NAVAL RESEARCH

REVIEWS

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Dr. Herbert Soloman is Professor of Statistics at Stanford University. He has gained international recognition for his pioneering applications of statistics and his contributions to statistical theory. Applications of his work have yielded insights in the physical, engineering, social, and even legal sciences, and have provided new tools for practitioners in these disciplines.

Scientist, Administrator and Educator, his career distinctions span both Government and academic service (including founding of the ONR program in mathematical statistics and the initiation of Defense Department activities in statistical quality control and reliability, and the analytical solution of military problems). He is a past President and Fellow of the Institute of Mathematical Statistics.

International Symposium on Magnetohydrodynamic Electrical Power Generation

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Introduction

This was the fifth of a series of International Symposia on Magnetohydrodynamic Electrical Power Generation. The meeting was held in Munich, Federal Republic of Germany, and was co-sponsored by the International Atomic Energy Agency (IAEA) and the European Nuclear Energy Agency (ENEA). The attendance at the meeting was approximately 250 with the largest representation from Germany (79). Other delegations included the USA (43), the USSR (37), France (15), the UK (14), Italy (10) and Japan (10). Other countries represented included Algeria, Argentina, Australia, Austria, Belgium, Bulgaria, Canada, Czechoslovakia, Greece, Hungary, India, Iran, Luxembourg, The Netherlands, Poland, Rumania, Sweden, Switzerland and Turkey.

In the interest of time, the rapporteur system was used in lieu of individual author presentations. The rapporteur, a carefully chosen expert in a specific area of magnetohydrodynamics, summarized and critically examined the papers in his particular session. There was ample time for individual authors to comment on their papers or the rapporteur's critique immediately following the rapporteur's statement. Following this, the session was open to the general audience for discussion and comment. The rapporteur system thus permitted the review of more than 100 papers in eight separate sessions by 20 rapporteurs. Simultaneous translation in the official languages (English, French, and Russian) was available. Translation into German was also available. In addition to the technical sessions, three round table discussions were held in each of the general technological aspects of magnetohydrodynamics: open-cycle MHD, closed-cycle MHD and liquid-metal MHD. The purpose of these round table discussions was to openly review the status of the three technological areas of MHD.

Table I shows the distribution of papers among major supporting countries. The distribution shows the rather heavy emphasis on open-cycle MHD technology. The four countries represented in Table I contributed about 74 percent of the technological papers.

The summary which follows is centered about the rapporteurs' statements, the round table discussions and comments from open

TABLE 1
DISTRIBUTION OF PAPERS AMONG MAJOR SUPPORTING COUNTRIES

	US	USSR	JAPAN	GERMANY
OPEN-CYCLE	12	14	10	5
CLOSED-CYCLE	7	10	1	9
LIQUID-METAL	4	6	2	3
TOTAL	23	30	13	17

discussions presented by the general audience. No attempt will be made to summarize the technical content of the Symposium. There are, however, a number of trends in MHD research that are now apparent and these will be discussed within the appropriate technical division of MHD research.

Open-Cycle MHD

The open-cycle round table was chaired by Dr. W. Brzozowski (Poland). Other members included A. E. Scheindlin (USSR), D. G. Zhimerin (USSR), Y. Mori (Japan), W. D. Jackson (USA) and H. D. Schilling (Germany). The chairman and panel agreed that considerable progress had been made in the area of open-cycle MHD since the Warsaw meeting in 1968. Indeed, it was unequivocally stated that the field has transcended from one in which large experiments are being used to obtain MHD data to one which will be concerned with the construction of full-scale pilot plants. One such pilot plant, called the U-25, has just been completed this year in the USSR, although it was scheduled for completion in late 1969. The technical specifications for this plant are contained in ONR Conference Report ONRL-C-23-68 by R. Roberts, dated 5 November 1968. Although the MHD portion of the plant is not large in terms of output power (25-MW design), the U-25 installation is unique in that it is actually a complete MHD/steam pilot plant from which realistic extrapolations to full-scale central stations employing MHD can be made.

Prof. Scheindlin showed a movie highlighting the construction details of the U-25 installation. One could not help being impressed by the immensity of the installation in terms of both physical size and capital cost. The plant is completely self-contained and includes: three preheaters which have the ability to preheat air to about 1100 K, an integrated oxygen generating plant for enrichment purposes, the necessary electrical inversion equipment to transform dc to high voltage ac, a seed recovery system capable of removing 99.2 percent of the seed material from the flow and an integrated bottoming steam plant. Scheindlin indicated that the capital cost of large integrated MHD/steam central station power plants would be about 140 rubles per kw installed. He further indicated additional work on preheaters would be carried out in the USSR with the goal of a preheat air temperature capability of 2000°C and a preheater lifetime of 10,000 hours. It was further stated that the lifetime of MHD installations should extend to 200,000 running hours with overhauls at about 8,000 hour intervals.

Brzozowski (Poland) reported the completion and preliminary operation of the 3-MW facility at Swierk. This experiment incorporates the pebble-bed heat exchanger technology developed under a joint program between Poland and France. The research is concerned with the design and testing of MHD ducts of cold and semi-hot construction and examines new techniques of duct construction employing the plasma spraying of insulators.

W. D. Jackson (USA) discussed the plans for open-cycle MHD development in the United States. These plans are more or less designed to implement the Office of Science and Technology report on MHD power generation, which was published about two years ago, through funding from the Office of Coal Research, U.S. Department of the Interior. The limited work currently under way on open-cycle MHD in the United States is being carried out at Stanford University, the University of Tennessee Space Institute and the Avco Everett Research Laboratory. The work at Avco is currently oriented toward the use of MHD for emergency power situations rather than base load operation. This emphasis, however, may shift as funding becomes available for development work.

