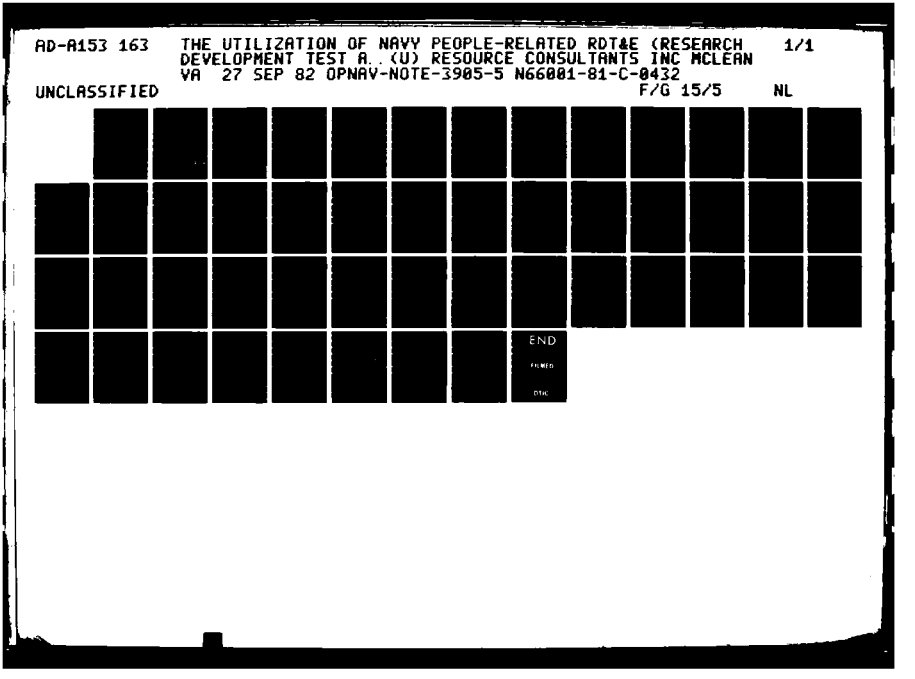
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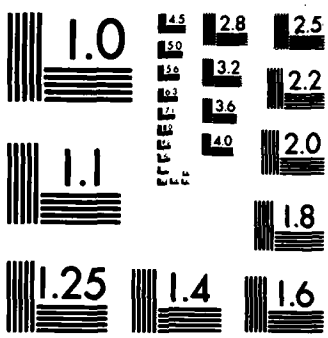

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OPNAVNOTE 3905

(1)

THE UTILIZATION OF NAVY PEOPLE-RELATED RDT&E

5th ANNUAL REPORT

FISCAL YEAR 1981

Contract N66001-81-C-0432

ASSEMBLED BY

NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER
SAN DIEGO, CALIFORNIA 92152

JUNE 1982

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, DC 20350

Canc: Aug 83
IN REPLY REFER TO
OPNAVNOTE 3905
Ser 987/360151
SEP 27 1982

OPNAV NOTICE 3905

From: Chief of Naval Operations

Subj: Fifth Annual Report on the Utilization of People-Related RDT&E

Ref: (a) UNDSECNAV Memo of 26 Sept 1978, Subj: Navy Manpower, Personnel and Training Research, Development and Studies (NOTAL)
(b) General Accounting Office Report FPCD 77-43 of 22 Apr 1977 (NOTAL)

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

1. Purpose. To promulgate the Fifth Annual Report on the Utilization of People-Related Navy RDT&E (enclosure (1)) and forward it for information and appropriate action. This report contains examples of the use of this R&D. It is a principal means whereby the Navy complies with the recommendations of references (a) and (b) that utilization be encouraged, that communication between the user and researcher be improved, and that utilization of this R&D be tracked.

2. Action

a. Addressees are requested to review enclosure (1) to identify any of the following:

(1) RDT&E that they have used but has not been reported in enclosure (1) or any of its predecessors.

(2) Completed RDT&E that might be useful in activities under their cognizance.

(3) RDT&E near completion that they should monitor to use when completed.

b. Any previously unreported instances of utilization should be reported to:

Commanding Officer
Navy Personnel Research and Development Center
Code 303
San Diego, CA 92125

c. Addressees desiring assistance in using completed RDT&E or in monitoring potentially useful R&D should direct inquiries to the appropriate R&D organizations as listed in enclosure (1).

d. Request appropriate action to be completed by 31 May 1983. Negative reports are not required.

3. Report. Symbol OPNAV 3905-1 has been assigned to the requirement contained in paragraph 2. This information will be requested yearly by notice.

C. O. PRINDLE

Deputy Director
Research, Development, Test & Evaluation

Distribution:
SNDL A1 (Immediate Office of the Secretary)
A2A (Department of the Navy Staff Offices)
A4A (CHNAVMAT)
A5 (Bureaus)
A6 (CMC)
C4F50 (Education & Training Program Development Center Branch)
C4K (Project Managers under the direct Command of the Chief of Naval Material)
C4L (Director of Navy Laboratories)
C20 (CNR Shore Based Detachment)
C34D (Human Resource Management Detachment)
C55A (Navy Occupational Development and Analysis Center)
C58D (Naval Air Technical Training Center Detachment)
C58H (Central Test Site for Personnel and Training Evaluation Program Detachment)
FF5 (Safety Center)
FF38 (Naval Academy)
FF48 (Human Resources Management Center CNO)
FH (Shore Activities under the Command of the Chief, Bureau of Medicine & Surgery) (less FH3 and FY25)
FJ (Shore Activities under the Command of the Chief of Naval Personnel)
FKA1 (System Command Headquarters)
FKA6 (Research and Development Activities)
FKR (Shore Activities under the Command of the Commander, Naval Air Systems Command)
FR1 (Chief of Naval Reserve)
FT38 (NAVSUBTRACENPAC)
FT54 (NAVSUBSCOL)

OPs 96, 093, 094, 095, 01, 02, 03, 04, 05

Copy to:
(see next page)

Copy to:

SNDL	21A	(Fleet Commander in Chief)
	24	(Type Commanders)
	26F	(Operational Test and Evaluation Force Command and Detachment)
	26H	(Fleet Training Group)
	26Q	(Nuclear Weapons Training Group)
	26V	(Landing Force Training Command)
	26KK2	(Petroleum Training Unit Pac)
	26DDD	(Fleet Combat Systems Training Unit)

OPNAVNOTE 3905

THE 5th ANNUAL REPORT

ON

THE UTILIZATION OF PEOPLE-RELATED NAVY RDT&E

Enclosure (1)

FOREWORD

This is the fifth annual report on people-related research, development, test, and evaluation (RDT&E) in the Navy. Since the first report in the series was published in 1978, covering fiscal years 1975-1977, a considerable number of accomplishments in the people-related areas of manpower, personnel, training, and human factors engineering have been described. These have included large-scale, multi-year programs as well as smaller project efforts in key areas.

The primary emphasis in these reports has been on the utilization of R&D products by Navy operational communities, and on the benefits in both cost and operational effectiveness resulting therefrom. An additional focus has been on the significant advances in the state of the art that many of these R&D efforts have contributed. It is possible for one who reads each of the utilization reports closely to note instances in which earlier efforts have laid the groundwork for later, related developments. This building process is crucial to the people-related RDT&E program, as it is in any scientific or technical endeavor.

The projects described here represent only a fraction of the overall program of people-related RDT&E being conducted at centers and laboratories throughout the Navy. The efforts reported are not unique; they are instead representative of people-related R&D products utilized in FY81 or being prepared for near-term implementation.

This report was compiled by the Navy Personnel Research and Development Center, San Diego. The manuscript was prepared by Resource Consultants, Inc., of McLean, VA, under Contract N66001-81-C-0432. Appreciation is expressed to participating personnel at each contributing command, and also to those individuals who contributed documentation, clarification, and sound advice while the report was in preparation. Inquiries and comments from sponsoring and user commands are encouraged.

CONTENTS

NPRDC PARTICIPATION

INTRODUCTION

The Setting

In his statement before the Subcommittee on Manpower and Personnel of the Senate Armed Services Committee on March 4, 1982, the Deputy Chief of Naval Operations (Manpower, Personnel and Training) (OP-01) commented:

> "... Navy's manpower, personnel and training challenge of the 80's is to man a growing Navy with sufficient manpower of the proper skill mix. We face this challenge during a period of increasing national commitments, a high tempo of fleet operations, and a declining manpower pool of 18-21 year old males."

This challenge is expressed in differing manner from time to time, and its exact character changes as there are adjustments in external factors such as the economy. Nonetheless, there is no reason to expect relief from its influence. In peacetime, the competing interests within and dynamic nature of our society are such that resource issues are not necessarily resolved in favor of national defense. On the other hand, those who are charged with national defense cannot relax their concern for the readiness of the force. In essence, we must make the absolute best possible use of the resources we are provided.

The Training and Personnel Systems Technology Program

Research and development is the enterprise in which we engage as a means to improve the use of our resources in meeting future needs. In the case of the men and women, civilian, military and Reserve, who people the Navy, the research and development program is titled within the Department of Defense as the "Training and Personnel Systems Technology (TPST) Program." The totality of the TPST Program in all the services approximates slightly more than 1% of the Defense research and development program.

The TPST Program develops and initiates implementation of new techniques in four categories related to the effective use of our human resources. These four categories, which form the organizational structure of this report, are:

- Manpower and Personnel
- Education and Training
- Human Factors Engineering
- Simulation and Training Devices

With changes in the policy and economic environments, in the structure of the operational forces, and in the demographic and sociological makeup of the nation as a whole, particular areas of effort at times assume greater relative importance. The emphases in TPST in the period of this report have been on efforts to:

- Maintain performance levels
- Predict the effectiveness of personnel
- Develop lower-cost training that is more effective and more available
- Build the technology base to meet future needs
- Make greater use of available microprocessor technology
- Enhance the impact of manpower, personnel and training in the weapon system acquisition cycle

The Purpose of the Utilization Report

This report is one means by which the Navy communicates its success in developing and implementing specific solutions to problems the service faces in the acquisition, training, utilization, and management of personnel. The report is intended to increase the utilization of newly developed training and personnel systems technology, and also to foster greater Navy-wide and interservice coordination of efforts in people-related RDT&E. In each project summary, emphasis is placed on the operational need that generated the effort, the manner in which the research products or results were (or will be) utilized, and the actual or potential "payoff". Each summary also includes a section which identifies the performing activity, sources of funding for the project, and sources of additional information. A diagram is provided illustrating the evolution of the effort through research, development and implementation. The successive levels are:

- *6.1: Research* — Scientific study and experimentation directed toward increasing knowledge in fields related to longterm national security needs.
- *6.2: Exploratory Development* — Efforts directed toward the solution of specific military problems, short of major development.
- *6.3: Advanced Development* — Development of systems or system components for experimental or operational test. A primary objective is proof of design concepts.
- *6.4: Engineering Development* — Design, fabrication, and testing of full-scale systems for operational application.

Emphases in this Report

The Utilization Report for FY81 focuses on work which has been completed recently and which emphasized improvements such as:

- Making the compensation system more effective
- Providing greater accuracy in predictions of personnel requirements
- Determining more accurately why people stay in the service and why they leave the service
- Utilizing recruiting resources more effectively
- Getting more information from the tests that are administered to people for classification and training purposes
- Making better use of computer systems to improve training effectiveness and efficiency
- Improving procedures for training in the basic skills of mathematics
- Adjusting training pipelines so that there is less training cost at the beginning of the first enlistment
- Reducing the costs involved in the preparation of software documentation
- Designing equipment on the basis of "how" maintainers accomplish maintenance tasks
- Using energy resources more efficiently
- Achieving a better integration of men and equipment in system performance
- Reducing the cost and increasing the safety of fire fighting training
- Improving the skills and reducing the cost of training for gunners firing an anti-armor weapon
- Expanding the use of voice technology to reduce the costs of training and improve the performance of systems operators

MANPOWER AND PERSONNEL

In the Department of Defense, Manpower and Personnel RDT&E involves "Development of techniques/methods for utilizing available personnel resources through improved selection, job assignment, organizational analysis and management techniques to meet combat-available and projected force needs."

The Navy must continually improve its manpower and personnel processes. These processes include: estimating life-cycle manpower requirements; developing more effective procedures for acquiring and classifying personnel; increasing productivity; and maintaining management capability to respond and adapt effectively to a changing force structure. A major focus at the present time is on finding ways to increase productivity and optimize the use of personnel resources while reducing or restraining costs.

Projects reported this year are:

- **Methods for Adjusting Military Pay**
- **Determining Shore Activity Workload from Fleet Configuration**
- **Survival Tracking System**
- **Improving the Allocation of Recruiting Resources**
- **Reasons for Separation**
- **Improving the Efficiency of Psychological Testing**

METHODS FOR ADJUSTING MILITARY PAY

Need

Annual increases in military pay are a relatively recent development. They began in 1963 but, until 1967, were made by the Congress when military pay was perceived as having fallen behind federal civilian pay. In 1967, Public Law 90-207 "indexed" changes in military wages to changes in the General Schedule (GS) salaries for civilian employees of the federal government. However, since 1962, GS salaries have been based on the principle of "comparability". Conceptually, this means that GS salaries are set approximately equal to civilian salaries for similar jobs. Further, GS salaries are supposed to be adjusted over time at a rate equal to changes in those same civilian salaries. These changes are guided by the annual survey of Professional, Administrative, Technical, and Clerical (PATC) workers conducted by the Bureau of Labor Statistics (BLS). This "automatic" adjustment mechanism has resulted in a systematic procedure for adjusting regular military compensation (RMC).

In 1980, Congress temporarily severed the link between military and federal civilian pay by granting an 11.7 percent military pay increase, as compared to a 9.1 percent civilian raise. At the same time, Congress questioned whether the PATC index and the resulting increase in GS salaries was an appropriate guide for adjusting military pay and, if not, what was appropriate. Prior to responding, the Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics) requested recommendations from the services. The Deputy Chief of Naval Operations (Manpower, Personnel and Training) (OP-01) was responsible for development of the Navy recommendations.

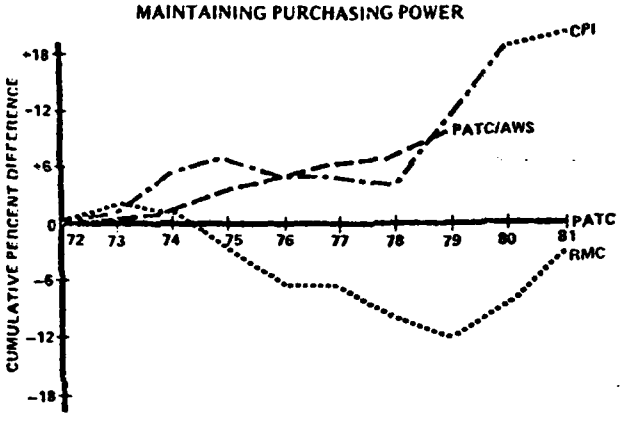
Approach and Results

The use of the PATC index to adjust military pay implicitly assumes that the occupations it surveys reflect job alternatives available to military members. However, PATC concentrates on white-collar occupations. Since most of the occupations of the enlisted force are of a blue-collar character, PATC is estimated to represent only about 10 percent of the enlisted force. Therefore, the need was to identify an index which fits better than PATC. Alternative indexes were identified and compared to PATC. Criteria for evaluation included the relative similarity of jobs in the military to those contained in the wages indexes; the timeliness and quality of the data contained in the indexes; and the ability of the indexes to maintain real purchasing power (i.e., to keep up with inflation).

Five indexes stood above the others relative to the criteria. They were: the PATC index; a combination of the PATC and the "blue collar" composite (BC) indexes; a combination of the PATC and area wage surveys (AWS) indexes; the private, non-agricultural production and nonsupervisory workers earnings (PVT/ NONAG) index; and an age-earnings profile index.

As compared to the 10 percent enlisted coverage of PATC, the PATC/AWS index accounts for approximately 60 percent of enlisted force jobs and 22 percent of the officer occupations. The PATC and PVT/NONAG indexes are considerably more timely than the other indexes, reflecting wage increases of 6 months prior or less. In contrast, PATC/AWS data would be 15 months old when used to adjust military pay. Moreover, since 1972 all wages represented by these indexes have suffered some loss in real purchasing power as measured by the Consumer Price Index (CPI). The chart which follows illustrates PATC/ AWS and PATC as compared to the CPI, using PATC as the baseline because it is the legislated index. RMC is also shown, illustrating that the PATC index, filtered through GS salaries, has not maintained a consistent relationship to CPI.

MAINTAINING PURCHASING POWER



Utilization

The results of this effort were used in an April 1981 OSD Pay Study convened to consider pay adjustment mechanisms. They were also used in a Pay Study beginning in February 1982. That Pay Study is expected to recommend to Congress an alternative to the PATC index.

Impact

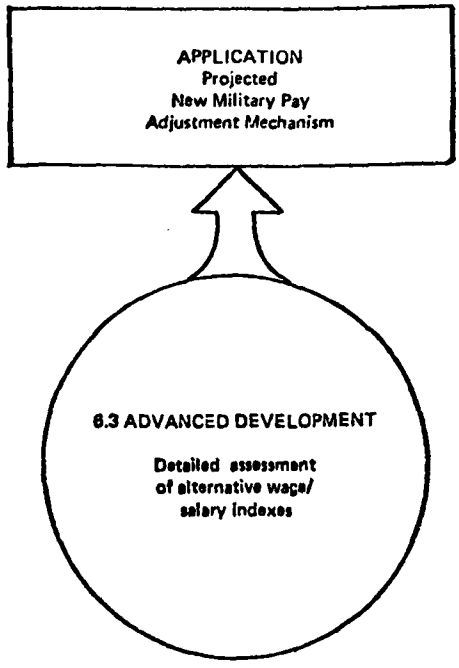
One vital component of military retention incentives is annual pay raises. However, to be effective, these pay raises must be competitive with wage growth in civilian occupations with which the military competes for talent. This research and development has identified a pay adjustment mechanism more representative of military

jobs — an index that accurately reflects relevant labor market forces.

Research and Development Notes

This work was performed by the Navy Personnel Research and Development Center (NPRDC) under the sponsorship of the Deputy Chief of Naval Operations (Manpower, Personnel and Training) (OP-01). The project identification was "Methods for Adjusting Military Pay", Z1182-PN.03, in Program Element 63707N, Manpower Control System Development. The responsible researcher was M. W. Rowe, NPRDC (Code 11), (714) 225-7388. Recent Technical Reports include NRPDC TR 81-1, *Review and Analysis of the Legislative History/Intent, Cost, and Value of Special Pay While on Duty at Certain Places,* November 1980; TR 82-12, *Methods for Adjusting Military Pay,* October 1981; TR 82-17, *Certain Places Pay: Current Inconsistencies and Suggested Alternatives,* November 1981; and TR 82-(), *The Reallocation of Military Pay Increases,* in press.

