AN ANNUAL REPORT

ON

THE UTILIZATION OF PEOPLE-RELATED NAVY RDT&E

FY 1975-1977

May 1978

Assembled by

Navy Personnel Research and Development Center
San Diego, California 92152

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, D.C. 20350

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From: Chief of Naval Operations
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Subj: Annual Report on the Utilization of People-Related RDT&E

Encl: (1) First Annual Report on the Utilization of People-Related RDT&E

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b. RDT&E that has been utilized but not reported.

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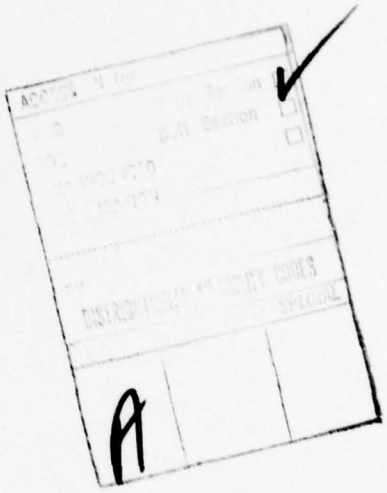

FOREWORD

The Navy intends to publish an annual report illustrating people-related research, development, test, and evaluation (RDT&E). This is the first such report and includes significant research from fiscal years 1975 through 1977. The development of this report was coordinated by the Navy Personnel Research and Development Center (NPRDC), San Diego, California, and the manuscript was prepared by BioTechnology, Inc., Falls Church, Virginia, under contract N66001-78-C-0072. The annual report emphasizes utilization of people-related RDT&E and contains (1) examples of results already in use, (2) advances in the technology base for near future use, and (3) current activities designed to increase RDT&E utilization.

RDT&E funding for people-related research is provided on the basis that research and development results can significantly impact on the operational readiness of naval forces by (1) providing the technology for efficient management and utilization of Navy personnel and (2) improving the performance of personnel and Navy weapon systems. This assumption of operational utility for RDT&E results has, over the years, sustained the growth and confidence in research and development support. Recently, however, this assumption has come under increasing scrutiny by policy makers within the Department of Defense (DOD) and in the Congress. Considerable interest and emphasis is being placed on making the research organization, and thereby the researcher, "accountable" and on making more research products "useful." Key decision makers are asking for confirmation that people-related RDT&E is, in fact, utilized to impact the operational readiness of naval forces.

In 1975, the House Appropriations Committee asked the General Accounting Office (GAO) to review human resources R&D in DOD. The GAO issued a report in April 1977 and recommended, among other things, that DOD improve its management system to increase the exchange of information between researcher and user. This annual report of RDT&E utilization represents one of the actions the Navy has initiated in response to the recommendations made by the GAO.

This report has not been prepared for researchers. The target audience is primarily policy decision makers within DOD, key legislative personnel of appropriate congressional committees, and users or sponsors from Navy operational and training commands.

This report does not cover the entire people-related RDT&E program of the Navy. The examples presented in the report are intended to show significant and interesting cases of RDT&E utilization or technology base advancement. However, the examples used are not unique – they are representative of the people-related RDT&E performed continually by the Navy.

Appreciation is extended to the official points of contact representing each of the contributing commands.

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INTRODUCTION

This report concerns people-related research, development, test, and evaluation (RDT&E) in the Navy. People-related RDT&E is a popularized term that has come into use in the last few years to refer to RDT&E activities that can be organized into four technical areas:

- Manpower and Personnel Technology
- Human Factors in Weapon Systems
- Education and Training Technology
- Training Devices and Simulators.

In short, people-related RDT&E is concerned with R&D activities to enhance the attitudes and performance of Navy personnel.

The Need for People-Related RDT&E

People-related RDT&E probably had its origin in the selection and classification testing during World War I. Since then, the scope has broadened to include all of the aspects of personnel attitudes and performance suggested above. The ultimate goal or application of people-related RDT&E is to make Navy personnel more effective and satisfied in their jobs, thereby enhancing overall Navy readiness.

People-related RDT&E is currently funded as part of the Training and Personnel Technology budget area within the Office of the Director of Defense Research and Engineering, and is a portion of the Science and Technology Program of that office. The need for people-related RDT&E can be inferred from statements in the Department of Defense annual report for FY 79 by Secretary of Defense Harold Brown. The following excerpt appears under the heading of *Readiness*:

> I consider our forces to be ready when they are well trained, have modern unit equipment in good operating order, hold war reserve stocks on which they can draw for the early stages of any conflict and are capable of timely response to crisis. Unfortunately, I cannot report that our forces, by this definition, are as ready as I would like them to be.
>
> There are several reasons for the current state of affairs. Our necessary efforts to conserve fuel have meant reductions in ground combat training exercises, Navy steaming hours, and flying hours for all services (although we have been able to make some substitutions for these losses, using simulators). Modernization, in some cases, has brought with it shorter mean-times to failure, longer repair times, and increased training requirements, as well as greater sophistication and capability of equipment. Inflation, increased pay, and the need to modernize our forces have meant curtailed funds for operation and maintenance.
>
> The conventional wisdom has been that, in an emergency, the neglect of readiness can be quickly overcome by a rapid infusion of resources. Whatever merit this wisdom may have had when the United States had ample time for extended mobilization, it is now out of date.
>
> We have not yet developed the methodological tools to show the precise sensitivity of readiness to changes in our commitment of resources. But loss of readiness is a cumulative process that takes time as well as money to reverse.

In the above excerpt, Secretary Brown acknowledges (1) a concern for our current state of readiness, (2) that modern equipment may in fact be more sophisticated, and (3) loss of readiness is a cumulative process that takes time as well as money to reverse. The third point is perhaps the most important with respect to the need for people-related RDT&E. Personnel readiness is dependent on all four technical areas of people-related RDT&E, viz., (1) Manpower and Personnel Technology, (2) Human Factors in Weapon Systems, (3) Education and Training Technology, and (4) Training Devices and Simulators. Each of these four areas must be continually advanced and applied and cannot be handled with "quick-fix" technology. Since people-related RDT&E is not nearly as familiar an activity as the physical and engineering sciences, mathematics, or environmental science, more clarification of its importance to the Navy seems in order.

Importance of People-Related RDT&E

First, consider the overall purpose of people-related RDT&E. As stated in a recent report by the General Accounting Office (GAO), that purpose "is to develop techniques, methods, and procedures for the most effective use of military personnel at the least cost." It is deceptively simple to say that our military personnel development must be cost-effective. Two unique facts must be recognized. First, military personnel are an integral part of our defense posture, and second, the performance and attitudes of military personnel can be enhanced just as the performance and reliability of hardware can be enhanced. The importance of these two facts is briefly elaborated below to clarify the impact of people-related RDT&E in the military.

People-related RDT&E is a small part of the RDT&E budget (less than 1%), but a proportionally larger part of our superior defense posture, maintained by research and development achievements. In support of this statement, consider the following rationales:

- There is general agreement that the Soviets have numerical superiority in weapons, but this is offset by our technology-base strength. This technology strength is not in hardware alone, but in people-related sciences as well. Recent history has substantiated the fact that a small, well trained, and highly motivated military force can overcome an adversary with far greater numerical superiority in troops and weapons.

- Military readiness is composed of two major elements, namely, personnel and material. Further, personnel readiness is a function not only of training, but also of other people-related RDT&E products, such as the selection process, human engineering (that is, the people-material interface), technical manuals and other documentation, and the motivation and morale of individuals and units. The readiness and reliability of our weapon and support systems can be no greater than the readiness and reliability of the personnel who operate and maintain them. Manpower and organizational effectiveness must be continually monitored and upgraded. The DOD annual report for FY 78 states: "U.S. defense needs are best met by long term stability in the military force structure." A few paragraphs later it is further stated: "if we are to attract and retain quality people within a force, U.S. military personnel management efforts must be carefully balanced between maintaining the attractiveness of service life and minimizing costs." It is common knowledge that there have been serious problems with respect to personnel turnover and personnel turbulence in the Armed Forces. Manpower problems such as these will only be resolved through solutions arising from people-related RDT&E.

- The cost of military training now exceeds $7 billion a year. These training costs must be reduced without sacrificing the benefits from training programs. Research and development to identify more cost-effective training methods and techniques is a key element of the RDT&E budget for training and personnel technology.

- The complexity and sophistication of military hardware has been accelerating since the end of World War II. Yet, the capabilities of the military personnel who must operate and maintain this hardware have, at best, remained constant and perhaps even diminished since the advent of the all-volunteer military. The man-equipment match is becoming more strained every year and will only become more compatible through the application of innovative techniques for human performance enhancement resulting from people-related RDT&E.

- Finally, the lowered birthrate of the 1960's and 1970's will result in a military age manpower pool that will shrink by 15% in 1985 and by 25% in 1992. The inevitable shortage of numbers and skills of people available to the Navy will create severe problems that can be lessened by people-related RDT&E. Otherwise, the possibility of a return to the draft or a significant increase in the defense budget looms as an unwanted consideration.

Research Progress, Utilization, and Transfer

The first sentence of this introduction stated that this report is about people-related RDT&E. The intervening material was presented to clarify what people-related RDT&E in fact is, and why it is important to the overall defense posture. The Navy recognizes, however, that it is not enough to conduct people-related RDT&E. The results must be utilized by the operational or training commands. Research utilization is not a matter of course. Utilization of research requires planned efforts to interpret, communicate, and implement the results. Some current Navy activities for increasing RDT&E utilization are discussed in the final section of this report.

In addition to planning for utilization, it is necessary to plan for research progress. In essence, this means initiating research projects which will advance the technology base and minimize the gap between

operational needs (utilization) and the people-related technology base available to address those needs. Therefore, a significant portion of the budget for Training and Personnel Technology is dedicated, and needed, for advancement of the technology base. Finally, research today is continually assessed for its potential transfer to other applications. The intrinsic value of an RDT&E program must, therefore, include considerations of research progress, utilization, and transfer. The body of this report thus consists of examples of (1) research utilization or applications and (2) technology base advancement. Technology transfer potential is discussed in both types of examples. Each of these areas is essential to obtain the maximum payoff from RDT&E efforts. Definitions of these areas are provided in the following outline:

- *Research Utilization or Application*
  Any change involving
  - Initiation or modification of regulations, orders, doctrines, policies, or manuals
  - Development or change of courses of instruction or training programs
  - Development or modification of equipment
- *Technology Base Advancement*
  Any advancement of the state-of-the-art involving
  - Basic research – scientific study and experimentation directed toward increasing knowledge and understanding in those fields related to long-term national security needs. It provides fundamental knowledge for the solution of identified military problems and furnishes part of the base for subsequent exploratory and advanced developments in defense-related technologies and new or improved military functional capabilities.
  - Exploratory development – all efforts directed toward the solution of broadly defined problems; short major development programs with a view to developing and evaluating technical feasibility
  - Advanced development – all projects that have moved into the development of hardware for test. The prime result of this type of effort is proof of design concept rather than the development of hardware for service use. Projects in this category have a potential military application.
- *Technology for Transfer*
  Any unique research data or applications available for transfer to
  - Other military operations
  - Non-military needs.

This introduction has attempted to define people-related RDT&E, clarify its impact on our defense posture, and establish the framework for the body of this report. No doubt the insightful reader will also ascertain that this introduction has tried to convey the importance of future support for people-related RDT&E. Perhaps there is no better way to close this introduction and proceed to some significant examples of Navy projects than to quote a respected source. Following is the concluding paragraph in the epilogue of the report to the President and the Congress, submitted by the Defense Manpower Commission in April 1978:

> People always have decided battles. There is no substitute for people who are courageous, motivated, prepared and willing. The overwhelming lesson of this report is that human considerations now have become primary in planning for the Nation's defense. It is for that reason that we believe without hesitation that Defense manpower is the keystone of our national defense.

RESEARCH UTILIZATION AND TECHNOLOGY BASE ADVANCEMENT EXAMPLES

This section of the report contains examples of recent (FY 75 – FY 77) Navy RDT&E projects which have either resulted in utilization in the Fleet or have significantly advanced the technology base. All of the examples have been prepared from materials or data supplied by the performing organization or principal investigator. The examples have been written in what is hopefully a clear, concise style. Terminology or jargon specific to the research community has been eliminated. The emphasis was to illustrate practical accomplishments rather than methodology. The Program Element number under which each project was funded is identified.

For ease of use, the examples have been organized under four technical areas within the RDT&E program in Training and Personnel Technology:

- Manpower and Personnel Technology
- Human Factors in Weapon Systems
- Education and Training Technology
- Training Devices and Simulation.

The material in each technical area is preceded by a listing of the examples which appear in that section. As stated earlier, these are representative examples and no attempt has been made to report on all people-related Navy RDT&E performed in FY 75 through FY 77.

MANPOWER AND PERSONNEL TECHNOLOGY

- Naval Academy Selection Procedures
- The Naval Personnel Pay Predictor, Enlisted (NAPPE) Model
- Success Chances of Recruits Entering the Navy (SCREEN)
- Improved Multifactor Weighting System for Enlisted Advancement
- Unbiased Recruit Assignment
- Productivity and Motivation
- Economic Research on Navy Manpower Problems
- Technique for Interactive Systems Analysis
- Laboratory Workforce Planning with a Conversational Manpower Model
- Career Counseling
- Force Structure Simulation Model (FAST) Development
- Conference on First Term Attrition
- Conference/Survey on Cost-Benefits of Recreation

NAVAL ACADEMY SELECTION PROCEDURES

Need/Objectives

The U.S. Naval Academy is a major source of commissioned officers. Every year, over 800 midshipmen are commissioned. Consequently, it is important that the men and women who seek admission each year are carefully screened so that opportunities are given to those who are most likely to succeed at the Academy and as officers.

In the past, Academy managers regarded the rate of voluntary resignations at the Naval Academy as too high. One of every three midshipmen failed to complete Academy training. Furthermore, the percentage of candidates selecting engineering, mathematics, and science majors was deemed too low (below 80%) to meet present and future service needs.

The project initiated to address these problems had dual objectives. The first was to modify the selection procedures to reduce disenrollment (losses) caused by academic failure and personal dissatisfaction. The second was to increase the proportion of midshipmen voluntarily majoring in (and remaining with) engineering and science. Funding comes from Program Element No. 63707N.

Approach and Results

The Navy Personnel Research and Development Center (NPRDC) analyzed all disenrollment records and selection procedures. Recommendations were proposed for consideration by the Academy Admissions Board, and two selection instruments were developed. One instrument was a Combined Disenrollment Scale (DIS) designed to identify those applicants most likely to disenroll. The second instrument was an Engineering-Science (ES) Scale, 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 as compared to those who would choose non-technical majors.

Utilization/Technology Base Advance

Since the development and evaluation of the Combined Disenrollment and Engineering-Science Scales, both have been adopted by the Academy for use in applicant selection. The success of the project is perhaps best expressed by referring to a letter to NPRDC from the Superintendent of the Academy, Rear Admiral Kinnaird R. McKee. Excerpts from the letter, dated 29 October 1976, follow:

> The Admissions Board began its selection of the Class of 1981 on 21 October. The procedures in use by the Board are based on the Center's analyses of the performance of previous classes. As a result of this work, we have a greater confidence in the validity and reliability of our process than ever before.
>
> The development and confirmation of validity of two special scales used in scoring the Strong Vocational Interest Blank last year helped us to exceed our goal of 80% voluntary enrollment in engineering/science majors and to reduce the attrition of midshipmen below that reported for any class at any other service academy.

The Combined Disenrollment Scale is believed to have contributed significantly to lowering the rate of voluntary resignations in the classes of 1977 and 1978. Also, the percentage of midshipmen voluntarily selecting an engineering or science major increased from 70% for the class of 1977 to 80% and 83.4% for the classes of 1978 and 1979, respectively.

Payoff/Potential

The potential dollar saving from using the new Scales, thereby reducing the number of disenrollees, has been calculated at more than $500,000 per year. Also, because of the successful use of the Engineering-Science Scale for selecting midshipmen, 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 in the NROTC must be increased.

THE NAVAL PERSONNEL PAY PREDICTOR, ENLISTED (NAPPE) MODEL

Need/Objectives

Navy planning and policy are marked by complex problems and conflicting objectives. One such problem is that of forecasting the Navy's military manpower budget to avoid cost overruns and personnel difficulties. Cost overruns can occur as a result of inaccurate estimates of either the personnel force (personnel arrayed by length-of-service [LOS] and pay grade) or the various pay rates. To control for the first source of error, forecasting models are being developed by the Navy Personnel Research and Development Center (NPRDC) to predict required obligations based on a desired or allocated man-year average by pay grade.

The objective of this effort was to develop a computer model to be used by the Navy's personnel managers to forecast the enlisted force structure based on longevity, transition rates, and the costs associated with future enlisted population. Funding comes from Program Element No. 62763N.

Approach and Results

The model, which is being used to monitor the characteristics of the force and its cost in basic pay, is formally known as the Naval Personnel Pay Predictor, Enlisted (NAPPE). NAPPE relies upon U.S. Navy and U.S. Naval Reserve force structure files dating back to 1957. Selected analysis techniques were applied to these files to find a particular set of models that would be appropriate for forecasting the LOS distribution. Various combinations of these forecasts were then compared to obtain a "best" forecast for the distribution. The results of the NAPPE forecasts are shown in Table 1. As indicated, the forecast error in the last three fiscal years using NAPPE was restricted to less than 0.20 of 1%. It is estimated that previous methods used for forecasting estimated basic pay resulted in errors of about 1% – which amounts to about $30 million in terms of the current budget.

