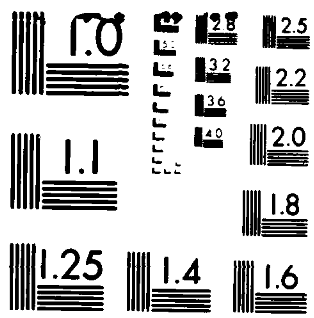
AD-A130 330 UTILIZATION OF PEOPLE-RELATED RESEARCH DEVELOPMENT TEST 1/1
AND EVALUATION(U) AIR FORCE HUMAN RESOURCES LAB BROOKS
AFB TX R M BUESCHER JUL 83 AFHRL-TP-83-4

UNCLASSIFIED F/G 5/9 NL

END
DATE
FILMED
8-83
DTIC


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

AFHRL-TP-83-4

AIR FORCE

HUMAN RESOURCES

UTILIZATION OF PEOPLE-RELATED RESEARCH, DEVELOPMENT, TEST, AND EVALUATION: FIRST ANNUAL REPORT

Edited by

Ruth M. Buescher

APPLICATIONS AND LIAISON OFFICE
Brooks Air Force Base, Texas 78235

June 1983
Final Technical Paper

Approved for public release; distribution unlimited.

LABORATORY

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility or any obligation whatsoever. The fact that the Government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise in any manner construed, as licensing the holder, or any other person or corporation; or as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The Public Affairs Office has reviewed this paper, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This paper has been reviewed and is approved for publication.

WILLIAM C. DeBOE, *Colonel*, USAF
Director, Applications and Liaison Office

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER AFHRL-TP-83-4	2. GOVT ACCESSION NO. AD-A130 330	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* UTILIZATION OF PEOPLE-RELATED RESEARCH, DEVELOPMENT, TEST, AND EVALUATION: FIRST ANNUAL REPORT		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Ruth M. Buescher		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Applications and Liaison Office Air Force Human Resources Laboratory Brooks Air Force Base, Texas 78235		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 99830999
11. CONTROLLING OFFICE NAME AND ADDRESS HQ Air Force Human Resources Laboratory (AFSC) Brooks Air Force Base, Texas 78235		12. REPORT DATE July 1983 13. NUMBER OF PAGES 68
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*		15. SECURITY CLASS *(of this report)* Unclassified 15.a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of this abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Air Force Reading Abilities Test
aircrew training devices
aptitude requirements
Armed Services Vocational Aptitude Battery
air refueling part-task trainer
computerized adaptive testing
E-3A flight simulator
first-term enlisted cost study
Logic Tree Troubleshooting Aids
maintenance resources interaction models

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This is the first Air Force report that focuses directly on the utilization of people-related research, development, test, and evaluation (RDT&E). Inputs associated with the several research projects described in this report were based on first-hand evaluations by Air Force operational commands and agencies. No effort was made to include all Air Force human resources research and development activities; rather, emphasis was placed on a representative sample of significant research utilization that resulted in both cost benefit and operational effectiveness.

DD Form 1473 EDITION OF 1 NOV 65 IS OBSOLETE
1 Jan 73

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE *(When Date Entered)*

Item 19 (*Continued*)

Maintenance Task Analysis
Organizational Assessment Package
person-job match
procurement of technical orders
retraining
simulator effectiveness
simulator for maintenance training
simulator training requirements
tactical flight simulation
Tanker/Transport/Bomber specialized training
transferability of skills

Item 20 (*Continued*)

This report contains relevant information on the need, solution, application, and payoff of 18 different research efforts. In most cases, the development from initial problem formation through final product application has been explained. Four broad research categories are covered: Manpower and Personnel, Education and Training, Human Factors, and Simulation and Training Devices.

AFHRL Technical Paper 83-4 June 1983

UTILIZATION OF PEOPLE-RELATED RESEARCH, DEVELOPMENT, TEST, AND EVALUATION: FIRST ANNUAL REPORT

Edited by

Ruth M. Buescher

APPLICATIONS AND LIAISON OFFICE
Brooks Air Force Base, Texas 78235

Reviewed by

Joe T. Hazel
Applications and Liaison Office

Submitted for publication by

William C. DeBoe, Colonel, USAF
Director, Applications and Liaison Office

FOREWORD

The Air Force plans to publish annual reports demonstrating the utilization of people-related research, development, test, and evaluation. Since this is the first such report, it includes significant research from fiscal years 1980 through 1982. This report was prepared jointly by personnel from the Air Force Manpower and Personnel Center, and the Applications and Liaison Office of the Air Force Human Resources Laboratory. Utilization of research products in the people-related areas of manpower and personnel, human factors, education and training, and simulation and training devices are described. The products of large-scale, multi-year programs, as well as of smaller project efforts in key areas, are included.

This report does not encompass the total spectrum of activities of the people-related research program of the Air Force. The examples presented here show some of the more significant and interesting cases of research utilization and of technology base advancement. They are, however, only a small representative sample of the people-related research performed continually by the Air Force. The primary emphasis in this report has been on utilization by Air Force operational communities and on the benefits in both cost and operational effectiveness resulting therefrom. Special attention has been focused on the users' perspectives. This report contains (a) examples of research results already in use, (b) advances in the technology base for near future use, and (c) current activities designed to increase such utilization.

This report has been prepared primarily for policy decision makers within the Department of Defense (DoD), legislative personnel of appropriate Congressional committees, and users or sponsors from Air Force operational and training commands. Funding for people-related research and development is provided on the basis that the results will significantly impact the operational readiness of Air Force units by providing the technology for efficient management and utilization of Air Force personnel and by improving the performance of personnel and Air Force weapon systems. This assumption of operational utility is increasingly requiring validation because justifications for funding requests are more carefully scrutinized. This report is one such validation effort prepared in response to a joint directive from Headquarters, United States Air Force/Deputy Chief of Staff, Manpower and Personnel, and Headquarters, Air Force Systems Command.

CONTENTS

	Page
INTRODUCTION	1
MANPOWER AND PERSONNEL	3
Armed Services Vocational Aptitude Battery	4
Enlisted Force Person-Job Match	7
Aptitude Requirements for Air Force Jobs	11
First-Term Enlisted Force Cost Study	14
Retraining and Transferability of Skills	16
Air Force Reading Abilities Test	19
Computerized Adaptive Testing	22
Organizational Assessment Package	25
EDUCATION AND TRAINING	29
Tanker/Transport/Bomber Specialized Training	30
Operational Test and Evaluation Handbook for Aircrew Training Devices	34
E-3A Flight Simulator Follow-On Operational Test and Evaluation	37
HUMAN FACTORS	39
Specifications for Maintenance Task Analysis and Logic Tree Troubleshooting Aids	40
Format Options for Procurement of Technical Orders	43
Maintenance Resources Interaction Models	46
SIMULATION AND TRAINING DEVICES	49
Simulators for Maintenance Training	50
Simulator Training Requirements and Effectiveness Study	54
Air Refueling Part-Task Trainer for Boom Operators	58
Tactical Flight Simulation	61

INTRODUCTION

This report describes recent Air Force "people-related" research, development, test, and evaluation efforts that have been utilized by operational commands or have contributed to the technology base that supports present and future operational needs of the Air Force. People-related research and development (R&D) is concerned with issues of manpower, personnel, and training. Its purpose is to enhance operational readiness by improving the attitudes, performance, and management of Air Force personnel.

People-related research is funded under the Training and Personnel Systems Technology program within the Office of the Under Secretary of Defense for Research and Engineering. This program has four major objectives, which also provide the organizational framework for this report. These objectives are:

1. Manpower and Personnel. To improve the ability of the Air Force to determine both quantitative and qualitative needs for people and to recruit and retain personnel in sufficient numbers based on current and future mission requirements.

2. Human Factors. To improve the design of weapon and support systems so that a wide range of personnel can operate and maintain equipment effectively. When well done, human factors R&D minimizes workloads, skill levels, and training requirements associated with Air Force systems.

3. Education and Training. To develop knowledges, skills, and attitudes in military personnel essential to effective performance of duty assignments throughout their careers.

4. Simulation and Training Devices. To improve the effectiveness of military training at reduced cost.

The Need for People-Related Research and Development

Today, the Air Force is equipped with the most advanced and complex weapon systems ever devised. Well-trained and highly-motivated people operate and maintain these systems. Yet, a look into the 80's and beyond shows developments that are at once exciting and promising, yet disquieting and challenging, and these appear to dominate the horizon. People face monumental changes in the way they work, handle information, and fight wars. The industrial revolution is being replaced by the information age. Travel beyond the earth's atmosphere is a reality. Every aspect of air power is changing rapidly. The events and conditions of the wars that threaten the United States now, and of those that may have to be fought in the future, forge an inseparable link between the airman and the scientist, the historian and the futurist.

Military training is a major activity of the Department of Defense (DoD). On an average day in Fiscal Year 1982 (FY82), about 205,000 active duty personnel and about 33,000 National Guardsmen and Reservists underwent some type of formal training in one or more of nearly 9,000 organized courses of instruction developed and maintained by the military training organizations.

The cost of this effort was about $9.5 billion in FY82, and the support of about 92,000 military and civilian personnel was required for formal instruction, instruction support, school administration, and student supervision. About 1.8 million officer and enlisted active duty personnel benefited from this activity in FY82. Every index indicates a diminishing ratio of training resources to training requirements. The solution to this dilemma is to increase training productivity through application of available and emerging high technology. It is essential that effective personnel and training research programs be maintained to supply timely information to decision makers in these areas.

The Importance of People-Related Research and Development

Although the military Services are fielding technically superior weapon systems, achieving designed-in performance requires that these systems be adequately manned, maintained, and supported. Otherwise, technologically advanced aircraft, ships, ordnance, and other systems will not perform as designed. They cannot do so without adequate attention to the reliability of the system's human component. This can be accomplished only through a continuing interface between system designers and manpower planners whose manpower requirements influence system design. People-related research and development can supply much of the information needed by system planners and designers.

The issues of recruitment, attrition and retention, training, morale, and readiness are all closely interlinked. High attrition, for example, means higher recruitment needs, increased training costs, and lower morale. Consequently, the research efforts reported here often have secondary impacts in a variety of areas other than their immediate focus.

There is growing evidence that the issue of manpower availability and trainability may be one of the most, if not *the* most, limiting factor on the amount of Air Force truly available in the future. In the words of George S. Patton, Jr., "Wars may be fought with weapons, but they are won by men. It is the spirit of the men who follow and the man who leads that gains the victory."

MANPOWER AND PERSONNEL

The Department of Defense defines the manpower and personnel area of people-related research, development, test, and evaluation as follows:

"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 Air Force requires a continuing supply of quality men and women who can operate and maintain sophisticated weapons and support systems. The identification, acquisition, and retention of a quality manpower pool is difficult. The proportion of quality men and women who are adaptable to military life is limited and their recruitment is subject to fierce competition from the civilian sector. The number of individuals of suitable age is declining now; therefore, it is even more difficult to attract individuals to the Air Force. It is incumbent upon the Air Force to ensure that every effort is made to identify individuals who might contribute to the Air Force mission, to assign them to jobs that match as nearly as possible their talents and aspirations, and to retain them in productive Air Force jobs as long as they are needed.

Projects in this category include:

1. Armed Services Vocational Aptitude Battery (ASVAB)
2. Enlisted Person-Job Match (PJM)
3. Aptitude Requirements for Air Force Jobs
4. First-Term Enlisted Force Cost Study
5. Retraining and Transferability of Skills
6. Air Force Reading Abilities Test (AFRAT)
7. Computerized Adaptive Testing (CAT)
8. Organizational Assessment Package (OAP)

ARMED SERVICES VOCATIONAL APTITUDE BATTERY

Need

The most effective use of available personnel is the basic goal of every organization. When individuals are placed on jobs for which they are not prepared, the result is frustration for the individual, expense to the organization, and a waste of manpower. Consequently, over the past 70 years, psychological testing has come into increasing use as a guide to improve personnel administration. Testing is used to lower training costs, to reduce risks in hazardous occupations, to optimize the allocation of scarce resources, to enhance retention of skilled and experienced personnel, and to increase on-the-job productivity.

Testing programs have been applied to two personnel-oriented tasks. The first is personnel selection, wherein the best qualified job applicants are chosen from those available. The second task is the more complex one of classification; an attempt is made to assign all selected applicants on the basis of personal abilities to the jobs in which they can be most effective. The ultimate goal for both procedures is the same: to maximize the overall effectiveness of the total organization.

From 1948 to 1975, the Air Force used multiple aptitude batteries to classify nonprior-service enlisted personnel. During this time, 10 different operational batteries were used. In early 1966, the Assistant Secretary of Defense for Manpower and Reserve Affairs directed the military Services to explore the feasibility of creating a common aptitude test battery. A working group consisting of personnel testing experts from each of the military Services was set up to study the feasibility of such a test battery and to develop a prototype. The Armed Services Vocational Aptitude Battery (ASVAB) was developed from this effort.

By direction of the Assistant Secretary of Defense (Manpower and Reserve Affairs), effective 1 January 1976, the Army became Executive Agent for the centralized management of ASVAB testing. As such, the Army assumed responsibility for managing ASVAB as the common DoD enlisted accessions test, both at Military Entrance Processing Stations and in the DoD High School Testing Program. The Air Force, however, continued as Executive Agent for ASVAB R&D with the Air Force Human Resources Laboratory (AFHRL) designated as the lead DoD laboratory. Thus, there exists an on-going requirement for AFHRL to develop new versions of ASVAB, to validate and standardize them, and to perform research and development (R&D) for ASVAB program improvement.

R&D Solution

This project was conducted by the Manpower and Personnel Division of AFHRL. It was performed in response to a request from the Personnel Testing Branch of the Air Force Manpower and Personnel Center as well as in response to a DoD directive. The approach taken in this project was initially a tri-Service effort. The Army, through its Behavior and Systems Research Laboratory (now the Army Research Institute), was the lead Service in an accelerated program to determine to what extent aptitude tests of the several Services were interchangeable. Test and measurement personnel from AFHRL and the Navy Personnel Research and Development Center collaborated with the Army in the development of the first ASVAB. The objective of the study was to identify which of the classification tests of the Army, Navy, and Air Force were interchangeable in terms of abilities and aptitudes measured, and from those so identified, to develop shortened forms to constitute an alternate inter-Service battery that would not require testing time in excess of 2-1/2 hours. Comparability of the several Service tests was determined from intercorrelations on a consolidated enlisted sample. This sample was stratified on the Armed Forces Qualification Test (AFQT) to provide a representative distribution of ability. The Army, Navy, and Air Force each provided 1,000 subjects, and the Marine Corps provided 300.

Seven sets of tests were identified as interchangeable: word knowledge, arithmetic reasoning, space perception, mechanical comprehension, shop information, automotive information, and electronics information. The Army Coding Speed Test was selected as a measure of clerical aptitude on the basis of separate validity studies.

It was necessary to abbreviate the tests identified as interchangeable so that the new battery would not exceed the time limit imposed. To this end, 25 items were selected from each set of three interchangeable tests to provide one test about half the length of each parent test. Items with a wide range of difficulty, from very easy to very difficult, were selected so that each new test could measure a wide range of ability. After editing, the selected items were organized into a battery of nine tests, the ASVAB. The new battery was standardized on a sample of 3,000 selective service registrants, again stratified on AFQT.