Program dynamics are:



DETERMINING SHORE ACTIVITY WORKLOAD FROM FLEET CONFIGURATION

Need

The United States Navy has a complex system of more than 1000 shore activities supporting its ships and aircraft. In addition, the shore activities must support each other. Some of the major activities include hospitals, shipyards, airfields, aircraft repair facilities, research laboratories, supply depots, activities which maintain and repair Navy buildings and roads, and many training bases.

One of the Navy's most intractable problems has been to forecast the effects that changes in fleet size or configuration have on the workload of these shore activities and their requirements for personnel to accomplish the workload. This effect must be forecast so that the people in the right skills and number are onboard the activity when the workload changes. The support personnel requirements are not only affected by the size and mix of the fleet, but also by its operating tempo and by indirect fleet demands channelled through other shore activities. Conversely, the Navy must also be able to determine the mix of fleet elements that can be supported by the shore establishment as it exists at the time in question. For example, in a past program analysis one issue centered on the increase of 6% per year (after inflation) in operations and maintenance funds during FYs 1973 through 1978, while the number of ships was decreasing. An inability to respond quantitatively to questions of this nature leads to pro rata personnel reductions at all shore activities, which usually results in uneven levels of fleet support.

Approach and Results

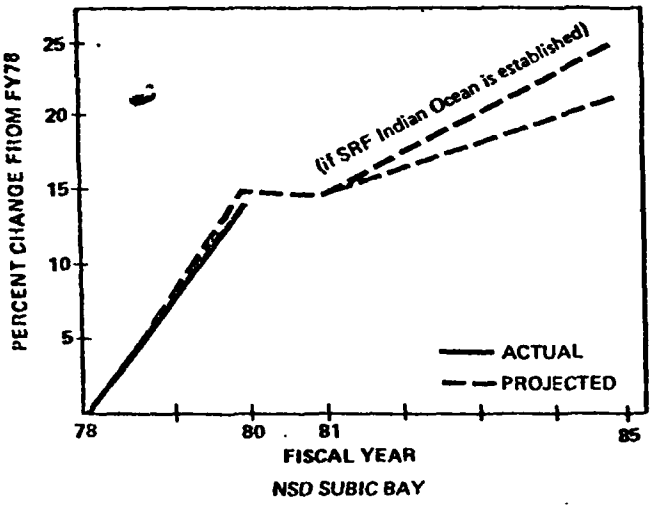
This research initially developed a computerized interactive input-output (I/O) model (CIOM, of the fleet-support demand network of the 11th Naval District (11ND). CIOM was discussed in the Fiscal Year (FY) 1980 Annual Report on The Utilization of People-Related Navy RDT&E. CIOM can be used to forecast workload at nine major 11ND shore activities, given a specified fleet configuration, and to estimate the percentage changes from base-year workload for these activities.

Next, an I/O model was developed for supply support to the Pacific Fleet. Data were collected and analyzed for Naval Supply Centers (NSCs) San Diego, Oakland, Puget Sound, and Pearl Harbor; Naval Supply Depots (NSDs) Yokosuka, Subic Bay, and Guam; Combat Store Ships (AFSs); and Submarine Tenders (ASs). Major emphasis was given to analyzing fleet demands by ship class, employment status, and homeport. Further, Navy shore activities were organized in an I/O matrix into workload sectors, so that the extent to which each activity depends on every other activity to produce support could be quantified using historical data.

The Pacific Fleet I/O Model was used to measure the effects of increased deployment in the Arabian Sea and Indian Ocean area. The model determined direct and indirect effect on supply workload at each Pacific Fleet supply activity in terms of the number of requisitions. For example, it determined the workload increase at NSC Oakland due to its role in support of the deployed

ships. In addition, the model determined the indirect workload increase at NSC Oakland due to increased demands on the supply depots and repair facilities which NSC Oakland supports in the Western Pacific.

Early in FY 1981, the Pacific Fleet I/O Model was verified using actual FY 1978 workload data. In addition, the impact that deployment patterns have on the number of supply requisitions was tested using actual FY 1980 ship employment data. As the figure below illustrates for NSD Subic Bay, the ability of the I/O model to forecast workload, given fleet configuration and operating tempo, was validated.



Actual/projected percent workload changes — — FY78 - 85

Utilization

The Pacific Fleet I/O Model was used to make workload projections for FY 1981 and FY 1985 for the seven NSCs and NSDs. The forecasts demonstrated the model's usefulness for resource allocation decisions and its versatility in determining the effects of changing fleet configuration and operating tempo on supply resources in the Pacific Fleet. The projections were used by supply resource sponsors in development of Program Objectives Memorandum (POM) 1983.

Fleet requisition demand rates of ships by type (e.g., destroyer, frigate) and status (in port, deployed, or in overhaul) which were developed for the I/O model were also used by the Naval Supply Systems Command and Naval Supply Centers as planning factors in making resource allocation decisions.

Payoff

The Assistant Deputy Chief of Naval Operations (Logistics) (OP-40) expressed appreciation for the work to the Commanding Officer, NPRDC:

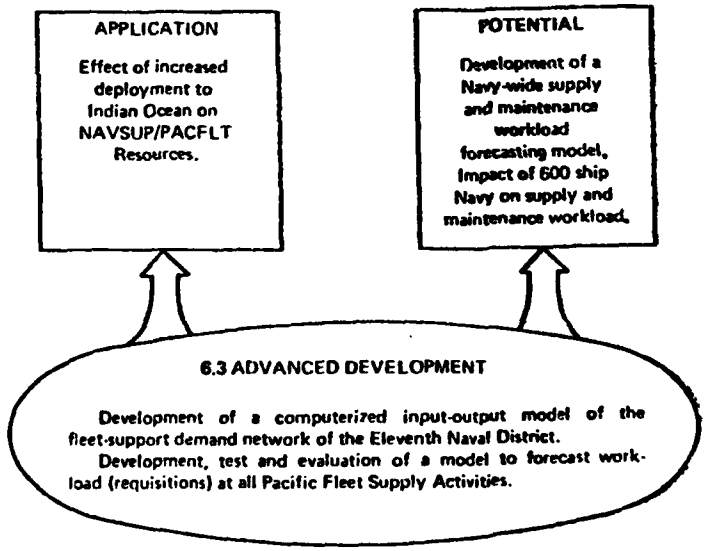
> "Logistics support requirements for the Pacific Fleet, obviously a current concern, will be a major topic of review in the near future. As the OPNAV staff prepares to develop its Program Objectives Memorandum for FY 83 - FY 87 (POM-83), the insights to be gained from ... (The PACFLT I/O Model) are likely to yield real-world resource allocation decisions. ... we are anticipating additional inputs during the coming months."

Expansion of the Pacific Fleet Input-Output Model to other functions and regions can be undertaken when funded. Extensions to other logistic functions, such as maintenance, would allow more accurate determination of the size of shore establishment (in terms of workload and manpower) needed to support a specified fleet configuration (number of ships, mix, operating tempo), and in determining what alternative fleet configurations a given shore establishment could support.

Research and Development Notes

This work was performed by the Navy Personnel Research and Development Center under the sponsorship of the Deputy Chief of Naval Operations (Manpower, Personnel, and Training) (OP-01). The project identification was "Determining Shore Activity Workload from Fleet Configuration", Z1186-PN.02, in Program Element 63707N, Manpower Control System Development. The responsible researcher was M. R. Shoecraft, NPRDC (Code 11), (714) 225-2971. The project has been documented in NPRDC Technical Note 80-16, *Modeling Logistics Support Requirements for the Pacific Fleet,* and Technical Report 82-1, *Supply Workload Implications of Increased Deployment to the Indian Ocean.*

Program dynamics are:



SURVIVAL TRACKING SYSTEM

Need

Many policies and programs in areas such as compensation, recruitment, and training are implemented by the Navy to influence the retention, training, performance, or career progress of enlisted personnel. All too often, however, data which track the behavior of individuals affected by these policies are missing, incomplete or difficult to obtain. This deficiency renders a comprehensive evaluation of policies and programs expensive and in some cases impossible to achieve.

Representatives from the Naval Military Personnel Command (NMPC) requested that the Navy Personnel Research and Development Center (NPRDC) assist in the development of a comprehensive automated system which tracks the progress of Navy personnel throughout their enlisted careers and permits quick retrieval of key information needed to evaluate new or existing policies and programs in an economical fashion.

Approach and Results

Informational requirements relevant to personnel policy decision making were identified. These requirements included:

- Longitudinal tracking of individuals so that the impact of policies can be evaluated over the entire career continuum.
- Data pertaining to significant career milestones and key decisions in order to monitor the effect of policies upon various events (e.g., advancement, attrition, reenlistment, assignment).
- Information identifying individuals as members of groups upon which personnel policies have been or may be focused. Such information includes age and sex, time of entry, test scores, term and type of enlistment contract, and others.
- Accuracy, portability, maintainability, and economy of the system so that policy evaluation is based upon current facts and figures and may be performed at minimal cost.

Next, existing sources of Navy information were evaluated. Data sources (e.g., Enlisted Master File, audit file) were chosen as input for the system. Quarterly extracts from these sources were derived which contained the data elements essential for policy evaluation. These items were selected on the basis of consultations with Navy organizations concerned with personnel policy formulation, implementation, and evaluation. A file structure was then developed which permits both rapid updating of personnel data and easy adaptation to various data processing configurations. Finally, a subfile structure and supporting inquiry mechanism was integrated into the system to provide rapid, economical access to key policy-relevant data.

The result is an operational system which may be expanded to included relevant data from additional sources as the need arises.

Utilization

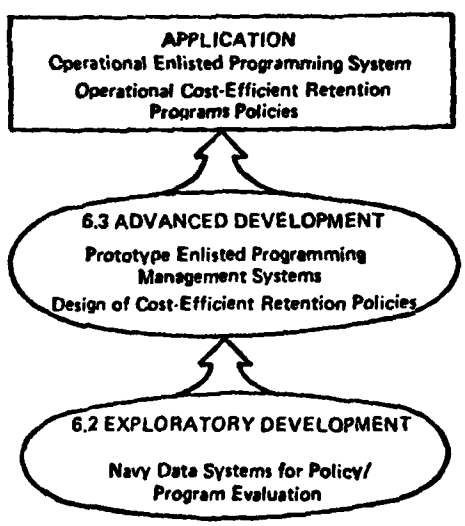
The initial operational system is installed at the Argonne National Laboratory computer facility at Argonne, Illinois. The system is accessible by NPRDC and NMPC personnel. It has been used to obtain information related to issues such as the impact of the programmed-school-input program on attrition, the effect of Project Upgrade on Navy strength planning, and the potential implications of a new female general detail program.

Guidance on the content and utilization of the system has been provided by NPRDC to personnel in NMPC and the Office of the Deputy Chief of Naval Operations (Manpower, Personnel and Training) (OP-01). Periodic assistance concerning system documentation and upgrading continues.

When required, follow-on research can develop system enhancements which will provide policy makers with ready access to an expanded set of information pertaining to retention and career development.

Research and Development Notes

Program dynamics are depicted in the following diagram:



This work was performed by the Navy Personnel Research and Development Center with the assistance of the Navy Military Personnel Command. Funding was provided in Exploratory Development Program Element 62763N, Personnel and Training Technology. The responsible researcher was Dr. J. I. Borack, NPRDC (Code 15), (714) 225-7286. The system is described in NPRDC TN 81-11, *The Enlisted Survival Tracking File*, April 1981.

Payoff

During FY 81, numerous pending policy decisions within OP-01 required data to be available on extremely short notice. NMPC used the survival tracking system to provide required data within hours at sharply reduced costs. For example, a single request for information which previously had cost the Navy approximately eight hundred dollars to process could be obtained for as little as ten dollars. Furthermore, the system provides findings which are in agreement with Navy statistics, thereby obviating the need for time and personnel for data reconciliation.

IMPROVING THE ALLOCATION OF RECRUITING RESOURCES

Need

In 1978, concerns were increasing about the ability of the All Volunteer Force to meet the defense manpower requirements of the nation. The economy was good and enlistments in the Armed Forces were down.

The quality of enlistments was also an issue because qualifying test scores were being questioned and the definition of "high school graduation" was broadening. Further, the population of 18 year olds was reaching a peak and forecasts predicted a steady decline of the age for military enlistment (17-21 year olds) over the next decade.

These factors caused greater attention to the means by which personnel are recruited into the services. However, the cost-effectiveness of many existing recruiting programs had long been questioned. Recruiting and advertising budgets for each armed service were identified as special interest items by the Congress. Advertising for enlistments on paid electronic media had been authorized by Congress in 1976. A prototype joint services advertising campaign had been developed and implementation was being debated. Individual service requests for budget supplements to meet anticipated enlistment shortages proliferated.

A need was identified by the Principal Deputy Assistant Secretary of the Navy (Manpower and Reserve Affairs) to examine marketing effectiveness and to quantify the relationships between enlistment achievement and marketing expenditures. The vast majority of these expenditures are concentrated on the maintenance and support of the field recruiting force and on various types of paid advertising. The two objectives were:

- To estimate a marketing effort response curve (as measured by the number of Navy enlistment contracts at various quality levels) to overall changes in the Navy advertising budget, the size of the Navy recruiting force, and a combined change in both policy variables.
- To conduct supplemental tracking, data collection and analyses so as to reasonably maximize the information about other recruiting policies and practices that effect recruiting success.

Approach and Results

A one-year field experiment was designed as follows:

- Advertising and recruiters were to be varied in a systematic and controlled way, independent of sales in prior periods.
- A broad range of each treatment variable was to be tested and treatments were to be replicated in multiple markets.
- A substantial body of supplemental data was to be collected for each market involved in the experiment, including both sales and marketing data for the other (competing) branches of the Armed Forces. In addition, a survey research program was to be conducted in selected markets.

The Area of Dominant Influence (ADI) was selected as the unit of analysis for the experiment. Individual counties are assigned to ADIs by the electronic media-rating services based on media-use patterns of sampled households. Of the over 200 ADIs in the United States, a subset was selected for experimental treatment. The treatment objective was to expose individuals in the treatment markets to the level and type of advertising and recruiters to which they would be exposed under the alternative budget levels being tested. Experimental treatments were randomly imposed in 26 markets. A total of 43 markets were involved as either control or treatment markets. In addition, 12 markets were used as the sample for a survey to:

- Enable the identification of any obstruction between the two marketing control variables, recruiters and advertising.
- Provide measures of the impact of recruiter and advertising treatment on a range of intermediate measures. These measures included awareness of advertising, recruiter contact, attitudes towards a variety of "life goals", perceptions of the Navy, and intentions to enlist.
- Enrich the Navy's understanding of the recruiting environment and process.

To achieve these aims, respondents were sampled at a variety of points in the recruiting cycle. Separate, independent samples were drawn at each point in the process. Questionnaires were administered in June of 1979 before any experimental intervention and again in June 1980, nine months into the experiment. The general target population questionnaire was administered by telephone using random digit dialing techniques. All other questionnaires were administered by Navy Recruiting or AFEES test station personnel in the form of written instruments.

Highly significant relationships between the number of recruiters present and the number of enlistment contracts were observed. Increasing the numbers of Navy recruiters also increases the Navy's relative share of enlistments. A four-to-six month learning period for newly-assigned Navy recruiters was also found. Enlistment contract production for new recruiters during this period is substantially less than that of experienced recruiters. In addition, a loss of productivity was noted for Navy recruiters who expected soon to leave recruiting duty. In one analysis, enlistment contract production fell off sharply beginning about one year before tour rotation. Advertising expenditures were observed to have significant effects on the number and type of enlistment contracts obtained. In addition, costs for achievement of enlistment contracts of various types through recruiting resource expenditures were estimated for those resources which had consistent and significant effects on contracts.

Recruiters show the strongest and most consistent effects on enlistment contracts. Hence, investments in recruiter resources bear relatively less financial risk. They are also the most expensive resource input at the margin. A cost per enlistment contract for recruiter input was estimated at about $2,000 compared with an average cost of marketing inputs per enlistment contract of about $1,000. The marginal cost per contract achieved through recruiter input rises steadily with "quality" constraints.

Advertising effects on enlistment contracts are not as strong or consistent as those for recruiters. These expenditures are thus "riskier". Nevertheless, where effective, advertising is highly efficient. The lowest marginal cost estimated is for Navy local advertising with respect to Navy high school diploma or graduate contracts. The cost is estimated at $200 per contract. The marginal cost per Navy enlistment contract for joint services advertising expenditures is generally under $1,000. Marginal costs for Navy national advertising were not estimated because aggregate effects were very small and inconsistent for this campaign. Hence marginal costs for this resource would be exceptionally high.

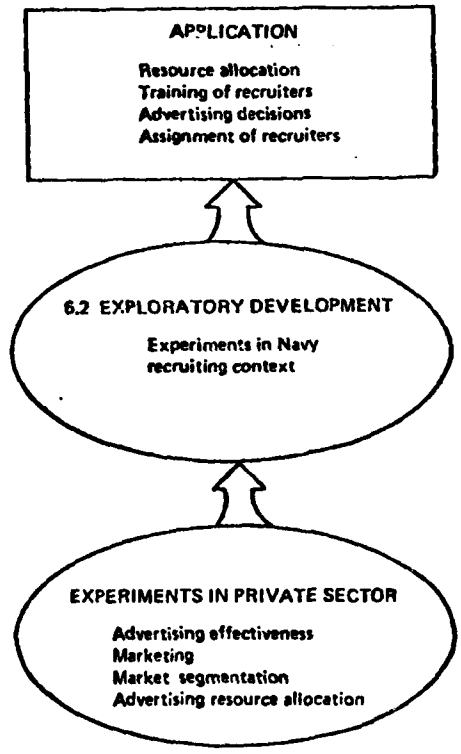
Utilization and Payoff

These results will enable the Navy Recruiting Command to allocate resources to advertising and to recruiters more effectively than before. Subsidiary analyses will enable recruitment planners to target more effectively those marketing campaigns directed at specific segments of the market such as Mental Groups I and II or women. The findings on learning and loss of productivity are being taken into account in determining how long recruiters should remain in a given location, how they can be brought up to speed most rapidly, and how their productivity can be kept at a high level during the latter part of their tour-of-duty. In addition, the knowledge gained enables the Navy to justify its recruiting budgets to the Department of Defense and Congress much more effectively.