Mori (Japan) commented on the national MHD program in Japan, and was not nearly as optimistic about MHD as his contemporaries on the Panel. He stated that because of Japan's "island like" nature, thermal pollution was not a problem but that air pollution was currently a serious problem. The Japanese have concluded that the air pollution from MHD open-cycle plants would be about 1-1/2 times higher than air pollution from gas turbines used for base-load power generation. They further concluded that MHD plant costs would be 10-15 percent higher than steam plant costs, not including the equipment necessary for the desulphurization of coal. The national program in Japan appears to be coming to a conclusion, and natural phase out of MHD programs by 1974 has been predicted by Mori.

Dr. H. D. Shilling (Federal Republic of Germany) was pleased with the progress of the field since the Warsaw meeting, and reported rather positive plans with regard to open-cycle MHD in the FRG. The Institute in Plasma Physics and MAN are jointly involved in open-cycle pulsed generator research at IPP while KFA Julich is constructing a long-duration facility called Vegas I. An additional long-duration facility, Vegas II, is expected to be operational in the 1972-1973 time period at a power level of 30 MW. Schilling concluded that open-cycle MHD was economically competitive with nuclear power in the FRG.

Closed-Cycle MHD

Some 46 papers were presented on the subject of closed-cycle MHD power generation, and as in past conferences, there was very little data presented on the behavior of non-equilibrium MHD generators. The kind of data that are of indispensable value in predicting the utility of the non-equilibrium generator is data on large generators which show actual load lines (I-V curves), the amount of enthalpy that can be extracted from the flow in the form of useful electrical power delivered to a load and the turbine efficiency of the generator (a measure of how isentropic the expansion is in the generator). Without information of this kind, it is not meaningful to come to positive conclusions regarding the utility of the non-equilibrium MHD generator for base load operation or other applications involving electrical power generation.

Significant experimental results on non-equilibrium generator operation were presented by Anzidei *et al.* (Italy) and Zauderer (USA). The results of Anzidei solve one of the main technological problems concerning the closed-cycle MHD channel design—that of electrical insulation of the plasma from ground. This problem has been so severe that Hall voltage saturation and breakdown at voltages of about 400 V/m seemed to be a foregone conclusion for the non-equilibrium generator. The Anzidei result showed it possible to construct an MHD generator to sustain Hall voltages up to 1100 V/m at an $\omega\tau$ (electron cyclotron frequency times mean collision time) exceeding three without saturation. The result is important in dispelling conclusions concerning Hall voltage saturation phenomena experienced by practically every researcher in this field.

Zauderer reported equally important results critical to the assessment of this field. In utilizing a shock tunnel MHD facility Zauderer reported the extraction of 10 percent of the stagnation enthalpy from the gas converted into electrical power into a load. He was able to demonstrate this result at a gas stagnation temperature of 2000 K with a generator isentropic efficiency (generator efficiency) of 30 percent. Zauderer concluded that with the use of thermionically emitting electrodes, heated to electricity conversion efficiencies of 15 to 20 percent should be attainable in the near future. The Zauderer work was done on a Faraday-type linear MHD generator with an inlet Mach number of about 2.5; the Anzidei result was obtained on a linear Faraday MHD generator with an inlet Mach number of about 0.8. To date, there is no conclusive evidence on the superiority of the supersonic or subsonic MHD generator. Both approaches need considerable research before it can be shown that one approach has considerable merit over the other.

The closed-cycle round table was chaired by Toschi (Italy); other panel members included Brederlow (FRG), Spilrain (USSR), Louis (USA) and Forster (ERG). There was considerable discussion on whether or not a suitable nuclear reactor could be constructed if non-equilibrium MHD was experimentally proven to be attractive for base load power generation. Forster expressed concern that the retention of fission products in the fuel of a nuclear reactor designed for gas stagnation temperature on the order of 2000 K would be virtually impossible. Way (USA) commented that it might be possible to utilize the nuclear reactor technology developed under the US Nerva program (nuclear rocket) for MHD applications, but that considerable design changes would be necessary and the Nerva would essentially have to be derated in temperature. Fission product release rates in the Nerva concept are a problem of a different order of magnitude since the design lifetime of this reactor is about 10 hours. Changing the reactor coolant from hydrogen to one of the noble gases and lowering the gas stagnation temperature to 2000 K appeared to be an interesting possibility for Nerva, according to Way. No information was presented on the fission product retention capability of this reactor.

Spilrain (USSR) cited interest in the Soviet Union in a non-equilibrium MHD closed-cycle concept employing the Rankine cycle (condensing working fluid). This cycle would use mercury seeded with cesium as the working fluid and would eliminate the compressor problem common to Brayton cycles. An experiment of this kind has been constructed in the Soviet Union, but as yet, no conclusive evidence concerning the utility of this concept has been presented. Prof. Kerrebrock (USA) commented unfavorably on the practicality of using liquid-metal plasmas in MHD generators because of the tendency of droplet formation during the expansion in the MHD generator while power was being produced. The liquid-metal droplets absorb a significant fraction of the electron energy and reduce the plasma electrical conductivity to unacceptably low values, according to Kerrebrock.

