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Human Factors Research in Aircrew Performance and Training: 1990 Annual Summary Report

D. Michael McAnulty, Editor
Anacapa Sciences, Inc.

June 1991

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United States Army Research Institute
for the Behavioral and Social Sciences

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FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency Under the Jurisdiction
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REPORT DOCUMENTATION PAGE		Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS --

2a. SECURITY CLASSIFICATION AUTHORITY --	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE --	

4. PERFORMING ORGANIZATION REPORT NUMBER(S) ASI690-339-90	5. MONITORING ORGANIZATION REPORT NUMBER(S) ARI Technical Report 930

6a. NAME OF PERFORMING ORGANIZATION Anacapa Sciences, Inc.	6b. OFFICE SYMBOL (If applicable) --	7a. NAME OF MONITORING ORGANIZATION U.S. Army Research Institute Aviation Research and Development Activity

6c. ADDRESS (City, State, and ZIP Code) P.O. Box 489 Fort Rucker, AL 36362-5000	7b. ADDRESS (City, State, and ZIP Code) ATTN: PERI-IR Fort Rucker, AL 36362-5354

8a. NAME OF FUNDING / SPONSORING ORGANIZATION U.S. Army Research Institute for the Behavioral and Social Sciences	8b. OFFICE SYMBOL (If applicable) PERI-S	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER MDA903-87-C-0523

8c. ADDRESS (City, State, and ZIP Code) 5001 Eisenhower Avenue Alexandria, VA 22333-5600	10. SOURCE OF FUNDING NUMBERS (Continued)			
	PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
	see II			

11. TITLE (Include Security Classification)
Human Factors Research in Aircrew Performance and Training: 1990 Annual Summary Report

12. PERSONAL AUTHOR(S)
McAnulty, D. Michael, Editor

13a. TYPE OF REPORT Interim	13b. TIME COVERED FROM 89/10 TO 90/10	14. DATE OF REPORT (Year, Month, Day) 1991, June	15. PAGE COUNT

16. SUPPLEMENTARY NOTATION   All research on this project was technically monitored by Charles A. Gainer, Chief, U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA), Fort Rucker, AL.

17.	COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Aviation safety Flight systems
05	08		Aviator selection testing Helicopter flight simulation
			Aviator training (Continued)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report presents summary descriptions of the research projects performed by, Anacapa Sciences, Inc., for the U.S. Army Research Institute Aviation Research and Development Activity at Fort Rucker, Alabama, under Contract No. MDA903-87-C-0523, entitled "Human Factors Research in Aircrew Performance and Training." During the period from 9 October 1989 to 8 October 1990, Anacapa personnel worked on 21 research projects and one technical advisory service in emerging aviation systems design, manpower and personnel programs, aviator training, and aviation safety research. The report also describes two research projects that were conducted under subcontract to Anacapa Sciences. The summary description for each project and the technical advisory service contains (a) a background section that describes the rationale for the project and specifies the research objectives; (b) a research approach section that describes the tasks and activities required to meet the project objectives; (c) a work completed section that may include research findings or, in the case of developmental activities, a description of the research products; and

(Continued)

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Charles A. Gainer	22b. TELEPHONE (Include Area Code) (205) 255-4404	22c. OFFICE SYMBOL PERI-IR

DD Form 1473, JUN 86   Previous editions are obsolete.   SECURITY CLASSIFICATION OF THIS PAGE

ARI Technical Report 930

10. SUMMARY OF FUNDING NUMBERS (Continued)

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
62785A	790	1211	C05
63007A	792	2204	C06
63007A	793	1210	C05
63007A	795	3309	C06
63007A	795	3405	C06

18. SUBJECT TERMS (Continued)

Helicopter gunnery
Maintainability
Pilot requirements
Symbology
System design
Workload prediction

19. ABSTRACT (Continued)

(d) a project status section that describes the projections for future research, if any.

Technical Report 930

Human Factors Research in Aircrew Performance and Training: 1990 Annual Summary Report

D. Michael McAnulty, Editor
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Office, Deputy Chief of Staff for Personnel
Department of the Army

June 1991

iii

The U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at Fort Rucker, Alabama, is contributing to the effectiveness of Army aviation by conducting a comprehensive human factors research program in support of aircrew performance and training. The ARIARDA research program encompasses the full scope of Army aviation, with projects in support of (a) emerging Army aviation systems, (b) aviation manpower and personnel programs, (c) aviator training programs, and (d) aviator safety programs.

This report summarizes research and products developed in all four of the above areas between 9 October 1989 and 8 October 1990 by Anacapa Sciences, Inc. Twenty-one projects are summarized. Nine describe research in support of emerging systems, three in aviation safety, two in support of manpower and personnel programs, and seven in support of aviator training programs. In addition, one technical advisory service and two subcontract projects are described. The projects in emerging systems and aviation safety are conducted within the mission of the Systems Research Laboratory at the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI). The projects in manpower and personnel are conducted within the mission of the Manpower and Personnel Research Laboratory at ARI. Finally, the aviator training projects and the technical advisory service are conducted within the mission of the Training Research Laboratory at ARI. Specific taskings are identified for each project or research area, and the use of the research findings or products is described in each summary report.

This summary report is designed to meet two important objectives. First, it provides a summary of research progress and accomplishments to U.S. Army weapon system managers, manpower and personnel planners, and training system developers and managers in their respective areas of responsibility. Second, it provides summary information to behavioral scientists who may be working on similar applied research issues, either in the Department of Defense or in other governmental, industrial, or university organizations.

EDGAR M. JOHNSON
Technical Director

v

HUMAN FACTORS RESEARCH IN AIRCREW PERFORMANCE AND TRAINING:
1990 ANNUAL SUMMARY REPORT

<u>EXECUTIVE SUMMARY</u>

Requirement:

Anacapa Sciences, Inc., has provided collocated research support to the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at Fort Rucker, Alabama, since 1981. The ARIARDA program supports the full range of Army aviation research requirements with projects that address issues in emerging aviation systems, aviation manpower and personnel, aviator training, and aviation safety. This annual summary report fulfills one of the contracting requirements. It describes the 21 research projects and one technical advisory service conducted by Anacapa Sciences researchers between October 1989 and October 1990 in support of the ARIARDA program. In addition, it describes two other research projects conducted for ARIARDA during the same time period under subcontract to Anacapa Sciences. The specific requirements that led to the initiation of each research project are discussed in the individual summaries.

Procedure:

There are substantial differences in the methods that were employed in the individual projects and in the technical advisory service. In some cases, the research approach was a scientific experiment in which selected variables were controlled, manipulated, and measured. In other cases, the research approach was a set of analytical or product development tasks. The specific research methods used in each project and the technical advisory service are described in the individual summaries.

Findings:

The Anacapa research projects were conducted in all four domains of the ARIARDA research program. Nine of the projects are in the emerging aviation systems domain. Seven of these projects address the prediction of operator workload in varying configurations of the AH-64, UH-60, MH-60K, CH-47, and MH-47E aircraft. the other two projects are concerned with the integration of maintenance considerations during the early design phases of new aircraft and the design of flight symbology.

Three projects are in the aviation safety research domain. One project addresses the crew requirements for the OH-58D helicopter. The other two projects are designed to identify crew coordination errors and to develop and evaluate crew coordination training programs. Two of the projects are in the manpower and personnel research domain; the objective of these projects is to develop and validate a new aviator selection test battery. Seven projects and the technical advisory service are in the aviator training research domain. One project is an evaluation of the special operations training course; the remaining projects are concerned with the development and evaluation of flight simulator training.

Finally, one of the subcontract projects was conducted in support of research on using a low-cost visual simulator for initial helicopter pilot training. The other subcontract project was conducted to identify helicopter crew coordination training requirements.

Utilization of Findings:

The results and recommendations of many of the projects and the technical advisory service will be directly implemented in the design of new aviation systems, in the selection and management of aviation personnel, and in aviation training at the Aviation Center, Fort Rucker, Alabama, and in Army aviation units around the world. This report provides Army systems managers, manpower and personnel planners, training system developers and managers, and researchers working in related fields with a summary of the research activities in their respective areas of interest.

HUMAN FACTORS RESEARCH IN AIRCREW PERFORMANCE AND TRAINING:
1990 ANNUAL SUMMARY REPORT

CONTENTS

CONTENTS (Continued)

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AAA	Army Audit Agency
AAWWS	Airborne Adverse Weather Weapon System
AHT	Automated Hover Trainer
AIRNET	Aviation Networked Simulator
AO	Aerial Observer
ARI	Army Research Institute for the Behavioral and Social Sciences
ARIARDA	Army Research Institute Aviation Research and Development Activity
ARTEP	Army Training and Evaluation Program
ASMIS	Army Safety Management Information System
ATHS	Airborne Target Handover System
ATM	Aircrew Training Manual
AVCATT	Aviation Combined Arms Tactical Trainer
AVSCOM	Aviation Systems Command
BBN	Bolt, Baranek, & Newman
BMQ	Basic Mission Qualification
CBAC	Cavalry Brigade - Air Combat
CMI	Contractor Mission Instructor
CMS	Combat Mission Simulator
CO	Commissioned Officer
CRM	Cockpit Resource Management
CWEPT	Cockpit, Weapons, and Emergency Procedures Trainer
DA	Department of the Army
DARPA	Defense Advanced Research Projects Agency
DCSOPS	Deputy Chief of Staff for Operations
DIG	Digital Image Generation
DOTD	Directorate of Training and Doctrine
DOTS	Department of Tactics and Simulation
EAO	Enlisted Aerial Observer
EAOC	Enlisted Aeroscout Observer Course
E&S	Evans and Sutherland
ETM	Emergency Touchdown Maneuver
FARP	Forward Area Refueling Point
FAST	Flight Aptitude Selection Test
FORSCOM	Forces Command
FRED	Fully Reconfigurable Experimental Device
FS	Flight Simulator
FWS	Flight and Weapons Simulator
FY	Fiscal Year
HF	Human Factors
IERW	Initial Entry Rotary Wing
IG	Image Generator
IHADSS	Integrated Helmet and Display Sighting System
IMC	Instrument Meteorological Conditions
I/O	Input/Output
IP	Instructor Pilot
ITEMS	Interactive Tactical Environment Management System

LHX	Light Helicopter Family
LOFT	Line-Oriented Flight Training
LOS	Line of Sight
LZ	Landing Zone
MANPRINT	Manpower and Personnel Integration
MFD	Multifunction Display
MMI	Military Mission Instructor
MOS	Military Occupational Specialty
MOST	Mission-Oriented Simulator Training
MOU	Memorandum of Understanding
MPT	Manpower, Personnel, and Training
MTP	Mission Training Plan
NASA	National Aeronautical and Space Agency
NFAST	New Flight Aptitude Selection Test
NOE	Nap of the Earth
NVG	Night Vision Goggles
OAG	Overall Average Grade
PF	Pilot Flying
PM	Program Manager
PNF	Pilot Not Flying
PNVS	Pilot Night Vision System
RFAST	Revised Flight Aptitude Selection Test
S&T	Selection and Training
SCTB	Simulator Complexity Test Bed
SME	Subject Matter Expert
SOA	Special Operations Aircraft
SOAR	Special Operations Aviation Regiment
SP	Student Pilot
TADS	Target Acquisition and Detection System
TAWL	Task Analysis/Workload
TEA	Training Effectiveness Analysis
TER	Transfer Effectiveness Ratio
TISPEECH	Texas Instruments Speech Processing Board
TOSS	TAWL Operator Simulation System
TOT	Transfer of Training
TRADOC	Training and Doctrine Command
TRS	Training Research Simulator
TSM	Training System Manager
UAFDL	University of Alabama Flight Dynamics Laboratory
UH1FS	UH-1 Instrument Flight Simulator
UH1TRS	UH-1 Training Research Simulator
UMSDC	Unscheduled Maintenance Sample Data Collection
USAALS	U.S. Army Aviation Logistics School
USAAVNC	U.S. Army Aviation Center
USAREUR	U.S. Army, Europe
USASC	U.S. Army Safety Center
VFR	Visual Flight Rules
WOC	Warrant Officer Candidate

HUMAN FACTORS RESEARCH IN AIRCREW PERFORMANCE AND TRAINING: 1990 ANNUAL SUMMARY REPORT

Introduction

Anacapa Sciences, Inc., has provided collocated research support to the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at Fort Rucker, Alabama, under a series of contracts that began on 1 September 1981. The current contract (No. MDA903-87-C-0523) requires the submission of an Annual Summary Report of research activities. This report describes the Anacapa research project activities and achievements during the period from 9 October 1989 to 8 October 1990. Throughout the report, this period is referred to as the current contract year.

Seven of the research summaries in this report describe individual projects that Anacapa Sciences personnel have worked on during the current contract year. Six of the summaries describe major, long-term research areas that are divided into 14 discrete projects. One summary describes a technical advisory service, which is extensive research support provided to projects that are directed by ARIARDA personnel. Finally, the last two summaries describe two research projects conducted for ARIARDA under subcontract to Anacapa Sciences.

Most of the summaries follow the same general format. Each summary begins with a background section that presents information needed to understand the requirement for the project. The background may include a brief review of the relevant research literature or describe the critical events that led to the initiation of the project or technical advisory service. Where appropriate, the relationship between specific projects in a research area is discussed.

When the need for the research cannot be clearly inferred from the background information, a statement of need or definition of the research problem is presented. This is followed by a concise statement of the project or research area objectives. Next, the research approach section presents a description of the activities that were planned to accomplish the research objectives. For some projects, the research approach is a scientific experiment in which selected variables are controlled, manipulated, and measured. For other projects, the research approach is a set of analytical or product development tasks.

The research approach is usually followed by one or more sections that describe the work completed on the project and

the research findings or, in the case of product development efforts, a description of the research products. In the technical advisory service summary, the research approach is followed by a description of the services provided by Anacapa personnel. The final section of each summary describes the work projected, if any. Where possible, this section also presents the current project milestones.

The projects summarized in this report represent only a portion of ARIARDA's research program. Numerous other projects are being conducted either in-house by ARIARDA personnel or under other contracts. During the current contract year, Anacapa personnel also provided temporary research, technical, administrative, and logistical support on other projects that are the primary responsibility of ARIARDA personnel and, consequently, are not summarized in this report.

The project summaries are presented in four content categories that reflect the research domains at ARIARDA. This organization is intended to assist the reader in locating a specific project summary within a research domain or in finding summaries that are closely related in terms of content.

The first five summaries describe nine projects in emerging aviation systems design. The next two summaries describe three projects in aviation safety research. The eighth summary describes two projects in manpower and personnel research. The next six summaries describe seven aviation training research projects and the technical advisory service that supported ARIARDA training research projects. The last two summaries describe the two projects that were conducted under subcontract to Anacapa Sciences; one project was in aviation training research and the other was in aviation safety research. The number of projects assigned to the four categories is not necessarily in proportion to the emphasis placed on each research domain.

Although each summary identifies the project director(s), technical advisor, or subcontract monitor, the Anacapa approach to research employs a team concept. This approach provides the optimum utilization of each scientific staff member's skills and ensures coordination among closely related projects. The scientific staff members are supported by an exceptionally efficient administrative and technical staff. All of the research effort is closely coordinated with ARIARDA personnel.

DEVELOPMENT OF A TASK ANALYSIS/WORKLOAD OPERATOR SIMULATION SYSTEM (TOSS)

Ms. Laura A. Fulford, Project Director

Background

Anacapa Sciences researchers, under contract to the Army Research Institute Aviation Research and Development Activity (ARIARDA), Fort Rucker, Alabama, developed a task analysis/workload (TAWL) methodology for predicting operator workload during the conceptual phase of new system development. The methodology was first applied to the Army's Light Helicopter Family (LHX) aircraft (e.g., McCracken & Aldrich, 1984). Subsequently, Anacapa personnel refined the mission/task/workload analysis methodology and produced operator workload prediction models for the AH-64A (Szabo & Bierbaum, 1986), the UH-60 (Bierbaum, Szabo, & Aldrich, 1989), and the CH-47 aircraft (Bierbaum & Aldrich, 1989). Each of the original workload prediction models was programmed in FORTRAN 77 on a Perkin-Elmer 3210 computer.

Need

The FORTRAN 77 programs for the LHX, AH-64A, and UH-60 workload prediction models incorporate the model decision rules into the program code. Time-consuming recompilations of the programs are required to incorporate even minor changes in the models. A TAWL operator simulation system (TOSS) is required that reduces the development time for implementing changes to models or creating new ones.

Objective

The primary objective of this project is to develop a software system that (a) can incorporate model changes without rewriting and recompiling the software, (b) is powerful and flexible enough to exercise any of the workload prediction models developed with the refined TAWL methodology, and (c) can be used directly by workload analysts. In addition, the software system should be written on a widely available computer and in a language that is easy to modify.

Approach

The TOSS software will be designed to store all model information peculiar to a specific aircraft in computer data files. The design will enable the user to change an existing model simulation by changing data files, thereby eliminating the need to alter the program to incorporate model changes, and to implement new computer models developed with the refined methodology merely by creating a new set of data files. Because data entry of model information using a standard text editor would be time consuming and subject to errors, a data base management system with specialized routines will be designed for entering and updating all of the data used in the workload prediction models. Each specialized routine will feature error checks to ensure the validity of the data files. The most critical data files will be protected by automatic backup procedures. Finally, a simple and consistent user-interface will be developed that can be used directly by workload analysts. To ensure good accessibility, the software system will be developed on the IBM AT compatible computer. Turbo Pascal will be used to ensure that the program source code can be easily modified.

Work Completed

During previous contract years, initial versions of TOSS were developed and extensively modified. The initial development of TOSS versions 2.0 and 3.0 are discussed in detail in Fulford (1990). Because of demand for the software from other agencies, plans were developed to document and release version 3.0. However, improvements to the user interface were required to facilitate the typical workload analyst's use of the program. Therefore, plans were made to develop and release a final version (4.0) of the software.