Research and Development Notes

The Chief of Naval Research sponsored this project in Program Element 62763N, Personnel and Training Technology. The project was initiated in 1978 and completed in 1981. The responsible researcher was Dr. B. T. King, ONR (Code 442), (202) 696-4741. The principal investigator was Mr. V. Carroll, Wharton Applied Research Center, University of Pennsylvania, Philadelphia, PA, 19104, (215) 243-4470. Technical reports are in preparation.

Program dynamics are:



IMPROVING THE EFFICIENCY OF PSYCHOLOGICAL TESTING

Need

Psychological tests play a central role in career selection of all Navy and Marine Corps personnel. In turn, career opportunities have a substantial influence on enlistment decisions, and performance in training has a substantial influence on training costs, on training motivation, and ultimately on force effectiveness. Therefore tests must accurately reflect an individual's capabilities. Unfortunately, improved test accuracy generally requires increased test length, which necessitates additional time.

However, both the Military Enlistment Processing Command (MEPCOM), which manages operations at the Military Entrance Processing Stations (MEPS), and Navy and Marine Corps training commands are under pressure to reduce testing time. For MEPCOM, every extra minute spent testing increases the probability that candidates will need overnight accommodations in commercial hotels. For Navy and Marine Corps training commands, testing time represents a substantial fraction of training time, and every man-day spent in training is a man-day not spent in line units which are critically short of trained personnel.

Obviously, if the efficiency of psychological tests were to be increased, more accurate testing could be accomplished without increased time. One idea for increasing the efficiency of tests is to use a more sophisticated procedure (polychotomous scoring) for scoring responses. Scoring models currently used to describe the performance of individuals on multiple-choice or free-response tests are dichotomous: an examinee who produces a correct response is scored "correct"; an examinee who produces an incorrect response is scored "incorrect". No distinction is made between the various incorrect responses. However, we know that examinees who do not know the correct answer are often either misled by a distractor or make an informed choice using whatever partial information they have. They seldom respond randomly. Polychotomous scoring would improve testing efficiency by capitalizing upon information in an examinee's choice of incorrect alternative. This has been a popular idea, but previous attempts to use polychotomous scoring have been disappointing.

A relatively new approach to psychological measurement known as latent-trait theory has substantially improved the ability to model correct-answer choice (i.e., dichotomous scoring). While there had been some work on a polychotomous latent-trait model, the models were very rudimentary and the statistical and numerical procedures were impractical. Therefore, this project was undertaken to develop a comprehensive latent-trait theory for polychotomous scoring.

Approach and Results

A latent-trait theory for the polychotomous situation needed two things: a performance model which describes test behavior as a function of the capabilities being measured; and procedures for examining the quality of incorrect response alternatives.

The work horses of polychotomous scoring are "response-category operating characteristics". These operating characteristics are mathematical functions which describe, in a probabilistic way, the relationship between an examinee's capabilities and his response choices. With a five-alternative multiple-choice problem, one could have as many as five operating characteristics, one operating characteristic for each alternative.

In figure 1, the operating characteristic for response option A, say, describes how the conditional probability of selecting option A varies as a function of ability. Statistical and numerical difficulties in estimating these operating characteristics had stymied previous attempts to develop a useable latent-trait theory for polychotomous-scoring.

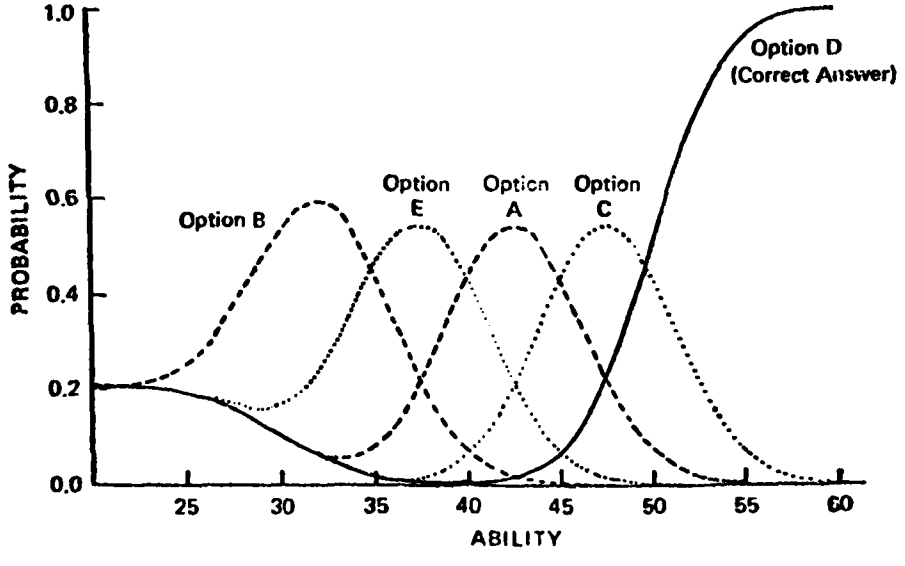


Figure 1

If response-choice is to be useful in improving the efficiency of multiple-choice tests, it must be informative. If the operating characteristic of option A, say, is very flat over a broad range of the individual's capabilities, the fact that an examinee chooses option A tells us little about his capabilities; a peaked operating characteristic would be more informative. Ideally, one would like to have very peaked unimodal operating characteristics for the incorrect responses, and a strictly-increasing operating characteristic which rises sharply to an asymptote for the correct response. Practically, one needs procedures for gauging the performance of a particular test item against this ideal. This work has developed indices for that purpose.

Technology-Base Advancement

Five years ago, useable latent-trait theory consisted entirely of models suitable for dichotomously-scored, free-response, unidimensional test questions. Although models for other response formats and other scoring schemes had been considered, formidable statistical and numerical estimation problems existed. This project has developed a latent-trait theory for almost any type of discrete-response unidimensional test question.

Results of this project have not only been described in technical reports but also have been implemented in exportable computer programs. Interim results have been described at annual ONR contractor's meetings attended by representatives of Navy research and development activities and operational commands. In addition, a three-day workshop to introduce users to these results and to the computer programs which implement them was held in March 1982. Results of the work appear in the proceedings of the 1977 and the 1979 Computerized Adaptive Testing Conferences and in the proceedings of the Fifth International Symposium on Multivariate Statistics. Results will also appear in Wainer, H. and Messick, S. (eds), *Advances in Psychometric Theory; A Festschrift for Frederic M. Lord*, Hillsdale, NJ: L. Erlbaum Assoc. (to appear).

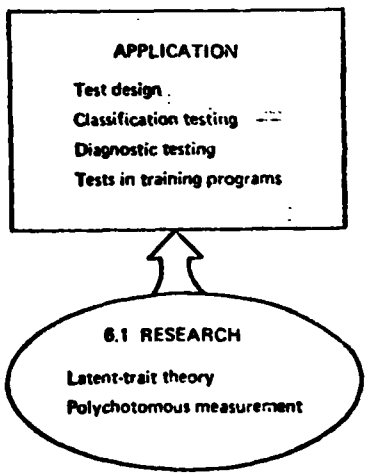
Impact

The benefits of this project come in terms of increased accuracy and efficiency of psychological measurement. These increases will result from better design of measurement tasks through the use of the distractor-assessment technology; more efficient use of each examinee's time through the increased accuracy of the information used in adaptive selection of problems which seem to be at his level; and more accurate scoring of an examinee's responses through the use of models which accurately reflect response choice.

Research and Development Notes

This project was sponsored by the Chief of Naval Research. It is titled "Statistical Techniques for Graded Response Items in Adaptive Psychological Testing." Funding was provided in Program Element 61153N, Defense Research Sciences, Subelement 42 Behavioral and Social Sciences. It was initiated in 1977 and completed in 1981. The responsible research manager was Dr. C. E. Davis, ONR Pasadena, CA, (213) 795-5971. The principal researcher was Dr. F. Samejima, Department of Psychology, University of Tennessee, Knoxville, TN, 37916. The work is summarized in Samejima, F. *Final Report: Efficient Methods of Estimating the Operating Characteristics of Item-response Categories and Challenge to a New Model for the Multiple-choice Item.* Knoxville, Tennessee: Department of Psychology, University of Tennessee, November, 1981.

Program dynamics are:



REASONS FOR SEPARATION

Need

The Navy has a continuing concern with the financial and "fleet readiness" costs of personnel attrition. A frequent strategy in the effort to reduce attrition rates is to conduct special surveys of the reasons people give for leaving the service. However, these surveys are very costly. They require a great deal of time to develop, administer in operational units, and analyze. Consequently, there is frequently a six-month lag between the time the information is needed and the time the final results are available. An ongoing management information system is needed to eliminate the many separate and "time-bound" data collection efforts. It will also provide a longitudinal "norm" base against which to evaluate trends and compare various groups of Navy personnel.

Approach and Results

Personnel separating from the Navy were asked to write out their reasons for leaving the service. These

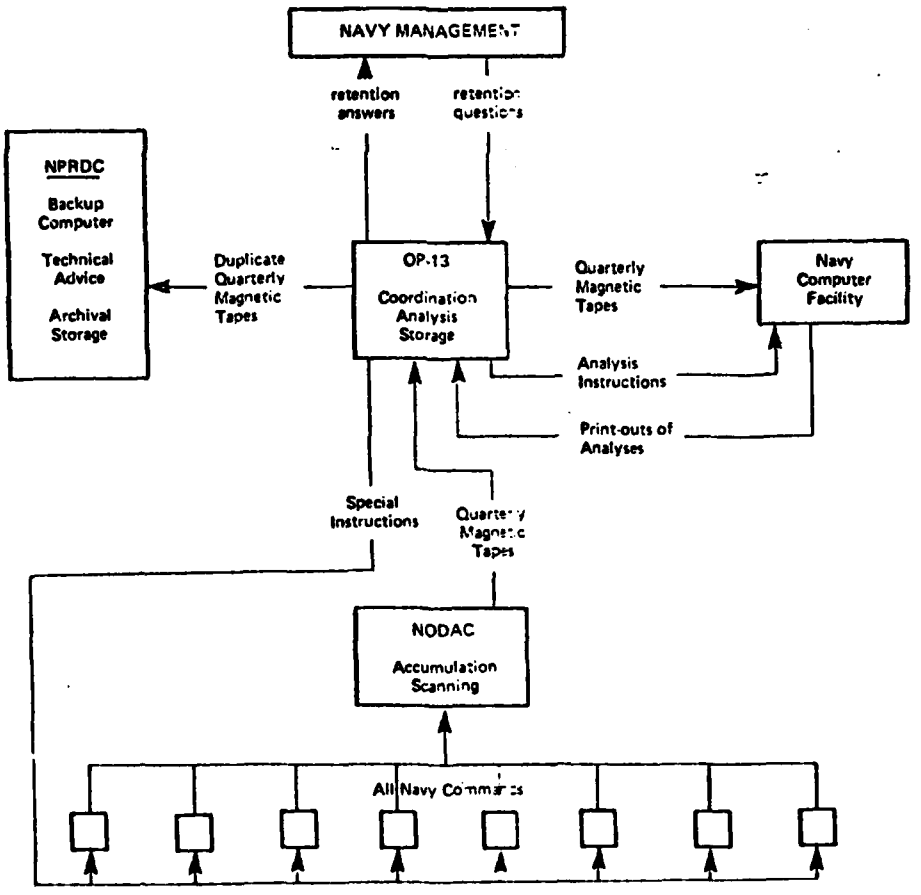
free-form responses were analyzed to derive the most frequently cited reasons. Based on the "most frequent" responses, as well as information from previous surveys, 30 reasons were chosen. Some of the criteria used in the selection of "reasons for leaving" were whether each item was:

- Within the power of the Navy to change
- General without being vague
- Different from other reasons
- A response that personnel would normally give when asked "Why are you separating?"

A questionnaire has been developed for administration to individuals leaving the service. Each person will be asked to indicate how important each of the 30 reasons was in the decision to separate. To facilitate the analysis of subgroups, various demographic items are included, such as rating, pay-grade, number of reenlistments, and marital status. A special answer section is included to provide quick and efficient collection of new types of information. All of these items (reasons for leaving, demographic information, and special answer) were combined to produce a two-sided optically-scannable form. The opscan format was chosen to make data collection, analysis, and display as efficient as possible. Computer programs were written to scan the questionnaires, store the information on magnetic tape, run various analyses, and print summary tables.

Utilization

This management information system was designed specifically for utilization by the Director, Military Personnel Policy Division (OP-13), and has been operational since December 1980. Personnel who leave the service complete the questionnaire. Questionnaires are forwarded to the Navy Occupational Development and Analysis Center (NODAC) in Washington, D.C. Questionnaires are analyzed and results are provided quarterly. Figure 1 illustrates the flow of information and system procedure.



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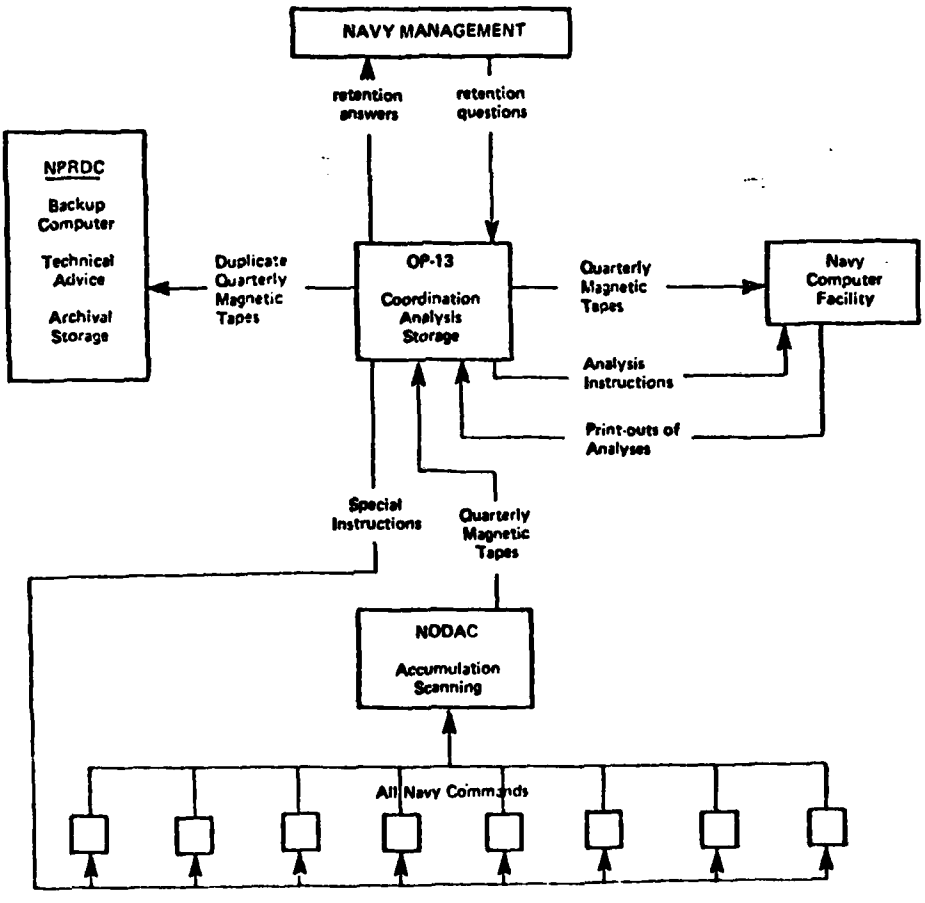


Figure 1

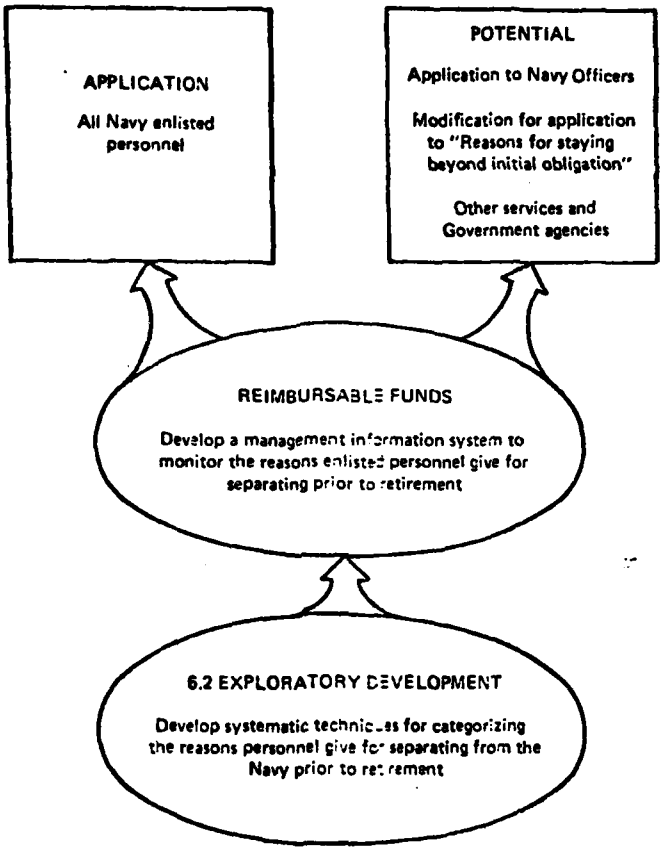
Impact

The automation involved in this system has reduced the cost of providing "reason for leaving" information. This information is used to develop policies and procedures related to retention. The impact of this system will be seen in its contribution to policies that result in reduced attrition.

Research and Development Notes

This project was performed by the Navy Personnel Research and Development Center (NPRDC). It was sponsored by the Deputy Chief of Naval Operations (Manpower, Personnel and Training) (OP-01), using Operations and Maintenance, Navy, funds. The responsible researcher was Dr. W. H. Githens, NPRDC (Code 12), (714) 225-2408. There are no Technical Reports published on this work.

Program dynamics are:



EDUCATION AND TRAINING

This area of People-Related RDT&E is defined in the Department of Defense as the "Development of education/training methods and media for managing, designing, and evaluating new-generation instructional systems for military application."

The Navy training establishment faces major challenges in trying to maintain personnel readiness to meet operational demands while it is faced with economic restrictions, manpower competition, and the increasing sophistication of weapons. New technology is being developed to focus training objectives on actual job requirements, to reduce training costs and improve efficiency, to improve the availability of training, and to adapt training to the needs of the individual.