Since its original development, ASVAB has been revised on a 2-year cycle with no break in effort. These revisions require repeated standardization and validation against Air Force and civilian criteria. Furthermore, ASVAB is revised periodically to offset test compromise; thus, this is a continuous program.

Application

The ASVAB has been utilized for the following purposes: (a) more efficient military personnel selection and classification, (b) improved service recruiting efforts, and (c) enhanced usefulness as a guidance device for high school counselors.

The ASVAB has been extensively modified to provide a single battery which is utilized by all the Armed Services. AFHRL has conducted a series of validation studies to ensure that this battery correctly screens and classifies enlistees. Typically, the ASVAB has been correlated with technical school grades. Validity coefficients against school grades were computed within each of 119 technical school courses in the Air Force. Within the aptitude areas, i.e., Mechanical (M), Administrative (A), General (G), and Electronics (E), the following ranges and median uncorrected validities occurred:

	M	A	G	E
No. of Courses	28	13	33	45
Range	.09-.69	.03-.42	.23-.61	.13-.67
Median	.35	.24	.43	.39

These validity coefficients indicate that the ASVAB is predictive, to a moderate degree, of Air Force technical school achievement.

Payoff

Another way of determining the impact of ASVAB is to estimate cost avoidance that occurs through its use. Demonstrating costs avoided through application of selection tests is not a simple matter. If a researcher could go out on the street and randomly collect young people and place them in an Air Force Technical School course, some would succeed, and some would not. In the ASVAB validation studies, a broad unrestricted street sample does not exist. There are no direct data on failure rates in the total sample; the only data pertain to the persons selected for training. However, the performance of the full sample can be projected by [redacted] means.

The following conservative estimates were used to compute annual cost avoidance: an average selection level of 50th percentile, a corrected validity of .5, a training attrition rate of 5 percent, and an average eliminee training cost of $5,000.

Based on a normal distribution, the attrition rate for an unrestricted sample would be 14 percent. To obtain the same number of graduates, an additional 7,326 airmen would be needed at an additional total training cost of $36,630,000 per year. Considering that the Air Force represents only 20 percent of the total Armed Services personnel, this estimation can be expanded to the tri-Service area. Then, DoD-wide avoidance in training dollars through use of ASVAB would be approximately 180 million dollars annually.

Need

It is essential that the Air Force have effective mathematical algorithms and operational software that yield more nearly optimum person-job matches (PJM), i.e., assign the right person to the right job. The matching of person characteristics and capabilities to skill requirements is the key ingredient in the classification of Air Force personnel. The Air Force needed to develop consistent classification procedures that would satisfy preentry and postentry phases of the enlistment process.

In December 1971, the Air Force implemented an assignment system for new enlistees--the Procurement Management Information System (PROMIS). This system provided direct telephone contact between recruiters and the Recruiting Services Accession Control Center (ACC), which could enlist applicants up to 6 months in advance.

The system had several disadvantages. First, the time required for recruiter interaction with the ACC greatly exceeded the initial estimates. This delay resulted in the telephone lines becoming saturated, and recruiters encountered a long delay before they could contact the ACC. Because of the batch processing nature of PROMIS, the job slots opened up by cancellations, and the new monthly quotas were posted all at once at known hours of the day and days of the month. This resulted in an overload situation on telephone lines as large numbers of recruiters all over the country attempted to secure contact with ACC and reserve the most desirable jobs for their prospects. For example, on February 27, 1974, July openings were posted for the first time. (July is typically a peak month for enlistments as high school seniors graduate.) Air Force recruiters flooded ACC with phone calls, and the overload began to tie up trunk lines for other telephone users all over Texas and then in other parts of the country. The telephone company quickly disabled the ACC inward lines to prevent reduced service to its other customers. A second disadvantage was that the assignment process did not approximate an optimal solution in that only minimum cutting scores were required. Third, the system did not provide recruiters with an up-to-the-minute status and management information (e.g., quotas were not immediately available on request).

With the advent of the zero-draft environment, and the disadvantages of the original PROMIS system, the Air Force identified the need for developing a computer-based assignment system. Initially, a small computer-based job reservation system was developed by the Air Force Human Resources Laboratory (AFHRL). This successful effort demonstrated the feasibility of developing a large-scale computer-based PJM system with AFHRL serving as the primary developer of the PJM specifications.

R&D Solution

AFHRL completed this effort in response to a request from Air Force Recruiting Service and the Personnel Procurement Directorate of the Air Force Manpower and Personnel Center. The general concept of a personnel selection and placement system is depicted in the following diagram. This concept served as the basis for the formulation of a personnel job assignment model which was the framework for the AFHRL preenlistment PJM research and development.

The approach involved, first, the establishment of a Job Properties Array that consisted of attributes or characteristics associated with jobs. Second, a Person Characteristics Array was established, consisting of those attributes of the individual applicants that would be linked to job criteria. Once these two arrays were available, the third step was to match the Job Properties with the People Characteristics. This, in turn, as the final step, gave a Predicted Payoff Array with each cell of the array representing the worth or "payoff" of a given individual in a given job.

Although the assignment process could be accomplished from the Predicted Payoff Array, that process would not always assign a person to the job that would give the highest payoff to the Air Force since many persons might be considered for the job. Therefore, the Predicted Payoff Array was converted to an Allocation Array which contained allocation indicators that reflected the desirability of each assignment for overall Air Force effectiveness.

The predicted payoff values assigned to each job for which a person was eligible were generated using a policy-specifying process and included an aptitude-job difficulty component, a technical school success component, a job area performance component, a variable fill component, and a minority/non-minority component. Once the payoff equations were developed for all Air Force specialties, a PJM prototype was demonstrated.

The pre-enlistment PJM system selects and assigns recruits to specific Air Force specialties or to one of the aptitude areas (i.e., mechanical, administrative, general, or electronics). In addition to the development of a pre-enlistment PJM system, AFHRL initiated and completed R&D on a post-enlistment Person-Job Match system. The system is compatible with the pre-enlistment system and provides an assignment system for those recruits in basic training who were assigned by the pre-enlistment PJM system to an aptitude area instead of to a specific Air Force specialty. Once in basic training, individuals receive their specific jobs via the post-enlistment PJM system. The post-enlistment system contains the additional variables of Preference Match and Interviewer Rating. Preference Match is the degree to which specialty matches trainee's specialty preferences collected during Basic Military Training (BMT). Interviewer Rating is the trainee's rating by a BMT classification interviewer on trainee's general potential for service success.

Through the AFHRL R&D, progress has been made in advancing the state of the art in PJM systems. Some of the highlights include the development of transportation algorithms for solving batch assignment problems, the implementation of new research findings into the operational PJM system, the development of a post-enlistment payoff generation system similar in style to the pre-enlistment system, and the advancement of the state-of-the-art in policy development techniques.

Application

On 1 November 1976, the PJM system became operational for preenlistment classification with Air Force representatives at 66 Armed Forces Examining and Entrance Stations (now called Military Entrance Processing Stations) linked by remote terminals to a Burroughs 6700 computer located at Randolph AFB, Texas. The PROMIS, which now included the PJM program, was renamed the Advanced Personnel Data System Procurement Management Information System (APDS-PROMIS).

An option given to a recruit is to allow the naming of a specific job preference, if any. If the recruit is eligible, the job will be one of the 15 or 16 jobs from which the recruit can select.

The recruit is shown the top 15 jobs out of 100 to 150 jobs for which that recruit is eligible. The ranking of the jobs is based on the components used within the algorithm. Studies have shown that over 40 percent of the recruits selected from the top three jobs and that over 90 percent selected from the top 15 jobs. Only about 10 percent of the recruits selected jobs from the other 100 to 150 jobs. The system is a vast improvement over the pre-PROMIS manual system since that system could only look at and offer a choice from a small number of available jobs. The pre-PROMIS system was operated manually by individuals who would look up jobs for recruiters calling in by phone from all over the United States. Every job for which a recruit was eligible could not be looked up, ranked, and presented to the recruit (a 15-second or less task on the present system). The pre-PROMIS system was set up to fill jobs and did not attempt to make optimal nor even good assignments.

The pre-enlistment PJM subsystem currently classifies approximately 60 percent of all Air Force recruits into guaranteed Air Force jobs in the pre-enlistment environment. The improved and expanded PJM subsystem for post-enlistment classification was developed in FY80 and is close to being implemented operationally by the Air Force Recruiting Service. This new system will replace the current post-enlistment classification system, called the Processing and Classification of Enlistees, and will optimally classify the remaining 40 percent of recruits who require job classification during BMT.

Payoff

The Air Force Recruiting Service estimated that the use of the PJM resulted in 1.7 million dollars in direct cost savings by eliminating over 100 unnecessary positions and by phasing out old equipment. A .75 million dollar cost avoidance resulted from bypassing expenditures budgeted for the previous system. The cost of the new system was 2 million dollars. Therefore, the overall cost savings was .45 million dollars. Although dollar savings were minimal, compared to the overall cost of the recruiting program, the most important benefit to the Air Force was a more effective work force and improved operational readiness. Furthermore, this system became the basis for the Air Force Guaranteed Enlistment Program and greatly contributes to a favorable Air Force recruiting image.

Through this AFHRL R&D, the Air Force is now provided with a computer-based assignment capability superior to any previous system. The PJM system is much better in terms of response time and provides a more nearly optimal assignment process than had been previously available. As an integral part of APDS-PROMIS, PJM continues to be the primary component of that system. Since implementation in 1976, the Air Force Recruiting Service personnel have run approximately two million PJM searches.

APTITUDE REQUIREMENTS FOR AIR FORCE JOBS

Need

One of the major organizational goals of the Air Force, and one of the greatest challenges for management, is ensuring that the most talented enlistees are assigned to the most demanding occupations. If high-aptitude personnel are assigned to jobs having low-aptitude requirements, talent will be wasted. On the other hand, if low-aptitude personnel are assigned to jobs having high-aptitude requirements, poor job performance will result. To the extent that manpower resources are not effectively utilized, operational readiness and mission effectiveness will be adversely impacted. Effective utilization of manpower becomes especially critical given the prospect of talent shortages. This is precisely the situation presently faced by the Air Force. Decreases in both the quantity and quality of personnel among primary recruiting age groups are projected for the 1980's. Consequently, effective talent utilization will more frequently surface as a pressing operational need. Continuous R&D of techniques to ensure effective utilization of manpower resources must be accomplished in order to prepare for a more effective Air Force.

Effective manpower utilization can be accomplished through the optimal allocation of talent. This requires, among other considerations, the measurement of both enlistee aptitudes and job aptitude requirements. Although satisfactory procedures are available to measure personnel aptitudes accurately, procedures used to establish job aptitude requirements were both unsystematic and subject to influence by extraneous factors. There was a definite need for a more reliable, quantitative procedure for establishing job aptitude requirements. In response to this need, the Air Force Human Resources Laboratory (AFHRL) initiated research to develop an empirically based, job-oriented methodology for establishing occupational aptitude requirements.

R&D Solution

This effort was conducted in response to a request from the Classification Branch of the Air Force Manpower and Personnel Center. The R&D approach involved the derivation of measures of the learning difficulty associated with each enlisted occupation. Occupational learning difficulty was defined as "the time it takes to learn to perform required occupational tasks satisfactorily." These measures were to serve as a job-centered frame of reference for use in the process of establishing aptitude requirements. Alignment of aptitude requirements so as to correspond to the order of occupations in terms of learning difficulty would ensure that the most talented enlistees are assigned to those Air Force occupations having the highest learning loads. Measures of learning difficulty were based on task-by-task evaluations by job supervisors and expert job analysts and were generated on a position-by-position basis. Research has indicated that ratings of task learning difficulty are reliable. High levels of interrater agreement are demonstrated when task difficulty is independently evaluated by job supervisors. The validity of the task rating procedure was established by demonstrating substantial convergence of ratings when judgments issue from independent sources and different measurement methods.

To date, occupational learning difficulty has been derived for over 200 enlisted specialties. This involved on-site observations of learning difficulty for over 10,000 tasks and the calculation of learning difficulty for over 100,000 tasks for more than 170,000 worker positions.

Application

This R&D on aptitude requirements has produced a reliable, quantitative methodology which has valuable applications for manpower management. It yields comprehensive measures of occupational learning difficulty for use in establishing aptitude requirements. The implementation of the methodology provides major advantages over the previous system. Air Force managers now have available comprehensive, job-centered information representative of the occupation as it occurs in the field. The methodology also permits systematic updates of aptitude requirements given future changes in occupations resulting from occupational restructuring, redesign, and/or the introduction of new tools and equipment.

In February 1981, Air Training Command and the Air Force Manpower and Personnel Center established an interorganization working group consisting of representatives from the Air Force classification, testing, recruiting, training, and research communities. The objective of the working group was to evaluate occupational aptitude requirements for all enlisted Air Force specialties. An evaluation of aptitude requirements on this scale had not been accomplished since the early 1950's.

Measures of learning difficulty for 200 enlisted occupations were transferred to the aptitude requirements working group for use in their evaluation. These measures were considered along with information from the training, recruiting, and operational communities for the purpose of restating the minimum aptitude requirements published in the Airman Classification Regulation, Air Force Regulation (AFR) 39-1. Aptitude requirements were adjusted based on the policy that the more difficult the occupation is to learn, as indicated by occupational learning difficulty, the higher the associated aptitude requirement should be.

The result of the evaluation was that aptitude requirements for over 150 Air Force specialties have been reaffirmed or adjusted. Revised aptitude requirements were published in the 30 April 1982 update of Air Force Regulation 39-1. The working group responsible for evaluation of minimum aptitude requirements stated that the establishment of mental requirements on the basis of such an empirical, job-centered frame of reference had never before been accomplished. Aptitude requirements R&D will play a significant role in the future optimal allocation of Air Force manpower resources.

Payoff

Aptitude requirements are the center of the personnel system. Adjustments in aptitude requirements have effects on the personnel classification, training, and recruiting communities. Consequently, the impact of major adjustments in aptitude requirements must be assessed. Research is continuing in this area with studies being conducted in the areas of recruiting and technical training. Investigations are underway to assess the impact of aptitude requirement adjustments on initial duty fill and should provide information concerning the impact of aptitude requirement adjustments on recruiting sufficient numbers of qualified personnel. Other research is devoted to determining the impact on technical training of modifications in the aptitudes of incoming students and should provide information concerning adjustments, in technical training courses, that are necessary to accommodate trainees having either higher or lower aptitudes.

FIRST-TERM ENLISTED FORCE COST STUDY

Need

The first-term enlisted force composes nearly 50 percent of the manpower in the Air Force, and it is in the first term that the greatest degree of managerial flexibility for structuring the enlisted force is provided. Each year, operational decisions must be made concerning the numbers and kinds of people that should be entered into the force on one hand and that should be reenlisted into the career force on the other hand. Recurring Congressional and DoD concern for the All-Volunteer Force has focused additional attention on first-term enlistees. Annually, during the budget planning process, questions are raised focusing on both the management and cost effectiveness of various aspects of the first-term force such as attrition, enlistment standards, and quality of accessions. These issues raise extremely difficult economic questions.

The Air Force has many models that address various aspects of the enlisted force. However, none of them provides both a quick response gaming capability and sufficient detail to show sensitivity to changing various first-term parameters. All the models are limited by their exclusion of a detailed cost module for handling the various costs associated with the first-term enlistment period.