TOSS 3.0

In October 1989, Anacapa personnel completed the draft TAWL/TOSS User's Guide and delivered it to ARIARDA. In February 1990, several changes were made to the text of the User's Guide and minor modifications were made to the software to address the issues raised during the ARIARDA review. On 21 February 1990, the final versions of the TOSS 3.0 User's Guide and software were delivered to ARIARDA. In March 1990, 225 copies of the software were generated at the request of ARIARDA. Submission of the copies completed all work on the TOSS version 3.0 project.

TOSS 4.0

During the current contract year, significant changes were made to produce version 4.0 (previously called version 3.1; see Fulford, 1990). Changes made to the software include the following additions:

- an introductory screen featuring the AH-64A aircraft;
- an increase of the maximum number of tasks, functions, and segments to 8000;
- a user-defined equation to compute a new workload estimate by combining other workload components and constants;
- the ability to simulate several segments without user intervention;
- a feature to halt simulation without waiting for the entire segment to be simulated;
- the display of the mean and peak for each workload component and the workload equation, the predicted length of the segment, and expected finish time on the simulation screen;
- the ability to view output from within the program;
- a feature to search for user-defined text in a number of routines;
- a task and function cross-reference report;
- the ability to work in TOSS while printing files;
- an import/export routine to convert TOSS data files to and from dBase file format;
- a workload conversion procedure to convert existing workload data into another scale;
- on-line help for the TOSS software that includes information about active keys, field descriptions, special codes, and ranges of valid data; and
- on-line help for the TAWL methodology that features information about workload rating scales, decision rules, randomization, and other topics.

In addition to the new features, numerous modifications were made to the TOSS software. The seven major changes are described in the following paragraphs.

First, the directory utility in version 3.0 was removed and replaced with a model selection routine that displays all models found on the selected disk drive. The routine permits a user to select, create, delete, back up, or restore model data files. Second, the six model parameters were edited using different screens in version 3.0. All model parameters

5

were combined into a single screen in version 4.0. With the single parameter screen, the state of the model can be quickly assessed and edited. Third, the 3.0 user had to access three different screens to edit task names, workloads, and subsystems. In version 4.0, these data are edited on a single screen. Also, a single report of these data was included in the Report Generator.

Fourth, a different interface was developed for editing function and segment decision rules. In version 3.0, lists of function and segment names were maintained separately from the corresponding function and segment decision rules. In version 4.0, the function and segment names are associated and edited concurrently with the decision rules. The user can scroll through the function names and highlight function decision rules. The task numbers and names contained in the highlighted decision rule are then displayed on the screen. The user interface is similar for segment decision rules.

Fifth, the interface for the function clash pairs was changed to display all of the clash pairs in a window environment. The user can scroll through clash pairs; insert, delete, or locate a particular record by entering two function numbers; or find all functions clashing with a particular function. In addition, the clash pair report was revised so that all the clashes associated with each function are printed after the function number. Finally, the clashes for a highlighted function can be displayed from within the segment decision rule editing routine.

Sixth, the subsystem summary page in the simulation output was modified to compute the percentage of time that each subsystem is used, the mean component workload for each subsystem, and the "Subsystem Impact" (% time x mean workload). The subsystem impact is an estimate of the relative effect that each subsystem has on each workload component.

Seventh, the colors used in TOSS to indicate different information on the screen are user defined in version 4.0. Previously, the colors were fixed and chosen by the developer.

Ancillary programs. Several improvements were made to the ancillary programs. The installation program was modified to allow greater hardware flexibility. A line chart to compare the average workload in a workload component for several segments in two models was added to the graphing program. Finally, the conversion program was updated to change version 3.0 data files to version 4.0.

User's guide. Because of the major changes in the user interface between versions 3.0 and 4.0, a new user's guide was required to support the software. A draft version of the user's guide for version 4.0 was completed by the end of the contract year.

Papers. Two papers about TAWL and TOSS were prepared for the October 1990 Human Factors Meeting. The first paper describes the use of the TAWL methodology in predicting operator workload. The second paper demonstrates TOSS 4.0.

Work Projected

The TAWL and TOSS papers will be presented at the annual meeting of the 1990 Human Factors Society in October 1990. TOSS version 4.0 will be tested, completed, and submitted to ARIARDA by the end of the calender year. The submission will include the update program, installation program, and User's Guide. Incorporation of ARIARDA review suggestions into these products will complete work on this project.

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Rucker, AL: Anacapa Sciences, Inc.

THE AH-64 WORKLOAD PREDICTION MODEL

Dr. David B. Hamilton, Project Director

Background

The Army's Air/Land Battle 2000 scenario presents a high-threat environment that places heavy workload demands on the combat helicopter aircrew. To increase mission effectiveness in this environment, the latest Army helicopters are equipped with advanced technology. This technology includes electronic sensor capabilities that increase both the amount and fidelity of information available to the crew.

One example in the current U.S. Army inventory is the AH-64A Apache attack helicopter. It was the first Army aircraft equipped with flight and weapon systems that allow missions to be conducted at night and under adverse weather conditions. The increased mission capabilities of the AH-64A aircraft have dramatically increased the amount of information that the crew must process. The AH-64A is equipped with automated flight and combat (acquisition, targeting, and engagement) technology that is intended to reduce crew workload. In some instances, however, the technology has either increased workload or simply changed the nature of the task without decreasing workload. High workload, in turn, reduces mission effectiveness, increases system manning requirements, and increases the training necessary for acquiring and maintaining flight proficiency.

One reason that technology has failed to reduce workload in Army aircraft is that human factors concepts were not adequately considered during the early stages of system design. For example, many of the subsystems in the AH-64A were not integrated to simplify the man-machine interface and reduce workload. In the past, a methodology for assessing the workload demands of emerging aviation/weapon systems did not exist. However, researchers from the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) and Anacapa Sciences have developed a methodology for predicting the workload demands placed on crewmembers by the advanced technology proposed for the multipurpose lightweight helicopter, the LHX.

Recently, Anacapa researchers refined the LHX methodology to support its application in evaluating workload in existing or developmental weapon systems; the refined methodology is called the Task Analysis/Workload (TAWL) methodology (see Hamilton, Bierbaum, & Fulford, 1990). In addition,

computer support for the methodology has been developed and named the TAWL Operator Simulation System (TOSS).

The methodology takes a multidimensional view of human capabilities that enables the system engineer to identify modifications that shift workload from one domain to another. For example, technology that reduces an aviator's need to maintain physical control of system functions often increases the aviator's role as a monitor. Thus, advanced technology may decrease psychomotor workload and increase cognitive workload. Because human cognitive ability is limited, system designers must avoid shifting all the workload associated with aircraft operations into the cognitive domain (or into any other single domain). Using the TAWL methodology, system engineers can better utilize crew capabilities and increase system effectiveness.

The Army is currently developing an improved AH-64 helicopter called the Longbow Apache. The man-machine interface will change substantially with the incorporation of two touch-screen multifunction displays and the removal of the majority of the switches and dials. The principal additions in the Longbow Apache will be the Airborne Target Handover System (ATHS) and the Airborne Adverse Weather Weapon System (AAWWS).

Need

The Army Aviation Systems Command (AVSCOM), St. Louis, Missouri, requested that ARIARDA apply the TAWL methodology to evaluate the workload in the AH-64A Apache and in the Longbow Apache currently being developed. In response to AVSCOM's request for support, ARIARDA tasked Anacapa to conduct the required research.

Research Objectives

The overall objective of the AH-64 workload prediction research is to determine the effect that advanced technology has on the workload of AH-64 attack helicopter crewmembers. The research is divided into the following three specific objectives:

- determine the workload for the current configuration of the AH-64A aircraft,
- predict the effect that Longbow design modifications will have on crew workload, and

10

- identify the AH-64 mission functions and subsystems for which design modifications will be most beneficial in reducing crew workload.

Research Approach

The research for meeting these objectives is divided into the following three projects.

Development of the AH-64A Workload Prediction Model

The development of a model to predict workload for the AH-64A aircrew will be divided into four tasks. The initial task will be to enter the mission/task/workload analysis data developed under a previous project (Szabo & Bierbaum, 1986) into a computer data base. The second task will be to develop and enter the function and segment decision rules into the computer. Function decision rules specify the sequence and time for performing the tasks in each function. The segment decision rules specify the sequence, time, and interaction of the functions in each segment.

In the third task, the TOSS software will be utilized to automate the workload analysis. The computer program will use the function and segment decision rules to combine the tasks to form functions and, in turn, to combine functions to form segments. The computer program will simulate the sequence of tasks that each crewmember must perform to accomplish the mission. From this simulation, the program will generate total workload estimates for each of five workload components (visual, auditory, cognitive, psychomotor, and kinesthetic) by summing the individual workload ratings for all the tasks that are performed concurrently. The total component workload predictions will be generated for every half-second interval in the segment. The estimates of component workload will identify points on the mission timeline where excessive workload (i.e., overload) will occur. Thus, predictions of total workload associated with the performance of concurrent and sequential tasks in the AH-64A baseline configuration will be generated.

In the fourth task, the results of the simulation will be reviewed to identify and correct any errors in the task/workload analysis data base. In addition, AH-64A subject matter experts will review the computer simulation of the crewmembers' actions during each mission segment to ensure that the model conforms with typical crewmember actions.

Validation of the AH-64A Workload Prediction Model

During the second project, the TAWL methodology and the AH-64A workload prediction model will be validated. The workload predictions yielded by the model will be evaluated by conducting part-mission and full-mission simulation research. In each instance, predictions of workload for specific tasks will be compared with objective measures of primary task performance, physiological measures of workload, and subjective measures of workload.

Finally, the results of the validation research will be used to refine the model. The research to validate the AH-64A model will not only establish the accuracy of the predictions of AH-64A workload prediction model, but will also establish the utility of the TAWL methodology for producing valid models of workload.

Development of the Longbow Apache Workload Prediction Model

During this project, the AH-64A computer model will be modified and exercised to predict how crew workload might be affected by the changes made to the Longbow model. The project consists of the following steps:

- establish a secure computer system for developing the model,
- identify the design changes that affect the operation of the system,
- conduct a task/workload analysis for each change,
- develop the function and segment decision rules for the changes,
- exercise the Longbow model to yield estimates of workload, and
- compare the estimates of workload for the AH-64A and Longbow configurations.

The results of this project will be used to estimate the differences in crewmember workload between the AH-64A and the Longbow Apache. The estimates, in turn, will assist design engineers in identifying the configuration of the AH-64A that produces lower workload.

Work Completed

Development of the AH-64A Workload Prediction Model

Under the previous contract, Szabo and Bierbaum (1986) conducted a task/workload analysis of all phases of the AH-64A attack mission. Seven mission phases were identified and divided into 52 unique mission segments. The segments were further divided into 159 unique functions with 688 individual tasks necessary to the mission. Finally, the subsystem, crewmember, and duration for each task was identified.

During the first three years of the current contract, both the task/workload analysis and the decision rules were extensively reviewed and revised. A preliminary version of the computer model was developed using a Perkin-Elmer mini-computer and FORTRAN programming language. The model was later reprogrammed using the TOSS software and an IBM personal computer. The model was exercised to produce preliminary analyses of workload for each of the mission segments, which were reviewed to ensure that the computer model accurately simulated the mission. In some cases, the function and segment decision rules were revised. A review of graphs of the workload predictions revealed a number of inaccuracies in the decision rules. By the end of the 1988-89 contract year, the AH-64A model was being revised to increase its accuracy. The changes included substituting interval rating scales for ordinal workload scales, revising the task/workload analysis, and revising the function and segment decision rules.

During the current contract year, revision of the model continued but was not completed because of work on higher priority projects.

Validation of the AH-64A Workload Prediction Model

During the previous contract year, a report (Hamilton, 1990) documenting the validation research approach was written and submitted to ARIARDA. The report calls for the measurement of several objective and subjective measures of workload to be used as validation criteria. In addition, a request was prepared and submitted to Forces Command (FORSCOM) for support in validating the AH-64A model.

During the current contract year, the FORSCOM request for support of this research was denied. The reasons for the denial were discussed with FORSCOM personnel and another

request for support was prepared with reduced requirements for personnel and Combat Mission Simulator resources. The revised research approach was submitted and an in-progress review of the validation research was conducted for ARIARDA approval.

Subsequently, three sets of materials were prepared for the validation research. First, materials required to collect the NASA-Task Load Index (the subjective measure of workload) were adapted for the AH-64A simulation environment. Second, rating scales were drafted to evaluate aircrew performance during the AH-64A mission. Finally, the materials were compiled for developing equal-interval workload ratings scales based on a sample from the AH-64A pilot population. Alternative methods of obtaining physiological measures of workload were evaluated for the validation research, but at the close of the current contract year physiological measurement equipment had not been acquired.

Development of the Longbow Apache Workload Prediction Model

During the previous contract year, a secure computer system was established for developing the Longbow Apache workload prediction model. The major modifications to the Longbow Apache were identified, changes to the composite mission scenario resulting from the modifications were analyzed, and the additional segments needed to model the changes were identified.

During the current contract year, progress on the Longbow task/workload analysis was delayed because of work on higher priority projects.

Work Projected

Development of the AH-64A Workload Prediction Model

During the next contract year, the model revisions will be completed and the revised model will be exercised to produce estimates for each of the mission segments. The technical report by Szabo and Bierbaum (1986) will be revised to reflect the final version of the AH-64A model. The workload predictions produced by the exercise of the model will be described in a research report.

Validation of the AH-64A Workload Prediction Model

Upon completion of the AH-64A model revisions, final ARIARDA approval of the detailed research plan, acquisition of physiological recording equipment, and identification and coordination of a research subject population, the validation research will begin. A report describing the results of the research will be prepared when the validation effort is completed.

Development of the Longbow Apache Workload Prediction Model

The task/workload analysis will continue. The necessary function and segment decision rules will be developed and the model will be programmed using the TOSS software. The model will be exercised and the workload predictions will be compared to AH-64A model predictions. Finally, a research report will be prepared to document the results of the model's predictions and the comparisons between the two AH-64 models.

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UH/MH-60 AND CH/MH-47 TASK/WORKLOAD ANALYSES

Mr. Carl R. Bierbaum, Project Director

Background

The Special Operations Aircraft (SOA) Program Manager's (PM) office at the Army's Aviation Systems Command has been tasked to develop an MH-60K and an MH-47E aircraft to support the Special Operations Forces. The SOA will consist of existing CH-47D and UH-60A airframes with increased power and new integrated cockpits. The integrated cockpit will replace the existing instrument and gauge configuration in both the CH-47D and UH-60A aircraft with four multifunction display (MFD) units.

The effect that the high technology modifications being proposed for the MH-60K and the MH-47E may have on crewmember workload must be evaluated to ensure that the crewmembers can utilize the many MFD options effectively. Anacapa Sciences personnel, under contract to the Army Research Institute Aviation Research and Development Activity (ARIARDA), have developed a methodology for predicting operator workload during system design. The workload prediction methodology was developed during the design of the Army's proposed multi-purpose lightweight helicopter, the LHX (Aldrich, Craddock, & McCracken, 1984; Aldrich, Szabo, & Craddock, 1986). The LHX methodology was subsequently refined and used to develop baseline workload prediction models for the AH-64A Apache (Szabo & Bierbaum, 1986), the UH-60A Black Hawk (Bierbaum, Szabo, & Aldrich, 1989), and the CH-47D Chinook (Bierbaum & Aldrich, 1990). Because ARIARDA had developed a successful methodology for conducting mission/task analyses and predict-ing workload, the SOA Aviation Project Office requested that ARIARDA develop a SOA scenario, conduct the mission/task analyses, and predict the crewmember workload for the MH-60K and MH-47E aircraft.

Research Objectives

The overall objective of this research area is to deter-mine the effect that the integrated cockpit modifications are likely to have on the workload of UH-60A and CH-47D crew-members. Specifically, the research is designed to:
- conduct a mission/task analysis of the MH-60K,
- determine the effect that the proposed MH-60K modifications will have on crew workload,
- conduct a mission/task analysis of the MH-47E, and

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- determine the effect that the proposed MH-47E
  modifications will have on crew workload.

Research Approach

The approach selected for meeting the research objec-
tives is a refinement of the Task Analysis/Workload (TAWL)
methodology that was developed for the LHX and the AH-64A
research projects. The UH/MH-60 and CH/MH-47 workload
analyses are divided into the two projects described below.

- In the first project, a mission/task analysis of crew
  workload will be conducted and a computer model of
  crewmember workload will be developed for the MH-60K
  helicopter. The MH-60K workload prediction model will
  be exercised and compared to the UH-60A model results
  to determine the effect that the MH-60K design modifi-
  cations are likely to have on crewmember workload.

- In the second project, a mission/task analysis of crew
  workload will be conducted and a computer model of
  crewmember workload will be developed for the MH-47E
  helicopter. The MH-47E workload prediction model will
  be exercised and compared to the CH-47D model results
  to determine the effect that the MH-47E design modifi-
  cations are likely to have on crew workload.

Work Completed

MH-60K Task Analysis and Workload Prediction Model

The development of the MH-60K workload prediction model
was completed during the current contract year. The MH-60K
mission begins with a departure from a base site. The pilot
flies contour from the base to a rendezvous point, where air-
to-air refueling is accomplished. After refueling, the pilot
flies nap-of-the-earth (NOE) from the rendezvous point to the
landing zone (LZ). The pilot then flies back to a rendezvous
point for refueling and continues to the base. The complete
mission is conducted at night with night vision goggles.
Preflight and postflight activities are not included in the
analysis.

The mission scenario was divided into five phases for
analysis. The five mission phases were divided into 15
unique segments, which were further divided into 71 unique
functions. Each function was described and assigned a numer-
ical identification code for entry into the MH-60K workload

model. The '71 functions were then divided into 234 tasks. The researchers prepared a description for each task, assigned it an identification code, and estimated the level of workload for six workload components. All the data were entered into the TAWL Operator Simulation System (TOSS) data files.

Subsequently, the researchers developed decision rules to combine the tasks into functions and to combine the functions into segments. The decision rules were then entered into the TOSS program and the workload prediction model was exercised to provide estimates of component workload at each half-second interval for each segment in the scenario. The workload estimates for the MH-60K were then compared to the workload estimates for the UH-60A performing an identical mission scenario.