Utilization/Technology Base Advance

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.

The Chief of Naval Personnel cannot exceed budget appropriations, and he must therefore be cautious with respect to personnel management actions. Since NAPPE results in less forecasting error, it helps to avoid problems such as reducing enlistments, encouraging early attrition, and delaying promotions.

Table 1
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

Payoff/Potential

The NAPPE model for personnel budget *forecasting* is only one of many efforts being devoted to improved management of human resources. The model could be expanded to include forecasts of other enlisted budgetary components, such as basic allowances, etc. Also, the Navy could develop an officer version of the model to forecast basic pay and, eventually, other officer costs.

SUCCESS CHANCES OF RECRUITS ENTERING THE NAVY (SCREEN)

Need/Objectives

The Navy's concern about the increasing number of premature losses of first-term personnel prompted the need to create a recruit screening tool to predict an applicant's chance of surviving the first year of service. The objective of this study was to develop a model for estimating premature losses in order to plan recruiting policy and screen applicants for enlistment. Funding comes from Program Element No. 65152N.

Approach and Results

The project was funded by the Office of the Chief of Naval Operations and conducted under the direction of the Center for Naval Analyses. Modeling efforts were utilized to produce the SCREEN table. The table is used to predict the chances of completing the first year of service based on education, mental group, age, and dependent status of Navy recruits. The SCREEN table was originally developed from loss rates obtained by tracking a group of recruits through the first year of service. A follow-on study showed that the predicted survival chances developed from the SCREEN model on the original group of recruits corresponded to their actual first year completion rate. In April 1977, a re-analysis of the variables in the SCREEN model was performed to compensate for changes in minority recruiting policies.

Utilization/Technology Base Advance

Navy personnel planners currently use SCREEN in planning recruiting policies with respect to the quality of accessions and in managing losses during the first year of service. This study is being continued by tracking the model group through the fourth year of service to examine the effects of service experience on premature loss rates. If certain patterns of training assignment, performance, and skill specialties are related to continuation, an in-service SCREEN can be developed to capitalize on these patterns for use in enlisted classification, distribution, and separation policy.

Payoff/Potential

The use of the SCREEN table to minimize first year losses also results in decreased recruiting requirements. This is evident from a $3 million decrease in attrition costs with no accompanying increase in recruiting costs for FY 77. Further, any improvement in this loss experience results in cost savings with respect to training investment. Modified versions of this system also have the potential for identifying probable first year losses for the other services.

IMPROVED MULTIFACTOR WEIGHTING SYSTEM FOR ENLISTED ADVANCEMENT

Need/Objectives

The selection of the best qualified candidate for promotion has been a long-standing and continuous concern of the Navy. The ramifications of the selection process extend into the area of retention rates, morale, and effectiveness of enlisted personnel, in general, and of minority personnel, in particular. Accordingly, in FY 72, the Navy Personnel Research and Development Center (NPRDC) initiated a project to analyze the existing promotion procedures and to investigate alternative promotion methods. The objectives of the research were to maximize the effectiveness of those enlisted personnel in positions of increased authority at the higher pay grades and to maximize equal opportunity. This was to be accomplished through the development of improved weighting procedures for a mix of such factors as knowledge, job performance, and seniority. Funding comes from Program Element No. 62763N.

Approach and Results

The approach to the project applied iterative techniques to multiple factor statistical analysis to achieve the precise quantitative weighting of selected promotion factors. One of the subsequent promotion systems was then used to select advancements to pay grades 4, 5, and 6. Another procedure was developed and used by a selection board to screen candidates for advancement to pay grades 7, 8, and 9.

Generally, the improvements in the weighting technique increased its effectiveness as a selection device. The results indicated that the candidates selected were better qualified in terms of all the factors than those selected by the old weighting procedures.

Comparison of a Black minority enlisted group with the White majority group showed that the relative percentage of eligible Black personnel receiving promotions for pay grades 5 and 6 increased significantly when the weighted promotion technique was applied. Pay grade 5 promotions increased from 67 to 84% when compared to the White group; at pay grade 6, the relative percentage changed from 50 to 100 for the Black group. This result is believed to be one of the most substantial improvements, empirically evaluated and documented, for any management or research and development approach to improving equal opportunity.

Utilization/Technology Base Advance

As a result of the project, more emphasis has been placed on the recognition of "on-the-job performance" as one of the promotion criteria. The cut-off scores on technical-knowledge examinations were reset at levels which improved the opportunities for candidates to compete on the basis of other factors as well. More emphasis has been placed on experience (i.e., seniority, awards, medals, etc.), leadership capabilities, and quality of performance, with increasing weight applied to the performance factor in the higher pay grades.

Implementation of the new selection techniques also permitted discontinuation of the time-consuming, manual procedures of the Meritorious Selection Board. This Board met annually to select a small number of "meritorious" candidates who had not been advanced in five or more tries.

This weighted promotion technique was developed and tested on the total Navy enlisted population competing for advancement, which represents the limits of possible utilization in the Navy.

Payoff/Potential

There are no hard figures presently available to assess the contributions of the weighted promotion system to readiness, training, and the overall effectiveness of Navy personnel. However, promotion of better qualified personnel usually increases such intangibles as motivation, personal pride, and esprit de corps which can positively affect retention.

UNBIASED RECRUIT ASSIGNMENT

Need/Objectives

The pre-1972 Marine manpower assignment policy failed to consider race as a factor in assigning recruits to training schools. The system tended to assign more minority personnel to "soft" skill training areas than to more highly technical areas. This unintentional imbalance came about because the assignment methods selected individuals in terms of absolute measured qualifications; this resulted in an assignment system that was detrimental to personnel who were fully qualified, but to a lesser extent. Some undesirable consequences were that minority personnel had fewer opportunities to acquire skills transferable to later civilian careers, more exposure to combat assignments, and more morale and disciplinary problems.

The objective of this project was to develop a computer-based recruit assignment system for the Marine Corps that would guarantee an unbiased (i.e., fair to minority personnel) matching of individual skills with post-boot camp training. Funding comes from Program Element No. 62757N.

Approach and Results

The Office of Naval Research funded a 2-year research effort to accomplish this objective. The research methods used included a systems analysis approach, computer programming, and probability modeling. The contractor developed a mathematical method to improve the existing recruit assignment system. In part, this was made possible by accepting the concept that race is a valid characteristic, necessary to the recruit assignment process.

Utilization/Technology Base Advance

This "fair share of minorities" facet of the Marines' Computer Based Recruit Assignment (COBRA) system is now an integral part of the operational system. It has been incorporated without compromising the overall quality of skill in the Marine Corps. Minority personnel who meet the minimum qualifications are now considered for assignment to "hard skill" technical schools, while all unqualified personnel remain ineligible for such training.

Payoff/Potential

The new system has been adopted throughout the Marine Corps and has resulted in an increased racial balance among all military occupational specialties, and this, in turn, should have a marked effect on motivation, morale, utilization of skills, and attrition rates throughout the Corps. High attrition escalates recruiting requirements and brings about waste in the form of unoccupied school seats; its most extreme effect is to reduce readiness because not enough people are available to man critical billets.

PRODUCTIVITY AND MOTIVATION

Need/Objectives

Increased productivity of Navy civilian and military personnel is a necessary goal as manpower costs continue to escalate. This project was an exploratory development effort to determine the feasibility of extending theoretical assumptions concerning human performance and productivity into actual work settings. The research directly addressed the effect that various organizational and personnel factors have upon individual productivity.

The objective of this project was to develop a performance model for predicting individual productivity and diagnosing the effect of organizational reward systems. Funding comes from Program Element No. 62763N.

Approach and Results

During FY 75, scientists at the Navy Personnel Research and Development Center (NPRDC) began the development of a performance prediction model based upon an assessment of individual ability and motivation to work. During that year and FY 76, the model was applied to clerical workers to determine whether it could accurately account for their current rates of performance. The model did account for individual productivity with a fairly high degree of accuracy. Furthermore, the methods employed identified specific factors responsible for high and low levels of productivity in particular jobs.

Changes in performance were evaluated following the design and implementation of an incentive management program for several similar work groups. One such evaluation analyzed the performance of a keypunch section of a naval data processing department. The performance model predicted that when a reward is made contingent on a particular and reasonable performance level, individuals will strive to achieve the performance level to gain the reward. The rewards included monetary bonuses for performance that exceeded predetermined work standards. The amount of these bonuses was related to the degree by which standards were exceeded.

As a direct result of the implementation of the performance prediction models, the daily work backlog of the keypunch center was reduced to near zero during the incentive period (Figure 1). Average weekly overtime hours for the key entry section were also reduced to near zero (Figure 2). Additionally, key stroke rate averages were increased during the incentive period from approximately 8500 key strokes per hour to approximately 10,200 per hour (Figure 3).

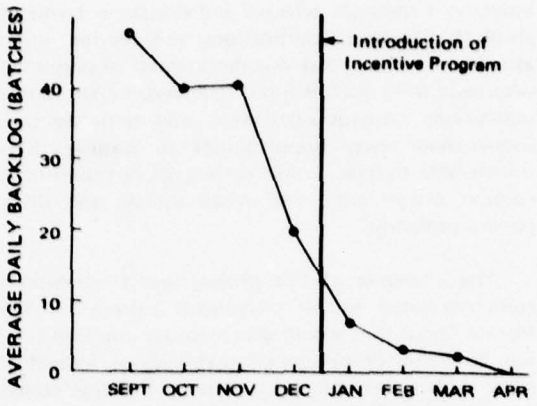

Figure 1. Work Backlog in Batches Per Day for the Pre-incentive and Incentive Periods. (Reduced backlog in December was due to a reduced work volume associated with shipyard closure during that month).

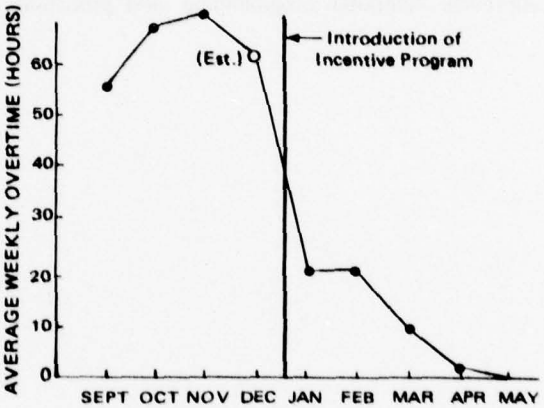

Figure 2. Average Weekly Overtime Hours for the Key Entry Section during the Pre-incentive and Incentive Periods.

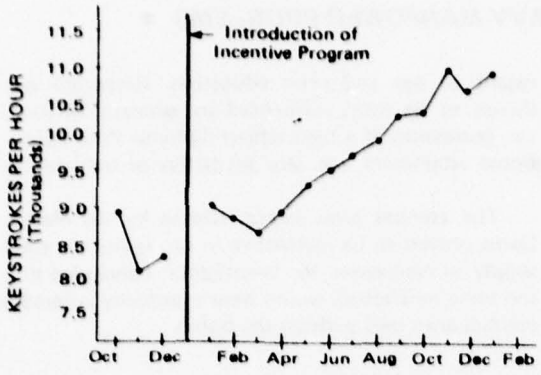

Figure 3. Keystroke Rate Averages (n=23) for the Pre-incentive and Incentive Periods.

Utilization/Technology Base Advance

The keypunch center project represents the first application of the performance prediction model in government and military settings. The usefulness of the model has been demonstrated with a restricted variety of organizational changes. Future efforts will expand the number of tasks being examined in larger and more complex organizations.

More recent utilization was reported by Mare Island Naval Shipyard in a letter dated January 10, 1978:

> This shipyard implemented the performance contingent reward system in the Data Entry Section of the Computer Operations Division on 1 April 1977. In addition to the monetary reward provided to the employees, there has been a noticeable improvement in morale, a reduction in turnover, and reduced absences. There are a number of other management benefits resulting from this program of which increased productivity is the most significant. Meaningful standards have been developed and implemented to provide methods of measuring operator performance, predicting workload, scheduling workload, and to insure an equal distribution of workload to employees. These standards also provide the base upon which the monetary awards are calculated. As a result of our experience with this program, it is highly recommended as an effective tool for the management of ADP Data Entry which provides an appropriate incentive to employees for increased productivity.

Payoff/Potential

Using the first quarter 1977 data, a forecast was made that the Long Beach Naval Shipyard would realize a modest $1,360 cost saving in 1977 even after all start-up costs for the project were written off. This, however, was an underestimate since efficiency continued to climb after the first quarter. Using the initial forecast and extending the results to the other Navy shipyards, savings of $508,000, $1,700,000, and $3,200,000 have been projected for 1, 3, and 5 years, respectively. Experience with a similar project at the Mare Island Naval Shipyard indicates that the forecast is conservative.

ECONOMIC RESEARCH ON NAVY MANPOWER PROBLEMS

Need/Objectives

The end of the draft brought about a broad range of technical and operational problems associated with recruiting and other manpower functions within the Navy and Marine Corps. In response to this, the Office of Naval Research initiated a project to address the following issues:

- The development of a system to forecast the force strength of the Marine Corps in the face of attrition
- Identification of factors influencing the capacity for training and retention
- Assessment of the combat arms bonus offered to Marine enlistees in certain occupational categories.

Funding comes from Program Element No. 62763N.

Approach and Results

Econometric modeling, computer analysis, statistical analysis, and file building were used to compile and analyze the information gathered throughout the project.

One product of the research was a "maximum likelihood model" that forecasts the force structure (size) of the Marine Corps under realistic conditions of attrition. The method provides accurate projections up to 12 months.

Another outcome of this research was the development and application of a contingency table approach to determining recruiting policies with regard to age and prior education. Retention was shown to be most influenced by educational level, i.e., possession of a high school diploma. Prior educational attainment was also predictive of trainability.

The combat arms bonus offered by the Marine Corps proved to be ineffective in increasing the total supply of manpower; the investigators concluded that the same individuals would have eventually entered a combat arms unit without the bonus.

Utilization/Technology Base Advance

The results of the project have prompted the Marine Corps to use the maximum likelihood model to provide quantitative recruiting objectives that can be adjusted as the forecasts change. The findings relative to education as a predictor of retention and education as an indicator of trainability were implemented in new Marine Corps policies:

- Increased quotas were set for high school graduates.
- Occupational assignment was modified to take into account the level of education.

Payoff/Potential

The modeling techniques and filing system developed for and used by the Marine Corps have applications to Navy manpower problems. In addition, the statistical programs developed during the project provide powerful tools for understanding the implications of many proposed management and policy changes within the services.

TECHNIQUE FOR INTERACTIVE SYSTEMS ANALYSIS

Need/Objectives

Manpower costs continue to rise, even as the personnel inventory declines. The need for significantly improved determination and allocation of manpower requirements can only be met by the use of computer models. Although systems analysis traditionally has been used to obtain the necessary data for design or evaluation of hardware systems, this analytic capability is no less desirable for "soft systems." The objective of this project was to develop a Technique for Interactive Systems Analysis (TISA) as an analytic tool for the design and management of personnel organizations or systems. Funding is under the aegis of the Manpower Requirements and Resources Control System, Program Element No. 63707N.

Approach and Results

TISA was developed by the Navy Personnel Research and Development Center. It permits the use of traditional systems analysis methodologies (e.g., cost-benefit analysis) on "soft" systems in a computerized and conversational manner (Figure 1). For example, TISA can represent a management information system, using as building blocks all the significant communications data (e.g., recurring transmissions of flows of information) that comprise the system. It uses networking algorithms to access and structure data from computer files, applies various analyses to these data, and displays resulting system networks by computer graphics via functional block diagramming.

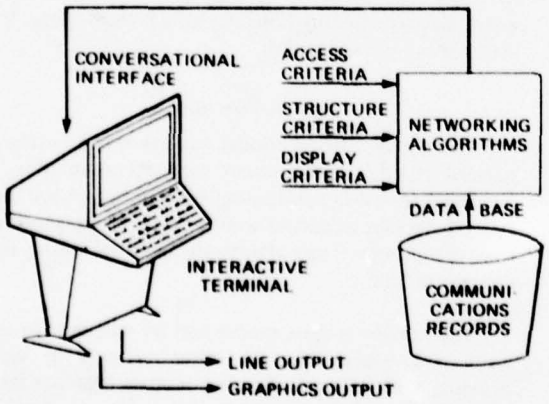

Figure 1. TISA Structure.

TISA can assist manpower managers in:

- Assessing the state of the current system at the onset of a major development effort (i.e., to establish a baseline)
- Identifying deficiencies in the manpower system and probable candidates for further R&D
- Providing a convenient and effective means for assessing the progress of a development effort at any point in its evolution.

Utilization/Technology Base Advance

In FY 76, the TISA computer package was converted from the PDP-10 computer at the Brookings Institution in Washington, D.C., and made operational on the UNIVAC 1110 computer at the Naval Undersea Center in San Diego.

TISA has been used within the Bureau of Naval Personnel (DCNP for Management Information, PERS-3) to assess the present and future automated data processing requirements of that organization. The application used a data base which included more than 300 organizational entities which collectively identified more than 600 communication linkages as necessary to the performance of basic operating, administrative, and planning tasks. The same data base was employed to uncover strategies and constraints concerning possible reorganization and an impending move of part of the Bureau from Washington, D.C. to New Orleans. TISA was used to answer such questions as "What is the density and criticality of communications between two or more nodes in the organization?"