To resolve these problems, the Air Force Human Resources Laboratory (AFHRL) initiated research and development (R&D) to identify and develop a compilation of costs and attrition data to assist Air Staff in addressing economic and operational questions, and in analyzing the variable interrelations pertinent to the first-term enlisted force.

R&D Solution

This effort was conducted by the Manpower and Personnel Division of AFHRL in response to a request from HQ USAF, Directorate of Personnel Plans, Analysis Division. This R&D project consisted of two phases. Phase I was performed in coordination with the requesting agency and was directed at establishing the scope of the study by identifying the specific cost factors and economic parameters commonly used in policy and cost analyses. A preliminary categorization was developed and reviewed by HQ USAF to ascertain what data were available from the Cost and Management Analysis Office of Air Training Command. In Phase II, a collection and analysis of existing economic and cost data and data-collection systems relating to the first-term enlisted force were made.

The product of this effort is a handbook which assembles available Air Training Command cost and attrition data for each entry-level Air Force Specialty. Costs related to recruiting, basic military training, and initial technical school training are included, as well as travel costs to first duty station. When possible, costs are also identified as marginal, average, fixed, total, variable, direct, indirect, or a combination of these. An examination of the rationale for computation of several of the costs was also made. A proposed computational scheme for determining the cost of successful and nonsuccessful enlistee training was also presented.

Application

The results of this effort have provided immediate benefit to decision makers within Headquarters, Air Force. The handbook of first-term economic and cost data was delivered to Headquarters, Air Force, in September 1981. The cost handbook assembles under one cover a wealth of diverse and difficult-to-retrieve cost data displayed in a consistent, easily understood format.

Cost factors presented in the handbook were used as the basis for a cost study of optimal terms of enlistment for each Air Force specialty. As a result of this study, 6-year enlistments were opened up to more Air Force Specialty Codes, since it was more cost effective to retain airmen than to train new recruits in these specialties. The cost-factor data have also been utilized, specifically, as input to an enlisted force model being designed and programmed by the Analysis Division of the Directorate of Personnel Plans, Headquarters, Air Force. This model relates manhour production to pay tables to determine the cost of replacing recruits.

Payoff

By providing a more accurate and dependable collection of costs relative to the accession and training of recruits, the AFHRL R&D has enhanced the Air Force capability to respond quickly to high-level policy and budget issues and has provided researchers and analysts with a tool by which they could assess the economic implications of various policy options in the management of the first-term enlisted force.

RETRAINING AND TRANSFERABILITY OF SKILLS

Need

Air Force managers rely heavily on the capability to retrain enlistees from one occupational specialty to another in coping with the continuing problem of manning shortages and overages in career fields. The Air Force retraining program is an essential part of the airman personnel management system.

Approximately 10,000 airmen retrain annually, and Air Force managers expect this number to continue during the foreseeable future as a result of improvements in equipment and weapon systems and the attendant changes in personnel requirements. Retrainees fall into a variety of subgroups, including personnel who disqualify in their current skill, personnel who retrain in conjunction with reenlistment, other voluntary retrainees from overage career fields, personnel selected for involuntary training, personnel in the Continental United States (CONUS)/Overseas imbalance specialties who are surplus to CONUS requirements, and technical school eliminees. Retraining occurs at virtually every years-of-service point.

Once a retrainee qualifies at the appropriate skill level in the new military specialty, there is no identification of the individual as a retrainee in the personnel management system. Consequently, except for recent retrainees, it has been impossible to track retrainees as a group and assess their performance in their new assignments. Despite the substantial contribution of the retraining program to personnel management, the performance, progress, and accommodation of retrainees to their new occupations have not previously been systematically studied. Research and development (R&D) was needed to overcome this deficiency and to provide a base of experience from which to proceed. The opportunity to evaluate the efficiency of the operational retraining system was needed to determine the types of retraining actions that are operating smoothly and the actions that are generating adjustment and performance problems.

R&D Solution

This effort was carried out at the request of the Directorate of Personnel Programs, Headquarters, Air Force. A comprehensive evaluation program that systematically tracked the performance of enlisted retrainees and their progress in their new occupations was initiated. The structure of the study was organized around four principal issues identified as having to do with the retrainee's progress in the new specialty beginning with technical training, subsequent on-the-job performance and adjustment, and overall career progression. Of special interest was the distinction between voluntary and selective retraining actions.

Information on retrainees was obtained from two sources. Historical personnel data from 1973 to 1979 maintained at the Air Force Human Resources Laboratory served as the basis for evaluating technical school outcomes and skill and grade progression. In addition, a large scale field survey was conducted in 1980. Retrainees and their supervisors responded to inquiries about performance and adjustment and selective retraining issues.

The historical data permitted comparisons of all retrainees who attended basic technical schools between 1973 to 1977 and nonprior-service airmen attending the same schools during the same time. The samples included 19,885 retrainees and 231,317 nonretrainees. Two criteria were defined: final school grade and attrition. Rather than just a gross comparison of the two groups, investigators took into account the effects of aptitude scores that have been shown to influence performance in technical school. The aptitude variable was also important because of the present policy to permit waivers of minimum aptitude scores for retrainees. For the retrainee group, additional information was collected about their time in service and background experience at retraining. Researchers expected that some optimum time in service or particular type of background experience would increase the chances of success in technical school.

Results of this study provided empirical support for the viability of the retraining program. In technical school, at each aptitude level, retrainees typically performed better than nonretrainees both in terms of percent passing the course and in the achievement levels of those who did pass. Retrainees achieved course grade levels that justify the current 10 point discount or aptitude waiver.

The other major findings with regard to technical school performance had implications for who should be retrained and when. As would be expected, retrainees with higher aptitudes performed better. The amount of time in service before retraining also influenced performance, with more service time leading to better expectations for success up to a point at about the end of the retrainee's fourth tour. Type of background experience was also shown to have an effect. Airmen who transferred between Air Force specialties in the same aptitude areas had some advantage over those who changed into different aptitude areas.

The skills, abilities, and performance of retrainees once they were on the job in the new specialty were also examined. Supervisors contacted through the field survey were asked to provide job performance assessments of individual retrained airmen under their immediate supervision as well as of nonretrained airmen for comparative analysis. Ratings from supervisors on about 13,000 retrainees and 5,000 nonretrainees were collected. On these supervisor ratings, considerable overlap in ratings of the retrainees and nonretrainees in terms of both skills and abilities and performance was found. Also, supervisors were asked to identify a cut-off point in time beyond which nonvoluntary retraining actions should not be considered. Supervisors (75 percent) identified 15 years as the cutoff point for involuntary retraining actions.

The next major issues addressed in the study were job and career progression, which were evaluated by comparing skill upgrading, promotion, and retention. To accomplish this, an historical data base containing about 1/2 million cases for years 1977 to 1979 was developed. Survey data provided supplemental information on the job and career progression issues.

Data revealed that the time required for retrainees to upgrade was less than or equivalent to that for nonretrainees at fixed time-in-specialty intervals. Survey data were consistent with the historical data. Supervisors reported that retrainees required both less time and less help to upgrade. The retrainees themselves felt that their skill level was commensurate with their technical ability and job knowledge. Promotion data indicated that, overall, lower percentages of retrainees were promoted.

To supplement historical retention data, information on reenlistment was collected from the field survey. When asked what impact retraining had on likelihood of reenlistment, both supervisors and retrainees responded that retraining had a positive effect. That is, the likelihood of reenlistment typically increased after retraining.

Another issue was retrainees' adjustment to their new specialty. Briefly, supervisors gave both retrainees and nonretrainees equally high marks on the adjustment indicators.

A final issue was selective retraining with particular emphasis on a comparative assessment of voluntary versus selective retraining actions. The findings indicated that selective retraining impacts negatively on morale, motivation, and productivity, but that there were management factors which could be employed to attenuate the negative impact.

Application

The Directorate of Personnel Programs has initiated policy and procedural changes based on the results of this research. It has brought about a refocusing of the Air Force Retraining Advisory. In the past, the Advisory consisted essentially of a compilation of shortages, by grade, in the various specialties. Using this approach, typically 20,000 to 30,000 shortages were listed, whereas only around 10,000 retraining actions per year occurred. Since most retraining actions are voluntary, this approach did little to ensure that retrainees flowed into the skills where the greatest need existed. The Advisory is now more carefully focused, limiting the shortage list to the anticipated total size of the retraining group, placing the retraining slots in the skills with the most severe grade shortages.

A recent change to the Retraining Program was supported by data from this R&D effort. Previously, nonvolunteers were retrained regardless of time in service. Retraining decisions now include the addition of a time in service cutoff (13 years) for retraining nonvolunteers. This decision was based on the 75-percent supervisor agreement on 15 years as a maximum cutoff for non-voluntary retraining.

Payoff

Improvements in the selection/approval of retrainees based on this R&D effort will increase technical school graduation rates and will result in higher morale and better job performance. Assignments that optimize skills transfer will result in dollar savings through lowered attrition as well as through reductions in training time required for retrained personnel to achieve proficiency in their new occupations.

AIR FORCE READING ABILITIES TEST

Need

Illiteracy problems in the military Services have been a concern of the Department of Defense for years. Many Air Force organizations have been administering commercially published reading tests to military personnel. The Army and the Navy also have relied on commercial reading tests. These tests have been used for assignment to remedial training programs, for counseling students, and for determining reading levels of airmen in various occupational specialties. However, because as many as 12 different reading tests were used by Air Force agencies, it was impossible to make comparisons across groups or to provide uniformity of treatment for personnel.

Consideration was given to adopting a single commercial reading test for entire Air Force use. But this was infeasible because Air Force norms would still need to be established since the Air Force is a more restricted population than the national population. If Air Force norming was necessary, it was a small further step to develop a distinct Air Force Reading Abilities Test (AFRAT). Furthermore, in developing a unique reading test, Air Force managers would offset royalties charges to commercial publishers and would maintain control of the reading test. Thus changes, refinements, and improvements would be possible, which could not be accomplished with commercial tests. Also, norms could be adapted as conditions changed.

The Air Force Human Resources Laboratory (AFHRL) conducted a study to evaluate the capability of the Armed Services Vocational Aptitude Battery (ASVAB) to determine the reading ability skills of applicants for enlistment. The ASVAB and the Gates-MacGinitie reading tests were administered to 2,432 subjects. A high correlation of .79 was found between the ASVAB General Technical composite and reading grade level. It was concluded that the ASVAB was a valid reading assessment device and was screening out most applicants with marginal literacy skills.

As a front-end screening device, the ASVAB was useful; however, several factors made the ASVAB unsatisfactory as a general purpose reading assessment instrument. The ASVAB composites contain several short subtests covering different ability factors. The General composite includes Arithmetic Reasoning in addition to the verbal subtests of Word Knowledge and Paragraph Comprehension. Most women perform slightly better than do men on verbal tests; however, they generally do somewhat less well than do men on Arithmetic Reasoning. When the General composite is used to gauge reading ability of women, underestimation will result in the majority of cases.

A brief reading assessment device was frequently needed after enlistment. For many purposes, administering the entire ASVAB was too time-consuming. Furthermore, frequent and repeated use of the ASVAB would compromise its primary purpose. For individual measurement, therefore, a more content specific and reliable measure of reading than that based on ASVAB was desired. A decision was made to develop an Air Force specific reading abilities test in two equivalent (alternate) forms. This was to be a brief reading assessment device that could be administered to large numbers of individuals.

R&D Solution

This project was conducted by the Manpower and Personnel Division of AFHRL in response to a request from the Personnel Testing Branch of the Air Force Manpower and Personnel Center. The development and norming of the AFRAT was designed to standardize the assessment of reading ability of Air Force personnel and replace the commercial reading tests that have been used throughout the Air Force. The goal of this effort was to develop a reading test with appropriate norms.

Two parallel or comparable forms of AFRAT were developed. This reading test consists of 45 vocabulary items in a synonym format and 40 comprehension items consisting of one or several paragraphs followed by one or more questions. The comprehension items require either paraphrasing or making inferences from the passages. All items are multiple-choice with four alternatives, with a total test time limit of 50 minutes.

Samples of enlistees totaling 12,983 were tested for various analyses. The proportion of correct item responses was .85 for both Forms A and B. When correct responses on individual items were correlated with correct responses on the total test, the average item to test total correlations were .60 and .62 for Forms A and B, respectively. The relationships of AFRAT forms to three commercial reading tests were moderate-to-high (.60 to .67). The interrelationship between Forms A and B was somewhat higher (.73). In addition, subtest and total score variances for Forms A and B were equal.

Percentiles were computed for AFRAT scores and Reading Grade Level (RGL) scores from a composite of three commercial tests. AFRAT forms were equated to an average RGL through use of an Air Force selection composite as an anchor test. Raw-score-to-RGL conversion tables for the 4th through the 12th RGL were generated for AFRAT subtest and total scores. In addition, percentile norms for Air Force personnel were generated. Because they were based on Air Force subjects, these computed percentile and RGL norms should be appropriate for enlistees.

A number of studies were conducted correlating technical school grades with AFRAT scores. The median, or average, validity coefficient with technical training grades was .40 for an experimental version of AFRAT. This indicates a moderate but significant relationship. Those airmen with RGL scores of 9.0 or less had an average training grade of five points below that of all other airmen. This indicates that the AFRAT was a valid predictor of technical training performance to a moderate degree. Operational results for AFRAT will be monitored to ensure that the test does function as anticipated.

Application

Based on the norming and validation studies, the AFRAT was implemented Air Force wide in April 1982 as an operational test supporting many formal training programs and on-the-job training. It is used in Basic Military Training to screen/identify poor readers for discharge or remediation. Airmen with reading problems can be identified more accurately, thus reducing the costs associated with training failures caused by reading problems.

Payoff

The AFRAT filled a void. Previously, more than 12 different reading tests were used in the Air Force, resulting in a problem concerning interpretation of test scores. Now, two forms of a single test are used to assess literacy skills. Use of AFRAT provides a better assessment of Air Force student personnel reading ability and allows for comparison of groups across occupations and major commands, and individuals over time.

Reading capabilities of samples of first-term airmen can be evaluated at several points in order to develop an accurate picture of the nature and extent of reading abilities of Air Force student personnel. Also, reading abilities of students who have taken remedial training in Basic Military Training can be evaluated at the 2-year and 4-year marks to determine whether their improved abilities remain stable or decay over time. By using a single test, comparisons between different types of remedial programs can be made. Thus, AFRAT results are providing an important data base for future reading research.

Need

As a result of the increased availability and improved capabilities of electronic computers, there has been a growing interest in new methods of testing. A joint-Service project is underway to design, develop, test, and evaluate a system for automated, adaptive administration of military personnel selection and classification tests. The objectives of this effort are to develop a cost-effective Computerized Adaptive Testing (CAT) system suitable for nation-wide implementation in the Military Enlistment Processing Stations, and to design the system so that it can replace the paper-and-pencil Armed Services Vocational Aptitude Battery (ASVAB). Adaptive testing is the dynamic tailoring of test difficulty to each examinee's ability contingent on performance at earlier stages of the test. Such computer-generated adaptive tests should allow determination of aptitudes with fewer test items than with conventional paper-and-pencil tests, thus proving to be not only more precise, but more cost-effective as well. A research and development (R&D) project was undertaken to develop a computerized measurement system for selection and classification uses and to estimate its impact on the effectiveness with which the Air Force selects its new accessions and places them on the job.