A report of the MH-60K workload predictions and the comparison with the UH-60A workload predictions was prepared and submitted to ARIARDA in June 1990 (Bierbaum & Hamilton, 1990a). The results of the comparison indicate little difference in the predicted workload for the MH-60K and UH-60A aircraft. Overload conditions in both aircraft occurred only during threat encounters.

MH-47E Task Analysis and Workload Prediction Model

During the current contract year, work was completed on the development of an MH-47E workload prediction model. The MH-47E mission scenario, mission phases, segments, and functions are the same as those identified for the MH-60K. However, only 230 tasks were identified for the MH-47E. A report of the MH-47E workload predictions and the comparison with the CH-47D workload predictions was prepared and submitted to ARIARDA in September 1990 (Bierbaum & Hamilton, 1990b). The results of the comparison indicates little difference in the predicted workload for the MH-47E and CH-47D aircraft. Overload conditions in both aircraft occurred only during threat encounters.

Work Projected

Unless revisions are required to the draft report (Bierbaum & Hamilton, 1990b), no further work is anticipated on this project.

19

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DESIGN AND APPLICATION OF FLIGHT SYMBOLOGY

Dr. Richard Weeter, Project Director

Background

The AH-64A attack helicopter is the first Army aircraft to feature the Pilot Night Vision System (PNVS). The PNVS is a display system that enables crewmembers to conduct attack missions at night and in adverse weather by providing an infrared image of the external visual scene. The PNVS presents a 30° x 40° field of view to the pilot's right eye via a 1 inch in diameter cathode ray tube mounted on the pilot's helmet. A set of 27 symbols, intended to provide critical flight and targeting information, can be projected onto the field of view.

The PNVS symbology consists of alphanumeric, position, size, and shape-coded symbols. Some of the symbols, such as the heading scale and lubber line, are adaptations of traditional electromechanical instruments that appear at fixed locations on the display. Many of the other symbols are unique, dynamic representations of spatial information. Symbols, such as the projected center line of the aircraft or the computed impact points of weapons, may appear, disappear, or move on and off the display as a result of changes in the aircraft or sensor orientation.

Little empirical research has been conducted to evaluate symbology formats (Buckler, 1978a, 1978b; Schmit, 1977). To date, no empirical research has been identified that evaluates whether the PNVS symbology format enhances or degrades information transfer during mission tasks. Nevertheless, the current Department of Defense military standard for symbology formats, MIL-STD-1295A(AV), is patterned after the AH-64A PNVS symbology set (Department of Defense, 1984). In the foreword of that document, the authors acknowledge the need for research on symbology format design.

Historically, however, the development of symbology has been evolutionary rather than systematic (Shrager, 1977). An example is the symbology developed for the Army's MH-60K and MH-47E special operations helicopters (International Business Machines, 1988). Different symbols are used to present some of the same basic flight information represented in the PNVS symbology format, but no information is publicly available to explain how the new symbols were developed or how the new symbology format will affect crew performance.

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23

Need

Currently, there is no widely accepted research methodology for addressing critical symbology design issues or for evaluating the effectiveness of existing symbology sets. Therefore, a methodology is needed to evaluate the effectiveness of the AH-64A PNVS symbology set, which represents the current military standard in symbology formats. The methodology must address whether the symbol coding dimensions are compatible with the cognitive processes of AH-64A crewmembers. Ideally, successive experiments will culminate in the development of symbol and display format design criteria. The resultant symbology should (a) be compatible with the known visual and cognitive capabilities of aviators, (b) present information that can be interpreted accurately and efficiently under stressful conditions, and (c) complement rather than interfere with information available from the natural external visual scene and from sensor-provided imagery.

The Army Aviation Systems Command (AVSCOM) tasked the Army Research Institute Aviation Research and Development Activity (ARIARDA) to initiate research to meet these needs. Anacapa Sciences personnel began work on the project in February, 1987.

Project Objectives

There are two objectives of this project: (a) to develop a methodology for evaluating aircraft display symbology and (b) to conduct empirical evaluations of the existing AH-64A PNVS symbology.

Research Approach

Following a review of the literature, a selective visual attention approach was chosen to evaluate the PNVS symbology because it provides a method of empirically comparing the demand of attending to visual stimuli. In some types of selective visual attention paradigms, subjects perform fundamental visual tasks similar to those required of pilots using aircraft visual displays (e.g., Lyon, 1987; Williams, 1982). These experiments revealed a number of factors that affect attentional performance on visual tasks. For example, Eriksen and Hoffman (1972) demonstrated that efficient encoding of information from visual displays can be detrimentally affected by the number, nature, and proximity of noise elements. Pilots using aircraft visual displays with several

symbols in close proximity, a condition described as display clutter, have reported similar encoding difficulties. Lyon suggested that rapid attention shifts may be a measurable component of skilled performance in vision dependent tasks.

The cueing procedure for the cued line-of-sight (LOS) symbol in the AH-64A PNVS symbology set was selected for the initial evaluation. The purpose of the cued LOS symbol is to indicate to the pilot where the copilot-gunner is looking. The procedure uses two different cues, a one-dot cue and a two-dot cue, to indicate one of the eight search areas in the PNVS field of view. The cueing dots also have a secondary purpose: they flash to indicate that an Integrated Helmet and Display Sighting System (IHADSS) boresight is required.

Three experiments were designed to evaluate the cued LOS symbol. The three experiments address differences in the one- and two-dot conditions, differences in presentation duration, the effects of the secondary cueing meaning, and the effects of practice on cueing accuracy. In addition to evaluating the cued LOS symbol, the experiments were designed as a test of the selective attention paradigm for evaluating symbology design.

Work Completed

During the previous contract year, three selective visual attention experiments were conducted to evaluate the PNVS cueing procedure. Experiment 1 was conducted to evaluate the task demand of attending to each of three cueing conditions: no-dot, one-dot, and two-dot. The results from six subjects indicate that attending to the two-dot cue is more difficult than attending to the one-dot cue at the fastest presentation durations. Accuracy was significantly higher in the no-dot condition except at the slowest presentation duration. In the one- and two-dot conditions, accuracy increased as the presentation duration increased; at 133 ms, the average percentage of correct identifications was approximately 94%.

Experiment 2 evaluated the effectiveness of the one- and two-dot cues in a target acquisition task. For the 10 subjects in Experiment 2, the one-dot cue was more effective than the two-dot cue at presentation durations of less than 267 ms. As in Experiment 1, accuracy increased as the presentation duration increased. Performance gradually improved for both the one- and the two-dot cues during the first 768 trials. There was no significant improvement for either cue between 768 and 1,280 trials.

In Experiment 3, the same 10 subjects who participated in Experiment 2 continued to perform the target acquisition task, but on one-half of the trials the cueing dots flashed to simulate an IHADSS boresight requirement. Accuracy with both the one- and two-dot cues was significantly degraded by the presence of flashing dots. The subjects showed no significant improvement in accuracy across trials.

The results of the three experiments indicate that (a) the two cueing methods (one- and two-dot) are differentially effective in cueing shifts of visual attention at short presentation durations, (b) the ability to use the cues improves with practice, and (c) the secondary purpose of the cueing dots significantly interferes with their primary purpose. The results led to four recommendations for possible design options, training considerations, and further research: (a) redesign the Cued LOS procedure to create equally effective cues for all portions of the field of regard, (b) develop a different method for indicating a boresight requirement, (c) provide extensive practice in using the cueing procedure, and (d) advise the pilots to ensure they are interpreting the cue accurately before beginning a search for the Cued LOS. In addition, the ability of the selective visual attention paradigm to detect these effects indicates that it is an appropriate method for evaluating some aspects of existing and proposed aircraft display symbology formats.

During the current contract year, a report (Weeter & McAnulty, 1990) describing the literature in selective visual attention and the three experiments evaluating the cued LOS was drafted and submitted to ARIARDA. Following the ARIARDA review, the report was revised and submitted in final format.

Work Projected

Submission of the report completes the planned work on this project. Unless additional research is directed by ARIARDA, no further work will be conducted to evaluate the PNVS symbology set.

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HUMAN FACTORS DESIGN FOR
MAINTENANCE OF ARMY AVIATION SYSTEMS

Dr. John W. Ruffner, Project Director

Background

Even though there have been advances in the quality of maintenance training programs and job performance aids in recent years, Army aviation maintenance capabilities have not kept pace with the requirements. Army aviation systems have continued to increase in sophistication and complexity with little or no accompanying increase in maintainer skill levels and capabilities. Increased system complexity has resulted in increases in both the amount and complexity of maintenance requirements, particularly in the area of fault diagnostics. For example, Baker (1990) found a growing consensus among Army managers that there are not enough qualified soldiers to maintain the increasingly sophisticated aviation systems.

Several manpower and personnel factors have contributed to the disparity between aviation maintenance requirements and maintenance capabilities. First, it has become increasingly difficult for maintainers to achieve the skill levels required to maintain modern Army aviation systems during their first term of enlistment (Bond, 1987). Second, attrition among Army aviation maintainers has been high. Less than 40% of those trained in an aviation maintenance military occupational specialty (MOS) have reenlisted in the Army following their first 4-year term (U.S. Total Army Personnel Command, 1989). Attrition after the first enlistment term has produced a lack of both skilled maintainers and supervisors who are available for training the maintainers during their first term.

Third, the problem is likely to worsen. Over the next five years, a steady decline is projected in the traditional military target recruitment group of 18- to 21-year-old males in the U.S. population. The Army will have to compete with the other military services and with the civilian sector to attract the most capable individuals from the reduced recruitment pool (Dierker, Brandt, & Jerrigan, 1987). To attain the required maintainer manpower levels, the Army will have to recruit a larger percentage of individuals who traditionally have had lower, maintenance-related aptitude levels than at present. Consequently, the average maintenance-related aptitude level of recruits is expected to decrease, thus increasing the training burden.

The discrepancy between maintenance requirements and maintainer capabilities is especially critical given the high costs of maintenance. Each year, approximately 25 - 30% of the annual budget for the Department of Defense has been expended for maintenance of military systems. The total maintenance costs for a piece of equipment throughout its life-cycle has often exceeded its acquisition costs (Christensen & Howard, 1981). Maintenance costs have often accounted for the highest percentage of an aviation system's total life-cycle costs.

In response to these problems, the Army initiated the Manpower and Personnel Integration (MANPRINT) program during the mid-1980s to ameliorate the manpower, personnel, training, human factors, health hazard, and safety problems associated with fielding complex systems. The primary objective of the MANPRINT program was to influence the design of military systems as early as possible so they can be operated and maintained by soldiers who possess the aptitudes, knowledge, and skills that the Army predicts will be available when the systems are fielded (Department of the Army, 1987).

In support of the MANPRINT program, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) developed a set of MANPRINT tools to enable system designers to predict the manpower, personnel, and training requirements for a proposed design (Booher & Hewitt, 1990). Once estimated, the requirements are compared with the system operation and maintenance performance requirements and with the predicted numbers, skill levels, and training of operators and maintainers. The tools are designed to enable designers to simulate the effect of different combinations of manpower, personnel, and training (MPT) variables on overall system performance and to provide a basis for evaluating MPT tradeoffs.

Although the MANPRINT tools are useful for evaluating the effect of MPT variables on system maintenance, they have two major shortcomings with respect to equipment design. First, the tools do not assess the effects of equipment design (human factors) variables on the maintainability of a proposed system. The user is required to supply estimated repair times for each component before running the simulation. The times are estimated as deviations from baseline levels for similar components in comparison systems. Thus, the validity of the times and the accuracy of the simulation depend on the similarity of the comparison systems to the proposed system. Second, although the tools are designed to work together to estimate the impact and interactions of MPT constraints and requirements, they do not allow the user to evaluate the effect of equipment design variables on MPT

requirements or of tradeoffs between MPT variables and equipment design variables.

Need

The literature suggests that equipment design is a major contributor to aviation system maintenance effectiveness. Current Department of the Army policy requires that maintainability be designed into systems and equipment rather than introduced through post design modifications suggested by test results, field complaints, or product improvement initiatives (Department of the Army, 1987). Therefore, there is a need (a) to understand the effects of equipment design variables on aviation system maintenance and their interactions with MPT variables and (b) to develop tools for estimating the combined effects of MPT and human factors (HF) variables on maintainer performance.

In December, 1987, the Army Research Institute Aviation Research and Development Activity (ARIARDA) directed that Anacapa Sciences initiate research to address human performance problems in the area of Army aviation maintenance. During the first project conducted in this research area, Ruffner (1990) reviewed the literature on Army aviation maintenance, maintainability design, and several HF tools that were judged to be potentially useful for improving the maintainability design of Army aviation systems. He concluded that computer simulation models of maintainer performance have the highest utility for improving maintainability design and that a need exists to develop a comprehensive, integrated tool for predicting the maintainability of a proposed aviation system. Ideally, this tool should allow the user to predict the effects of a proposed system's design features on its maintainability as well as on its MPT requirements.

Research Objective

Before developing a comprehensive, integrated, prediction tool, a better understanding is required of the problems that exist in the maintenance of Army aviation systems. Therefore, this research project was designed (a) to develop a procedure for identifying problem areas in Army aviation maintenance and (b) to determine if the problem areas might be attributed to MPT or HF deficiencies. The research was limited to the two newest helicopters in the Army inventory, the UH-60A and the AH-64A.

Research Approach

The research approach was divided into two overlapping phases. During the first phase, fact-finding visits were scheduled to the U.S. Army Aviation Logistics School (USAALS), Fort Eustis, Virginia, and to field maintenance units at Fort Campbell, Kentucky, and Fort Hood, Texas. The purposes of the visits were to receive an orientation to maintainer training and to identify maintenance training and field maintenance problems and issues.

During the second phase, analyses were planned for historical maintenance data contained in the U.S. Army Aviation Systems Command (AVSCOM) Unscheduled Maintenance Sample Data Collection (UMSDC) data base. The purposes of the analyses were to identify the types of data available and to assess their utility for identifying Army aviation maintenance problems attributable to MPT or equipment design deficiencies.

Work Completed

Fact-Finding Visits

The visit to the USAALS was conducted in November, 1989. AH-64A and UH-60A instructors and subject matter experts (SMEs) indicated that the factors having the greatest impact on institutional maintenance training are insufficient training time and antiquated training equipment.

The visits to AH-64A and UH-60A maintenance units at Fort Campbell were conducted during April and May, 1990; the visit to the AH-64A maintenance units at Fort Hood was conducted in July 1990. SMEs at these locations indicated that the following factors have the greatest impact on field maintenance performance:

- excessively high equipment failure rates,
- insufficient personnel,
- excessive extra duties,
- a lack of institutional training in critical skills (e.g., troubleshooting),
- a lack of senior noncommissioned officers to support supervised on-the-job-training, and
- inaccessibility of high failure rate components.

32

Maintenance Data Base Analyses

Historical maintenance data were obtained for the AH—64A and UH—60A for the period 1 January 1987 to 31 December 1989, using standard AVSCOM statistical programs and reports. This period was chosen to provide relatively recent maintenance data and to minimize the influence of short-term problems (e.g., storm damage). At the end of the contract year, data summaries were completed for the AH-64A.

After examining all the variables available in the UMSDC data base, three variables proved useful for identifying potential problem tasks: maintenance events, man-hours used, and maintainer MOS. A maintenance task was judged to be a potential problem task if it met at least one of these criteria:

- it occurred frequently, as indicated by a large number of maintenance events;

- it accounted for a large number of man-hours; or

- it required one or more MOSs that were difficult to recruit, expensive to train, or in short supply.

A list of 161 potential AH-64A problem tasks was generated by identifying AH-64A components and tasks that had a high number of maintenance events and man-hours. For each task, data were obtained on the MOSs that performed the task and the average task performance times for personnel in each MOS. Although the UMSDC data base provided information useful for identifying the MOSs, it did not provide recruiting, training, and supply data.

The results indicate that the highest number of potential problem tasks were in the Avionics, Airframe, Rotor, Drive, and Target Acquisition and Designation Systems (TADS). Across all the components, the most frequently occurring types of potential problem tasks were repair and remove/replace. MOS 67R (crew chief, mechanic) was the MOS that performed the highest percentage of potential problem tasks, followed by MOS 35K (avionics mechanic) and MOS 68J (fire control repairer). The data for the 161 potential problem tasks were organized into a separate data base that can be used during follow-on analyses.

Conclusions

The results of the fact-finding visits suggest that there are maintenance problems for the AH-64A and UH-60A that are attributable to MPT or HF deficiencies. The results of

the analyses of the UMSDC data base suggest that it is useful for identifying potential problem tasks. Data are provided that can be used to prioritize the tasks according to the criteria of interest and to select tasks for follow-on analyses.

However, the data base does not contain sufficient information to determine if the potential problem tasks are due to MPT or HF deficiencies, as opposed to reliability, supply, or administrative deficiencies. Determining the probable causes will require additional research, such as a detailed task analysis or survey of maintenance SMEs.

Work Projected

A report describing the results of the AH-64A data analysis will be completed and submitted to ARIARDA for formal review. If directed by ARIARDA, further research (e.g., completion of the UH-60A data analysis, detailed task analyses) will be conducted in this research area.

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OH-58D WARRIOR CREW REQUIREMENTS

Dr. John W. Ruffner, Project Director

Background

Historically, the OH-58 aircraft has been employed in the unarmed aerial observation role with one rated pilot accompanied by an officer observer or an enlisted aerial observer (EAO). In January 1990, the Secretary of the Army directed that the role of the OH-58D helicopter be expanded to include armed reconnaissance, light attack, and multi-purpose missions. To achieve this, the OH-58D was modified to carry HELLFIRE and STINGER missiles, 2.75 in. rockets, a 2,000 pound cargo hook for external sling loads, and external seats for troop transport. Thus equipped, the helicopter is known as the OH-58D Warrior, or the Multi-Purpose Light Helicopter, and can be used for rapid deployment to worldwide contingency operations.