Liquid-Metal MHD

The liquid-metal MHD round table was chaired by R. D. Radebold (FRG). Other members included E. E. Spilrain (USSR), M. Petrick

(USA) and J. Sterlini (France). Radebold and Spilrain both expressed significant concern over the fact that single-fluid cycles (condensing ejector cycles) are severely limited in efficiency. Spilrain commented that even on paper, the single-fluid systems, with many optimistic assumptions, have calculated thermal efficiencies on the order of 14 percent. This is insufficient for base load considerations except as a topping plant to a high temperature steam plant. It was pointed out by Radebold, however, that the single-fluid cycles have impressive power densities. As such, these cycles may have limited applicability to situations where low weight and low volume are an overriding consideration, such as in space.

Petrick (USA) discussed his effort on the two-phase liquid metal cycle employing mixtures of liquid metals and noble gases as a two-phase working fluid. Typical liquid-metals might be sodium or lithium (depending on the source temperature) while the noble gas constituent would be argon or helium. The two-phase liquid metal MHD cycles have a decided advantage over the condensing ejector cycles in terms of thermal efficiency. Petrick's studies indicate overall cycle efficiencies as high as 50 percent for lithium-helium working fluid. The efficiency of the two-phase systems, however, is particularly sensitive to the difference in phase velocity in the generator (slip) and the ability to expand the flow to high void fractions (0.65 entrance to 0.85 exit) in the MHD generator. Petrick stated that his program was designed to experimentally examine these uncertainties in the immediate future.

Kant, Sterlini and Bidard (France) reported considerable progress on the construction of test facilities in France related to liquid metal MHD research. This was surprising since France has officially phased out of MHD research while the Kant test facility and the Bidard test facility represent investments on the order of one-half to one million dollars each over the time period of about a year. Kant reported interest in testing single-phase generators while Bidard and Sterlini are only interested in the two-phase system, similar to Petrick's.

Aladiev (USSR) reported on the operation of a complete MHD loop which produces electrical power directly from thermal energy. The loop operates with potassium as the working fluid at a top temperature of 1600°F. A single-phase cycle (condensing ejector) is employed and the output electrical power is 2kW. Aladiev did not willingly comment on the overall efficiency, but unofficial comments indicate about 2-3 percent thermal. This is what would be expected from a condensing ejector cycle at this power level.

Summary

The principal development was the completion of the Soviet U-25 plant. This confirms that sufficient experience with open-cycle MHD

)r some countries to proceed with the construction and evaluation of complete MHD pilot plants. Open-cycle base load plants appear to be economically competitive with other power producing schemes in some countries and can possibly attain efficiencies of 50 percent. It was further stated that open-cycle MHD plants can help reduce both thermal and air pollution problems connected with base load power generation.

For close-cycle MHD, the most noteworthy results are the extraction of a significant amount of enthalpy from the gas in the form of electrical power (10 percent) in a large generator and experimental results that show electrical isolation of the plasma from ground. It now appears possible that with the reduction of electrode voltage drops and proper channel geometry, the enthalpy extraction can be increased to 15 or 20 percent at generator turbine efficiencies exceeding 60 percent. This would make the non-equilibrium generator attractive for base load power generation as a topping cycle.

The condensing ejector-type of liquid-metal MHD cycle appears to be limited in efficiency to less than 10 percent thermal. This would appear to rule out these cycles for base load power generation. The high-power density of these cycles, however, may be attractive in situations where efficiency is not a primary factor. The two-phase liquid-metal MHD cycle, however, shows promise of high efficiency and good power density, and may possibly have application as a topping cycle or as a base load independent plant.

Neon Tested as Breathing Gas for Deep Divers

The use of crude neon instead of helium as the major breathing gas component in deep saturation dives has been proven feasible during initial Navy experiments with human subjects.

Crude neon, which consists of 72 to 78 percent neon with helium making up the balance, does not create the speech problem associated with helium, and there is less body heat loss than with helium. However, neon's greater density increases the work breathing at great depths, and helium would continue to be the preferred gas at such depths for the present.

A long-range study of the use of crude neon was initiated in 1964 at Ocean Systems, Inc., Tarrytown, New York, funded by both the Office of Naval Research and the Bureau of Medicine and Surgery. The program started with single-celled organisms and animal experiments. In 1969, crude neon was used briefly during a simulated excursion dive by four men to 825 feet in a pressure chamber test conducted by the Naval Medical Research Institute, Bethesda, Maryland.

Early this year Ocean Systems in its study ran a more complex experiment designed to test the ability of divers to engage in work while breathing a neon-oxygen mixture.

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SKYHOOK

CDR William Wilson
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The ONR SKYHOOK Program has passed another scientific milestone with the completion of the 1971 balloon flight series which were conducted from the Churchill Research Range in northern Manitoba, Canada. This season marked the completion of the twelfth successful year of high-altitude balloon-borne research from that location. The program is not limited to flight operations in high latitudes but is a global program with the capability to provide total balloon flight support for government agencies and universities.

As SKYHOOK enters the twenty-sixth year of continuous operation, it is found that the program has grown to include routine southern hemisphere balloon flights and rapid responsiveness to requests for flights in extremely remote polar areas. To aid in identifying each series of balloon flights, the operation is named for the geographic location; thus, SKYHOOK Churchill may be added to the list which includes SKYHOOK: Panama, India, Australia, Iceland, Peru and many sites within the North American continent.

