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HUMAN RESOURCES

AIRCREW TRAINING DEVICES:
INSTRUCTIONAL SUPPORT FEATURES

By

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Logistics Research Branch
Wright-Patterson Air Force Base, Ohio 45433

January 1981

Final Report

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

ROSS L. MORGAN, Technical Director
Logistics and Technical Training Division

RONALD W. TERRY, Colonel, USAF
Commander

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This report presents relationships between aircrew training device (ATD) instructional support features and training requirements. Instructional support features include ATD hardware and software capabilities that permit instructors to manipulate, supplement or otherwise control student learning experiences. The instructional features addressed are (a) freeze; (b) automated demonstrations; (c) record and replay; (d) automated cuing and coaching; (e) manual and programmable sets of initializing conditions; (f) manual and programmable malfunction control; (g) ATD-mounted audio visual media; (h) automated performance measurement; (i) automated performance alerts; (j) annunciator and repeater instruments; (k) closed circuit television; (l) automated adaptive training; (m) programmed mission scenarios; (n) automated controllers; (o) graphic and text readouts of controller information; (p) computer →

Item 20 Continued:

controlled threats; (5) computer managed instruction; (6) recorded briefings; (8) debriefing aids; and (7) hardcopy printouts. Each feature is discussed, as appropriate, in terms of (a) its operation, (b) related features, (c) instructional values, (d) observed applications, (e) utility (use-related) information, (f) related research, and (g) design considerations.

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PREFACE

This report describes a portion of a study of Air Force aircrew training using simulation as one part of a total training system. The study was initiated in response to a Request for Personnel Research (RPR-77-9) from Headquarters, USAF (AF/XOOTD).

This is one of seven technical reports prepared for the Air Force Human Resources Laboratory, Logistics and Technical Training Division, under Contract F33615-77-C-0067, Simulator Training Requirements and Effectiveness Study (STRES). The reports are identified in Chapter II of this document.

The work was performed from August 1977 through February 1980 by a team made up of Canyon Research Group, Inc.; Seville Research Corporation; and United Airlines Flight Training Center. Canyon Research Group, Inc. was the prime contractor; Mr. Clarence A. Semple was the Program Manager. The Seville Research Corporation effort was headed by Dr. Paul W. Caro. The United Airlines effort was headed initially by Mr. Dale L. Seay and subsequently by Mr. Kenneth E. Allbee.

Mr. Bertram W. Cream was the AFHRL/AS Program Manager. Other key members of the AFHRL/AS technical team included Dr. Thomas Eggemeier and Dr. Gary Klein. A tri-service STRES Advisory Team participated in guiding and monitoring the work performed during this contract to assure its operational relevance and utility. Organizational members of the Advisory Team were:

Headquarters, USAF
Headquarters, Air Training Command
Headquarters, Tactical Air Command
Headquarters, Strategic Air Command
Headquarters, Military Airlift Command
Headquarters, Aerospace Defense Command
Headquarters, Air Force Systems Command
Tactical Air Command, Tactical Air Warfare Center
Air Force Human Resources Laboratory
USAF Aeronautical Systems Division
Air Force Test and Evaluation Center
Air Force Manpower and Personnel Center
Air Force Office of Scientific Research
Navy Training Analysis and Evaluation Group
Army Research Institute for the Behavioral and Social Sciences

The authors wish to express their gratitude to the hundreds of people in the United States Air Force, Navy, Army, Coast Guard, NASA, FAA and industry who contributed to this program by providing technical data and participating in interviews and technical discussions during program data collection.

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CHAPTER I

INTRODUCTION

The U.S. military services have been users of flight training devices and simulators for over half a century. These training media, known collectively as aircrew training devices (ATD), include cockpit familiarization and procedures trainers, part-task trainers, operational flight trainers, weapons systems trainers, and full mission trainers. In recent years, use of ATDs has increased to the point that the devices represent major aircrew training resources, and their effective and efficient design and use is a matter of continuing concern.

In response to this concern, the U.S. Air Force undertook a programmatic study of factors involved in their design and use. This program was titled Simulator Training Requirements and Effectiveness Study (STRES). The general objectives of STRES are to define, describe, collect, analyze and document information bearing on the cost and training effectiveness of flight simulators. Topic areas covered in the program are: fidelity; instructional support features; simulator utilization; life cycle costs; and worth of ownership. Products of the program are intended for use by those who manage and use simulators for training, evaluate simulator requirements, design, procure, and maintain these devices. Chapter II describes the STRES effort in more detail.

This volume is one of seven prepared during STRES. It addresses concerns related to the design and use of ATD instructional support features. Other volumes prepared during the program are identified in Chapter II.

BACKGROUND

The history of flight simulation has been one of constant technological improvements. Most of these have focused on improving fidelity. As a result, modern digital flight simulators look, feel and respond more like their aircraft counterparts than ever before. One effect has been improved acceptance of simulators by instructors and students.

An effectively designed training simulator, however, is one that not only promotes user acceptance, but also takes advantage of the unique training opportunities that can be provided through simulation. ATDs offer freedom from many of the instructional constraints associated with aircraft as training devices. For example, instructional efficiencies can easily be obtained; performance assessment opportunities are improved; and, new tactics can be evaluated, which might not be possible in the air.

PURPOSE OF THIS REPORT

The purpose of this report is to define a comprehensive set of instructional support features, develop criteria for matching the features with training requirements, and present principles for their design and use. Specifically, the objective of this report is to evaluate currently installed features and review newly evolving technology for future applications.

This report is based on analysis of currently installed instructional features and a review of the scientific and professional literature. Gaps exist in this evolving technological area. The gaps remain to be filled by experimental research. Thus, the report also identifies information shortfalls on the design and use of instructional support features to alert users of the report to potential risk areas, as well as to guide future research.

It is anticipated that primary users of this report will be operational training, management and engineering personnel tasked with developing ATD specifications. Additional users may include engineers and training psychologists involved in detailed ATD design; operational users whose job is aircrew training using ATDs; and operational personnel and training psychologists tasked with test and evaluation of instructional support features.

FIDELITY-PLUS

For years, training psychologists have emphasized that ultra high fidelity probably is not necessary for training many aircrew tasks. They have further argued that training effectiveness, and particularly training efficiency, could be improved if ATD designs did not mimic corresponding aircraft and systems so closely. Their points are valid, but their approach has, on occasion, lead to confusion.

One theme of their argument has been that designing ATDs to be capable of doing only those things possible in aircraft may result in high fidelity, but does not take advantage of the fact that ATDs are not aircraft. A second theme has been that adding capabilities to ATDs that are not inherent in aircraft results in lower fidelity. The baseline for the second theme is that whatever the aircraft can do equals 100% fidelity, and any departure from this, either in terms of lesser capabilities or added capabilities, is a departure from 100% fidelity. This approach has seriously confused both the fidelity issue and the ATD instructional design issue.

