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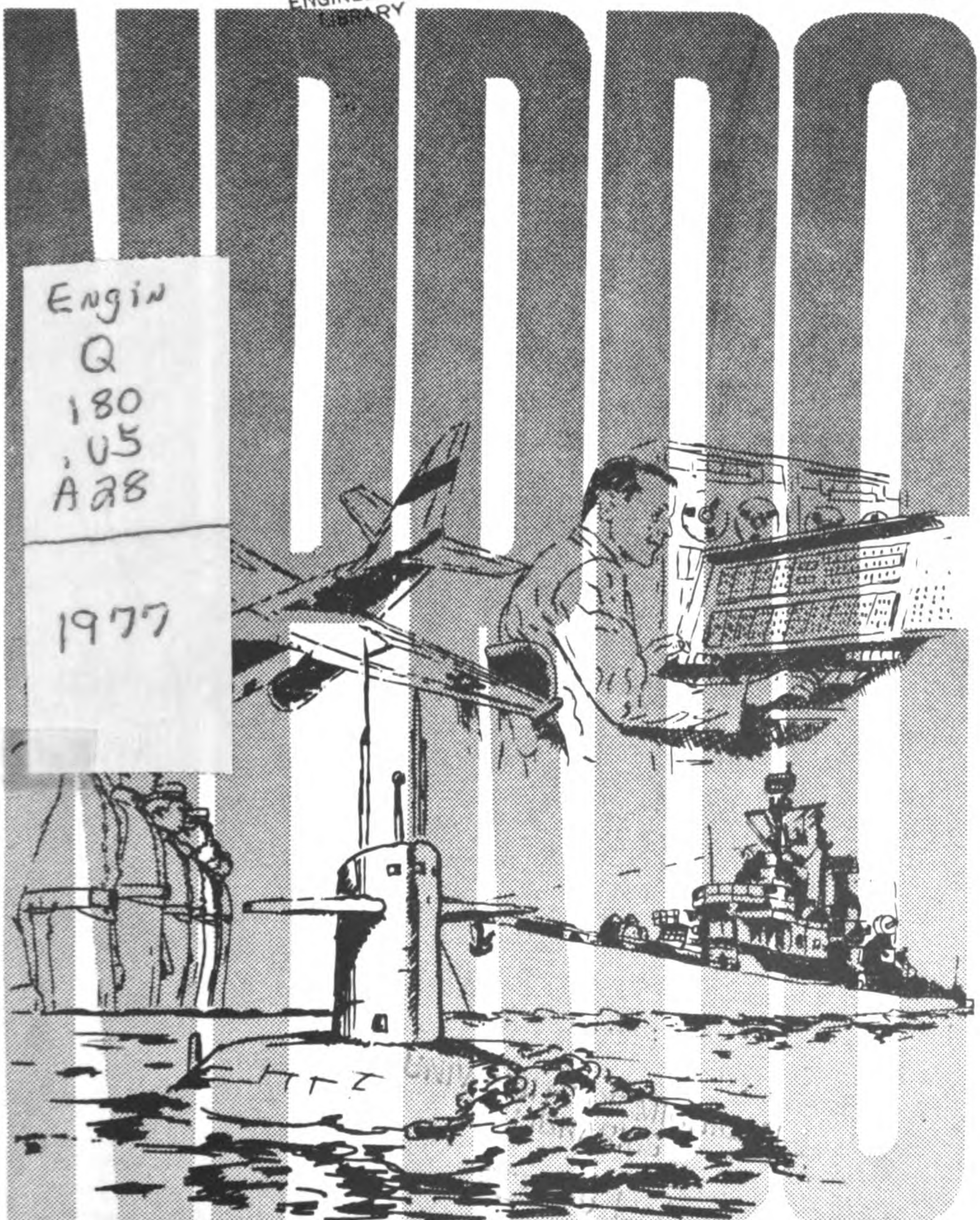

PROFILES IN SCIENCE

Dr. Marvin D. Dunnette

Dr. Marvin D. Dunnette is Professor of Psychology and Director of the Graduate Program in Industrial and Organizational Psychology at the University of Minnesota. He also is President of Personnel Decisions Research Institute (PDRI), a nonprofit research foundation devoted to behavioral science research in areas relevant to societal needs and problems.

From 1960-1974, he was Principal Investigator and Director of the Center for the Study of Organizational Performance and Human Effectiveness which was supported by several continuing grants from ONR. Over the last several years, he and his colleagues at PDRI have studied organizational effectiveness in the Navy, done developmental work on a Personnel Status Index for the Navy, and are currently carrying out a large-scale study of Navy and Marine Corps recruiters which is supported by the Navy Personnel Research and Development Center.

Dr. Dunnette is the editor of the *Handbook of Industrial and Organizational Psychology* which was published early in 1976 by Rand McNally Co. He also edited *Work and Non-Work in the Year* 2001 consisting of a series of original papers commissioned with funds granted by ONR's Division of Psychological Sciences and is author of the widely used textbook *Personnel Selection and Placement.*

At present, Dr. Dunnette's major research activities involve the prediction of patterns of drug resistance/use/abuse among adolescents and the development of improved methods of analyzing job and task effectiveness and the correlates of such effectiveness in organizational work settings.

PREFACE

The Navy Personnel Research and Development Center was established in May 1973 as the principal Navy activity for conducting human resources RDT&E in the areas of manpower, personnel, education, and training, and to serve as the coordinating activity for all human resources RDT&E for the Navy. Originally, the Center was placed under the management control of the Chief of Naval Personnel. However, in May 1975, management control shifted to the Chief of Naval Material. At this time, the Center's mission was expanded to include RDT&E support and services to the Systems Commands and to the CNM laboratories as necessary to augment and stimulate human factors efforts in the design, development, test, and evaluation of new systems for operational use.

NPRDC presently has a staff of more than 300, including a military contingent of approximately 30 officers and enlisted personnel. Disciplines represented by this group include psychology, mathematics, and management sciences. In addition to the central offices and laboratory facilities located on Point Loma, the Center operates field offices in Washington, D.C.; Norfolk, Virginia; Memphis, Tennessee; Moffett Field, California; Pensacola, Florida; and Jacksonville, Florida. These sites were established in order to facilitate interaction with mission sponsors and their subordinate functional organizations who are responsible for programming of R&D programs in the manpower, personnel, human factors, and education/training areas.

The scientific efforts are divided among 11 major program areas: Management of People and Organizations, Measurement of Job Performance, Management Systems, Development of Training Technology, Information and Decision Processes, Test and Application of Training Systems, Attitude and Motivation, Performance Enhancement, Acquisition and Initial Service, Design of Manned Systems, and Applied Psychobiology.

A fundamental strategy used by NPRDC in conducting people R&D is by viewing Navy personnel–during and after service–as a system; that is, by studying the various components (e.g., selection, training, performance) of this system in the interactive setting in which they reside. The expected consequences of the approach is a well planned, timely, and relevant R&D program to help identify, develop, and maintain an increasingly qualified and effective force of people to man the Navy over the next decade, and to do this in the face of changing social trends, fluctuating manpower pools (in quantity and quality), and increasing numbers of complex jobs and growing manpower costs. Further, through the realization of associated goals, it is hoped that all parts of the Navy will come to recognize the Center as their principal agent in people R&D and as a source of information and expertise in those matters relating to the personnel systems.

The articles in this issue of Naval Research Reviews touch upon a sample of the Center's total work during its formative years. Appreciation is expressed to the editorial staff of the Reviews for providing this opportunity.

Selection Procedures at the Naval Academy

Norman Abrahams
Acquisition and Initial Service Program

The Navy Personnel Research and Development Center has developed selection techniques that have enabled the U.S. Naval Academy to meet two major admissions objectives: (1) lowering the rate of voluntary resignations and (2) reaching the 80 percent selection of engineering, mathematics, and science majors (directed by the Bureau of Naval Personnel). The selection techniques described in this article are the Combined Disenrollment (DIS) Scale and the Engineering-Science (E-S) Scale.

Background

The U.S. Naval Academy is a major source of commissioned officers (Figure 1). Every year, over 800 midshipmen are commissioned at an average cost of $70,000. Consequently, it is imperative that the several thousand young men and women who seek admission each year be carefully screened to ensure that appointments be given to those who are most likely to succeed at the academy and as officers.

In the past, the Academy's primary screening device has been a quantitative index called the Candidate Multiple, made up of a weighted composite of seven selection variables, including test scores, high school standing, high school activities, and recommendations. Those variables reflecting an academic component (i.e., test scores and high school records) received about two-thirds of the weight, while high school activities and recommendations received the remaining one-third. Through the use of rigorous selection procedures that included the Candidate Multiple, about 20 to 25 percent of the applicants were appointed to the Academy. However, in spite of this rigorous selection system, one of every three midshipmen failed to complete Academy training. It is apparent from these statistics that improvement in the selection system for the Academy would be desirable.

All midshipmen must select a major academic field in the spring of the "plebe" year, which is, in contrast to civilian colleges, relatively early in the college career. Once this choice has been made, it is very difficult to switch to a different major—again in contrast with civilian colleges. Thus, it is very important that the initial choice be an appropriate one—for both the midshipman and the Navy.

Until recently, the choice of major was made from four broad groups: (1) Engineering, (2) Science, (3) U.S. and International Studies/English and History,

Figure 1 — The U.S. Naval Academy is a major source of comissioned naval officers. Applicants are selected by a Candidate Multiple Composite that includes the Combined Disenrollment and Science-Engineering Scales developed by NPRDC.

and (4) Management. However, these groups have now been restructured into three areas: (1) Engineering-Weapons, (2) Mathematics–Science, and (3) Humanities-Social Science (which includes the management curriculum). Further, the Academy was directed by the Bureau of Naval Personnel to increase the proportion of engineering and science majors from 65 percent to approximately 80 percent. This increase is necessary if the Navy is to meet present demands and future requirements for high quality naval officers with engineering and science backgrounds. The rationale behind this requirement is spelled out in *The Majors Programs* (1974), a Naval Academy publication which is provided to all applicants:

> The Naval Academy policy on the selection of majors is clear. Each midshipmen selects a major which will meet the needs of the Navy and at the same time be interesting to him. The needs of the Navy take first priority and it has been determined that 80 percent of the Class shall take a technical major, i.e., Group I (Engineering-Weapons) or II (Mathematics-Science) and 20 percent may choose Group III (Humanities-Social Science). Hopefully, the selection of majors by the Class of 1978 will meet the 80/20 quota. If the desired distribution is not obtained by an open, free selection process, steps will be taken to adjust the distribution to meet the Navy goals. (p. 9)

If the characteristics of incoming midshipmen remain the same (which is likely to be the case), there is little reason to expect that more of them will select engineering or science majors. On the other hand, if they are placed involuntarily into technical areas, whether by undue pressures, lottery, or other questionable means, serious losses to the Navy could result–in terms of premature separation, academic failures, frequent requests for change in major, and personal dissatisfaction. These losses could be minimized if Academy selection procedures could be modified so that those selected would be more likely to choose technical majors. This approach would allow the voluntary system of major selection to be retained and, at the same time, meet selection requirements.

Strong Vocational Interest Blank

The Strong Vocational Interest Blank (SVIB) was developed by E. K. Strong and has been used successfully in civilian occupational research over the last 40 years. The 1966 version of the SVIB has been administered to Naval Academy midshipmen since that year as part of an NPRDC research program. In 1966, 1967, and 1968, all midshipmen completed the SVIB during their first week at the Academy. In 1969, they were administered the SVIB on a voluntary basis as part of the application procedure. Beginning in 1970, for selection of the Class of 1975, it became a required part of the application packet.

The 1966 version contains 399 items relating to activities in the following 23 basic interest areas:

Public Speaking	Mathematics	Medical Service
Law/Politics	Science	Social Service

Business Management	Mechanical	Religious Activities
Sales	Nature	Teaching
Merchandising	Agriculture	Music
Office Practices	Adventure	Art
Military Activities	Recreational	Writing
Technical Supervision	Leadership	

Combined Disenrollment Scale (DIS)

As a first step in developing the Combined Disenrollment Scale (DIS), NPRDC researchers analyzed all disenrollment records available at the Academy. They found that 53 percent of all disenrollments were classified as motivation problems and 30 percent, academic failures. The remaining 17 percent was ascribed to medical problems, conduct, aptitude, etc.