The projects summarized in this Annual Report are:

- **Improving the Navy's Computer-Managed Instruction System**
- **Computer-Assisted Study Management in a Navy "C" School**
- **Enhancing Computational Capabilities**
- **Reducing Front-End-Loaded Training**

IMPROVING THE NAVY'S COMPUTER-MANAGED INSTRUCTION SYSTEM

Need

The Navy operates a large-scale computer-managed instruction (CMI) system that handles more than 9,000 students daily. Its objective is to train students in the shortest possible period of time to specific performance objectives. An analysis of the system identified several major problems: inappropriate use of instructors, and inefficient methods for scoring CMI tests, were two of these problems. The Chief of Naval Education and Training (CNET) and the Chief of Naval Technical Training (CNTECHTRA) requested research and development to solve these problems.

Approach and Results

The approach taken to providing a validated role for CMI instructors involved: developing a role model, comparing the role model and actual instructor roles in the CMI schools, and developing a training program for instructors that would provide the skills and knowledge identified in the theoretical role as being necessary.

The training materials were provided for use in in-service training for instructors. Additionally, the role model and training materials were provided to CNET for inclusion in new versions of the curriculum for the formal Instructor Training course.

Solution to the problem of inefficient testing procedures involved two thrusts. One thrust developed a calculator-like device to be used by students instead of paper answer sheets. These devices, called Test Input Devices (TIDs), can store the student test question answers and then transmit them to the computer through a linking device. The TIDs have been prototyped and evaluated in a Basic Electricity and Electronics School (BE&E). In the evaluation, the TIDs were found to eliminate almost all mechanical data errors, and to save about 10 percent of the testing time compared to using the paper answer sheets.

The second thrust involved an analysis of the CMI system computer architecture and operational management structure, to identify areas that contribute to a slow system response time. A slow response time means students must wait to receive test results. This delay is costly. The analysis involved a task group comprised of representatives of the Navy Personnel Research and Development Center (NPRDC), CNET, CNTECHTRA, the Management Information and Instructional System Activity (MIISA, the managing computer organization), the Training Analysis and Evaluation Group (TAEG), and the CMI schools.

As a result of the analysis, alternative CMI system designs were developed that would provide better testing capabilities while improving system response time. CNET is implementing the best design through immediate system management changes, acquisition and implementation of necessary computer equipment, and development of a distributed computer system that retains central data control.

Utilization

The instructor role model is now being used in in-service training at several CNTECHTRA CMI schools. It has recently been distributed to all CMI schools. The materials have been provided to the Navy Instructional Program Development Center that is responsible for the development of a new formal Instructor Training curriculum. This is the first time a CMI instructor's role has been developed on the basis of what the instructor should be doing as part of the instructional system, rather than what the instructor traditionally does. The technical approach taken provided a new means for defining "instructor" as new delivery systems come into existence.

The TIDs were evaluated by MIISA for proper electronic operation, and in the BE&E school for effective use in the CMI environment. The TIDs were evaluated by students, instructors, and researchers as easier to use and more effective than the more costly paper answer sheet scoring system. CNET and TAEG are now conducting an economic analysis to determine the extent of system-wide implementation. The Navy's CMI system is in the forefront of large-scale operational CMI systems but can still benefit from the incorporation of new computer technology developed during the last 5-6 years.

The results of all of these efforts were communicated to the users as progress was made, through task group meetings, personal contacts, formal briefings, and training program drafts. Formal technical reports followed later. This project has been noted for its close coordination with the user community that includes the several organizations making up the CMI system.

Impact

The results of this work will be used by CNET instructional management personnel and all fifteen CNTECHTRA schools using CMI. Instructor role model training will improve the utilization of instructor personnel. Results to date have demonstrated improved attitudes of instructors. As more courses are added to the CMI system, effective use of the available staff will continue to be important.

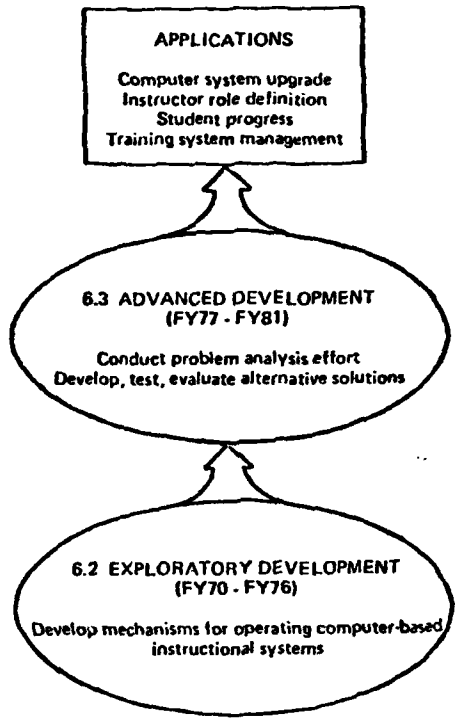
Replacement of the paper answering system with the TIDs will reduce test scoring errors and make a considerable savings in system costs. The cost of TIDs is projected to be amortized in about two years by elimination of the answer sheets and the associated optical mark readers.

The major payoff from this R&D project is the upgraded CMI system. Implementation is planned by CNET over the next two years. It should result in more effective management of the CMI instructional process.

Research and Development Notes

This work was performed by the Navy Personnel Research and Development Center under the sponsorship of the Deputy Chief of Naval Operations (Manpower, Personnel and Training) (OP-01). The project identification was "Improving Computer-Managed Instruction in the Navy," Z1176-PN.01, in Program Element 63720N, Education and Training. The principal investigator was Dr. N. H. Van Matre, NPRDC (Code 14), (714) 225-7122. The effort extended from 1976 through 1981. The project was previously described in part in the *Second Annual Report on Utilization of People-Related Navy RDT&E, April 1979.* Selected Reports and Notes issued include NPRDC Special Report 80-33, *Computer Managed Instruction in the Navy: I Research Background and Status,* September 1980; NPRDC Special Report 81-26, *Upgraded Navy Computer Managed Instruction: Analysis of Requirements for and Preliminary Instructional System Specifications,* September 1981; NPRDC Technical Note 80-10, *Theoretical Definition of Instructor Role in Computer-Managed Instruction,* March 1980; NPRDC Special Report 80-13, *Requirements and Characteristics of a Test Answer Input Device for the Navy's Computer Managed Instruction System,* March 1980.

Program dynamics are:



COMPUTER-ASSISTED STUDY MANAGEMENT IN A NAVY "C" SCHOOL

Need

The Study Management System (SMS) is a learning management procedure developed for Navy schools, featuring self-study of existing instructional material. Student interaction with the subject matter is ensured by study assignments, numerous study questions, and frequent tests with feedback. Both instructor-managed and computer-managed forms of SMS have been developed and evaluated in college classrooms and Navy Class "A" technical schools. The computer-managed form of the SMS is called CAISMS for "Computer-Aided Instruction Study Management System."

The Chief of Naval Education and Training (CNET) foresaw that the SMS had several potential benefits in Navy advanced school. Expectations included reductions of 15-20% in training time because of self-pacing; reductions of idle time waiting for courses to convene; particular appropriateness to maintenance-oriented courses requiring use of technical manuals and other job aids; and easier transferral to remote site use. Therefore the Navy Personnel Research and Development Center was requested to investigate the feasibility of SMS in a Navy advanced maintenance course.

Approach and Results

A three-week course on maintenance of a fathometer was selected by (CNET) as the course for experimentation. During the first phase of the project careful evaluation was done in the current course. Student and instructor behaviors known to be related to learning and memory were recorded.

During the second phase, three types of instructional materials were developed to support the implementation of SMS: materials to teach the use of the technical manual for the equipment; lesson assignments with appropriate study questions to form a student workbook; and a written testing program. All the test questions were designed to match existing learning objectives. About twelve man-months of effort were required for conversion. A manual describing procedures for converting similar courses was also developed for use by Navy instructors.

In the third phase, the instructor-managed SMS course was adapted to computer management. A microcomputer-based version of the CAISMS program was used to manage the instruction and testing. Conversion

of the SMS version of the course to CAISMS took less than a manmonth of effort. A manual describing operation and use of the microcomputer version of the CAISMS system was also developed.

Comparisons of the three versions of the course revealed that Navy instructors can adapt existing group-paced lecture-delivered courses to the SMS system with part-time guidance of an Educational Specialist. Both the SMS and CAISMS versions of the course teach the intended skills and knowledges. In addition, the SMS and CAISMS courses were more efficient than the original course. The amount of "hands-on" time was greater for SMS and CAISMS students, and they received much more instruction and practice in using the technical manual. The instructor easily managed the SMS version of the course.

The SMS conversion was highly cost-effective; time savings of 27% were achieved. The benefits observed with the SMS version of the course were successfully transferred to the CAISMS version of the course and a new instructional staff. The CAISMS program was successfully adapted to a computer system affordable and manageable for Navy schools.

Utilization

The SMS versions of the course are being considered for implementation at the Fleet Anti-Submarine Warfare Training Center, Pacific, San Diego, CA, and at the Naval Submarine School, New London, CT. In addition, the Chief of Naval Education and Training is considering other "C" and Fleet courses for conversion to the SMS, and is beginning acquisition of computer systems suitable for CAISMS.

The course examined in this effort is representative of many of the approximately 3000 Navy advanced courses that are offered each year. On the basis of the results observed in this effort, previous CAISMS evaluations, and many other studies concerned with self-paced instruction, it is probable that the benefits of SMS or CAISMS will transfer widely.

Impact

The conversion of the original three-week course to SMS took about one man-year of effort; similiar conversion times for similiar course can be anticipated. The conversion must be done by subject-matter experts, which in most cases would be the instructor(s) assigned to the course. These initial conversion costs are offset by the benefits that are associated with self-paced, flexible-entry course. If the time savings of 27% were maintained for, say, 100 students, then about two student man years will have been saved. Futher, reduced wait-time for courses, increased student throughput, and greater availability of courses for personnel assigned to ships, may be realized.

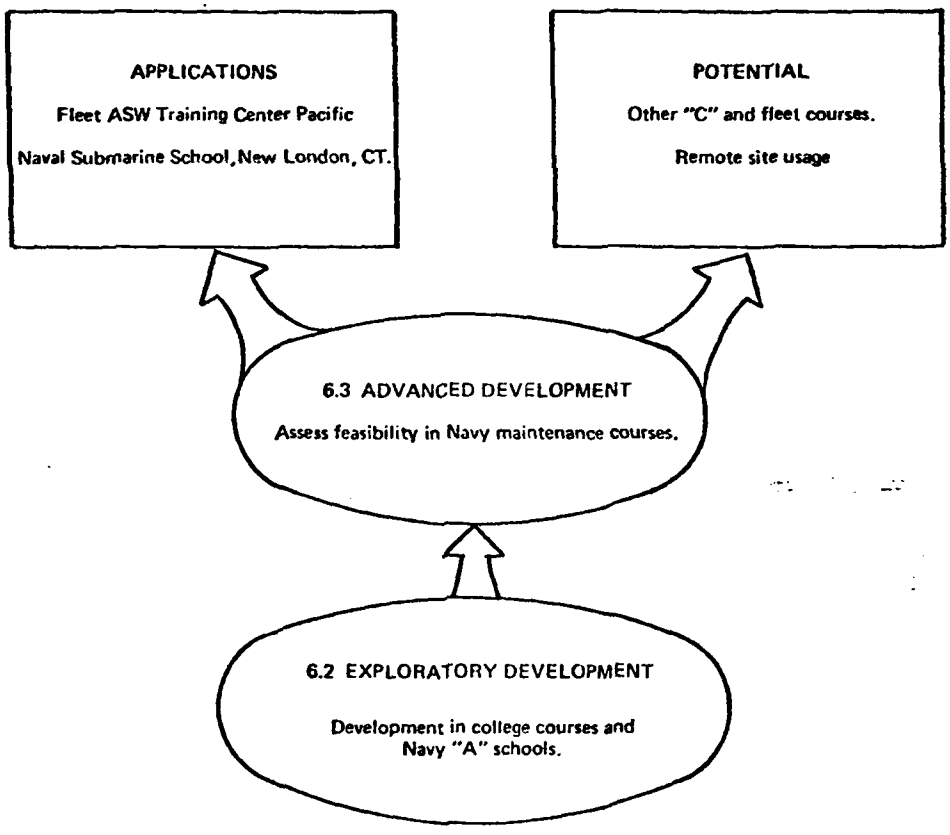
The conversion from SMS to CAISMS required less than a month of clerical effort. The major costs involved in converting an SMS course to CAISMS, however, are the initial computer purchase and subsequent maintenance costs. The computer configuration which is most appropriate depends on a number of variables. The microcomputer used in this project was purchased for about $10,000, has maintenance costs of about $500 per year, and may last up to five years depending on amount of use. Less expensive computers can also run the CAISMS system, but they may have to be replaced more frequently. An estimate for yearly computer costs is somewhere between $200 and $500, multiplied by the average or peak student load. However, computerization of the course may not result in benefits in addition to those which result from conversion to SMS. In this project, the CAISMS students showed small increases in test scores, but also took slightly longer to complete the course. In general, no substantial effectiveness or efficiency gains or losses were measurable relative to the SMS version.

Computerization could be cost-effective in instructor utilization. in the SMS course, instructors hand-scored and provided feedback for tests; this took nearly three hours per student. This is a clerical task which the CAISMS computer could perform. If it can be managed, the "saved" instructor time could be used to teach additional courses, or convert other courses to SMS or CAISMS.

Research and Development Notes

This effort was performed by the Navy Personnel Research and Development Center in 1980 and 1981. It was sponsored by the Deputy Chief of Naval Operations (Manpower, Personnel and Training) (OP-01) as "Improved Effectiveness in Course Design, Delivery and Evaluation," Z1175-PN.05, in Program Element 63720N, Education and Training. Previous Exploratory Development work had beeen accomplished in Program Element 62763N, Personnel and Training Technology. The Defense Advanced Research Projects Agency also provided funding. The responsible researcher was Dr. W. E. Montague, NPRDC (Code 13), (714) 225-7121. There are eight documents describing the work and the results of this project. The more recent are NPRDC TR 82-33, *Development, Test and Evaluation of the Computer-Assisted Study Management System in a Navy "C" School: Summary Report,* February 1982; Special Report (SR) 82-(), *User's Guide for Microcomputer Applications of CAISMS,* in press; and SR 82-(). *Procedures for Adapting Group-Paced Instruction Materials,* in press.

Program dynamics are:



ENHANCING COMPUTATIONAL CAPABILITIES

Need

The sophistication of military equipment is increasing; training budgets are not increasing at the same rate. To assure cost effective training, skills and knowledge essential to successful job performance in the fleet and subordinate skills necessary to master essential skills must be identified. Conversely, skills not required for successful performance must be identified and removed from entrance standards and course objectives.

Over 23,000 recruits who enter Navy Class "A" schools every year are trained in electronics maintenance. Before these recruits enter "A" school, however, they must successfully complete training in the fundamentals of electronics at one of the Basic Electricity and Electronics (BE/E) schools.

Although the selection requirements for the electronics schools are more stringent than for most areas of Navy technical training, many students are not prepared to begin the BE/E school curriculum. The BE/E

course and all subsequent electronics courses use mathematics to express relations in electronics systems. Deficiencies in mathematics appear to be prime contributers to unsatisfactory performance in electronics. Hence, a need exists to specify objectively the mathematics skills required to become a competent Navy electronics maintenance technician, to assess current skill levels, and to provide remedial training for the skills found deficient.

The original intent of this work unit was to specify the mathematics skills required to become a competent Navy electronics maintenance technician. However, at the request of the Chief of Navy Technical Training (CNTECHTRA), the effort was expanded to include the construction of diagnostic tests to assess a student's ability to perform identified BE/E mathematics prerequisites, and the development of remedial mathematics curriculum modules keyed to the diagnostic tests.

Approach and Results

The first step was to identify mathematics requirements. A survey form was developed for administration to instructors at the BE/E and electronics "A" and "C" schools. Seventy skills were identified from standard texts on mathematics for electronics. The purpose of the survey was to identify levels of importance of these skills to school success. The number of skills judged to affect performance at the BE/E school was 21, of which six were considered to be prerequisites and were not reviewed or taught in the BE/E School, two were reviewed in the school, and 13 were taught. Across all "A" schools surveyed, twenty-five percent of the math skills were considered to be prerequisites, 44 percent as reviewed, and 31 percent as taught. Across all "C" schools surveyed, fifty-two percent of the math skills were considered to be prerequisite, 29 percent as reviewed, and 19 percent as taught. Next, mathematics requirements for job performance were surveyed. Very little math use was found at the job station; however, over 50 percent of the respondents claimed that their math knowledge helped them on the job. The data resulting from the surveys provided the basis for determining the prerequisite mathematics requirements of the BE/E school.

Once identified, these prerequisites were broken down into subskill components which formed the basis for three diagnostic tests, each to be administered just prior to the point in the BE/E curriculum where mathematics skills were required. To accompany the diagnostic tests, mathematics learning modules were prepared. Each module was keyed to specific math items appearing on the diagnostic tests. The students performing poorly were remediated on the specific skills with which they were experiencing difficulty, thereby keeping remedial training time to a minimum.

Two hundred students enrolled in the BE/E school, Naval Training Center, San Diego participated in the pilot effort. Preliminary results indicated that, when compared with the traditional BE/E math modules, the experimental mathematics training made a significant difference in electronics performance in some areas. Overall, however, no significant differences were found in BE/E course performance and time to complete the course between students using either the traditional or experimental modules. Investigation to determine why there was little difference revealed that the mathematics skills of the experimental group were higher than normal so that the experimental modules could not show their effect.

Utilization

Efforts are currently underway to obtain a group of students whose math aptitude is judged by BE/E personnel to be more representative of the overall BE/E population. However, based on the positive direction of findings with the high aptitude mathematics group, the Chief of Naval Technical Training is preparing all four BE/E schools to convert to the experimental mathematics curriculum.

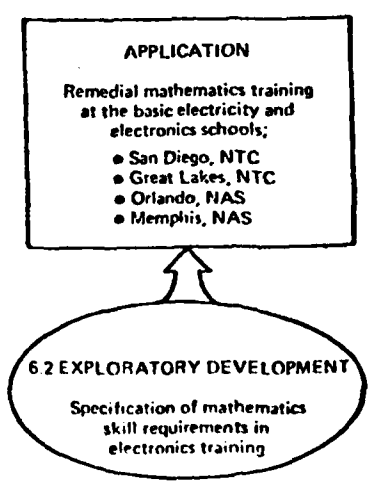
Impact

Proper training in mathematics skills required for learning electronics should serve to reduce the attrition and setback rate at the BE/E schools, and improve fleet performance. By diagnosing a student's mathematics difficulties through testing and then providing specially-designed materials, the amount of remedial work required will be reduced. This will decrease total training costs and preserve a more positive student self-concept.