Fidelity-plus is way of thinking about how to design and use ATDs as instructional tools while avoiding the nagging apprehension that fidelity must be sacrificed in the process. For example, highly accurate flight characteristics fidelity does not need to be sacrificed if the capability to freeze one or more axes of flight control is built into

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the ATD. Content of an out of the cockpit visual scene does not need to be degraded so that the ability to add cues of benefit to the student's learning process can be done at the instructor's discretion. Also, the capability to use an ATD for chock to chock mission training is not lost just because the device also incorporates capabilities allowing the instructor to freeze the mission temporarily, or to reinitialize the ATD to some other geographic point at the press of a button.

In short, fidelity does not need to be sacrificed to design and use simulators as unique instructional tools that are not constrained by the ways aircraft operate and must be operated.

INSTRUCTIONAL SUPPORT FEATURES

It is important to distinguish between fidelity features that enable certain training to be undertaken in ATDs, and instructional support features. An out of the cockpit visual scene is a fidelity feature that can make possible visual landing, air to ground weapon delivery or air refueling training. Such visual task training would not be possible without the fidelity feature. However, some have referred to out of the cockpit visual simulation as an "instructional feature" because it makes certain instruction possible. This is not how the term instructional support feature is used in this report. As used here, instructional support features are ATD hardware and software capabilities that allow the instructor to manipulate, supplement and otherwise control the student's learning experiences with the intent of promoting the rate at which skills are learned and maximizing the levels of skills achieved (Hughes, 1978).

There has been a long term interest in finding ways to capitalize on unique training opportunities offered by properly designed ATDs (Smode and Hall, 1966; USAF, 1978; and Hughes, 1978). A recent survey (Caro, 1977) found that unique ATD training capabilities often are not capitalized on. The same was found true in the present program.

Instructional support features offer one means of capitalizing on unique training capabilities inherent in well designed and used ATDs. Virtually all ATDs incorporate some type of instructional support feature intended to promote training quality control, efficiency and effectiveness. Some features, such as record/replay and problem freeze, have been incorporated into ATDs for a number of years. Others, such as programmed mission event control and automated performance measurement, are relatively new technologies. Still others, such as automated adapative training, are largely although not totally in laboratory stages of development.

Instructional support features offer many potential ATD training benefits when they are properly designed and used. These include:

Making it possible to use productive training
methods that cannot be used in aircraft;

Tailoring training to individual student needs;

Making more productive use of available training
time and instructor assets;

Enhancing the standardization of training and the
evaluation of operational readiness;

Relieving instructors of routine, non-productive
tasks through automation;

Controlling the simulated environment and aircraft
conditions;

Improving capabilities to diagnose student learning
problems and focus instruction;

Providing learning oriented performance feedback;
and

Controlling training problem complexity and
difficulty.

INSTRUCTIONAL SUPPORT FEATURES AND TRAINING TASKS

Many designers and users of ATD instructional support features have
assumed that the value of a feature is directly linked to the type of
task being trained. They have assumed, for example, that some features
are best suited for training approach and landing, while other features
are better suited for training air refueling.

This assumption was evaluated throughout the program and was found
to be incorrect. What was found is that the value of instructional
features hinges strongly on the student's stage of training (i.e. skill
and knowledge levels) and the ways the feature can be used by
instructors to support the training of students at different stages of
skill development. This finding had an important impact on the
organization and content of this report, as discussed in the next
section.

INSTRUCTOR FUNCTIONS AND INSTRUCTIONAL SUPPORT FEATURES

An important thrust of this report is that the design or use of any
instructional support feature has meaning only in the context of:
1) the manner in which it supports the instructor in providing
meaningful instruction effectively and efficiently; and 2) the manner in
which it supports the student by helping him to learn faster and perform

better. In other words, instructional support feature design and use must focus on the payoffs they can provide. Hardware and software characteristics of any feature, by themselves, have little practical meaning.

Organization of this report focuses on the instructor and student support roles discussed above. The primary organizing mechanism was to ask: Can a particular instructional support feature be a useful tool for instructors in using ATDs in the doing of their job? An answer to this question, in turn, requires some analysis of what an instructor does during training in ATDs.

The instructor's job is made up of many activities that contribute to the larger role of training. Functions are used here to describe the general types of activities that instructors (and, occasionally, console operators) perform in the use of simulators for training.

Functions performed by people often are more difficult to define and get agreement on than are functions performed, for example, by major aircraft subsystems. This is true of instructor functions. The main reasons is that the process of instruction often involves doing several functions at the same time or in relation to one another. In other words, it is acknowledged that the instructor's job is not simply a series of duties performed in isolation from each other. For example, individualizing training is not done in isolation from monitoring and evaluating performance. The two go together.

On the other hand, if it is acknowledged that instructor functions are not really independent, then the various functions can at least be dealt with one at a time in order to define them, examine relationships among them, and to illustrate how instructional feature technology may help instructors in doing these many things.

Table 1 defines seven instructor functions involved in the use of ATDs. Instructional support feature technology that has known or potential value as a tool for the instructor to use in performing each function also is presented. The functions and their definitions are adapted from previous work (Semple, Vruels, Cotton, Durfee, Hooks, & Butler, 1979) that dealt with the instructor's role in pilot training and the development of instructional support technology to aid the instructor in performing his role.

The functions presented in this section are limited to those involved in the use of ATDs. Thus, they do not address other job requirements such as collateral duties, platform lecturing, or the development of instructional materials. Also, it is recognized that details of the way each function is performed in the operational environment vary depending on student characteristics, the type of device being used and the types of training provided. Effects of such

Table 1. Instructor Functions and Related ATD
Instructional Support Features

Instruct. Instruct means to direct the growth of skills and knowledges by giving knowledge and information in a systematic way. Related support features are:

> Freeze; automated demonstrations; record and replay; manual and programmable sets of initial conditions; automated cuing and coaching; ATD-mounted audio/visual media; and manual or programmable malfunction control.

Monitor/Evaluate Performance. Monitor means to observe and check the quality of performance for specific purposes. Evaluate means to determine the meaning and significance of observed performance values. Related support features are:

> Automated performance measurement; automated performance alerts; closed circuit TV; and performance monitoring displays (plotter/position displays, perspective displays, event annunciators, repeater instruments, and synthesized (CRT) repeater instruments.

Control/Individualize Training. Control means to direct or regulate training events. Individualizing training is a special case of controlling where training is tailored to the student's specific skills and abilities. Related support features are:

> Automated adaptive training; and programmed mission scenarios

Controller. Instructors or ATD operators often play the roles of air traffic controllers, or control the actions of simulated threats. Related support features are:

> Automated controllers (incorporating computer generated voice and speech understanding systems); graphic or text readouts of controller information; and computer controlled (iron pilot) adversaries.

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Table 1. (Continued)

Prepare. Prepare means working out beforehand the details of what is to be trained and how it is to be trained during a period of instruction. For the purposes of this report, preparing focuses on highly individualized, proficiency advanced training where the instructor is required to make training content decisions as a matter of routine. The related support feature is:

> Computer managed insructional system, with specific capability to track training objectives achieved and yet to be achieved separately for each trainee.