It seemed reasonable to expect that midshipmen who disenrolled for each of the various reasons would have responded differently to SVIB items than midshipmen who completed Academy training. However, because of limited sample size and low rates of disenrollment for reasons other than motivation and academic failure, it was decided to develop scales for only those two categories.

The ideal procedure for scale construction would have been to compare SVIB responses of graduates with those of members of each of the two selected disenrollment categories. However, as of March 1970, when the disenrollment data were obtained, none of the classes for which SVIB data were available had been commissioned. Thus, data for only the remaining midshipmen in the Class of 1971 were used, since these students were most likely to receive commissions.

The motivational scale was constructed from the 121 item responses that differentiated between the motivational disenrollees and the remaining midshipmen. The academic scale was constructed from the 56 responses that discriminated between the academic dropouts and the remaining midshipmen. The two scales were then combined to form the Combined Disenrollment Scale (DIS). This scale has since been evaluated on a number of different classes and situations. Results showed that it was useful in identifying those applicants who were most likely to disenroll. Detailed information on the development of this scale is available in a study by Abrahams and Neumann (1973).

Engineering-Science (E-S) Scale

The development of the Engineering-Science (E-S) Scale was based on the assumption that there are identifiable and measurable differences in the vocational interests of midshipmen who would voluntarily choose engineering or science majors and the interests of those who choose other majors such as humanities, management, and international relations. If information about such individual differences in interests were made available, it could be utilized in candidate screening to ensure that those most likely to choose engineering or science curricula would be selected.

At the time the E-S Scale was developed, the Class of 1973 was the most recent class for which SVIB data were available. Thus, this class was selected for use in scale construction. When the responses of those who ultimately chose an engineering-science major (N = 502) were compared with the responses of those who chose "other" majors (N = 368), it was found that 75 item responses differentiated between the two groups. These differences were identified by examining each individual item (each of which concerned a particular activity or job field) to find out whether the engineering and science majors responded significantly more often with "Like" than did the other majors. To illustrate, take Item 83, which concerns the Scientific Research Worker. Sixty-five percent of the engineering-science majors indicated that they "liked" this field, compared to only 40 percent of the second group. In contrast, 10 percent of the E-S group endorsed "dislike," compared to 35 percent of the second group. All the items that were answered differently by the two groups were included in the Engineering-Science Interest Scale, and scoring weights were assigned such that an applicant obtaining a high score on the scale would be more likely to choose an engineering or science major than one obtaining a low score.

To illustrate the practical significance of using the E-S Scale in a selection situation, NPRDC researchers prepared an expectancy chart. This was done by dividing the E-S score distribution for the Class of 1976 into five nearly equal samples and computing the percentage of midshipmen with an engineering-science major within each sample. As shown in Figure 2, those midshipmen in the top fifth of the score distribution selected an engineering-science major three times as frequently as those in the lower fifth. Further, 82 percent of applicants who are otherwise qualified and who score at or above the 60 percentile of the scale can be expected to select an E-S major. Since only 67 percent of the Class

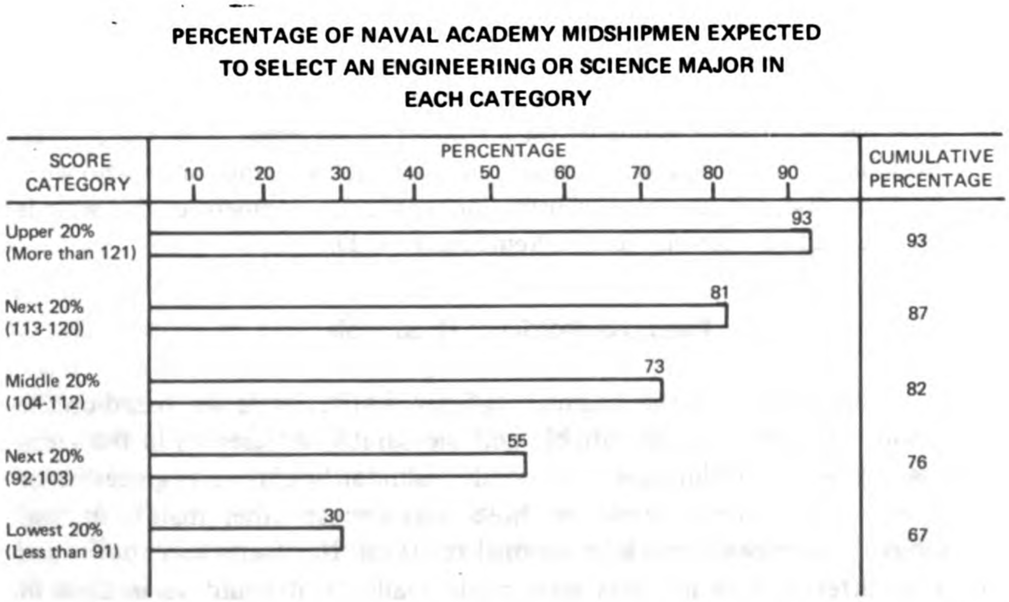

Figure 2 — Expectancy chart showing the relationship between the Engineering-Science Scale and choice of major for the Naval Academy Class of 1976.

of 1976 actually selected an E-S major, implementation of this scale is expected to result in an increase of 15 percent in the numbers of applicants who eventually select an E-S major. To examine the stability of these results, a second expectancy chart was developed for the Class of 1977. Results were comparable to those for the Class of 1976.

Although the evidence clearly demonstrated that a powerful and potentially useful relationship exists between measured interests and choice of majors, several other factors had to be considered before the E-S Scale was adopted by the Academy. Specificially, it had to be empirically demonstrated that use of the scale in selection decisions would not impair performance on other dimensions of success, such as leadership ratings, academic performance, etc. Also, use of the scale could not be recommended if those scoring high on engineering and science interests were more likely to disenroll than those scoring low. Results of statistical analyses showed that selecting on measures of engineering or science interests had no adverse effect on performance in other areas. Detailed information on development of the E-S Scale is available in an NPRDC Technical Report (Neumann and Abrahams, 1974).

Scale Implementation

Since the original development and evaluation of the Combined Disenrollment and Engineering-Science Scales, both have been adopted by the Academy for use in applicant selection. The Combined Disenrollment Scale is believed to have contributed significantly to lowering the rate of voluntary resignations in the Classes of 1977 and 1978. The E-S Scale was used informally to make decisions between otherwise equally qualified applicants for the Class of 1978. As an apparent result, the percentage of midshipmen voluntarily selecting an engineering or science major increased from 70 percent for the Class of 1977 to 80 percent for the Class of 1978. Similarly, when the scale was integrated into the selection composite for the Class of 1979, 83.4 percent of the Class chose a major in the science and engineering categories.

Current Research

At present, NPRDC researchers are engaged in evaluating various components of the Academy's Candidate Multiple. For instance, one component—high school extracurricular activities—is being examined to determine whether it is useful in predicting various measures of success at the Academy. Also, because of the successful use of the Engineering-Science Scale for selecting midshipmen most likely to choose an engineering or science major, a similar scale is being developed for application to the NROTC Scholarship Program. As in the Academy program, the proportion of engineering and science students participating in the NROTC program must be increased.

Future plans include evaluating vocational interests to determine whether they are useful in predicting tenure among Academy graduates and disenrollment among NROTC participants.

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Preenlistment Screening of Male Applicants

Each year, many thousands of nonprior-service male applicants are accepted for enlistment in the Navy. Using satisfactory completion of obligated service as a criterion of effectiveness, large numbers of these enlistees are considered ineffective. The high financial costs of these losses to the Navy, and the personal costs to the individuals involved, make research efforts directed at developing an improved personnel selection system mandatory. Research conducted in all branches of military service has demonstrated that satisfactory military performance is related to various types of life history or background information. The number of years of eduction completed is often the most effective predictor of successful adjustment to the demands of service life. Such background data can be employed in a personnel selection model to evaluate a person's probability of success. Screening out applicants with an unacceptable risk level can reduce premature attrition. Using multiple linear regression analysis, NPRDC developed a mathematical model that employs selected background information to predict an individual's probability of success.

Applying Psychobiology

Bernard Rimland
Applied Psychology Program

During the last decade, major advances have been made in several areas of biology and physiology which relate to behavior. Despite the scientific significance of these developments, few attempts have been made to apply them to everyday problems in the field of personnel and training. While medical people have tracked many of these findings, their interest traditionally has been in preventing and treating disease and, within the military, in screening out those who fail to meet minimum standards, rather than in maximizing the performance and utilization of normal, healthy individuals.

The Navy Personnel Research and Development Center, recognizing that many of these unused findings and methods were potentially of great value to the Navy, established the Applied Psychobiology Program (APP) in 1975. The goal of the APP is to increase the effectiveness of Navy personnel by (1) improving screening and selection procedures and (2) developing means of enhancing individual performance. Since most of NPRDC's efforts to date have focused on the problem of improving selection procedures through psychobiological methods, this paper is primarily addressed to that area.

Performance Prediction

The range of individual differences in human performance is much wider than generally appreciated. Whenever it has been possible to measure any dimension in which humans vary—whether that dimension has been physical, chemical, or behavioral—the range of variation has been truly enormous (Weschler, 1952; Williams, 1956; Williams & Rimland (in press)). For example, in some of the studies conducted by industrial psychologists, production supervisors have been asked to estimate the range of differences in performance between the most and least productive of their experienced workers (excluding trainees and newcomers). Their estimates usually range from about 10 to 30 percent. Yet, when actual "hard" production figures are gathered, even for such simple tasks as typing, card punching, and machine sewing, results show that productivity differences range from 200 to 300 percent. As the difficulty and complexity of the task increase, the range increases. To illustrate, a study of the time taken by computer programmers to complete a standard program showed a range of 2300 percent. No doubt equally large differences would be found between individuals performing military assignments.

Most testing for personnel screening and assignment to training, whether in the military or the civilian world, is based on paper-and-pencil tests. Such tests

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do a fair-to-good job of identifying those who will succeed in school-type settings, such as civilian schools and colleges, and in military training. Unfortunately, however, they leave much to be desired in predicting successful on-job performance (Ghiselli, 1966; Rimland, 1972). Psychologists have been butting their heads against this stone wall for well over half a century, and modern technology has been of little help. Although modern computers allow them to do in minutes what took months to do with desk calculators, they still come up with the same answer: Paper-and-pencil tests do not predict on-job performance. Any method of measuring individual differences that would permit Navy personnel managers to make optimal assignments would greatly increase the Navy's overall effectiveness. The mediocre cook may have had the makings of a great sonar operator; the fairly good navigator may have been a superb fighter pilot. It is important to determine how such assignment errors can be avoided.

Enter Psychobiology

Researchers at several laboratories have begun to unravel a few of the secrets of the differing roles played by the right and left hemispheres of the brain. These findings are an outgrowth of an attempt to treat incapacitating epilepsy by surgically severing the corpus collosum—the bridge of nerve fibers that connects the two hemispheres. When patients so treated were tested psychologically, results revealed remarkable differences in the functions of the hemispheres (Dimond & Beaumont, 1974; Ornstein, 1972). Briefly, the function of the dominant hemisphere (the left for most people) is to process verbal, logical, and "rational" information in a sequential or linear fashion. The function of the other hemisphere, which has been described as spatial, nonlinear, simultaneous, judgmental, holistic, and intuitive, is not yet well defined.

Actually, of course, virtually all tasks require the use of both hemispheres. However, when you look at a photograph of a crowd and try to pick out the faces of the people you know, your judgmental right hemisphere is working hardest. When you compose a letter, solve an equation, or answer a multiple-choice question, your logical left brain bears most of the load.