TISA was also delivered and made operational on the UNIVAC 1108 computer at Lackland Air Force Base in FY 76. Members of the Air Force Human Resources Laboratory were given demonstrations and training sessions on TISA to assist with the Air Force Integrated Simulation Evaluation Model project. Finally, a TISA user's manual was completed that can be used as an operating guide and a programmer's systems reference.

Payoff/Potential

TISA has potential as a "data management" tool in a management information system or resource management system development effort.

LABORATORY WORKFORCE PLANNING WITH A CONVERSATIONAL MANPOWER MODEL

Need/Objectives

With the current emphasis on accurate cost projections within the Department of the Navy, management personnel at the Naval Underwater Systems Center (NUSC) are concerned with those manpower policies that impact on ceilings, budget, and average grade of the work force.

The objective of the project was to develop a recruiting requirements model which would predict as closely as possible a set of manpower needs for NUSC. Further intent was to provide the technology to permit two-way dialogues between the manpower analyst/manager and supporting computer models in a manner which would allow the inputting of appropriate feedback to the computer-generated model.

The model development was originally carried out by the Office of Civilian Personnel, Department of the Navy. NUSC has also received support from the Navy Personnel Research and Development Center. Funding comes from Program Element No. 63707N.

Approach and Results

The NUSC has developed a number of tools to accomplish its manpower planning. Automated personnel data systems, statistical data and reports, integrated financial or personnel files, and long-range staffing plans were used to compile information and assess the utility of manpower planning models. Application studies have been under way since 1972. One of the most promising of these studies is the Conversational Use of the Recruiting Requirements Model (CURRM). This model recommends how many people must be hired/fired considering such variables as internal transfers, attrition, and budget and ceiling constraints.

The value of the conversational computerized model is that alternative solutions can be quickly analyzed under various problem constraints. Thus, the impact of different policies can be judged.

Utilization/Technology Base Advance

The CURRM model was installed at NUSC in 1976 and is now fully operational. It is the mission of the model to allow managers to apply a given solution, to examine its effects, to make changes in their decisions, and to discern the probable outcomes of these changes. By receiving inputs from designated sources, they are able to estimate projected costs. Figure 1 illustrates the system information flow.

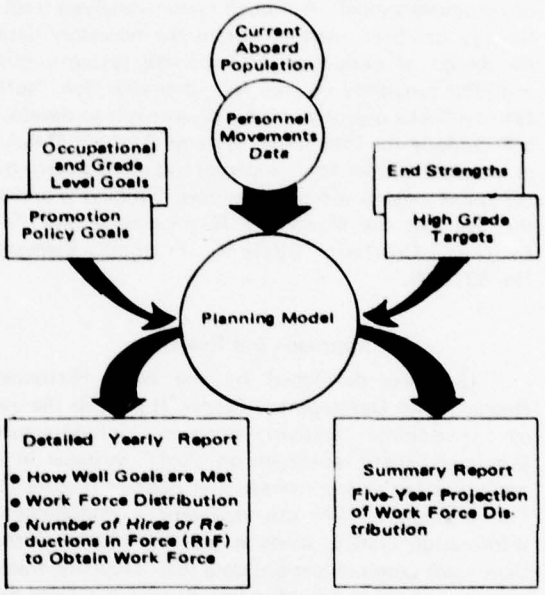

Figure 1. CURRM Model Information Flow.

By utilizing the current conversational version of the model, the management of NUSC is able to monitor trends and alternative solutions to a variety of manpower planning strategies. The Naval Underwater Systems Center finds the model most useful for establishing general trends.

Payoff/Potential

The conversational model has become an integral part of NUSC's management support capabilities. It has been useful in estimating the number of job and billet vacancies expected over various time periods so that management can effectively institute hiring and promotion plans.

The conversational model can be adapted for use with new technology in other systems as well, bringing multi-period planning models together with organization design models in order to project individual man-job assignments.

CAREER COUNSELING

Need/Objectives

With the initiation of the all-volunteer force, the military found its manpower resources diminishing considerably. Navy reenlistments were at a low of less than 20%. As a result, the Office of Naval Research supported an expanded career counseling program intended to increase the proportion of qualified first termers who reenlist. The objectives of this project were:

- To develop techniques for identifying first-term enlisted personnel who possess skills and performance records desirable in the career force
- To enhance the impact of division officers and enlisted career counselors on reenlistment decisions
- To assist in developing a career counseling system with special emphasis on retaining highly qualified individuals.

Funding comes from Program Element No. 62763N.

Approach and Results

Systems analysis, surveys of naval personnel and their wives, and computer simulation of the career counseling process contributed to the development of an effective career counseling system. Specifically, the study demonstrated the important role of wives in reenlistment discussions and decisions. Furthermore, it determined that large proportions of critical groups (97% of the wives and 60% of the first termers) were not reached by the original career counseling program. Group career counseling techniques, individualized training techniques for career counselors, and automated scheduling and record keeping procedures were among the measures developed to enhance career counseling effectiveness.

Utilization/Technology Base Advance

This research program was a major source for 47 recent initiatives in the Management By Objectives (MBO) system of the Chief of Naval Operations and Chief of Naval Personnel. Findings from this study were used by the Bureau of Naval Personnel as a basis for revising the Naval Career Counseling Program. The Navy Recruiting Command, the Family Studies Branch of the Naval Health Research Institute, and the other military services have also utilized the results of this research.

Payoff/Potential

The retention rate increased from 20% in 1972 to 40% in 1975, exceeding the goal set by the Chief of Naval Operations. Effective career counseling which contributes to desired retention rates also has cost benefits in several areas. Recruiting goals can be reduced; training loads for basic technical skills are decreased, and mission performance is improved because competent, experienced people remain in the Navy.

FORCE STRUCTURE SIMULATION MODEL (FAST) DEVELOPMENT

Need/Objectives

The Bureau of Naval Personnel has a continuing need to determine the feasibility of attaining manpower requirements and the long-term effects of personnel policies. Over the years, many separate techniques or methods were developed and used to provide answers to particular personnel planning issues. However, the interactions of the separate issues, particularly when extended over several years, were difficult to forecast. Further, it was similarly difficult to test, in advance, the implications of major personnel policies. What was needed was to integrate many of these needs into a simulation model with which the user could converse. One such effort is the Force Structure Simulation Model, popularly known as FAST.

The objective of FAST is to simulate the flow of active duty enlisted personnel through the force structure to reveal problems in force configuration, feasibility of meeting manpower objectives, and budget implications of current or proposed policies. FAST was developed over several years and has been used extensively by Navy planners. Funding comes from Program Element No. 62763/63707N.

Approach and Results

The Navy Personnel Research and Development Center (NPRDC) developed the initial version of FAST in 1974. The enlisted personnel system was modeled by developing data along four primary dimensions of the force structure, viz., pay grade, length of service, occupational specialty, and time (i.e., fiscal year). The quantities contained in the force structure represent the result of various personnel flows such as attrition, retirement, demotions, nonreenlistment, and promotions. These and other variables were selected because of such considerations as homogeneity and stability of behavior, availability of historical data, and sensitivity to policy control. FAST has two features that represent significant improvements over other manpower models: (1) The user can directly control certain aspects of the models internal computations, and (2) the model can constrain both its actions and the actions of the user in a manner similar to the way in which the real-world system is constrained.

The data processing system that supports the FAST model was developed over a number of years in response to short-term needs. In FY 77, a major effort was undertaken to integrate the various aspects of the FAST data processing system and to provide system documentation. All programs and program interfaces were examined and reprogramming was carried out as necessary. A scenario has been developed for verification and validation of the FAST model by (1) forecasting a recent year of history and comparing the forecasted results with actual data and (2) performing a multi-year forecast in which the distribution of force structure parameters can be analyzed.

Utilization/Technology Base Advance

The Bureau of Naval Personnel has been utilizing the FAST model since 1974. The Chief of Naval Operations also uses FAST for manpower programming during the Planning, Programming, and Budgeting System (PPBS) cycle. Among the many types of personnel planning issues for which the model can be utilized are the following:

- Prediction of Petty Officer advancement resources by pay grade and rating have been made and compared favorably with the FY 77 actual results of those taking advancement-in-rating tests.
- A methodology was developed to apply policy constraints on the length of service distribution of advancements. The method allows for the definition of promotion zones by pay grade with upper and lower limits.
- New methods for the estimation of demotions, incorporating length-of-service constraints, were implemented.
- A new method was developed for computing the distribution of advancements employing minimum time-in-service policy constraints.

Payoff/Potential

The new FAST model is expected to be fully implemented by FY 78. Future plans and milestones call for:

- Implementation of a new method for distributing advancements using minimum time-in-service policy constraints
- Design and implementation of an advancement optimization model to evaluate long-term effects of alternative advancement strategies
- Implementation of new methods for estimating prior service gains by rating, pay grade, and length of service
- New strategies for the allocation of recruits and non-designate apprentices to ratings in coordination with "A"-school planning data and future requirements for petty officers.

CONFERENCE ON FIRST-TERM ATTRITION

Need/Objectives

Attrition is a very costly problem: It drives up the demand for recruits, increases training costs, adversely affects military readiness, and it may have long lasting effects on the individuals who drop out. When attrition throughout the Department of Defense reached a new high in 1976, the Office of Naval Research was asked to assume responsibility for a conference to address the problem of enlisted attrition. The objective of the conference was to assemble information on attrition of first-term enlisted personnel from the Armed Forces, to identify issues that can be addressed by R&D, and to put them in priority order for their possible contributions to manpower planning. Funding comes from Program Element No. 62763N.

Approach and Results

The conference brought together research and development and operational people from all the services. In addition, papers were commissioned by the contractor from researchers nominated by a steering committee. Evening workshops and round-table sessions, structured to give a cross-service mix of participants and speakers, produced a number of policy and research recommendations.

Utilization/Technology Base Advance

The papers and related discussions of the conference placed a new emphasis on the organizational or structural factors (as opposed to the characteristics of individuals) that appear to influence attrition. They pointed out, for example, that the quality of low level management (i.e., supervision by petty officers) is an important factor. They stated a need for changes in recruiting practices, particularly those which lead recruits to have unrealistic expectations about service life. In addition, they recommended new data bases to enable the services to maintain more up-to-date understanding of attrition. Certain specific jobs were shown to have disproportionately high attrition rates, suggesting that the demands of some occupations could be redistributed. A major area of uncertainty was the economics of attrition: What is an "optimum" level of attrition? How much will remediation cost, and what is the likelihood that specific policy changes will reduce attrition?

Payoff/Potential

The Office of the Secretary of Defense (OSD) asked each of the services to report on policies that were modified or new research that was undertaken as a result of this conference. Both the Navy and Marine Corps have initiated research stemming from the conference recommendations.

The knowledge assembled by the conference about the behavior of young people in relation to employing organizations has possible wide applicability to non-military institutions both in and out of government.

CONFERENCE/SURVEY ON COST-BENEFITS OF RECREATION

Need/Objectives

In recent years, Navy comptrollers and congressional personnel have been concerned about the continued high cost of supporting Navy recreation programs ($100 million in FY 74) in the face of significantly higher salaries instituted as a result of the all-volunteer force. The Office of Naval Research (ONR) was asked by the Assistant Chief of Naval Personnel (Personnel Affairs) to examine recreational cost-benefits. An inquiry by the Smithsonian Institution (under contract to ONR) determined that relatively little was known in either military or civilian sectors. Consequently, a conference was organized to bring together civilian experts and Navy recreational specialists, and later, a survey of enlisted personnel was conducted. The objective was to assemble and assess the benefits of Navy recreation programs in relation to their costs and to determine researchable issues that would contribute to knowledge about recreational benefits. Funding comes from Program Element No. 62763N.

Approach and Results

The conference included presentations from academic institutions, from Navy personnel, and from other experts. A technical report of the proceedings was prepared including abstracts of all presentations, recommendations for research, and recommended policy actions. The subsequent survey sampled 11,000 personnel at 16 shore bases throughout the United States.

The findings of the conference and survey covered the following areas:

- Limitations of conventional cost-benefit approaches to assessing recreation and some alternatives, e.g., the application of economic techniques for estimating what individuals would be willing to pay for recreation
- Some sociological perspectives on leisure practices and how they are changing, e.g., expectations of greater diversity
- Issues in Navy recreation about which little is known, e.g., client-user characteristics and needs
- Innovative steps to test alternative recreation policies, e.g., the use of "token economies" as a way of measuring demand
- Cost-avoidance methods for use in evaluating and reshaping the Navy recreation program
- A policy option for "pay-as-you-play."

Utilization/Technology Base Advance

The Assistant Chief of Naval Operations for Personnel Affairs was able to utilize the results of these projects to identify areas in the recreation program which personnel were willing to pay for. This resulted in the new "recreational self-sufficiency" policy which literally precluded the program from going "bankrupt" while maintaining the morale benefits.

Findings concerned with the "perceived dollar value" of recreation programs to Navy personnel were also determined and used to evaluate the contribution of recreation to reenlistment decisions.

Payoff/Potential

The data from the recreation conference and survey study can be used by researchers and policy makers concerned with attrition, recruiting, morale, and motivation. While it is difficult to present simple cost-benefit statements, the order of magnitude of dollars involved gives some idea of the value of the recreational program. Consider, for example, the following:

- The budget for recreational programs was $100 M in FY 74.
- The survey revealed a perceived out-of-pocket saving of $350 per person; Navy-wide this represents approximately $180 M per year.
- If recreation were eliminated as a free benefit, the study revealed that a pay increase of $485 per person per year would be necessary to offset this; Navy-wide this represents approximately $230 M per year.

HUMAN FACTORS IN WEAPON SYSTEMS

- V/STOL Human Factors Planning
- Design of an Integrated Bridge System
- Shipboard Facilities Maintenance
- Software Design Specifications for an Interactive Medical Diagnosis System
- Color Coding of Cockpit Displays
- Landing Signal Officer (LSO) Display System
- Sensor/Display Quality for Target Acquisition
- Human Factors Engineering Technology for Voice Interactive Systems (VIS)
- Navy Technical Information Presentation System (NTIPS)
- Documentation of Ejection Procedures
- Computer Assisted Methods for Human Factors Engineering Design and Evaluation
- Human Factors Engineering Technology for Test and Evaluation of Systems

V/STOL HUMAN FACTORS PLANNING

Need/Objectives

The Navy has a strong interest in V/STOL aircraft because of the operational flexibility inherent in the vehicle concept. The piloting factors required in the design and operation of such aircraft are crucial due to the unique type of flying involved. Furthermore, accident rate experience with V/STOLs to date (Figure 1) shows two disconcerting trends. First, the current V/STOL accident rate is increasing, which is contrary to the typical experience when introducing new aircraft, and secondly, "pilot factor" as a contributing cause seems alarmingly high. With respect to this last point, the data shown in Figure 1 represent 21 accidents, 16 of which occurred in the V/STOL flight regime (i.e., conversion flight, landing, or take-off). Of these 16, 11 had "pilot factor" as a contributing cause. The Naval Air Development Center (NADC), therefore, initiated a program to provide human factors support early in the design of V/STOL aircraft.

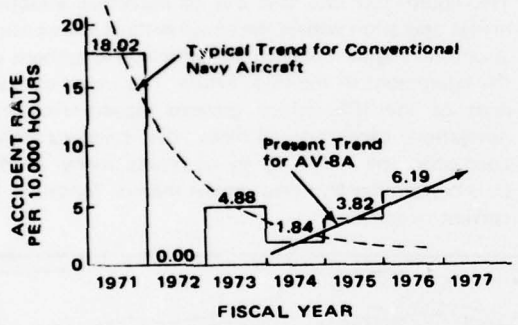

Figure 1. Accident Rate for AV-8A V/STOL Aircraft.

The Naval Weapons Center (NWC) was tasked to synthesize past experience with fixed-wing V/STOL aircraft. The resulting documentation was to be used in planning human factors support of Navy V/STOL programs. Funding comes from Program Element No. 63701N.

Approach and Results

A review and synthesis of the literature pertaining to piloting factors in fixed-wing V/STOL design was conducted. Special emphasis was placed on control/display system requirements. This effort resulted in two documents for use primarily by human factors personnel.

The first document summarizes current knowledge and lessons learned from past experience with fixed-wing V/STOL aircraft. The review indicates that the central problem in past designs has been excessive pilot work load. The results also show that display technology improvements alone cannot solve the piloting problems. The document provides a data base organized by specific aircraft as well as by mission- and vehicle-related factors unique to the V/STOL concept.

The second document provides introductory material on the aerodynamics, propulsion, and flight control technology for V/STOL aircraft. This report is intended to be a "primer" to provide background material on V/STOL technology and operations.

Utilization/Technology Base Advance

The documents resulting from this project represent both a contribution to the technology base and a job performance aid for human factors personnel engaged in the design of V/STOL aircraft. The documents are used to define the human factors work which must be done, to identify crucial areas and systems in the program (e.g., the aircraft's stability augmentation system), and to provide general guidelines for human factors engineering. The V/STOL technical base program has been restructured to take these findings into account.

The principal user at this time is the Naval Air Development Center. About 250 copies of the report have been distributed to all three services and a number of industrial organizations.

Payoff/Potential

This small project has the potential to (1) immediately provide a basis for incorporating human factors engineering into the early stages of V/STOL design and (2) ultimately contribute to the reduction of "pilot factor" accidents.