An important issue that accompanied the modification was whether the OH-58D Warrior should be fielded with an authorized crew of two aviators or with the original Table of Organization and Equipment manning of one rated pilot plus an EAO (MOS 93B). In July 1990, the Training and Doctrine Command Systems Manager for the OH-58D requested that ARIARDA conduct research to investigate the potential benefits of adding a second pilot to the authorized OH-58D Warrior crew. ARIARDA developed a research plan and requested that Anacapa Sciences provide research support in August 1990.

General Research Objective

The general objective of this research is to provide the Army with a "quick-look" analysis of crew performance for the OH-58D Warrior with either a dual pilot or pilot-EAO crew. The research addresses flight safety, mission flexibility, combat effectiveness, and crew endurance under conditions of stress and fatigue, with emphasis on crew performance with night vision goggles. Specific research objectives are identified for each Anacapa Sciences task under the research approach.

Research Approach

Six research tasks were identified in the ARIARDA research plan:

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- conduct a literature review,
- perform an analysis of OH-58 accidents,
- develop and conduct structured interviews with OH-58D pilots and EAOs,
- compare Multitrack Test Battery data from EAOs and aviator candidates,
- perform a tactical mission simulation in the Army's AIRNET facility, and
- perform an in-flight evaluation of OH-58D missions with dual pilot and pilot-EAO crews.

Anacapa Sciences personnel were directed to provide technical assistance on the first task and were given primary responsibility for performing the second, third, and fifth tasks.

Literature Review

The objective of this task is to review the literature relevant to the OH-58D crew mix question. To assist in accomplishing this objective, Anacapa Sciences personnel will review the course programs of instruction (POIs), flight training guides, and student handouts for the OH-58A/C and OH-58D Aeroscout Observer Courses and for the OH-58D Aviator Qualification Course.

OH-58 Accident Analysis

This task has two specific objectives: (a) to identify instances where the on-board presence of a second aviator potentially would have avoided or minimized the mishap and (b) to identify specific deficiencies attributable to having a nonrated crewmember occupying the left seat. To accomplish these objectives, Anacapa researchers will review recent OH-58 accident cases archived in the Army Safety Management Information System.

Structured Interview

The objective of this task is to obtain the opinions of pilots and EAOs about factors affecting the most appropriate crew composition for the OH-58D Warrior, particularly those factors that affect aircrew coordination. To accomplish this objective, Anacapa researchers will develop and administer a structured interview to OH-58D experienced aviators and crewmembers.

AIRNET Simulation

The objective of this task is to examine the performance of alternative crew mixes in a tactical OH-58D Warrior simulation. To accomplish this objective, Anacapa researchers will develop and run tactical scenarios in the AIRNET simulator located at the U.S. Army Aviation Center. In the tactical scenarios, the OH-58D Warrior aircrews would engage a simulated opposing force.

Work Completed

Literature Review

Anacapa Sciences personnel reviewed current POIs, flight training guides, and student handouts for the courses that are relevant to the OH-58D crew requirements issue. The following documents were reviewed:

- Aeroscout Observer Course POI, Course Number 600-93B10 (42);
- Aeroscout Observer Course Student Handout;
- OH-58 Enlisted Aeroscout Observer Course Flight Training Guide, Course Number 600-ASI-ZI;
- OH-58D Aeroscout Aerial Observer Qualification POI Course Number 600-ASI-W5 (93B) 4C;
- OH-58D Field Artillery Aerial Observer Qualification POI, Course Number 250-F31 (4J); and
- OH-58 Aviator Qualification Course POI, Course Number 2C-SI IA/2C-152D (4A).

Information from the POIs on course duration, flight time, training device time, and specific subjects trained was extracted, summarized, and submitted to ARIARDA.

OH-58 Accident Analysis

Anacapa Sciences personnel extracted summary data from the Army Safety Management Information System for all OH-58 Class A - E accidents involving crew error that occurred between October 1983 and July 1990. The cases were reviewed to find instances in which a lack of air sense, poor attitudes about crew coordination, or inadequate knowledge of emergency procedures contributed to the accident. These cases were selected because they may provide the basis for establishing the minimal qualifications for the second crewmember in the OH-58D Warrior.

In the initial review, the Class A - C accident cases were categorized into those involving single pilots, dual pilots, and pilots plus aerial observers (AOs). Cases were also identified that require a more detailed analysis of the entire accident folder located at the U.S. Army Safety Center (USASC). Each case was reviewed by at least two analysts who compared their reviews and resolved any differences.

Instructions for the detailed review of each accident folder were prepared, the relevant data to be extracted were determined, and a form was developed for recording the information. The information included the type of mission, flight environment, phase of flight, workload levels, stress/fatigue levels, experience levels for each crewmember, the errors that were committed, and their causes. The analysis also included an assessment of the actions required to assist the pilot flying to preclude or minimize the accident and of the specific skills and knowledge that were needed to provide the assistance.

Each accident report selected for detailed review was examined by at least two analysts, and their reviews were compared to resolve any differences. Finally, the data were analyzed and comparisons made for each crew combination to determine if there was evidence in the accident data to support a specific crew composition for the OH-58D Warrior aircraft.

An analysis of the mishap summaries (Class A - E) was initiated to look for specific evidence related to a lack of air sense, poor crew coordination attitudes, or knowledge of emergency procedures. At the end of the contract year, approximately half of the cases had been analyzed.

Structured Interview

Anacapa Sciences personnel began work on this task by identifying OH-58D Warrior crew composition issues that needed to be addressed during the interview. The primary sources of information were:
- a questionnaire developed by the Directorate of Combat Developments about the fighting capabilities of the OH-58D Warrior under different crew compositions;
- discussions of dual pilot versus pilot-EAO crew composition issues with OH-58D instructor pilots (IPs) from the Training System Manager (TSM) - Scout office of the Directorate of Evaluation and Standardization;

- a review of the literature on (a) OH-58D tasks, techniques, and tactical deployment procedures and (b) aircrew coordination issues; and

- specific aircrew coordination issues identified in the ARIARDA research plan.

Project personnel developed a draft version of the structured interview form, which was reviewed by ARIARDA and a TSM-Scout IP and subsequently revised. The final version of the interview form consists of two parts. In Part I, the respondent is asked to provide background information about relevant OH-58D experience (e.g., recent assignments, flight experience). In Part II, the respondent is asked about (a) the knowledge, skill, and ability requirements of the OH-58D Warrior crew during reconnaissance, light attack, and multipurpose missions; (b) crew coordination requirements; and (c) crew endurance and fatigue. In the crew coordination requirements section, the respondent is asked about five specific crew coordination issues: mission understanding, information exchange, workload management, cross-monitoring, and team relationships/aircrew climate.

The research plan originally called for the project personnel to conduct interviews with OH-58D aviators and EAOs in two Forces Command (FORSCOM) units. However, data collection in FORSCOM units was indefinitely postponed because of the deployment of U.S. forces for Operation Desert Shield. Therefore, the interviews were restricted to aviators at Fort Rucker with experience flying the OH-58D. By the end of the contract year, interviews had been conducted with three OH-58D aviators who were attending the Officer Advanced Course.

AIRNET Simulation

Anacapa Sciences personnel began work on this task by reviewing documents describing the tactical employment of the OH-58D Warrior. Subsequently, they developed tactical scenarios based on the reconnaissance (cavalry) and light attack missions that could be run in the AIRNET facility. The researchers also made a preliminary coordination visit to the AIRNET facility to review vehicle placements for the two mission scenarios. However, the evaluation of the crew composition issue in the AIRNET facility was indefinitely postponed in August 1990 because of the deployment of U.S. forces for Operation Desert Shield. In August 1990, the researchers prepared and delivered a memorandum to ARIARDA to document the details of the tactical scenarios and to make recommendations about experimental procedures.

Results

Literature Review

OH-58D EAOs initially qualify for the 93B military occupational speciality by completing the OH-58A/C Aeroscout Observer Course. During this course, the students learn to navigate, perform communications tasks, conduct reconnaissance, and acquire basic flight skills. In addition, they receive instruction on general aviation subjects and OH-58A/C aircraft operations. The course lasts 14 weeks and 3 days with 67 hours of flight time, of which 9 hours are devoted to EAO primary flight training

EAOs receive additional training and qualify for the W5 speciality skill identifier by completing the OH-58D Aeroscout Observer Course, which lasts 7 weeks and 3 days. During this course, the students receive 28 hours of instruction using the Classroom Systems Trainer, 20 hours using the Cockpit Procedures Trainer, and 41 hours of actual flight time. Nineteen of the 41 flight hours consist of minimal instruction in flying the OH-58D under normal visual flight rules conditions and in performing emergency handling tasks. The majority of the remaining time is spent in familiarization training with the OH-58D communications and navigation systems, the Mast-mounted Sight System, and the Airborne Target Handover System.

EAOs receive only about one half of the flight training provided to OH-58D aviators, with about one fourth of the EAOs' flight training hours devoted to hands-on flying. After assignment to an operational unit, EAOs are required to fly a minimum of 70 hours in the left seat semiannually and to receive 2 hours of training in emergency handling tasks every 90 days. In summary, EAOs are minimally qualified to fly the OH-58D if the pilot becomes incapacitated and are not trained to fly an aircraft that is damaged or disabled.

OH-58 Accident Analysis

Anacapa researchers reviewed 657 OH-58 Class A - E accident cases involving crew error during the period of October 1983 to July 1990. Thirty-four Class A - C cases were identified that required a more detailed review. Complete data were available at the USASC for 30 of the 34 cases: 9 of the accidents were single pilot, 14 were dual pilot, and 7 were pilot-AO crews.

Overall, the evidence associated with crew composition, flight experience, workload, stress/fatigue levels, and the types of errors committed by the crews in the accident sample does not offer strong support for either the pilot-AO or the dual-pilot crew mix. The workload levels were generally higher for the dual-pilot crews, but this is probably due to the more demanding missions and flight environments (e.g., nap-of-the-earth flight with night vision goggles) flown by these crews. Because many of the cases involved obstacle strikes, the primary assistance that the pilot flying needed was help with obstacle clearance, which does not require any special knowledge or skills. A few single-pilot cases appeared to indicate a need for a second pilot. However, the apparent need for a second pilot was contradicted by similar dual-pilot cases in which the second pilot failed to provide the assistance needed to avoid the accident.

The accident data do suggest that the lack of air sense, poor crew coordination, and inadequate knowledge of emergency procedures occurs more often in OH-58D mishaps than in OH-58A/C mishaps. This implies that the more complex OH-58D may require a more skillful crew, possibly including two fully qualified aviators. This is especially true for emergency procedures in which AOs receive little if any institutional training.

Structured Interview

The three aviators interviewed had recent experience flying the OH-58D Warrior with Task Force 118 in the Persian Gulf. The total flight experience of the aviators ranged from 1,100 to 1,200 hours; flight experience in the OH-58D ranged from 450 to 550 hours. The aviators' experience was limited to dual-pilot OH-58D crews; none of the aviators had experience flying with an EAO.

The aviators strongly preferred the dual-pilot crew option over the pilot-EAO crew option. They believed that a second pilot brought a more highly developed air sense and tactical mission sense to the crew. Thus, they believed the second pilot improved the capabilities of the aircraft, increased crewmember endurance, increased mission effectiveness, enhanced mission safety, and increased the likelihood of recovering the aircraft when the pilot flying became disoriented or incapacitated.

Of the aircrew coordination issues addressed, the aviators believed a second pilot was more likely to have a common understanding of mission requirements, to perform more

43

effective premission planning, to announce decisions affecting the other crewmember's actions, to request assistance from the other crewmember when overloaded, and to cross monitor the other crewmember's performance. The aviators identified the most critical factors favoring a dual-pilot crew as (a) mission factors (e.g., workload, task priority, and time pressure), (b) the flight environment (e.g., flying with night vision goggles over water), (c) safety, (d) cost (i.e., the minimum amount of additional time required for an aviator to acquire proficiency in left-seat tasks), and (e) flexibility in crewing the aircraft.

Work Projected

Literature Review

Submission of the summaries of the POIs and flight training guides completes Anacapa's technical assistance on this task. Unless directed by ARIARDA, no further work is planned on the literature review.

OH-58 Accident Analysis

The remaining Class A - E case summaries will be reviewed to determine if there is a basis for determining minimal qualifications for the second crewmember on the OH-58D Warrior helicopter based on air sense, crew coordination attitudes, or knowledge of emergency procedures. In addition, a draft report summarizing the research approach and findings will be prepared and submitted to ARIARDA.

Structured Interview

Interviews will be scheduled with OH-58D aviators who have experience flying with pilot-EAO crews. After the interviews are completed, their responses will be compared to those of the aviators who have only dual-pilot experience. In addition, a draft report summarizing the research approach and findings will be prepared and submitted to ARIARDA.

AIRNET Simulation

Unless additional directions are received from ARIARDA after the freeze on FORSCOM assets is lifted, submission of

the tactical scenarios and recommendations for their utilization completes the activities on this task.

Final Report

The work accomplished and the work projected for this project will be described in ARIARDA's final report on the OH-58D Warrior Crew Mix.

AVIATION SAFETY RESEARCH

Ms. R. Coleen Thornton and Mr. Joseph L. Zeller, Jr.
Project Directors

Background

As early as the 1950s, the identification of training content and techniques that enhance the coordinated perfor-mance of aircrews was a concern of military researchers (Sherwood, 1953). More recently, the commercial transport aviation industry has focused on increasing the safe and efficient operation of aircraft through training in Cockpit Resource Management (CRM) (Jensen, 1987, 1989; Povenmire, 1989) and its cornerstone, aircrew coordination (Helmreich, 1986). CRM is defined as the utilization of information, equipment, and people as resources to achieve safe and efficient flight operations (Lauber, 1980). Conclusions drawn from research projects and from accident and incident data bases support the importance of effective CRM and the need for related training in aviation.

As the importance of evaluating aircrew performance and improving aircrew coordination skills has become more appar-ent, both simulator and classroom training have been employed more frequently to improve CRM skills in commercial and mili-tary aviation. One method utilized by commercial aviation to evaluate and improve CRM skills is Line-Oriented Flight Training (LOFT), a flight simulation technique designed to resemble operational line flying. A similar simulator tech-nique used by the Air Force, Mission-Oriented Simulator Training (MOST), was designed to reflect the unique nature of military missions.

Classroom CRM training generally concentrates on dimen-sions thought to influence aircrew performance, such as interpersonal skills, leadership, communication, and stress management. A training program may include classroom presen-tation, practice and feedback, and reinforcement of learning (Foushee, 1985). These courses attempt to create a collegial atmosphere in which crewmembers share problem solving and decision making responsibilities.

Unfortunately, the majority of research and training programs developed to enhance flight safety and aircrew mission performance is directed toward fixed wing aircraft flying at high altitudes. Very little research has investi-gated aircrew coordination within the Army's primary flight regime: rotary wing aircraft flying at low altitudes in a

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tactical environment, frequently at night and over terrain with marginal visual contrast. These tactical constraints demand aircrew coordination skills that increase performance and safety in a time pressured environment typically not present in commercial aviation. Differences between Army rotary wing flying and fixed wing flying suggest that the adoption of fixed wing training programs may produce less than optimal results.

Need

In 1990 the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) identified several deficiencies in the Army's current training of aircrew coordination. For example, aircrew coordination is loosely defined and assessment procedures are unclear. In addition, aircrew skills thought to be important for enhanced safety and mission performance are injected haphazardly into training programs at various levels of the Army. Therefore, there is a need to determine the essential aircrew coordination skills for Army rotary wing flying and to develop methods for assessing and improving these skills.

Project Objectives

The overall objective of this research area is to develop and evaluate an aircrew coordination training program designed to meet the requirements of the Army's rotary wing flight regime. Specifically, the research is designed to accomplish the following:

- determine the types of and extent to which errors in aircrew coordination contribute to Army aviation accidents,

- determine the relationship between aircrew coordination and performance on mission tasks,

- develop measures of aircrew coordination and methods of evaluating performance on aircrew coordination,

- develop a prototype aircrew coordination training program, and

- evaluate the effectiveness of the prototype training program.

Research Approach

During the previous contract year, work in this research area was reported under the title "Accident Scenario

Training." However, as work progressed, ARIARDA more clearly defined the scope of the research area and directed Anacapa to extend it beyond the development of accident scenarios that were based on the findings of accident investigations. Two projects are currently included in the research area: (a) Accident Data Base Analysis and (b) Development and Evaluation of An Aircrew Coordination Training Program.

Accident Data Base Analysis

The accident data base is the U.S. Army Safety Center's (USASC) Army Safety Management Information System (ASMIS), which contains the results of all Army Class A-C aviation accident investigations. Two analyses will be conducted of all the rotary wing accidents occurring between 1983 and mid-1989 that were attributed to human error. In the first analysis, the accident data will be reviewed to determine if aircrew coordination was a possible causal factor. In the second and more detailed analysis, the types of aircrew coordination errors, if any, that contributed to accidents will be identified and classified into error types. In these analyses, aircrew coordination is defined as the interaction between crewmembers (communication) and actions (sequence or timing) necessary for flight tasks to be performed efficiently, effectively, and safely. If an aircrew error does not involve an interaction failure, it is not considered a aircrew coordination error.

Development and Evaluation of an Aircrew Coordination Training Program

The research approach for this project is divided into four phases. In Phase 1, preliminary research will be conducted to (a) identify aircrew coordination requirements for helicopter aircrews that fly in tactical environments, (b) identify aircrew coordination training deficiencies, (c) develop performance and evaluation measures, and (d) develop experimental techniques and training procedures. Because little is known about rotary wing crew coordination, an observational rather than experimental approach will be used for the preliminary research. The observations will provide information necessary to develop hypotheses and techniques for subsequent experimentation.

In Phase 1, 20 UH-60 crews assigned to an aviation field unit will be observed conducting a standard tactical training scenario in the UH-60 Flight Simulator (FS). The training scenario will be constructed to simulate missions for which

the aviators normally train. The 2-hour scenario will comprise three segments: a resupply mission, an air assault mission, and an instrument flight mission. The segments of the scenario will vary in difficulty without exceeding the capabilities of the majority of the crews.