Brief. Brief means giving final training session instructions to the student, coaching him through the events of the mission in advance, questioning him to determine his readiness for the upcoming training, and providing remedial instruction in weak areas. The related support feature is:

> Recorded briefings of training session instructions and coaching information.

Debrief. Debrief means to review with the goal of evaluation combined with instruction. Related support features are:

> Remote replay of flight profile or crewstation display information; and hardcopy printouts of flight profile or performance measurement data

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factors are noted, when appropriate, in the information presented on each instructional feature.

Not all relevant issues fall conveniently into any of the instructor function categories. The following two issues also are addressed in this report, although they do not appear in Table 1: 1) instructor/operator console design/location; 2) and instructor/operator training as it relates to the use of ATD instructional support features.

REPORT ORGANIZATION

Separate chapters deal with each instructor function. Content of each chapter is structured to provide common sets of information on each related instructional support feature. The following information is presented in the main body of this report separately for each instructional support feature.

Summary. The discussion of each instructional support feature starts with a summary statement. The feature is defined, and the state of knowledge on the design and use of the feature is summarized.

Feature Description. Each instructional support feature directly related to a specific instructional function is described separately. Where a particular feature supports more than one instructor function, it is considered in detail under the function to which it has the strongest relationship. Each feature is cross referenced to the other instructor functions it supports.

Related Support Features. Instructional functions are interrelated. It is logical, therefore, that instructional support features should be addressed in an integrated, mutually supportive framework. For example, total system freeze may have value during automated demonstrations. Also, automated adaptive training is predicated on workable automated performance measurement and automated testing for learning problem diagnosis. This section presents linkages between the feature under discussion and other features, as appropriate.

Instructional Values. The instructional values most often assumed or attributed to each feature are identified and discussed. Additionally, this section presents selected instructional principles associated with the proper use of each feature.

The U.S. Army (Wheaton, Fingerman, Rose and Leonard, 1976) recently completed a program to identify principles of instruction, assess their theoretical benefits, and assess research evidence on the benefits of each principle. A product of their research was a theoretical and empirical assessment of the extent to which support presently exists for each instructional principle.

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A total of 97 instructional principles was assessed by Wheaton, et al. Each was rated separately on the basis of theoretical and experimental support. Instructional principles of apparent intuitive value are relatively easy to create. The question is: Can they be supported on sound theoretical and empirical bases? Often, this is not the case. Therefore, for this report, instructional principles supported by an empirical confirmation rating of good to excellent were separated from the rest so that well established instructional principles could be associated with observed and projected uses of the instructional support features addressed in this report.

The principles thus identified are presented in relation to commonly assumed, often untried, but potential training values of instructional support features. The reasons for doing so are to stimulate creative thought on applications of this evolving technology area while at the same time advising on realistic bounds that are in keeping with the present state of knowledge.

Not all instructional support features are directly related to principles of training. Some, for example, simply are associated with training efficiency, instructor workload, and the best use of training time. An example is ATD initialization to a set of conditions. In the example, time required to "fly" and configure the ATD to desired states can be shortcut. In other instances, training principles are involved and are identified.

Observed Applications. Training programs and devices observed during the program that incorporate the instructional support features under consideration are summarized. The purpose is to identify existing applications of the feature and provide the reader with a general background on interview and observational data sources.

Obviously, present practices in the design and use of instructional support features should not set limits for the future. Thus, present day designs and uses are discussed only when they provide illustrations of particularly good or poor characteristics and, therefore, may be of value to the reader.

Utility Information. Content of this section deals with a spectrum of factors that can influence acceptance and use of an instructional feature. The range of factors initially investigated included: reliability and maintainability; ease of use; frequency of use; user acceptance; and a variety of variables that impact on the acceptability and utility of individual instructional support features and combinations of features.

During the program it was found that reliability and maintainability were not isolated to particular features. Rather, these factors are embedded within total ATD reliability and maintainability. For example, automated performance measurement, where it exists, usually is not a separate hardware/software capability. Rather, it is an integral part of the ATDs design. Thus, features typically do not fail in isolation. The entire simulation either operates or does not operate.

Similarly, frequency of use of a feature is more a function of instructor/operator training, training program objectives and student skill levels than anything else. For example, the use of record/replay may be greater when the student is relatively naive to the task than when he is highly experienced. This section addresses, feature by feature, these and related considerations.

Related Research. Specific research results and other information developed during the program are presented separately for each feature. Information shortfalls also are set forth in this and related sections. On-going research activities are identified as they relate to present information shortfalls.

Instructional support features represent a largely neglected research area. Their possible values and limitations are largely, although not totally, assumed based on experience and judgement. This report combines judgement, experience and research findings (where they exist) regarding the values and limitations of instructional features in the context of specific instructional functions and training requirements. Additional research on instructional feature design and use is sorely needed. Until it is performed, many design and use recommendations really are just hypotheses.

Design Considerations. This section presents guidelines for implementing instructional support features in ways that will enhance support of the instructional process and promote ease and effectiveness of use of the features by instructors, operators or students, as appropriate.

Conditional judgements also are made on possible designs and applications of features currently in developmental stages and for which no operational or research experience of consequence exists.

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CHAPTER II

THE STRES PROGRAM

INTRODUCTION

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

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

Because of the advantages simulation can offer over other aircrew training media, it is current Air Force policy that ATDs will be used to the fullest extent to improve readiness, operational capability and training efficiency. Implementation of this policy requires specific technical guidance. Information upon which to base that guidance is sparse, however, and the information that does exist is not always available to those who need it. The STRES program was intended as a means of identifying and making available ATD design, use, cost and worth information to support relevant Air Force policies. The information is intended to provide guidance for the enhancement of present training, as well as for the focus of research and development needed to enhance future simulation-based training.

PROGRAM STRUCTURE

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

> Criteria for matching training requirements with ATD fidelity features;

> Criteria for matching ATD instructional features with specific training requirements;

> Principles of effective and efficient utilization
> of ATDs to accomplish specific training
> requirements; and
>
> Models of factors influencing the life cycle cost
> and worth of ownership of ATDs.

The Air Force plan for accomplishing these objectives involves a four-phase effort. Phase I, which was concluded prior to the start of the present study, was an Air Force planning activity to define and prioritize the total effort. Phase II, the effort described in the series of reports identified below, was a 29 month study that involved collecting, integrating, and presenting currently available scientific, technical, and operational information applicable to specific aircrew training issues. Phase II also involved the identification of research and development efforts needed to enhance future simulator training. Phase II was conducted by a team composed of Canyon Research Group, Inc., Seville Research Corporation, and United Airlines Flight Training Center. Phase III is planned to be a research activity that will provide additional information on important simulation and simulator training questions that cannot be answered with currently available data. Finally, building on Phases II and III, Phase IV is planned as an Air Force effort to integrate findings, publish relevant information, and provide for updating of the knowledge base as new information becomes available.

