as a sonar platform. At any rate, EVA programs have been established for the direct support of ASW systems development. Since these programs were begun, the overall need has grown to that of a base of information sufficient for supporting a world-wide operation. To meet the need, EVA programs have generally adopted the twofold objective:

1. to understand the processes of underwater acoustic propagation and to develop accurate models of them; and

2. to determine techniques and methods that are effective in exploiting the favorable characteristics of the ocean and minimizing the effects of the unfavorable characteristics.

The work in environmental acoustics to date has not proved adequate to do the job. Most ocean transmission processes of use to developers must be simulated with large uncertainties due to high risk of the assumptions involved. This is true despite the fact that data collection programs have produced large stores of ocean environmental data. These data, however, are largely unusable by most systems developers.

The main problems associated with the data on hand are listed below:

1. The data are either environmental or acoustic but not both (both are necessary).

2. The data were collected for too narrow a purpose and hence are of extremely limited usefulness.

3. The data are not faithful recordings or are not properly annotated to permit interpretation.

4. The data are not completely reduced and/or reported.

5. Primarily, the data are not reduced and published in the form which would be directly useful to systems developers.

These problems are a result of deficiencies in experiment design, equipment limitations, and the program management structure.

The most important data which apparently are missing pertain to the temporal and spatial properties of acoustic parameters (e.g., propagation loss and ambient noise) and also to the documented evolution of meaningful (to systems developers) EVA models which have been validated at least according to some stated criteria. It should be pointed out that these particular data are becoming the concern of experimental data collection programs. So, things should be improving to some degree.

A great amount of the work in systems development is in tradeoff analyses. An estimate of performance as a function of systems configuration is one basis upon which a meaningtul tradeoff study can be conducted. Obviously, the very ability to make a reasonable performance estimate is dependent upon whether or not one has adequate EVA data.

Generally, a developer has access to some environmental models at his own activity. There are many more discussed in the literature. With those of his choice, he then assumes a particular form of the "sonar equation" and generates some measures of sonar performance based on what generally amounts to typical but not necessarily representative data.

Many problems facing systems developers today can only be solved if the adequacy level of EVA support is raised.

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