Each aircrew will receive a standard mission brief and be allowed 2 hours to conduct premission planning. After completing the premission planning, the aircrew will enter the UH-60 FS and begin its mission. The UH-60 FS will be equipped with four video cameras that will provide continuous views of each crewmember's face, the center console of the UH-60 FS, and the visual scene observed by both crewmembers. Video and audio recordings will be obtained for each aircrew from the time the aircrew activates the communications systems until they exit the UH-60 FS.

Aircrew task performance will be measured relative to conventional flight standards and in terms of aircrew coordination. Measures of aircrew coordination will be developed to examine patterns of intracrew communication for effective and ineffective aircrews during the three mission segments.

The Phase 2 effort will develop a prototype training program that addresses aircrew coordination training deficiencies identified in Phase 1 and the analysis of the USASC accident data base. The Phase 3 effort will evaluate the training effectiveness of the prototype training program. In Phase 4, the aircrew coordination training program will be revised and delivered for implementation. Detailed approaches for Phases 2 - 4 will be developed on the basis of the Phase 1 results.

Work Completed

Accident Data Base Analysis

The analyses of the ASMIS data base have been completed. In the initial review, two analysts provided subjective ratings of the degree to which crew coordinations errors contributed to 369 human error accidents that occurred over the past 6 years. Aircrew coordination errors were rated as possibly contributing to 129 of the human error accidents. A more detailed analysis of these cases was conducted jointly by USASC, ARIARDA, and Anacapa Sciences personnel. The detailed analysis identified 84 separate crew coordination errors in 76 of the accidents. The aircrew coordination accidents accounted for approximately 15% of all aviation accidents, and the percentage was increasing during the

50

6-year period. Aircrew coordination errors were 1.5 times more prevalent in night accidents than day accidents. More aircrew coordination errors occurred in the UH-60 and OH-58 aircraft than individual-type errors. Finally, ensuring that the aircraft was clear of obstacles was the task most frequently involved in aircrew coordination errors.

The analysts then classified the crew coordination errors into the following nine problem areas:
- positive communication,
- announcing decisions,
- assigning clearance responsibilities,
- directing assistance,
- offering assistance,
- assuming controls,
- sequencing actions,
- prioritizing directions, and
- crew assertiveness.

Development and Evaluation of an Aircrew Coordination Training Program

Phase 1 of the research approach has been initiated. The results of the accident data analyses were used to develop a representative tactical scenario that provided opportunities for crew coordination errors to affect performance. The scenario was developed with the assistance of instructor pilots from the 101st Airborne Aviation Regiment. During May 1990, the tactical evaluation scenario was installed in the UH-60 FS and refined. Additionally, all observations and recording of data for 20 aircrews flying the tactical mission scenario were completed during the month. The video recording equipment consisted of four remote-head, charge coupled device cameras positioned inside the UH-60 FS to provide three views of the crew and one view of the computer-generated visual scene. The cameras were connected to video recorders; the UH-60 FS intercommunication system was connected to the audio recorders and synchronized with the video. By the end of the contract year, the audio portions of 17 mission videotapes were transcribed for the tactical and instrument mission segments.

Mission effectiveness analyses. Checklists were developed to summarize the performance of each aircrew during selected phases of the mission. The phases include threat encounters, stabilator failures, inadvertent entry into instrument meteorological conditions (IMC), and a nonprecision instrument approach. The checklists were used to

51

analyze the videotapes and transcriptions to produce measures of mission effectiveness.

With minor exceptions, stabilator failures and inadvertent entry into IMC were handled well by all the aircrews. However, there were some differences in performance between aircrews in the navigation, threat encounter, and instrument approach measures. All but three aircrews deviated from the designated route of flight during the air assault segment of the mission. Of the 36 deviations identified, 23 were attributed to individual errors in navigation, 6 to poor aircrew coordination, 4 to deviations to evade threat encounters, and 3 to reasonable tactical decisions where the crew remained oriented at all times. Five aircrews had less than four threat encounters with mean durations ranging from 5 to 12 seconds. The remaining aircrews either had more encounters or their encounters lasted longer than 12 seconds. During the instrument approach, 3 aircrews performed unsatisfactorily (e.g., descended too early, flew the wrong course, failed to maintain track to the airfield). Although they made minor errors related to the procedures turn or altitude rate, the remaining aircrews flew a successful approach.

Aircrew coordination analysis. The pattern of crew communication served as the principal measure of aircrew coordination. Two analysts, working independently, decomposed the aircrew's verbal comments into individual message units and classified each message unit on three dimensions: category (e.g., inquiries, directives), subcategory (e.g., system status input), and topic (e.g., navigation, mission). Then, the analysts compared the message unit classifications and reconciled all coding differences. The preliminary findings indicate that intracrew communication and aircrew performance may covary. For example, poor navigational aircrews had a higher percentage of message units concerning terrain identification and a lower percentage of anticipatory message units than did good navigational aircrews.

Work Projected

Accident Data Base Analysis

No further work is anticipated on this project by Anacapa Sciences personnel.

Development and Evaluation of an Aircrew Coordination
Training Program

The remaining transcripts will be coded and entered into
a data base for analysis. Analyses of communication and mis-
sion effectiveness will be conducted to identify the nature
of the relationships between communication patterns, type of
mission, and mission performance measures. From these analy-
ses, recommendations and objectives for an aircrew coordi-
nation training program will be developed for UH-60 aircrews.

A project report will be written to document the re-
sults of the communication and mission effectiveness analyses
and to make recommendations for CRM training. Subsequently,
a prototype aircrew coordination program will be developed,
evaluated, and delivered for implementation into the Army
aviation training program.

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DEVELOPMENT AND VALIDATION OF THE NEW FLIGHT APTITUDE SELECTION TEST (NFAST)

Dr. D. Michael McAnulty, Project Director

Background

The Army's original pilot selection battery, the Flight Aptitude Selection Test (FAST), was developed in response to the unacceptably high attrition rates in the Army flight training program during the 1950s. The FAST comprised two overlapping batteries, one for commissioned officer (CO) applicants and one for enlisted and civilian applicants to the Warrant Officer Candidate (WOC) program (Kaplan, 1965). The FAST, implemented in 1966, resulted in a substantial reduction in the flight training attrition rates.

In 1975, the FAST was revised to produce a single battery with fewer, shorter, and more reliably scored subtests. Eastman and McMullen (1978) selected 7 of the 12 FAST subtests for retention in the revised FAST (RFAST). They also eliminated subtest items that had poor psychometric characteristics (e.g., too easy or hard, low variability). The RFAST, implemented in 1980, was approximately one-half the length of the original FAST.

Subsequent research, however, indicated the need to develop a new FAST (NFAST) battery. Although Lockwood and Shipley (1984) found that the RFAST score and performance in initial entry rotary wing (IERW) training were significantly correlated, they concluded that the low percentage of variance accounted for by the RFAST indicates it has limited utility in predicting IERW performance. Oosterhof and Dohme (1984) identified several problems with the RFAST, including biased items, poor graphics quality, and the lack of an alternate form for retesting. Oosterhof and Dohme developed an alternate FAST to remedy the problems they had identified, but they did not develop any new tests for the selection battery.

As the first step in developing the NFAST battery, IERW instructor pilots (IPs) were asked to judge the type and importance of the abilities that are required to perform critical IERW tasks. Analyses of the task-ability ratings indicated that 24 abilities in the psychomotor, perceptual, language, and cognitive domains were required for successful performance in IERW. Abilities were selected for test development on the basis of their rated importance, amenability to paper-and-pencil measurement, and probability of reliable measurement (McAnulty, Jones, Cohen, & Lockwood, 1984).

In the second step, nine new tests were developed and administered to 290 subjects as an experimental NFAST battery. Eight tests were each designed to measure a unique ability and one test was designed to measure a complex of abilities required for the successful completion of IERW training. The battery also included four standardized tests for comparison with the new tests. The results indicated that the complex ability test and six of the unique ability tests assessed reliable individual differences in the abilities of interest (McAnulty, Cross, & Jones, 1986). The remaining two unique ability tests had undesirable statistical characteristics or provided only redundant information.

Need

The U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) has a continuing requirement to evaluate and improve the tests that are used to select applicants for the Army IERW training program. As indicated in the Background section, an NFAST battery is needed to improve the reliability and validity of the IERW selection process and to provide an equivalent form to be used for retesting IERW applicants.

Research Objective

The general objective of this research area is to develop a more effective battery of IERW selection tests. To accomplish this objective, the following research and development tasks must be performed:

- develop two alternate forms of the NFAST battery,

- conduct preoperational research to validate and equate the alternate forms of the NFAST battery, and

- produce and pretest the operational versions of the NFAST battery.

Research Approach

This research is part of the ongoing ARIARDA program in aviator selection and classification. The current aviator selection research is divided into two projects. The first project (NFAST Validation) is a predictive validity investigation. The results of the experimental battery analyses will be used to develop two alternate forms of an NFAST validation battery. The preoperational validation research will be conducted (a) to determine the relationship between the NFAST tests, other predictor data, and performance in IERW training

and (b) to test the equivalence of the alternate forms of the battery. During this project, measures of IERW performance will be identified and collected as flight training criteria.

The second project (Operational NFAST Development) is the development of the operational NFAST battery. The results of the validation analyses will be used to produce two alternate forms of the NFAST. In addition, all ancillary materials (machine scorable answer sheets, administrative manuals, scoring and equating manuals, selection criteria) will be prepared for operational use. The operational battery and ancillary materials will be pretested on a sample of current IERW students. The pretest results will be used to make any final modifications to the tests and ancillary materials before they are submitted to ARIARDA for implementation.

Work Completed

Preoperational NFAST Validation

The validation battery development, data collection, and analysis activities on the NFAST Validation project have been completed. The results of the experimental battery research were used to develop two alternate forms of the NFAST validation battery. Each form consists of modified versions of the complex test and the six unique ability tests that had acceptable psychometric characteristics. In general, the validation battery tests are approximately two-thirds the length of the experimental battery tests. Finally, a knowledge test of helicopter operations and aerodynamic principles was adapted from the RFAST battery for inclusion in the validation battery. The items on the knowledge test are identical on both forms. Each form of the validation battery requires approximately 4 hours to administer.

Between March and October 1987, the alternate forms of the NFAST battery were administered to approximately 97% of the CO and WOC flight students during their first week of IERW training. When the test administration segment was completed, usable test data had been collected from 377 CO and 341 WOC students. IERW performance data were collected for these students until they either graduated or were eliminated from training.

Test results. Analyses of the test data indicate that the flight student performance on the validation battery, excluding the helicopter knowledge test, is similar to the general population performance on the experimental battery.

The average difficulty levels are near .50 despite the more restrictive time limits that were imposed on the validation tests, and the variances indicate that substantial individual differences in ability are being measured by the tests. The internal consistency estimates of reliability are also within an acceptable range. Performance on the two forms of the battery is very similar except for one of the unique ability tests. Test performance by the CO and WOC students is also quite similar, although the CO students scored significantly higher (p <.01) on four of the tests.

The results also indicate that the helicopter knowledge test is not difficult and that there is limited variability in the scores. WOC students scored significantly higher on the test than the CO students. However, there is no difference in performance by either student group on the two forms of the test. Because the two forms are identical, this result indicates there was no systematic sampling bias in terms of aviation-related knowledge in assigning students to the alternate forms of the NFAST battery.

Training results. Three types of IERW performance measures were collected about the students who participated in the NFAST validation: administrative changes (elimination and training setback data), flight hour data (number of flight hours required to complete each phase of training), and IERW training grades (academic and flight). The primary performance criterion was the Overall Average Grade (OAG), which is a weighted composite of the academic and flight grades. IERW performance data collection was completed in January 1989. Of the 718 students in the data base, 696 either completed IERW or were eliminated from training for flight or academic deficiencies; the remaining students were eliminated for nondeficiency reasons or were transferred for training under a different syllabus. The validation analyses were conducted using the 696 students who graduated or were eliminated for deficiency reasons.

Validation results. The results of the validation data analyses indicate that the alternate forms are approximately equal in predictive validity and that a subset of the tests in the battery will significantly improve the IERW selection process. Across all subgroups (e.g. forms, ranks, training track, education levels), three of the tests (the complex Flight Planning test, the Chart Use test, and the Helicopter Knowledge test) consistently had high regression coefficients (R of approximately .50) on the OAG and other criteria. Cross validation analyses indicated that the regression equations were stable and are likely to generalize to the applicant population. Utility analyses demonstrated that fewer

eliminations and deficiency setbacks will occur using the three NFAST tests. When the NFAST and RFAST tests were used in combined regressions, the Cyclic Orientation test also entered the equations.

During the current contract year, a draft report was prepared to document the preoperational validation method and results. After being reviewed by ARIARDA, additional information was identified that should be included in the report. Statistical analyses were conducted to provide the required information and work was begun to incorporate the information into the final report.

Operational NFAST Development.

The results of the validation research were used to modify the validation battery for operational use. The modifications included shortening the test length, changing items with unsatisfactory characteristics, revising the test instructions, and improving the graphics and format of the tests. In addition, the Cyclic Orientation test was selected from the RFAST for retention in the operational NFAST battery. New ancillary materials were also developed for the operational battery. A test administration manual was drafted and a new answer sheet was designed for the NFAST. The answer sheet requests additional biographic information that the validation analyses indicated was related to successful performance in IERW.

Between October 1989 and June 1990, the 2-hour operational battery was pretested on a sample of 217 students waiting to begin IERW training. The results indicate that the modifications generally had their intended effect without adversely affecting the psychometric characteristics of the tests. One item on Chart Use test Form E was identified that required further revision; changes to the test chart graphics had resulted in two answers being equally correct. In addition, the pretest data were used to evaluate the effects of standardizing the test scores and correcting the scores for guessing.

Final revisions (changing the Chart Use item, formatting the tests and repaginating, etc.) were made to the alternate forms of the NFAST and to the administration manual. Both documents (McAnulty, 1990a, 1990b) were submitted to ARIARDA for review and implementation.

Work Projected

Preoperational NFAST Validation

The initial revision of the report documenting the NFAST validation research will be completed by November 1990. Additional requests for revisions will be completed as soon as they are received. Submission of the final report to ARIARDA will complete the scheduled activities on this project.

Operational NFAST Development

The results of the operational battery pretest will be incorporated into the preoperational validation report. In addition, a scoring manual and an NFAST information pamphlet will be prepared. Preparation of the operational materials will be completed in February 1991.

Operational NFAST Research

After the NFAST is in operational use, follow-on research will be required to ensure that applicant performance on the test batteries is within acceptable limits, that administrative procedures are being followed, and that the selection criteria are valid. Depending on the results of the follow-on research, a second validation investigation may be required that uses an unrestricted sample (i.e., not already selected for flight training) of IERW applicants.

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TRAINING EFFECTIVENESS ANALYSIS OF THE AH-1 FLIGHT AND WEAPONS SIMULATOR (FWS) FOR UNIT TRAINING

Dr. D. Michael McAnulty, Project Director

Background

This research area was initiated in response to two taskings from the Directorate of Training and Doctrine (DOTD) to the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at the U.S. Army Aviation Center (USAAVNC), Fort Rucker, Alabama. One tasking originated at the USAAVNC and the other originated at the Department of the Army (DA). The taskings have been discussed in detail previously (see Cross & Gainer, 1987; Kaempf, 1988). Therefore, only a brief review of the taskings is presented in this report.

USAAVNC Tasking

The Army Audit Agency (AAA) audited the Army's Synthetic Flight Training System twice, first in 1981 and again in 1984. The audit reports (AAA, 1982, 1985) stated that, although flight simulators had reduced training costs and improved training at the USAAVNC, the Army had not determined the effects of using flight simulators to train aviators in operational units. Both reports concluded that the Army had not adequately quantified the return on its investment in flight simulators procured for aviation unit training.

In response to the audits, the Commander of the USAAVNC tasked DOTD to initiate research to address the issues raised by the AAA. In 1985, the Director of DOTD formally tasked ARIARDA to plan and conduct the needed research. Subsequently, ARIARDA and Anacapa personnel initiated three research projects in the AH-1F Flight and Weapons Simulator (FWS): backward transfer and skill acquisition in the FWS, transfer of training in the FWS for emergency touchdown maneuvers (ETMs), and transfer of training in the FWS for gunnery skills. The first two projects have been completed (Kaempf & Blackwell, 1990; Kaempf, Cross & Blackwell, 1989); the third project was planned but was later subsumed under the work conducted for the DA tasking.

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DA Tasking

In 1986, the issues concerning developing flight simulation training programs and fielding flight simulators were reviewed by the Office of the Deputy Chief of Staff for Operations (DCSOPS). Subsequently, the DCSOPS directed that training effectiveness analyses (TEAs) be conducted for each of the Army's flight simulation systems. The analyses were intended to serve as the basis for developing effective training strategies and programs. ARIARDA and Anacapa developed and submitted a research plan (U.S. Army Research Institute, 1986) that addressed the utilization of flight simulators in operational environments. In June 1987, the Commander of the Training and Doctrine Command (TRADOC) approved the TEA research plan and authorized ARIARDA to implement the research.

Gunnery Training Focus

Concurrent with the TEA tasking, the Department of Tactics and Simulation (DOTS; formerly the Department of Gunnery and Flight Systems) at the USAAVNC revised the helicopter gunnery training manual (FM 1-140). The revised manual (designated TC 1-140) specifies the gunnery training requirements and performance standards for aviation units. Before issuing the revised manual, however, DOTS requested that ARIARDA incorporate into the TEAs an analysis of the proposed crew gunnery training programs. The objectives of the analysis are (a) to determine whether simulators can be used to train crew gunnery tasks effectively in aviation units and (b) to determine the resources required to support crew gunnery training programs.