Background

The SKYHOOK Churchill program originated in 1959 when five scientific experiments were flown on rather small polyethylene balloons. Subsequent years have seen an increasing number of scientists participating in the program and great technological advances in ballooning, which have been developed in response to demands from the scientific community. Also, there has been considerable change in the management of the Range during this period. The original organization of the Canadian Defense Research, Northern Laboratory, which was under military control, has shifted to the present civilian management of the Churchill Research Range (CRR), which was officially established in 1962. General management of CRR was assumed by the National Research Council of Canada in 1965 and continued under the joint funding of that agency and NASA until 1970. CRR is now operated at a reduced level of acticity under the National Research Council of Canada with limited or no outside funding.

Flight Operations

The SKYHOOK Churchill 1971 field program began 29 June which was slightly later than the normal commencement date. The starting time was established by considering meteorological and fiscal constraints and choosing the best five week period for balloon flights. In years past, the pace of operations was more leisurely and in general 20 to 30 balloons were flown over an eight to ten week period. For the past two seasons the total number of flights has declined, with the result that the program has been compressed to get maximum scientific data in the shortest possible time. The pace for this season was such that a scientific payload was launched about every two days with an average flight time of approximately 20 hours. Several of the flights had unique scientific requirements and for the first time two major experiments were flown on the same balloon. It is noteworthy that while only 13 balloons were flown, 29 separate scientific experiments were performed. Whenever possible, a single dedicated flight will be assigned a "piggy-back" payload; which is a small, light and uncomplicated addition to the main experimental payload. As in past years, some of the "piggy-back" payloads were provided by university groups from other countries; among this year's participants were Rikkyo University, Tokyo, Japan.

All balloon launches occur in an area near the main runways of Churchill Research Range. Generally, the balloons are released in the early hours of the morning when surface winds are very light or completely calm. The scientific requirements of the experiment dictate the altitude at which the balloon must fly. The payload gross weight determines the volume of the balloon which is to satisfy both specific requirements. The system is launched (as seen in Figure 1) with a small volume of helium gas which has sufficient lifting force to lift the gross weight of the system (balloon, payload, ballast and instrumentation) to the designed or theoretical altitude. When the balloon obtains theoretical float altitude, it achieves a state of equilibrium with the surrounding stratospheric air-mass, establishing zero pressure differential across the balloon wall. This type of balloon is commonly referred to as "zero-pressure" balloons.

It is possible to alter the altitude of the balloons once the theoretical ceiling has been reached. On command from the master ground station, a special valve, which is located in the metal top plate of the balloon, can be driven to the open position thus releasing some lifting gas. The amount of lift that is decreased from the system is measured by the length of time the valve is commanded open. Normally the balloon system is "stepped down" at 15 minute intervals of "valve open" command. Using this method, an experimenter can gain exposure at several altitudes during the same flight. While this operation requires an artful touch and more than a little skill, it is considered a routine operation for SKYHOOK flights.

Complete flight following services are provided from both the master station, which is located at CRR, and a down range station, which is

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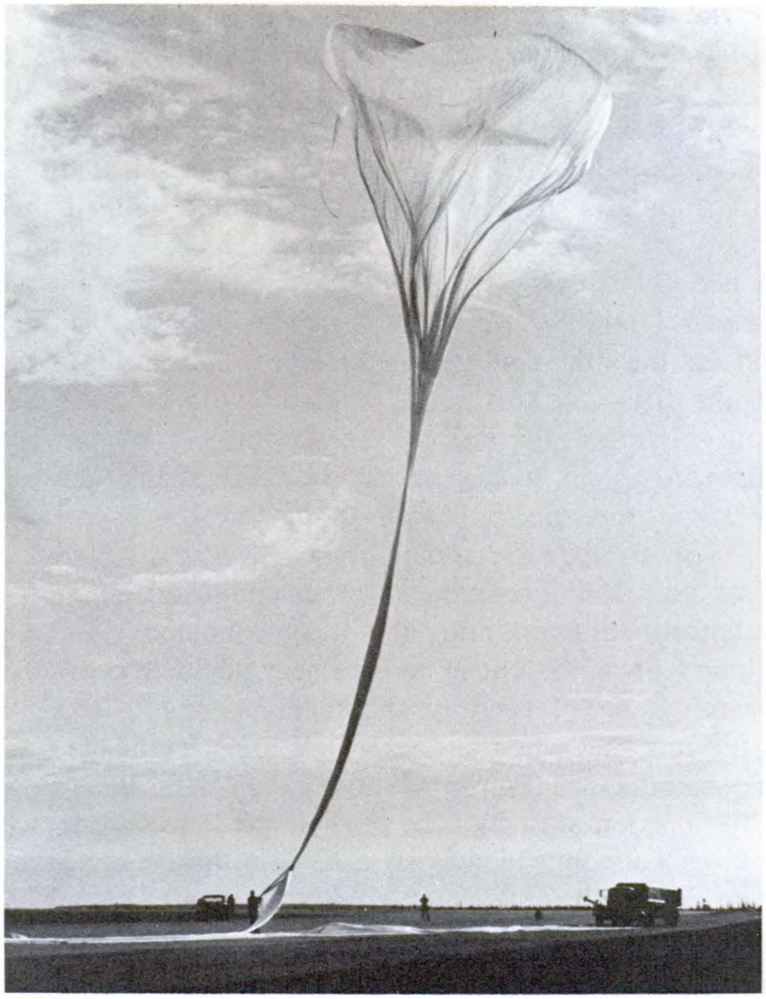