Formal training, in public schools, colleges, or the military, is, by necessity, presented in a linear, sequential way. The more logical the organization and presentation of the material, the better. People whose left hemispheres are especially powerful—the same people who earn high scores on paper-and-pencil tests—find themselves well suited to academic work. If these people also have strong right hemispheres and good interhemispheric connections, they will be able to cope with the multidimensional, nonlinear demands of the real world and to perform effectively on the job as well as in the classroom. However, people who do not have sufficient left-brain aptitude (call it IQ) to master large amounts of verbal and logical material will not be able to function well in many jobs. For example, an individual may have a superb right hemisphere, from the standpoint of performing as a sonarman or air traffic controller. He may be able to visualize and keep track of several objects moving in different directions, at different speeds, and at changing altitudes in three-dimensional space. Given these abilities, it appears that he should be able to integrate ambiguous auditory and visual signals from a sonar console. However, this will be true only if he has the left-brain aptitude required to master the factual information and abstract theory that each sonar trainee must learn before he can function effectively.

A major working hypothesis of the Applied Psychobiology Program is that paper-and-pencil tests measure primarily left-brain functions but do not provide a useful index of right-brain adequacy—even though the test content (e.g., block counting, spatial orientation, etc.) may appear to measure nonverbal functions. If this hypothesis is true, it follows that optimal assignment cannot be achieved until a way is found to measure the effectiveness of an individual's right hemisphere.

Brain Wave Testing Technology

Several years ago—before the formal establishment of the Applied Psychobiology Program—NPRDC began a series of brain wave studies, with ONR support, in collaboration with the Langley Porter Neuropsychiatric Research Institute (LPNRI) of San Francisco. This collaboration has proven very beneficial to both groups. LPNRI has some of the most sophististicated brain testing equipment and some of the most knowledgable people on this subject in the world. For example, the Director of Research at LPNRI, Dr. Enoch Callaway, is a world authority on individual brain wave differences and is the author of a recent—and the only—book on the subject (Callaway, 1975). NPRDC, because of its proximity to such training activities as the Naval Training Center and the Marine Corps Recruit Depot, is able to obtain subjects for brief periods of experimental testing. Even more important, the Center is in a position to follow up the individuals tested to determine whether they (1) were successful in boot training, basic training, and advanced technical training, (2) are considered proficient by their supervisors, (3) are advanced to a higher pay grade, (4) manage to remain in the Navy for the full term of their enlistment, and (5) are declared eligible for reenlistment.

Experimental testing is carried out on state-of-the-art equipment, based on a Data General NOVA 2 Central Processing Unit (CPU) with 16K core, 16 bit word length, hardware multiply and divide, and direct memory access with a floppy disc unit. The CPU and floppy disc unit, along with an EEG amplifier, filter circuitry, and alphanumeric oscilloscope, are mounted in a single cabinet (Figure 1). The unit is 76 cm high, 61 cm deep, and 56 cm wide and weighs about 40 kg, which makes it field portable. Because of its small size and relatively low cost, it is feasible to install similar units at recruiting and training centers throughout the United States to supplement information now obtained from paper-and-pencil testing.

Several studies are now underway. Subjects are briefed as to the purpose of the study and asked if they wish to participate. If they agree, they sign an "informed consent" form. They are then fitted with a Lycra helmet (see Figure

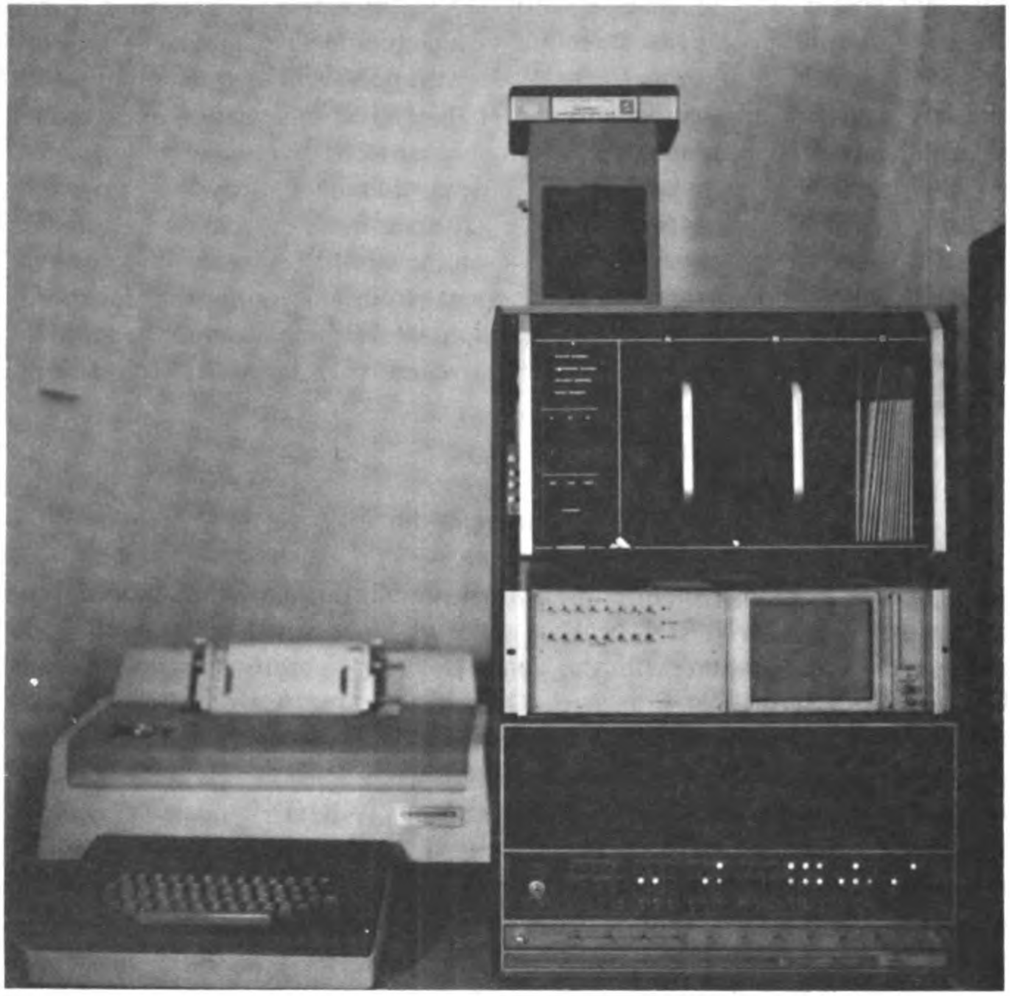

Figure 1 – Computer used in brain wave analysis (right). Cabinet contains the central processing unit, EEG electronics, and floppy disc. Also shown are the keyboard and high speed printer.

2) and familiarized with the computer scope. Because of the computer's sensitivity, visible brain wave signals can be easily distorted by "muscle artifacts," caused by such bodily movements as squirming, nodding, or even clenching teeth. Thus, the subject is given a hand-held switch that he may use, if necessary, to put the computer in a "time out" mode if he wants to change his position or otherwise make himself more comfortable. LPNRI has developed software which causes the computer to automatically delete such "noises." When this software has been adapted for NPRDC's use, the "time out" mode can be eliminated and testing will be speeded up considerably.

After hookup has been completed, which takes 5 to 10 minutes, the subject enters a small, soundproof chamber and is asked to perform a designated task. Currently, the tasks are simple sensory ones such as counting light flashes or intermittent sound signals. In the future, when a planned graphic capability

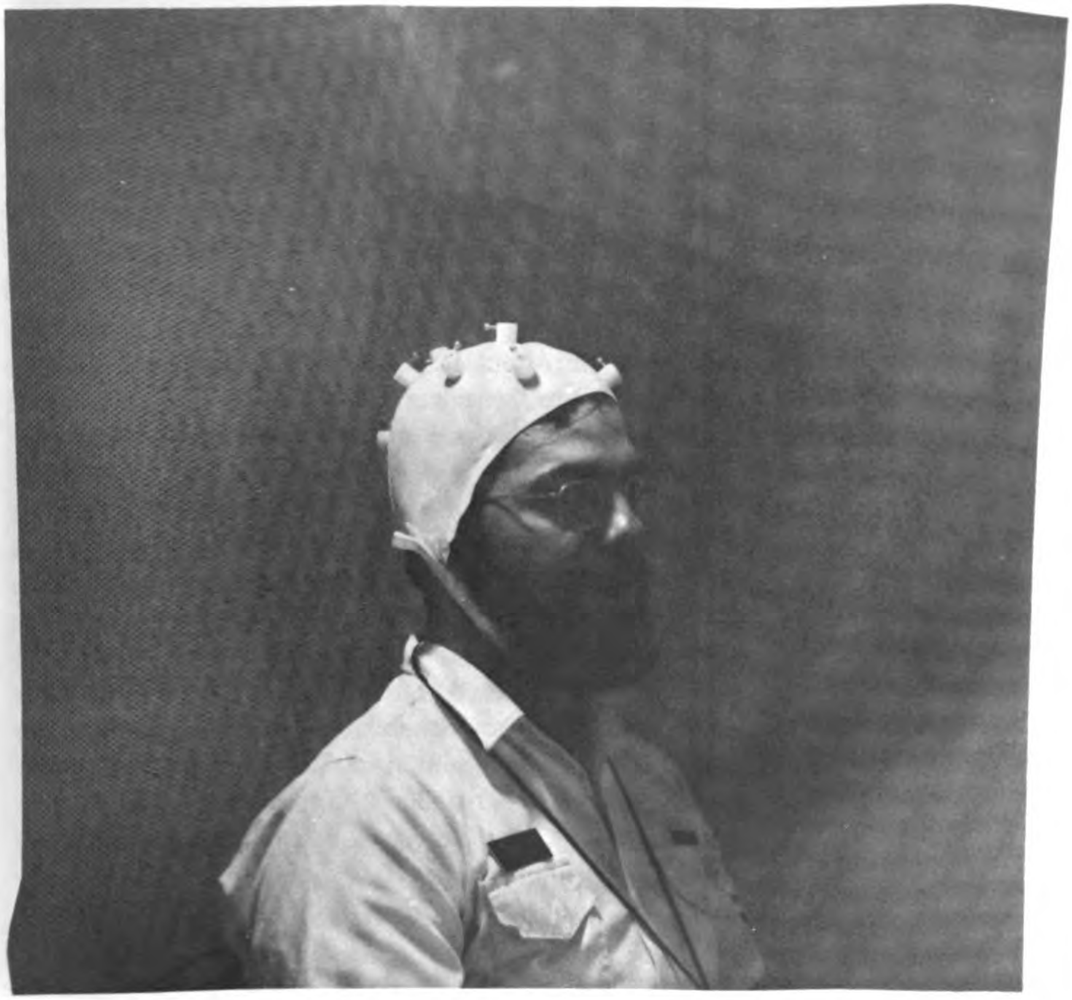

Figure 2 — Subjects who participate in NPRDC's brain wave studies are fitted with a Lycra helmet and asked to perform simple sensory tasks.

becomes available, more complex learning or problem-solving tasks will be presented. Also, plans have been made to test experienced subjects working at real or simulated consoles or instrument panels, using either an advanced form of helment or an alternate electrode attaching system, in an attempt to identify the differences between those experienced personnel who are highly proficient and those who are marginal or average.

While the subject is performing the present simple sensory tasks, the computer records and calculates brain wave signals, in real time, providing whithin seconds a highly quantified record of the brain's latency, amplitude, habituation, and variability in responding to the sensory signals. Further, it provides all of this information for each of ten recording sites separately for the right and left hemispheres. Through newly developed software programs, it is possible to determine any similarities in the wave forms emanating from the recording sites—a total of 28 interactions among the brain areas—again in real time (Callaway & Harris, 1975). After the testing is completed, which takes from 10 to 15 minutes, the subject usually takes paper-and-pencil tests and results are compared with the brain wave test results.

Brain wave data have been obtained from the samples described below and statistical analysis has been initiated:

- *Random recruit population.* Several hundred recruits at the Naval Training Center, San Diego were tested as part of a large-scale study designed (1) to determine how various brain wave measures relate to paper-and-pencil tests and (2) to compare the two kinds of tests as predictors of training and posttraining performance.