A tri-service Advisory Team was formed by the Air Force to help guide STRES. The team has participated in two ways. One was to assist in the Phase I program planning. The second has been to provide guidance and evaluative feedback during Phase II to ensure that products of the phase would be operationally relevant and useful. Operational users of ATDs and the research community were represented on the Advisory Team.

A principal task of the Advisory Team was to participate in the development of objectives and guidelines for the conduct of the Phase II technical effort. As a focus for those efforts, a set of "high value" operational tasks was identified. The tasks selected were those for which potential ATD training benefits were judged to be greatest, and for which information on ATD design, retrofit, use, and worth was believed to be incomplete or lacking. These tasks also provided a focus for identifying questions and issues reflecting the information needs of operational personnel that were to be addressed during Phase II efforts. The high value tasks identified by the Advisory Team are:

> Individual and formation takeoff and landing;
>
> Close formation flight and trail formation, both
> close and extended;

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Aerobatics;

Spin, stall and unusual attitude recognition, prevention and recovery;

Low level terrain following flight;

Air refueling;

Air-to-air combat (guns and missiles); and

Air-to-ground weapons delivery.

SOURCES OF INFORMATION

Information from two sources was collected during Phase II to address the objectives of STRES. One source was the professional and technical literature. This literature included books, conference proceedings, professional journals, research reports, military manuals and regulations, and policy statements. The second source was military and civilian personnel whose experiences related to the objectives of the study. Information was obtained from these personnel during visits to organizations to which they were assigned.

Literature Review

Computer searches were made at the outset to identify literature relevant to all facets of the Phase II effort. In addition, each contractor team member was responsible for identifying documents pertinent to his responsibilities that may have been missed in the computer searches. In these individual efforts, articles pertinent to the various activities of colleagues were regularly encountered. Each investigator was aware of the information needs of his colleagues, and frequent communication among team members assured that colleagues would be apprised of articles of potential value to their tasks. Hence, the search for literature of concern to the preparation of a given volume of the STRES report series, while systematically compiled by those specifically responsible for that volume, was expanded through the efforts of the entire team.

To provide integration and focus to these literature search efforts, one group of the STRES team was specifically responsible for identifying articles of potential interest to all team efforts, as well as for preparing comprehensive abstracts of selected documents that appeared particularly valuable. These abstracts appear in a separate volume of the STRES report series.

More than 1,100 documents were identified during these efforts as potentially relevant. These were further screened according to the currency and completeness of information provided and the integrity of

the experimental and analytic methods used. As a result of this screening, approximately 400 documents were found to be useful for STRES purposes.

Site Visits

A considerable body of information also was obtained from organizations, both government and commercial, whose personnel are involved in the design, procurement, evaluation, management, and use of ATDs. ATD manufacturers, research and development agencies, and a commercial airline were visited in addition to Air Force, Army, Navy, and Coast Guard military training sites. At each organization, extensive data were obtained through observations, interviews, and document reviews. The training organizations visited and the topics of primary interest at each are listed in Table 2. Table 3 lists non-training organizations that were visited and corresponding interest topics.

Specific objectives of the interviews and other data collection efforts varied, depending on the type of organization visited and the purpose of the visit. Manufacturers and research and development agencies were visited to assess current and projected technology and to review ongoing and planned efforts bearing on STRES program objectives. ATD using organizations were visited to obtain a variety of information related to types and effectiveness of training accomplished, uses of various types of devices in accomplishing the training, ATD design characteristics, worth of ATD ownership, and ATD life cycle costs. Detailed interview guides were used.

STRES PHASE II REPORTS

Seven reports were prepared to document Phase II efforts and findings. They are:

Semple, C.A. Simulator Training Requirements and Effectiveness
    Study (STRES): Executive Summary. AFHRL-TR-80-63. Wright-
    Patterson AFB, OH: Logistics and Technical Training Division,
    Air Force Human Resources Laboratory, January 1981.

Semple, C.A., Hennessy, R.T., Sanders, M.S., Cross, B.K., Beith,
    B.H., & McCauley, M.E. Aircrew Training Devices: Fidelity
    Features. AFHRL-TR-80-36. Wright-Patterson AFB, OH:
    Logistics and Technical Training Division, Air Force Human
    Resources Laboratory, January 1981.

Semple, C.A., Cotton, J.C., & Sullivan, D.J. Aircrew Training
    Devices: Instructional Support Features. AFHRL-TR-80-58.
    Wright-Patterson AFB, OH: Logistics and Technical Training
    Division, Air Force Human Resources Laboratory, January 1981.

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Table 2. Training Sites Included In Program Surveys

Sites and Units	Topics of Interest
Altus AFB, OK (MAC) 443rd Military Airlift Wing	C-5 transition training
Castle AFB, CA (SAC) 93rd Bomb Wing	KC-135/B-52 transition training
Denver, CO United Air Lines Flight Training Center	DC-10/B-737/B-747 transition and continuation training
Eglin AFB, FL (TAC) 33rd Tactical Fighter Wing	F-4 continuation training
Fort Rucker, AL US Army Aviation Center	UH-1/CH-47 undergraduate and transition training
Langley AFB, VA (TAC) 1st Tactical Fighter Wing	F-15 continuation training
Mobile, AL US Coast Guard Aviation Training Center	HH-3/HH-52 transition and continuation training
NAS Cecil Field, FL VA-174 and Light Attack Air Wing One	A-7E transition and continuation training
NAS Jacksonville, FL VP-30 and Patrol Wing Eleven	P-3C transition and continuation training
Plattsburgh AFB, NY (SAC) 380th Bomb Wing	FB-111 transition training
Reese AFB, TX (ATC) 64th Flying Training Wing	T-37/T-38 undergraduate pilot training
Tinker AFB, OK (TAC) 552nd Airborne Warning and Control Wing	E-3A transition and continuation training

Table 3. Sites Visited For Management, Research,
Development, Engineering and Cost Surveys

Sites and Agencies	Topics of Interest
Pentagon Headquarters, USAF	Management of Air Force ATD resources, and life cycle costs
Randolph AFB Headquarters, ATC	Management of the use of ATDs in undergraduate pilot training, and life cycle costs
Langley AFB, VA Headquarters, TAC	Management of the use of ATDs in fighter aircrew training, development of ATD requirements, and life cycle costs
Eglin AFB, FL (TAC) Tactical Air Warfare Center	Procurement, development and evaluation of ATDs
Luke AFB, AZ (TAC) 4444th Operational Training Development Squadron	Development of training and ATD requirements
Williams AFB, AZ Air Force Human Resources Laboratory (AFHRL/OT)	ATD research
Wright-Patterson AFB, OH Air Force Human Resources Laboratory (AFHRL/LR)	ATD research
Fort Rucker, AL US Army Research Institute for the Behavioral and Social Sciences	ATD research
NASA Langley Research Center Langley, VA	ATD research
McDonnell Douglas Corp. St. Louis, MO	ATD design and research
Singer-Link Corp. Binghampton, NY	ATD design, procurement and evaluation
Navy Training Analysis and Evaluation Group Orlando, FL	ATD research and life cycle costs