Figure 1 — Launching a large volume scientific balloon at Churchill Research Range

located at Uranium City, Saskatchewan, some 600 miles away. The balloon system is electronically monitored so that a continuous position and altitude track are available to both stations. As the flight nears Uranium City and the Athabaska River network, the recovery aircraft commences a search for the balloon and its valuable payload. Initially, the balloon is located by electronic means. Once visual contact is established, the flight is terminated by command from the pursuing aircraft. Termination results in destruction of the balloon and parachute descent of the payload. Visual confirmation of the balloon descending is an important safety factor and precise location of the payload impact point is of prime importance to the investigator. Normally, the payload is recovered from the wilderness by helicopter. For the past several years, the SKYHOOK recovery team has employed a Jet Ranger helicopter, which can expeditiously recover payloads up to about 1000 pounds in weight. Speedy recovery means shorter time between flights and more scientific accomplishment per unit time. During the past six years not a single payload has been lost on a SKYHOOK Churchill flight.

Highlights

The 1971 flight series was not without some triumphs and disappointments. Although fewer balloons were flown this year, the balloon volume was significantly larger and the program costs were about constant. The largest balloons used were 33.4 million cubic feet in volume, which were the largest balloons ever used in the Churchill program. Unfortunately, two of these giant aerostats failed as they were launched under ideal weather conditions. Because the balloons were on the outer edge of the state-of-the-art of balloon manufacture, the loss was accepted philosophically and re-flight of the scientific payload was accomplished on another model balloon.

For the first time at CRR, balloons in the 18 million cubic foot class were flown successfully, thus allowing cosmic ray data to be gathered at altitudes in excess of 142,000 feet. Quite aside from the altitude records established and the noteworthy recovery rate was the outstanding spirit of cooperation shown by the various scientific parties and the splendid organizational effort displayed by the flight service contractor, Raven Industries, Sioux Falls, South Dakota. And so the SKYHOOK 1971 Churchill program is complete; thirteen flights were attempted and 29 experiments were conducted with a wealth of scientific data gathered—another scientific milestone.

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In a simulated excursion dive down to a depth of 400 feet two men breathed the mixture for 30-minute periods and performed various exercises and tasks. In general the performance tests showed no measurable difference between helium and crude neon as inert gas components.

In an expansion of this work a second experiment with crude neon was conducted as part of a 24-day saturation dive just completed in which four subjects in a dry pressure chamber descended step-wise to a depth of 1,200 feet. The dive was directed by Dr. C. J. Lambertsen at the University of Pennsylvania Medical Center in a program jointly sponsored by the Office of Naval Research and the Bureau of Medicine and Surgery.

During the descent, crude neon was introduced into the helium-oxygen mixture for short periods. Since the neon is heavier than helium, this had the effect of increasing the gas density of the mixture. The experiment therefore additionally provided the first

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Methods for Analysis of Fleet Tactical Effectiveness and Performance (MAFTEP)

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Introduction

One cannot help but feel that much of the previous work done in measuring fleet tactical effectiveness and performance has expended a great deal of effort in arriving at answers without first framing the proper questions or formulating the correct methodology. This article is a description of a research program conducted by the Director, Naval Analysis Programs (Code 462) under the Naval Applications and Analysis Division (Code 460) which seeks to overcome this basic problem.

Background

MAFTEP had, as its precursor, the Fleet ASW Data Analysis Program (FADAP). FADAP research designed and developed a standardized methodology for the collection and processing of data from anti-submarine warfare (ASW) operations and exercises. Procedures developed under FADAP research are now operational. ASW exercises are reconstructed at major fleet commands and data is collected at the Naval ASW Data Center, White Oak, Maryland. Managerial responsibility has been transferred to the Naval ASW Data Analysis Division of the Anti-Submarine Warfare Project Office (ASW-144). Experience gained during the evolution of FADAP from a research to operational system indicated that extensive analytic work was required to complement and capitalize on large data bases, such as FADAP, in order to provide more accurate estimates of effectiveness and to reduce the degree of uncertainty in future Navy system selections. The objective of MAFTEP is to utilize fundamental techniques of mathematics, operations research, information sciences, as well as those of engineering and the physical sciences to develop the basic methodology and methods which will enable us to "frame the proper questions." Since the program covers many relevant aspects of fleet tactical effectiveness, any models or methods that are developed must be tested with realistic data obtained from fleet operations or scientific observations.

MAFTEP Project Areas

Since the inception of the MAFTEP project in 1970 a number of research projects have been funded. However, since these projects were either FADAP follow up or were transitional, they will not be discussed here.* Research in MAFTEP initially will not cover every problem in performance, effectiveness and readiness analysis. At present, eleven viable topics have been identified which are relevant to current Navy problems.

TOPIC I: *Comparative Analysis of Objective Functions and Criteria of Performance Used in Naval Analysis Studies*

Current study techniques use a wide variety of mathematical terms incorporating probability to describe expected performance. For this reason, it is often impossible to compare the results of several studies concerned with the same mission, or to identify the data and manipulations that support the study conclusions. Work in this topic has been assigned to two firms: Ketron, Inc. of Malvern, Pennsylvania and Ultrasystems of Newport Beach, California.

The purpose of the Ketron contract is to perform a comparative analysis of objective functions and measures of effectiveness used in naval exercises, simulations and studies. Objective functions used in mission and weapon system analyses will be defined and critically evaluated and ranked in perspective with regard to their mathematical precision, operational applicability, and general relevance. This comparative analysis will include a discussion of the relative advantages and disadvantages, pitfalls in usage, and placement of these functions in the decision making process. The result will be a definite catalog for use by military commanders and their staffs in the evaluation of studies.