Research and Development Notes

The Navy Personnel Research and Development Center performed this work during the period 1977 to 1982. The project was "Enhancement of Computational Capabilities", and it was funded in Exploratory Development Program Element 62763N, Personnel and Training Technology. Dr. M. S. Baker, NPRDC (Code 15), (714) 225-6803 was the responsible researcher. Five technical reports have been published, including NPRDC TR 82-3, *Mathematics Course Requirements and Performance Levels in the Navy's Basic Electricity and Electronics Schools,* October 1981, and TR 82-5, *Mathematics Requirements of Electronics Ratings in the Job Environment,* October 1981.

Program dynamics are:



REDUCING FRONT-END-LOADED TRAINING

Need

The Navy's current approach to technical training is "front-end-loaded"; that is, technical training is provided immediately after recruit training. As a result, heavy investments are made in "A" school and "C" school training while high uncertainty exists with respect to return on that investment. Thirty to forty percent of the individuals who begin technical training never reach a related shipboard job. Many who complete training ashore have difficulty in adapting to life aboard ship and therefore perform at marginal levels. The end result is an intolerably low return on first term enlisted technical training.

One means of reducing the costs of early training is to apply job performance aid (JPA) technology. Numerous studies of JPA applications over the past 10 years have improved maintenance and made more effective use of available personnel. In 1976, the Director, Naval Education and Training (OP-099) initiated this project to test and evaluate the application of job performance aids. As the project has developed, the scope has been significantly broadened. It now includes the development and test of an innovative personnel system. The Deputy Chief of Naval Operations (Manpower, Personnel and Training) (OP-01) has continued support for the project, and the Commander-in-Chief, U.S. Pacific Fleet has endorsed it favorably.

The objective of this work is to develop, implement, and field test an experimental personnel system which will:

- Provide early job assignment on-board ship directly after recruit training, using JPAs.
- Eliminate front-end-training by distributing shorebased and shipboard training.
- Individualize career advancement paths.
- Improve utilization of "lesser aptitude" personnel, i.e. those currently considered "non-school eligible."
- Improve retention.

Approach and Results

The approach taken is based on the premise that current Navy personnel problems have their roots in the personnel system itself and therefore can best be addressed through a total "systems approach". Therefore, an Integrated Personnel Systems Approach (IPSA) was devised. It considers training design, JPA design, career structures, advancement channels, incentives and the quality and quantity of personnel resources available. Coupled with a cost tradeoff model, IPSA was employed to evolve a new personnel system concept entitled Enlisted Personnel Individualized Career System or "EPICS". The NATO Seasparrow Surface Missile System (NSSMS) is the vehicle for the test and evaluation of EPICS.

EPICS products to date include:

- Digital system troubleshooting aids.
- EPICS documentation materials.
  - — Recruiting pamphlet for potential EPICS personnel.
  - — Sailor's Handbook for EPICS sailors that describes the EPICS career model.
  - — Orientation Pamphlet for briefing middle and top level leaders.
  - — EPICS Administration Guide for the EPICS shipboard administrator to facilitate management of the EPICS program.
- EPICS job design for NSSMS.
- NSSMS instructional packages:
  - — Self-teaching exportable modules.
  - — Shorebased training packages.
  - — Training management support materials and career counseling guidelines.
- NSSMS fully proceduralized job performance aids (84).
- NSSMS partially proceduralized job performance aids (114).
- NSSMS troubleshooting job performance aids.

Utilization

Most of the components required for the implementation of EPICS in the fleet for the test and evaluation have been completed. An OP-01 steering group was established to insure EPICS is implemented to the fullest extent possible. Briefings and orientations were provided at all levels, from OP-01 to the work center supervisors aboard each participating ship. All EPICS sailors have been installed onboard 30 DD-963s and 4 CVs. The first shorebased training course has been in operation since June 1981. The curriculum development of the second shorebased school has been completed and the school began operation in October 1981. Data for the test and evaluation have been and are continuing to be collected. Analysis of the test and evaluation findings will provide detailed data for use in judging whether or not Navy-wide implementation should be undertaken.

Upon completion of the test and evaluation, an IPSA development guide will be compiled. This guide will be a handbook that delineates the guidelines, algorithms, cost benefit and cost effectiveness trade-offs, and baseline data developed over the life of the project. Potential users of the IPSA handbook are agencies and individu-

als who are responsible for or are developing a JPA-based integrated personnel and training system. IPSA can be use to evaluate alternative system designs and to determine the role of JPAs early in the system acquisition process. Generalization to other systems and ratings requires the acquisition of JPAs and training materials for those ratings selected, and support documentation.

Impact

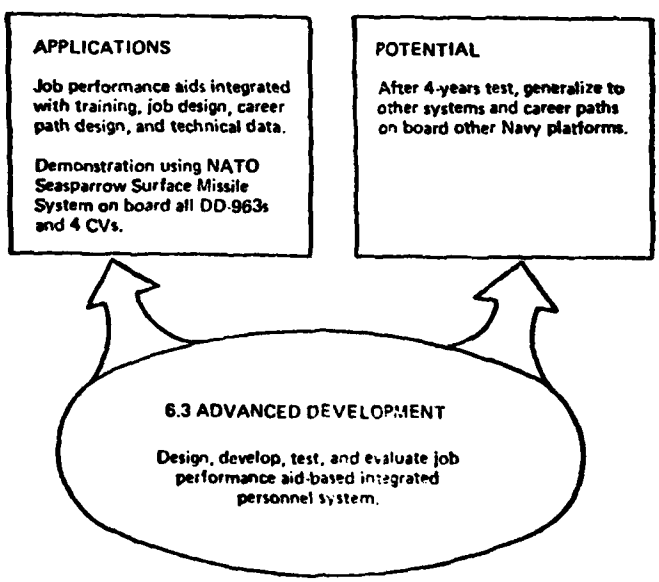
Other than the more long-term benefits noted as objectives of the project, several products will have direct and immediate benefit to the operating Navy. These products include:

- JPAs on the NSSMS fire control and launcher systems which are to be used by "A" school graduates to facilitate early performance.
- Innovative digital troubleshooting aids (State Tables) which are being validated and produced for general fleet distribution.
- A five-module self-administered ship indoctrination program adaptable to general ship use. Currently, three PACFLT DD-963s are using the series in that fashion. The Commander-in-Chief, U.S. Atlantic Fleet and Chief of Naval Education and Training are evaluating the shipboard indoctrination package for Navy-wide use.
- Instructional aids for NSSMS system operation and maintenance, which may be used for all Combat Systems Department personnel for basic operational and maintenance instruction on the NSSMS system.
- Troubleshooting JPAs for the launcher system which can be used as learning aids during "C" schools.

Research and Development Notes

The Navy Personnel Research and Development Center has been the performing laboratory for this project. The title is "Enlisted Personnel Individualized Career System (EPICS)", Z0828-PN, in Program Element 63720N, Education and Training. The responsible researcher is Dr. R. E. Blanchard, NPRDC (Code 17), (714) 225-6617. The project started in 1976 and will complete in 1985. Technical Reports and Notes are available. Important among these is NPRDC TN 80-14, *Integrated Personnel Systems Approach (IPSA): Enlisted Personnel Individualized Career System (EPICS) Model.*

Program dynamics are:



HUMAN FACTORS ENGINEERING

In the Department of Defense, human factors engineering is defined as the "Development of improved methods and technologies for the analysis, design, and evaluation of equipment/systems for safer and more efficient operation and maintenance."

The Navy needs equipment and support systems designed in such a way that people can do their jobs faster, more accurately, and more safely when they operate, maintain, or employ equipment. The Navy's research and development program in human factors engineering is involved in all systems, from their initial formulation to test engineering specialists in various development agencies and contractor firms.

Projects in this category include:

- **Designing Software Documentation**
- **Designing for Maintainers**
- **Energy Management in Navy Family Housing**
- **Matching Men and Machines**

DESIGNING SOFTWARE DOCUMENTATION

Need

Sensor and weapon systems performance is critically dependent on computers whose cost and reliability are determined primarily by their software. Maintenance and re-fitting of that software are usually performed by individuals other than the original designers, and are therefore heavily dependent on the software documentation available. Many techniques have been adopted for the representation of software but there has been little evaluation of their general utility. The specification of the most helpful types of current and proposed documentation techniques to aid programmers would sharply reduce the life-cycle costs of computer-based equipments. Also, when documentation is suitable, there is less need to re-initiate the design and development process and thus there is a considerable saving in time to get the re-programmed system back on line.

Approach and Results

This research program started with the selection of several techniques for representing software and ordering the events in the programs. Three forms of representation — ideograms, constrained language, and narrative statements — were combined with three ordering techniques — sequential, branching, or distributed —to make nine documentation formats. These formats were evaluated in programs that solved complex engineering functions (computation of a rocket trajectory), manipulated large data bases (an inventory control problem), or combined both problem types (an airport traffic control program).

Programmer performance was measured in several tasks: understanding the organization of a software program, location and correction of errors in software code, comprehension of code, and modification of code. In each task, measures were taken of completion times, error occurrences, and frequency of use of various commands and computer resources.

Significantly superior performance resulted when a sequential ordering technique was coupled with the use of constrained language. This type of format is the basis of one currently-used technique known as program design language (PDL).

Utilization

The documentation technique that proved to be most effective under a wide range of conditions and measurements has been generally adopted by NASA-Goddard, IBM Federal Systems Division, General Electric Company and the International Telephone and Telegraph Corporation. The Marine Corps Tactical Support System Activity has accepted it for test report plan documentation and the technique has been incorporated into a programming course sponsored by a professional organization, the Institute of Electrical and Electronic Engineers. In addition, several Navy Laboratories and Centers (e.g., the Naval Research Laboratory and the Pacific Missile Test Center) are exploring the potential operational software packages as system changes are introduced.

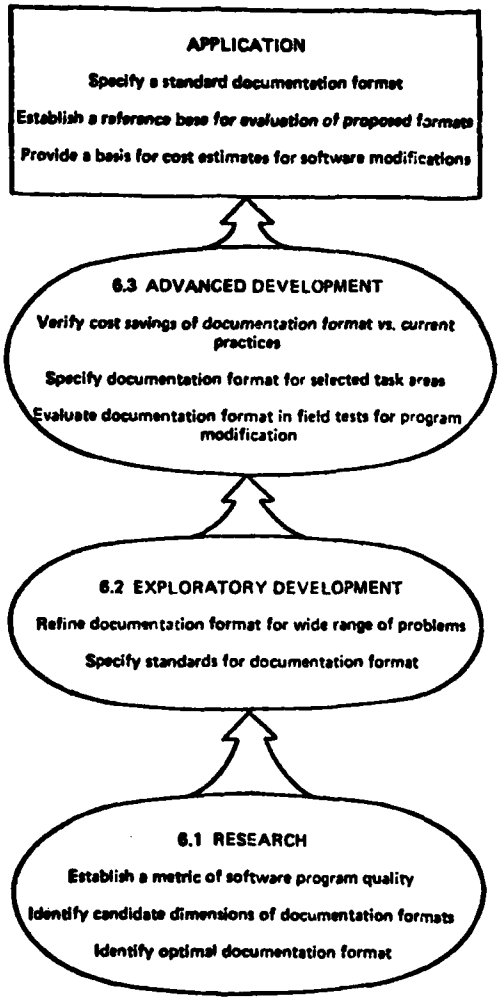
Impact

Software development costs for computer-based systems both in military and commercial use now command 90% of total costs. Current dollar investment in software development of naval systems is difficult to estimate but for FY 73 it was calculated to be between $1.0 - 1.3 billion, which was about 4% of the Navy budget that year. The costs are estimated to have tripled by FY77. Many techniques are in use for documenting software and PDL is estimated to be employed in about 10% - 30% of those programs. Good documentation permits about a 25% - 40% reduction in life-cycle costs since those data are in use continuously. Estimates of improvement that could be projected by extending the use of techniques with the characteristics of PDL range from 1 - 10%. Based on these estimates a conservative estimate of cost savings that would have been possible in FY 77 ranges between $5 - 50 million per year.

Research and Development Notes

This project was performed under the sponsorship of the Chief of Naval Research, by the General Electric Company, Information Systems Programs, 1755 Jefferson Davis Highway, Arlington, Virginia. It is one of a cluster focused on the enhancement of human-computer interaction. The project was funded in Program Element 61153N, Defense Research Sciences, Subelement 42, Behavioral and Social Sciences, project RR042-09, Engineering Psychology. The responsible researcher was Dr. J. J. O'Hare, ONR (Code 442), (202) 696-4502. General Electric Company's principal investigator was Dr. E. Kruesi. The project was initiated in 1979 and will be completed in 1982. There are several technical reports available, dealing with the effects of symbology and spatial arrangement on the comprehension of software specifications (TR-80-388200-2, October 1980), in a debugging task (TR-80-388200-4, August 1981), in a coding task (TR-81-388200-3, February 1981), and in a modification task (TR-81-388200-5), December 1981).

Program dynamics are:



DESIGNING FOR MAINTAINERS

Need

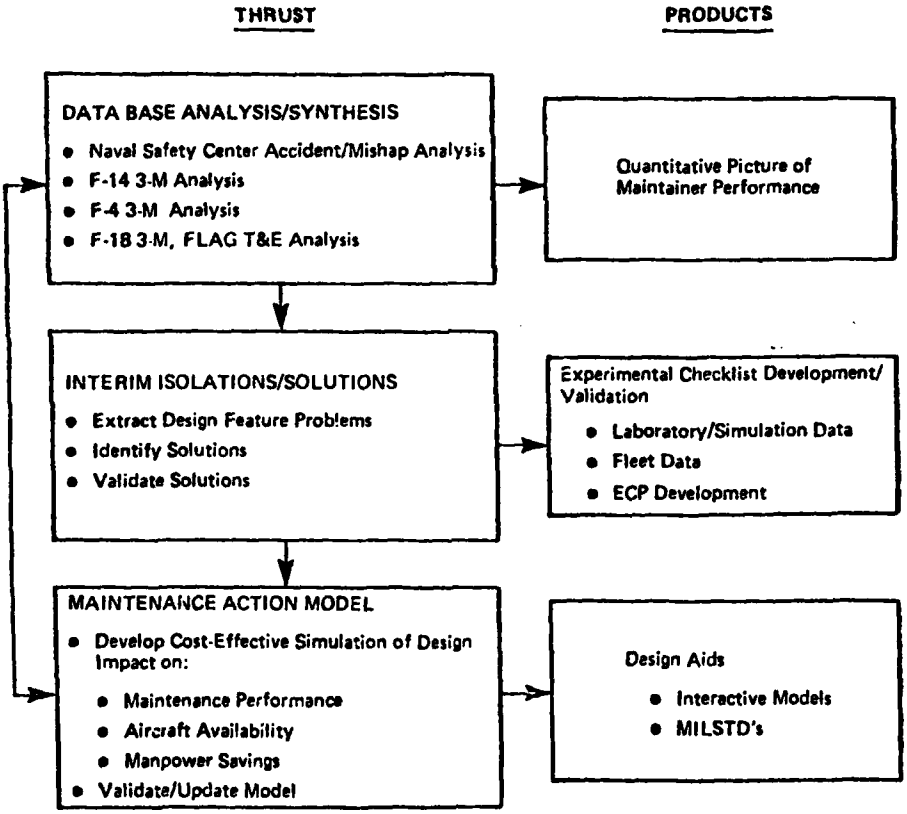
The problem of maintaining airborne systems has grown considerably over the past two decades. With the increased size and ever-growing complexity of modern aviation weapon systems, the costs of maintenance are increasingly a disproportionate portion of the Department of Defense budget. Furthermore, as many as 1/3 of all military personnel may be detailed exclusively to maintenance and support functions. However, traditional solutions to this problem have not worked—a typical squadron today may have available only about 50% of its aircraft for full operational use. For example, an analysis of F-14 3-M data reveals that because of excessive mean elapsed maintenance times (EMT), a $2.3B excess inventory of F-14's is needed to maintain a prescribed, mission-capable force; and that maintainer errors (e.g., diagnostic false alarms, or maintenance-produced damage) alone result in a requirement for an additional 1.23 maintainers *per aircraft* merely to recover from maintainer performance errors.

Clearly, when it comes to operational readiness, reliability is and always has been a key issue. But because of the acceleration in the complexities of subsystems which characterize modern aircraft, even if overall system reliability could manage to sustain or improve present day levels, measured maintainability ($\bar{M}$) would continue to decline. While such technological advances as built-in-test (BIT) and modularization certainly show promise, early predictions for their success were quite probably overly optimistic (e.g., BIT reliability for the F-14 is disappointing). Furthermore, the dwindling supply and increasing costs of a qualified population of organizational-level maintainers serve to exacerbate the problem.

The essence of $\bar{M}$ is fast, safe, efficient repair, and at its heart are people-related variables — factors such as diagnostic behavior, decision/ cognitive complexities, accessibility, psychomotor coordination, anthropometric matchups, transfer of training, and systematization. These human factors must be comprehensively and systematically examined, and the performance-based discoveries which research provides must be elegantly intermeshed. The Commander, Naval Air Systems Command has sponsored a technology development program to meet this need.

Approach and Results

The approach involves three thrusts as depicted in the diagram below. Each thrust contributes its own product, and each also supports the other thrusts.



The first thrust is an analysis and synthesis of organizational-level maintenance performance data. Several platforms are involved, although there is a concentration on tactical air, particularly on F-4, F-14, and F-18 data.

The Safety Center analysis involved the culling of a 1977-1980 bank of accident and mishap data, in order to extract inferences about the relationships between equipment design features, standard maintenance procedures, and the safety and efficiency of maintenance. Despite the methodological problems associated with examining a data base not designed for this type of analysis, several key human factors problem areas have been isolated, and recommendations for improvement are being formulated.

The F-14 and F-4 analyses began with an identification of subsystems for which chronological analyses of 3-M reports show a high incidence of maintainer diagnostic (i.e., false alarm) errors, and a high incidence of damage by remove-repair or replacement. Subsequently, a performance-based model of the design features associated with these maintainer errors was developed. It shows that a given investment in design modifications leads to a quantifiable improvement in maintenance performance (decreased EMT), and a predictable gain in aircraft availability, coupled with a decrease in necessary manpower. Furthermore, the F-14 and F-4 analyses led to a procedure by which experimental, organizational-level data can be collected in order to validate the rationale behind forthcoming engineering change proposals (ECPs).