R&D Solution

In producing the CAT system, two separate elements are needed: psychometric construction of the adaptive-testing procedures and tests, and engineering development of the system to implement those procedures and tests. The Navy Personnel Research and Development Center is responsible for the engineering development of the system and the Air Force Human Resources Laboratory (AFHRL), for constructing the tests. The AFHRL effort was carried out in response to a request from the Personnel Testing Branch of the Air Force Manpower and Personnel Center.

The psychometric procedures required writing computer programs and subroutines to accomplish adaptive item presentation and item scoring. From this, a model CAT was developed and installed at the San Antonio Armed Forces Examining and Entrance Station where approximately 150 applicants for enlistment were tested with three adaptive tests: Word Knowledge, Arithmetic Reasoning and Space Perception. Adaptive test scores were found to correlate highly ($r = .82$) with ordinary paper-and-pencil test scores.

As a prelude to developing operational item banks, the following questions posed themselves: (a) How can the special item statistics be estimated? (b) How can item banking be automated? (c) How many items are required for an operational item bank? (d) How can items be linked from separate testings to a common item metric?

The first of these questions asked how to estimate item parameters and was answered via a large scale simulation study comparing four extant methods on three specific ability distributions. Results indicated the desirability of rectilinear or normally distributed samples of about 2,000 subjects in order to get useful correlations between true and estimated item parameters (r_{ac} = .89, r_{bb}= .98, r_{cc}= .56). The question pertaining to item banking was answered by developing a comprehensive array of software and estimation procedures, including a test construction module and an item editor module.

An empirical investigation of the techniques showed that the performance of item pools could be accurately estimated for score means (10.5 vs. 10.16), standard deviation (4.3 vs. 4.0) and reliability (.80 vs. .72). A simulation study was conducted to answer the question of how many items are necessary for an item bank. Results showed that between 200 and 300 items were optimal, yielding a correlation between true and estimated ability of .982 with -.98 bias and .294 average absolute difference between them.

Similarly, simulation studies, involving sample sizes from 250 to 2,000, investigated several designs for linking item parameters. The results indicated specific designs were advantageous for specific needs and conditions. It was concluded that efficiency losses due to linking would be limited to 1 percent. Based on this knowledge, operational item banks in the nine non-speeded Armed Services Vocational Aptitude Battery (ASVAB) ability areas is proceeding. The project is based on the responses of over 100,000 applicants for military enlistment and will be completed in 1983.

Two additional projects are noteworthy. First, a validity study of two types of adaptive testing for jet engine mechanics was conducted. In this study, 450 technical training students were given adaptive and ordinary tests. No differences in validity were found, although the adaptive test reached its maximum validity in 1/2 to 2/3 the number of items. Finally, an investigation of noncomputerized adaptive tests was run which administered one of three prototype paper-and-pencil adaptive tests to 711 basic airmen. The areas tested were Word Knowledge and Arithmetic Reasoning. Correlations of the adaptive test with the Armed Forces Qualification Test were .56, .51, and .63 for the prototype and equal to the AFQT paper-and-pencil subtest correlation. The effort provided a successful demonstration that adaptive testing can be conducted without a computer.

Application

The AFHRL is a recognized leader in the field of CAT. A goal-oriented series of efforts is underway to develop both prototype and operational item pools, as well as to advance the state of knowledge regarding the theoretical basis of adaptive testing. These efforts are directed at completing the knowledge as it applies to the Laboratory's responsibility to the Joint Services Computer Adaptive Testing Interservice Coordinating Committee. This R&D is designed to achieve the objectives necessary under the tasking of this commitment.

CAT is scheduled to become operational in FY85 and will eventually permit the Air Force and the other Services to implement the ASVAB in an adaptive testing system. These efforts support the DoD scheduled implementation date and already provide a great many of the analytic tools needed to support such a system in the development of conventional bias free tests. These R&D efforts are viewed as covering the first steps in the development of a computer-based selection and classification system using adaptive testing concepts. Successful implementation of CAT for ASVAB usage will be followed by application of perceptual motor ability tests, as well as the traditional paper-and-pencil aptitude-type tests. Interest and attitude measurement could also more easily be incorporated than is possible with paper-and-pencil tests.

Payoff

More than 4 hours are required to prepare and administer the ASVAB form; testing alone takes about 2-3/4 hours. Tailoring the test to the individual would reduce current test duration by 50 percent or more. Replacement of all printed test material by electronic media would eliminate the susceptibility to errors inherent in manual score handling. Implementation of an efficient and valid computerized measurement system would add precision to the decision made concerning the selection and job placement of new accessions and promises to be more cost-effective than conventional paper-and-pencil tests, especially by reducing testing time and the possibility of misclassification, or need for later attrition or reclassification and retraining. Logically, CAT should reduce test compromise and provide greater sensitivity across the full range of examinees' aptitudes. The computerized measurement system could be administered during enlistment processing by all the Services. These projected benefits will be tested for empirical validation in further R&D efforts.

ORGANIZATIONAL ASSESSMENT PACKAGE

Need

Within organizations, management personnel are concerned with how well their organization meets its objectives. These objectives are frequently measured in terms of productivity, cost savings, and retention of personnel. The Air Force is vitally concerned with the organizational effectiveness of its units. The Leadership and Management Development Center (LMDC) has the mission of providing consultative services to Air Force installations throughout the world in order to increase organizational effectiveness. In addition, LMDC is responsible for providing leadership and management education Air Force-wide. A methodology was needed for measuring organization effectiveness and identifying leadership and management problem areas. The primary use of the instrument would be to diagnose organizational climate and indicate possible problem areas for further attention. The results of the evaluative techniques would also provide curriculum input in terms of the types of leadership/management skills that need to be taught or enhanced and the leadership styles that are effective in different Air Force situational environments (i.e., different types of organizations). An assessment package was needed to provide means of gathering leadership/management style, situational environment, and criteria data and of relating each to the other.

R&D Solution

This project was conducted by the Manpower and Personnel Division of the Air Force Human Resources Laboratory (AFHRL) in response to a request from the Leadership and Management Development Center of the Air Training Command. A 1976 study by Hendrix developed the Three Component Leadership Effectiveness Model. This model considered organizational effectiveness to be a function of the criterion selected, the managerial style employed, and the situational environment--which includes the manager's subordinates, peers, and other personnel in the environments. This contingency model was tested by a computer simulation. Situations were created by presenting a leader with a six-factor profile that depicted the situation. Next five proposed leadership styles were presented from which the leader selected one as being most appropriate for the situation and implemented it (i.e., input the selection into a computer). Feedback to the operator (by computer simulation output) then told how successful the leader's performance was. After exposure to 200 situational profiles, the leader's behavior was captured using a regression model. An individual's policy, once captured, could then be applied to new situations to see if it was a valid predictor model.

The Organizational Assessment Package (OAP) was designed to measure the basic components of the Three Component Organizational Effectiveness Model. The Supervisory Job Inventory was designed to measure managerial style, while the situational environment is measured by two sections of the OAP: the Background Information section and the Organizational Job Inventory. The criteria are satisfaction, organizational climate, and perceived productivity. These are measured by the sections entitled Job Satisfaction Questionnaire, Organizational Climate Inventory, and Perceived Productivity Index.

Items within each of the OAP sections have been written to measure certain factors. The Background Information section contains biographical information items and items associated with factors in the situational environment. The factors in the situational environment that the items attempted to measure included (a) organizational level of work group, (b) work group type, (c) work group size, (d) group member maturity, (e) organization's geographic region, (f) extent to which work group meetings are used to establish goals, (g) extent of communication between work group members, and (h) stability of work hours.

The situational environment was in part measured by the Job Inventory. The Job Inventory centers on five basic factors (Core Job Dimensions): (a) skill variety, (b) task identity, (c) task significance, (d) autonomy, and (e) feedback from the job. These factors were measured by the Job Inventory, plus one additional work-related factor, (labeled Work Interference). This additional factor deals with the extent and adequacy of (a) added duties, (b) equipment and supplies, and (c) provided work space.

In the criterion area, organizational climate was measured by the Organizational Climate Inventory, which included the following hypothesized factors: (a) communications, (b) general organizational conditions, (c) employee concern, (d) employee commitment, (e) decision making, and (f) recognition. Another criterion area was job satisfaction, which was measured by the Job Satisfaction Questionnaire. This questionnaire contained 30 items which included descriptions of 30 factors, such as Feeling of Helpfulness, Social Contact, Self-Improvement Opportunities, and Job Security. The last criterion was perceived productivity and was measured by seven items contained within the Perceived Productivity Inventory section. The items measured perceived productivity in terms of the work group's (a) quantity of work output, (b) quality of work output, (c) performance when high priority work arises, (d) whether flow of work to or from the work group is impaired, (e) frequency of crash projects, (f) work group output, and (g) comparison of work group performance to that of other work groups.

A small validation study was conducted at Lackland AFB to refine the instruments. The results were used to delete items that did not intercorrelate well with the stated factors and to establish simple correlated relationships between variables in the situational environment and managerial area with criteria items. The OAP previously described is the result of revisions based on data collected from the Lackland study.

Potential organizations for testing the OAP were identified. These included the Army Research Institute for Behavorial and Social Sciences; Headquarters, Air University; and the LMDC. The revised versions of inventories were submitted to field testing on a sample of 4,786 Air Force personnel at six bases representing six major commands. The composition of the sample was 86 percent male, 14 percent female, 65 percent enlisted personnel, 17 percent officers, and 18 percent civilian personnel. A few of the significant differences found were that, overall, those who were in an organization more than 36 months scored higher on the previously identified criteria than did individuals of shorter tenure. Supervisors of larger numbers of people also scored higher than did other groups of individuals. A supervisor who used work-group meetings to set goals and to solve problems had workers who were more satisfied and who perceived productivity and the organization's climate to be better. Civilians reported higher job related satisfaction than did officers and airmen. Airmen perceived work group productivity to be lower than did officers and civilians.

The application of the OAP system is Air Force-wide, and its use has high impact potential; therefore, continuing research and development efforts are directed toward ensuring the validity and reliability of this process. The LMDC conducted a study at Eglin AFB, correlating workers' perception of productivity as determined by the OAP and 14 independently derived measures of productivity. Preliminary analyses of the data showed a very high relation between these two measures. Two reliability studies were accomplished by the LMDC Directorate of Research and Analysis. A 5-week test and retest made a factor-by-factor assessment on responses of 19 personnel at the Academic Instructors School at Maxwell AFB. Pearson correlations on 20 factors ranged between .51 and .96, with only two falling below .70.

Application

The application of the OAP was immediate and widespread. It is now the major instrument for organizational diagnosis used by management consultants from LMDC and other agencies throughout the Air Force. More than 140,000 individuals have completed these surveys.

Administration of the survey is the first step in the consultation process. The survey is given to a stratified random sample of the organization to which LMDC has been invited. This means that the sample is so drawn that it is made up of the same proportions of the different levels as is the entire organization. Within the levels, each and every individual has an equal chance of being included in the sample. Thus the small sample is representative of the entire organization, and sample results may legitimately be generalized to the entire organization. The results of the survey are an important feature in the assessment of the organization. The results are handled in a confidential manner between LMDC and the client. After approximately 5 to 6 weeks for analysis, feedback of data is then provided to commanders and supervisors within the organization. When specific problems are encountered, a consultant and supervisor develop a management action plan designed to resolve the problem at the level of the organization. Within 6 to 9 months, the consulting team returns to readminister the survey instrument as a means to help assess the impact of the consulting process.

The data from each OAP administration effort are stored in a cumulative data base currently containing over 100,000 records for research purposes. These data are aggregated by work-group codes developed for this instrument. The data may be recalled by demographics such as personnel category, age, sex, Air Force Specialty Code, pay grade, time-in-service, and educational level. Through factor analysis, the 93 attitudinal items are combined into factors which cover job content, job interferences, and various types of supervisory and organizational areas.

Problems can be more specifically and precisely defined through the use of the OAP system. Survey results point consultants toward potential problem areas which, when resolved, lead to increased efficiency in organizations. Some of the benefits include enhanced job satisfaction, improved supervisor/subordinate relationships, and increased retention and productivity. Representative of empirically based information obtainable from use of the OAP is that related to productivity. Four leadership skills or characteristics have been identified as critical in achieving high productivity from subordinates: (a) setting specific goals, (b) making responsibilities clear, (c) asking for task improvement, and (d) emphasizing job relevance.

The OAP was used as the sole instrument of the organization assessment by the Deputy for Armament Systems. As a direct result of administering the OAP, a Supervisory Survey Feedback Training course was developed as a joint endeavor with LMDC and the Air Force Institute of Technology. A follow-on survey conducted by LMDC indicated dramatic changes in the organization. Communication at every level had improved, and with it, the morale and satisfaction of personnel. Problem areas had been solved where it was possible to do so at the Deputate level; if needed, problems were elevated to receive high level attention. The Deputate for Armament Systems increased its output more than 16 percent in one year.

This totally new approach to consulting has been lauded by industry and schools such as Harvard Business School, Massachusetts Institute of Technology, and Carnegie-Mellon University. The same work previously done by 20 people can now be done more efficiently by 6 to 8 people.

Payoff

One Air Force Systems Command center had allocated .75 million dollars for a contract with a consulting agency. When the LMDC consulting reputation reached this center, no outside contract was let; LMDC did the consulting with a savings of .75 million dollars to the Air Force. This center estimated that two million dollars in consulting costs were avoided over time.

The OAP has been successfully transferred to private industry. A representative of a large industrial firm stated, "You have allowed us to develop a capability for Human Resource Management which is far superior to anything developed and used by industry. This is the most sophisticated and effective approach to management consultation I have seen."

EDUCATION AND TRAINING

The Department of Defense defines the education and training area of people-related research, development, test, and evaluation as follows:

"Development of educational/training methods and media for managing, designing, and evaluating new-generation instructional systems for military application."

The Air Force must continue to develop technology that will lower training costs while actually improving training and maintaining personnel readiness to meet operational demands. Toward this end, new technology is being developed in the Educational and Training area as indicated by the following examples. First, critical training and performance problems associated with advanced Air Force systems are being answered, especially operator coordination and team performance and training for team-operated command and control systems. Second, the evaluation, management, and delivery of Air Force On-the-Job Training through the development and demonstration of an integrated training system will be undertaken. This effort will result in computer-based systems for administration, management, and delivery of instruction in new technical training applications. A final example is a technology base for training high level and quickly perishable skills in simulated combat environments. This base will be provided through development and application of new instructional methods, techniques, and devices for use in training and assessing aircrew skills at undergraduate, upgrade, and combat crew continuation training levels.

Projects in this category include:

1. Tanker/Transport/Bomber (TTB) Specialized Training
2. Operational Test and Evaluation (OT&E) Handbook for Aircrew Training Devices
3. E-3A Flight Simulator Follow-On Operational Test and Evaluation (OT&E)

TANKER/TRANSPORT/BOMBER SPECIALIZED TRAINING

Need

The Air Force has an established requirement for manned aerospace weapon systems. The need exists to maintain the Air Force capability to provide high-quality mission-oriented flight training to Undergraduate Pilot Training (UPT) students. This capability must be maintained in order to sustain an adequate supply of skilled pilots, thus contributing to the total defense posture of the United States. The opportunity to produce graduates better trained in the skills and procedures required for their initial assignments at significantly lower operational costs dictates that a Specialized Undergraduate Pilot Training (SUPT) program be initiated as soon as possible.