Table 3.   -   (Continued)

Sites and Agencies	Topics of Interest
Naval Training Equipment Center, Orlando, FL	ATD research and life cycle costs
Navy Personnel Research and Development Center San Diego, CA	ATD research and life cycle costs
US Army Project Manager for Training Devices (PM-TRADE) Orlando, FL	ATD research and life cycle costs
Hill AFB, OK (AFLC)	ATD life cycle costs
Holloman AFB, NM (AFTEC)	ATD life cycle costs
Luke AFB, AZ (TAC)	ATD life cycle costs
Offutt AFB, NE (SAC)	ATD life cycle costs
Scott AFB, IL (MAC)	ATD life cycle costs
Travis AFB, CA (MAC)	ATD life cycle costs
Williams AFB, AZ (ATC)	ATD life cycle costs
Wright-Patterson AFB, OH (ASD)	ATD engineering and life cycle costs

Caro, P.W., Shelnutt, J.B., & Spears, W.D. Aircrew Training Devices: Utilization. AFHRL-TR-80-35. Wright-Patterson AFB, OH: Logistics and Technical Training Division, Air Force Human Resources Laboratory, January 1981.

Allbee, K.E., & Semple, C.A. Aircrew Training Devices: Life Cycle Cost and Worth of Ownership. AFHRL-TR-80-34. Wright-Patterson AFB, OH: Logistics and Technical Training Division, Air Force Human Resources Laboratory, January 1981.

Prophet, W.W., Shelnutt, J.B., & Spears, W.D. Simulator Training Requirements and Effectiveness Study (STRES): Future Research Plans. AFHRL-TR-80-37. Wright-Patterson AFB, OH: Logistics and Technical Training Division, Air Force Human Resources Laboratory, January 1981.

Spears, W.D., Sheppard, H.J., Roush, M.D., & Richetti, C.L. Simulator Training Requirements and Effectiveness Study (STRES): Abstract Bibliography. AFHRL-TR-80-38. Wright-Patterson AFB, OH: Logistics and Technical Training Division, Air Force Human Resources Laboratory, January 1981.

The content of the first four of these reports, i.e., ATD fidelity, instructional features, utilization, and cost and worth of ownership, is interrelated. As an aid to the reader in accessing related information, these four reports were cross-referenced. Within a single volume, other chapters where related information is discussed are referenced. When the cross-referenced information is in another volume, that volume is identified by abbreviated title (Fidelity, Instructional Features, Utilization, or Cost) as well as by chapter. For example, Utilization, Chapter IV, would indicate that related information will be found in Chapter IV of the report titled Utilization of Aircrew Training Devices. As an additional aid to the reader, the Executive Summary volume reproduces the tables of content of all four technical volumes to provide a consolidated listing of topics addressed in each.

APPROACH TO THE INSTRUCTIONAL SUPPORT FEATURES SURVEY EFFORT

Literature Review

Articles identified during the literature search were screened for relevance to ATD instructional support features. The screening was not restricted to the immediate domain of this report, however, for the perspective needed to answer questions related to feature design and use frequently required knowledge of broader issues such as the nature of the training being undertaken, student entry level skills, and instructional feature technology. Also, information concerned primarily with phenomena and principles of learning and related instructional practices was needed for a comprehensive assessment of ATD instructional support features.

Site Visit Activities

Activities of study team members responsible for the instructional support feature area during visits to sites identified in Table 2 included inspection of available simulators and related training aids, and observation of demonstrations of pertinent aspects of their capabilities and use. The majority of time was spent, however, in intensive interviews with instructors involved in ATD use, ATD console operators, and pilots undergoing training. Additionally, maintenance personnel were interviewed on the reliability of ATD consoles and instructional features. A detailed interview guide (Appendix A) was used, and notes were recorded during and following the interviews.

Detailed information relating specifically to instructional support features included: 1) training objectives; 2) training methods and techniques used; 3) types of ATDs used in training each objective; 4) the roles of instructors and ATD console operators; 5) instructional support features available in the ATDs; 6) instructor and operator training in the use of available features; 7) desirable and undesirable feature design characteristics; and 8) types and extents of their use for the training being provided. As shown in the interview guide, information pertaining to the overall training programs was also acquired so that utilization practices involving available instructional support features could be put into perspective.

Interviews with key personnel were the principal information gathering technique used during visits to the training sites indicated in Table 2. Interview guides used at the training sites served as checklists for topics to be addressed at each agency. The thrust of visits to sites shown in Table 3, however, was to obtain information about research in progress or planned, advanced simulation technology, present and anticipated regulatory requirements, and policies that could contribute to improved future ATD training programs. Information gained from these sources also broadened the perspective from which practices at training sites could be viewed.

CHAPTER III

INSTRUCT

FUNCTION DEFINITION

The primary reason for using an ATD is to instruct. Other uses include proficiency checks and research. The formal definition of instruct is to impart knowledge and/or skill in a systematic fashion.

Instruct is a broad functional concept that has different meanings to different people and can incorporate wide sets of training activities and techniques. For the purpose of this chapter, instruct is defined as consisting of four highly interrelated sub-functions: 1) providing correct procedures; 2) providing technique information; 3) critiquing; and 4) providing feedback information.

RELATED FUNCTIONS

The reader is directed to the following chapters that address functions related to the instruct function:

Chapter IV,   Monitor and Evaluate Performance

Chapter V,   Control and Individualize Training

INSTRUCTIONAL SUPPORT FEATURES ADDRESSED

The instructional features addressed in this chapter are:

Freeze

Automated demonstration

Record and replay

Automated cuing and coaching

Manual and programmable sets of initializing conditions

Manual and programmable malfunction control

ATD-mounted audio visual devices

FREEZE

Summary

Freeze is a common ATD instructional feature. It allows the instructor/operator to stop all or part of ATD system operations by fixing the value of one or more computational parameters. Seven variations on the basic freeze capability were identified during program site visits. Instructional values of the feature depend on the variation being used. Assumed instructional values include: reduce or otherwise control trainee task loading; simplify flight control and related procedural tasks; enable more productive instructor-student interaction; and enable OFTs, PTTs and FMTs to be used for procedures training when other means are not available. Other potential values are discussed in this section. Relationships are presented between alternative freeze capability designs and intended uses. It is concluded that four variations of freeze (total system freeze, flight system freeze, position freeze, and parameter freeze) are sufficient for practically all aircrew training applications.

Feature Description

The freeze feature allows simulator parameters to be fixed at values existing when freeze is operated. Some or all device parameters associated with the student's task can be fixed. The freeze feature can be operated manually by the instructor, or it can be operated automatically when specified parameter values are exceeded, as in the case of "crash". The feature and its variations have the greatest potential application in OFTs, PTTs and FMTs. Observed variations of the freeze feature are defined below to provide standard definitions for use in subsequent discussions.