The Ultrasystems study and comparison of objective functions and performance measures used in major Navy studies is intended for use by analysis staffs. They will undertake the generalization of objective functions within missions and assess mission types based on mathematical procedures such as minimax games, utility theory, and statistical decision theory. A set of principles will be derived for defining measures of effectiveness and for establishing resource measures of effectiveness relationships using a common language and data structures compatible with the type being collected in fleet exercises. Example formulations of objective functions, criteria for their selection, and limitations on their use will appear in a guidebook for naval analysts. Specific attention

*Readers desiring additional information should request a copy of "Plans for New Studies and Analysis Work in ONR Project NR 364-000" of 15 May 1970 from ONR Code 462.

will be given to procedures for recognizing and reconciling multiple effectiveness measures, where the units are incommensurate, into composite measures.

TOPIC II: *Statistical Methods for Design and Testing of Fleet Exercise Data*

It is expected that work under this topic will be based on recent developments in sampling, analysis of variance, and computer-assisted testing of multiple hypotheses. Experience gained in the FADAP program and similar projects will be used in order to develop standardized tests that can be used to evaluate in advance the data plans for a proposed exercise, and to specify a set of post-exercise analyses that can examine the quality, consistency, and homogeneity of observed data. It is intended that the procedures developed under this topic should help identify errors and inconsistencies in large volumes of data (from automatic recorders as well as manually-recorded raw data forms) required in projected Navy-wide performance data systems.

TOPIC III: *Analysis of Countermeasures, Deception Devices and Methodology Involving False Information*

Work in this topic will have the objective of developing ways of collecting data and analyzing countermeasures, deception devices, and tactics which are intended to deceive. Past studies have tended to concentrate on specific equipment, or strategies. As a result, there is no existing general model nor manual on the data required to evaluate such phenomena. The decision maker or analyst evaluating a scheme intended to generate or see through false information lacks a starting base line, standard measures of performance, and a methodology for evaluating the cumulative effect of false and true data inputs. This topic is of increasing importance as locating and tracking devices become more sophisticated and as coordinated operations yield opportunities for complex planned deceptions.

TOPIC IV: *Methods for Obtaining and Analyzing Human Judgment Data From Fleet Exercises*

Current methods of analyzing fleet exercises either assume optimal human judgment or produce and historical record of decisions. In order to conduct penetrating analyses of fleet exercises it will be necessary to consider both the planning and decisions made during operations as an endogenous variable. MAFTEP seeks to develop methods for definition, collection, and analysis of data on human judgments which occur in the planning stage and the actual at-sea exercises.

The problem posed in bounding this problem is in itself difficult. For that reason, it was decided that initial work could be served best by investigating a subset of the topic. This is being done in conjunction with Engineering Psychology Programs (ONR Code 455) and it seeks to determine the effects of various operational conditions on sonar operator detection performance to form a basis upon which to expand. Using several different scenarios, Human Factors Research of Goleta, California will develop and validate a model of sonar operator performance as a theoretical means for differentiating among operational situations, and for relating performance observed in experimental situations to expected performance in actual operational situations.

TOPIC V: *Methods for Combining Qualitative and Quantitative Statements on Fleet Performance*

A frequent criticism of effectiveness models is that they do not produce results which can be verified from fleet experience, such as exercises, or even controlled tests. In order to overcome this deficiency, MAFTEP seeks to perform a comparative analyses of the methods, procedures, and judgments which produce qualitative and quantitative statements about overall performance. Useful ways are being sought to integrate overall readiness ratings, individual Operational Readiness Inspections, O&R reports, fleet exercise reports, and equipment failure reports.

Apart from the physical and mathematical characteristics of an effectiveness model and the environmental data which it uses, the model should be an "ideal" representation of the physical process which it represents. The real world consists of a series of problems related to equipment and crew. In practice systems either operate, operate with decreased performance, or do not operate. The equipment and personnel operate with varying efficiency. Analytic Sciences Corporation of Washington, D.C. will treat reliability of airborne weapons systems and their components as a function of both catastrophic failure in terms of mean time between failure and dynamic aging which corresponds to equipment which, although functioning, is no longer operating at design efficiency. The definition of this combination of types of reliabilities and a recommended method of applying it to models will lead toward a better understanding of tactical effectiveness and improved correlation with at-sea exercise data.

TOPIC VI: *Method for Incorporating Time-Preference Judgments in Weapon Systems Studies*

In assessing alternative options for allocation of resources in weapon systems studies, the decision maker is often influenced by a time-phased sequence of benefits or costs, rather than by the overall benefit/cost ratio. These preferences, while legitimate and valid inputs to the decision usually are not explicitly stated and rarely, if ever, are treated analytically. The development of a methodology to treat these preferences in an explicit and quantitative fashion would increase the efficiency of the military decision-making process in two ways: *i.e.*, by allowing a consistent set of criteria to be used in a variety of studies and by facilitating review at higher management levels.

TRW Systems Group of McLean, Virginia will develop a methodology based on elements of decision theory and utility theory, which will permit discounting of future benefit streams to determine the present value of time-phased resource allocation options. In addition, an attempt will be made to enable this methodology to be applied a posteriori to previous analysis to determine what combination of discount rates and utility functions are consistent with previous study recommendations.