DESIGN OF AN INTEGRATED BRIDGE SYSTEM

Need/Objectives

The design of the bridge of Navy surface ships has not changed significantly since World War II. Functions such as navigation and collision avoidance require bridge watch standing personnel to have a continuous, up-to-the-minute picture of the potentially dense environment around them, sometimes under rapidly changing circumstances. Furthermore, rising manpower costs and diminishing manpower resources lend additional weight to the need for more effective bridge operations.

In 1972, a Shipboard Manning and Automation Project Office was established at the David W. Taylor Naval Ship Research and Development Center and charged with finding ways to reduce bridge watch standing on Navy ships. The first effort was a pilot program conducted to investigate the feasibility of bridge manning reductions on existing ships. The integrated bridge system (IBS) project was then established to address long-range needs.

The objective of the integrated bridge system was to demonstrate a potential for reducing surface ship bridge watch manning requirements while maintaining or improving operational effectiveness. Funding comes from Program Element No. 62757N.

Approach and Results

The pilot program examines the feasibility of reduced bridge manning through integration of existing equipment and introduction of automation into a centralized work station for bridge watch standers. Based on the results from 17 ships participating in the pilot program, it was demonstrated that some immediate reduction in bridge watch standing could be achieved.

The approach of the Integrated Bridge System Project was based on the premise that improvements in bridge functions could be achieved largely through integration of state-of-the-art equipment with selective automation and more effective procedures. These functions included navigation, maneuvering, communications, surveillance, administration, and safety. The goal of reduced manning with the same or increased effectiveness was achieved through centralization, consolidation, and automation of new and existing bridge equipment along with a redistribution of watch-standing tasks and associated bridge procedures.

The experimental system consists of two major consoles and peripheral bridge remote equipment. The equipment was laid out to maximize effective bridge operation within the constraints of the existing structure. Figure 1 shows the general arrangement of the equipment in the pilot house. The major component of the IBS, which governs maneuvering and navigation capability, utilizes the standard Navy computer, the UYK-20, to automate many of the time-consuming and error-prone manual functions in current operations.

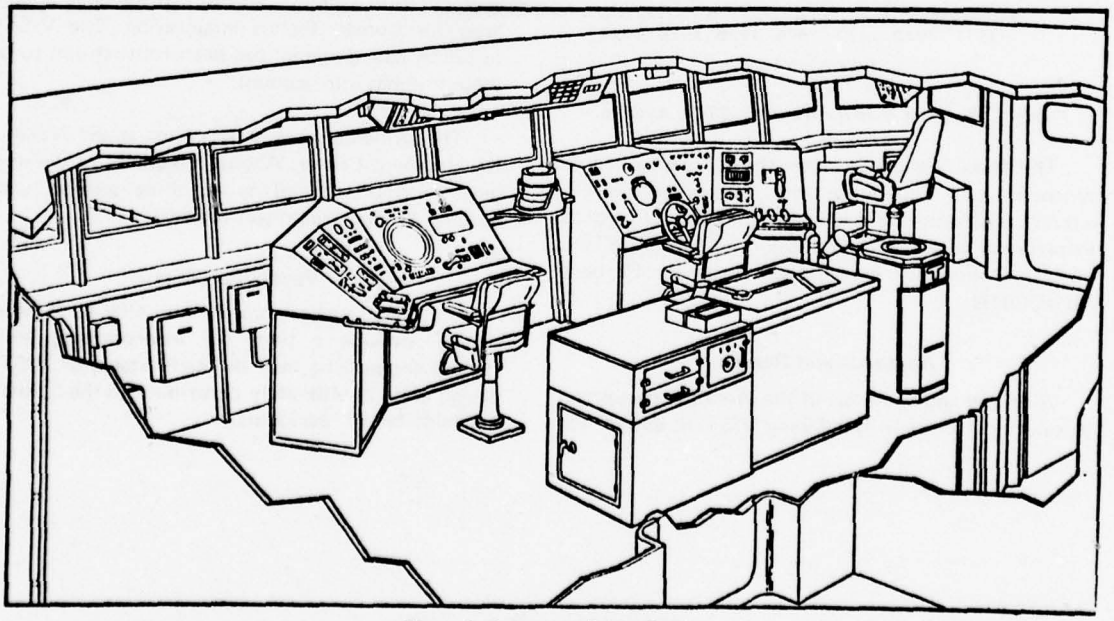

Figure 1. Integrated Bridge System.

The system was installed and tested onboard the USS MCCANDLESS (FF 1179) during January-July 1977. Results of the at-sea evaluation showed conclusively that bridge manning requirements could be reduced significantly while simultaneously improving the bridge effectiveness. Specific reductions in watch standing depend upon the particular readiness conditions under which the ship is operating. Table 1 provides some of the results from the study aboard the USS MCCANDLESS.

Table 1

Reductions in the Number of Watch Standing Personnel when Utilizing the Integrated Bridge System under Various Readiness Conditions

Condition Number	Readiness Description	Conventional Bridge Manning	IBS Manning
I (AS)	General Quarters (Anti-Submarine Warfare)	21	17
III	Wartime Cruising	15	7
IV	Peacetime Cruising (Formation)	14	7

Utilization/Technology Base Advance

The technology resulting from this project may be applied to both new construction and existing surface ships. At present, collision avoidance and navigation systems for surface-effect ships, hydrofoils, and the Coast Guard WMEC 270 class ships are being developed based on the technology from this project.

Payoff/Potential

If an integrated bridge system concept were implemented on new Navy ships, the decrease in manpower required on the bridge during most operational conditions would free personnel for other tasks. The effect would be increased cleanliness, readiness, and longer life for the ship.

Developmental costs, as well as actual installation costs, are considered minimal. They are outweighed by the expected advantages: increased manpower effectiveness, reduction in confusion, and the occurrence of fewer collision situations.

SHIPBOARD FACILITIES MAINTENANCE

Need/Objectives

The Navy has a continuing need to maintain the cleanliness, appearance, and material condition of its ships. Historically, facilities maintenance (housekeeping, cleaning, and preservation) has required a significant expenditure of man-hours, at sea and in port, and has thereby reduced availability of shipboard personnel for other duties and technical advancement. With the advent of the all-volunteer force structure and the consequences of new design trends, fewer people are available to perform the required facilities maintenance (FM). This, coupled with long-term problems of inadequate facilities maintenance equipment, materials, training, and management, has resulted in wasted manpower and material and premature deterioration of ships' conditions.

The David W. Taylor Naval Ship Research and Development Center, Annapolis (DTNSRDC/A), assisted by the Navy Personnel Research and Development Center (NPRDC) and supported by operational ships in the Fleet, has undertaken a project to develop new facilities maintenance concepts which will reduce the number of personnel and man-hours required for this continuing shipboard activity. The specific objectives of the project are to develop a system of equipment, procedures, manpower organization, training, and management techniques and to test them in actual shipboard environments. Funding comes from Program Element No. 62757N.

Approach and Results

The project was initiated in FY 74 with a systematic analysis of FM tasks which led to the identification of more effective (1) organization, management, and technical information; (2) equipment, materials, and environment; and (3) training. During FY 76, the new system was successfully demonstrated aboard the USS TRIPPE (DE 1075). Results from this feasibility demonstration included:

- FM man-hours were reduced by 20 to 40%.
- Spaces maintained were generally rated as satisfactory or better with respect to overall appearance and cleanliness.
- Job skill and knowledge of FM personnel increased.
- The overall FM program received generally favorable ratings.

Utilization/Technology Base Advance

This project is not yet completed. Detailed results will be available in 1979/1980. However, as a result of the feasibility demonstration, the following preliminary utilization is underway:

- The Guided Missile Ship Acquisition Program Office (PMS-399) requested and received support in developing an innovative FM system tailored to the FFG-7 class ship. Currently, the USS OLIVER HAZARD PERRY has some of the innovations installed.
- The Commander, Naval Logistics Command, Pacific Fleet (COMNAVLOGPAC), and the Naval Development Training Center/Fleet Maintenance Assistance Group, Pacific (DATCFMAGPAC), also requested and received support from the project office in developing and testing the innovations for the DD 963 class ships.
- Other potential user organizations in both the Atlantic and Pacific Fleets and the Naval Ship Engineering Center (NAVSEC) have been continually briefed and made aware of the research findings.

Payoff/Potential

Table 1 presents estimates which have been made for a frigate (FF-1052 class) and a nuclear powered carrier (CVAN) in terms of manpower savings from FM innovations.

Table 1
Estimated Manpower Savings
Through FM Innovation

	Per Ship FF-1052 Class	Per Ship CVAN
Current FM Weekly Workload in Man-Hours	1387	10,910
Estimated % Savings	20-30%	20-30%
Estimated Man-Hour Savings/Week	277-416	2,182-3,273
Estimated Number of Men	6-9	51-76
Estimated Life-cycle Dollar Savings	$1.35M–$2.02M	$11.5M–$17.1M

Other potential payoff areas include:

- Cleanliness and improvement of shipboard spaces – Quality of all FM work will be improved.
- Satisfaction – It is estimated that ships' officers will express positive opinions concerning the effects of FM innovation in all areas including training, habitability, increased efficiency, and manpower utilization.
- Materials expenditures – Targeted expenditures for paint, FM materials, etc. will be decreased.
- Skill/Knowledge – It is estimated that FM workers will demonstrate significantly improved capability to understand and perform FM.
- Habitability – Ship spaces will be considered more habitable by the people who live and work in them.

SOFTWARE DESIGN SPECIFICATIONS FOR AN INTERACTIVE MEDICAL DIAGNOSIS SYSTEM

Need/Objectives

Medical diagnosis and fault location in electronics equipment both require a "troubleshooting" approach. In either case, the cause of a dysfunction is determined by measuring the system's reaction to prescribed and controlled stimuli. Each step in the diagnostic sequence depends on results from previous steps in the sequence.

The objective of this project is to design a software package to enable a computer to construct the logical sequence necessary to diagnose a medical problem. Funding comes from Program Element No. 62766N.

Approach and Results

There are distinct requirements for diagnostic expertise: (1) technical ability to obtain the necessary measurements and (2) knowledge of all the conditional measurement sequences so that optimum data are collected at each step. If the fundamental abilities and knowledge required in a particular specialty can be built into a computer system, then the demands on the diagnostician may be reduced.

In FY 76, the Navy Personnel Research and Development Center (NPRDC) devised system design principles for a software package to aid in medical diagnosis. The field of physical medicine and rehabilitation was used to examine the feasibility of the concept: A physician would construct a logic tree of diagnostic sequences so that a properly trained technician using a computer could perform a sound diagnostic sequence. The software was debugged and verified through utilization of historical medical records.

Utilization/Technology Base Advance

NPRDC, in collaboration with the Naval Regional Medical Center (NRMC), San Diego, devised a software package that would conduct the appropriate diagnostic sequence to reveal neural lesions involving the upper limbs. This package was implemented on a computer system by NRMC and has the following characteristics:

- It requires minimal knowledge of computers on the part of the user.
- It allows for the construction of arbitrary logic trees.
- The user may override the logic tree or enter unsolicited data.
- The system is fast, efficient, and inexpensive to run.

The present system has also been used as a rudimentary training device, although it was not designed for that purpose.

Payoff/Potential

Potential benefits are not limited to the medical profession. Payoff could be expected in any highly technical field in which fault diagnosis must be accomplished by a complex logical procedure. Such payoff would come in the following ways:

- Reduction in the number of skilled professionals required
- Increase in the quantity of fault location work accomplished per unit of time
- Increase in the quality of fault location work.

COLOR CODING OF COCKPIT DISPLAYS

Need/Objectives

The increasing sophistication of airborne weapons and aircraft avionics has greatly increased the requirements to display information to the aircrew. All of the military services have RDT&E programs for integrated cockpit instrumentation. The Navy is pursuing its Advanced Integrated Display System (AIDS); the Air Force program is the Digital Avionics Instrumentation System, and the Army is developing fiberoptic displays and solid state electronics to replace conventional helicopter engine dials and gauges. The development of airborne computers and color cathode ray tubes (CRT's) now makes it feasible to provide color-coded displays to the aircrew. However, the usefulness of color has not been established. The question of real performance advantages in using color rather than other types of coding must be researched and answered before design commitments are made.

The specific objective of this project at the Naval Weapons Center was to evaluate the advantages and disadvantages of color coding in aircraft cockpit displays (e.g., CRT displays). The project was requested by the Naval Air Systems Command (NAVAIR) (Air 340F and D) and coordinated with the Naval Air Development Center (NADC). Funding comes from Program Element No. 62763N.

Approach and Results

A series of laboratory experiments was designed to investigate the effectiveness of color coding for potential cockpit application. The experiments investigated: (1) the effect of color on monitoring malfunction indications while engaged in a target detection task and (2) the relative effectiveness of black and white, single-color, or two-color coded displays.

Videotape recorders, monitors, and response recorders were set up in an equipment room. The subject had a display/response unit with as many as three TV monitors and buttons for making target response or malfunction response inputs. Additionally, the subject's TV monitors could be reviewed under conditions of red and white illumination.

Experiments were conducted in which both target detection and malfunction detection times were recorded. Performance with the black and white displays was used as a standard of comparison for performance with color and color-coded displays. Percent performance change was calculated. A variety of findings resulted and will help to determine where specific applications of color are warranted. In general, the experimental results indicated that there is a slight advantage to color-coded displays over black and white displays (Figures 1 and 2).

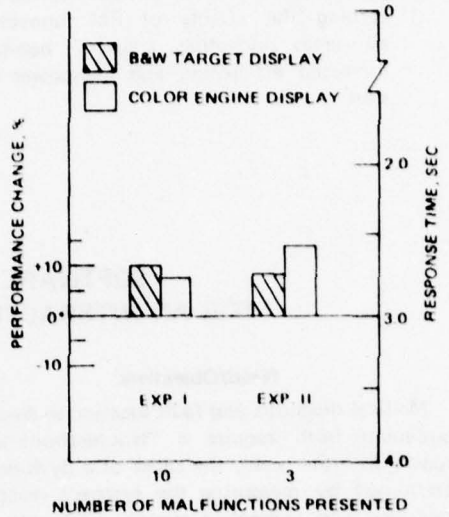

Figure 1. Percent Performance Change and Response Time for Experiments I and II.

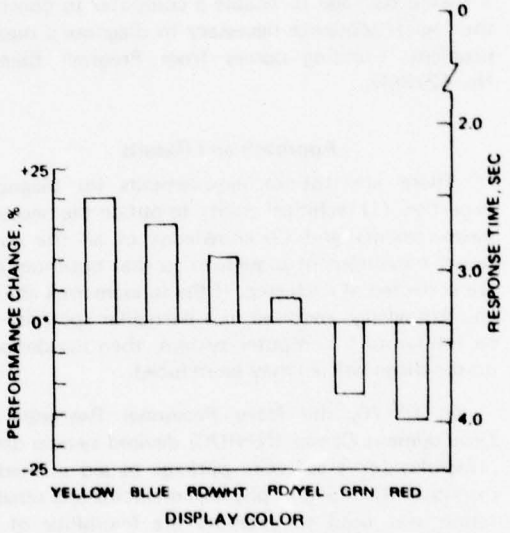

Figure 2. Percent Performance Change With Color Relative to B&W Displays for Experiment III (Averaged Across Three Displays).

*The performance baseline (0%) is the mean response time found for experiments in which all displays were shown in B&W.

Utilization/Technology Base Advance

The information from this project has been used as the basis for the decision to use monochrome CRT's in the first Advanced Integrated Display System. The state-of-the-art for monochromatic displays is well advanced, at least for CRT representations, and requires only moderate developmental effort.

Information obtained from the literature review and the continuing experiments is being maintained as a resource for future R&D. Technical reports and briefings have been used to disseminate information from this project, and NADC human factors engineers have made written design recommendations to NADC design engineers based on this project.

Payoff/Potential

The use of a monochrome CRT rather than a multicolor display in the first AIDS system represents a cost saving of about $8,000 per display. If color coding were not used, a saving of perhaps $15,000 per aircraft would be realized. The human payoff is in the improved crew performance with the selected use of color.

LANDING SIGNAL OFFICER (LSO) DISPLAY SYSTEM

Need/Objectives

Carrier-based aircraft land at speeds up to 140 knots, day and night, and sometimes in low visibility conditions including rain and fog. The Landing Signal Officer (LSO) coordinates with the approaching pilot, provides guiding signals, and decides whether the aircraft can land safely. In minimum weather conditions, the LSO may have only 2 or 3 seconds to make this decision. Because of the complexity and critical nature of this task, the training period to qualify LSO's for *one* aircraft type is about 14 months. Each year there are accidents, some fatal and extremely costly, that might have been avoided had the LSO had an information display system that fully met his information needs. The purpose of the project, therefore, was to determine the information needed by the LSO and to develop a display system to provide it. Funding comes from Program Element No. 61153N.

Approach and Results

The original research into this problem was sponsored by the Office of Naval Research (Aeronautics Programs) and subsequently supported by the Naval Air Systems Command. A detailed analysis was performed on the information required by the LSO to perform his tasks, with particular focus on those areas where his judgment might be aided by the display of critical aircraft performance parameters (e.g., line-up, glide slope, air speed, sink rate, range). The information requirements were incorporated into an innovative, see-through display system which provides the information while still permitting the LSO to monitor the aircraft visually during the entire approach.

Utilization/Technology Base Advance

The Navy has built a prototype unit of the display system and conducted operational evaluations ashore at the Naval Air Test Center and at sea on the USS RANGER. The results of the evaluation indicated overwhelming approval of the new display system. Some 45 LSO's participated in the evaluation and indicated that the new display will improve both the safety and efficiency of carrier landing operations.