> Total System Freeze. All system parameters are frozen, including flight control, propulsion, navigation and weapons. The entire simulation ceases to function from a training standpoint. For systems equipped with platform motion, the motion system is driven to a neutral position, at a safe rate, allowing for exit from or entry into the ATD.

> Flight System Freeze. Flight control and propulsion system parameters are frozen, together with latitude, longitude, altitude and heading. The net effect is that the ATD ceases to "fly". However, all other simulated systems remain operational and can be used for instructional purposes without the burden of having to fly the ATD. This freeze variation functionally converts an OFT or FMT to a CPT.

> Automatic Freeze. This variation of freeze commonly is called "crash". Crash occurs automatically when specified parameter values are exceeded. Automatic freeze, as commonly implemented, causes all ATD parameters to reinitialize to specified values, thus

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interrupting the mission. For systems equipped with platform motion, the motion system is driven to a neutral position at a safe rate.

Crash Override. Crash override disables automatic freeze.

Kill. This freeze variation is similar to but not identical with crash. Kill can be operated either automatically or manually to indicate a lethal weapon hit. Cockpit indications and motion system operations are identical with crash. In most applications, however, the ATDs software is programmed to freeze all operational parameters, rather than automatically reinitialize them to predetermined values.

Kill Override. Kill override unfreezes system parameters frozen by the kill function. This enables the mission to continue without the need to reinitialize the ATD.

Parameter Freeze. This variation of freeze enables the instructor to fix the value of individual parameters, usually from the instructor/operator console. The values of one or more parameters can be frozen at any given time. Typical uses include freezing just altitude, heading or the roll axis of flight control.

Attitude Freeze. This is a variation of parameter freeze where values for pitch, bank and heading are frozen simultaneously. Latitude and longitude may or may not be frozen, depending on the implementation. Motion platform position also is frozen at the angular values existing when attitude freeze is selected, at least in present implementations.

Position Freeze. This variation freezes values of latitude and longitude only. Thus, the ATD continues to "fly", but it "goes nowhere" geographically.

Related Support Features

Relationships of freeze to other instructional support features are summarized below. All relationships were observed during site visits.

Record and Replay. A number of ATDs have the capability to record parameter values and use these data to recreate system behavior for students and instructors to use in a review mode. The use of total system freeze is common in devices during replay. It has proved useful to stop the replay to reduce the task load on the student to allow for improved performance problem diagnosis and instruction, and simply to stop the replay to allow reinitializing the ATD. (See the record and replay section of this chapter)

Automated Demonstrations. Automated demonstrations permit the standardized presentation of a mission segment or an entire simulated flight. As in replay, the ability to system freeze has proved useful to stop the demonstration to allow for student questioning or instruction, and simply to stop the demonstration to allow reinitializing the ATD. (See the section of this chapter on manual and programmable sets of initializing conditions)

Initialize ATD. Total system freeze was used in all ATDs surveyed to stop an ongoing exercise as the first step in reinitializing the ATD. (See the section of this chapter dealing with manual and programmable sets of initial conditions)

Instructional Values

Three instructional values commonly are assumed for the freeze feature. The most common is to provide for more productive instructor-student interaction. Total system freeze and flight system freeze support this use, because many task requirements are removed from the student's task load. This often provides for improved instructional opportunities. Also, total system and flight system freeze variations provide a stable (non-moving) crewstation environment which, for example, allows the instructor to stand immediately outside an ATD cockpit, with the canopy open, but without an unacceptable safety hazard. Uses of attitude freeze or position freeze, in combination with parameter freeze, were observed during the program as ways of achieving flight system freeze for the above purposes.

A second instructional value is the reduction of student task loading in cases where the instructor may not be present or elects not to intervene directly. Flight system freeze and position freeze support this ATD use. For example, either the instructor or the student may request a temporary halt in the ATD training session so the student can review checklists, charts or other necessary documents; reorient himself geographically; or discuss crew roles and coordination with other crewmembers. Taking a rest break also is a proper use of freeze.

A third instructional value is that simplifying flight control tasks during initial training may speed the learning of new flight control skills. Parameter freeze is suited to the control of individual flight parameters or axes. For example, altitude can be frozen while training is focused on bank and heading control. Similarly, heading can be frozen while training is focused on pitch and power control. No experimental evidence is known that either supports or refutes the effectiveness of using parameter freeze in this manner for fixed wing pilot training. At the time this report was written, instructor experience with this use of parameter freeze was insufficient to allow the forming of stable opinions.

The following instructional principles, supported by research, are involved in the assumed values and proper uses of freeze.

Control cues to ensure that the student is forming proper associations; i.e. responding appropriately to the correct cues. Freeze can be used to teach and reinforce correct associations.

Stimuli used in training should be nearly identical to job stimuli unless this fidelity increases problem difficulty in initial phases of training to unacceptable (unproductive) levels. Parameter, position or attitude freeze can simplify problem difficulty.

Emphasize differences between correct and incorrect cue forms.

Three additional instructional values of the freeze feature were observed during the program. Their applications are more situation specific than the ones discussed above.

The first application is termed controlled demonstration. In the general case, flight parameters are selectively frozen to limit the progress of the simulation in time and space. For example, position freeze may be selected so that the ATD's geographic reference is fixed during a final approach to a visual landing. The instructor could then use pitch and power control to demonstrate runway visual scene perspectives for a properly executed approach, or an approach that is too high or too low. This use of freeze should benefit the student's learning to distinguish visual cues associated with an acceptable approach from those of an unacceptable approach. The advantages are that the cues are presented systematically by the instructor, and students can systematically learn differences between correct and incorrect cue patterns. It is not necessary to let the student make mistakes in order to learn the cues associated with the mistakes.

The second application involves training resource management. Occasionally it is necessary to share resources among ATDs. Position freeze can aid this sharing. For example, some ATDs share model board visual capabilities. Position freeze can be used to temporarily "halt" the flight of one ATD while another uses the available visual system. Similarly, some ATD complexes require one controller to control several simulated flights. Particularly during ground controlled approaches, it is convenient and instructionally sound to position freeze some ATDs while another is given precision control information.

A third application of freeze is to create a procedures training environment in an OFT, PTT or FMT. A common criticism is that OFTs and FMTs frequently are "misused" as procedures trainers. However, if a separate procedures trainer is not available, or if it is instruction-ally necessary to temporarily interrupt ongoing training for remedial procedures training that is needed for productive use of remaining

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training time, then freezing position variables and flight control parameters is highly desirable.

Observed Applications

The freeze feature was present in various forms in all of the OFTs, PTTs and FMTs observed during the program. Table 4 presents a summary of the variations of freeze that were observed. Additionally, variations of freeze are being incorporated into the following ATD designs: A-10; B-52; C-130; F-5; and F-16.