In response to the DOTS request, the TEA program focused on the effectiveness of flight simulators for training gunnery tasks in attack helicopter aviation units. ARIARDA and Anacapa personnel planned and initiated three research projects for gunnery tasks: TEA of the FWS for Conducting Gunnery Training, TEA of the AH-64A Combat Mission Simulator (CMS) for Conducting Crew Gunnery Initial Qualification Training, and TEA of the CMS for Conducting Crew Gunnery Proficiency Sustainment Training. The FWS TEA is described under this research area; the CMS TEAs are described in the next research area (see pp. 71 - 76).

Previous FWS Research

Previous research has concentrated on performing flight tasks and emergency procedures and on acquiring flight skills in the FWS; it has not directly evaluated the issue of skill sustainment or the forward transfer of sustainment training from the FWS to the AH-1. Kaempf, Cross, and Blackwell (1989) found that experienced AH-1 pilots required simulator specific training to perform flight tasks in the FWS. The pilots attributed their performance difficulties primarily to the FWS visual system and handling qualities. Kaempf, et al. also found that 36 of 40 flight skills could be acquired in the FWS, but that multiple training iterations were required to attain a minimum standard of performance Finally, Kaempf and Blackwell (1990) investigated the effect of FWS training for five emergency maneuvers that were prohibited in the aircraft for safety reasons. They found that unit aviators, who initially exhibited uniformly poor performance on the maneuvers, were able to improve their skill in the FWS but required additional aircraft training to perform the maneuvers successfully.

Problem

The Army has made a significant investment in the development and acquisition of motion-based, visual flight simulators for its rotary wing aircraft. Visual flight simulator systems have been developed for the AH-1F, AH-64A, CH-47D, and UH-60 helicopters and deployed to aviation units. The Army's primary objective for flight simulation is to provide training devices in which operational aviators may sustain their flight and tactical skills. However, little empirical data currently exist (a) to demonstrate that flight simulators effectively and efficiently provide this type of training and (b) to guide the Army in developing training programs that include an optimum mix of training conducted in the aircraft and flight simulator. Empirical data are needed to ensure that the Army receives the maximum return on its investment in flight simulators.

The FWS limitations found in previous evaluations indicate that forward transfer of training research is needed before the FWS is used extensively for training unit aviators. Because the previous efforts have only addressed the acquisition of flight and emergency procedure skills, research about the effectiveness of the FWS for sustainment training and gunnery training is particularly important.

65

Research Objectives

The primary objective of this research is to evaluate the effectiveness of the AH-1 FWS for sustaining crew gunnery proficiency in operational units. In addition, data are needed to develop unit training programs that provide an optimal mix of flight simulator and aircraft training and to determine the simulator and ammunition resources required to sustain aerial gunnery skills.

Research Approach

Fifty current AH-1F aviators in U.S. Army, Europe (USAREUR) aviation units will be assigned to one of three groups: one control and two experimental. Each aviator's initial proficiency on crew gunnery tasks will be evaluated during an initial live-fire gunnery exercise. Following the initial live-fire evaluation, the aviators will enter a 13-month gunnery training program. In addition to the normal unit training, the Experimental Group 1 aviators will receive gunnery training in the FWS every month and the Experimental Group 2 aviators will receive gunnery training in the FWS every 3 months. Aviators in both experimental groups will be restricted on the gunnery tasks they can practice in the aircraft. The Control Group aviators will receive the unit's normal training in the aircraft but will be restricted on gunnery practice in the FWS. The effectiveness of the FWS for sustaining gunnery skills will be tested by comparing the performance of the three groups during a final live-fire exercise.

Work Completed

In October 1988, USAREUR officials authorized ARIARDA to conduct the TEA of the FWS and tasked V Corps and VII Corps to provide resources to support the experiment. V Corps divided the tasking between two aviation units (n = 12 and 13); VII Corps provided 26 AH-1F aviators from one unit to participate in the research. Because of logistical and scheduling considerations, each of the aviation units entered the experiment as its training schedule permitted and proceeded independently of the other units.

An AH-1F Aviator Questionnaire was developed and administered to AH-1F aviators in USAREUR units. The questionnaire contains 44 items requesting information about personal history, flight experience, current duty assignment, experience with AH-1F weapon systems, and opinions about flight and

gunnery training. The objectives of the questionnaire are to describe (a) the aviators participating in the TEA and (b) the population of AH-1F aviators from which the participants were selected. Approximately 200 AH-1F aviators responded to the questionnaire, including the 51 TEA aviators.

Two other data collection instruments were developed for the TEA: the Diagnostic Gunnery Skills Test and the Post-flight Debriefing Form. The Diagnostic Gunnery Skills Test comprises 32 items designed to test the aviators' knowledge of the AH-1F weapon systems and gunnery techniques. All aviators completed the test prior to their initial live-fire exercise. The Postflight Debriefing Form comprises 16 items that document the training that the aviators receive in the aircraft in conjunction with their training in the FWS. Gunnery and tactical tasks are emphasized on the form. All aviators were instructed to complete a debriefing form immediately after each flight in the aircraft.

The three participating units conducted their initial live-fire exercises in January, April, and May 1989, respectively. Following the initial live-fire exercises, Experimental Groups 1 and 2 began the TEA training program. The TEA training program was designed to sustain proficiency on specific gunnery tasks within the context of mission scenarios. During each FWS training session, the aviators planned and executed an attack mission prepared by Anacapa personnel and AH-1F standardization pilots. Nine attack missions were developed for the FWS training sessions. During each FWS training session, a data collector recorded several performance measures, including total engagement time, target effect, flight time in each crew station, and number of rounds expended.

In July 1989, the Chief of ARIARDA directed that Anacapa terminate work on the FWS TEA by 30 August because of a funding shortage. During the next 3 months, ARIARDA personnel continued the FWS training and data collection. Also during this period, one of the V Corps units withdrew from the research project. Anacapa personnel resumed work on the project in November 1989.

The remaining V Corps unit conducted their final live-fire exercise in February 1990. The VII Corps final exercise was conducted in August 1990 after being postponed from the scheduled April-May 1990 range dates. During the final exercise, each crew fired the VII Corps Crew Qualification Table (Table VIII). Table VIII comprises 10 engagements fired from seven firing positions. The crews fired the 20mm cannon five times, the 2.75 in. rockets four times, and the TOW missile once during the exercise. Four of the firing

positions were single engagements and three of the positions were combined engagements. Data collectors recorded measures of target effect, engagement time, and exposure time for each engagement. Scoring standards varied as a function of the weapon system used, the range to the targets, and whether it was a single or combined engagement. Crews that did not qualify on the first gunnery run (700 of 1000 possible points and 7 of 10 go ratings) were required to rearm and reshoot the engagements they had failed.

Final live-fire data were collected on 6 V Corps crews and 12 VII Corps crews. In addition to the V Corps unit, withdrawal, additional crews were lost because of early aviator transfers, medical groundings, changes in pilot-in-command status, and aviator transfers during the VII Corps range postponement. Four of the retained crews were in the control group and seven crews were in each of the experimental groups. Despite the aviator attrition, the retained crews in each group were approximately equal in age and relevant experience when they completed the AH-1F Aviator Questionnaire. However, there were substantial differences between the two Corps in the amounts of training received and the live-fire exercise conditions. For example, two of the V Corps crews were unable to qualify on Table VIII because of a shortage of usable ammunition. Therefore, the conclusions drawn from the project are based primarily on the VII Corps data.

At the end of the contract year, a preliminary analysis of the live-fire data had been conducted. Although the results were not always statistically significant because of the small number of crews in each group, four tentative conclusions were drawn from the data. First, the FWS trained crews generally performed better than the control crews during the final live-fire exercise. The FWS trained crews had higher scores on the first gunnery run, had more crew qualifications on the first run, and required fewer gunnery runs to qualify than the control crews. Second, the performance of the two experimental groups was similar during the exercise. The small performance differences between them generally favored the quarterly training group.

Third, the largest FWS training effect was an improvement in 20mm gunnery performance. Performance probably improved because of the training on the methods of employing the 20mm weapon. Fourth, significantly fewer rockets were required to achieve crew qualification by the experimental groups. However, some live-fire practice is still needed because not all the experimental group crews qualified on the first run. Instead of replacing live-fire practice, the FWS

training probably prepares the crews for utilizing their limited range time more effectively.

Work Projected

During the next contract year, the FWS TEA data analyses will be completed and a report and briefing will be prepared to document the method and results. No additional work is currently planned in this research area, but the results of the FWS TEA project indicate the need for further transfer-of-training evaluations.

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TRAINING EFFECTIVENESS ANALYSIS OF THE
AH-64A COMBAT MISSION SIMULATOR

Dr. David Hamilton, Project Director

Background

In response to a Department of the Army (DA) tasking in 1986, the Army Research Institute Aviation Research and Development Activity (ARIARDA) initiated two AH-64A Combat Mission Simulator (CMS) training effectiveness analyses (TEAs). In 1988, the Department of Tactics and Simulation (DOTS; formerly the Department of Gunnery and Flight Systems) requested that the projects focus on the acquisition and sustainment of helicopter gunnery skills in the CMS. The DA tasking and the DOTS request are discussed in detail in Cross and Gainer (1987) and in Kaempf (1988) and are summarized below.

DA Tasking

In 1986, DA tasked ARIARDA, through the Training and Doctrine Command (TRADOC), to plan and initiate TEAs of each of the Army's flight simulator systems. The TEAs were intended to investigate the utilization and training effectiveness of Army flight simulator systems in operational field units and to provide a basis for developing effective training strategies. In response to the tasking, ARIARDA and Anacapa developed a research plan comprising a series of related research projects (U.S. Army Research Institute, 1986). Each project was designed to investigate the effectiveness of a flight simulator system for training a specific set of tasks (e.g., weapons tasks, contact flight tasks, and emergency flight tasks) in an operational environment.

DOTS Request

Concurrent with the DA tasking, DOTS proposed revisions to the training manual for Helicopter Gunnery (FM 1-140). FM 1-140 defines the training requirements and performance standards for the Army's aerial gunnery training program. The revised manual, Helicopter Gunnery - Coordinating Draft (TC 1-140), contained significant changes to the crew gunnery training requirements and standards for the AH-64A aircraft. For example, DOTS proposed to conduct all AH-64A crew gunnery training and qualification in the CMS. That is, no live rounds were provided for crew training and qualification;

live rounds were provided only for training attack helicopter teams and for conducting combined arms live-fire and joint air attack team exercises.

Before issuing the revised manual, however, DOTS requested that ARIARDA conduct research to evaluate the effectiveness of the CMS for training and sustaining crew gunnery skills. In response, ARIARDA agreed to focus the TEAs on the issues raised by the DOTS. Two projects were designed to investigate CMS gunnery training: TEA of the CMS for Conducting Crew Gunnery Initial Qualification Training and TEA of the CMS for Conducting Crew Gunnery Proficiency Sustainment Training.

Coordination problems with the Apache Training Brigade at Fort Hood, Texas, have indefinitely halted the initial qualification project. Because no research has been conducted on the initial qualification project, the remainder of this summary focuses on the proficiency sustainment project.

Problem

The Army uses high fidelity flight simulators to augment and, in some cases, replace the training that aviators receive in the aircraft. The Synthetic Flight Training System program is viewed as a cost-effective means of acquiring flight skills. In the Coordinating Draft of TC 1-140 (Department of the Army, 1988), DOTS proposed that flight simulators may also be an effective alternative to live-fire training in the aircraft for both the acquisition and sustainment of crew gunnery skills. However, there is little empirical data to demonstrate the effectiveness of flight simulators for augmenting gunnery training. Empirical data are required to demonstrate that flight simulators can train gunnery skills effectively and to determine the extent to which training conducted in flight simulators can be used to conserve other training resources, such as aircraft flight time and live ammunition.

Research Objectives

This research is designed to meet three major objectives:
• determine the effectiveness of the CMS for sustaining crew gunnery skills,
• provide data to help establish an optimum combination of aircraft and flight simulator training for the sustainment of crew gunnery skills, and

- provide quantitative information about the AH-64A
  gunnery standards established in TC 1-140.

Original Research Approach

The proficiency sustainment project was designed to
evaluate the effectiveness of the CMS for sustaining gunnery
skills. The research design proposed that AH-64A crews from
the 6th Cavalry Brigade - Air Combat (CBAC) be assigned to
either a control group or one of two experimental groups.
The crews' initial gunnery skills will be measured during a
pretest live-fire gunnery exercise. All gunnery training
received by each group will be controlled for 1 year after
the pretest live-fire gunnery exercise. After 1 year, the
crews' gunnery skills will be evaluated during a posttest
live-fire gunnery exercise. The effectiveness of the CMS
will be evaluated by comparing the difference in performance
between the pretest and posttest exercises and between the
three groups.

Initial Research Effort

In April 1989, the research began as described above
when live-fire performance data were collected at the Dalton-
Henson Multi-Purpose Range Complex at Fort Hood, Texas. The
6th CBAC assigned only 15 crews to the project because of
anticipated personnel turnover. Consequently, the 6th CBAC
planned to conduct gunnery evaluations for additional crews
during an August live-fire exercise.

In August 1989, baseline live-fire data were collected
for an additional 12 crews. However, 4 of the crews tested
in April were no longer able to participate in the research.
At the close of FY89, there were 9 crews in the control
group, 8 crews in Experimental Group One, and 6 crews in
Experimental Group Two. During September, data were col-
lected during the first of 10 scheduled gunnery-specific
training sessions in the CMS.

By November 1989, crew attrition was so high that the
research design was reevaluated. The possibility of con-
ducting the research over the course of an entire year was
precluded by the attrition of participating crews. There-
fore, ARIARDA and Anacapa developed an alternative research
plan and briefed it to 6th CBAC personnel in January 1990.

Revised Research Approach

The revised research plan is divided into four phases. During Phase 1, an initial evaluation of AH-64A crew gunnery performance will be conducted during a live-fire exercise and during a CMS test scenario. The primary measures of gunnery performance collected during the live-fire exercises and the CMS test scenario will be target effect and engagement time. Additional information will be collected during the live-fire exercises about the number of 30mm rounds and rockets expended to qualify on Table VIII - Crew Gunnery (Department of the Army, 1990). All participating aviators will complete a demographic survey describing their current skill and training.

In Phase 2, crews will be assigned to one of two groups: one that receives scenario-based gunnery training in the CMS and one that does not train gunnery skills in the CMS. The training will be conducted over a period of only 6 months to minimize the impact of crew attrition. The frequency of other no CMS gunnery training activities will be recorded during this period.

As in Phase 1, Phase 3 crew gunnery performance will be measured during a final live-fire exercise and in the CMS. During Phase 4, the data will be analyzed, recommendations drafted, and the results reported. The effectiveness of the CMS will be evaluated by measuring the differential performance of the training groups between the pretest and posttest in the CMS and the live-fire exercises.

Work Completed

Initial Gunnery Performance Evaluation

Between 25 March and 26 May 1990, an initial evaluation of AH-64A crew gunnery performance was conducted during live-fire exercises at the Dalton-Henson Multipurpose Range Complex, Fort Hood, Texas. Performance measures were collected on 30 6th CBAC crews participating in the project. The data on crew gunnery performance was obtained from the Area Weapons Scoring System, the squadron Standardization Instructor Pilots, and the AH-64A videotapes. Over 1,700 data base records were produced describing the environmental conditions, the engagement time, and the target effect of each 30mm, rocket, and HELLFIRE engagement fired during the exercise. In addition to the performance measures, each of the participating aviators completed a demographic questionnaire.

Of the 30 crews, 16 were assigned to the CMS training group and 14 were assigned to the no CMS training group.

In April 1990, DOTS released an Approved Draft of the TC 1-140 (Department of the Army, 1990). In this version of the TC 1-140, DOTS did not propose that all AH-64A crew gunnery be conducted in the CMS. Instead, the Approved Draft requires that "simulators and live-fire exercises be integrated into a successful gunnery training program." In contrast to the previous document, the Approved Draft allocates more ammunition to crew training than to any other level of gunnery training. The change in policy, however, did not reduce the department's interest in this research project.

Because of an upgrade to the CMS, the initial CMS gunnery performance testing did not begin until 23 June. All crews completed the initial CMS test scenario by 30 June.

CMS Gunnery Training

Between 1 July and 15 September 1990, each CMS gunnery crew received five scenario-based gunnery training sessions in the CMS. To document the frequency of other gunnery training activities, a postflight debriefing form was prepared and distributed to each project aviator. The aviators were instructed to complete the forms after flights in the AH-64A aircraft or sessions in the CMS or Cockpit, Weapons, and Emergency Procedures Trainer (CWEPT). All CMS gunnery training was completed by 11 September 1990.

Final Gunnery Performance Evaluation

The final live-fire exercises were completed between 12 and 26 September 1990. Of the initial 30 crews, 18 were retained until the end of the project (9 in each training group). Because of limitations on ammunition and range access, project crews were allowed to fire each gunnery engagement only once for day and once for night. Performance measures were recorded as described in Phase 1. The final CMS performance evaluation was completed between 21 and 29 September.

Work Projected

During the next contract year, the project data will be analyzed as soon as a secure data processing computer is acquired. Briefings and a final report will be prepared and

submitted to ARIARDA. All planned work on this project will be completed early in the following calendar year.

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EFFECTIVENESS OF AIRNET IN TRAINING
COLLECTIVE ARTEP TASKS

Dr. Beth W. Smith, Project Director

Background

Assessments by the Directorate of Combat Developments (1982, 1983, 1986) at the U.S. Army Aviation Center (USAAVNC), Fort Rucker, Alabama, revealed several deficiencies in the training of Army aviators to perform collective tasks. Specifically, the Battlefield Development Plan (1986) identified deficiencies in the training of air-to-air operations, anti-armor operations, sustained aviation operations, air assault operations, suppression of enemy air defense, special operations missions, aerial reconnaissance, combat maneuvers, search and rescue operations, target acquisition and handover, and aircraft survivability. The Battlefield Development Plan attributed the deficiencies to constraints that prevent adequate training on collective tasks in the aircraft. Among the most important constraints identified are the following:

- training ranges are insufficient in number, size, and topographic diversity to conduct effective collective-task training,

- the high cost of aircraft, fuel, ordinance, and logistic support limits the frequency of collective-task training exercises, and

- collective training in the aircraft under realistic conditions increases the likelihood of crashes and laser accidents.