- *Marginal recruit population.* About 100 recruits from the above sample were judged to be of marginal value to the service, based on their test scores and reading ability. Some of these recruits have subsequently been discharged. Analysis of brain wave data for those who were discharged shows that they responded differently to stimulation than those who were allowed to remain in the service (Lewis, Rimland, & Callaway, in press). If this preliminary finding is confirmed in subsequent samples, the brain wave approach may have found its first operational application: screening out those destined to fail before they are enlisted into the Navy. At present, about half of those enlisted are discharged prematurely. If brain wave testing can be used to identify those whose mental or emotional competence makes them a poor risk for enlistment, administrative and training costs will be reduced and the sense of failure experienced by the prospective dropouts will for many be eliminated.

- *ASW trainees.* Twenty-eight incoming students at the Fleet ASW School in San Diego were tested in a project designed to improve selection methods for ASW trainees. Results of brain wave tests will be correlated with those of a large battery of paper-and-pencil tests and other measures in an attempt to solve this difficult selection problem.

- *Flight officers.* A squadron of Navy fighter pilots and radar intercept officers at Miramar Naval Air Station was tested, using both a choice-reaction time testing device designed by Gary Poock at the Naval Postgraduate School and NPRDC's brain wave testing device. Data derived will be used in an attempt to predict such criteria as flying skills and carrier landing proficiency. (For this testing, NPRDC employed its new mobile test facilitiy—a 37-foot soundproof van equipped for a variety of personnel and training research studies.)

There is, of course, no assurance that the results of these studies will lead to the discovery of a method for measuring right-brain function or that such a method, if found, could be used to predict on-job performance. However, there are hints that they are on the right track. For example, several laboratories have reported that the delay (latency) in the brain's response to a sensory stimulus is correlated with IQ: the faster the brain's reaction, the more efficient the brain functions. Other laboratories report marked differences in the wave characteristics of the right and left hemispheres, depending on the type of task in which the subject is engaged. Lawyers, who tend to use their logical left hemispheres, are reported to differ considerably in brain response from artists and sculptors, who emphasize spatial right hemisphere functions.

Other Challenges in Applied Psychobiology

Although the use of brain wave testing as a substitute for, or a supplement to, paper-and-pencil aptitude testing is presently the primary interest of the Applied Psychobiology Program, the program plans to investigate a number of other problems–both in personnel selection and in performance enhancement.

One such problem in personnel selection research is determining how individual variations in stress tolerance affect Navy performance. The range of differences is unquestionably great–it runs all the way from the wartime heroes who act coolly and competently in the face of great personal danger to the recruit who caves in emotionally during the tribulations of boot camp and is sent home as unsuitable for military service. It is clearly not sufficient to find men capable of performing well on the job, if they are capable only when they are not under pressure.

Failure under stress is not a new problem to the military. Civil War buffs report finding rusty but still loaded muskets on the battlefields, apparently abandoned when their frightened owners took to their heels during battle. One such musket had reportedly been loaded with five rounds, one atop the other–a testimonial to the state of mind of the would-be soldier. The advent of modern warfare did not decrease the severity of the stress problem–Marshall (1951), in a widely quoted study, found that only a small minority of front-line troops in World War II ever fired their guns at the enemy. Through brain wave technology, the APP hopes to develop methods for use in identifying those who can continue to function even when danger is imminent or when they are required to function in an extreme overload situation.

Another selection problem that merits investigation is how monotonous jobs affect performance. O'Hanlon (1965) conducted a study in which subjects were required to watch a simulated sonar screen for a 2-hour period. He found that half of them remained vigilant throughout the trials but that, for the other half, vigilance performance dropped off dangerously after a time. Further, he found that the subjects' blood adrenaline level closely paralleled their vigilance accuracy throughout the trial period. The steady performers had stable blood adrenaline levels, while those who faltered showed a closely related drop in their blood adrenaline levels. It is important to determine whether these findings can be applied to the identification of high-vigilance personnel.

Two areas of performance enhancement research are of particular interest to NPRDC. The first is using information from brain wave analysis or muscle potential analysis, tailored to the individual, to tell the student if he is learning properly or to tell the watch stander if he is adequately attending to his task. The second involves determining how environmental factors affect human performance. In this regard, Ott (1973) has demonstrated that the power spectrum of ambient light has profound effects on human health and behavior. Since many naval personnel operate under artificial light for prolonged periods (e.g., submariners), it may be possible to enhance their performance by providing a balanced spectrum of light.

Additional applications of psychobiology to the Navy's personnel and training problems are envisioned. For now, the development of aptitude testing through brain wave technology not only promises to help the Navy to identify the talent it needs but also to enable persons in the civilian sector to learn about their aptitudes and abilities. The other parts of the Applied Psychology Program are also expected to produce benefits that will enhance human performance in many civilian settings as well as in the Navy.

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Models for Planning Manpower Requirements and Personnel Resources

Joe Silverman
Management Systems Program

The manner in which the Navy's human resources are allocated among competing needs has a far-reaching impact on both cost and operational readiness. As a result, resource allocation techniques employed by top Navy managers have become an important area of research and development. In manpower and personnel planning, these techniques often take the form of mathematical and statistical models embedded in large-scale, computer-based management systems. These models are symbolic representations of large manpower or personnel systems that enable managers to experiment on the model before they introduce changes to the system and thus determine what effects these changes would have. Use of such models not only permits a wide array of specific policies to be analyzed, but also increases the manager's understanding of complex manpower and personnel systems and reveals shortcomings in the quantity and quality of data used to develop manpower and personnel plans and policies. The latter is particularly important since, as with tactical combat decisions, the effectiveness of human resource management depends heavily on the timeliness, relevance, and accuracy of the information that influences decisions.

Techniques for managing human resources usually focus on (1) personnel utilization, (2) manpower requirements, or (3) personnel resources. Personnel utilization models usually concern the selection, training, assignment, and promotion of individuals. Since such models have undergone extensive development and are in common use in the Navy and the other military services, they will not be discussed in this paper.

R&D in the manpower area centers on problems of determining requirements based on current workload and prospective missions. The problem of allocating manpower assets among support activities is particularly difficult because each of the activities has a different relationship to Fleet operating units and to the other activities. For example, the manning requirements of a naval air station depends on workload demands placed on the station by squadrons, aircraft carriers, and tenant activities. Similarly, the manning of a supply center requires information on demands from the Fleet and from other shore activities. Consequently, changes in Fleet size or operations have a highly differential impact on elements of the shore establishment.

Models for managing personnel resources often deal with problems of forecasting the wide variety of flows within the personnel system and of controlling that system within budgetary constraints. For example, it is necessary to predict the levels of attrition and nonreenlistment in order to estimate the number of future petty officer vacancies, which, in turn, is used as the basis for determining enlisted advancements, recruitment, and training plans. Models to develop adequate recruitment and promotion plans, to assess retention and loss management policies, and to evaluate alternative goals for both grade and career structure can help solve personnel resource problems.

Ship-to-Shore Input-Output Model

As indicated previously, one of the Navy's most intractable problems concerns the effect that changes in Fleet configuration or structure have on the shore establishment and its requirements for manpower. Such changes are reflected in increases or decreases in Fleet size, in shifts in the mix of ship and aircraft types, or in decreases or increases in the activity level or operational deployment of the Fleet. These factors, alone or in combination, imply changes in the need for shore support and, therefore, in the need for shore-based manpower requirements. To further complicate the problem, while the level of shore support is dictated by Fleet needs, its output is constrained by budgetary limits, by personnel ceilings, and by the way shore activities are organized.

All of these considerations raise four important questions regarding Fleet support:

- Given a change in Fleet size or in its level of operations, how will requirements for Fleet support change and how will those changes be reflected in the need for shore-based manpower?
- With a particular configuration of shore activities, what level of Fleet support can be expected? As a corollary, what effect does the closure of certain shore activities have on other support units and on the Fleet?
- How do specific budgetary constraints and personnel ceilings on support activities affect their output to the Fleet and what are the consequences for manpower requirements?
- How do changes in technology affect the need for manpower in support activities? For example, what are the direct and indirect effects of labor-saving devices?

Questions of this type can be answered by using a technique known as Leontief input-output (I/O) analysis. This is a method for determining the economic or workload relationships that exist among a set of activities and, consequently, the effect that changes in one or more activities have on the other activities in the same system. While I/O models are conventionally used in national economic forecasting, they appear to have potential for microeconomic applications—specifically, workload forecasting.

I/O models operate on a data matrix that reveals the economic relations among sectors or, in the Navy example, the network of mutual support among activities. A hypothetical network of such linkages is provided in Figure 1. As shown, the Manpower Pool provides personnel to the Fleet and to a variety of shore activities. These activities, in turn, provide support in the form of supplies,

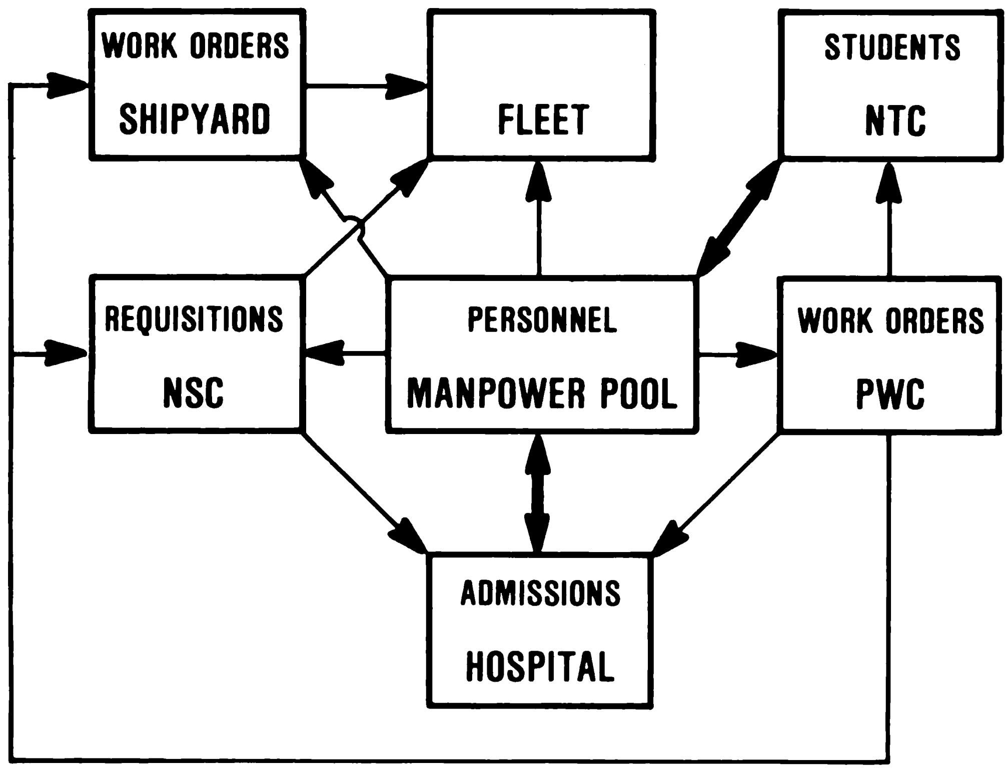

Figure 1 — Hypothetical network of support linkages among the Fleet and elements of the shore establishment.

facility maintenance, and health care to other shore activities, the Manpower Pool, and the Fleet. This simplified example shows how some activities provide direct Fleet support, and others, indirect support. I/O analysis is particularly useful in estimating the indirect effects; that is, the second and higher order impacts that one activity has on another through intermediate activities. For example, changes in the Fleet have a direct impact on a shipyard and a supply center, and they also have an indirect impact on the supply center through the shipyard.