The F-18 analysis arose from an application of state-of-the-art human factors principles aimed at satisfying the stringent M criteria which were contractually specified for that aircraft. As 3-M data become available for this newly-deployed weapon system, several hundred human factors and maintainability features which the F-18's design incorporated are being monitored and the data analyzed.

Utilization

The ultimate objective of this effort is the development of a set of design aids, including a maintenance action model, and appropriate Military Standards (MILSTDs) and Military Specifications (MILSPECs). Currently, to validate the approach and the interim solutions derived thus far, retrofit recommendations are being formulated and tested. One example is the development of an engineering change proposal (ECP) directed at improving the maintainability of the F-14's fire detection sensing element. An analysis of 3-M data revealed that the average elapsed maintenance time per sensing element maintenance action was nearly four hours. Investigations showed that the maintainers themselves had developed simplified procedures rather than follow current procedure standards. Although this solution eliminates some portion of the excessive EMT, the procedure is itself time-consuming, and is often impractical in close-quarters environments. The recommendation of the Designing for Maintainers project was to provide a relatively simple adapter to circumvent any access requirement external to the engine nacelle, at an estimated EMT savings of two to three hours (i.e., 50-75%) per maintenance action. Validation of this estimated impact is in progress, as is a simulated evaluation of the overall cost-effect impact on the F-14 community. This procedure by which data analysis leads to problem isolation, from which proposed solutions are identified and validation then follows, provides immediate fleet solutions. It also provides the technological base for the ultimate development of design aids. These aids are the tools which will allow for the incorporation of HF principles at the earliest conceptual phases of aircraft evolution.

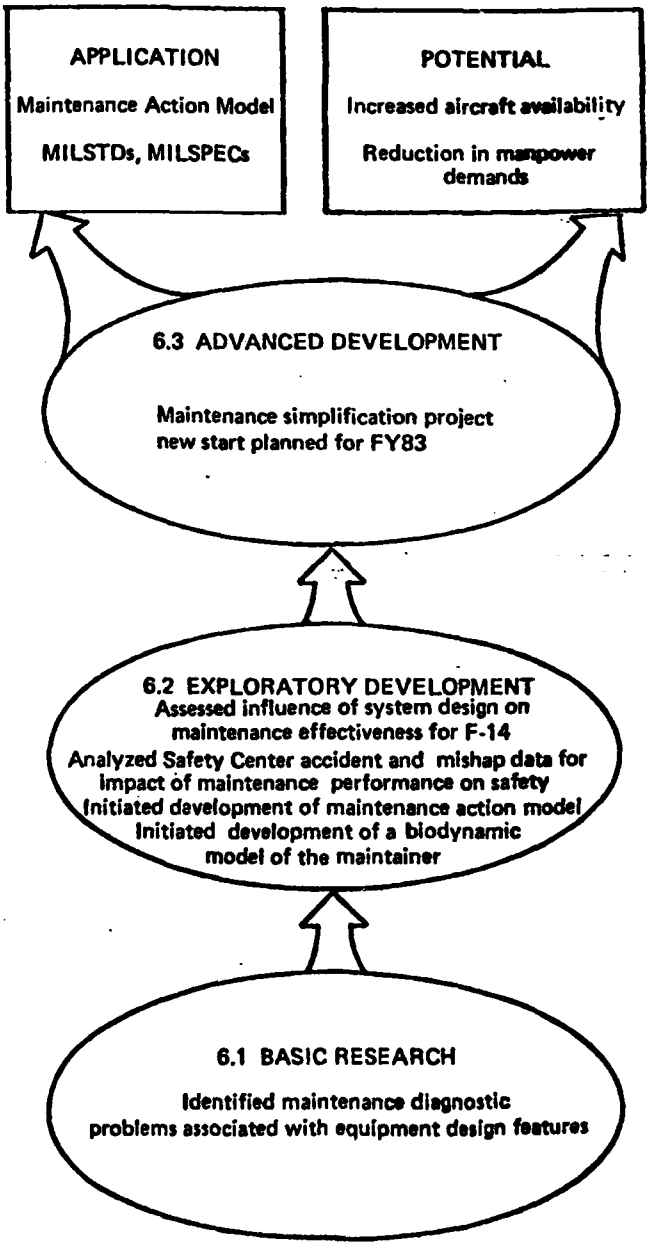
Impact

Maintainer errors can be reduced substantially if design is effectively blended with emphases on training and job performance aid development. Under study conditions, maintainer errors were reduced by as much as 97%. This would translate to nearly 25% improvement in the utilization of available manpower resources.

Research and Development Notes

The performing activity for this project is the Naval Air Development Center (NADC), Warminster, PA. The project title is "Design for Maintainers" and it is funded in Program Element 62757N, Human Factors and Simulation Technology. The principal investigator is LT D. K. McBride, MSC, USNR, NADC (Code 6021), (215) 441-2561. Among many of the publications from this project have been NADC-79218-60, *Design for Maintainers: Final Report*, 1982; and NADC HFTM 81-06, *Human Factors in Design for Maintainability*, 1982.

Program dynamics are:



ENERGY MANAGEMENT IN NAVY FAMILY HOUSING

Need

Declining energy supplies and skyrocketing energy costs have made it essential that the Navy emphasize conservation. In Navy family housing, substantial reductions in utility consumption have been made through technological and structural modifications. These "passive" conservation approaches require little or no active participation by residents. However, a large component of reduction in energy consumption depends on the individual consumer. As housing facilities are improved, the behavior of the consumer becomes a more important source of savings through energy conservation. The challenge is to develop methods for gaining the active participation of energy users in the conservation process. Recognizing this need, the Navy Facilities Engineering Command (NAVFACENGCOM) requested that the Navy Personnel Research and Development Center (NPRDC) develop practical approaches to bring about active resident participation in utility conservation.

Approach and Results

Studies of energy conservation in the civilian population have demonstrated the applicability of behavioral strategies to the reduction of utility consumption. However, families in Navy housing are influenced by factors not common in the general population. Although savings are possible, these factors must be considered in designing energy conservation programs. The factors include the historical nature of housing benefits and their administration, the policy of including utilities in rent, master-metering of housing complexes so that individual consumption rates are not available, and regulations preventing the use of incentives for conservation achievements.

The first phase of the effort was to describe the conservation-related attitudes and practices of Navy family housing residents and to evaluate a conservation program for master-metered housing sites. Results indicated that substantial energy savings are possible, that personal communication is important for obtaining resident involvement, and that changes in consumption tend to endure after cessation of the program.

Based on this background, practical guidelines were defined for energy conservation programs in Navy family housing sites. Principles identified as contributing to the effectiveness of the design and implementation of past tests of energy conservation programs in Navy family housing were:

- Communicate personally with residents
- Vary program intensity
- Provide conservation information
- Set conservation goals
- Express Navy concern
- Demonstrate housing support
- Involve the entire family
- Develop and maintain proconservation attitudes
- Provide feedback on usage
- Commend conservation efforts

A manual was written with sections corresponding to each of the principles. For each principle, there is a brief explanation, a description of how it can be applied, and an appendix providing specific information, materials, and examples. The manual provides housing administrators with an efficient, step-by-step approach to designing and conducting a local energy conservation program over an extended time period.

Utilization

The manual, *Energy Management for Navy Family Housing: A Manual for Voluntary Residential Energy Conservation,* was delivered to NAVFACENGCOM in October 1981. NAVFACENGCOM requested NPRDC to develop a second package, to provide documentation and training materials on the techniques available for housing managers to monitor and control utility costs. Work is in progress to develop material on procedures for conducting energy audits of existing facilities to identify areas for structural or hardware improvement projects, relationships between energy consumption and housing maintenance, and performance characteristics and new technologies available for inclusion in acquisition of new hardware or new construction. A manual will be prepared to distribute these new materials to housing managers.

Training programs on managerial techniques and educational approaches are being developed for the Family Housing Management Institute. These will be presented and evaluated at the Institute during 1982.

Impact

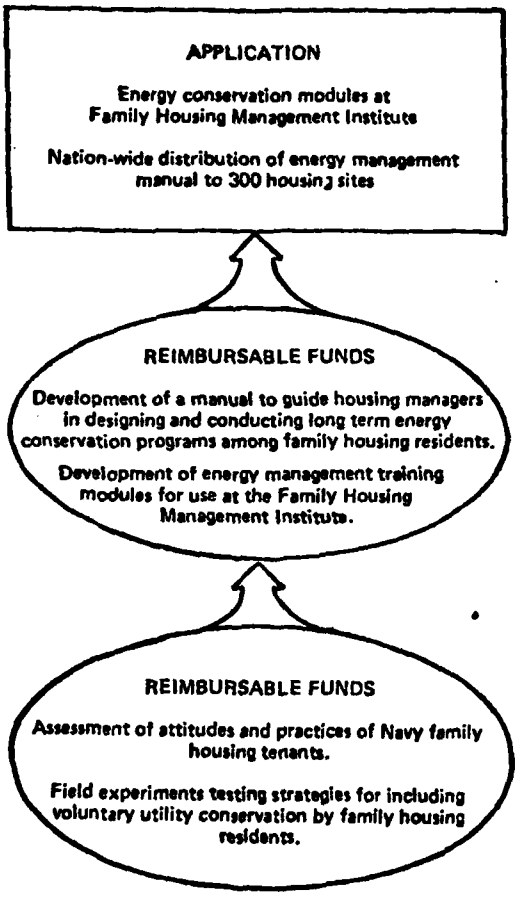
Training of housing managers in utility conservation is expected to curb utility cost overruns which divert funds from housing maintenance.

The savings to be realized from utility conservation have been estimated to range from 15-50%. A realistic estimate is 20-25%. Projections are that energy costs will double in five years. The cost avoidance to be achieved by energy management will thus continue to grow in importance.

Research and Development Notes

This project is being performed by the Navy Personnel Research and Development Center under the sponsorship of the Commander, Naval Facilities Engineering Command. The responsible researcher is Dr. B. Feher, NPRDC (Code 16), (714) 225-2191. In addition to the manuals and materials already described, NPRDC Technical Report 82-20, *Energy-related Attitudes of Navy Family Housing Residents* is available, as are several papers which have been delivered by NPRDC project members at various meetings. The Energy Management Manual previously described is NPRDC Technical Report 82-22.

Program dynamics are:



MATCHING MEN AND MACHINES

Need

The circumstance is rare, if it ever occurs, in which a weapon system functions independently from any human involvement. The range of human involvement will vary: in some cases, only a few knobs and dials may have to be manipulated and read at appropriate times; in other cases, operator involvement is of such strong and continuing nature that the human is truly a major subsystem. Certainly, for the pilots and NFOs in high performance Navy aircraft, the latter situation pertains.

However, cockpits represent space, weight, and other factors which must be considered carefully in design. Further, many displays, mechanisms, and furnishings are built into the cockpit for operational and life support purposes; the occupant must be able to fit, touch, see, move, hear, pull, push, turn, and otherwise perform specific tasks at various points in the mission profile. As more and more sophistication is incorporated into systems while the performance requirements for the system continue to escalate, the capability of the system to accommodate the human operator and the operator to accomplish the tasks set by the system, become more and more a matter of concern.

Many aspects of the hardware design process are based on "best guess" or subjective decisions by designers and engineering managers. Typical of these decisions have been the physical grouping and location of displays and controls, the allocation of crewstation panel space, and the selection of labels and abbreviations. However, inappropriate control and display arrangements create serious reach problems for operators. Therefore, under the sponsorship of the Deputy Chief of Naval Operations (Air Warfare) (OP-05), and the Commander, Naval Air Systems Command, work was undertaken to provide a better basis for decisions in the design process.

Approach and Results

Several computer routines addressing specific design-related problems areas were developed. All routines are interactive—that is, the user can work with the computer to use and adjust the models in order to test various alternative designs. The collective group, identified as Interactive Design Support Models (IDSM), consists of:

- Panel space allocation (CUBITS)
- Labeling and abbreviation (ABBREV)
- Crewstation Assessment of Reach (CAR)
- Automated Operational Sequence Diagram (AOSD)
- Functional Grouping of Controls /Displays (GROUP)

CUBITS

Current design procedures for the determination and allocation of panel space for controls and displays of the various systems integrated into aircrew stations do not involve adequate consideration of the purpose and characteristics of those devices. CUBITS developed a systematic and objective computational method for the allocation of panel areas in aircrew workspaces. The procedure is based on the criticality of the control or display to crew safety and mission effectiveness; the frequency of utilization; and the amount of information which is conveyed by the operator to the system through control actuation or which is conveyed to the operator by the display presentation.

ABBREV

In crewstation design the various displays and controls are usually arranged on panels as functional groups serving a common system or subsystem purpose. The display and control groups are designed and installed to provide the operator with all the information and control required for the employment of the various integrated system capabilities. In many cases, display panels that provide the status of a system are located separately from their control panels, due to highly limited space in the crewstation and to operator reach limitations. As a result, clear, concise, and consistent labeling to allow rapid and accurate association with these dislocated displays and controls is essential for effective aircrew performance. The objective of this effort is to produce a computer model for the systematic selection and abbreviation of the labeling for crewstation controls and displays.

CAR

In the past, design standards required that a crewstation be compatible with the 3rd and 98th percentile aviator. In attempting to comply with this requirement, the crewstation designer was forced to assume perfect correlation among body measurements. An analysis of the assumed 'constant percentile' aviators vs. the actual aviator population indicated the need to design and evaluate crewstations according to the actual measurements of the intended operators. The evaluative method must be sufficiently rapid to minimize expenditures and must be convenient enough to ensure that the analyst will employ the technique. To this end, the Crewstation Assessment of Reach (CAR) Model was developed. The purpose of the CAR Model is to establish the actual percentage of naval aviators that can be accommodated in the critical areas of a given crewstation geometric configuration. The model examines hand and leg control positions, seat movement to establish over-the-nose vision, and head clearance for a representative sample of the naval aviator population. Figure 1 illustrates.

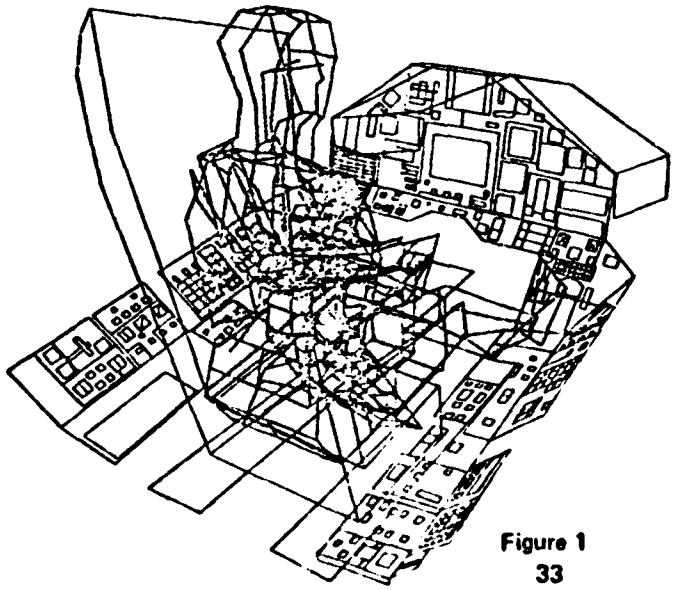


Figure 1

AOSD

An Operational Sequence Diagram (OSD) is a sophisticated graphic elaboration of task analysis procedures. OSDs allow a sequential, time-based description of a system's operation. They display system element functional relations, information and material flow, sequential distribution of operation,and identify subsystem control and information inputs and outputs. Although graphic OSDs are of tremendous value in system design, the tedium and cost associated with modifying and regraphing diagrams substantially reduces their utility. The objective of the Automated OSD effort is to provide a computerized interactive graphics method for creation and updating of OSDs with minimum manual redrafting.

GROUP

The placement of controls and displays relative to one another within a crewstation can be carried out in numerous alternative ways. In general, the best arrangements will be those which minimize learning time and which produce fewest errors during operation. The GROUP procedure uses the inherent meaning in the words for a device label as a description of the function of that device. Grouping is carried out by placing more closely together those devices which have more of their functions in common. This is accomplished by quantifying the extent of likeness among devices, and by statistical grouping procedures.

Utilization and Payoff

CUBITS has been applied on a number of aviation systems, including the S-3A, SH-3H, PROTEUS, LAMPS MK-II, AIDS (Advanced Integrated Display System), LINEBACKER, IACS (Integrated Avionics Control System), DAIS (Digital Avionics Instrumentation System), and LAMPS MK-III. ABBREV has been applied to the S-3A, SH-3H, PROTEUS, LINEBACKER, and IACS. CAR has been applied to the F-18 and LAMPS MK-III. As a result of these applications, benefits such as the following have been realized:

CUBITS

- On the PROTEUS program, there was a 90% reduction in time spent to accomplish typical maintenance tasks as compared with the original panel design.
- For SH-3H TACAN, operator functions were grouped logically and the random intermix of dissimilar control devices was eliminated.
- Recommendations for improvement of space allocation and layout for all displays and controls were produced for the F-18 program.
- Application to the LINEBACKER program resulted in the introduction of appropriate push-button switching to improve system operability and reduce error.
- A reallocation of the panel space to permit use of improved input switching concepts resulted from application to IACS.
- In DAIS, CUBIT resulted in recommendations for optimum utilization of control/display panel space and served as a guideline for comparative evaluations and competitive designs.

ABBREV

- For LAMPS, ABBREV resulted in a 20% reduction in both operator "time-to-learn" and "time-to-operate."
- In the F-18 program, application resulted in contractor changes to the system.
- Application to the LINEBACKER program reduced both the likelihood of operator error and the length of training required to reach operational proficiency.