The system is going into production and will be implemented on all carriers within the next 2-year period. Similar studies have been performed at other carrier work stations with similar results.

Payoff/Potential

An airplane crash aboard a carrier can damage or destroy the aircraft plus other planes and equipment and temporarily stop operations from that carrier. Cost savings from utilization of the LSO display are difficult to project; however, the cost of carrier-based aircraft alone can run between $6 and $16 million. While it is not possible to attribute any given number of aircraft saved to the LSO display, officers aboard carriers feel certain that use of this display will lead to safer landing operations, thereby reducing casualties and damage costs and improving carrier operational efficiency.

SENSOR/DISPLAY QUALITY FOR TARGET ACQUISITION

Need/Objectives

A number of airborne weapon systems are being developed which require operator performance with television and forward-looking infrared (FLIR) systems. For example, the A-6E, A-7E, and the OV-10D aircraft have FLIR systems under development. Design questions concerning the operator's performance, specification of system parameters, and methods of system evaluation have been presented by engineers to human factors personnel at the Naval Weapons Center (NWC).

The objective of this particular project was to relate engineering descriptors of sensor and display parameters to human operator performance. Application of the results should improve target acquisition ranges. Funding comes from Program Element No. 62763N.

Approach and Results

A number of laboratory experiments were conducted at the Naval Weapons Center to measure the effects of image or picture quality from a TV or FLIR sensor on operator performance at detection, recognition, and identification of targets. Small, square targets were placed against a plain background, viewed by a TV camera, and displayed to the subject on a TV monitor. Subjects were required to perform various tasks related to target acquisition while the quality of the images was manipulated by varying the size and the number of raster lines making up the image.

A number of variables including (1) such operator factors as training, experience, and briefings; (2) target factors, such as size, shape, contrast, and surroundings; (3) atmospheric conditions, such as sun angle and atmospheric attenuation; and (4) the imaging-system characteristics, such as frequency response and spectral sensitivity, can affect target acquisition performance. However, when these variables are not limiting (i.e., do not degrade performance), scan line number and size can be used to predict operator performance, as shown in Table 1.

The data from this project have resulted in some design changes, and specifications for some engineering parameters have been established.

Previous research at NWC, the Air Force Aerospace Medical Research Laboratories, and the Army Night Vision Laboratory provided the foundation for this project.

Table 1
Scan Line Requirements

Task	Scan Lines Required	Performance Level % Correct
Detection of small, isolated targets		
18% Inherent contrast	3	100
7% Inherent contrast	5	100
Construction equipment detection	9	
Ship recognition*	9	80
Vehicle recognition	10	80
Building, bridge recognition	10	100
Aircraft recognition	12	80
Recognition (given detection) of 3 vehicles	12	85
Large target identification	20	
Detection of 3 vehicles in moving imagery (time-limited search required)	20	85

*From data to be published at NWC

Utilization/Technology Base Advance

The A-7 program office used the data from this project to direct the A-7E FLIR Head-Up Display development. Contractors both in the U.S. and England were monitored and directed in the application of these data. Acceptance tests have also been conducted.

The F-18 human factors effort used the information to aid the contractor in display specifications for the aircraft. The infrared engineering community at NWC has reviewed and evaluated mathematical models of FLIR performance in light of these results; these models are used for FLIR design and to generate FLIR design specifications.

Technical reports documenting all work have been prepared and issued. An initial distribution of 250 copies of the reports was made; in addition, 35 requests have come from other potential users. Human factors personnel have also participated in design meetings and as members of design teams and have provided expertise as requested.

Payoff/Potential

Applications from this project to system design (e.g., A-7 FLIR and F-18 FLIR and displays) will result in improved target acquisition ranges. This, in turn, will result in a higher probability of weapon launch and reduced aircraft vulnerability. As an example, if improved display image quality reduces operating time by 4 seconds, the probability of a

successful target attack is raised from .20 to .25 (an increase of 25% in the number of targets that can be attacked). These results have come from a joint services weapon delivery study.

It is important to note that many organizations, principally in the aerospace industry, have requested copies of the report from this project, and the work has served to structure continuing research in industry. In addition, reports have been sent to other countries under data exchange agreements. The data resulting from this research would also be useful in television communications work.

HUMAN FACTORS ENGINEERING TECHNOLOGY FOR VOICE INTERACTIVE SYSTEMS (VIS)

Need/Objectives

Modern aircraft require the pilot to observe more information than he can understand and operate more controls than he can easily handle. He is also required to do this in increasingly crowded cockpits. One way of reducing visual workload (and errors caused by overload) is to provide the pilot with the ability to input data or interrogate the system by voice and to receive auditory information about system status.

The objective of this project is to develop and demonstrate an alternative mode of operator communication termed a Voice Interactive System (VIS). Funding comes from Program Element No. 62757N.

Approach and Results

The Naval Air Development Center (NADC) is conducting this project. Current efforts are attempting to determine applications of Voice Interactive Systems (VIS) in crew station design, performance measurement, and training simulation systems. The approach provided for:

- Systematic examination of existing complex controls and displays in order to determine which components could most effectively be augmented by the application of VIS
- Determination of the ability of VIS to monitor, measure, and score verbal communications among crewmembers and other personnel (i.e., ground controllers, other aircraft, etc.) and, more significantly, identification of the crew actions (i.e., commands used to activate control settings, such as radio frequencies or data entries) which are initiated or terminated through speech commands
- Identification of airborne crewmembers for whom the application of VIS for training should yield more adequate information concerning a trainee's progress, provide trainee performance feedback, and reduce training costs by simulating one or more persons in multiple-person training situations.

The above efforts involve both identification of areas for the application of VIS and consideration of the technical feasibility of a given application in terms of the present state-of-the-art capability of voice technology.

Utilization/Technology Base Advance

NADC work focused on the development of processors for comprehension of word meanings and on identification of the most valuable potential airborne applications of VIS. Available documentation now provides systematic examinations of the existing control and display complexes and evaluations of possible VIS applications. Crew actions, such as commands to activate control settings, which are or could be initiated and terminated through voice commands have also been identified. The output of these application studies has been used to develop the conceptual framework necessary for a detailed implementation program.

A voice recognition and systhesis system is currently being adapted for the Navy's Advanced Integrated Display System (AIDS) simulator to allow inclusion of VIS capability in AIDS engineering development.

Payoff/Potential

It is anticipated that techniques developed and proved by the project will have wide application in future naval systems. The technology, although being developed for an airborne application, can be used to unburden operators of surface and subsurface systems as well.

NAVY TECHNICAL INFORMATION PRESENTATION SYSTEM (NTIPS)

Need/Objectives

Serious deficiencies exist in Technical Information (TI) accompanying hardware systems in the Fleet. Consequently, material readiness is reduced through poor maintenance, training, logistic support, and operations. Typical deficiencies are:

- Increasing complexity and volume of TI coupled with decreasing reading and comprehension ability of new Navy personnel
- Delays in providing initial documentation and in updating documents to reflect configuration changes and correct errors
- Inconsistencies between technical documentation for training and technical documentation for logistics
- An excessive number of errors and other inadequacies
- Escalating costs of developing and distributing TI.

As a result of these deficiencies, there has been a growing dissatisfaction and underuse of technical information among Fleet operating, maintenance, and training personnel.

To correct these problems, the Naval Ship Research and Development Center (NSRDC) at Carderock was tasked to develop the Navy Technical Information Presentation System (NTIPS). When completed and implemented, this will be a Navy-wide system for the generation, distribution, and control of TI for use in system operation, maintenance, training, and logistic support. Funding comes from Program Element No. 62757N.

Approach and Results

A systems approach is being taken to develop a single process for the complete control of systems-related TI. The needs of all user communities are being considered concurrently. Human factors engineering technology and other supporting technologies such as logistics, micrographics, automatic data processing, and publishing are being applied and developed. The program is being carried out in three phases:

I. System and Feasibility Tradeoff Analysis

II. Critical Element Testing and Detailed NTIP System Design

III. Prototype Test and Implementation Recommendations.

Utilization/Technology Base Advance

Phase I has been completed with four major accomplishments. First, actual problems experienced with TI in the Fleet, the various system commands, and the training command were identified. Secondly, the current state-of-the-art in TI generation, distribution, and control was assessed, together with current procedures in the Department of Defense and elsewhere. Thirdly, evolving human factors and supporting technologies in TI were also assessed and synthesized:

- A concept for effecting a user-data match for TI has been defined. This concept involves the application of human engineering principles to the design, development, and use of TI. The key is a methodology to achieve an effective balance among the various combinations of personnel characteristics, job tasks, environmental conditions, training considerations, maintenance philosophy, and appropriate TI formats and media. The concept also involves establishment of specifications for readability/comprehensibility.
- Current and emerging technologies have been assessed by type of medium and by applicability to specific NTIPS functions, such as data acquisition, content generation, replication, and distribution. Included are microforms (microfiche and microfilm), video disc techniques, holographic media, advanced automated (digitized) procedures for input, storage, output, and transmission of text and graphics, as well as required instrumentation for display, demand output, and interactive manipulation of data. Hybrid (e.g., audio-visual) systems were also investigated.

Finally, a preliminary NTIP system concept was developed (Figure 1) and will serve as the basis for the detailed NTIPS design effort in Phase II.

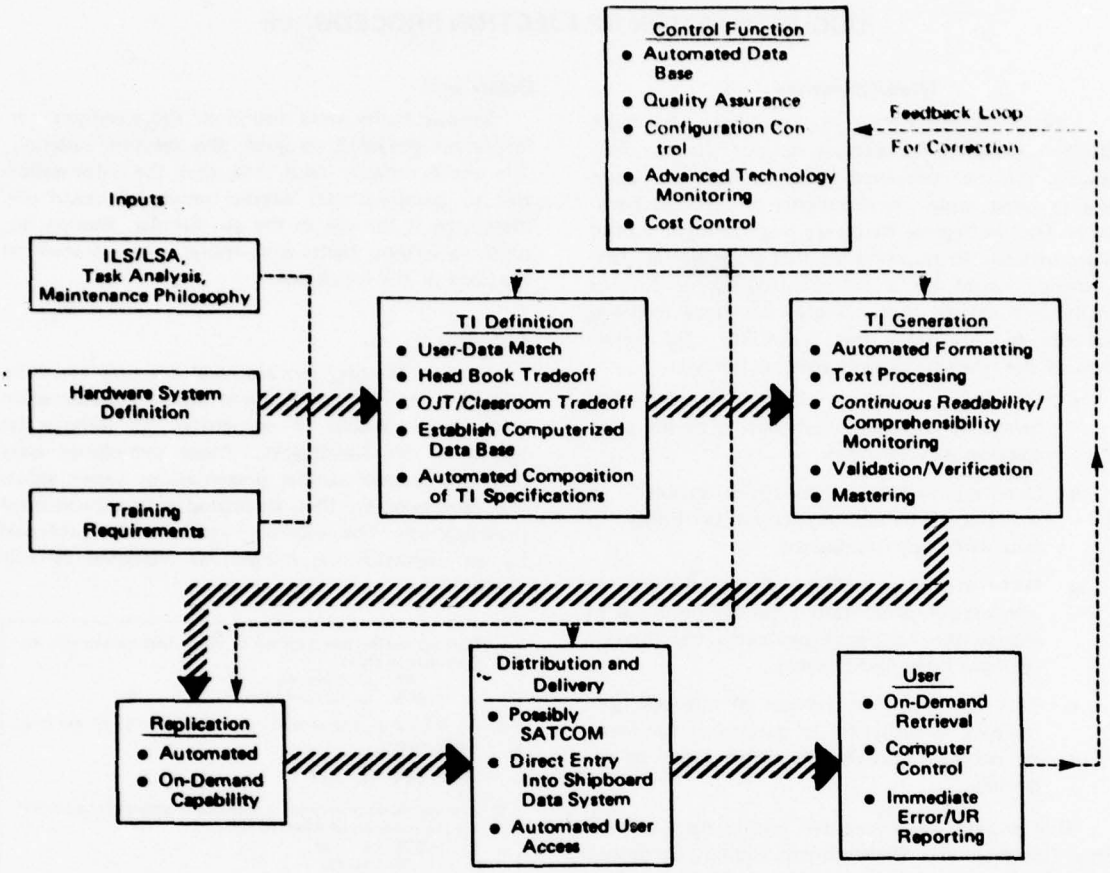

Figure 1. NTIPS Preliminary System Concept, Alternative III.

Payoff/Potential

When implemented, NTIPS will assist the Fleet in several ways. From the perspective of operators and maintenance technicians, it will represent an improvement in:

- Technical information quality and consistency – The user-data match process will help insure that the new TI will be written at a level to match the ability of the user and will be presented in a format and medium suited to his job tasks and working environment.
- Accuracy of the TI – Improved quality assurance procedures and speedier resolution of errors and configuration mismatches between hardware and the TI will result from a better system for configuration control and remedial action and update procedures.
- Homogeneity of the basic technical content presented to the user – first in his service school ashore, later in his shipboard training, and finally in his working assignment (operating or maintenance). NTIPS will provide coordinated TI for the training, operating, and maintenance communities.
- Availability of TI – More efficient and standardized methods of generation, replication, distribution, feedback, and update are inherent in NTIPS.
- Opportunity to apply cost savings resulting from NTIPS to improve Fleet readiness in other areas – The Navy currently maintains a $5 billion inventory in TI and spends hundreds of millions of dollars in these areas annually. Savings of no more than 10% could represent $50–$100 million annually in new TI alone. These savings could be diverted to other areas where funds are badly needed. In addition, time saved aboard ship by eliminating inaccurate or inefficient TI can represent a significant contribution to readiness.

DOCUMENTATION OF EJECTION PROCEDURES

Need/Objectives

Fifteen percent of the crewmembers who must abandon disabled jet aircraft do not survive. This fatality rate has remained constant over the years despite large scale improvements in ejection hardware. The ineffective hardware improvement caused Navy officials to hypothesize that poor aircrew performance could be a contributing factor to this costly loss of life. Accordingly, the Navy initiated research to investigate this possibility. The objectives of the research project were as follows:

- Determine whether faulty aircrew performance could be contributing to the poor ejection survival rates.
- Determine whether information problems in the pilots' handbooks could be linked to poor aircrew performance.
- Determine whether state-of-the-art in information presentation has the potential to reduce the handbook problems and thereby improve crew performance.
- Test an improved version of the ejection-relevant information to determine the levels of aircrew improvement which could be expected.

This project was supported jointly by the Naval Ship Research and Development Center, Carderock and the Naval Air Systems Command (Code 531). Funding comes from Program Element No. 63727N.

Approach and Results

Objective 1

Analysis of ejection accidents indicated that aircrew errors occurred in all phases of the ejection and survival process. The pre-egress phase (viz., ejection decision) and the survival and rescue phase were most prone to error, and the pre-egress errors were particularly costly. A separate Naval Safety Center study showed that, on the average, about 40% of the ejection fatalities were caused by a delay in initiating ejection. These data cast suspicion on both the ejection decision and the ejection procedures (viz. slow procedure performance could delay ejection).

Objective 2

Serious faults were found in the handbook information provided to guide the ejection decision. The most notable fault was that the information was so complex that aircrew personnel could not memorize it for use in the air. Similar, though not quite so serious, faults were found in the procedural portions of the handbook.

Objective 3

Human factors, job aid, and training literature provided numerous state-of-the-art presentation techniques capable of correcting the deficiencies found in the handbooks. These techniques were used to prepare sample presentations which pilots and crewmembers then compared with conventional presentations. The improved versions were preferred by an overwhelming margin, as indicated by Figure 1.

1. Do you prefer the detailed or simplified version of the Dive Angle chart?
   - 4% ☐ Detailed
   - 96% ☒ Simplified
2. Do the rules of thumb increase the usability of the Dive Angle chart?
   - 82% ☒ Yes
   - 18% ☒ No
3. Are the "rules of thumb" a reasonable approach to clarifying the question of when to eject?
   - 93% ☒ Yes
   - 7% ☒ No

Figure 1. Sample Preference Responses.

Objective 4

State-of-the-art techniques were applied to improve the ejection guidance in the handbook for a training jet. A control group of student pilots and naval flight officers studied the conventional instructions while an experimenta group studied the improved instructions. Four tests were used to assess the effect of the study on initial learning and retention. The experimental group outscored the control group on all four tests. Regarding the all-important ejection decision, subjects who studied with the new, improved material outscored the control group by more than three to one (65% correct vs. 20% correct). Figure 2 graphically indicates these differences.

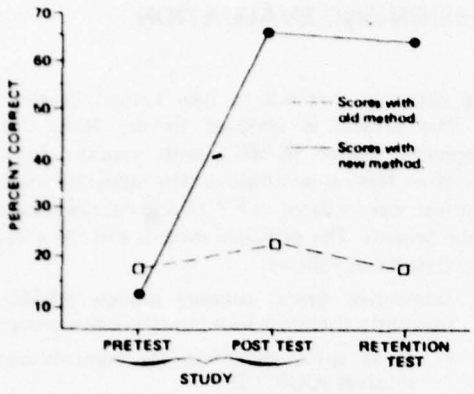

Figure 2. Ejection Envelope Decision Assessment.

Utilization/Technology Base Advance

This research shows that documentation is an inexpensive means of fostering learning and recall. This is a significant finding regarding an airman's performance of time-critical (no time to refer to a book or chart), hazardous (errors can cause death or injury) actions.