Extensive studies have shown SUPT to be a more cost-effective method for providing an effective pilot training program beyond the mid-1980's than is the present generalized or single-track program. In 1972, a mission analysis study, led by an Air Staff/Major Command general officer steering group, supported SUPT. In 1977, the Air Force Vice Chief of Staff directed a study that concluded SUPT would "provide a higher quality UPT graduate due not only to the added training requirements which can be taught, but also because training is oriented toward a better transition into the follow-on training in the combat crew training squadron." To continue pilot training under the current generalized program would create a numerical insufficiency in T-38 trainers in 1986. SUPT will allow effective use of the T-38 for fighter/attack/reconnaissance specialized track training beyond the year 2000. In June 1980, the Secretary of the Air Force approved the SUPT concept for future UPT. This approval justifies further planning and programming actions to implement SUPT.

R&D Solution

A research and development effort was initiated (a) to identify the special training requirements which SUPT would entail for Tanker/Transport/Bomber (TTB) pilots, (b) to develop a method for generalizing any given subset of tasks selected for TTB training to the entire domain of tasks, and (c) to develop a methodology for use in the measurement of aircrew performance. This effort was conducted by the Operations Training Division of the Air Force Human Resources Laboratory (AFHRL) in response to a request from Headquarters Air Training Command (ATC). This effort represents Phase I of a three-phased cooperative program between AFHRL and ATC. Phase I involved the identification of training requirements for a TTB pilot training course. During Phase II, ATC developed a syllabus to teach these requirements, and during Phase III, this syllabus will be tested.

Phase I required the compilation of the training requirements for B-52, KC-135, C-9, C-5, C-141, and C-130 aircraft. This follow-on training prepares UPT graduates for the mission requirements of their initial assignment. Questionnaires and other data-gathering instruments were developed to conduct 17 different interviews with a total of 30 training staff and 27 instructor personnel and to survey 97 staff, flight, academic, and simulator instructors and 63 students. An inventory of training requirements was developed for each of the aircraft previously listed. It contained 22 functional task areas and 108 specific tasks. The functional areas included such tasks as takeoff, landing, trail formation, and crew coordination. In order to specify those general training functions that were common for all the aircraft, a definition of commonality was adopted which required that a training function be common to all aircraft considered in the study. Following such a definition, the training functions having the most commonality were tentatively identified as (a) cruise, (b) asymmetrical thrust flight, (c) crew coordination, and (d) checklist usage, pacing, and procedures.

A method was then developed for estimating the benefits to be derived by the Military Airlift Command (MAC) and Strategic Air Command (SAC) from SUPT training in these task areas. Data were provided by the answers, given by SAC and MAC training personnel, to questions about what UPT graduates need to know. Additional data were provided by SAC and MAC training manuals which listed the tasks to be taught. Finally, information was needed on such task attributes as frequency, duration, and criticality. Estimates of data in these areas came from the manuals, from the questionnaires and interviews, and from the recent military experience of personnel conducting the study.

Anecdotal evidence was collected from the C-130 Airlift School at Little Rock AFB, which has actually been teaching students with both generalized UPT and SUPT backgrounds and has had a chance to compare their performance. (The generalized UPT graduates are from the Air Force, whereas the Navy UPT graduates who go to C-130 school have been through specialized training in multi-engine propeller aircraft.) The four instructors who were interviewed reported that the Navy student pilots are better prepared initially for asymmetric thrust procedures, checklist pacing, crew coordination, performance, and other activities which concern multi-engine operation in general.

The SAC and MAC interviews, which were much more extensive, produced comparable results. When asked to list the students' weak areas and the training that caused recent UPT graduates the most trouble, instructors reported crew coordination, asymmetrical thrust and lack of rudder usage in general, checklist usage pacing, and communications. Landings were also listed, with the major problems caused by the different landing pitch attitudes between T-38 and the TTB aircraft.

KC-135 personnel identified instrument procedures as the major problem area, with the weakest proficiency being slow/incomplete cross-check. The cause appears to be the students' limited initial flight director system background and then later exposure to the KC-135 FD-109 system for the first time at the transition school. The C-141 and C-130 training supervisors and instructors listed low-altitude approach procedures as an area that could be improved. These low approaches, like the KC-135 FD-109 system problem, are command-unique since SAC aircraft do not fly the low-altitude structure. Clearly, SUPT could remedy some of these problems.

Application

Graduates will be more knowledgeable in multi-engine operations and in their ability to overcome asymmetric thrust problems after participation in a Specialized Undergraduate Pilot Training program. A particularly beneficial aspect of the dynamic observer (teaching technique by which one trainee observes the training situation and the actions of another) program is that during the early phases of training the observer can handle the communications and then, after becoming more proficient in flying the aircraft, more knowledgeable of procedures, and more experienced in radio operation, this student can accomplish all three. (The transition schools have used this method for years.) Thus, the TTB graduate will be much better prepared in all phases of communication. Realistically, in the T-38 the pilot cannot refer to the checklist during all situations or all phases of flight. In the TTB trainer aircraft it will be possible and realistic to use the checklist in the manner that SAC and MAC desire. Therefore, checklist usage and pacing will be another task in which the entering student will be better prepared. The TTB trainer aircraft will fly a standard multi-engine traffic pattern and will undoubtedly have a landing attitude and other characteristics closer to the larger MAC and SAC operational aircraft than does the T-38. Consequently, the student will be better prepared in landings and patterns under instrument flight rules. Since the TTB trainer will have a minimum crew of two, there must be some coordination between the two crewmembers. The TTB graduate will thus have a basic understanding of crew coordination.

A simple formula was developed and applied to three phases of T-38 training: classroom instruction, simulator missions, and flight. For each phase, a benefit ratio was calculated. This is the ratio of the projected training hours that could be replaced with TTB-specific training in a dual track program. Thus the larger the value of the benefit rating the more benefit there would be in using TTB-specific hours to replace hours considered to be irrelevant.

Application of the formula indicated that the most likely benefits of SUPT training would include significantly better preparation of pilots for the initial phases of flying skill development after assignment to SAC and MAC. The benefit to be received is that of being able to set higher standards for the students, resulting in more experienced and proficient graduates--a better entering product for the transition schools. This, in turn, should result in more effective training in the initial transition phases.

Development of an aircrew performance measurement system was approached by defining the scope of performance measurement in general, narrowing that scope to the TTB case, specifying modes of measurement, and recommending a general mode for each task under consideration. In addition, examples of rather detailed specifications were given for an automated performance measurement system. The similarity of the proposed measurement concepts to those being implemented for the C-5A Performance Measurement System was noted.

Payoff

The results of this R&D effort guided the ATC development of the TTB syllabus of training for SUPT. It helped ATC course developers determine which training tasks to include in the TTB training track syllabus. Ultimately, all UPT Wings and all of the flying MAJCOMS will benefit from the ATC use of this syllabus.

This work provides a logically and empirically constructed data base on which to build a TTB training syllabus. The approach developed a method that addressed the extent to which specific tasks can be expected to transfer to other tasks not covered by the training program. This information can be used to answer questions concerning cross-training between TTB aircraft, as well as design questions regarding alternative configurations for a TTB trainer aircraft and supporting simulator. A candidate performance measurement system incorporating work under progress with the C-5A provides relevant information for ATC assessment of the TTB aircrew performance.

Need

Present Air Force plans envision the acquisition of numerous and expensive aircrew training simulators through FY90. Because their total procurement cost is expected to exceed $3 billion, it is imperative that these simulators have proven effectiveness in training the tasks for which they are intended. To ensure that this is properly accomplished, Air Force directives require that operational tests and evaluations be performed on each system. As these devices exist for the purpose of training, the evaluation of training effectiveness will constitute a significant portion of the estimate of their military utility. Prior to this R&D effort, there was no standard methodology for addressing the issues involved in the determination of system training effectiveness. This condition was primarily due to the scope of this multidisciplinary task. Consequently, a dedicated effort, using a team of appropriate specialists, was necessary to provide a solution to the problem.

R&D Solution

The Operations Training Division of the Air Force Human Resources Laboratory (AFHRL) was responsible for this effort accomplished in response to a request from the Air Force Test and Evaluation Center. The approach consisted of a comprehensive review of the operational test and evaluation (OT&E) literature and official directives, site visits to Department of Defense test and evaluation agencies, and technical discussions and interviews with knowledgeable personnel in the military and civilian OT&E communities. Relevant information from the fields of psychology, training, and engineering were included to ensure that the handbook provided thorough coverage of key areas, such as training effectiveness, media utilization, human factors engineering, and device reliability and maintainability. To help ensure that the handbook would be of optimum utility to its intended users, a series of reviews and coordination meetings were held with Air Force test and evaluation personnel from the Major Commands and the Air Force Test and Evaluation Center at each stage of development.

There are three general functions with which the aircrew training device (ATD) OT&E test manager/director must be concerned and for which coverage in the three volumes of the handbook was deemed appropriate.

Volume I. Planning and Management is concerned with both general and specific ATD OT&E planning and management issues. It provides a guide for prospective users of the handbook and contains executive summaries of the organization and content of the handbook volumes. Also discussed are the ATD acquisition process, the types of tests and evaluations and their objectives, and organization roles and responsibilities. Further, Volume I covers the ATD OT&E planning, execution, and reporting procedures. Finally, ATD acquisition and event flow are discussed.

Volume II. Operational Effectiveness Evaluation treats the assessment of ATD training utility during OT&E. This volume provides a general tutorial on the fundamentals of ATD utilization, evaluation concepts, and evaluation approaches. Specific training evaluation techniques are presented. Finally, in recognition of the fact that ultimate ATD effectiveness is also very much a function of its instructor/operator station (IOS) design, Volume II provides highly specific guidance for IOS evaluations.

Volume III. Operational Suitability Evaluation is concerned with the impact of various operational suitability factors such as reliability, maintainability, availability, and logistics supportability on the overall usefulness of the ATD. Volume III is intended to provide the ATD OT&E test manager/director with basic understanding of the suitability areas (i.e., what is done and by whom) and provides specific "how to" techniques. Although the technical methods and procedures will be handled by the appropriate engineers and technicians during the conduct of an OT&E suitability evaluation, the handbook gives overall guidance and direction.

Application

The three-volume OT&E handbook published by AFHRL provides a standardized guide for OT&E of ATD training effectiveness. The utility of this product has not yet been empirically established, due to its recent publication date. Strong face validity, plus the fact that it is the only comprehensive, standard guide available, has brought it wide acceptance. Through its use, a data base will be built up and will provide empirical evidence for evaluating the procedures outlined in this handbook.

The Tactical Air Warfare Center (TAWC) stated that this handbook is the most operationally useful AFHRL R&D technical report published in 1981 and 1982. The handbook was made possible by close consistent user involvement in all phases of the effort. Most program managers in TAWC have been issued copies of the handbook to perform OT&E of aircrew training devices.

The Military Airlift Command (MAC) stated that AFHRL studies have served as a training resource for course managers and as a guide to developing quality training programs. Without this help, they would have required more people and a longer development period and would have developed a lower quality end-product.

MAC planning for the Follow-On Operational Testing and Evaluation (FOT&E) of a new low-level navigator visual simulator will be based on the recommendations of this handbook. The decision whether to purchase up to nine additional visual systems with a total cost of approximately $80 million will be based on results obtained during this FOT&E. If these visual systems are purchased, they will provide huge cost avoidance.

Payoff

MAC could not fully document exact cost savings because their new aircrew training programs were not introduced until October 1982. However, substantial savings are expected because of reduced flying requirements in the actual aircraft, thus making that valuable time available for other vital Air Force requirements.

This R&D product (a) provides Air Force leadership with direction in making decisions for allocating huge expenditures on aircrew simulators and (b) provides the operational Air Force units consistent methodology in the planning and conduct of aircrew simulator test and evaluation programs for a variety of systems. It is expected that application of this methodology will result in increased efficiency and reliability in operational test and evaluation of training equipment. The benefits should be cost savings in the conduct of the test and improved reliability and validity in the test findings.

E-3A FLIGHT SIMULATOR FOLLOW-ON OPERATIONAL TEST AND EVALUATION

Need

The history of operational training research and development has demonstrated that on-site operationally oriented research is difficult when compared to evaluations conducted in a laboratory environment; however, the results provide more usable data. The most critical problem is control of extraneous variables. Unless this problem is properly handled, the results are confounded and inferences are difficult, if not impossible. Tactical Air Command (TAC) did not possess sufficient in-house R&D resources to evaluate the E-3A flight simulator capability to satisfy the flight crew simulator's training requirements. R&D support from the Air Force Human Resources Laboratory (AFHRL) provided TAC with the expert knowledge and techniques needed for evaluating the training capability of the simulator.

R&D Solution

The Operations Training Division of AFHRL responded to the TAC request to evaluate the simulator's instructional features as they relate to psychological fidelity and training capability. AFHRL behavioral scientists developed evaluation questionnaires and conducted standardized interviews with 13 instructor pilots, 6 instructor flight engineers, and 6 radio aids console operators. The objective was to evaluate the compatibility of the flight simulator instructional features and the consoles as compared with operator functions. Mock-up panels of the flight simulators were provided for the taped interview appraisals which addressed human factor aspects and the fidelity and training capability of the simulator. An effort was made to identify any incompatible features/characteristics, their impact on training, and possible improvements. Data were collected on both the psychological fidelity and the training capabilities of the simulator's training features.

After statistical analysis of the data, AFHRL scientists identified improvements for the features that would enhance the training capability and improve training effectiveness of the simulator. Recommended improvements were concerned with the reduction of the number of software switching operations required, identification of and relocation of instructor-operator displays and controls, and replacement of the visual system with a computer image generating system.

Application

Through this effort, data were provided to aid in identifying tasks that are fully trainable in the simulator and creditable toward flying training. TAC reported that incorporation of the AFHRL-recommended changes in training effectiveness and operational effectiveness significantly aided further development and refinement of the E-3A mission crew training program. Additional instructional tasks are possible with the improved Instructor Operator Station.

Payoff

Reduction in number of software switching operations resulted in simplification of operating procedures and minimization of opportunities for error. Recommendations have been incorporated into the three new, recently acquired, E-3A Flight Simulators. This payoff includes an increase in flying safety through optimizing the training potential of the equipment.

HUMAN FACTORS

The Department of Defense defines the human factors area of people-related research, development, test, and evaluation as follows:

"Development of improved methods and technologies for the analysis, design, and evaluation of equipment/systems for safer and more efficient operation and maintenance."

Continued inflation and constrained budgets mean that Air Force weapon systems must be developed, operated, and maintained with maximum efficiency and effectiveness so as to provide and maintain individual unit operational readiness at the minimum life-cycle cost. Technology is at the stage during which relatively large improvements can be obtained from modest costs applied at the critical conceptual and design stages of weapon system development. Current technical programs that have outstanding payoff potential include the following: (a) demonstration of techniques for predicting and controlling manpower and training costs of weapon system ownership as a function of weapon system design characteristics, (b) integration of the many separate data bases currently used to track the support requirements of major systems, and (c) development of computer simulation models and other analytical tools for managers to use in assessing the combat capabilities of their maintenance organizations.