Because of the constraints on live training in the aircraft, the use of training devices was identified as an alternative method of collective-task training. In 1987, the USAAVNC established a Memorandum of Understanding (MOU) with the Defense Advance Research Projects Agency (DARPA) to develop a prototype combined-arms tactical trainer that can be used to eliminate some or all of the deficiencies in collective-task training. The MOU led to the development of the aviation networked simulation system (AIRNET).

AIRNET is a research and development tool and serves as the proof-of-concept for the simulation networking of rotary wing aircraft. The device was to be developed in three phases: Fully Reconfigurable Experimental Device (FRED), Generic, and AIRNET Specific (formerly 60% Solution). The subsequent training device procured and fielded by the Army

will be referred to as the Aviation Combined Arms Tactical Trainer (AVCATT).

In June 1988, the Directorate of Training and Doctrine (DOTD) at the USAAVNC tasked the Army Research Institute Aviation Research and Development Activity (ARIARDA) to assist in evaluating AIRNET for training the Army Training and Evaluation Program/Mission Training Plan (ARTEP/MTP) tasks. In addition, ARIARDA was tasked to provide recommendations about design modifications that are likely to increase AIRNET's training effectiveness. Finally, the tasking requested that evaluations be conducted for each phase of development. In September 1988, ARIARDA directed Anacapa Sciences to design and conduct evaluations of the AIRNET device.

Research Objectives

The general objective of this research area is to evaluate the AIRNET device for training collective ARTEP/MTP tasks. There are four specific objectives for the research projects in this area:

- identify the ARTEP/MTP tasks for the Attack Helicopter Company and the Air Cavalry/Reconnaissance Troop that can be performed in AIRNET,

- evaluate the degree to which functions, segments, and phases of the ARTEP/MTP tasks can be realistically performed in AIRNET,

- determine the modifications to system features required to accommodate the ARTEP/MTP tasks that cannot be performed in AIRNET, and

- identify the navigation-related skills and mission tasks from the Enlisted Aeroscout Observer Course (EAOC) that can be adequately trained in AIRNET.

Research Approach

Three projects were designed to meet the objectives of this research area. Each project is discussed separately in the following sections.

Effectiveness of AIRNET in Training Collective ARTEP Tasks

In the first project, information about the training value of AIRNET's developmental phases will be obtained by evaluating experienced crewmembers' ability to perform

selected flying tasks in each device. The rationale for this approach is that effective training on a task cannot be accomplished in AIRNET if an experienced crewmember who performs it routinely in the aircraft cannot perform it adequately in AIRNET.

This research project will focus on aviators' ability to perform collective tasks and selected individual tasks in AIRNET. The Aircrew Training Manual (ATM) and the ARTEP/MTP tasks for the Attack Helicopter Company and Air Cavalry Reconnaissance Troop will be reviewed to select the collective and individual tasks. Performance rating scales based on selected ATM and ARTEP/MTP tasks will be developed to identify inadequate system features. Questionnaires will be developed to obtain user opinions about individual and mission task performance and the technical capabilities of AIRNET. Finally, a training scenario will be developed that will include the selected collective and individual tasks.

As each phase of the AIRNET device is installed, experienced aviators will perform the evaluation scenario. Researchers and instructor pilots will rate the aviators' task performance in the devices. The participating aviators will then complete the questionnaires to provide input on device deficiencies and needed improvements.

Analytic Assessment of ARTEP Tasks

In the second project, the degree to which mission tasks can be realistically performed in AIRNET will be analyzed as a function of the systems and performance capabilities required to perform each task. First, a composite mission scenario for an attack helicopter company will be decomposed into phases, segments, functions, and tasks. Second, a rating scale will be developed to assess how well each task can be performed in the AIRNET device. Anacapa researchers will assess task performance at the individual, crew, team, and collective levels. Subsequently, experienced AIRNET aviators will review the analyses and recommend any necessary changes.

Evaluation of the Aeroscout Observer Course

In the third project, a training effectiveness evaluation will be conducted to determine the feasibility of providing skill acquisition training in AIRNET. Students from the EAOC will be divided into three training groups for the evaluation. One group of EAOC students will be trained

in the aircraft, one group will be trained in the classroom, and one group will be trained in the Generic AIRNET device. Differences in the effectiveness of the training procedures will be determined by comparing their performance on navigation and mission tasks in the OH-58 aircraft.

Work Completed

Effectiveness of AIRNET in Training Collective ARTEP Tasks

The research on the FRED and Generic AIRNET devices were conducted during the previous contract year. The evaluation of the FRED resulted in improvements to the flight charac-teristics and weapon systems included in the Generic AIRNET configuration. Evaluation of the Generic AIRNET device resulted in the identification of several system deficiencies that hindered adequate task performance. Several design features were directly related to the inadequate performance of 70% of the collective tasks. Experienced aviators who participated in the evaluation perceived the Generic AIRNET as inadequate for training operational aviation units.

A preliminary report (Thomas, 1989) of the evaluation was submitted to DOTD during the previous contract year. During the current contract year, the research approach and prelimi-nary summary data were presented at the second annual confer-ence on simulation sponsored by the Royal Aeronautical Society in London, England (Thomas & Gainer, 1990). Following the conference, further data analyses were conducted and a draft report was prepared and submitted for in-house review. Summary data tables were provided to DOTD at the end of the contract year to supplement the preliminary report.

Analytic Assessment of ARTEP Tasks

In June and July 1990, Anacapa researchers conducted a systematic assessment of the degree to which task blocks (e.g., functions, segments, and phases) could be performed in AIRNET at the individual, crew, team, and collective levels. A composite scenario that identified the mission phases, segments, and functions was developed on the basis of the ARTEP/MTP for an Attack Helicopter Company (Department of the Army, 1988). Only the mission segments that are flight related or that can occur in a helicopter were included in the analysis. A 5-point rating scale ranging from completely performable to not performable was used to assess how well each task can be performed in the AIRNET device. The ratings were based on the presence and operability of the required

system components and on how realistically the distinct functions can be performed in AIRNET. After the ratings of the Generic AIRNET device were completed, two experienced AIRNET aviators reviewed and confirmed the results of the analysis.

Of 100 unique functions required to perform the composite mission, 77 were rated as at least partially performable in AIRNET. A rating of partially performable indicates that some major system requirements are not available or have limited operability, or that system performance is noticeably different from the aircraft. Six functions were rated as marginally performable, indicating that the functions could only be performed with a significant loss of realism. Seventeen functions could not be performed at all, primarily because of three missing system features: an automated target handover system, a remote laser designation capability, and a rocket weapon system. Six of the seven mission phases were rated as partially performable; only the Target Engagement phase was rated as marginally performable in AIRNET.

A report (Smith, Bierbaum, & McAnulty, 1990) on the analytic assessment of ARTEP tasks was prepared and submitted to ARIARDA on 1 August.

Evaluation of the Aeroscout Observer Course

A transfer-of-training experiment was conducted to assess the training effectiveness of the Generic AIRNET device for acquiring navigation and mission task skills. Forty-six students in the EAOC were assigned to one of three training groups. The control group received training only in the aircraft. One experimental group received navigation and mission acquisition training in AIRNET. The second experimental group received navigation training in the aircraft and mission training using the table top method (i.e., verbal rehearsal). The training concentrated on eight navigation-related skills and four Air Cavalry/Reconnaissance Troop ARTEP/MTP mission tasks.

Subsequently, the students' performance on these tasks was evaluated in the aircraft. The number of aircraft hours required to reach task proficiency and the checkride grades on those tasks were collected for all students. Questionnaires were developed and administered to obtain user information on navigation and mission task performance and on technical performance issues related to acquisition training in AIRNET.

Student and instructor pilot responses on the question-
naire suggest that AIRNET training may be beneficial for two
mission tasks (call for indirect fire and adjust indirect
fire), but the training benefits were not large enough to
have a statistically significant effect on either the air-
craft hours required to reach proficiency or the students'
grades on the final checkride. Summary data tables were
provided to DOTD at the end of the contract year to assist in
cost-benefit estimates of conducting training in AIRNET. A
draft report was prepared and submitted for in-house review.

Work Projected

Effectiveness of AIRNET in Training Collective ARTEP Tasks

Necessary changes will be made to the draft final report
for this project and the final product will be submitted to
ARIARDA. Changes in the proposed configuration of the final
AIRNET developmental stage and uncertainties about product
delivery have indefinitely postponed further device evalua-
tion. Submission of the final report on the Generic AIRNET
evaluation will therefore complete work on this project.

Analytic Assessment of ARTEP Tasks

Submission of the project report completed all planned
work on this project.

Evaluation of the Aeroscout Observer Course

Reviewer comments will be incorporated into the final
draft of the training effectiveness report. Submission of
the report will complete all work planned for this project.

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EVALUATION OF SPECIAL OPERATIONS AVIATION REGIMENT (SOAR) CONTRACTOR MISSION INSTRUCTORS

Dr. Kenneth D. Cross, Project Director

Background

The Selection and Training (S&T) Detachment, 160th Special Operations Aviation Regiment (SOAR), Fort Campbell, Kentucky, conducts Basic Mission Qualification (BMQ) training for prospective special operations crewmembers. The BMQ training is an intensive night vision goggle (NVG) low-level navigation course that includes an introduction to new aircraft systems. Traditionally, the S&T Detachment has utilized active duty aviators as military mission instructors (MMIs) for BMQ training. Although active duty MMIs are capable of accomplishing the requisite training, their use reduces the number of trained aviators available for assignment to operational units. One potentially effective method for increasing the number of active duty aviators available for assignment to operational units is to employ contractor mission instructors (CMIs) for BMQ training.

In September 1989, the Army Aviation Systems Command (AVSCOM) requested that ARIARDA evaluate the feasibility and effectiveness of employing CMIs. ARIARDA, in turn, tasked Anacapa Sciences to conduct the evaluation. The project was initiated in July 1990.

Need

Because the S&T Detachment has not previously used CMIs, there is a need to evaluate the feasibility and effectiveness of employing CMIs to accomplish the training currently being conducted by active duty aviators. In addition, the S&T Detachment has indicated a need to review and upgrade the BMQ training materials.

Research Objectives

There are three general objectives for this research project:
- evaluate the instructional training materials for possible upgrade,
- evaluate the training effectiveness of CMIs, and
- evaluate the cost effectiveness of utilizing CMIs versus MMIs.

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Research Approach

Anacapa researchers developed a research plan designed to address the research objectives for three of the aircraft systems trained by the S&T Detachment. The plan proposes a single research strategy for the CH/MH-47, UH/MH-60, and MH-6, with minor modifications to provide for the unique characteristics of each aircraft.

The existing training program will be reviewed to gain an understanding of the BMQ training objectives and the methods being used to accomplish the objectives. Project personnel will examine the training program, note the types of instruction, and select instructional material that can be upgraded. In addition, they will identify measures of training effectiveness that currently exist in the program and determine what additional measures should be developed.

The class members for each of the three aircraft will be divided into a control group, instructed by MMIs, and an experimental group, instructed by CMIs. Subjects will be assigned to a group on the basis of their aviation experience and the results of a Commander's Evaluation checkride.

The effectiveness of the MMIs and CMIs will be evaluated in several ways. Academic classes taught by CMIs and MMIs will be evaluated by an observer from the S&T Detachment. Academic examinations will be developed to compare student performance on subjects that are taught by CMIs and MMIs. Students will also perform BMQ tasks on the OMEGA and the Rockwell Cockpit Management System hot bench trainers. Subject matter experts will observe the performance and complete evaluation gradeslips. Finally, student flight performance will be evaluated for each phase of training. In conjunction with the performance evaluations, cost data will be collected to evaluate the cost effectiveness of the CMI program.

Work Completed

Between July and October 1990, preliminary planning meetings were conducted with members of the S&T Detachment to (a) review the adequacy of the academic instructor and student handout materials, (b) identify subject areas in which materials should be revised or developed, and (c) identify evaluation areas for determining the training effectiveness of the CMIs. During these meetings, the S&T Detachment indicated that CMIs should be evaluated on all

phases of flight instruction and the following academic subjects:

- local flying area,
- CAM Reg 95-1 with waivers,
- naval air operations,
- visual flight rules (VFR),
- forward area refueling points (FARP),
- mountain operations,
- jungle operations, and
- desert operations.

In addition, the 160th SOAR agreed to provide instructor pilots to conduct flight evaluations at the end of each phase of flight instruction. The evaluators will be experienced instructors who have taught at least one previous class of BMQ students. SERV-AIR Corporation was given responsibility for employing the CMIs. By August 1990, they had employed two UH-60, three CH-47, and one MH-6 CMIs.

Work Projected

At the beginning of the next contract year, evaluation instruments will be developed for the MMI-CMI comparison. The instruments will include a demographic questionnaire, instructor evaluation forms, performance test protocols, flight evaluation forms, and academic tests. With the assistance of the CMIs, members of the project staff will determine which training materials should be upgraded. Training and cost-effectiveness data collection will begin with Class 91-2 in February 1991 and continue with Class 91-3 in April 1991. After the data are collected and analyzed, a briefing will be prepared and presented to the commander of the 160th SOAR, and a research report will be drafted to document the results of the evaluation.

SIMULATOR COMPLEXITY TEST BED FOR
THE PHOTO BASED MODELING SYSTEM

Mr. Gary W. Coker, Project Director

Background

In 1991, the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at Fort Rucker, Alabama, will take delivery of one of the most complex and powerful helicopter flight simulators ever procured by the Army. The simulator is a modular system that allows the rapid reconfiguration of system parameters to produce both high- and low-fidelity simulations of various aspects of the AH-64 helicopter mission. The system will use a fiber-optic, helmet-mounted display device with eye-tracking area-of-interest insets, a high-performance image generator (IG) with three hardware eyepoints, tactical environment software capable of providing multiple simultaneous simulations of intelligent forces using rule-based artificial intelligence, and other advanced technology.

The simulator is the principal component of the Simulator Complexity Test Bed (SCTB) research program under development at ARIARDA. The SCTB program is designed to answer research questions about the amount of simulation fidelity required to train specific tasks in the AH-64 helicopter. In addition, the simulator capabilities will allow ARIARDA researchers to conduct experiments in areas such as air-to-air combat that have been difficult or impossible to conduct with less advanced systems.

Need

This project was initiated in response to a tasking by ARIARDA to Anacapa Sciences to provide data base modeling support for the SCTB research simulator. When completed in 1991, the SCTB simulator will provide state-of-the-art simulation fidelity capabilities in both the visual imagery it can generate and the accuracy and complexity of the tactical scenarios it can simulate. Utilizing the full capabilities of the simulator will require a skilled team of computer scientists to provide data base modeling and tactical programming support. The SCTB system will be delivered with an off-the-shelf data base of the state of Arizona. However, the Arizona data base may require modifications for use in the SCTB program. In addition, new data bases for other environments (e.g., Fort Rucker) and ongoing data base

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modeling will be required as new experiments are planned and executed.

Project Objectives

The primary objective of this project is to provide data base modeling support to the SCTB project. The specific objectives of this project include:
- training Anacapa personnel in the theory and techniques associated with flight simulation and data base modeling, and
- providing an in-house data base modeling capability for the SCTB research program.

Approach

After receiving the required training, Anacapa computer scientists will build computer models of real-world objects (e.g., terrain, aircraft, ground vehicles, weapons systems, and cultural features) for visual data bases needed to meet the research requirements. The work will include modifying the Arizona data base and building completely new models and data bases, such as Hanchey Army Heliport. Models will be built to meet the following requirements:
- provide the highest fidelity possible,
- provide multiple levels of detail that can be degraded to address simulator fidelity research questions, and
- use modular construction to allow for rapid reconfiguration.

Work Completed

This project was initiated in October 1989. Work completed during the current contract year includes data base modeling training for the Anacapa computer scientists and developing a model of Hanchey Army Heliport.

The modeling training was divided into three phases. In the first phase, Anacapa personnel collected and reviewed all the available information related to the SCTB program. The data base modeling literature was searched and relevant reports were obtained and reviewed. All available information pertaining to the SCTB data base modeling system and its capabilities was obtained from the manufacturer. Computer-based training software packages were identified, procured, and used for training in the SCTB programming language (Ada).

Flight simulation concepts and techniques were studied using the ARIARDA Training Research Simulator. Finally, several meetings were held with the developers of the simulation system components, such as the Interactive Tactical Environment Management System (ITEMS), to obtain detailed knowledge about the operation of these systems.

In the second training phase, a 6-hour seminar entitled "Basics of Data Base Modeling" was developed and presented to all ARIARDA and Anacapa personnel currently involved in flight simulation projects. The seminar consisted of lectures and practical exercises for the participants.

The third training phase consisted of 10 weeks of intensive data base modeling training on the SCTB's ESIG-1000 IG. The 10 weeks were divided into four separate sessions, each lasting 2 - 3 weeks. The training was conducted between April and August 1990 at the Salt Lake City, Utah, facilities of the SCTB visual system manufacturer.

During the first session, the attendees were provided access to modeling system hardware and software used to generate code for data base models, to graphical workstations used to preview and debug models, and to a full-function one-channel IG for real-time, full-motion viewing of fully rendered data bases. During the four sessions, the attendees studied the following topics:

- producing data base models using Ada;
- creating correct geometry for data base models;
- structure of ESIG-1000 data bases;
- IG transfers and real-time system commands;
- level-of-detail processing;
- surface modeling, including color and texture;
- acquiring photographic texture using the Photo Based Modeling System;
- modeling lights (e.g., directional lights, beacons, and strobes);
- creating moving models;
- Static Model Systems, animation, and special effects;
- high-fidelity modeling;
- top-level design of data bases (requirements analysis, IG resource budgeting, and terrain concerns);
- using the Correlated Data Base tools for automatic terrain generation and feature placement; and
- Height Above Terrain, Collision Detection, and Line-of-Sight Ranging.