TOPIC VII: *Analysis and Definition of False Contact Probabilities*

Current models used to measure and predict the performance of ASW forces do not adequately handle the frequent "false contact" or "false target" events, *i.e.*, those occasions when a sensor contact is reported and treated as a submarine threat for some time, but later or in reconstruction are determined to be non-submarine. Some models often treat these occurrences as an independent set of events, at some simple average rate; however, they fail to collect and utilize the associated information to calculate probabilities as a function of many factors or to place them in a sequential decision model in order to evaluate tactical doctrine and equipments.

Daniel H. Wagner, Associates, Inc. of Paoli, Pennsylvania will analyse information on such events and identify those parameters now neglected such as the maneuvering situation at the time of the reported target and type of mission objective. The project will include the formulating and testing sets of mathematically more complex models believed capable of representing and summarizing the variety of incidents observed in at-sea exercises. The data will be suitable for improved versions of ASW Master Models being produced by the Director Antisubmarine Warfare Programs (Op-95) and the Systems Analysis Office of the Anti-Submarine Warfare Project Office (ASW-14).

TOPIC VIII: *Dynamic Analysis of Anti-Submarine Warfare*

Historically, ASW systems have been designated with the torpedo delivering submarine as the threat. As a result analysis methods used for ASW systems have evolved which follow a classic pattern. The most common measure of ASW system effectiveness is the conditional probability that an ASW system will detect, classify, localize, and kill a target. Implicit in this form is the assumption that the reaction time of as ASW system in a multiple contact environment can, somehow, be satisfied, and thus the time-dependent dynamics of the situation can be suppressed.

Stanford Research Institute of Menlo Park, California will seek to define those measures of effectiveness that integrate the functional measures of ASW performance with the dynamic aspects of system operations, formulate ASW operational processes in a queuing terminology, assess the adequacy of this terminology, and recommend a conceptual model structure and associated ASW system evaluation. This structure will consider coordination and interference between commands, platforms, sensors and weapon systems.

The problem of ASW analysis as viewed by a submarine commander while having the same objectives and limitations described in the previous paragraph may be viewed as a self-contained single unit ASW system. For this reason, Operations Research, Inc. of Silver Spring, Maryland, will study the problem from the submarine point of view in order to provide an alternative to the simple one-way sequence of detection, classification, localization, approach, attack and kill because these functions can overlap, occur in different sequences, have multiple occurrences or exist in the presence of false information.

TOPIC VIX: *Models for Evaluating Performance of Navy Forces in Coordinated Operations*

The objective of this topic is to develop the basic structure of models capable of representing the coordinated operations of a number of platforms and weapons systems. Such problems are sometimes called multi-sensor system effectiveness modelling.

Methods are needed for comparing the performance of forces employing various combinations of sensors and weapons when the degree of communications and coordinated action has a major effect. In ASW the presence of submarines may be inferred statistically from aircraft, surface ship, submarine, buoy, satellite, and surveillance information. The time, facilities, and capacity for communications, processing, and interpretation of, action response to such information is as important as the individual system performance parameters. Recognizing the difficulties involved in estimating the effect of such probabilistic interactions combined with the variety of threats and environmental conditions under which the interactions may occur, this task seeks to develop feasible designs for models that explicitly include probabilities about sensor performance, communication, command-control functions, and weapons parameters. The study will hopefully develop ways of testing the feasibility and value of team action.

TOPIC X: *Measurement of Human Factors in Navy Performance Analysis*

Work in this topic is intended to develop methods for collecting standardized data on human performance from fleet exercises, and for integrating such data with existing and planned data files. Although some information on expected and observed human performance are available in fleet exercise data and reports, detailed, standardized methods should be developed for statistical analyses aggregating the results of many exercises in terms of parameters of personnel training skills, information time delays, and other human factors. The goal of this task is to develop a comprehensive list of the types of human factor data that might be useful to explain variations in fleet performance, and to develop by means of specific examples a basic plan and methodology for the processing and analyses of such data. Case studies may be included to indicate the kind of conclusions that could be drawn and the value to the future Navy of such evidence in policy questions.

TOPIC XI: *Cost-Effectiveness Systems Analysis of the Overall Life Cycle Process of Hull, Mechanical and Electrical Equipment*

This analysis will examine the entire process by which design, development, procurement, fleet introduction, use, overhaul, and replacement decisions are made for hull, mechanical and electrical equipment.

The intent is to develop an analytic system for the function performed at each echelon in order to provide the capability of evaluating current and potential alternative systems for organizing and carrying out these functions.

(Continued from Page 11)

significant data on how well divers can perform as the gas in their lungs becomes denser due to the greatly increased pressures at depths well below 1,000 feet. It has been feared that the resulting increased effort required to breathe might limit the performance of useful work at these depths.

At a depth of 1,200 feet the subjects breathing neon had a gas density in their lungs equivalent to breathing helium at a depth of 5,000 feet. Significantly, it was found that the subjects were able to compensate within limits for the physical and mental handicaps produced by this dense atmosphere and to perform some useful work. In actually penetrating to these depths, however, there may develop other physiological or psychological problems about which no pertinent scientific data are presently available.

On the Naval Research Reserve

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University of Rochester
Rochester, New York 14627

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5945 N.W. Rosewood Drive
Corvallis, Oregon 97330

Deep Ocean Study Expands

Philosophers of an earlier age attempted to describe the universe in terms of the harmonic relationships of music. Scientists and engineers today at the Rosenstiel School of Marine and Atmospheric Science of the University of Miami are sending and receiving continuous waves of sound across a fixed range through miles of seawater for periods as long as 25 months in an effort to establish and describe relationships between variations in the amplitude and phase of transmitted sound and variations in the ocean environment. The way a deep-pitched hum emanating from an underwater loudspeaker on one side of the Gulf

Stream sounds by the time it reaches sensitive recording instruments on the other side can tell them a lot about conditions in between.