Projects in this category include:

1. Specifications for Maintenance Task Analysis and Logic Tree Troubleshooting Aids (LTTAs)

2. Format Options for Procurement of Technical Orders

3. Maintenance Resources Interaction Models

SPECIFICATIONS FOR MAINTENANCE TASK ANALYSIS AND LOGIC TREE TROUBLESHOOTING AIDS

Need

Significant progress has been made in developing new techniques for preparation and presentation of technical data for maintenance. These developments have included improved maintenance task analysis procedures for developing the data base and improved formats for presenting technical data, Job Guide Manuals (JGMs), and Logic Tree Troubleshooting Aids (LTTAs). Experience has demonstrated that JGMs and LTTAs are superior to conventional technical orders. It is generally recognized that a comprehensive maintenance task analysis is necessary for the development of good JGMs and LTTAs. Application of these technologies has been hindered by a lack of suitable specifications for use in procuring technical data. A suitable specification for the procurement of JGMs was available. However, no suitable specifications were available for the procurement of LTTAs and for the maintenance task identification and analysis (MTI&A) research and development (R&D). An effort was needed to develop specifications in these two areas.

R&D Solution

This effort was conducted by the Logistics and Technical Training Division of the Air Force Human Resources Laboratory (AFHRL) in response to a request from the Air Force Logistics Command. A thorough review of the state-of-the-art in performing the MTI&A was accomplished to provide the basis for developing the draft specification. This was accomplished by first reviewing the literature in the area and then conducting extensive interviews with government and industry personnel who are knowledgeable of and experienced in current MTI&A procedures. Interviews were conducted with industry personnel who have had experience in conducting research to develop MTI&A procedures and with personnel who have had experience in managing and conducting MTI&A programs. Interviews were also conducted with Air Force and Army personnel who have had experience in procuring MTI&A based technical data. The results of the literature review and interviews were analyzed and used to provide the basis for developing the MTI&A requirements included in the specification.

The draft specification requires that the contractor accomplish specific tasks to ensure that all required maintenance tasks are identified and that all information required to prepare effective JGMs and LTTAs is developed. The tasks include the development of (a) a task identification matrix to identify all required tasks and specify the level of maintenance (intermediate, organizational, depot) at which they are to be performed, (b) a description of the intended user (abilities, training, experience), (c) listings of required support equipment and special tools, (d) guidelines for determining the level of detail to be included in JGMs and LTTAs, (e) an analysis of possible equipment faults and resulting symptoms, (f) effective step-by-step procedures for accomplishing each task, and (g) action trees outlining a troubleshooting strategy to isolate each possible fault. A special section is provided for accomplishing the MTI&A for systems for which Logistic Support Analysis data are available. The draft specification is suitable for the procurement of MTI&A for organizational and intermediate levels of maintenance. The specification establishes firm requirements for conducting the MTI&A but allows the contractor considerable freedom in how the analysis is accomplished. The specification may be used to procure MTI&A for development of a data base for use in developing other types of manuals.

The state-of-the-art in preparing and using LTTAs was reviewed to provide the basis for developing the draft specification. This review was accomplished by searching available literature and then conducting extensive interviews with government and industry personnel with experience in developing, using, and evaluating LTTAs. The results of the interviews were analyzed to provide the basis for establishing the requirements for developing LTTAs. The goal was to develop a specification that establishes basic requirements for developing LTTAs that will result in improved performance while still providing enough flexibility to be suitable for application to a wide variety of applications.

The draft specification provides specific and general requirements for the development of LTTAs. These include requirements for (a) task analysis, (b) development of troubleshooting procedures, (c) development of checkout procedures, (d) presentation formats, (e) preliminary information, (f) supplemental and support information (wiring diagrams, theory of operation, etc.), (g) varying levels of enrichment, and (h) dual level presentation. The specification is suitable for use in procuring LTTAs for use with all types of equipment: electrical, electronic, mechanical, pneumatic, hydraulic, optical, and combinations thereof. It is suitable for procurement of LTTAs for use at the intermediate and organizational levels of maintenance. The specification may also be used for the development of checkout and logic tree procedures for use in other types of manuals.

Another outcome of this effort was a handbook for use in conjunction with the draft MTI&A specification. The handbook provides an overview of MTI&A processes followed by a listing of fundamental requirements to be performed prior to the actual start of MTI&A. Once the analyst has become knowledgeable of the preliminary requirements, the handbook provides the direction on how to perform MTI&A.

Application

The major user of this research is the Air Force Logistics Command, but the real user is ultimately the entire Air Force. Logistics Command maintenance managers stated that information derived from this effort is being utilized to write a standard on acquisition of technical orders. Already they have noted increased aircraft readiness, reduced downtime, and reduced turnaround time. They estimate multi-million-dollar savings in reduced maintenance costs and improved readiness.

Specifically, the troubleshooting procedures which resulted from the LTTA specification are enabling all levels of maintenance personnel to troubleshoot more accurately and thus, to use fewer spare parts. The MTI&A specification is resulting in technical data that are more complete, more accurate, and more usable by the technician. The result is improved maintenance, especially by first-term technicians.

Payoff

The handbook is a major source of material for a short course on technical data management being taught by the Air Force Institute of Technology. The use of the handbook considerably strengthens the performance of a new or inexperienced technical order manager. The use of the handbook should significantly improve the quality of technical data procured for Air Force use. The contents of the handbook provide detailed guidance to the technical order manager about all aspects of technical order acquisition, including determining requirements, selecting options, and managing the procurement process. This is resulting in technical orders that are timely, correct, and meet the informational needs of the users. Better maintenance should be the end result.

FORMAT OPTIONS FOR PROCUREMENT OF TECHNICAL ORDERS

Need

Technical orders are publications outlining the procedures for operation and maintenance of Air Force equipment and systems. Such documents must be responsive to the changing needs of the Air Force and to the changes that are continually occurring in procedural data techniques.

In recent years, several types of improved formats for technical data for maintenance have been developed and approved for use in the Department of Defense. Examples of the improved formats include Job Guide Manuals, Logic Tree Troubleshooting Aids, Fully Proceduralized Job Performance Aids, and Functionally Oriented Maintenance Manuals. Available research results indicate that these formats have significant advantages over conventional technical orders. Further, the results indicate that each type is more appropriate for some applications than for others.

Although the advantages of the new formats have been demonstrated, little progress has been made in applying them to Air Force technical data programs. This is due in part to the fact that many technical-data managers are not sufficiently familiar with the new formats so they can effectively select and apply them. To overcome this problem, a handbook was needed to provide technical data managers with information on available formats, guidelines for selecting the most appropriate format for a given application, and guidance on the special problems involved in developing and procuring technical data in each format.

R&D Solution

The Logistics and Technical Training Division of the Air Force Human Resources Laboratory initiated a research and development (R&D) effort in response to a request from Air Force Logistics Command. The purpose of this project was to assemble information that would be useful to Air Force Technical Order Managers and other personnel concerned with acquiring data for use in developing technical orders. To that end, three distinct objectives were established:

1. To identify technical order acquisition requirements and problems, along with existing formats and guidelines.

2. To determine the specific information, requirements, procedures, and guidelines that should be made available to the Technical Order Manager.

3. To develop a handbook of data and procedures for requirements determination; format selections; and acquisition, development and implementation of technical orders.

The approach to meeting these objectives was, first, to gather information relating to the needs of the Managers by interviewing technical order professionals from both the Air Force and private industry. This stage of the work also included a review of available formats, specifications, and applicable literature. The second phase involved analysis of these data, with the selection of candidate formats and guidelines and the development of additional guidelines. Finally, the text and introductory presentation materials were prepared.

Data were analyzed through screening and categorization as to principal character (e.g., format versus media), and the existence and availability of descriptive information, test data, and preparation guidelines. Any format-based technique that had all three types of data was designated a potential candidate for inclusion.

The identification of specifications and guidelines involved the composite listing of all potentially useful specifications and guideline documents, noting the document and its most recent issue, the Services using the specification, and the equipment and manual types for which it was applicable. The research team selected the most significant specifications from this listing. From the literature review, a comprehensive bibliography was established which included more than 130 research type publications.

The final step was to determine which format-based techniques should be recommended for inclusion. The ground rules established for this selection began with the techniques that were already determined to be format-based and to have both descriptive data and test data available. Empirical test results from previous R&D efforts by the Air Force, Army, Navy or industry were required before any format-based technique, specification, or guideline was included.

Application

Utilization in the operational community is one indicator of the validity of an R&D product such as a handbook. The technical order handbook has met with positive reception and is widely used within the logistics community.

The F-16 System Program Office stated that the handbook assessment of the F-16 Job Guide concept is proving helpful in structuring not only the F-16 Job Guide Technical Order content but the overall F-16 technical order verification effort. This office forwarded the handbook to the Tactical Air Command and to the Air Force Test and Evaluation Center for further study and possible implementation.

The 6510th Maintenance and Supply Group stated that there has been a serious lack of current information in this vital area in the Air Force and that the technical order handbook fills the current need for a consolidated source of quality information available to Technical Order Managers. Other available documents do not present information in sufficient detail to train personnel adequately for dealing with the complexities and problems associated with the acquisition and management of technical orders.

The handbook will be used at the Air Force Test and Evaluation Center to enhance the training program for personnel involved in the technical order acquisition and verification process. Additionally, the handbook will provide training to personnel from the using and supporting commands assigned to the Combined Test Force. The handbook will also be beneficial to Technical Order Managers at the System Program Offices. The information in the handbook provides detailed explanations and instructions for developing an effective technical order acquisition and management program including such items as improved statements of work and verification plans. This improved awareness of technical order acquisition will result in greatly improved, more cost-effective technical orders.

A statement from the Directorate of Integrated Logistics Support of the Deputate for Simulators affirmed the usefulness of the technical order handbook saying that study of the handbook and a 2-week course at the Air Force Institute of Technology (AFIT) would bring a new Technical Order Manager to the same level of proficiency as 1-1/2 years of on-the-job training. This handbook is the primary source of information for the Technical Order Acquisitions Course (Systems 10) being taught at AFIT. Since May 1982, more than 75 students have completed this course. This is a 2-week on-going course, and additional students will continue to benefit from this manual.

Payoff

Use of the technical order handbook should significantly improve the quality of technical data procured for Air Force use. The contents of the handbook will provide detailed guidance to the Technical Order Manager about all aspects of technical order acquisition, including determining requirements, selecting options, and managing the procurement process. This will result in technical orders that are timely and correct and that meet the informational needs of the users. Better weapon system maintenance should be the end result.

Need

The growing concern with weapon systems readiness issues has resulted in greater efforts to forecast accurately the manpower, support equipment, and spare parts required to support a given level of flying activity. Determining the cost-effective mix of these resources poses a continuing management problem. As new aircraft enter the weapons inventory and operating and maintenance procedures change, there is a recurring need for reliable estimates of the spares, support equipment, and manpower resources necessary to support the desired level of operational activity. Such estimates enable Air Force managers to allocate personnel and material resources to new as well as existing organizations, thus ensuring combat readiness.

Failure rates and frequency of maintenance were traditionally predicted in terms of aircraft flying hours. However, in many cases, field data show a poor correlation between these variables. Maintenance appears to be related to more specific utilization variables, such as cycles, landings, sorties, and bursts fired. In some cases, it may be a function of more than one such variable. Lack of information on the appropriate variable(s) to use as a base measure can introduce substantial error when predicting maintenance action rates on new equipment from field experience on similar items used in a different operational environment.

The Air Force Human Resources Laboratory (AFHRL) has developed supporting techniques for use with the Logistics Composite Modeling (LCOM) to forecast the maintenance manpower requirements for new and existing weapon systems. Changes in the spares and/or support equipment levels had been shown to require changes in the manpower forecasts, and the converse was also true. Therefore, an advancement in the modeling technology to provide for the interactive forecasting of these resources was needed. Research and development (R&D) was carried out to establish the interactive effects of manpower, spares, and support equipment for a given weapon system in a peacetime environment. Further study extended the simulation and modeling technique to an initial wartime surge environment.

R&D Solution

The Logistics and Technical Training Division of AFHRL was responsible for this effort, conducted in response to a request from the Directorate of Acquisition Policy of the Air Force Systems Command. The F-15 operational fighter weapon system was selected for study, and the research program progressed through the following stages: (a) determine essential variables, (b) define available data sources, (c) develop experimental simulation plan, and (d) examine quantitative effects of variations in input variables on weapon system performance. The major variables considered in performing the LCOM simulation were weapon system definition, maintenance requirements, and operations requirements. Prime data sources for this study were Air Force and contractor publications, Air Force maintenance data reporting, and structured interviews with operations and maintenance personnel. The experimental simulation plan examined 40 performance measures as a function of (a) three variations in flying programs including 10, 20, and 30 flying hours per aircraft per month, (b) two maintenance concepts, including cannibalization and deferred maintenance, and (c) three resource levels of baseline, average, and minimum for manpower, spares, and support equipment. The operations and maintenance performance measures, evaluated in each test structure, were categorized in operations, aircraft, manpower, shop repair, spares supply, and support equipment measures.

This R&D effort has shown that computer simulation of F-15 operations and maintenance, enhanced with mathematical modeling of performance, yields a powerful analytic tool for estimating resource needs of a weapon system. Of the classes of models examined, the following results were indicated for peacetime environments. (a) Operations and aircraft performance measures tend to change predominantly as a function of manpower level and utilization rate. (Spares levels help predict many measures in these categories at specific utilization rates.) (b) Maintenance workload measures are best predicted with simple models that rely on manpower and spares levels. (c) Changes in aircraft utilization rates introduce a great deal of variance in nearly all measures, and of the models tested, those which take into account interactions among spares, manpower, and support equipment enhance the predictive power of simpler models that exclude these interactions. (d) Cannibalization tends to reduce slightly the importance of spares levels on personnel and shop repair measures. However, in general, cannibalization affects operations and aircraft only when the flying schedule becomes severe. It should be noted that while the overall level of spares was varied in these simulation experiments, an optimum distribution of stock within any level was always assumed. Deficiencies in the allocation of specific parts would show a greater impact. (e) While support equipment levels account for some variation in most measures, when this variable is included, the overall predictive power of a mathematical model tends to be reduced. Some anticipated improvements in the models are anticipated which may remedy this deficit.

Further R&D extended the simulation and modeling technique to an initial wartime surge environment. LCOM was used to simulate 30 days of surge flying activity assuming a fully operational wing of 72 F-15s and various resource levels. Three levels of manpower, four levels of spares, and three levels of support equipment were combined factorially, yielding 36 separate simulations. The interactive effects of the three resources were examined for 40 weapon system performance measures. Two regression models were then derived for each measure, one which included surge day and resource types as predictive terms, and a second which treated all variations over days as error.

The major sources of variance in 40 performance measures were attributed to spare parts supplies and day-of-surge activity. As spares supplies available at the beginning of simulation were increased, the period for which the heavy flying demands necessary in a wartime surge scenario were sustained increased. As resource levels were quickly exhausted on the early days of the surge, flying activity tended to deteriorate rapidly across days. Manpower, support equipment, and interactions among the three principal resources accounted for smaller portions of variance than did either spares levels or days, but did enhance predictive capabilities for most LCOM measures.