After completing the training course, Anacapa computer scientists were capable of generating complete visual data bases for the SCTB's ESIG-1000 IG.

In May 1990, work began on modeling Hanchey Army Heliport at Fort Rucker, Alabama. In preparation for developing the model, the computer scientists studied aerial photographs and a site map to determine the overall geography of the area. Next, the computer scientists studied blueprints for each of the structures on the Heliport. Finally, the computer scientists visited the airfield to observe its actual geography, vegetation, building geometry and coloring, surface textures, light placement, undocumented structures, and dynamic attributes such as ground vehicles and airfield clutter.

Initial modeling work consisted primarily of developing the building geometry. Subsequent work consisted of developing intrastructure and interstructure priority solutions, assigning color values to building surfaces, developing Ada programs to implement the designs, and debugging the models using modeling system tools. At the end of the contract year, the work consisted of developing each model, a master program to integrate all models into a single data base section, and a preliminary terrain design for the airfield.

Work Projected

During the next contract year, the work on Hanchey Army Heliport will be completed. Photographic texture will be incorporated into the model and the completed model will be integrated into the Arizona data base. Anacapa data base modelers will continue training on the SCTB system's real-time software, configuration management, and coordination of software subsystems. Upon delivery of the complete simulation system in 1991, Anacapa will provide ongoing data base modeling services in support of the SCTB research requirements.

TECHNICAL ADVISORY SERVICE: SUPPORT TO THE UH-1 TRAINING RESEARCH SIMULATOR (UH1TRS)

Mr. Richard J. Jamison, Technical Advisor

Background

The U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) has initiated a low cost visual helicopter simulator test bed research program using the cockpit and motion base system of a UH-1 Instrument Flight Simulator (UH1FS). The current version of the test bed is configured as a UH-1 (Huey) helicopter and is called the UH-1 Training Research Simulator (UH1TRS). The existing high fidelity UH1FS cockpit with its five degree-of-freedom motion base were retrofitted with three collimated out-the-window displays presenting one channel of imagery to each of the two front windows and the second channel to the right side window.

To save development costs, only those instruments required for primary phase flight training are active in the UH1TRS. The instruments include the attitude gyro, airspeed indicator, altimeter, vertical speed indicator, turn and bank indicator, and torque meter. The simulator cockpit includes instructional support features for use by the instructor pilot (IP), such as freeze/reset, begin/stop, a prerecorded demonstration flight, and an **instant replay** that repeats the last 75 seconds of flight. Aural cues are provided to support flight training. Engine, transmission, and main rotor sounds vary in loudness as a function of airspeed and power setting; the wind sound varies only as a function of airspeed. The sound of landing skids scraping the ground is simulated as a cue for the aircraft moving while on the ground.

From the control console, the simulator operator can communicate with the cockpit via an intercom system to control the training session. The operator can activate the simulator motion base, change initial conditions (e.g., aircraft location on the data base), add wind or turbulence, control training conditions (e.g., record/playback of a demonstration flight), or print a graphic plot of a recorded flight parameter, such as altitude, as a function of time.

Four UH1TRS transfer-of-training (TOT) experiments have been completed to date. Each TOT experiment required 10 randomly selected initial entry rotary wing (IERW) student pilots (SPs) to complete eight contact phase maneuvers to

standard in the UH1TRS. Iteration counts were recorded for
each maneuver. When the SP completed three successive itera-
tion counts to standard, pretraining was considered complete
for that maneuver. With the exception of the fourth experi-
ment, which substituted 9 hours of UH1TRS time for 11 hours
of flight time, the experimental group SPs joined the remain-
der of the class (control group SPs) on the first day at the
flight line. Iterations to criterion were recorded on the
eight selected maneuvers for each SP in the aircraft.

A transfer effectiveness ratio (TER) was calculated for
each maneuver in each experiment. Negative TERs were found
in some of the experiments. However, overall data from the
four experiments showed that the experimental group SPs
required fewer iterations in the aircraft and that a positive
TER was achieved for each maneuver.

Research Approach

Multiple experiments are planned for the UH1TRS to
evaluate the effectiveness of the simulator for training IERW
students, to determine how much fidelity is required for
effective simulation, and to determine the optimum combina-
tion of aircraft and simulator training. Each experiment
will follow the basic paradigm described for the previous
experiments. IERW students will be assigned to either a
control or an experimental group, differential training will
be conducted for the groups, and student performance in the
aircraft will be measured following the initial training.

Support Provided

During the current contract year, two additional
research projects were conducted in the UH1TRS. The first
experiment was conducted to determine the contribution of
motion to the effectiveness of the UH1TRS for training IERW
students in primary maneuvers. The maneuvers selected for
training were takeoff to hover, stationary hover, hover taxi,
hover turn, and land from a hover. Twelve warrant officer
candidates who had not yet started IERW training were
selected as SPs. Instruction was provided by IPs qualified
in the UH-1 aircraft.

The second experiment evaluated the effectiveness of an
automated hover trainer (AHT). The AHT was designed to aid
IERW SPs in learning basic hovering skills with minimal IP
supervision. The AHT utilizes artificial intelligence to
determine the degree of proficiency at which an SP is
performing a hovering maneuver. At the beginning of the

94

maneuver, the flight controls are degraded to the point that massive inputs are required to elicit a response from the UH1TRS. As the SP learns to control the UH1TRS within school standards, the artificial intelligence program increases the sensitivity of the controls until the SP is flying the true aeromodel.

Anacapa personnel provided the following support to the two UH1TRS projects:

- attended meetings and assisted in planning the motion/ no motion and AHT experiments,
- evaluated software programs developed for the UH1TRS,
- operated the UH1TRS and recorded data in support of the motion cue (motion versus no motion) experiment,
- operated the UH1TRS and collected data in support of the AHT experiment, and
- analyzed data and constructed briefing charts.

Results

The results of the first experiment indicate that the motion base does not facilitate the training of selected maneuvers for IERW students in the UH1TRS. The results of the AHT experiment indicate that SPs can be trained in hover related maneuvers utilizing the artificial intelligence program.

Work Projected

Anacapa personnel will continue to provide research support for projects using the UH1TRS.

MODIFICATION AND UPGRADING OF THE ARIARDA UH-1 TRAINING RESEARCH SIMULATOR (UH1TRS)

University of Alabama Flight Dynamics Laboratory
Subcontract No. ASI SubTR-690-90-2

Dr. Kenneth D. Cross, Subcontract Monitor

Background

The UH-1 Training Research Simulator (UH1TRS) is a low cost visual helicopter training simulator that was engineered and fabricated by U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) personnel and their contractors. The TRS is a 2B24 simulator (UH-1 instrument flight training simulator) equipped with a low cost visual system and improved equations of motion. The TRS was developed to assess the effectiveness of using a low cost visual helicopter simulator for training novice aviators to perform basic flight maneuvers. Research findings have shown that training in the TRS transfers well to the aircraft for most, but not all, flight maneuvers. The data indicate that transfer of training on some maneuvers is limited by shortcomings in the simulation and modeling of the UH-1 aircraft, particularly shortcomings in the aerodynamic math model.

The acquisition of hover skills (stationary hover, hover taxi, hovering turns) are among the most difficult and time consuming skills that flight students must acquire. Observation of the acquisition of hover skills in both the TRS and the aircraft led ARIARDA personnel to hypothesize that (a) the conventional methods used for training hovering skills are far from optimal and (b) an automated hover training capability could be developed for the TRS that would greatly increase the rate at which hover skills are acquired in the TRS.

Need

To conduct the research that is planned for the TRS, the TRS must be upgraded to provide advanced training capabilities, such as automated hover training, and to improve its simulated flight characteristics, especially the aerodynamic model. There also is a need to reinstall a two-channel, digital image generation (DIG) system and associated visual display system to return the TRS to the configuration previously evaluated.

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Objectives

This project has three primary objectives. The first objective is to evaluate the shortcomings in the current aerodynamic model and to refine the model as necessary to improve training transfer from the TRS to the UH-1 aircraft. The second objective is to develop an automated hover training capability for the TRS. The third objective is to replace the Evans & Sutherland (E&S) graphics system with a previously purchased graphics system and to configure the TRS for advanced training research.

Approach

Because Anacapa Sciences personnel did not possess the specialized skills required to accomplish the objectives of this project, ARIARDA directed that Anacapa negotiate a subcontract with the University of Alabama Flight Dynamics Laboratory (UAFDL) to perform the following tasks:

- evaluate shortcomings in the current UH1TRS aerodynamic model, obtain or develop an improved model, and implement the improved aeromodel;

- develop an expert-system-based application of the automated hover training mode;

- install a new cockpit interface processor; and

- replace the E&S DIG system in the TRS with the Bolt, Branek, & Newman (BBN) 120TX DIG system.

Work Accomplished

Anacapa negotiated a subcontract with the UAFDL to be performed from March 9, 1990 to December 31, 1990. Because the majority of the work was performed during the Anacapa contract year and before the annual summary report was prepared, all the UAFDL subcontract work is included in this summary.

Refine Aerodynamics Model

Since rotor inflow modeling and ground vortex dynamics are critical in simulating translational lift effects, the literature was surveyed to determine the size and strength of the ground vortex as a function of altitude and helicopter forward velocity. The literature review also revealed that adding the first harmonic inflow component to rotor inflow

computations can improve trim control deflections during translational lift.

Because of the limitations imposed by the TRS computers, the National Aeronautical and Space Agency (NASA)-Ames ARMCOP model was selected as the best alternative for implementing the UH-1 helicopter flight model upgrade. Personnel from UAFDL obtained an updated version of the programs that model ground effect and inflow dynamics from the NASA-Ames Research Center and incorporated it into the TRS program. The updated model was verified by comparing trim deflections with and without the first harmonic inflow term; the inflow term was also verified.

The ARMCOP model was implemented at Fort Rucker in July 1990. The model contains flight condition matrices for 16 airspeeds and 21 altitudes--a total of 336 flight condition matrices. Subsequently, a ground vortex model was developed and added to the ARMCOP model. This model uses a simplified circular vortex of size and strength that is dependent upon helicopter forward velocity and altitude. Finally, refinements to the flight condition matrices were made to model the collective trim map more accurately.

Develop Automated Hover Trainer

An early version of the automated hover trainer, developed under a prior contract, was modified in accordance with the requirements established by ARIARDA personnel. The modifications provided the capability to select from four hover maneuvers (hover, hover taxi, hover takeoff and land, and hover turns) and to select from three control choices (manual auto-help level changes, auto-forward and -backward level changes, and varying evaluation). In addition, the modifications provided for (a) an Iris-based performance monitoring and operator control, (b) an automatic initialization of the simulation in a hover, and (c) improved flying qualities.

The modified automated hover trainer was then augmented with a rule-based expert system. Eighteen rules were defined through interviews with instructor pilots and an analysis of the general requirements for proficient hovering. The rules were incorporated into CLIPS, an expert system shell developed by NASA-Johnson Space Center for use in mission planning. CLIPS software was implemented on PC-MS-DOS as well as IRIR 2400 workstations.

A Texas Instruments speech processing board (TISPEECH) was purchased and interfaced with the CLIPS expert system. With this system, flight simulation data are used by the expert system to fire rules that are violated. When the frequency of violations of a particular rule increases beyond a prespecified threshold, voice feedback informs the student of the problem. Hence, the voice feedback system enables the automatic hover trainer to provide aural assistance to the student pilot without human intervention.

The automated hover trainer software was converted from the E&S configuration to the BBN 120TX. Three versions of the modification were attempted to solve the problem of high communication overtime caused by the BBN 120TX image generators. Although this labor-intensive effort was beyond the scope of the contract, it was accomplished without a cost extension.

Install New Cockpit Interface Processor

The Heurikon Model HK68 microcomputer was replaced by a Heurikon Model M130 with a 20 MHz 6820 microprocessor. The new UNIX Version 5.3 necessitated rewriting all the Heurikon programs to reenable program access to hardware input/output (I/O) boards. Global memory was designed and built to support rapid communication of data between the Heurikon and the Array Processor. Because of the Heurikon architecture, it was necessary to change the addresses of many of the I/O boards that are used for driving the TRS controls, instruments, and motion base. The higher speed of the new Heurikon enabled project personnel to write software to implement driver programs for a variety of instruments.

Install BBN 120TX DIGs

The E&S DIG system was removed from the TRS and replaced with the BBN 120TX. As part of the BBN 120TX installation, the structure for mounting the mirror-beamsplitter optics and the TV color monitors on the TRS motion base platform was re-designed. Three 25 in. DELCOM RGB RS170 monitors were installed and the mounting structures were modified to support and align the new equipment. Software in the MicroVax and Array Processor was modified to give the rotation and scale factors to produce the correct fields of view. A special cage was built and installed on the TRS platform for housing the power supply needed to drive the monitors.

Subcontract Work Projected

All planned work on this subcontract was completed by 31 December 1990. Unless additional research is directed by ARIARDA, no further work will be conducted by the UAFDL.

DEVELOPMENT OF A METHODOLOGY FOR MEASURING
BOTH CONSCIOUS AND SUBCONSCIOUS ASPECTS OF AIRCREW
COORDINATION IN ARMY HELICOPTER OPERATIONS

Klein Associates Inc.
Subcontract No. ASI SubTR-690-90-3

Dr. Kenneth D. Cross, Subcontract Monitor

Background

The Army Research Institute Aviation Research and
Development Activity (ARIARDA) is conducting a multiphase
research effort designed to increase the safety and mission
effectiveness of Army aviation by improving the coordination
between Army helicopter crewmembers (e.g., see Thornton &
Zeller, 1991). One phase of this research program was to
observe the performance of UH-60 aircrews performing a tac-
tical mission scenario in the UH-60 Flight Simulator (FS).
The UH-60 FS research was designed to (a) identify aircrew
coordination requirements under the Army helicopter flight
regime, (b) identify aircrew coordination training defi-
ciencies, (c) develop performance and evaluation measures,
and (d) develop experimental techniques and training
procedures.

Klein and his associates have developed a methodology
for capturing individual and team decision making during
aircrew simulator performance (e.g., Klein & Thordsen, 1990;
Thordsen, Galushka, Klein, Young, & Brezovic, 1990; Thordsen
& Calderwood, 1989; Thordsen & Klein, 1989). Because of the
potential utility of the team decision model for determining
Army aviation crew coordination requirements and training
deficiencies, ARIARDA directed that Anacapa Sciences estab-
lish a subcontract with Klein Associates Inc. to participate
in the UH-60 FS research phase. The resulting subcontract
was executed between 1 April and 1 October 1990.

Subcontract Objectives

The overall goals of the ARIARDA crew coordination
research program were described in the Background section.
Three specific objectives were established for this
subcontract:

- identify Army aircrew coordination deficiencies,
- determine the feasibility of using team decision
  models to aid in training crew coordination, and

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- make recommendations for training observers and
  instructors in using the team decision model
  techniques and categories for improving crew
  coordination.

Subcontract Research Approach

Three members of the Klein Associates Inc. staff were
scheduled to participate in the UH-60 FS research project
(see Thornton & Zeller, 1991 for details). The Klein staff
planned to observe the performance of 10 UH-60 crews during
the tactical mission scenario and to conduct interviews with
the crewmembers after the simulator session. In addition,
they planned to observe the premission planning activities of
three of the UH-60 crews. Subsequently, they planned to use
the team decision model to analyze their observations and
interviews.

Subcontract Work Completed

All the work proposed under this subcontract has been
completed. Staff members from Klein Associates Inc. col-
lected data during the UH-60 FS research, conducted data
analyses to identify crew coordination deficiencies, devel-
oped training recommendations, and prepared and submitted a
project report (Thordsen, Klein, & Wolf, 1990) to ARIARDA.

The results of the Klein analyses indicate that the team
decision model methods can be adapted for observing crew
decision processes during helicopter missions. Five critical
deficiencies were identified during the simulated missions.
The first two deficiencies occurred during premission plan-
ning. First, the crews did not adequately evaluate the
commander's intent in the mission order. As a result, they
were unprepared to improvise when the mission plan did not
cover contingencies encountered during the flight. Second,
the crews did not conduct sufficient mental rehearsal of the
mission during premission planning. Without adequate
rehearsal, the crews failed to anticipate critical mission
aspects and did not fully share a common mental model of the
mission.

The other three deficiencies were identified during the
execution of the mission. First, the crews failed to main-
tain an appropriate time horizon. That is, the crew must
anticipate and coordinate events (e.g., changes in heading)
approximately 30 to 60 seconds ahead of their occurrence. If
the crew's time horizon is too advanced, the pilot flying
(PF) cannot maintain the information in memory and must

obtain supplementary directions. More typically, poorly coordinated crews were behind the time horizon and failed to anticipate and coordinate their activities in time to execute them.

Second, the pilot not flying (PNF) in poorly coordinated crews tended to micromanage the activities of the PF. That is, the PNF gave micro-level commands (e.g., stop here, turn now) without providing information about the progress of the entire mission (e.g., crossing the forward line of troops, 3 minutes from the landing zone). This type of coordination left the PF disoriented about the progress of the mission and required the PNF to give constant directives to the PF, often to the exclusion of other duties (e.g., making radio calls).

The final deficiency was the insensitivity of the crew-members to confusion in the other pilot. That is, the crew-members failed to anticipate the information needs of the other pilot or to confirm the receipt of information from the other pilot. This deficiency resulted in either uncoordinated crew performance or excessive cross-checking by the crewmembers to obtain the necessary information.

In addition to identifying crew coordination deficiencies, Thordsen, Klein, and Wolf (1990) present recommendations for training the aviators to avoid the identified coordination errors and for training observers and instructors to identify and remediate crew coordination problems. They also discuss modifications needed for their team decision model to be applied to helicopter flight and describe methods for representing aircrew coordination for research purposes.

Subcontract Work Projected

Submission of the final report (Thordsen, Klein, & Wolf, 1990) completes the planned work on this subcontract. Unless additional research is directed by ARIARDA, no further work will be conducted by Klein Associates Inc.

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