To determine the feasibility of using input-output analysis for manpower planning, a simplified model of the Eleventh Naval District (San Diego and Long Beach geographical regions) was developed. The scope of this model was restricted to 28 sectors, including supply, R&D, public works, hospitals, repair facilities, a training center, a missile range, air stations, a naval station, separate sectors for civilian and military manpower, and, of course, the Fleet. The output of these activities was measured by logistics data that, while somewhat spotty and inaccurate, was sufficient for illustrative purposes. When this data was arranged in a matrix, the rows and columns of which represented the different activities in the model, it was possible to compute the technical coefficients to link the outputs of the various sectors. For example, the relationship between the supply center and a shipyard could be expressed by the number of supply requisitions for each man-hour of ship repair.

Several applications of I/O analysis were made, testing the effects of changes in Fleet size and location, as well as the effects of a major base closure. Figure 2 shows how a ten percent cut in the Fleet would affect activities in the San Diego and Long Beach areas. Not only would the military personnel be cut approximately ten percent, but the amount of support required from other activities would be considerably reduced, particularly from the San Diego Naval Station, the Miramar Naval Air Station (near San Diego), and the Long Beach Naval Hospital.

Figure 3 demonstrates the effect that relocating 41 ships (about 50 percent) from Long Beach to San Diego would have on supporting activities. The

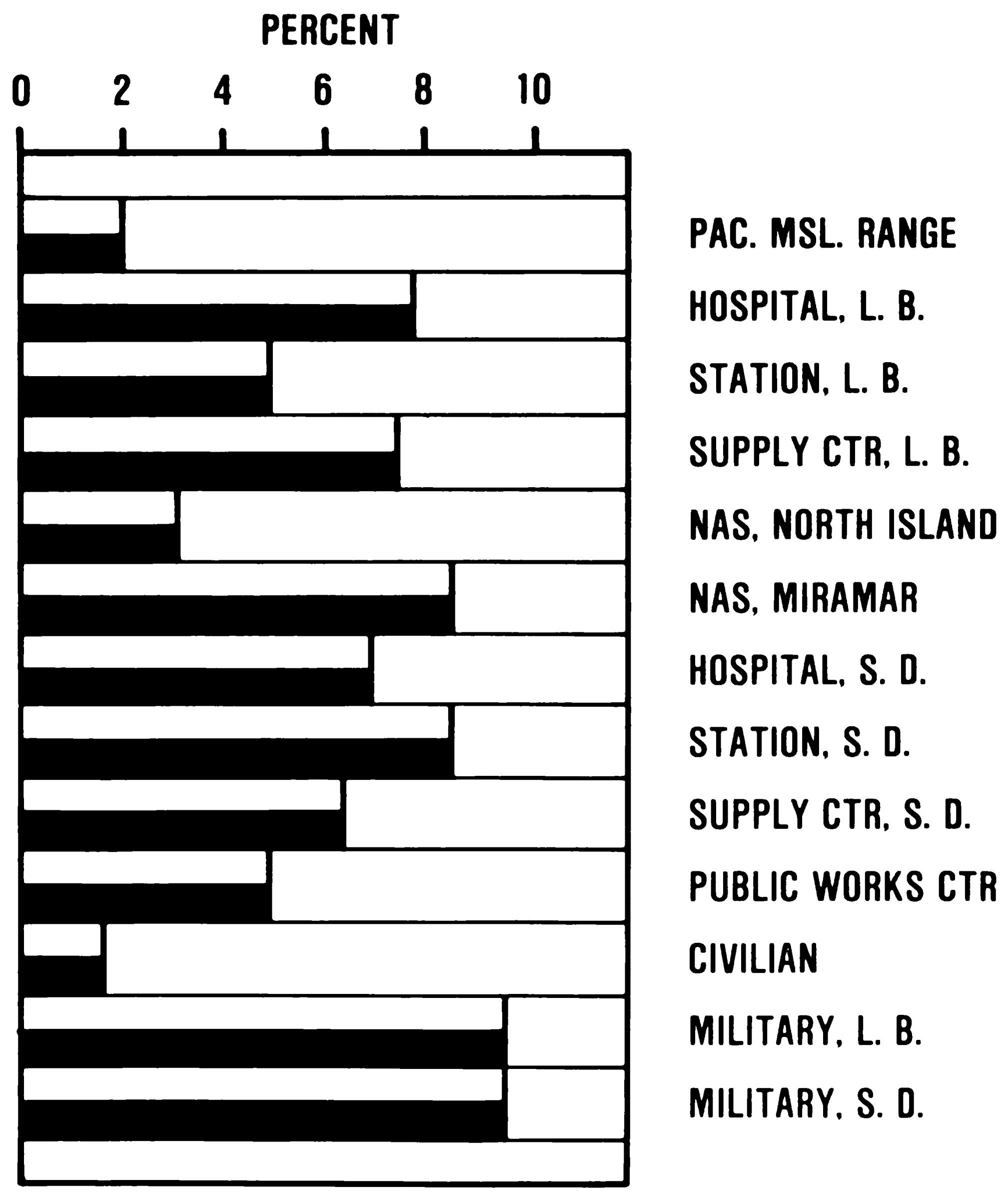

Figure 2 — If the Fleet were cut by ten percent, the workload of supporting activities would be considerably decreased.

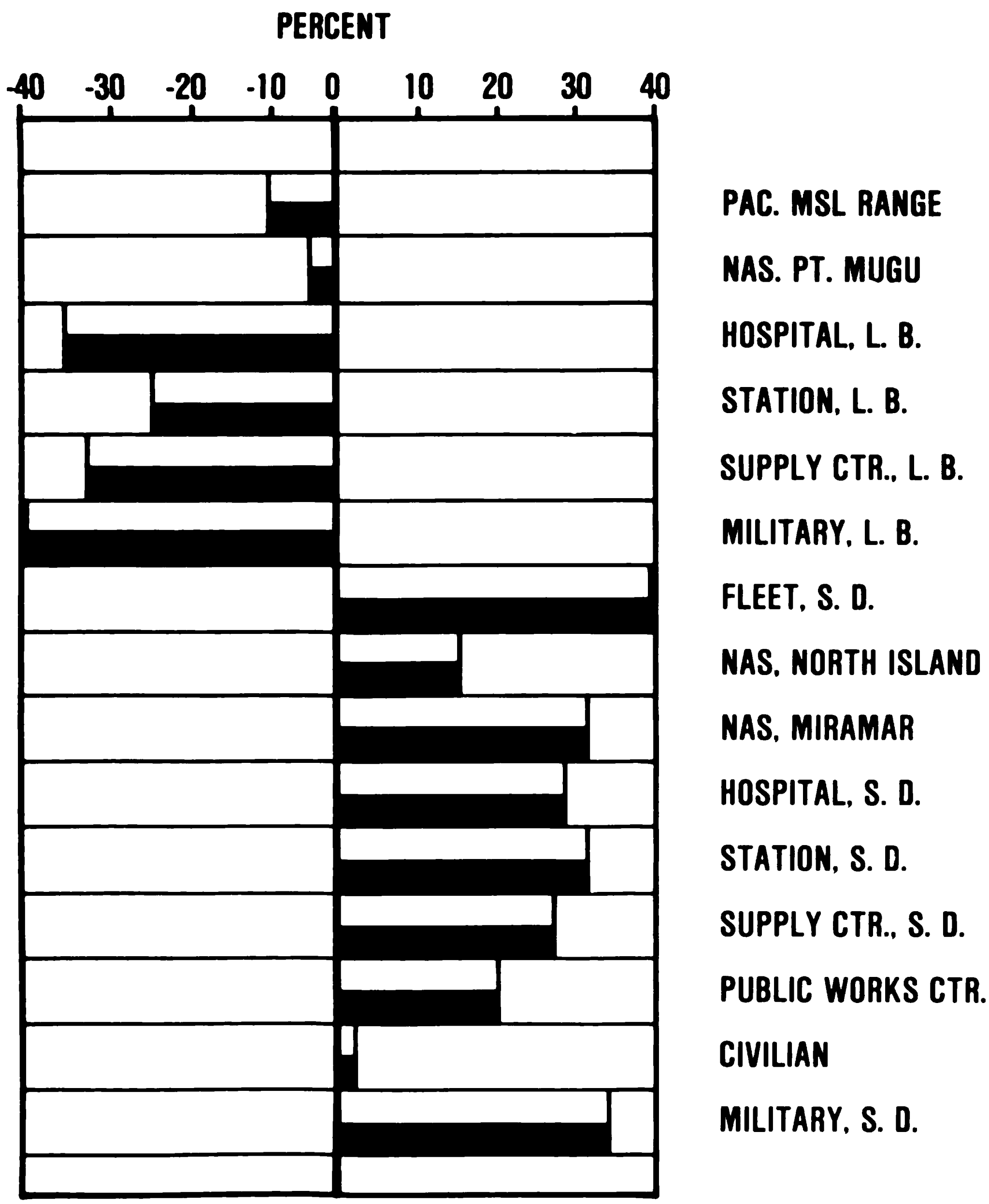

Figure 3 — If 41 ships (about 50 percent) of the Fleet homeported at Long Beach were relocated at San Diego, the workload of supporting activities at Long Beach would be considerably decreased while that of San Diego activities would be considerably increased.

military personnel in the Long Beach area would be decreased about 40 percent, and those in the San Diego area, increased about 38 percent. Similarly, support required from the Long Beach Naval Hospital would be decreased about 38 percent, while that required from the San Diego Naval Hospital would be increased by about 30 percent. Other Long Beach and San Diego activities would be affected in a similar manner.

Finally, Figure 4 shows the estimated decreases in support required if the Naval Training Center at San Diego was closed. This figure includes both direct (solid bar) and indirect (hatched bar) effects. As shown, the impact would be greater for the Public Works Center (about 17 percent) and the Naval Supply Center (about 10 percent).

Before an I/O model for Navy manpower planning can be fully implemented, a number of data-related problems must be solved. First, comprehensive and accurate data on the output of each activity and the destination of that output must be obtained and carefully organized. Second, data on the Fleet's support demands must be obtained and classified by ship type, movement, and status to determine the effects of changes in Fleet configuration and deployment. Third, it may be necessary to develop specialized computational methods for modelling the large number of Navy activities and the variety of individual customers for each activity. Other problems concern the output characteristics of naval support activities. For example, the outputs of some activities are

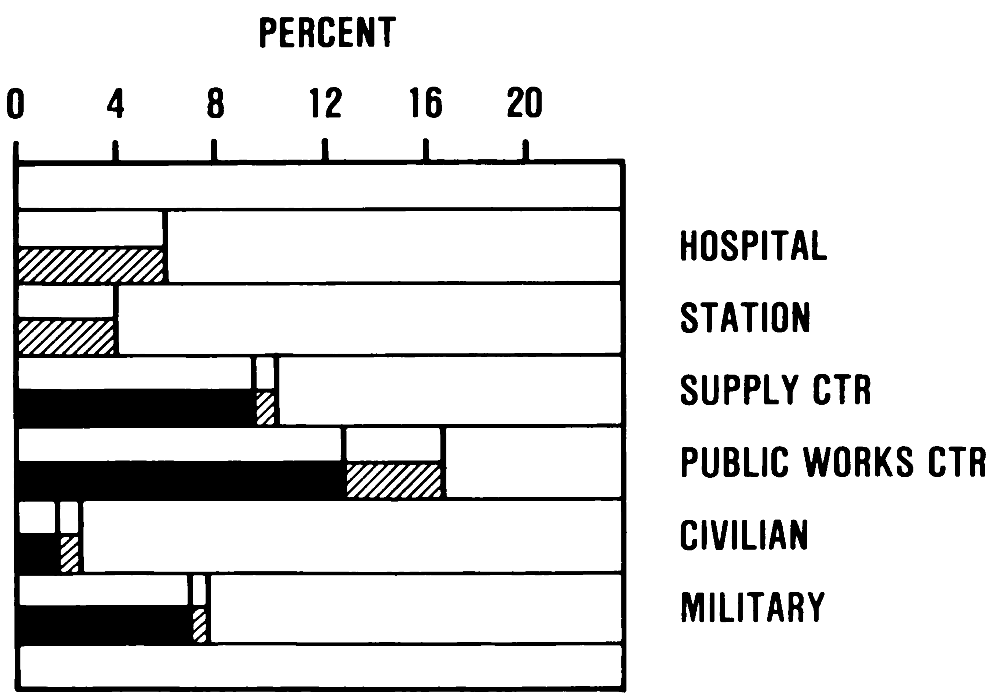

Figure 4 – If the Naval Training Center at San Diego were disestablished, the workload of other supporting activities at San Diego would be considerably decreased. Direct effects are indicated by the solid bar, and indirect, by the hatched bar.

constrained by the resources available rather than being an expression of external demands—a situation which poses some problems for I/O analysis. In addition, some activities have multiple outputs that also create some special modelling problems.