Payoff/Potential

Naval Air Systems Command may redo the ejection-relevant information in the handbooks of key aircraft, monitoring the ejection accident statistics to discern any effect on "delayed ejections" and fatalities. Considering the fact that individual pilot replacement costs are now being estimated at more than one million dollars, the potential payoff is indeed significant.

COMPUTER ASSISTED METHODS FOR HUMAN FACTORS ENGINEERING DESIGN AND EVALUATION

Need/Objectives

Current aviation systems are experiencing significant operational and safety deficiencies. Many of these deficiencies are attributable to inadequate consideration of operator and maintainer capabilities during system design. Problems, such as excessive operator work load, inappropriate automation and crew utilization, and confusing displays and warning systems, can degrade system performance and increase accident risk. The Naval Safety Center estimates that such design deficiencies result in 30 to 40 aircraft losses annually at a cost of $115 million. Even where human engineering support has been available for emerging systems, as in the LAMPS and F-18 programs, human engineering has not been optimal because of lack of techniques to provide timely and objective inputs to design decision makers. The timeliness, accuracy, and objectivity of human factors engineering inputs to design decision makers can be improved, and this is the general goal of this project.

The specific objectives of the project are to develop computer models and techniques which extend and improve the capabilities of human factors engineers to provide effective support for developing weapon systems. This technology can result in:

- Increased mission effectiveness through improved function allocation and automation, optimal crew station design, and verified capability of operators to perform mission tasks
- Reduction in life-cycle costs arising from late engineering changes necessitated by early design errors
- Increased impact of human factors recommendations through specific focus on conceptual and early design phase problems
- Fuller exploitation of human factors data by training personnel
- Predictions of expected system performance as a function of varying operator skill and training levels.

Funding comes from Program Element No. 62763/63701N.

Approach and Results

The computer assisted methods (CAM) project is a collection of related computer models and techniques, in various stages of development, which permit the rapid and timely application of human factors data and methods to new system development. The project is assigned to the Naval Air Development Center (NADC) with support from several other Navy organizations. The model development effort was initiated in FY 71 and has continued until the present. The principal models and the areas they address are as follows:

- Interactive design support models (IDSM). Currently there are four models in this group:
  - panel space allocation for controls and displays (CUBITS)
  - development of standardized and meaningful labeling and abbreviation (ABBREV)
  - analysis of operator/maintainer performance when handling equipment (Equipment Handling)
  - evaluation of operator capability to reach all displays and controls; crew station assessment of reach (CAR).
- Simulation of the human operator (HOS). This model provides the human factors analyst with the capability to simulate the performance of an operator following a defined scenario. The model will also simulate the performance variability found both within and between trained operators.
- Computer function allocation and evaluation system (CAFES). This area actually consists of four computerized models and a data management system (DMS) for the transfer of intermediate products between models. The four CAFES models are:
  - function allocation model (FAM) – identifies the most effective allocation of system functions among operator/hardware/software components
  - workload assessment model (WAM) – identifies potential operator overload, the location of the problem, and the probable cause
  - computer aided design (CAD) – provides capability for graphical representation of proposed panel layouts, relocation of panel components, rescaling of panels, and production of panel drawings
  - crew station geometry evaluator (CGE) – determines the compatibility of proposed crew station designs with anthropometric dimensions of operators and identifies control and display interference problems.

Utilization/Technology Base Advance

The application of these models is intended to provide maximum impact in conceptual design and early detail design. Principal users to date have been NADC systems analysts, design engineers, human factors engineers, and defense contractor personnel. Table 1 summarizes the applications of Computer Assisted Models to date.

Table 1

Applications of Computer Assisted Models

System/Program	Model						
	FAM	WAM	CGE	CAR	CUBITS	HOS	ABBREV
F-18		C	C	C	C		
LAMPS			C	C	C	C	
AMPA/VPX	S	S			P	S	
A-7E			C	C			
VFX/V/STOL		C					
V/STOL(A)	P	P		P		P	
P-3C (Update)		P				Q	
S-3A					C		
F-14 CILOPS				S	S		S
Avionics Effectiveness						Q	
Proteus					C		
Digital Avionics Information System (USAF)					C		
Integrated Airborne Communications System (IACS)					C		
Linebacker (USCG)					C		
FOTARS Photo POD							S
A-18		P	P	P	P		

LEGEND:

C = COMPLETED
Q = ONGOING
S = SCHEDULED
P = PROPOSED

Payoff/Potential

The requirement for timely, accurate, and objective human factors engineering data and techniques in weapon system design is increasing. This requirement can only be met by the use of high speed computer capability to reduce the time delay and to relieve the tedium and potential inaccuracy inherent in manual approaches. Sophisticated computer models, algorithms, and automated data handling methods can organize and evaluate the massive task structures and background data generated during modern system design. The techniques produced and evaluated by this project can be utilized during the design and evaluation of all future Navy aircraft, surface, and subsurface crew stations. Furthermore, the techniques, since they are generic and not Navy-unique, can and have been utilized by the Army, Air Force, NASA, and industry. CAR, for example, has been converted for in-house use by companies such as Northrop and IBM and is being modified by NASA for space shuttle design.

An example of the kind of impact which can be realized from early application of human factors engineering technology is available from the F-18 aircraft design. The crew station assessment of reach (CAR) model was applied to the initial design drawings. The analysis revealed that only 20% of the aviator population would be able to use all critical controls. The seat, stick, and emergency controls were relocated and redesigned using CAR recommendations. The percentage of aviators now accommodated increased to 80%.

HUMAN FACTORS ENGINEERING TECHNOLOGY FOR TEST AND EVALUATION OF SYSTEMS

Need/Objectives

The test and evaluation (T&E) of naval weapon systems includes an evaluation of the effectiveness of the human as a component in the total system. This research project was initiated by the Pacific Missile Test Center as a result of deficiencies uncovered in the human factor evaluation process by the Navy, including the lack of adequate design criteria and insufficient T&E methodology. Although the human factors requirements during system development are mandated by Department of Defense directives, a formal, structured approach is necessary to coordinate and integrate activities during the entire T&E cycle.

The objective of the project was to develop an operationally oriented approach to insure the successful inclusion of human factors engineering (HFE) principles and procedures during the test and evaluation of naval weapon systems. Funding comes from Program Element No. 63701N.

Approach and Results

The research methods employed in this project ranged from simple direct observation to computer modeling of evaluation systems. The major emphasis, however, was on the employment of field research methods.

There were three major task areas within the HFE T&E project. They were:

- Methodology
- Communication
- Implementation.

These tasks were undertaken to provide systematic approaches to the evaluation, documentation, and implementation of human factors requirements, assumptions, and data throughout the evolution of naval systems.

Each task area addresses a unique aspect of Navy HFE T&E. The methodology T&E tasks provide procedures, methods, and techniques for evaluating Navy systems. The communications task will provide procedural documentation for conducting and reporting on human factors evaluation as well as information, education, and training of operational and managerial personnel in human factors and system development. The implementation task sets requirements for evaluation report contents and specifications for assuring inclusion of test results in future design efforts.

Utilization/Technology Base Advance

Several products of the program have been operationally integrated into system design. They include:

- Human Factors Test and Evaluation Manual (HFTEMAN). HFTEMAN has been used in the tactical electronic reconnaissance processing and evaluation program (TERPES) to set guidelines for conducting auditory testing on the TERPES system.
- Feedback Loop Action Generation System (FLAG). This is a computer filing system which maintains records of human engineering deficiencies. FLAG assists in locating the analysis and design deficiencies associated with types of aircraft, missions, displays, and controls. Systematically analyzing the data can provide a means to avoid past design errors.

These methodologies have been applied on the F-18, S-3A, and P-3C weapon systems.

Payoff/Potential

The HFTEMAN has been distributed to Army, Navy, and Air Force commands engaged in operational test and evaluation. In addition, McDonnell-Douglas and Northrop are using it in developing the F-18. The FLAG system has also been used to track deficiencies on the F-14 and EA-6. Any organization that must conduct field appraisals on simple or complex systems should be able to employ the conceptual model and specific methods, techniques, and procedures developed in this research effort.

EDUCATION AND TRAINING TECHNOLOGY

- Feasibility of Various Shipboard Instructional Delivery Systems
- Personnel Readiness Training
- The Navy's Computer Managed Instruction System
- Instructional Systems Development and Effectiveness Evaluation
- Individualized Instruction in Mess Management Training
- Modeling the Costs of Specialized Training

FEASIBILITY OF VARIOUS SHIPBOARD INSTRUCTIONAL DELIVERY SYSTEMS

Need/Objectives

Increasing manpower costs, combined with increasing preference for one-tour enlistments, have resulted in renewed concern for economizing the Navy's first-tour training costs. This concern has stimulated studies to examine the feasibility of shifting some portion of technical training to the shipboard environment. Such a shift could require a substantial increase in the number of documents aboard ships.

At this time, approximately 864,000,000 pages of printed on-board training materials are published annually by the Chief of Naval Education and Training. Included are Personal Qualification Standards, Rate Training Manuals, Correspondence Courses, and Advancement in Rate Examinations. In addition, contractor provided equipment manuals and factory training materials support training on board ship. Any proposal to significantly increase the volume of printed documents to be stored, used, and maintained there will meet serious Fleet resistance.

The Navy's Training Analysis and Evaluation Group (TAEG) initiated a study to evaluate the feasibility of producing innovative forms of paper, microfiche, and electronic media for on-board training programs. Alternative state-of-the-art instructional delivery systems are being researched and evaluated to determine cost-effective systems. Funding comes from Program Element Nos. 62656N and 62757N.

Approach and Results

A series of related projects has been undertaken to develop a final design concept. At the conclusion of these studies, recommendations will be made to the Chief of Naval Education and Training concerning which media to use for on-board training in the 1980's. Two such projects have been completed.

Five alternatives to the current publishing system were evaluated. These included the use of word processors, text editors, electronic composers, typesetters, and digitized graphics. An automated publishing system has been recommended which offers the following savings: (1) $1.5 million annually in printing costs through the use of typesetting and (2) $200 thousand annually in the labor costs of text editing through the use of multiterminal text editor systems.

The second project assessed the technical feasibility, training effectiveness, economic efficiency, and user acceptance of microfiche. Principal findings were:

- Navy recruits could use, with minimum instruction, any of the microfiche readers tested.
- The Grid map/pointer microfiche indexing system was found to be the most efficient.
- Sound/microfiche programs were positively received by both trainees and instructors.
- There was no significant difference between the performance of trainees using curricula printed on paper and that of trainees using curricula printed on microfiche.

Utilization/Technology Base Advance

The findings of these projects are being used, along with other information, to create a functional specification for an on-board instructional delivery system. The role of paper, microform, and electronic-based media will be defined. The specification will describe how on-board training materials will be authored, produced, distributed, used, and updated. It will define the role of computer aids in each of these phases, and the cost-effectiveness of the proposed approach will be compared with that of other options.

Payoff/Potential

Using the computer aided publishing system proposed by TAEG, annual savings of $1.7 million can be achieved in the production of existing training documents. Eighty percent of this effort is in support of on-board training.

Additional savings should result from the implementation of other findings in this series of studies. As an example, significant economies should result from the use of the computer aids for authors of instructional materials. Preliminary results suggest a time saving of at least 10 to 1 in writing symbol learning packages, when compared with present authoring techniques. When an appropriate set of author aids has been completed, this magnitude of saving should also be achieved in authoring training packages to teach procedures. If this can be accomplished, perhaps one-fourth of the Navy courseware development effort could be authored with computer aids.

PERSONNEL READINESS TRAINING

Need/Objectives

In 1972 a team of Navy Management Representatives was established to identify current training problems. One problem identified was that Fleet commanders lacked confidence in the ability of some shipboard personnel to perform significant aspects of their jobs. The team recommended development and evaluation of a personnel readiness training system for use in the Fleet. The project was performed by the Navy Personnel Research and Development Center (NPRDC).

The specific objective was to develop a system which would both identify and correct significant shipboard personnel performance deficiencies. Personnel readiness could thereby be continually upgraded. Funding comes from Program Element No. 63720N.

Approach and Results

Critical job demands of three Navy ratings were selected for study: (1) submarine Sonar Technician, (2) submarine Missile Technician, and (3) Boiler Technician. The research design required three groups of subjects within each specialty: a control group, a diagnostic feedback group (this group received feedback concerning diagnosed performance deficiencies), and a diagnostic feedback plus training group (this group also received self-instructional remedial training materials). All three groups in each specialty were given a diagnostic pretest and, after approximately 5 months, the same test was readministered.

Pretesting revealed substantial performance deficiencies in some job demands of all three ratings. In a few areas, feedback alone provided some minimal performance improvement, however, it was not enough to be of any practical significance. Feedback plus the remedial training materials produced substantial performance improvements for the Sonar Technicians, but the Missile Technicians and Boiler Technicians showed little evidence of improved performance. This lack of improvement was later discovered to be due to failure to use the assigned instructional materials.

Utilization/Technology Base Advance

Over 300 testing/training packages had been distributed to the Fleet as of early 1977. Both the Atlantic and Pacific submarine commands requested the Sonar Technician packages for nuclear ballistic missile (SSBN) and nuclear attack (SSN) submarines with the designated equipment and, in addition, they requested that similar packages be developed for other shipboard equipment. The sonar packages have also been distributed to several shore commands. The testing/training packages developed for the Boiler Technician and the Missile Technician have likewise been requested and distributed to operational and training commands in the Fleet.

This project is thus an excellent example of people-related research which originated to support an operational need, was developed to be used by operational and training commands in the Fleet, and has been distributed and utilized by Fleet personnel.

Payoff/Potential

The potential benefits from the Personnel Readiness Training project are exemplified by the results experienced by Sonar Technicians in the Fleet. The combination of diagnostic testing and remedial training materials yields significant improvements in critical aspects of this Navy technician's job. From the standpoint of the SSBN's mission, the sonar search task is the most important of those tested. Results of this task were fairly typical of those found on all tasks. As shown in Figure 1, the remedial training group improved significantly on the posttest while the performance of the other two groups remained substantially the same from pretest to posttest. The pretest performance levels of all three groups are considered to be inadequate for Fleet performance. Improvements such as those indicated in Figure 1 will improve sonar contact information and will reduce spurious information which can mask real contact information or be misinterpreted as relating to a nonexistent contact.

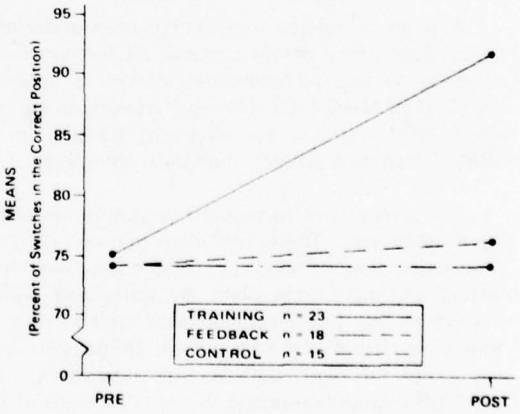

Figure 1. Pre- and Posttest Performance on the Sonar Search Task.

By utilizing the products from this project, selected job demands critical to Fleet readiness can be continually monitored and upgraded.

THE NAVY'S COMPUTER MANAGED INSTRUCTION SYSTEM

Need/Objectives

The general principle that military training should be designed to train students in the shortest period of time to specific performance objectives emerged dramatically in the early 1970's. It became clear that careful training analyses and the employment of effective training techniques would be the endeavor of future training developers. As a result, the Naval Technical Training Command (NTTC) and the Navy Personnel Research and Development Center (NPRDC) initiated a series of projects with the objective of establishing a computer managed instructional system designed to assist in the development of cost-effective, time-constrained, individualized instruction systems. Funding comes from Program Element No. 63720N.

Approach and Results

The Navy's Computer Managed Instruction (CMI) System is basically a decision-making technique. By relying on a large data base, it determines which segment of instruction is appropriate to the student. Depending upon the structure of the curriculum, CMI is also capable of directing the student to a particular segment of instruction at several different levels of difficulty. It can direct a student to repeat the entire instruction, repeat segments of it, or lead him to a different form of presentation.

The CMI system was developed and evaluated on three organizational billets in an A-7E squadron. Graduates of the conventional training sequences were compared with graduates of the experimental sequences. The evaluation demonstrated that the experimental trainees required considerably less training time (ranging from 10% to 61%) than their conventionally trained counterparts. Follow-up of these two groups of trainees indicated that experimentally trained personnel performed superior to or as well as conventionally trained students. Some of the materials from all three programs were also used for on-the-job training in the operational squadron.

Utilization/Technology Base Advance

At present, six courses of instruction at nine separate schools utilize the Navy's Computer Managed Instruction System. These schools are located at four separate major training centers. During the early part of 1978, several additional courses, two additional schools, and one more major training center will be added to the system. The present schools include nearly 7,000 students, and 3 years from now, this number will exceed 13,000 at 24 separate schools.

Payoff/Potential

The concept of individually paced instruction utilized by the Navy's Computer Managed Instruction System has demonstrated a reduction in training time of approximately 50%, and hence, a projection for substantial cost avoidance. Furthermore, the results of several evaluations reveal that slightly higher test scores were achieved on the final examination by the students in this mode of instruction.