Many instructional features, including freeze, cannot be directly related to specific task training requirements. This is because features like freeze primarily are means to other ends. Such means frequently are not unique to the tasks being trained. Rather, they involve the application of instructional methods and procedures. The instructional feature, in this case, provides an important capability. The capability is to enable the use of appropriate instructional methods and procedures. For example, the need to interrupt a training session for a rest break is not unique to the tasks being trained. Similarly, the need to reduce student task loading distractions while diagnosing a performance deficiency and prescribing correct procedures or techniques is not unique to specific training tasks. The issues are addressed further in the section titled design considerations.

Utility Information

The frequency of use of freeze capabilities varied significantly among the sites visited. This was due to differences in student skill levels and to differences in instructional practices. Freeze was used more frequently when the tasks being learned by students in ATDs were relatively or totally new to them. Also, the use of freeze hinged on the use of other instructional support capabilities, such as automated demonstrations, record and replay, and ATD reinitialization.

Total system freeze is used most frequently. It is the common means for stopping simulations for entry and exit, and for starting the simulation when all crewmembers are at their positions. Total system freeze also is used to temporarily stop automated demonstrations or replays for verbal instruction, and to terminate them to reinitialize the ATD. Total system freeze also is necessary for ATD maintenance.

Flight system freeze was used most frequently during undergraduate and transition training. The instructional use was to relieve students from flight control task loads so that other instructional activities could take place in a more favorable learning environment. Maintenance and evaluation uses were to stop ATD flight progress to calibrate and to make measurements. Cases were observed where position freeze, attitude freeze and parameter freeze combinations had to be used to cause the same effects produced by flight system freeze.

Table 4. Surveyed ATDs Equipped With Freeze Feature

Type of Training	Aircraft Simulated	Freeze Capabilities
Undergraduate Pilot Training	T-37/T-38	Total system, position, parameter, and automatic
	UH-1	Total system, parameter, automatic
Transition & Continuation Training	F-15	Total system, position, parameter, automatic, crash override, kill, kill override
	F-14	Total system, automatic, crash override
	A-7E (NCLT)	Total system
	FB-111	Total system, position, parameter, automatic, crash override
	B-52	Total system, position automatic, crash override
	HH-53 H-3	Total system, parameter, automatic, crash override
	P-3C	Total system, position automatic, crash override, parameter
	E-3A	Total system, position, automatic, crash override, parameter

Table 4. (Continued)

Type of Training	Aircraft Simulated	Freeze Capabilities
	C-5	Total system, attitude, automatic, crash override
	B-747 DC-10	Total system, attitude, position, parameter, automatic, flight system

Automatic freeze (crash) is common. Instructors and console operators indicated a strong preference for crash override as a companion freeze variation. This was due to the fact that all crash implementations that were observed caused the ATD to reinitialize to a predetermined set of conditions or required instructor/operator intervention to reinitialize the ATD following crash. Crash override disabled automatic freeze and allowed the training exercise to continue without the need to reinitialize. Crash override was viewed as a very desirable feature for this reason.

The kill variation of automatic freeze was observed in only one ATD. In that application, kill froze ATD parameters at the values existing at weapon impact. Thus, reinitializing was not involved. This was viewed favorably by instructors. The complementary feature, kill override, was used to unfreeze following kill or to override kill and avoid freezing. Kill override was viewed as a very desirable feature.

Position freeze was found to be a useful tool to stop the progress of simulated flight so that visual system model boards could be shared among ATDs and so that a single console operator could act effectively as a GCA controller for groups of ATDs. Neither of these goals could have been achieved conveniently and unobtrusively without position freeze. The acceptance of this freeze variation also is indicated by user investigations of it as a tool for demonstrating ground scene perspectives for maneuvers involving closure with the ground.

Observed instructional uses of attitude freeze were to create CPT environments in OFTs and FMTs. Depending on the attitude freeze implementation, parameter freeze (e.g. altitude) also had to be used in some ATDs to achieve the desired flight system freeze effect. When training objectives and needs required a "CPT mode", instructor acceptance of being able to achieve the mode was high. Attitude freeze, with or without parameter freeze, also was used by maintenance personnel for troubleshooting, calibration and system checkout in both military and commercial operations.

Uses of parameter freeze in fixed wing ATDs, other than uses described above, were solely for maintenance or maintenance avoidance purposes. Fixed wing instructors who were interviewed never used parameter freeze to simplify flight control tasks by, for example, freezing heading so that training could focus on vertical axis control. The reason sited was the departure from what can be done in the air. This probably is not a valid position, at least for early flight training.

Related Research

No experimental research was found that systematically dealt with the design or use of ATD freeze capabilities. However, Hughes (1979) independently arrived at many of the conclusions presented in this

section based on training research observations and applications of instructional principles.

Design Considerations

Design considerations for any instructional support feature, including freeze, must center on intended uses. One apparent trend in ATD design is toward expanded flexibility. For freeze, the ultimate flexibility is achieved by freezing combinations of individual parameters. While some training applications might benefit from the ability to individually freeze ATD parameters, using parameter freeze to accomplish all desired freeze effects would be cumbersome for the instructor/operator.

A far better approach is to identify the uses to which freeze will be put to support training needs, and then to incorporate into ATDs the freeze variations that meet those needs. This approach simplifies instructor/operator tasks while ensuring meaningful control over the training environment. The following design guidelines present uses of freeze together with the freeze variations that best match each use. Definitions of freeze variations are those presented at the beginning of this chapter.

Uses	Freeze Variations
Start and stop ATD to enter and exit, temporarily interrupt automated demonstrations or replays, or prepare to reinitialize.	Total system freeze
Eliminate flight control and navigation task loading to better enable systems and procedures training.	Flight system freeze
Enable geographic reorientation of the student, demonstrate visual scene perspectives, or timeshare training resources (e.g. model boards or traffic controllers).	Position freeze
Exercise control over the number of axes of flight to be controlled simultaneously.	Parameter freeze (specified parameters)
Maintenance troubleshooting, calibration and evaluation.	All of the above

Maintenance uses of freeze were not investigated indepth during the program. The reader is advised to seek independent guidance on the uses of freeze for maintenance.

AUTOMATED DEMONSTRATIONS

Summary

Automated demonstration (auto-demo) in an ATD permits the device to reproduce a previously established segment or phase of flight without direct intervention by the student or the instructor. It is commonly assumed that the instructional value of auto-demo lies in the presentation of a performance model that the student can observe and analyze to guide his own task performance. To date, the feature has been limited to more sophisticated ATDs. Design of this feature requires consideration of the types of training the ATD is intended to support, and the difficulties of auto-demo construction prior to the decision to incorporate the feature in an ATD design. For example, it is likely that auto-demo has its greatest value when the student is unfamiliar with the basic task or aircraft-unique specifics of the task he is learning.

Description

Auto-demo permits the standardized presentation of a mission segment or entire simulated flight. All cues of consequence, including the visual scene (if present), motion system, primary flight controls and displays, crew communications, and sensor displays are reproduced for the selected mission segment or maneuver. Through computer control, the ATD operates as though skilled aircrew members were at the controls.