Nevertheless, substantial progress in solving these problems has been made over the last year, and it will soon be possible to test an I/O model using more accurate and comprehensive economic data. This test will make it possible to estimate the cost of Navy-wide application of I/O analysis. Given the continuing changes in Fleet size, mix, and operations and the constraints imposed on the shore establishment, the I/O approach provides a framework for more effective allocation of a limited and costly resource—manpower.

Naval Personnel Pay Predictor, Enlisted (NAPPE) Model

Once manpower has been allocated to various activities, the Navy must meet manpower demands by drawing from the reservoir of personnel available for assignment. One of the most important constraints on the size and skill distribution of the personnel inventory is the budget for military personnel, and the single largest component of that budget is basic pay for enlisted personnel.

The budget for military personnel is estimated and submitted to Congress for approval well in advance of its expenditure. To accurately estimate the cost of the future force of enlisted personnel, the distribution of those personnel must be forecasted over both grade and longevity. This is because military pay is tied to both grade and time in service.

Significant problems can result from even small errors in budget forecasting. If the budget for basic pay of enlisted personnel is underestimated and it appears that cost overruns will occur, it is extremely difficult to avoid such overexpenditures without taking actions that would seriously degrade Fleet readiness. For example, when overexpenditures appear imminent, it is often necessary to reduce in-year personnel expenses on short notice. This is achieved by (1) retarding promotions, which has deleterious effects on personnel morale, promotion opportunity, and retention, (2) delaying recruitment, which affects the quality and volume of input, (3) instituting early release programs, which result in the premature loss of trained personnel, and (4) degrading other budget elements such as travel (PCS) and subsistence if funds could be transferred between budget accounts. The latter has serious implications for rotation ashore, assignment, and other personnel movements necessary to achieve Fleet readiness.

On the other hand, if basic pay is overestimated and the Navy has a year-end surplus in its military account, the Navy will have failed to acquire the level of Fleet readiness (defined in terms of numbers of personnel by grade and experience) for which funds were authorized by Congress. Further, the credibility of future Navy budget requests will suffer because of the present failure to "buy" the force levels that were appropriated. In either case, it is clear the R&D efforts to improve military pay forecasting can yield potential savings well beyond the small investment required.

As noted previously, the annual budget for military pay is based on the number of personnel in each paygrade and longevity interval throughout a fiscal year. Since the distribution of personnel by grade is largely determined by personnel planners who schedule enlisted promotions and recruitment month by month, the major problem of forecasting basic pay centers on longevity distribution. Because of the relative stability in aggregate personnel flows, it was possible to develop a statistical model, known as the Naval Personnel Pay Predictor, Enlisted (NAPPE), that predicts the number of personnel in each year of service.

Using an historical data base, NAPPE first computes a survival rate for each period, which reflects the proportion of personnel with a given length of service at a specific point in time who "survive" to the next point in time with increased longevity. These survival fractions are smoothed to produce forecasts of the next and subsequent periods. By taking the predicted length of service distribution, together with the pay grade population determined by Navy management, NAPPE is able to generate a pay grade by length of service matrix through an iterative process. The model then multiplies the resulting personnel matrix by statutory rates of pay to produce a cost estimate for each quarter. Results are then summed to produce a fiscal year forecast.

NAPPE forecasts were validated aginst actual basic pay using historical populations. The results are shown in Figure 5. It is estimated that previous

NAPPE VALIDATION:
PERCENT ERROR IN FORECASTING BASIC PAY

Fiscal Year	Years Forecast From Base		
	1	2	3
64	.22		
65	.10	.51	
66	.60	.55	.05
67	.96	2.38	2.29
68	.29	1.63	3.15
69	.37	.75	2.34
70	.36	.72	.96
71	.37	.36	.29
72	.51	.82	.49
73	.18	.80	1.11
74	.12	.50	1.27
75	.14	.23	.37
Mean Error	.35	.84	1.23

Figure 5 – By using the Naval Personnel Pay Predictor, Enlisted (NAPPE) Model to forecast enlisted basic pay, the forecast error in the last 3 fiscal years was restricted to less than 0.20 of 1 percent.

methods used for forecasting enlisted basic pay resulted in errors of about 1 percent—which amounts to about 30 million dollars in terms of the current budget. Figure 5 indicates that, by using NAPPE, the forecast error in the last 3 fiscal years was restricted to less than 0.20 of 1 percent.

Although the NAPPE model has been implemented operationally, it is currently undergoing further development that should increase both its accuracy and ease of usage. In addition, plans have been made to extend its scope so that it can be applied to budget elements other than enlisted basic pay and to develop an officer version.

The input-output model for manpower planning and the NAPPE model for personnel budget forecasting are only two of the many efforts being devoted to improved management of human resources. Active use of such R&D end products by Navy managers promises to make effective use of scarce and costly human resources.

Container Offloading and Transfer System

At the request of the Navy Coastal Systems Laboratory, NPRDC has been studying the human engineering characteristics of heavy duty (150-200 ton) cranes to be installed aboard container ships of the future. The Navy will depend for many of its auxiliaries on the U.S. merchant fleet, which is now converting to container ships. NCSL has the task of developing a heavy crane system that will transfer cargo from ship to ship in both open and protected waters. Although heavy cranes have been used for many years at shore installations, the new system will be operated in the open sea in sea states up to three. Since pitching and rolling may severely stress the crane operator and cause him to drop his load on the deck or in the sea, it is necessary to design the system with as many human engineering safeguards as possible. In performing their analysis, NPRDC investigators observed eight cranes in operation, interviewed crane operators and designers, took videotape and 35mm photographs for later examination, and analyzed crane operating manuals. The eight cranes were ranked in terms of human engineering adequacy, and certain operational and safety features were recommended for the shipboard environment, including such characteristics as independent power control, safe load computer capability, and warning devices. Efforts in FY 1977 will include the development of human engineering requirements to be included in procurement specifications.

Instructional Systems Development—A New Approach to Flight-Crew Proficiency

Joseph C. McLachlan
Design of Manned Systems Program

Historically, Navy pilots and other flight crew members have received their training—and maintained their proficiency—by using operational aircraft. However, for the past several years, there has been a growing concern over the cost effectiveness of this training method. This concern has recently intensified with the astronomical growth in the complexity of the various airborne weapon systems and the attendant growth in cost to procure, maintain, and operate these systems. In addition, the state of the world economy, particularly in connection with the dramatic increase in the cost of oil and aviation fuels, has forced the Department of Defense to consider training alternatives.

To address this problem, the Navy has systematically increased the number of training simulators being designed and integrated into the various training systems, ranging from basic pilot trainers to highly sophisticated full mission simulators located at various operational training sites. Second, it has applied modern instructional theory to the development of training programs for operational aircraft. The general methodology used to develop these training programs is referred to as "Instructional Systems Development (ISD)."

The Navy Personnel Research and Development Center (NPRDC), long involved in personnel training programs, has developed and participated in the employment of a number of major ISDs. In addition, it has conducted appropriate research and development (R&D) studies when required to answer questions concerning instructional strategy, media selection, simulation and other trainer requirements, part-task trainer requirements, and evaluation techniques and procedures.

S-3A Training System

One such program was the S-3A Viking effort. The S-3A (see Figure 1) is a newly deployed carrier-based antisubmarine warfare weapon system—successor to the S-2F/G tracker. Its mission is to protect the carrier force from hostile submarine attack to a distance of several hundred miles. It has a flight crew of four: Pilot, Copilot, Sensor Operator (SENSO), and Tactical Coordinator (TACCO).

The S-3A represents a substantial advance in sophistication over its predecessor. It includes many acoustic and nonacoustic sensor systems, advanced navigational and communication equipment, and a variety of weapons delivery

Figure 1 — Because of the high cost of operating the Navy's S-3A, NPRDC was tasked to design a training system that would, to the extent possible, use training simulators rather than operational aircraft.

packages. All of these systems are integrated and controlled through a very high capacity on-board computer, the AN/AYK-10.

During the late 1960s and the early 1970s (during the S-3A's engineering design and development stages), it was determined that, if all R&D, procurement, and maintenance costs were considered, it would cost between $3500 and $4000 an hour to fly the S-3A. With the recent accelerating costs in aviation fuels, this figure has risen to something in excess of $4000 for each flight hour. Clearly, then, it is in the Navy's best interest to design a training system that would, to the extent possible, use training simulators instead of operational aircraft and that could be applied to other presently deployed and future weapon systems. This was the task undertaken by NPRDC.

Before the Instructional Systems Development (ISD) for the S-3A training system could begin, it was necessary to conduct a needs and goals anlaysis to determine (1) the specific requirements of the system and (2) whether the present S-2 training system could be modified to meet the training needs of the S-3A flight crews. Results of this analysis clearly indicated the need for a new training system for the S-3A weapon system. The S-2 training system could not be modified since the S-3A's crew functions are organized differently from and its avionics systems are much more complex than those of the S-2.

Once the decision had been made to develop a new training system using ISD, a complete task listing was developed. The sequential listing included all major tasks and subtasks performed by each of the four crew members, as well as those tasks performed by the crew collectively. This step, which commenced in FY 1972, was a long and difficult one, primarily because S-3A systems were still undergoing change and development. Although it was relatively easy to describe the major tasks of each of the operators, the description of subtasks, which were partially dependent on how specific pieces of hardware operate, required much more attention.

The next step in the S-3A ISD model was to organize all of the tasks and subtasks into a training format, translate them into training objectives, and classify them as to the kind of behavior required. That is, whether the task calls for recall or recognition behavior (memory level), the selection of a given instance as belonging to a particular class (concept classification level), or the use or application of a rule or principle (rule using level). It was of interest to the Navy to find that a large portion of the training for two crew members–the TACCO and SENSO–called for concept classification behavior. For example, the TACCO must classify a given situation as requiring a specific tactic and the SENSO, a given signal as characteristic of a specific target.

Once all the tasks had been classified in this manner, they were submitted to a media selection algorithm developed by Courseware, Inc. This algorithm determined the appropriate delivery system or media that should be used to attain the task objectives. It was during this phase, which commenced in FY 1973, that the number of simulators required for both operational training and proficiency maintenance was determined. Once the tasks which could be trained efficiently using simulators had been identified, cost analyses were performed to determine the number of simulators versus the number of operational aircraft which would be required. As it turned out, the ratio of simulators to operational aircraft was much higher than had been anticipated. As a result, the Navy was able to decrease the number of S-3A's under procurement and to increase the number of simulators being purchased. This action not only saved the Navy several million dollars but also markedly increased the potential for training efficiency and effectiveness.

In addition to simulators (ranging from weapon system trainers to digitally driven position simulators), selected methods and media included individualized student workbooks, videotape programs, and computer-assisted instruction (CAI). The projected use of CAI in an operational Fleet training environment was considered unique. Several systems were considered before the system called TICCIT (*T*ime-shared *I*nteractive *C*omputer *C*ontrolled *I*nformation *T*elevision) was selected. This system, which was developed under the sponsorship of the National Science Foundation, was specifically designed to deal with classification level and rule-using level behaviors. It was felt that judicious use of CAI would not only be helpful in training S-3A aircrew tasks, but would also increase the utility of the more complex simulators.

The training courses for each of the S-3A crew positions were developed by organizing the classified training objectives into common groups making up segments, lessons, and units. When this step was complete, a lesson specification document (LSD) was generated for each lesson in each course. The LSD provided a detailed prescription for the content of each lesson, including the kind and number of examples and practice problems to be produced, the requirements of graphics or other illustrative material, the organization or strategy required, and, finally, the type of evaluation instrument needed to determine whether students have mastered the lesson objectives.