INSTRUCTIONAL SYSTEMS DEVELOPMENT AND EFFECTIVENESS EVALUATION

Need/Objectives

Historically, the design and development of aviation weapon system training curricula has not been standardized. Aircraft simulators and instructional programs were individually designed and usually not evaluated after they had been turned over to the user. The need for a well structured, systematic method of determining training requirements, media selection, and other aspects of curricula development has long been recognized. In 1974, the Deputy Chief of Naval Operations for Air Warfare directed the Naval Air Systems Command to begin a formal aircrew Instructional System Development (ISD) R&D program. The scope of the program included operator and maintenance training for both emerging and existing aviation weapon systems.

The Human Factors Laboratory of the Naval Training Equipment Center (NTEC) undertook the project with the following general objective:

- Develop a comprehensive instructional system design guide which documents management and technical procedures for the acquisition of ISD programs for emerging and existing weapon systems.

Funding comes from Program Element No. 62757N.

Approach and Results

Instruction systems development is a process which applies systems logic to curricula development and instructional delivery. This process is designed to yield a complete and integrated instructional program that satisfies the training requirements for a weapon system throughout its life cycle. ISD evolved from other approaches used by the services, for example, Systems Approach to Training. However, the ISD approach offers a more comprehensive methodology to meet the needs of all personnel involved in the military training process.

The project, as undertaken by NTEC, is a two-phase effort. Phase 1 focused on the analysis and design of ISD aircrew training programs for each of four airborne weapon systems. These aircraft were the E-2C and the SH-2F, which were fully operational and had ongoing training programs for the aircrews, and the EA-6B and A-6E, which were undergoing major modification and required essentially new training programs. Phase 2 was concerned with the development and production of the instructional materials, procurement of required training equipment, training courses for instructors and squadron supervisory personnel, and implementation and evaluation of the ISD training program. The general approach of the project was to integrate state-of-the-art ISD technology and interservice experience into an ISD framework for use by contractors. A different contractor was selected for each aircraft and permitted to use his own training development techniques within the general ISD framework. Additionally, to provide a basic program structure, each contractor was required to provide both a task analysis and a training analysis to include:

- The development of measurable performance standards
- A media analysis
- A sequencing of instructional materials
- An organization of course content
- A determination of optimal instructional strategy.

Utilization/Technology Base Advance

The Phase 1 objective was completed for all four aircraft communities. One system, the SH-2F LAMPS, was funded for Phase 2 and implemented and evaluated in 1977. The E-2C system is currently in Phase 2. Funding constraints have delayed further implementation for the other two aircraft.

The ISD model developed for aircrew operator training has been modified for application to aviation maintenance training. A procurement, based on the modified model, is under way for maintenance training on the AN/AWG-10A, F-4 missile weapon system.

Current and planned utilization of the ISD process in the naval aviation weapon system communities is shown in Figure 1.

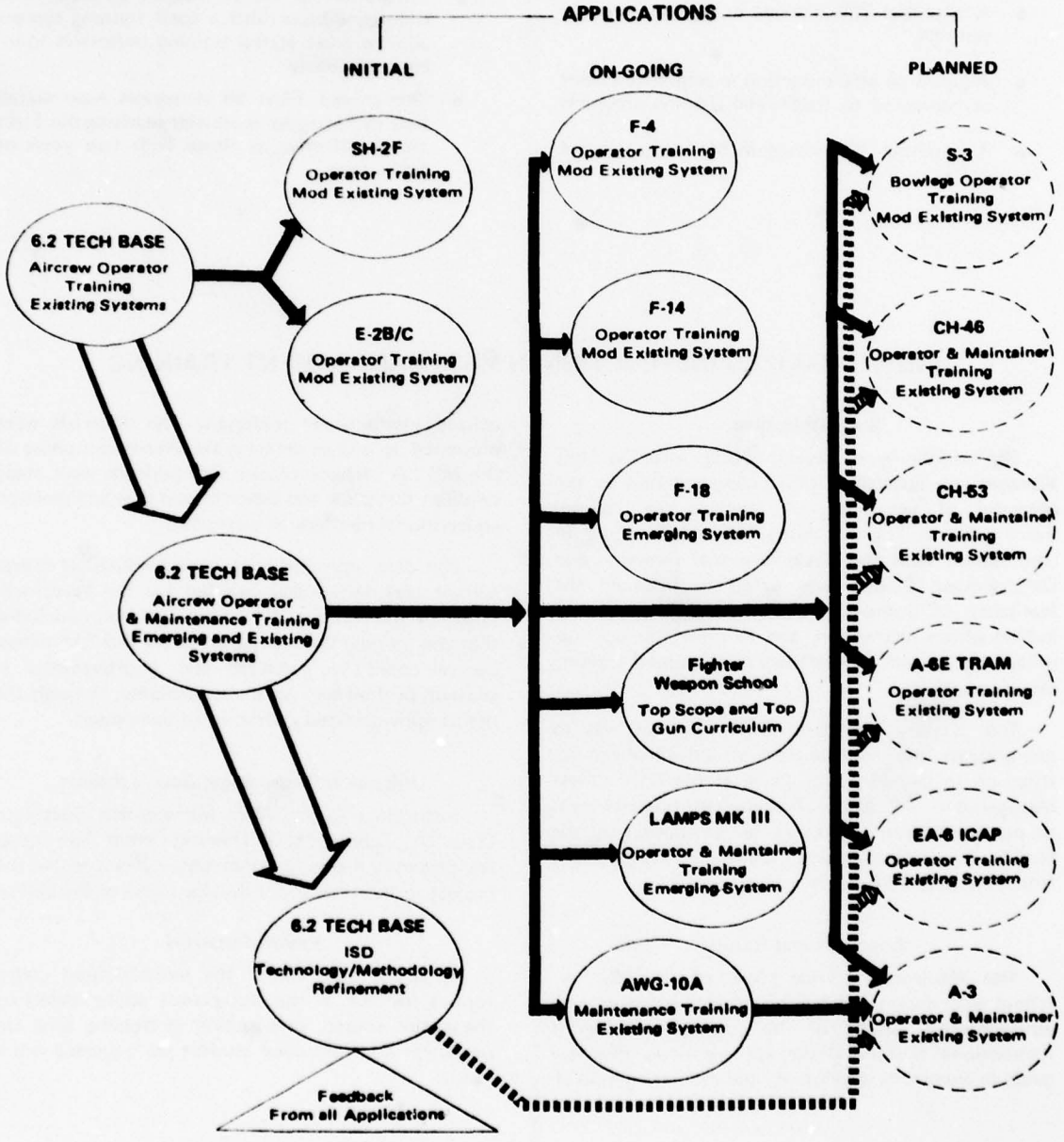

Figure 1. Transfer of ISD Technology.

Payoff/Potential

Applications of the ISD approach have been partially validated and the following benefits identified:

- A potential 25% increase in student throughput rate
- A potential 40% reduction in acquisition costs as compared to traditional training programs
- A potential 30% saving in life cycle support costs
- Increased training efficiency due to increased flexibility in student training scheduling, decreased aircraft training flight time, reduced overall training time, and more standardization
- Integration of the instructor, students, and training devices into a total training system able to meet stated training objectives more cost-effectively
- Operational Fleet air personnel have stated that ISD program graduates reaching the Fleet are as effective as those with two years of experience.

INDIVIDUALIZED INSTRUCTION IN MESS MANAGEMENT TRAINING

Need/Objectives

The combining of several ratings into the Mess Management Specialist (MS) rating resulted in the necessity of improving the existing "A" school training course. The U.S. Army Natick Laboratory, in conjunction with the Navy Personnel Research and Development Center, was asked to examine the feasibility of improving the existing training with individualized instruction, and to assess the applicability of the resulting materials to shipboard training requirements.

The primary objective of the project was to demonstrate the contribution of individualized instruction to overall performance at the Navy's Mess Management "A" school. A secondary objective was to provide training materials for evaluation by the Navy's Food Management Teams. Funding comes from Army RDT&E funds.

Approach and Results

The Wardroom Service phase of the MS "A" school was designated by the project sponsors as a representative sample of the course. The Navy's Instructional Systems Design approach was used as a guide in analyzing, developing, and evaluating individualized instructional materials. The materials were presented to a class entering the Wardroom phase of the MS "A" school course. Comparisons were made between this class and other classes that had received conventional methods of instruction.

The data indicated that an individualized course format was technically feasible for the Wardroom phase of the MS class "A" school. It was concluded that the training time required for the MS "A" school course could be reduced, and improvements in student proficiency could be achieved through the use of individualized instructional techniques.

Utilization/Technology Base Advance

Instructors in the Mess Management Specialist, Class "A" School, Naval Training Center, San Diego, are presently using the materials developed by this project in the Wardroom Service phase of the course.

Payoff/Potential

It is believed that if the individualized course format utilized in the study were implemented for the entire course, a reduction in training time and personnel and improved student performance would result.

MODELING THE COSTS OF SPECIALIZED TRAINING

Need/Objectives

Specialized training in the Navy consumes more than half of the total training budget. However, no current methodology exists which accurately sizes the specialized training budget or estimates the marginal cost of training. In response to this need, the Center for Naval Analyses was tasked by the Bureau of Naval Personnel to develop a resource model for specialized training costs.

Approach and Results

Data analysis techniques and computer modeling were used to define and develop a costing model. At present, the model reasonably determines the required funding for specialized training. Seventy percent of the total manpower costs can be accurately determined. The remaining 30% can be estimated by projection of past costs. Funding comes from Studies and Analysis funds.

Utilization/Technology Base Advance

The ultimate product of this project will be a system whereby the impact of tentative manpower decisions can be rapidly translated into accurate statements of training resource requirements. As such, this effort represents the required initial step in system development and is presently being used by the Navy to assist in projecting costs of specialized training.

Payoff/Potential

The project contributes significantly to management efficiency in decisions regarding source allocation. The ultimate system, as described above, would permit a more comprehensive decision-making capability.

TRAINING DEVICES AND SIMULATION

- Cost-Effective Simulation in Flight Training
- Air-To-Air Gunnery Trainer
- Simulated Avionics Maintenance Trainers
- S-3A ASW Weapon System Training

COST-EFFECTIVE SIMULATION IN FLIGHT TRAINING

Need/Objectives

Simulators customarily reflect much of the physical fidelity and functional capabilities of the operational system and its component subsystems. In most cases, the emphasis on operational realism is very costly and may not be necessary. In fact, there are many training situations in which simulation with a lower degree of fidelity may be justified. The key question is "how much physical fidelity is necessary to effect high transfer of training?"

Regardless of the degree of fidelity and related cost, it has been established that the way in which trainers are used significantly affects the amount of learning. Therefore, there is an equal need to determine proper training methods. The project's main objectives are:

- To develop advanced training methods to improve trainer effectiveness and reduce cost
- To develop guidelines for the systematic determination of training equipment/training methodology procurement strategies.

Funding comes from Program Element No. 62757N.

Approach and Results

This project, developed by the Naval Training Equipment Center (NTEC), is surveying selected flight training courses and development programs to identify areas where expensive operational flight training could be effectively replaced, reduced, or improved by the use of cost-effective training system management and/or low-cost simulators. Additionally, prototype flight simulation devices, such as the Night Carrier Landing Trainer (NCLT), Device 2F103, are being developed and field tested. Finally, a method for determining the type and level of fidelity required for effective training at low cost is being formulated.

Significant improvements in instructional system development can be achieved through this project. This research effort will provide information for establishing guidelines to relate fidelity of simulation to amount of transfer of training on a cost-effective basis. Some evidence has resulted suggesting that low-cost simulators can be as effective as expensive equipment if attention is given to learning task details and student requirements.

Utilization/Technology Base Advance

The intended goal of the project is the design of an efficient learning environment rather than an attempt to simulate the real world. Cost-effective criteria for the allocation of training goals among simulators, part-task trainers, and the aircraft are also required.

The A-7 Fleet Readiness Squadron (FRS), VA-174 at Jacksonville, Florida, has adopted the NCLT and the experimental training program developed under this project in an effort to minimize the need for recycling pilots who fail their initial carrier qualification. Failure to qualify on the first attempt necessitates an additional flight-hour investment of about 19%. The data reveal that, of the pilot group *not* utilizing the NCLT, 44% fail to qualify initially. Pilots utilizing the NCLT experience only an 8% failure rate. This dramatic reduction in pilot recycling will, of course, produce substantial savings in flight time.

As fall-out to the project, a computer-generated, performance-feedback technique was developed which provides immediate landing decision information to the pilots undergoing training. VA-174 began evaluating this technique in May 1977.

Payoff/Potential

The final results of this project and the ongoing evaluation at Jacksonville will provide the Navy training community with a means to answer the question of device fidelity and cost trade-off within a given set of training objectives. The area of cost-effective simulation is of vital interest to all military services as well as to commercial and civilian aviation. Simulator technology will benefit primarily from data on required levels of fidelity, an area of primary interest and little information.

AIR-TO-AIR GUNNERY TRAINER

Need/Objectives

Naval aircraft weapons training programs are currently encountering difficulties due to the limited number of instructors available, the increasing cost of ammunition, and the problems of maintaining airspace to conduct live-firing exercises, either air-to-air or air-to-ground. Those firing areas previously established are in danger of being lost because of public criticism, expansion of inhabited areas, and increased usage of existing airspace.

The objective of this project, performed by the Naval Training Equipment Center (NTEC), is to develop a system capable of providing adequate, low-cost, realistic training in weapons firing for air-to-air gunnery. The T-2 training aircraft is to be used as the experimental vehicle. Funding comes from Program Element No. 62757/64703N.

Approach and Results

The approach to the project development relied on eye-safe laser technology. Exploratory research begun in 1967 produced a promising technology base. Exploratory applications included a Tank Gunnery Trainer, a Helicopter Door Gunner Trainer, a Laser Marksman Rifle Trainer, and the Universal Infantry Weapons Trainer.

The T-2 air-to-air gunnery project began in 1973. T-2 aircraft were equipped with laser transmitter and receiver units (attacker) and glass retroreflectors (target aircraft). Figure 1 is an artist's concept of this T-2 installation. Test sorties flown with the laser-equipped aircraft were quite successful, prompting the commanding officer of the training organization to recommend continued development "to allow earliest possible introduction of the system into the basic jet training program."

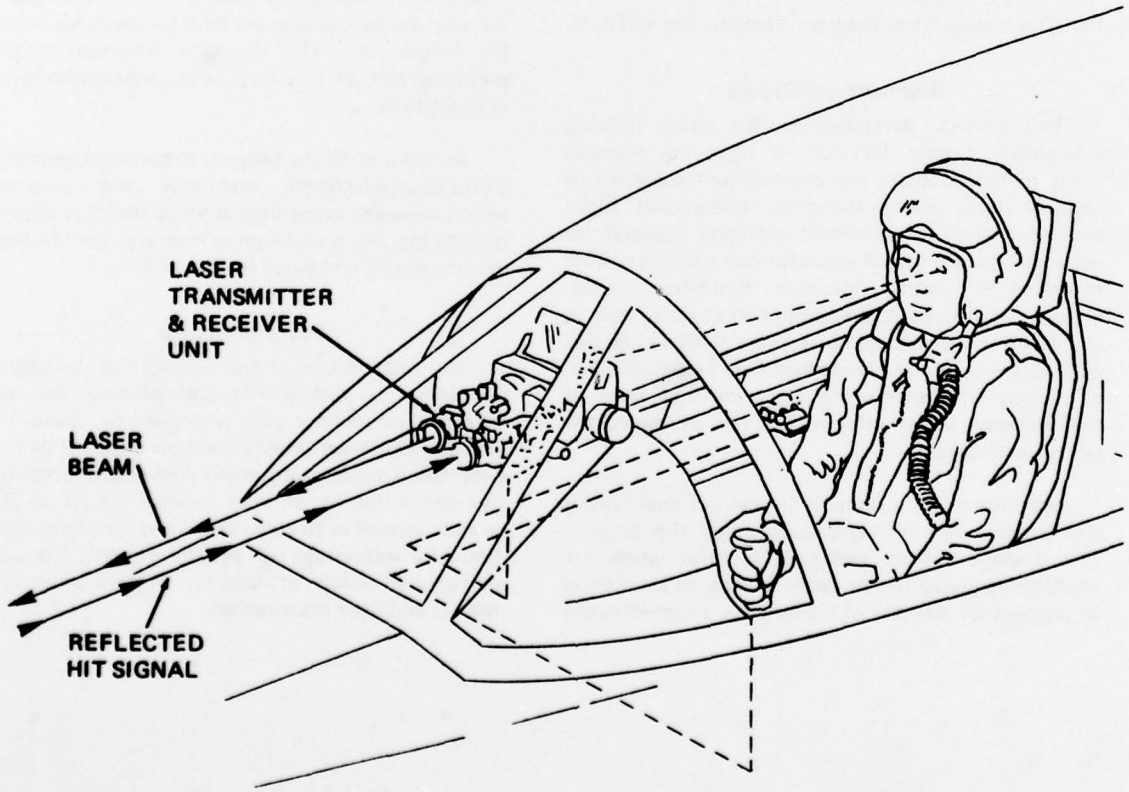

Figure 1. Artist's Concept of Laser System Installed in T-2 Aircraft.

To this end, two systems for use in air-to-air gunnery will be developed:

- A low-cost, fixed-pipper system to be installed in T-2 training aircraft for initial pilot training
- A movable-pipper system for installation in Fleet aircraft capable of providing realistic gunnery and air-to-air combat training.

Using design criteria and technology developed in-house, specifications for a fixed-pipper system for the T-2 training aircraft were prepared; proposals were evaluated, and a contract was awarded on 27 September 1977 for five engineering models. Development will require approximately 12 months. After acceptance, the units will undergo test and evaluation by Naval Air Test Center (NATC), Patuxent River, Maryland, and by Operational Test and Evaluation Force (OPTEVFOR), Norfolk, Virginia for about six months. Certification for service use is anticipated by March 1979.