CAR

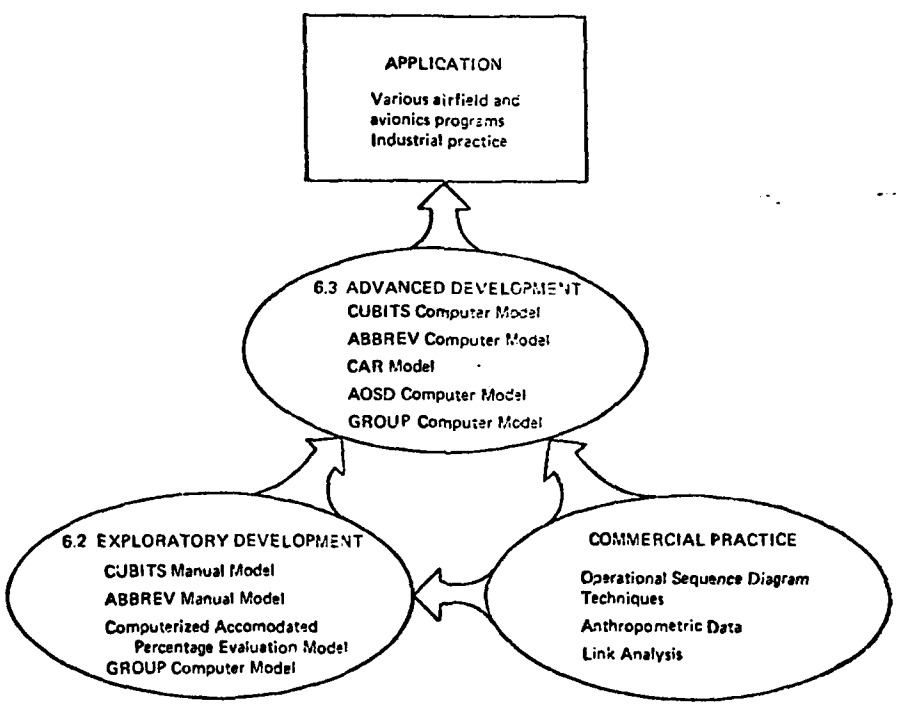
- On the LAMPS program, CAR disclosed six reach problems in cockpit geometry. These problems were corrected during later development.
- Application to the F-18 resulted in the identification of several serious deficiencies in aircrew reach to critical controls in the cockpit. The controls were relocated, resulting in a 60% increase in accommodation of aircrew population.

The value of these models has been recognized by the aviation industry, as well as the National Aeronautics and Space Administration. Users now include the NASA Johnson Space Center, McDonnell Douglas Corporation, Northrop, IBM Corporation, Clark Equipment Company, and Sikorsky.

Research and Development Notes

The performing activity for this project is the Naval Air Development Center (NADC), Warminister, PA. Early portions of the effort were accomplished with funding from Program Element 62757N, Human Factors and Simulation Technology. Later effort was funded in project W1189-PN, "Computer Assisted Methods for Human Factors Engineering Design and Evaluation," Program Element 63701N, Human Factors Engineering Technology Development. Among the principal investigators have been CAPT P. R. Chatelier, MSC, USN (202) 695-9777; CDR P. M. Curran, MSC, USN (202) 696-4713; Dr. J. Hobson (215) 441-2561; CDR C. W. Hutchins, MSC, USN (202) 696-7443; CDR N. E. Lane, MSC, USN (305) 646-5317; Mr. P. Linto (215) 441-2561; and Dr. N. Warner (215 441-2516. Among many Technical Reports and other documentation are Dynamation, Inc., Report No. 7905-1, *Design Procedure for an Information Transfer Method ("CUBITS") of Allocating Panel Area for Aircrew Station Controls and Displays,* May 1979; Analytics, Inc., TR-1398, *The Human Operator Simulator. Vol II: HOS Users Guide (revised),* May 1979; Analytics, Inc., TR-1400, *The Crewstation Assessment of Reach Program: Recommendations for Modification and Enhancement,* September 1979; Analytics, Inc., TR-1400.06B, *CAR-II: A Revised Model for Crewstation Assessment of Reach,* June 1980; Analytics, Inc. TR-1400.08B, *Adapting the Human Operator Simulator Model to Large System Evaluation (draft),* January 1981; and Analytics, Inc., TR-1400.12A, *Analysis of the Decision Aid Evaluation Capability of the HOS/HOPROC System,* April 1981.

Program dynamics are:



SIMULATION AND TRAINING DEVICES

In the Department of Defense, this area of People-Related RDT&E involves the "Development of cost effective training equipment and technology that produce the needed performance for operation and maintenance of military systems.".

The Navy needs training devices and simulators for several purposes: to improve readiness through realistic exercise; to reduce training costs; to increase safety during practice of dangerous activities; and to reduce the destructive impact of training activities on the environment.

Projects in this category include:

- **Advanced Fire Fighting Training**
- **Anti-Armor Missile Flight Training**
- **Applications of Computer Voice Technology**

ADVANCED FIRE FIGHTING TRAINING

Need

Few occurrences can rival the impact on any seasoned mariner of a catastrophic fire at sea. An uncontrolled fire on board a Navy ship threatens life and hazards equipment and the ship itself. Thrust into the situation of a fire at sea, even relatively inexperienced personnel rise to the occasion and perform heroically in fighting the blaze. However, routine mistakes are just as commonplace as heroics. Utilization of improper extinguishing agents; lack of coordination between fire fighting teams, which negates effective response; and failure to isolate the source of additional flammables; are illustrative.

All Navy recruits are exposed to the rudiments of Navy. fire fighting procedures while going through recruit training. In addition, advanced fire fighting training must be provided for all personnel assigned to fire fighting parties, engineering personnel, personnel assigned to flight or hanger deck duties, and personnel who routinely handle flammable or explosive materials. However, Fleet Fire Fighting Schools cannot meet these training requirements due to a lack of modern training media and instructional delivery systems. There are also other problems, such as need for faster turnaround time between training events, and a need to reduce safety hazards to personnel. Overall, there is a lack of capability to present fire situations safely in realistic scenarios and ship-board environments for the quantity of personnel requiring training.

Further, existing firefighting trainers are not consistent with the need to minimize the introduction of unnecessary pollutants into the atmospheres. Trends in regulations on air and water pollution necessitate the development of a nontoxic, nonpolluting fire fighting training environment which is consistent with the criteria for clean air and water established by the Environmental Protection Agency, state and local ordinances.

To meet these needs, the Director, Naval Education and Training (OP-099) established a requirement for development of improved fire fighting training systems. The requirement has continued under the sponsorship of the Deputy Chief of Naval Operations (Manpower, Personnel and Training) (OP-01), with strong supporting interest by the Director, Submarine Manpower and Training Requirements Division (OP-29), the Director, Surface Warfare Manpower and Training Requirements Division (OP-39), and the Chief of Naval Education and Training.

Approach and Results

Exploratory development by the Naval Training Equipment Center identified a viable alternative to existing smoke abatement techniques. A new approach to the generation of fires in a controlled environment used a clean burning gaseous fuel (propane) in conjunction with a logic control unit and extinguishment sensors. Sensors detect the quantity and location of an applied extinguishing agent and send signals via the logic unit to control the flow of propane gas. The degree of realism is predetermined by sensor arrangement and responsiveness to the various actions of sweeping the extinguishing agent over the sensors.

Based on acceptable feasibility tests, a fire fighting trainer model was built and tested. The model featured two simulated oil fires and a simulated electrical panel fire. In a separate effort, the generation of "training smoke" was also investigated. Successful testing of the model paved the way for engineering development of a prototype fire fighter trainer.

Phase I of the prototype fire fighter trainer (device 19F1) consisting of five fires, was constructed at the Fleet Training Center, Norfolk, Virginia, and accepted by the Navy in February 1981. The 19F1 is a bi-level structure containing eight compartments representative of a shipboard environment. At one side of the top level is an instructor control room. Figure 1 illustrates.

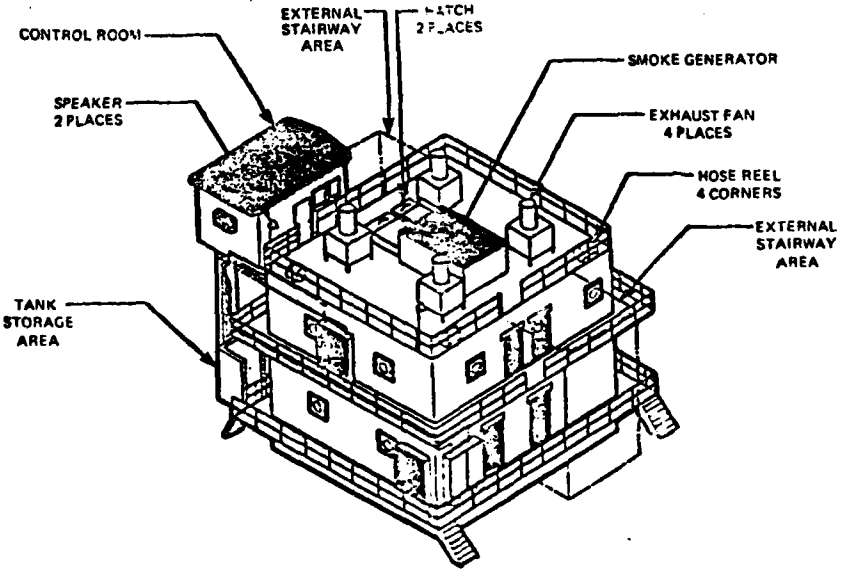


Figure 1

Mock-ups of shipboard equipment are installed (Figure 2) and obstructions normally encountered onboard ship are included for realism. Gas burners are installed so as to produce a realistic fire.

Payoff

The Advanced Fire Fighter Trainer, Device 19F1, provides a realistic shipboard setting for training Navy personnel in shipboard fire fighting techniques in a safely

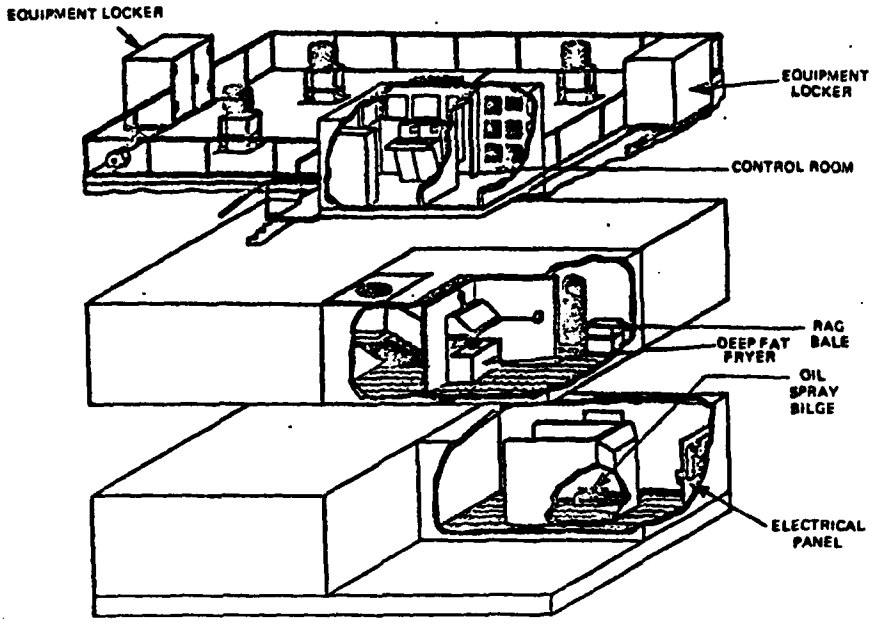


Figure 2

Students enter the 19F1 from the roof top "main deck" and proceed below in the same manner as they would on a ship. Extinguishing equipment is all standard shipboard type. Nonflammable, minimally polluting, smoke is generated in modified commercial equipment and piped to compartments to provide realistic for the trainees. Substitute but realistic fire fighting agents are used to reduce material costs and to simplify the treatment of water and air to remove pollutants.

Utilization

Government testing of Device 19F1 for the first five fires met all contractual requirements. Realism, training cues and fire performance were favorable. After some changes, environmental impact constraints have, for the most part, been satisfied. The trainer with seven fires is scheduled to undergo operational suitability and training effectiveness tests in 1982. As a result of the development and construction of Device 19F1, the Navy has the capability to simulate effectively, in a controlled environment, a variety of training fires that are perceived by the student as realistic to the situation, class and type of fire, and type and method of extinguishment. Utilization of the propane burner and a sensor-driven computer system has fulfilled the requirement for rapid ignition, shutdown and restart, as well as displaying the characteristics of flame flare-up, spreading, and reflash if not properly extinguished. For training realism, environmentally acceptable smoke can be introduced when required.

controlled environment. EPA constraints have been satisfied and little or no pollution control equipment is required to meet effluent constraints. The technique of simulating the various classes of fires with propane burners affords significant cost reductions through controlled use of gas fuel in lieu of combustibles and using cost-effective substitute extinguishing agents. Elimination of combustibles also speeds up turnaround time for training and reduces preparation and clean-up costs.

Device 19F1 was designed to be expanded to include a complete scenario of fire types representative of shipboard situations. Utilized by highly trained instructor personnel, Device 19F1 offers the potential for a highly efficient, well instrumented and controlled test platform to evaluate new fire fighting equipment and techniques. Already, data developed during the initial evaluation of Device 19F1 are being utilized to aid in the development of a new generation of Navy fire fighting trainers.

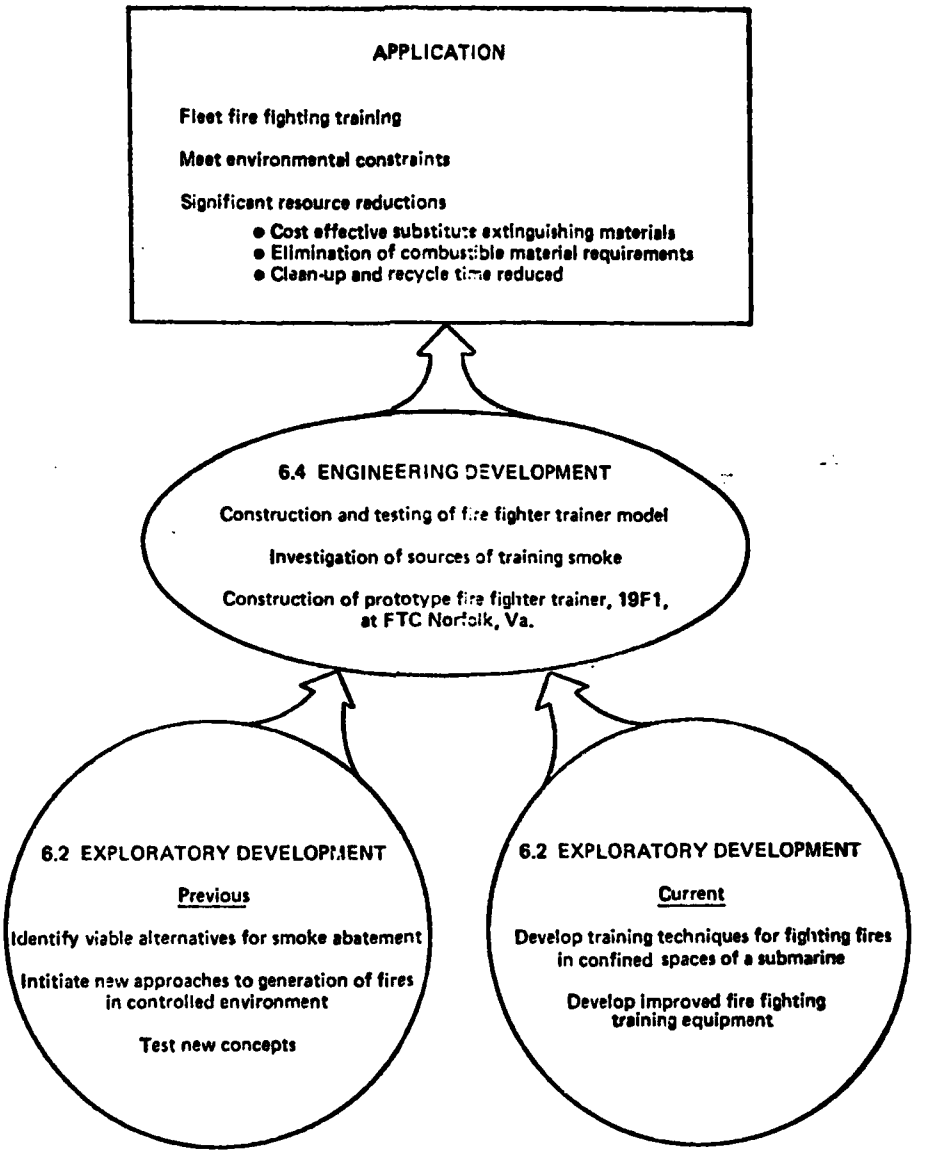
The technology can be applied to training for Navy civilian fire fighters (for example, at Naval Air Stations and in shipyards) by configuring the specific fire situation with the necessary sensors and burners. Similar application can be made to the training requirements of the firemen of any municipality.

Research and Development Notes

The Naval Training Equipment Center is responsible for development of the prototype Navy Fire Fighting Trainer, the 19F1. The project is titled "Advanced Fire

Fighting Simulator", S0790-PN, in Program Element 64703N, Training Devices Prototype Development, sponsored by the Deputy Chief of Naval Operations (Manpower, Personnel and Training) (OP-01). A previous Exploratory Development project was funded in Program Element (PE) 62757N, Human Factors and Simulation Technology. A new exploratory development funded by PE 62757N was initiated in FY82 to investigate unique requirements for effectively fighting fires in submarines and to develop improved fire fighting training equipment. The responsible researchers are Mr. F. M. Sciascia, NTEC (PD301), (305) 646-5031 and Mr. E. Swiatosz, NTEC (N731), (305) 646-5964. The principal investigator is Mr. R. Ambrozy, Advanced Technology Systems, 1701 Pollitt Drive, P.O. Box 950, Fairlawn, NJ 07410, (201) 794-0200. The project started in 1976 and will complete in 1984. A previous description was provided in the *2nd Annual Report of the Utilization of Navy People-Related RDT&E*. Additional information may be found in an article entitled "New Developments in Navy Fire Fighter Trainers"; *Proceedings, 1st Interservice/Industry Training Equipment Conference;* (NAVTRAEQUIPCEN IH-316), 27-29 November 1979, p. 217-227.

Program dynamics are:



ANTI-ARMOR MISSILE FLIGHT TRAINING

Need

The U.S. Army and Marine Corps now have in their weapon inventories an anti-armor missile known as DRAGON. It is a guided missile system designed for either offensive or defensive operations within a 1,000 meter range. DRAGON can be carried by a man. Fired from a bipod launcher, the missile is tracked optically by a gunner and guided automatically to the target by electrical signals transmitted via a wire link. The gunner fires the DRAGON missile by depressing the safety and squeezing the trigger. Then the gunner must keep the sight on the target. However, immediately upon squeezing off the round, the gunner is deafened by the sound of the igniting rocket motor; forced backward by a recoil force; just as suddenly finds himself rolling forward with the rocket tube and sight tilted downward due to weight loss as the rocket exits the tube. At the same time, he is sitting in a cloud of smoke which marks him as a target and obscures his view through the sight as he tries to pick up the target. The gunner must quickly overcome all these distractions because he has a $5,000 missile under his control heading for a target. He must regain his sight picture and smoothly track the target, ignoring the missile which may be prominent in his sight picture. To score a hit, the gunner must overcome many perturbations that can spoil his aim. A well qualified, steady, highly trained individual is required as the gunner. However, the use of live weapons for qualifying gunners would be inordinately expensive; also employing a training system which does not incorporate the perturbations described would not provide qualified gunners.