Sound will traverse great distance underwater, and the deep sound channels of the sea echo with the clicks, squeaks and whistles of animals, the whir of propellers, and the rumbles of falling rocks. Oceanographers and sonar operators have known for years that the speed of sound through water varies with depth, density, temperature and pressure. In 1961, Dr. John C. Steinberg, a research physicist at the Miami School, saw possibilities for learning about these effects by setting up an acoustic range or sound path between Miami and Bimini, a Bahamian island 43 nautical miles across the Straits of Florida. With a sound source installed 65 feet below the surface of the sea on the continental slope on the Miami side of the Straits, the fixed receiving hydrophones off Bimini, Dr. Steinberg hoped to reduce variability that could be traced to source and receiver motions.

The Office of Naval Research (ONR) considered the plan, found it had merit; with ONR support, Dr. Steinberg and co-workers at the School of Marine and Atmospheric Science set out to take measurements along the proposed path to determine specifications for the undersea sound system. A transducer to transform electrical current into mechanical vibrations would be surrounded by a 25-foot frame of air-filled pipes to act as a focusing reflector. A hydrophone, or underwater microphone, would be placed in front of the source as a monitor, and bottom-mounted hydrophones located at distances of 3, 7, 42 and 43 miles from the projector would provide information concerning modulations of the acoustic signal. To minimize drift, a precision-controlled signal of 420 Hertz was chosen. An essential part of the propagation study would be the instrumentation for continuous and simultaneous readings of environmental factors.

Professor Morton Kronengold, the principal investigator, who has been working with the project since its inception said that the design philosophy was based on the concept of a system capable of providing measurements of a number of parameters on a continuous basis for periods exceeding one year. On this capability would rest the success of experiments which involve the generation and analysis of continuous time series, designed to study acoustic propagation over daily, lunar and seasonal cycles.

A number of years, and the skills of many investigators trained in different aspects of underwater acoustics, oceanography and engineering were required to establish the range. A way of receiving and processing the flood of incoming data had to be innovated. Here engineers based inland at the University of Michigan Cooley Electronic Laboratories could be of help. Dr. T. G. Birdsall, a leader in the field of signal processing, realizing the opportunities for research the fixed installations could offer in the study of acoustics, joined with the researchers at the University of Miami, now called "The Acoustics Group," in a combined effort named "Project MIMI" for Miami-Michigan.

More time was needed to work out and learn from the problems of conducting very long transmission tests. This experimental period brought satisfaction to William Green, University of Miami engineer who planned and supervised ocean installations, and Jack Loewenstein, who with his staff, designed the onshore electronic systems.

Now with the technology of the sound probe reliable data correlations are being revealed by on-line analog and digital computers in the laboratory in Miami. Investigators are constructing models relating acoustic fluctuations to water temperature, tide height, and wind direction. A very strong relation with the ebb and flow of the tides in the Straits has been noted, along with significant temperature dependence.

A measure of the success of Project MIMI was the recent announcement by Dr. F. G. Walton Smith, Dean of the School of Marine and Atmospheric Science, of the extension of the acoustic propagation study into the west central Atlantic, from Eleuthera in the Bahamas to Bermuda, a sound path of 750 miles. Dr. Smith called the deep ocean study a natural outgrowth of the acoustical-environmental research initiated in the Straits of Florida, and lauded the multidisciplinary enterprise that made it possible.

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Dr. Scott Daubin, head of ocean engineering at the School, described the project as developing a "macro-tool" that will enable marine and atmospheric scientists of the future to recognize large scale environmental phenomena—circulations of the sea, air-sea interactions—that ordinarily require many observations over long periods and vast distances.

Porpoise Taught to Drive Away Shark

Porpoises apparently can be trained to drive off sharks and consequently could act as bodyguards to protect divers and other Navy personnel from shark attacks, a Navy study shows.

Working under contract to the Office of Naval Research, scientists at the Mote Marine Laboratory, Sarasota, Florida, have been able to teach a porpoise to move aggressively toward a shark on command and drive him away. The study is part of a broad program of research aimed at a better understanding of the biology and behavior of sharks in order to develop effective defense against them.

Sharks present a possible hazard to naval personnel engaged in swimming, diving, salvage or rescue work or survival at sea. Presently, there are few effective measures of protection against them.

Since porpoises have never been observed to be aggressive toward sharks, they have to be taught to attack them. Training was conducted in a specially designed experimental pool of the Mote Laboratory, using a 450-pound Atlantic bottlenose dolphin named Simo and brown sharks.

After several weeks of conditioning, Simo upon command readily approached and drove away a seven-foot shark introduced in the pool from an adjacent channel. The commands were in the form of acoustic signals from an underwater beacon.

Because of their intelligence and adaptability, porpoises have previously been employed experimentally to perform a variety of useful tasks such as carrying tools and messages, turning valves, or locating "lost" equipment and divers. This is the first time, however, that they have been trained to ward off sharks under experimental conditions.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Arlington, Va. 22217. Requests for subscriptions should be directed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.75 per year in the U.S. and Canada; $2.25 per year, foreign; $0.20 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

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One of the balloon flights conducted during the 1971 Churchill program. *See page 8.*

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