With respect to the regression models that were developed with simulation results, it was shown that a simple model which included predictive components based on manpower, spares, and equipment generally did not provide stable or accurate estimates of system performance. Variance percentages accounted for with this first type of model ranged from 6.60 percent to 78.65 percent. Substantial increases in predictive strength were obtained from a model which, in addition to components based on the three resources, included the linear and quadratic days components. This model predicted from 12.04 percent to 99.5 percent of the variance in the 40 performance measures. The increase in predictive strength appears to justify the added complexity of the second model.

Finally, the second model type yielded encouraging results concerning the application of simulation and mathematical modeling techniques to the surge environment. However, the treatment of interdependencies among performance measures is an aspect of modeling which can be improved. Simulation results showed strong relations among many performance measures, relations which were ignored in the regression models employed. A model of performance change which postulates a causal relation between the measure of interest, other performance measures and resource quantities can improve the current models. The first model was tested and validated. The extension into a second model has not yet been validated, but verification studies are ongoing.

Application

This R&D will be helpful to all Air Force LCOM users, working with both developing and operational weapon systems. The products of this study provide a means of predicting the maintenance demand rates of aircraft subsystems. The increased accuracy in predicting maintenance demand rates, used in conjunction with the newly developing support resource forecasting models, will allow for more accurate estimations of the requirements for maintenance manpower, spares, and support equipment.

Payoff

These models and equations provide a means to determine resource requirements for desired levels of readiness. They also provide the means to perform trade-offs among various mixes of manpower, spares, and support equipment in terms of effects on dollar costs and on the ability of a system to meet peacetime readiness and wartime employment objectives.The products also provide insight into the determiners of equipment failure (design characteristics, environmental factors, operations requirements), thus allowing for corrective actions to be taken where maintenance demands are unusually high or otherwise unacceptable.

SIMULATION AND TRAINING DEVICES

The Department of Defense defines the simulation and training devices area of people-related research, development, test, and evaluation as follows:

"Development of cost-effective training equipment and technology that produce the needed performance for operation and maintenance of military systems."

Improved simulator training technology will help ensure Air Force operational readiness and effectiveness. Significant opportunities exist with flight and maintenance simulators. An example is through the use of the Advanced Simulator for Pilot Training. A full-visual research flight simulator, the ASPT is utilized to develop innovative methods for flight simulator training of tactics in air-to-air, air-to-ground, and terrain-following warfare. Improved flight simulator hardware is being developed to support these training requirements. Also, the performance capabilities of flight simulators are being improved with special emphasis on developing and demonstrating improved visual image generation and projection techniques to provide more realistic visual displays. Additionally, maintenance training will be made more cost effective by the development and evaluation of maintenance simulators. These devices permit the simulation of malfunctions and allow hands-on maintenance training and troubleshooting to take place without tying up or damaging expensive real hardware.

Projects in this category include:

1. Simulators for Maintenance Training
2. Simulator Training Requirements and Effectiveness Study (STRES)
3. Air Refueling Park-Task Trainer for Boom Operators
4. Tactical Flight Simulation

Need

The demand for highly trained technicians to operate and maintain the sophisticated Air Force systems has increased at a rapid rate over the past decade. New aircraft are continually being developed for tactical and strategic missions. These aircraft, which feature improved electronics and avionics, have created the need for an advanced method of training maintenance technicians to diagnose and correct system defects. Most training in avionics maintenance is conducted using actual equipment trainers. This equipment is in short supply, is very expensive, and because of the safety issue both for personnel and the equipment, "hands-on" experience with actual system equipment is severely limited. As a training device, actual equipment does not readily permit the controlled presentation of malfunctions representative of troubleshooting problems occurring frequently in operational settings. Less expensive real-time simulators do possess the capability for troubleshooting training which incorporates hands-on practice to increase troubleshooting skill on a sample of field-related maintenance problems. In addition to improved skills training, properly designed computer-based training simulators also have the potential to release more expensive actual equipment for operational readiness. To this end, objective data are required to determine the conditions and alternative simulation designs that result in job-competent personnel for the least cost.

R&D Solution

The Logistics and Technical Training Division of the Air Force Human Resources Laboratory (AFHRL) initiated a comprehensive research project to develop promising areas of simulation technology as it applies to Air Force maintenance training. This effort was carried out at the joint request of the Engineering Branch of the Aeronautical Systems Division, the Office of Training Technology of the Air Training Command, and the Training Programs Division in Personnel Programs of Headquarters, Air Force. There have been several research and development (R&D) projects conducted within the following areas: Fidelity Requirements, Troubleshooting Trainers, Handbooks and Model Specifications, and Field Evaluation of Simulated Aircraft Maintenance Trainers.

Fidelity Requirements

To date, two major simulators have been developed and evaluated to investigate the impact of engineering fidelity on cost effectiveness and training efficiency. The first device was a three-dimensional simulator of the 6883 Automatic Test Station. This device simulates the converter/flight control test station for the F-111D aircraft. It was designed to provide the highest possible fidelity in terms of both operational and physical fidelity. A two-dimensional simulator has also been developed. This was developed specifically for comparison with the three-dimensional simulator so that a number of design parameters could be explored. With these two simulators and the actual equipment all available at the same time, in the same course, and used by the same instructors, a unique opportunity was created to evaluate many of the parameters that impact both cost and training effectiveness. Students were assigned to one of three training devices in the course in such a way that the only difference was in terms of the trainer used. Students entering the Converter/Flight Control Systems resident course were systematically assigned to one of the three training devices. Troubleshooting performance, paper-and-pencil tests, and supervisory rating forms were developed through extensive field interviews of subject matter experts and were administered to compare the training. The supervisory rating forms for specific tasks were obtained from the field to provide additional feedback related to job performance at the duty station. Therefore, a comparison was conducted relative to the training and cost effectiveness among the training devices for a specific sample of students confronted by a specific set of tasks.

The findings of this comparative study were as follows:

1. No significant performance differences among the three training alternatives were obtained.

2. Trainees were proficient (average score 85 percent) in procedural tech order tasks in all three training conditions.

3. Trainees performed at the same level in troubleshooting tasks in all three training conditions.

4. The life-cycle cost per student hour for the actual equipment was 3.7 times greater than for the low fidelity simulator and 2.6 greater than for the high fidelity simulator.

5. Student attitudinal acceptance of the simulators was very positive. Instructors' rank order preference of the three training devices was first, actual equipment; second, high fidelity device; and third, low fidelity device.

Troubleshooting Trainers

An effort is presently underway to investigate the potential for interactive computer graphics to provide general purpose simulation capability for maintenance training with an emphasis on practice in diagnosing and correcting faults. The objectives of this effort are (a) to demonstrate the feasibility of using interactive graphics simulation as a cost-effective alternative to Actual Equipment Trainers (AETs), (b) to investigate the training effectiveness of graphics simulation, (c) to develop a functional specification for a low-cost stand-alone interactive graphics learning environment, and (d) to explore such issues as color, fidelity, and resolution requirements. The basic hardware configuration consists of a high resolution color graphics terminal and video disk unit with graphic overlays. This R&D will produce a graphics simulation for the 6883 Automatic Test Station and specifications for a low-cost device targeted for tri-Service use. Furthermore, the test bed can be considered as a prototype system for establishing functional specifications for a variety of training simulations. This prototype can be used to develop simulations for new/different systems and equipment.

A parallel effort is underway to investigate the potential of a general purpose, microfiche-based Flight Simulator Troubleshooting Trainer designed to develop the troubleshooting skills required in the maintenance of flight simulators. Both the graphics simulator and the Flight Simulator Troubleshooting Trainer are designed to foster troubleshooting and diagnostic skills in contrast to operating procedures. Collectively these two studies, and others in the program, are designed to obtain a wide range of simulation applications that can be generalized to other maintenance training environments.

Handbooks and Model Specifications

An ongoing series of investigations have been directed at improving available techniques for determining and documenting the training needs associated with new weapons systems. This has been documented in a handbook detailing the decision logic involved in determining training requirements and a model specification to facilitate the documentation of those training requirements. A parallel development resulted in a similar handbook and model specification to aid procurement personnel in converting these training requirements into procurement specifications. An effort currently underway is investigating the logistic considerations that impact on the acquisition, operation, and maintenance of trainers and simulators. This effort will culminate in the production of a series of decision aids to facilitate tradeoff analysis and cost minimization strategies during the early phases of weapon system acquisition.

Application

Collectively these studies have demonstrated that simulators for maintenance training can provide efficient and effective training. The simulators have been shown to provide comparable training at less cost.

Another independent study on the "Cost-Effectiveness of Maintenance Simulators for Military Training" by Orlansky and String presented the following results. The cost to develop and fabricate one unit or a simulator was less than 60 percent of the cost of its counterpart actual equipment trainer in 7 of 11 cases investigated. The cost of fabricating an additional unit of the simulator was less than 20 percent of the cost of its counterpart actual equipment trainer in 9 of these 11 cases. Acquisition and use of a maintenance simulator over a 15-year period would cost 38 percent as much as an actual equipment trainer, according to the only life-cycle cost comparison that has been reported. Since maintenance simulators and actual equipment trainers are equally effective and since maintenance simulators cost less, it is concluded that maintenance simulators are cost effective compared to actual equipment trainers. This finding is qualified because it is based on a limited number of comparisons, because effectiveness is based primarily on school achievement rather than on-the-job performance and because it is based primarily on acquisition rather than on life-cycle costs.

The Air Training Command has successfully used AFHRL prototype simulators to train aircraft technicians at Lowry AFB without breaking or degrading the operational equipment. Simulators bridge the gap between the student's basic military training and "hands-on" apprentice experience on the actual equipment. It is reasonable to expect, but as yet unproven, that such "hands-on" experience at the school will result in less flightline training to learn maintenance procedures. Less training time on the flightline means (a) less overall training cost, (b) less chance of damage to expensive aerospace systems, and (c) increased operational readiness.

Payoff

The big payoff of properly designed maintenance training simulators occurs, however, in the variety of training content that the simulator can provide. Some of these training devices offer students a safe and quiet environment in which to practice what has only been theory up to this point in their maintenance career. Simulators are capable of supporting training in troubleshooting by presenting realistic malfunctions under controlled conditions. In the practice mode, the student performs maintenance procedures in a step-by-step manner using the appropriate technical order or job guide. The number or type of simulated malfunctions can be changed at will since it is a software-based system. A student who errs can be visually cued by the computer, and the erroneous actions can be automatically measured, tabulated, and presented to the instructors.

Further, the use of operational equipment to teach certain maintenance procedures requires large volumes of fuel. On the simulator, the system response to student inputs is identical to that of the aircraft but no fuel is required. Power requirements for the simulator are also lower. Although operational equipment tends to be a heavy power user, some maintenance simulators operate from "household current."

The experience and information gained from follow-on maintenance simulation R&D is providing the basis for more effective decisions in the development and procurement of simulation devices in lieu of actual equipment trainers. The program has developed improved methods for determining whether or not the training requirements justify the need for a simulator or trainer. Studies within the Deputates for Simulators and Engineering of the Aeronautical Systems Division are underway toward improving the methodology for defining engineering specifications and improving acquisition strategies.

Need

Aircrew training is an expensive and time-consuming endeavor. At one time or another, virtually all known training methods and media have been used to develop operationally ready aircrews and to maintain their skill levels. To meet these training needs in a cost-effective manner, the military Services have shown increased interest in the use of simulators and related training devices. These training media, known collectively as aircrew training devices (ATDs), include cockpit familiarization and procedures trainers, part-task trainers, operational flight trainers, weapon systems trainers, and full mission trainers.

Recent requirements to economize on aircraft fuel have provided strong impetus for the increased interest in ATDs, but other factors have contributed as well. The other factors include increasingly congested airspace, safety during training, cost of operational equipment used for training, and a desire to capitalize on training opportunities that ATDs provide for training that cannot be undertaken effectively, safely, or economically in the air.

Because of the advantages simulation can offer over other aircrew training media, Air Force policy dictates that ATDs will be used to the fullest extent to improve readiness, operational capability, and training efficiency. Implementation of this policy requires specific technical guidance. Information on which to base that guidance is sparse, however, and the information that does exist is not always available to those who need it. Phase II of the overall Simulator Training Requirements and Effectiveness Study (STRES) program was conceived as a means of identifying, integrating, and making available current simulator training information necessary to support relevant Air Force policies. The base of information provides guidance for the enhancement of present training and focuses research and development needed to enhance future simulation-based training.

R&D Solution

This effort was carried out by the Logistics and Technical Training Division of the Air Force Human Resources Laboratory (AFHRL) at the request of the Rated Management Division of the Directorate of Operations of the US Air Force Headquarters.

Studies of the design, use, life-cycle costing, and worth of ATDs were conducted at AFHRL.

The primary objectives of the overall STRES program were to define, describe, collect, analyze, and document information bearing on four key areas:

1. Criteria for matching training requirements with ATD fidelity features.

2. Criteria for matching ATD instructional features with specific training requirements.

3. Principles of effective and efficient utilization of ATDs to accomplish specific training requirements.

4. Models of factors influencing the life-cycle cost and worth of ownership of ATDs.

The Air Force plan for accomplishing these objectives involved a four-phase effort. Phase I was concluded prior to the initiation of the present study. It was an Air Force planning activity that defined and prioritized the total effort. Phase II was a 29-month study that involved collecting, integrating, and presenting currently available scientific, technical, and operational information applicable to specific aircrew training issues. Phase II also involved the identification of research and development (R&D) efforts needed to enhance future simulator training. Phase III is planned to be a research activity that will provide additional information on important simulation and simulator training questions that, as expected, could not be answered based on currently available data. Finally, building on Phases II and III, Phase IV is planned as an Air Force effort to integrate findings, publish relevant information, and provide for updating of the knowledge base as new information becomes available.

A tri-Service Advisory Team was formed by the Air Force to help guide STRES. A principal task of the Advisory Team was to participate in the development of objectives and guidelines for the conduct of the Phase II technical effort. As a focus for the effort, a set of "high value" operational tasks was identified. The tasks selected were those for which potential ATD training benefits were judged to be greatest and for which information on ATD design, retrofit, use, and worth was believed to be incomplete or lacking. These tasks also provided a focus for identifying questions and issues reflecting the information needs of operational users that were to be addressed during Phase II. The high value tasks identified by the Advisory Team were (a) individual and formation takeoff and landing, (b) close formation flight and trail formation, both close and extended, (c) aerobatics, spin, stall and unusual attitude recognition, prevention and recovery, (d) low-level terrain following, (e) air refueling, (f) air-to-air combat, both guns and missiles, and (g) air-to-ground weapons delivery.

Information from two sources was used to address Phase II program technical objectives. One source was the professional literature, including books, professional journals, and research reports. Approximately 1,100 potentially relevant documents were identified. About 400 of these contained information that was sufficiently current, complete, and methodologically sound to be of value to program objectives.

A second information source was the experience of people intimately involved in the design, use, and costing of ATDs. Included were ATD manufacturers, R&D organizations, an airline, and operational ATD users in each of the military Services. A broad spectrum of ATD designs and uses was surveyed. Detailed interview guides were used.

Seven reports were prepared to document Phase II of this effort. Briefly, significant findings on the four key issues are outlined below:

Fidelity Features

The first general STRES objective dealt with fidelity. Fidelity is defined as the degree to which cue and response capabilities in a simulator are similar to those in the actual aircraft so that learning of specific tasks in the device will enhance performance of those tasks in the actual aircraft. Specific fidelity issues addressed were visual and motion systems.