The movable-pipper system for Fleet-type aircraft will use the same design as the fixed pipper for the transmitter and receiver. However, the system must be "slaved" to the aircraft fire control system to insure that the movable pipper properly tracks and lines up on the target. Specifications for the movable pipper, including fire control radar interfacing and air frame mounting, will be prepared and a contract awarded. Development will require approximately 12 months for five units. Test and evaluation by NATC and OPTEVFOR will require about 9 months with service acceptance expected in December 1979.

Utilization/Technology Base Advance

Products of the exploratory research phase are currently in use. The Tank Gunnery Trainer, first developed by the Naval Training Equipment Center, is now a Federal stock item being used by the Army (600 units) and the Marine Corps (30 units). The Marine Corps plans to use the Laser Marksmanship Rifle Trainer to identify trainees who will have problems firing the M-16 rifle. They can then receive additional training to increase their probability of success in live-fire qualification. In addition to its training effectiveness, this use of the laser trainer is expected to halve the amount of ammunition expended by each trainee, thus producing enormous cost-savings.

Payoff/Potential

The primary benefit from this program is the enormous cost-saving to be realized through the substitution of lasers for live ordnance. Additionally, there are significant benefits in areas of life-cycle integrated logistics, support costs, manpower, flexibility, and safety to be realized from this development:

- Training can be conducted at any time in all normally authorized flying areas. There is no requirement for scheduled target times at specific firing ranges.
- The amount of simulated ammunition capable of being expended is unlimited.
- The training is realistic in that hits scored and recorded by the laser system must be in the same dispersion pattern as that resulting from the use of live rounds. The system is range-gated so that no hits are scored unless firing is initiated within a prescribed range increment. Instant feedback for scoring purposes is provided.
- Present requirements for ordnance personnel will be reduced; arming and dearming of the weapons are not required; ammunition does not have to be loaded, and maintenance of the laser system will require less effort than that required with actual weapons.
- The gun pod carried on the aircraft will be greatly reduced in size, thus reducing the fuel requirements of the aircraft.
- Target weather will no longer be a limitation to successful completion of training.
- The safety aspects are readily apparent; there are no hazards to personnel or equipment.

SIMULATED AVIONICS MAINTENANCE TRAINERS

Need/Objectives

For many years, the Navy has been conducting its maintenance training in a time-accepted manner. A specified period of classroom training is devoted to theory accompanied by some degree of demonstration or hands-on application with the use of actual operational equipment. The trainee then applies this theoretical knowledge during a phase of on-the-job training before attaining minimal capability as a technician in the Fleet.

This system of training has become unacceptable in modern times due to the increasing complexity of new weapons systems, the variety of equipment being introduced or already existing, and the continuing need for modifications. Furthermore, the cost of operational equipment for training purposes has become prohibitive, and too much time is required to train today's technicians to function effectively.

Therefore, the maintenance training approach must be revised to provide maximum training effectiveness at minimum overall cost, in the shortest period of time. The Department of Defense has designated the Navy as the lead service in assessing this training problem and assigned it to conduct research leading to a more efficient solution while, at the same time, effecting coordination with the efforts of the other services. As a result, the Naval Training Equipment Center (NTEC) developed this project. The objectives are:

- To develop and *evaluate* an intermediate level experimental model simulator for avionic subsystems in the electronic, electromechanical, and mechanical areas
- Concurrent with the experimental effort, to develop a prototype simulator for these avionic subsystems in the F-18.
- To develop general intermediate- and organizational-level specification guidelines for future procurement.

Funding comes from Program Element No. 62757/64703N.

Approach and Results

Initial research at the NTEC Human Factors Laboratory concluded that some degree of simulation was needed to decrease maintenance training costs and increase effectiveness. Simulation can be achieved with either two-dimensional representation, such as pictures, TV, and graphics, or with three-dimensional fabrications which allow hands-on application with software-induced responses. Further study of curriculum requirements and instructor recommendations revealed that the use of simulators, together with the application of computer-aided instruction, would provide individualized, self-paced training, increased instructor-student interaction, and consistent student evaluation capabilities. The results of the NTEC initial efforts in simulation were conclusive enough to proceed into advanced and engineering development phases for the avionics maintenance trainers.

Utilization/Technology Base Advance

An electronic experimental model of the A-7E Head-Up Display (HUD) test set has been developed and delivered to NTEC where it is being modified to include optics training. The simulator will be delivered to the training detachment at Naval Air Station, Cecil Field, in early 1978. The remaining experimental models and the F-18 prototype developments are ongoing and are scheduled to be completed in late FY 81. Work on the other out-year objectives is also proceeding.

As a result of technology developed in the exploratory and advanced areas of this endeavor, project expansion is expected in future years as the prototype systems are successfully evaluated. In aviation, all future aircraft introductions into the Fleet can be accompanied by maintenance technician training simulation systems. For example, the simulator for the F-18 avionics is scheduled to be operational at the same time as the arrival of the aircraft in the Fleet.

Payoff/Potential

The cost of the electronic experimental (A-7E HUD Test Set) simulator demonstrates the savings to be realized when compared to Actual Equipment Trainer (AET) usage: $1200 K for the AET versus $500 K for the simulator. Table 1 indicates projected savings for several planned applications.

Table 1

Maintenance Simulation Technology Applications at NTEC

Applications	Costs	
	AET	Simulator
Air		
• A-7E HUD/Test Set	1.2M	0.6M
• VAST	4.0M	2.0M
• (F-18 Flight Control Electronic Set)	To Be Determined	
Surface		
• DD 1052 Hagen Automatic Boiler Control Operator and Maintenance Trainer	0.5M	.05M
Subsurface		
• Trident Air Conditioner and Compressor Operator and Maintenance Trainers	0.4M	0.2M
• Trident Submarine Integrated Radio Room Operator and Maintenance Production Trainers	20.0M	3.6M

Other benefits include the following:

- Full task hands-on application will reduce training time.
- Fewer instructors will be required to train more students.
- Availability and configuration update conditions will be continually maintained by software inputs.
- Unlimited fault insertion capability will be possible.
- Automation will provide for objective instruction, briefing, debriefing, and evaluation.
- Training will be standardized.
- Safety standards regarding equipment as well as the trainee will be realized.
- Time required for on-the-job training will be significantly reduced.

These research efforts in avionics maintenance training are expected to contribute to a massive expansion in the use of simulation in the post-1980 years in surface and subsurface training as well.

S-3A ASW WEAPON SYSTEM TRAINING

Need/Objectives

This project was initially presented to the Chief of Naval Operations and the Naval Air Systems Command through the S-3A Program Office. The S-3A is a new and sophisticated air antisubmarine warfare (ASW) weapon system which requires an efficient, cost-effective training system to maximize available resources while providing the Fleet with well trained operators. To address this situation, the Navy Personnel Research and Development Center (NPRDC) was assigned the task of developing a complete training program for the four crewmembers of the S-3A. Funding is from Aircraft Procurement, Navy and Weapon System R&D funds.

Approach and Results

Utilizing the general methodology referred to as "Instructional Systems Development" (ISD), the researchers established a training course which included simulators, individualized student workbooks, videotape programs, and computer-assisted instruction (CAI). The use of CAI in an operational Fleet training environment was considered unique. The particular CAI system selected was TICCIT (Time-shared Interactive Computer Controlled Information Television), which had been developed under the sponsorship of the National Science Foundation. The project generated all of the instructional materials, tests, simulator exercises and flight exercises, determined the types and numbers of simulators required, and designed an ongoing evaluation program valid for the life of the weapon system. The evaluation program revealed a problem, for example, in teaching the S-3A copilot to operate the Integrated Control System (INCOS), which interacts with the on-board computer for ASW activities. To resolve this problem, a new training course based on PLATO IV (Programmed Logics for Automated Teaching Operations) was developed.

Utilization/Technology Base Advance

As a direct result of the project's cost analyses, the Navy requested that six operational aircraft originally budgeted not be purchased. The money saved was used to purchase a variety of simulation devices (digitally driven position simulators, operational flight trainers, and weapon system trainers). The weapon system simulators, in particular, provide practice in essential skill areas which cannot be developed using operational aircraft.

The S-3A training program was devised and is in use at Air Antisubmarine Squadron Forty-One (VS-41), Naval Air Station, North Island. Currently, the contractor is conducting a formal, analytical and empirical evaluation of the instructional program. The evaluation is scheduled for completion in FY 78.

This incorporation of ISD, simulator training, and CAI into an operational training program provides the Navy with an efficient and exceptionally cost-effective alternative to operational flight-crew training.

Payoff/Potential

The Navy is realizing a net saving of $5 to $6 million per year from the introduction of this S-3A training system. To fly the S-3A for one training hour costs over $4000; one hour of full weapon system simulator time costs approximately $400. The training program also allows a net decrease in flight time of approximately 15 hours per pilot/copilot by careful substitution of simulator hours. In conjunction with this project, the trainer purchase costs themselves were reduced by more than $10 million over initial estimates.

This R&D work for the carrier-based S-3A is being applied to the P-3A1B retrofit and the P-3C, the Navy's land-based patrol planes. The resultant training programs will be implemented by patrol squadrons in 1978. All future sophisticated, team-oriented weapons systems can certainly be expected to benefit from this program and the methodology developed for the S-3A.

CURRENT NAVY ACTIVITIES FOR INCREASING RDT&E UTILIZATION

In 1977, the Secretary of Defense received recommendations from the GAO for increasing the use of RDT&E results. The GAO report stated:

> We recommend that the Secretary of Defense take the necessary action to strengthen the management of the use of human resources research and development results. Such action should provide for establishing
>
> - criteria to identify results with immediate use potential,
> - improved communications between researchers and users,
> - effective monitoring of utilization, and
> - a management mechanism for resolution of issues between researchers and users preventing use of research and development results.

The Navy recognizes that it is not sufficient to conduct people-related RDT&E. It is also necessary that operational and training commands then utilize the results. Furthermore, the Navy recognizes that research utilization is not a matter of course; it must, therefore, be an integral part of the doctrine of research management. Navy research management personnel have the responsibility to identify and even anticipate operational needs, to implement research results in the Fleet, and to provide on-going test and evaluation programs. Simply stated, the research management objectives are to improve research relevance and utilization.

Several new Navy activities have been undertaken to respond to the GAO recommendations. Brief descriptions of some of these activities follow.

RDT&E APPLICATIONS PROGRAM

In FY 76, the Navy Personnel Research and Development Center established an Applications Program to facilitate the introduction and use of RDT&E end products. This effort is improving the relationships among the researchers, sponsors, and users of end products from the initial determination of an operational problem through to the implementation of the solution.

THE 1977 NATIONAL SYMPOSIUM OF THE MILITARY SERVICES ON UTILIZATION OF PEOPLE-RELATED RDT&E

In June 1977, the Navy Personnel Research and Development Center (NPRDC) sponsored and conducted a 3½ day national symposium on the utilization of people-related research. Symposium participants included RDT&E managers, scientists, and operational practitioners from the Department of Defense, other government agencies, industry, and universities. The purpose of this symposium was to assess the problems and needs of research utilization, principally within the military establishment. Special attention was given to an assessment of current problems in research utilization, an exchange of information on the state-of-the-art, the development of policy recommendations for improving research utilization within the military services, and an outline of the parameters for future research utilization.

The 1977 symposium thereby provided a forum for active discussion of the problems of research utilization in the military services. The program agenda encompassed a review of current research utilization activities in the Armed Forces, Federal agencies, and private industry. Some key DOD decision makers and potential users of military research from the operational community presented their views on research utilization.

The symposium provided the first major opportunity for a diverse group, representing a broad spectrum of interests, to discuss this important topic with reference to military research and development. An Executive Summary of this symposium was published in order to provide participants with (a) an overview of the symposium's aims and organization, (b) a synopsis of the main conclusions and recommendations reached by conferees during four days of meetings, and (c) a discussion of the symposium's impact. The proceedings have been published as *NPRDC Special Report 78-3*.

NAVY RDT&E UTILIZATION, MONITORING, AND TRACKING

A monitoring system to track the utilization of RDT&E products is being studied at the Navy Personnel Research and Development Center. The objectives of the system are to:

- Enhance the utilization of RDT&E products that would support policy development and resolve operational problems
- Identify categories of potential users who would benefit from a proposed research activity and characterize the type of benefit anticipated
- Provide a systematic process for generating preliminary utilization plans including strategies for disseminating and facilitating application of project outcomes
- Provide a system and process for estimating R&D costs, implementation costs, and cost-benefit ratios
- Provide a mechanism for monitoring the plans and activities of R&D projects related to research utilization. (This mechanism should include a method for tracking an R&D product from initial development until at least two years after completion of the project.) Such tracking should provide information on the use of a product, users, type and degree of impact, spread or spinoff effects, approximate implementation costs, and cost-effectiveness.
- Provide a means for comparative analysis among three major categories of data: (1) *actual* data obtained from the tracking measures, (2) *forecast* data on analogous measures developed during the R&D phases, and (3) *equivalent* data based on previous or alternative ways of dealing with the particular problem or need that the new product was designed to meet.

CRITERIA TO IDENTIFY RESULTS WITH IMMEDIATE USE POTENTIAL

Tentative criteria have been developed to test the intended use (or impact targets) of RDT&E results. Some of the recipients of the R&D results and the areas of interest to each group are listed below:

- Operational commanders
  - Changes in doctrine
  - Changes in procedures
  - Information on human capabilities and limitations
  - Modification in requirements for manpower or equipment
- Personnel and manpower managers
  - Changes in management policy or techniques
  - Change in planning capability
  - Changes in manpower requirements
  - Solutions to specific problems
  - Information on which to base R&D requirements
- Training managers
  - Development of or change in courses of instruction or training programs
  - Development of requirements for training curricula and equipment
  - Development of or change in instructional delivery methods and media
  - Changes in management policy or practices
  - Training device prototypes
  - Information on which to base long-range objectives and further R&D requirements
  - Evaluation of specific materials and procedures
- System developers
  - Information on human capabilities and limitations
  - Evaluation of specific designs
  - Human factors engineering (HFE) design principles
  - Efficient ways of applying HFE
  - Changes in development management factors
- R&D community
  - Information about human capabilities and limitations
  - Information on the effectiveness of various personnel training methods
  - Solutions to technical problems
  - Indications of further R&D requirements.

TRISERVICE AND NASA HUMAN FACTORS ENGINEERING TECHNICAL ADVISORY GROUP (TAG)

There is persistent criticism within DOD and Congress about the lack of coordination among the services' research efforts. In 1977, the Navy took the lead in initiating a triservice and NASA Human Factors Engineering Technical Advisory Group (TAG). The broad objective of TAG is to enhance working-level coordination among government laboratories and organizations performing human factors engineering RDT&E.

Although the TAG is not a Navy organization, the first meeting of the group was held at the Naval Air Development Center in August 1977. Representatives from all three services and NASA attended. Meetings of the TAG will be held semiannually, and the chairperson will rotate annually among the Army, Navy, Air Force, and NASA.

The formal operating structure, goals, and scope of the TAG are still being worked out. However, the charter members agreed that the concept will allow a sharing of many kinds of data, common funding of efforts, and a better development of human factors engineering products and capabilities.

RESEARCH AND DEVELOPMENT INFORMATION SYSTEM (RDIS)

In support of the effort to coordinate the manpower, personnel, education and training, and human factors engineering R&D programs within the Navy, the Navy Personnel Research and Development Center is developing a Research and Development Information System (RDIS). This system will provide for the collection, review, organization, update, analysis, and dissemination of information regarding all Navy, Marine Corps, Army, and Air Force people-related R&D efforts. The initial data base contains information on Navy activities at the work-unit level.

When fully implemented, RDIS will comprise a comprehensive R&D data base that will allow the various projects to be mapped or clustered so that interactions can be identified. For example, common elements among work units could be identified to determine homogeneous program topics; areas of mutual gain through pooled efforts could be defined; funding profiles across various research areas could be prepared; and research objectives could be compared in behavioral terms throughout R&D activities. As a result, the management and research community concerned with people-related problems will have a definite and responsive behavioral data base with which to interact, leading to greater total effectiveness of their R&D efforts.

ANNUAL REPORT ON THE UTILIZATION OF PEOPLE-RELATED NAVY RDT&E

This report is the first in a series of annual reports the Navy intends to publish describing the utilization of people-related RDT&E. It includes examples of present utilization and technology base advancement relevant to future utilization. These annual reports are expected to stimulate communication and understanding among researchers, users, and policy makers.

TECHNOLOGY TRANSFER COORDINATION

The policy of the Department of the Navy is to promote military-civilian technology transfer and cooperative development on a systematic basis. It encompasses (1) transfer of technology developed by the Department of the Navy–for National Defense purposes to the civilian sector where such technology can be profitably utilized in non-military applications, (2) identification of common interests, and (3) exploration of the feasibility of cooperative funding and development of such programs. Hence, Navy RDT&E commands have appointed Technology Transfer Coordinators.

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This is the first annual report of the utilization of people-related Navy RDT&E. It includes examples of both utilization and technology base advancement from FY 75-77. The examples are organized within four technical areas: Manpower and Personnel Technology, Human Factors in Weapon Systems, Education and Training Technology, and Training Devices and Simulators. Each example is discussed in terms of Need/Objectives, Approach and Results, Utilization/Technology Base Advance, and Payoff/Potential.

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