A study conducted for the Army had indicated serious shortcomings in the capability of the Army to train individuals effectively in the use and employment of the DRAGON anti-armor missile weapon system. During the final stages of development of the Universal Infantry Weapons Trainer (UIWT) by the Naval Training Equipment Center (NAVTRAEQUIPCEN), a proposal was made to the Army Project Manager, Training Devices (PM TRADE) to initiate a follow-on effort to develop a DRAGON trainer. The Army concurred in the requirement and sponsored development. Subsequently, the Marine Corps also stated a requirement and provided funding.

Approach and Results

Personnel from NAVTRAEQUIPCEN visited Army and Marine Corps sites conducting DRAGON training and brought "expert" personnel to Orlando to participate in an initial effort to define precisely what the nature of training had to be. The determination was made that an effective DRAGON trainer had to present to the trainee the complete range of problems of the gunner: that is, smoke, noise, recoil, weight loss, and the need to maintain a sight picture as the missile is guided onto the target.

The effects of weight loss and recoil when the weapon is launched are simulated by mechanical attachments to the DRAGON bipod. Real-time video graphics are generated for the gunner's sight picture and include a simulated missile, rocket thruster firings, rocket exhaust smoke, and launch and final explosions. Smoke is simulated by modulating the background video level of the gunner's sight picture. Sound is controlled by a microcomputer interfacing with a programmable sound generator to provide missile gyro wind-up, missile launch explosion, rocket thruster motor firing, target hit explosions, and missile impact explosions. Simplified missile flight dynamics equations and a computer program solve the missile position along its flight path, insert it into the gunner's sight picture, and determine hit or miss at the end of run. Utilization of actual missile flight dynamics equations allows training of new personnel and refresher training for experienced gunners. Figure 1 is an artist's concept of the DRAGON Anti-

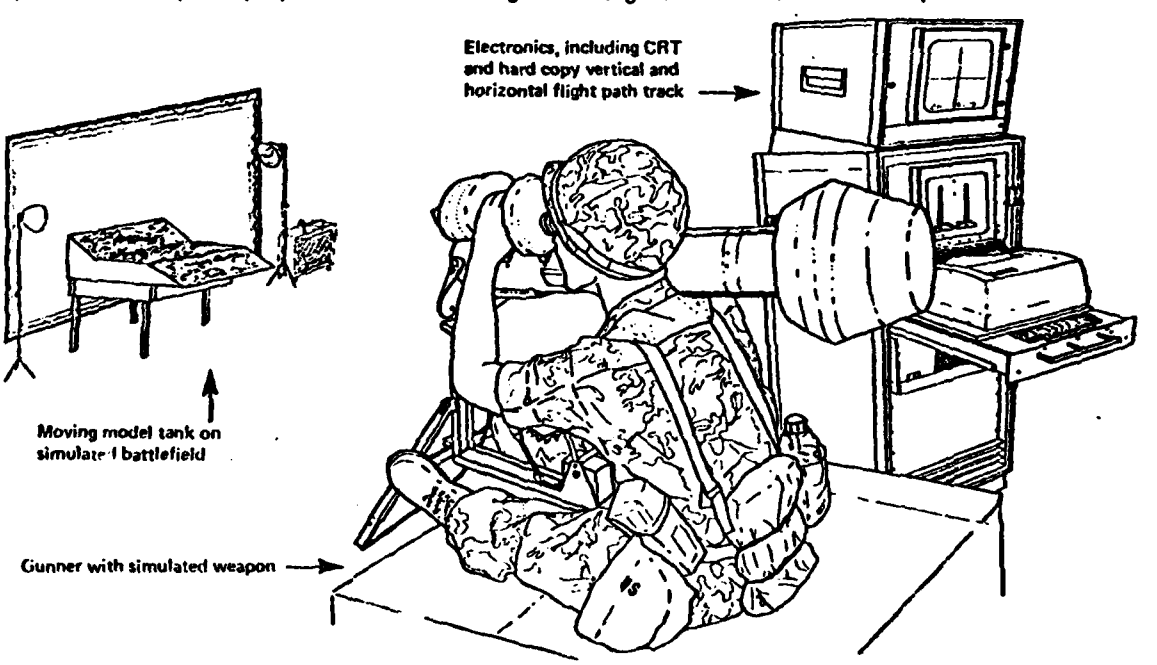


Figure 1

Armor Missile Flight Simulator. Army and Marine Corps personnel who have fired the experimental simulator have reported it to be an excellent trainer. A Marine Corps Fleet Project Team indicated the simulator will increase first round hits for the novice as well as provide outstanding advanced level training.

Utilization

The trainer incorporates all of the features of the actual operational missile system, and can provide real-time feedback to both the trainee and instructor with regard to trainee performance. Instrumentation is included in the simulator launch tube to monitor how well the trainee is holding down the launcher prior to launch. Feedback monitors follow the progress of the missile from time of launch to end of run and graphically describe the trainee's control of the missile flight. Video monitors also permit the instructor to see the gunner's sight picture during missile flight. After a missile flight, a reprise of the gunner aiming error or missile flight may be called up on a hardcopy printer. Target scenarios may also be varied because the target tank is moved independently from the gunner's weapon simulator; if the trainee does not get set up and fire a missile in a predetermined time, the tank's main gun turret can be moved and made to simulate fire at the gunner.

Payoff

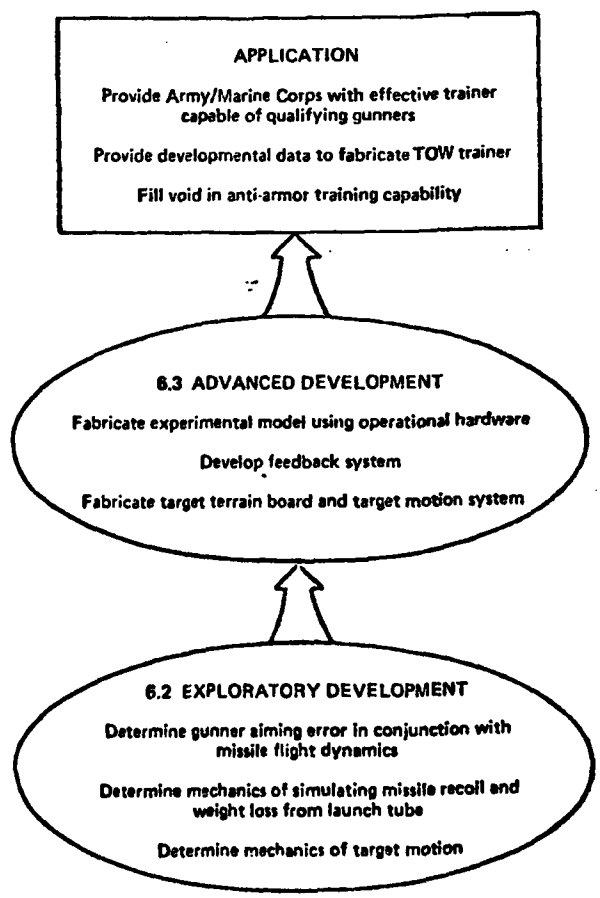
The DRAGON Anti-Armor Missile Flight Simulator will provide the Army and Marine Corps with an effective trainer capable of qualifying novice and advanced level gunners. The Army has noted that the current inventory of similar devices does not address the key issue of gunner qualification. The high cost associated with firing live DRAGON rounds makes it financially impossible to use that method to conduct gunner qualification and weapon proficiency. The DRAGON trainer will significantly reduce training costs by eliminating the need for live missiles and expendable target vehicles. In addition, all trainees, rather then only a few, will get actual hands-on experience in a firing scenario using modified operational equipment having the same weight and launch sequence characteristics as the real weapon.

The DRAGON simulator technology is readily adaptable to an entire anti-armor family of weapons. Current plans are to proceed with the development of a TOW heavy anti-tank missile simulator. TOW is similar to DRAGON but has three times the effective range and is usually vehicle mounted.

Research and Development Notes

Development of this training system was a responsibility of the Naval Training Equipment Center. The responsible researcher was Mr. A. H. Marshall, NTEC (N731), (305) 646-5464. Funding was provided by the Army in Program Element 62727A, Non-System Training Devices Technology, and by the Marine Corps in Program Element 63732M, Marine Corps Advanced Manpower Training Systems. Additonal information may be found in an article by Marshall, A. H. and others entitled "Anti-Armor Missile Flight Simulator," *Proceedings, 3rd Interservice/Industry Training Equipment Conference and Exhibition,* American Defense Preparedness Association, November 30-December 2, 1981, pp. 288-293. A report entitled *Simulated Tank Anti-Armor Gunnery System (STAGS-D) Dragon Trainer,* November 1981, has been published.

Program dynamics are:



APPLICATIONS OF COMPUTER VOICE TECHNOLOGY

Need

The complexity and sophistication of modern weapon systems have significantly increased the scope of training needed to provide qualified operators and maintainers of these systems to the Fleet. The decrease in operational time devoted to training caused by energy constraints has placed further demands on the training community not only to develop initial skills but also to provide for maintaining proficiency in skills previously acquired. Further, present training concepts go far beyond individual skill training to include team applications involving multi-skill participation. Therefore, since the mid-1970's there has been strong emphasis on the development of training by means of simulation. Modern simulation systems require greater numbers of top quality instructors capable of assuming more workload than has been previously demanded. Instructor quality and continuity must be maintained in a training environment faced with continually increasing demands.

Recognizing these training challenges, considerable effort has been focused on the development of advanced training technology. Capabilities exist today through automation to alleviate the increased requirements being placed on instructors. Computer voice technology is one of these automated capabilities which has proved to be effective in several application areas. The technology has potential for extensive implementation in present and future training systems.

To facilitate transition from the technology base into application, a Computer Voice Technology Indoctrination Course has been developed. Its objective is to disseminate information on the capabilities of voice technology, identify potential application, and describe design procedures for incorporating the technology in simulation training systems.

Approach and Results

Computer voice technology involves voice recognition and speech generation. Voice recognition technology has evolved from research involving computer recognition of single letters, to groups of letters, to single words, to groups of words. The requirement has been to increase the vocabulary capability. Speech generation capabilities have been available for some time, and the basic concepts of this technology are not new. Speech synthesizers have been adapted and developed into voice response systems for business, industrial, educational and military applications.

Utilizing the principles of voice recognition and speech generation, the Naval Training Equipment Center developed models which were incorporated into prototype training systems, the Precision Approach Radar and the Air Intercept Controller Training Systems. These prototypes were evaluated at schools. On the basis of these evaluations, guidelines were prepared for incorporating computer voice technology into simulation training systems.

A Landing Signal Officers (LSO) training system is now under consideration, in which student LSOs will control tactical aircraft landing on a carrier. Computer voice technology will be used for commands and aircraft responses. Figure 1 illustrates the concept. Additionally, computer voice technology is being adapted to augment or replace conventional instructor functions, thus easing the administrative workload and scope of instruction required of the instructor.

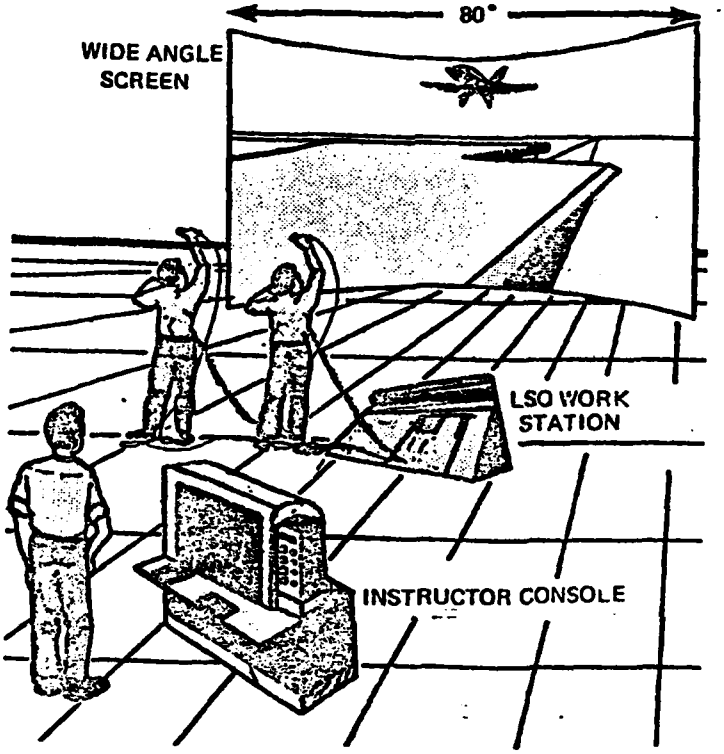


Figure 1

The guidelines were also used as the basis of an indoctrination course on applications of voice technology. The course includes the following information:

- Hands-on demonstrations illustrate available technology and its application.
- Computer speech generation is defined. Technology characteristics and the three types of speech generation (digitized, word-generated and phoneme-generated) are described. Guidance is provided for selection of the type to be used.
- Computer voice recognition principles are presented. Emphasis is given to the recognition process, entering voice patterns into the computer, speaker dependence/independence, isolated word and connected word recognition, vocabulary size, and speech understanding.
- The principles of speech generation and voice recognition are related to the instructional system design process. Requirements analysis, voice

technology capabilities, operating and human factors design considerations, and preparation of specifications, are discussed.

Utilization

Potential applications of computer voice technology in training systems include:

- Systems in which the voice is used to control the computer and/or to issue information from the computer, including aircraft cockpit management and certain maintenance applications.
- Speech related tasks in which vocal advisories or commands are required, or there is voice interaction such as in controller training.
- Providing data entry in computerized training systems when hands and eyes are otherwise occupied, such as in vehicle or aircraft operation training.
- Systems in which voice recognition can be used to measure student performance, such as controller training or command and control applications.
- Utilizing speech generation to ask questions or give directions which require verbal responses from the student.
- Aiding the instructor in equipment setup, providing instruction and briefing capabilities.
- Replacing the instructor with a computer model in systems requiring high interaction between instructor and student.
- Team training applications in which not all team members are present.
- Maintenance training applications in which step-by-step procedures are to be followed.

Impact

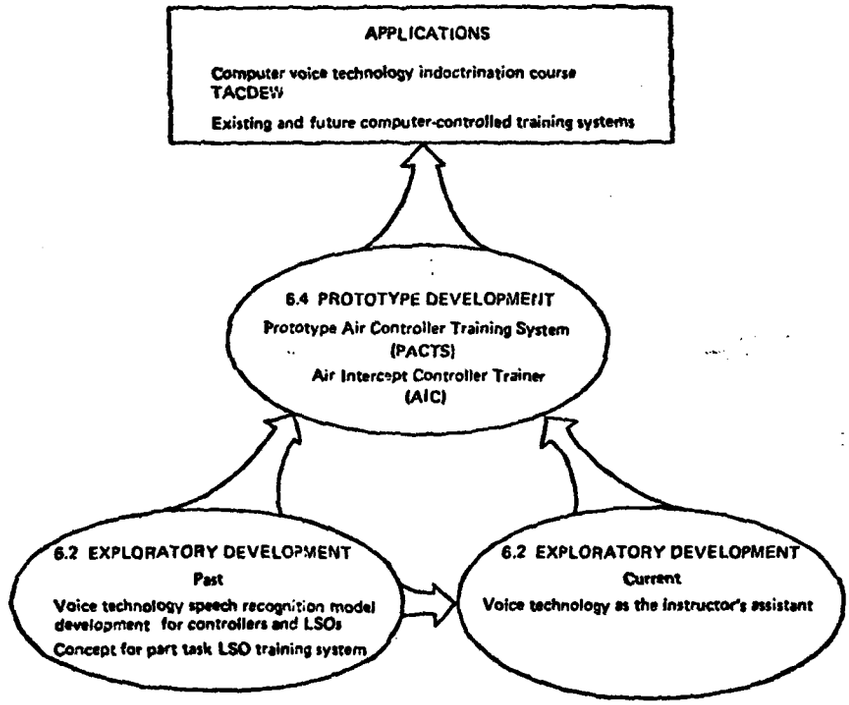
The technology has high potential for incorporation into tactical team training environments involving interactive skills. The computer can model team members, substitute for individual performers and provide performance data. Plans are being developed to incorporate computer voice technology into complex Navy training systems such as the Tactical Advanced Combat Direction and Electronic Warfare (TACDEW) System.

Expected results from continuing research will enhance instructor effectiveness in computer-based training systems by decreasing instructor requirements and workload; providing consistency in training; providing freeze, replay, and critique capabilities; and providing automated interaction among the instructor, the trainee, and the training system.

Research and Development Notes

The Naval Training Equipment Center has been responsible for the development of prototype training systems using voice technology. Exploratory Development was accomplished under Program Element 62757N, Human Factors and Simulation Technology. Engineering Development was sponsored by the Deputy Chief of Naval Operations (Manpower, Personnel and Training) (OP-01) in Program Element 64703N, Training Devices Prototype Development, as projects W0290, "Prototype Air Controller Training System (PACTS)", and W0291, "Air Intercept Controller Trainer (AIC)". Advanced Development of another application, "Individual Adaptive Training System", W1203, is sponsored by OP-01 in Program Element 63733N, Training Devices Technology. The responsible researcher is Dr. R. Breaux, NTEC (N71), (305) 646-5529. The principal investigators are Mr. R. Lynchard and Mr. M. Blind, Eagle Technology, Inc., 3165 McCrory Place, Suite 235, Orlando, FL 32803. Project W0290 was previously described in the *3rd Annual Report of Utilization* for FY1979. There have been 42 technical reports issued in this program. One of the more recent papers describing the state-of-the-art is "Guide for Voice Technology in Navy Training Systems," by B. Breaux, Michael E. McCauley, and Paul E. Van Hemel, in the *Proceedings, 3rd Interservice/Industry Conference and Exhibition,* American Defense Preparedness Association, November 30-December 2, 1981, pp 135-142.

Program Dynamics are:



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