Visual systems are vital for training most piloting tasks in aircraft simulators. R&D, as well as operational experience with visually equipped simulators, indicate that training in such devices does transfer to inflight performance for the tasks of individual aircraft approach and landing.

Platform motion systems are relatively common in the modern trainer and have been assumed to benefit training by contributing to the realism of the training environment. However, R&D findings indicate that pilots are often unaware of whether platform motion systems have been turned on or off.

Instructional Support Features

The second general STRES objective dealt with relations between instructional support features and specific simulator training requirements. Instructional support features include all of the hardware and software capabilities of a device that will permit an instructor to control the student's learning experience. A general finding was that the use of instructional support features is directly related to pilot skill level and associated instructional requirements rather than to the tasks being trained.

Utilization Principles for Aircrew Training Devices

The third general STRES objective addressed efffectiveness and efficiency of simulator use. Any training device, regardless of its sophistication, is only one element in the total training system, and will be only as effective as its utilization allows it to be. Thus, the ways in which the training is conducted, the selection of the instructors, and the monitoring and evaluation of the training will all impact on training device effectiveness. STRES researchers found the more effective simulator training programs were those in which instructors have been trained "to teach" and were taught specifically how to use these devices and their instructional support features.

Life-Cycle Cost

The fourth objective of the program was to develop models of the factors influencing the life-cycle costs of simulators. The life-cycle cost model permits decision makers, through the use of cost factors and actual cost data, to determine costs of training device alternatives throughout their usable life. The model also can be used to determine the factors that influence these costs.

Application

The Strategic Air Command stated that recommendations from the STRES reports have been analyzed for implementation on future simulator acquisitions. These reports have been used to definitize changes for both existing and future simulators. Findings on the proper location of instructor stations were used to develop the B-1B Weapon System Trainer. Several changes were made to instructor training programs, future trainer specifications, monitor and evaluation concepts. The R&D results were used as background information in recent Air Staff meetings/briefings on a future acquisition program.

The Rated Management Division of Headquarters, Air Force, found the STRES reports a "good reference document that draws together all previous research on training devices...excellent primer for newly assigned personnel." After reading the STRES executive summary, managers at HQ USAF seriously questioned the need for platform motion on the simulator for the B-1B aircraft and initiated a follow-on program to develop a conclusive position on platform motion for large aircraft simulators. If motion is eventually deleted, life-cycle costs will decrease. A preliminary estimate would be an overall cost savings of 10 million dollars for deleting motion on the B-1B simulator program.

The Military Airlift Command (MAC) is using STRES as backup material and supportive data. The study provides good source material to be used in developing and acquiring new training devices. Each of the five course managers dealing with simulation have been issued a copy of Aircrew Training Devices Utilization Report. This volume was used as a standard reference during development of training programs for effective use of the new C-130 flight simulator. Use of this report significantly reduced the time required for program development and more importantly, gave users clear direction on proven ways to use simulators. A second report, Aircrew Training Devices Fidelity Features has been used extensively to evaluate fidelity features of the C-130 simulator and the visual system. Use of the new C-130 simulator will reduce MAC formal school flying hour requirements by at least 9,000 hours per year. Part of this reduction comes from increased simulator capabilities, but a significant part will come from proper application of these capabilities.

The future research plans volume of the STRES report series identifies the research needed to fill in information gaps that were anticipated from the outset of the study. As anticipated before the initiation of STRES Phase II, complete, high confidence answers could not be found for some major questions concerning ATD design and use. In some instances, information concerning a given question had never been collected systematically, or the practical utility of a given training concept or ATD design feature had never been addressed. In other cases, prior research could not be applied directly to current training questions. Subsequent experimentation and evaluation are still required to provide the empirical data needed for scientific documentation. The base of information developed in Phase II provides guidance for the enhancement of present training and focuses the R&D needed to enhance future simulation-based training.

Payoff

This project documented available information about ATDs, indicating the training effectiveness, worth-of-ownership, advantages, and constraints of various aspects of aircrew simulators for specific high value training requirements. Management and operational personnel now have a single source of all simulator features R&D.

AIR REFUELING PART-TASK TRAINER FOR BOOM OPERATORS

Need

The economic rewards for using specialized simulators known as part-task trainers to satisfy particular aircrew proficiency requirements are well established, and have been successfully demonstrated by many military and commercial aviation training programs. The preferred approach has been to use these simulators to provide both initial skills training and refresher training in specific mission elements. In 1974, the Air Force identified the need for modern simulators to supplement the training available through in-flight practice.

The Strategic Air Command (SAC) identified boom operator air refueling training as one area where simulation could be effectively applied. The heavy commitment of the KC-135A refueling aircraft to support Air Force-wide operational and pilot training sorties sharply reduced its availability for boom operator training. Thus, SAC KC-135A student boom operators were hampered in developing hands-on air refueling skills because of limited flying time. Training aids (films, slides, and mock-ups) provided a means for the student to conceptualize some operator skills, but the aids did not allow an instructor to present and explain basic refueling cues and did not give the student hands-on experience. As a result, a need existed to provide the student boom operators a means for effective practice of air refueling tasks in the safety and efficiency of a ground environment.

SAC identified this specific requirement in 1974 for a state-of-the-art refueling simulator with proven reliability and training capacity. From this requirement, an Air Force program was begun to design, fabricate, and test a Boom Operator Part-Task Trainer (BOPTT).

R&D Solution

The Operations Training Division of the Air Force Human Resources Laboratory (AFHRL) responded to the SAC requirement by drawing on its in-house expertise to perform initial operational test and evaluation while at the same time conducting three transfer-of-training studies. A preliminary evaluation of the training capabilities of the BOPTT was performed at Wright-Patterson AFB in February 1978. The purposes of this qualification operational test and evaluation were to provide an economical and early look at the training potential of the BOPTT and to permit identification of correctable deficiencies.

The preliminary evaluation, based on judgments of eight highly experienced SAC instructor boom operators, found that fully acceptable training was provided by the simulator; that the fidelity of the simulator was adequate; and instructional features were useful and necessary adjuncts for certain training tasks. Subsequent transfer-of-training investigation demonstrated the validity of these subjective judgments.

To completely satisfy all test and evaluation objectives, SAC requested that AFHRL address four primary issues in boom operator simulator training in the operational environment. The overall goal of the study was to make long-range determinations of the cost effectiveness of simulator training of boom operator skills in a limited flying environment. These determinations were to include consideration of undergraduate training in the Combat Crew Training Squadron (CCTS), training of instructor boom operator personnel, and device usage to maintain the proficiency of experienced personnel. Specifically, the four primary objectives of the study were as follows:

1. Determine the transfer of training from the BOPTT to the KC-135A aircraft for the CCTS boom operator student.

2. Evaluate the BOPTT training effectiveness for the instructor boom operator in the Central Flight Instructor Course (CFIC) when the BOPTT serves as the sole training device.

3. Investigate boom operator skill degradation and reacquisition for experienced personnel by substituting the BOPTT for the KC-135A aircraft as the practice medium.

4. Evaluate the cost effectiveness of the BOPTT in the CCTS program.

To address these issues one transfer-of-training study was dedicated to the CCTS area, one to the CFIC area, and one to the skill retention area. The subjects were 59 students enrolled in the boom operator CCTS program at Castle AFB. Results of the CCTS research indicated that all student groups trained in the BOPTT required significantly fewer air refueling attempts (50 versus 71) to reach proficiency in KC-135A air refueling skills than did students trained by the standard syllabus. In boom operation, procedures and communications, all BOPTT trained students were superior or equal to the students in the standard syllabus.

Results of the evaluation of the BOPTT training effectiveness for the instructor course showed that instructor trainees who received all training sessions in the BOPTT demonstrated proficiency equal to that of instructor trainees who received all training in the KC-135A aircraft. This one-to-one training transfer ratio afforded by the direct substitution of BOPTT training for aircraft training was a striking confirmation of the simulator's effectiveness.

Results of the skill maintenance research and development (R&D) revealed that no measurable degradation of boom operator skills occurred for the two test periods--60 and 120 days. This was due to the high competence level of the personnel used as subjects. Consequently, no conclusions could be drawn concerning the effectiveness of the BOPTT in maintaining the proficiency of highly skilled boom operators. Evidence from the other two studies would lead to a prediction that the device should be effective in this application.

The fourth primary objective was to evaluate BOPTT cost effectiveness in the CCTS program. There were two difficulties encountered in meeting this objective. First, accurate fixed-costs information on SAC boom operator training, sufficiently detailed to satisfy precise accounting procedures, was not available. Second, an Air Force cost effectiveness model sensitive to critical training parameters did not exist.

Fortunately, SAC did have cost data on the overall expense of training a CCTS boom operator. These cost data were broken down by training phase and identified the direct costs in the flight phase. Although this information was not as "fine-grained" as desired, it was complete enough to be usable for Initial Operational Test and Evaluation purposes. The second difficulty was overcome by using a very simple "substitution" model. In this model, the costs associated with BOPTT operation, weighted by the demonstrated transfer-of-training ratio for the devices, were compared to official SAC program cost figures.

Using this simple model, the analysis of the potential savings that could be realized through proper BOPTT utilization in CCTS presents an extremely favorable outlook. According to SAC accounts, costs to graduate a CCTS student are $77,007. Of this figure, $65,043 is incurred in the flight training phase, with $31,419 being a direct expense. When control group data are considered, the mean number of aircraft refueling contact attempts required by CCTS students to reach proficiency was approximately 71. This translates to an average cost of $442.52 per contact attempt. The equivalent cost in the BOPTT is $24.00 per contact attempt.

Application

The BOPTT was shown to be an efficient medium for training all aspects of boom operator skills. The data indicate that the transfer-of-training value from the BOPTT to the aircraft was 67 percent in the CCTS program and 100 percent in the CFIC program. The cost savings potential of the BOPTT is most impressive. Using SAC figures as a basis for calculation, it was estimated that proper utilization of the device could avoid over 1 million dollars in CCTS program costs per year. This estimate does not include the savings in personnel costs (student time and instructors) that would also accrue. The findings of the AFHRL study has resulted in numerous substantial changes in the CCTS and CFIC training materials and programs. SAC indicates, further, that the AFHRL study results have been used extensively in developing a KC-10 boom operator training program for the KC-10 aircraft.

Payoff

The data may be interpreted to show that, without suffering a loss in student proficiency, a reduction of 20 aircraft contact attempts may be made by directly substituting BOPTT for the KC-135A. Since performing a contact attempt in the BOPTT costs $418.52 less than performing its counterpart action in the aircraft, the total savings per CCTS student would be $8,370.40. Based on an estimated CCTS output of 170 students per year, the resultant savings would be over 1.4 million dollars annually.

TACTICAL FLIGHT SIMULATION

Need

The experience of the National Aeronautics and Space Administration in successfully training crews to perform moon landings, which could be practiced through simulation only, has demonstrated the value of simulating tasks that are impractical or impossible to practice in the real situation.

Experiences of the Air Force and Navy during the Vietnam era indicated that pilot performance in a combat situation could be considerably improved by providing the pilot with experience in flying mock air-to-air engagements against dissimilar aircraft and against the types of ground defenses that would be encountered in combat.

This need for realistic training in a combat environment led directly to the establishment of the Red Flag and Blue Flag exercises by the Tactical Air Command (TAC) and similar training exercises by other commands. While such exercises are excellent test beds for new tactics on a squadron or wing level, the duration is frequently too short for the evolution of new tactical approaches or for exploration of the relative effectiveness of alternative strategies on an individual pilot level.

With the use of a high fidelity, full mission simulator, such as the Advanced Simulator for Pilot Training (ASPT), pilots can be exposed to a large number of combat simulations of sufficient fidelity in a short period of time to provide optimum situations for development of offensive and defensive skills. The use of such simulation of the combat mission has the potential of developing the pilots' abilities to react to the ever-changing mission requirements with flexibility and judgment, based on "experience." A study was undertaken to determine whether the simulator could be used in this extended role.

R&D Solution

In March 1979, the Operations Training Division of the Air Force Human Resources Laboratory (AFHRL) conducted a feasibility study in tactical scenarios at the request of TAC. Combat ready A-10 aircraft pilots flew a simulator mission in which they were to destroy an enemy tank with their 30mm gun. The simulated combat ground environment employed a modified air defense system including anti-aircraft and surface-to-air missiles to thwart the A-10 pilot's mission. Each of seven combat ready A-10 pilots flew 20 runs consisting of ingress to the target area, attempt to destroy the tank, and egress from the hostile environment.

All seven pilots showed increased capacity to perform both offensively and defensively after repeated training runs in the simulator. The composite curve displayed a clear acquisition phase at the beginning, followed by a leveling off during the mid-trials and then a marked end spurt during the last few trials. On the basis of whether the pilot hit or missed the target, survived, or was destroyed, a chi square analysis was performed. The overall analysis showed statistical significance at the 0.05 level. This simply means that the pilot's offensive scores (hitting the tank) and defensive procedures (survival) are highly correlated. When the morning performance was compared with the afternoon performance, there was a significant increase in survival and offensive capabilities in the afternoon.

This being the first attempt to use the ASPT (or any other simulator) for the production of a full combat scenario, the preliminary results are quite encouraging. The visual system was programmed to almost full capacity to produce the battle environment in which the pilots were free to fly and develop their own tactics in destroying the target and surviving the threat environment. In this sense, the pilot is operating in a completely open loop fashion, as would largely be done in true combat, and as such, may be able to develop the flexibility and problem solving strategies pilots have to develop in actual combat. The learning curves indicate the pilots are acquiring and integrating appropriate information so as to improve their tactical performance.

Application

It appears that the simulator may be able to supply an important training methodology for tactics development. With the development of greater computer capacity, the visual and other systems may be capable of producing dynamic changing combat environments that would allow the combat ready pilot to maintain his combat skills at a very high level. Flight simulation should fill the training void of those flying tasks that are impractical or impossible to practice in the real aircraft.

Continued development of combat environments with increasing variability and flexibility is needed to test thoroughly the total concept of simulator tactics development. As a follow-on from such development, comparisons should be made between the performance scores in exercises such as Red Flag with pilots trained in simulation and with pilots who have not had such exposure. Such a program could very well determine what sort of transfer of training is taking place from the simulator to the flying mission.

Assuming that the seven pilots comprised a representative sample and that the outcomes did indicate transfer of training, an analysis was done to estimate the payoff, in terms of combat outcomes, that might be expected if pilots were to receive realistic combat training in simulators. The tool for analysis was a computer war game based on a large-scale, central European combat scenario. The purpose of this analysis was to examine how simulator training might affect battle results during the early, high-risk days of war--the first 4 days--when pilots fly their first 10 missions and are either lost or survive as combat-experienced pilots.

Payoff

The learning curves derived from this study were input to the computer war game. Analyses of the war game results suggest that if simulator training could maintain pilots' combat skills at a fiveor six-mission experience level, the following advantages might be achieved during the first 4 days of combat:

1. 60 percent increase in tanks destroyed per aircraft lost.

2. 14 percent reduction in total enemy ground strength (as compared to results from pilots not having simulator training), with overall enemy force reductions equivalent to using 45 percent or more Close Air Support/ Battlefield Air Interdiction sorties.

3. 20 percent improvement in force ratio between friendly and enemy units, thus enhancing ability to influence campaign actions beyond the initial 4 days of conflict.

LMED

8