The actual production of the instructional materials, student tryout and evaluation, and instructor training began in early FY 1974. Approximately 30 Navy subject matter experts, assisted by instructional psychologists and media production specialists, spent almost a year in developing 2000 hours of basically individualized instruction, including 400 hours of CAI. As various segments were produced, they were tried out on samples of the student population and revised as required. At the same time, instructors, including those with flight, simulator, CAI, and other classroom responsibilities, were trained in the ISD model and in student evaluation and management (see Figure 2).

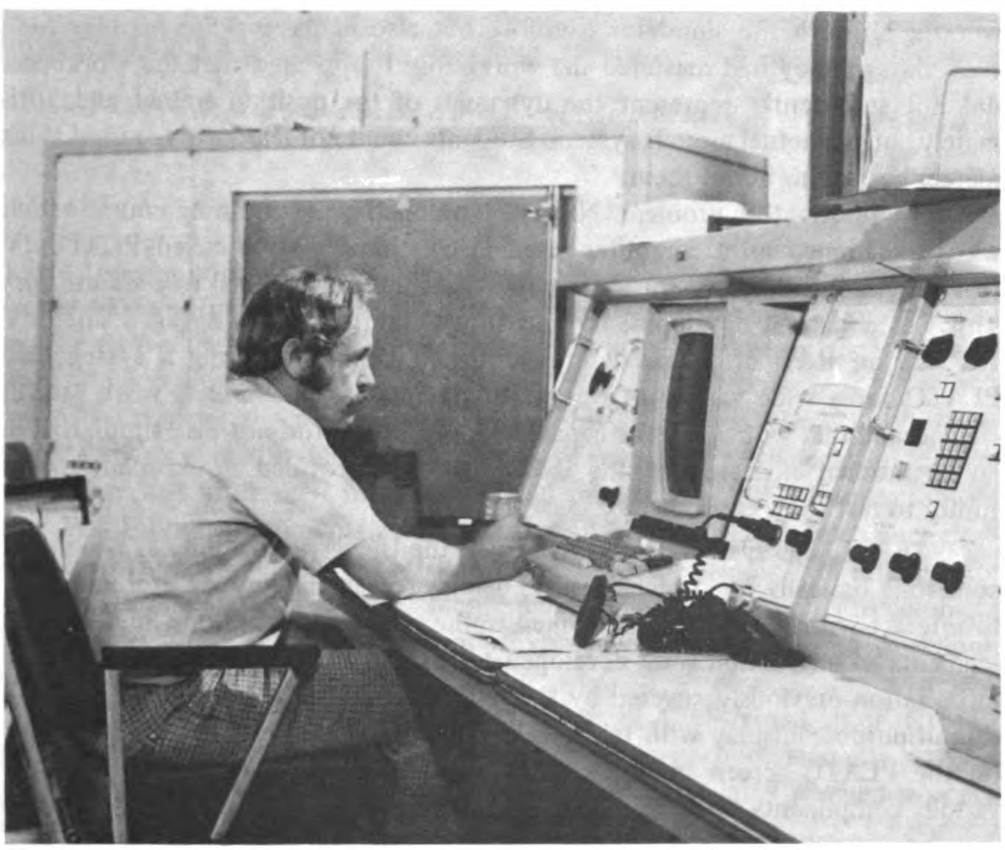

Figure 2 – This weapon system trainer is one of the S-3A training facilities located at the Naval Air Station, North Island (near San Diego). Instruction for operating this device was developed under the Center's S-3A aircrew training program.

Computer-Based Training Using PLATO IV

Quality control is critical to the success of any developing process. In the case of the S-3A, it began early in the developing cycle and is continuing into the present. As a result, changes are constantly being made to the S-3A training program, and problems involving instructional completeness, accuracy, format, delivery, etc. are being isolated and resolved. For example, during the early evaluation stages, it became apparent that the flow of instruction between some of the workbooks and their associated positional trainer exercise was very inefficient. Specifically, the problem existed in teaching the operations of the Integrated Control System (INCOS) in the S-3A copilot position. The INCOS panel is composed of a trackball and numerous switches which are used for interacting with the S-3A's on-board computer for ASW activities. A student training for the copilot position must be able to master the INCOS before he can continue with the rest of his training course.

Originally, the student copilot spent 1 day (8 hours) studying a workbook which described the functions of each INCOS component, followed by 1 hour in a complex positional simulator working through problems under instructor guidance. At the completion of the simulator exercise, he was given a mastery test, also in the trainer. Results showed that copilot students not only had difficulty working through the simulator exercises but also in passing the mastery test, even though they had mastered the workbook. It appeared that the workbook did not sufficiently represent the dynamics of the position trainer and, ultimately, of the actual aircraft system. Students could not learn the required skills merely by reading about them.

To resolve this problem, NPRDC developed a new training course which was programmed on a computer-based instructional system called PLATO IV (for *P*rogrammed *L*ogics for *A*utomated *T*eaching *O*perations) (see Figure 3).[1] This was a natural development, since the Center had been engaged since FY 1973 in an R&D effort to determine the feasibility of using a system like PLATO for a wide variety of Navy training applications. Since a work project was needed that would test the capabilities of PLATO for part-task simulation in an operational environment, the INCOS problem provided an excellent opportunity to test these capabilities.

The PLATO system itself is located at the University of Illinois. Terminals, consisting basically of a touch-sensitive display screen and a typewriter keyboard to interact with the system, are linked to the system via telephone lines. Several segments of instruction were developed for use on PLATO, including all of the information previously covered by the INCOS workbook. The INCOS panel and a multipurpose display with tableaus, symbology, and readouts were presented on the PLATO screen by the computer program, and the functions of the various components were simulated by computer logics. The student was able to

[1]This part of the S-3A work was performed under NPRDC's Development of Training Technology Program.

Figure 3 – By using computed-based instructional systems like PLATO IV, S-3A copilots can acquire skills needed to perform tracking tasks, thus greatly reducing training costs for the Navy.

touch the component of the INCOS being shown and the simulated tactical plot would be modified as it would be in an actual flight situation. The computer program gave the student immediate feedback as to his performance and kept track of his training time.

To compare the performance of students trained on PLATO with those using workbook instruction, all students were given tests in the position simulator before and after their instructor-guided practice exercises. Results showed that PLATO-trained students performed as well *before* the position trainer exercise as workbook students did *after* the exercise. Other findings of interest are:

1. PLATO-trained students required approximately 3½ hours to complete basic instruction, as compared to approximately 8 hours for the workbook students.

2. During the simulator practice session, PLATO-trained students completed significantly more practice problems than the workbook students.

3. On the final mastery test, PLATO-trained students reached mastery significantly quicker than the workbook students.

These findings indicate that it may be possible to eliminate *both* the workbook instruction and the simulator practice for these particular instructional segments by the appropriate use of PLATO or a system like PLATO.

Applying instructional technology to aircrew training, using simulators to increase training efficiency and effectiveness, and integrating various CAI devices into the Navy's operational training programs—all alternatives to operational flight-crew training—offer the Navy a brighter as well as an economically sound future.

Source Data Automation

NPRDC is supporting BUPERS in the analysis and modification of its Manpower and Personnel Information System (MAPMIS), which is used for personnel actions such as assignment and promotion and for financial management. MAPMIS has been found to contain relatively large sources of error that can adversely affect personnel and budgetary control actions taken by BUPERS. Initial NPRDC efforts were (1) a cost-benefit analysis of MAPMIS and (2) an analysis of field requirements for automation. The current data entry system was costed and compared to various distributions of minicomputers and terminals. In FY 1977, a more extensive effort directed at improving all the Navy's automated information systems will be pursued. This effort will consist of the following elements: (1) development of design criteria and measures of effectiveness, (2) investigation of probable causes of error and timeliness and determination of problem areas with the greatest payoff, (3) development of design techniques and candidate design approaches, (4) collection of baseline data from existing manual and automated systems, and (5) design of a test bed system and development of plans to test it. Specific efforts to support the BUPERS MAPMIS will continue, such as the design of forms for use with an automated system, and prototype system testing.

Diagnostic Performance Tests + Remedial Training = Enhanced Job Performance

Edward J. Pickering
Measurement of Job Performance Program

A consistent finding of performance testing of Fleet personnel (e.g., Abrams & Pickering, 1962, 1963; Anderson, 1963; Anderson & Pickering, 1959) is that significant numbers of these personnel are not adequately proficient in key aspects of their jobs. Even when supervisors are aware of such deficiencies (which often is not the case), they have no readily available means of correcting them. To address this problem, the Navy Personnel Research and Development Center (NPRDC) initiated the Personnel Readiness Training (PRT) program (Laabs, Main, Abrams, & Steinemann, 1975) in 1973. In this ongoing study, critical skill deficiencies are being identified through diagnostic tests, and attempts are being made to remedy them by prescribed training.

Background

The operator and maintenance tasks listed below, each associated with a specific technical rating, were chosen to assess the feasibility of the PRT program. This was done to increase the likelihood that the results of the evaluations could be generalized to other Navy technical ratings.

1. Operator tasks performed by submarine Sonar Technicians (STs) on the AN/BQR-20A passive, real-time frequency analyzer.
2. Maintenance tasks performed by Missile Technicians (MTs) on the FBM submarine missile test and readiness equipment (MTRE MK 7, MOD 2).
3. Operator and maintenance tasks performed by Boiler Technicians (BTs) on the 1200 psi steam boiler plant.

Prototype diagnostic tests and shipboard training procedures were developed for these tasks and shipboard evaluations currently are underway. For each of the three applications, the evaluation involves three treatment groups: Control, Diagnostic Feedback, and Prescribed Training. Members of the Control Group are tested and given only very *general* feedback as to their performance. For example, an ST might be told that, over the AN/BQR-20A tasks tested, he used the controls correctly about 80 percent of the time. Members of the Diagnostic Feedback Group are tested and given *specific* feedback on their performance. In this case, an ST might be told that he is deficient in using the range switch and the gain controls. Finally, members of the Prescribed Training Group are tested, given specific feedback, and provided with instructional materials to correct their deficiencies. Three to six months after the pretests, posttests are given to all members of each group.

This experimental design was chosen to answer two questions. First, to what degree will the knowledge of specific deficiencies as determined by the diagnostic test stimulate appropriate remediation and provide an increase in skills and knowledges greater than that of the Control Group? Second, how much further will skills and knowledges be enhanced by prescribed training in the form of instruction modules tailored to remedy specific deficiencies?

Personnel from 12 ships (either surface ships or submarines, depending on the application) are involved in each evaluation—four for each of the three experimental groups. When all pre- and posttests have been completed, group results will be compared to determine program effectiveness.

Sonar Technician (ST) Application

Results suggest that the AN/BQR-20A (Figure 1), a relatively new and highly sophisticated frequency analyzer, is not being operated to its full capabilities. This is partly because the operator's task has not been well delineated in training documents. Different tactical situations and operating environments require different configurations of the BQR-20A controls to optimize the detection of targets.

Figure 1 — Submarine Sonar Technician operating the AN/BQR-20A passive real-time frequency analyzer.

The ST application is limited to a single operator and includes most tactical employments of the BQR-20A. Diagnostic tests were designed to assess both knowledges and skills required for detection, tracking, and contact investigations. The knowledge test consists of 42 multiple-choice items covering aspects of operation not covered by the performance test. The performance test requires the ST to set up the equipment for search, contact investigation, tracking, ping interception, and signal-to-noise ratio calculation. In this test, the BQR-20A is driven by tapes which contain simulated sonar signals. The test emphasizes procedural accuracy in setting up the controls in accordance with operational doctrine. Controls whose settings have little effect on the system's performance are not considered in scoring. Also, those for which a particular setting may be a matter of choice, such as CRT brightness, are considered to be operated properly unless the setting chosen exceeds an acceptable range. For example, the brightness control would be scored as incorrect only if the CRT was so bright or so dim that contact information might be lost or obscured.

The total training package includes six self-instruction units on various aspects of system operation. Supplementing these lessons are logic trees which provide guidance in proper set-up procedures for various tactical situations and drills in which a trainee performs on the actual equipment. Using a checklist, a peer points out errors as the trainee works through the drills.

Testing has been completed for the ST application. Results indicate that the combination of diagnostic testing and remedial training yields significant improvements in performance. From the standpoint of the SSBN's mission, the search task is the most important of those tested. The results on this task are fairly typical of those found on all tasks. As shown in Figure 2, the Training Group improved significantly on the posttest while the performance of the other two groups remained substantially the same from pre- to posttest.

Missile Technician (MT) Application

The scope of the MT application had to be limited by selecting skills and knowledges from critical tasks. This was done by (1) reviewing the Personnel Performance Profiles that list the skills and knowledges necessary to maintain the MTRE, and (2) analyzing the Trouble and Failure Reports relating to MTRE to identify problem areas.

Any approach which required all testing to be carried out on the actual equipment would make inordinate demands on training facilities at the off-crew sites. To minimize such demands, the diagnostic test is composed of performance items on specific test equipments, aspects of MTRE maintenance which lend themselves to simulation, and MTRE itself. The diagnostic test yields scores which permit individualized prescription of remedial training.

There are four MT tests: (1) a paper-and-pencil troubleshooting test, which requires an MT to follow a troubleshooting sequence and gives immediate feedback, (2) a test on the use of test equipment, including an oscilloscope, a John Fluke differential voltmeter, and a Simpson volt-ohm-microammeter, (3) a

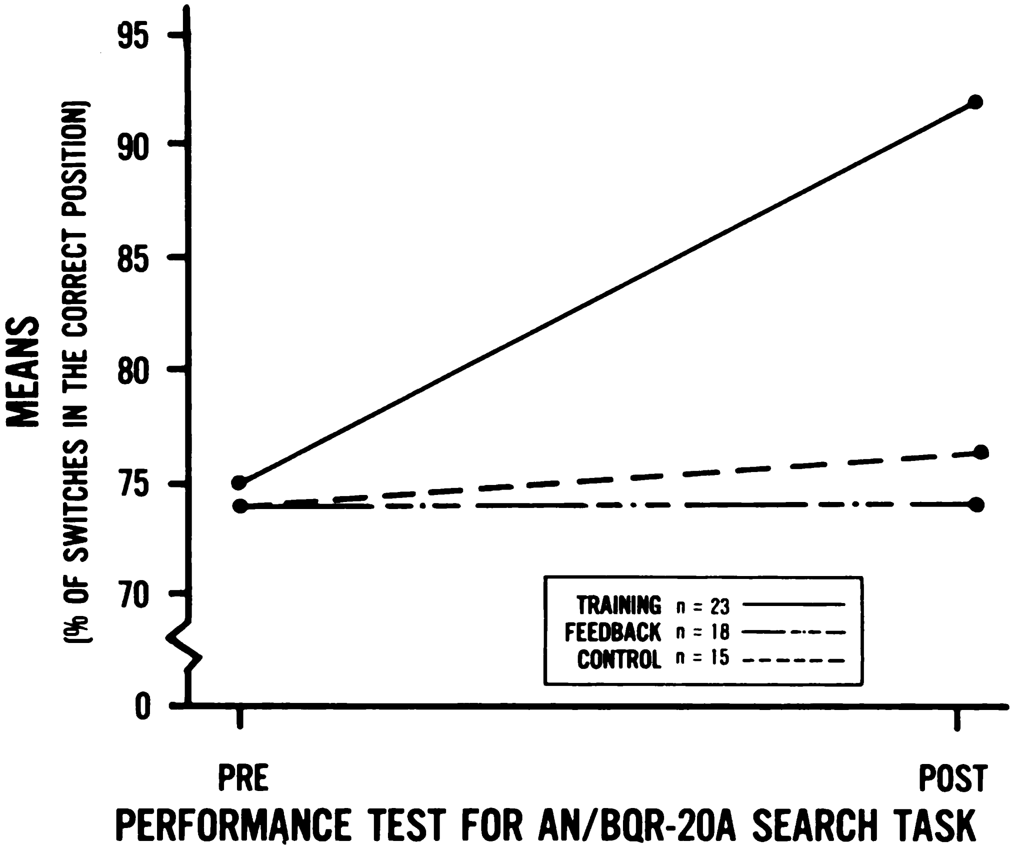

Figure 2 — The combination of disgnostic testing and remedial training significantly improved the performance of Sonar Technicians.

hands-on troubleshooting test, given to the MT in each crew who has primary responsibility for MTRE, and (4) a performance test covering three Standard Maintenance Procedures (SMPs), given to the MTs in each crew who do not have primary responsibility for MTRE.

Pretesting of the MTs has been completed and posttesting is underway. In general, the pretest results show that substantial deficiencies exist in all areas (troubleshooting, SMPs, and use of test equipment).

Boiler Technician (BT) Application

Operation of the 1200 psi steam propulsion plant (Figure 3) requires the coordination of several BTs operating different equipments. This adds to the complexity of the plant's operational problems and makes the determination of performance requirements and task selection difficult. Further, the training problems experienced by the BTs are magnified by the adverse environment in which they work.

Two BT tests were developed. The Basic Mechanical Procedures test is the 107-item multiple-choice test with different questions keyed to each of the 13

Figure 3 — Boiler Technician follows Engineering Operational Sequencing System diagram in assessing performance of 1200 psi steam propulsion plant.

modules of the Propulsion Engineering School's core curriculum. These modules cover basic mechanical skills and knowledges in such areas as valves, bearings, and pumps. The test was validated by giving a large number of questions to one group before it completed the Propulsion Engineering School's core curriculum and to another group after it completed the curriculum. Questions were then selected which maximally discriminated between the two groups.

The second test covers the Engineering Operational Sequencing System (EOSS), a system which, if used properly, will lead to steaming the propulsion plant in accordance with good engineering practices. A test of the use of EOSS requires the BT to demonstrate the ability to locate EOSS materials, to read EOSS charts, and to follow the diagram. Different parts of the test are keyed to the four lessons of the EOSS programmed instruction module. These lessons cover introductory material, Engineering Operational Procedures, Engineering Operation Casualty Control, and EOSS management.

These diagnostic tests yield profiles of BT's strengths and weaknesses in basic mechanical knowledges and utilization of EOSS materials and allow individual prescription of training modules for detected deficiencies. Pretest results have revealed a variety of weaknesses which the remedial training materials should substantially reduce.

Conclusions

Findings to date lead to two main conclusions: First, diagnostic testing of MTs, STs, and BTs shows that deficiencies in skills and knowledges do exist.

Second, the ST data clearly show that remedial training consisting of shipboard self-instruction can be used to overcome skill and knowledge deficiencies. Such a test and shipboard training program probably would work best where testing can be done on shore and where demands on operational units are kept to a minimum. Also, it probably would work better with single pieces of equipment like the BQR-20A than with large systems like the 1200 psi steam propulsion plant.

A final report is expected by the end of the calendar year. This report will provide general recommendations covering the application of a diagnostic testing/shipboard training system to Navy job skills in critical areas.

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Essential Skills

The Navy tries to minimize costly school failures and setbacks by initial recruit screening and subsequent occupational classification testing. Despite these efforts, there is evidence that significant numbers of Navy personnel enter training programs with inadequate reading skills. NPRDC has documented the reading deficiency problem in the Navy and ascertained its effects. These data are being used to develop a short reading test for use at recruiting stations, and to develop a technical reading training program. Out-year planning calls for (1) the development of a computer-driven voice synthesizer to train basic language skills and (2) an investigation of the status of math skills among Navy trainees.

Research Notes

At-Sea Facilities Maintenance

As part of the Navy's manning reduction program, NPRDC developed a prototype project to apply advanced facilities maintenance techniques of cleaning to ships and thereby reduce the number of personnel and man-hours required for this task. As it is currently performed, facilities maintenance requires an excessive expenditure of man-hours and resources. During FY 1976, NPRDC's new system was successfully demonstrated aboard USS TRIPPE (DE 1075). Innovations fell into three categories: (1) organization, management, and technical information, (2) equipment, materials, and environment, and (3) training. An eight-man team of facilities maintenance specialists was established and a management information system was designed for use aboard ship. As a result, facilities maintenance man-hours were reduced by 20 to 40 percent, maintained spaces were rated satisfactory or better with respect to appearance and cleanliness, the skill and knowledge of facilites management personnel increased, and the overall program received favorable ratings. New tests planned for FY 1977 will cover an entire ship and will include new and more advanced cleaning devices and techniques.

Landing Vehicle Assault

The Landing Vehicle Assault being developed for Marine Corps use will project troops from over the horizon ships to interior battle areas at high speeds — over 25 knots. The effects of motion and other environmental conditions (noise, heat, and fumes) during transit to the beach may reduce the individual Marine's combat capability upon landing. NPRDC is conducting a study to provide habitability and manning design guidelines for reducing environmental effects on performance and to develop procedures for demonstrating troop performance adequacy. Initial study results identified environmental problem areas and established habitability design criteria. Design guidelines included recommendations for the installation of motion-dampening seats, improvements in ventilation, and the use of sound-absorption material to reduce noise. A preliminary test plan has been developed for evaluating test vehicle design adequacy in coastal landing trials at Camp Pendleton. The plan calls for testing Marines, after landing, in rifle firing, obstacle course traversal, and motor-visual tracking tasks. In FY 1977, the effort includes detailed planning and implementation of the troop performance tests to be conducted under NPRDC supervision.

Utilization of Women in the Navy

Since 1972, the number of enlisted women in the Navy has quadrupled and the programmed end-strength of 20,000 has been reached. Women, as a minority in the workforce, differ from racial and ethnic minorities because of their gender and the legal constraints on their military functions. When women's representation remained under the legislative limit of 2 percent of the enlisted force, they could be absorbed without difficulty. Today, however, almost all of the permanent shore billets designated for female personnel have been filled and males are expressing concern over the preservation of an equitable sea/shore rotation schedule. Thus, the increasing utilization of women has created problems for all of the services, but unlike those encountered before when women were mobilized under wartime conditions.

For the past 2 years, NPRDC has been conducting research on Navy women. The program is multifaceted and includes the following projects:

- An on-site study of the problems encountered when women are assigned to formerly all-male units in the Navy. Aviation squadrons, an amphibious battalion, and a harbor craft unit are a few of the commands that have recently been integrated and are providing case history data for this project.
- Sexual stereotypes among male and female recruits are being measured to identify attitudes that may interfere with good human resource management. A trend analysis of the extent of such beliefs among entering personnel will be conducted to determine whether a change is occurring over time.
- The reasons why proportionally more women leave the Navy during their first year than men do are being investigated. Preenlistment variables are being distinguished from service-linked variables as a first step in determining whether high-risk women can be identified before they enter the Navy.
- The attitudes of enlisted women and men and Navy wives toward the possibility of shipboard assignments for Navy women are being surveyed. In addition, the experiences of civilian women who serve on nonmilitary vessels are being compiled to determine what kinds of problems have been encountered and resolved.
- Men's and women's perceptions of the organizational climate of the Navy are being monitored. A study of enlisted personnel, published in 1976, indicated that females at the higher paygrades feel isolated from their workgroups, whereas males have a sense of solidarity. An analysis of officers' perceptions is now underway.

During FY 1977, several of the attitudinal projects will be completed and the results incorporated into leadership courses and workshops. The screening instrument for high-risk women will be developed and crossvalidated. In addition, the military research conducted during the past decade in Australia, Canada, and the United Kingdom will be integrated and published as a summary of the utilization of women in the armed forces of the major English-speaking countries.

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Cover Caption

Artist's (M. Hillman) concept showing several aspects of NPRDC's mission. The Center is the Navy's principal activity for conducting human resources RDT&E in the areas of manpower, personnel, education, and training, and is the coordinating activity for all human resources RDT&E for the Navy.

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