Auto-demo requires substantial two-way communication between ATD controlling software and hardware, and crew station controls and displays. Given this requirement, auto-demo is found only in more sophisticated, computer controlled ATDs, such as OFTs, PTTs, and FMTs. ATD hardware and software must be configured to induce changes in the configuration/operation of the simulated subsystems without any intervention on the part of the student or the instructor.

Technically, auto-demo can be constructed for any segment of flight. Thus, for example, an ATD could, on command, takeoff, fly straight and level, perform aerobatic or air combat maneuvers, deliver weapons, fly a standard approach, and land without the student or instructor operating any primary controls.

Related Support Features

The following list identifies relationships to other instructional features. Some of the relationships now exist in ATDs; others are offered as candidates for future ATDs.

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Record and Replay. The ability to record the performance of the
pilot and the aircraft, and to present that performance to the
student and instructor in a review mode exists in a number of ATDs.
Record and replay has served as one method for creating auto-demo
presentations. The capability to fly-out of the replay (i.e.,
assume manual control) appears necessary for efficient creation of
auto-demo presentations (or to hand control back to the student).

Freeze. Freeze allows the instructor/operator to suspend some or
all device parameters associated with the student's task. This can
range from suspending all parameters (total system freeze) through
suspending of only one parameter (e.g., just pitch control or axis
freeze). Where the use of the auto-demo feature has been observed,
system freeze also has been used to interrupt the demonstration for
verbal interactions with the student, and to halt the demonstration
so the ATD can be reinitialized. (See the freeze section of this
chapter).

Automated Briefing. Automated (canned) briefings offer highly
standardized verbal commentary to accompany standardized
demonstrations. One initial entry rotary wing training device
surveyed incorporated this capability. It was judged to be
valuable, was used to provide standardized commentary during
automated demonstrations, and was the only available source of
instructional commentary during periods when students used the
device without the direct supervision of an instructor. One airline
that was surveyed similarly used canned briefing to guide practice
when an instructor was not present.

Synthesized Controller. Synthesized speech (i.e., computer
generated speech) represents a new instructional support technology
that, to date, has not been incorporated into many ATDs. If such a
capability were incorporated (e.g., an automated GCA controller) it
is only logical that the synthesized speech messages should be
incorporated as a facet of a GCA or other similar demonstration.
(See Chapter VI, Controller Function)

Instructional Values

Two instructional values commonly are assumed for auto-demo. The
most common is that the feature provides a performance model that the
student can observe, analyze, pattern his own behavior pattern after,
and use as a reference for self-evaluation in subsequent training trials
or during operational flying. Associated with this is the fact that the
student's workload is considerably reduced during auto-demo, which
provides a better opportunity to observe relationships among cues and
their relationship to system behavior, interact with the instructor, or
attend to an automated briefing. Similarly, instructor workload is
considerably reduced, allowing a better opportunity for instructional
interaction with the student.

A second commonly assumed value acknowledges that automated demonstrations may be the only way to show the student what is expected of him. It has been common practice in the design of virtually all ATDs to exactly reproduce the aircraft crewstation physical configuration. When the crewstation is either single seat (e.g., F-15) or incorporates controls and displays necessary to execute manual demonstrations at only one crew position (e.g., F-4), the opportunity for an instructor to enter the crewstation and do a hands-on demonstration is excluded. Therefore, the only remaining avenue for a demonstration is by means of auto-demo.

The following learning principles are involved in the instructional benefits described above and in the proper use of auto-demo:

Prevent decay of recall by increasing the meaningfulness of the material learned, i.e., by providing organization of related facts and principles.

Control cues to make sure that the student is forming the proper associations, i.e., responding appropriately to the correct cues.

Use programmed demonstrations of procedures up to but not beyond the ability of the student to understand the procedures.

Emphasize cues that cause mediating responses, e.g., self-instruction and natural associations.

A number of non-traditional uses of auto-demo were identified during the course of the STRES program. No research evidence exists that either supports or refutes their value for particular training applications. The possible uses are presented here to stimulate thought and promote research into their potentials. They represent a departure, in some instances, from the flight training model. The flight training model is an approach to training that patterns the way aircrew training is done in an ATD directly after the way comparable training is done in the aircraft. The approach often imposes limitations on ATD use that stem from the ways aircraft must be used for training.

Non-Ideal Performance Models. Present mechanizations of the auto-demo provide a "perfect" performance model for the student to pattern after. A related use would be to demonstrate certain aspects of undesirable performance, such as typical errors committed by learners at various stages of skill development and, even more important, the consequences of those errors. The "ideal" performance model could then be brought into play to demonstrate accepted recovery procedures.

Tactics Development. Related to the performance model application is the use of the auto-demo feature as a method to record (e.g. on magnetic tape), evaluate and critique newly developed or proposed tactics. In this application, the auto-demo feature would be used

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to present the tactical evaluation to individuals and organizations (e.g., R&D groups, operational squadrons, etc.) who are not directly affiliated with the organization that developed the tactics. They, in turn, could use the demonstration to train their personnel, and could use their own record-replay feature to develop alternative sets of tactics that could be returned (e.g. on magnetic tape) to the tactics proponent for review and comment. This kind of inter-change of concrete tactical presentations could accelerate the exploitation and adoption of improved tactics and provide the basis for new instructional applications of existing ATDs.

The same tactical development dialogue application has potential for communicating specialized or limited tactics information in an extremely useful form. Consider the example of a requirement for a strike against a specific target (base, troop concentration, etc.) with known defenses and very restricted (politically or physically) approach and escape corridors. The auto-demo feature could be used to simultaneously brief and train at their home bases all units who are to participate in the strike.

Introduction to Aircraft Characteristics. A different use of auto-demo is to present airframe characteristics under normal and abnormal conditions. This allows the safe and controlled presentation of, for example, normal versus asymmetrical flap extension, the effects of different types of structural damage, or asymmetrical/hung external stores. It also can be used to introduce the student to stall and/or departure characteristics of the aircraft. These demonstrations could include all relevant visual, motion and auditory cues. Obviously, a high level of ATD flight characteristics fidelity would be required. (See the Fidelity Volume, Chapter IV)

Slow Motion Demonstrations. All auto-demo capabilities known to exist now are used only to present demonstrations in real time. Questions of continuing interest are: 1) Would slower than real time demonstrations enable the learner to better analyze cues and responses associated with maneuvers and form better internal models of expected performance? and 2) Who might benefit most from slow motion demonstrations: undergraduate, transitioning or continuation pilots?

Answers to these questions presently are not available either from operational experience or controlled research. One initial entry rotary wing training device was observed that has a one-half time replay capability, and hence a one-half time demonstration capability. This non-real time capability was not used because it was "not realistic". The C-130 ATD which presently is being procured will incorporate real time, one-half time and one-quarter time auto-demo capabilities. Systematic use of these existing or soon to exist capabilities should be undertaken to provide insights into the training value of slow motion demonstrations. Similarly,

controlled laboratory experimentation should be undertaken. Both types of research are needed to determine the training value of this "unrealistic" approach and to determine for which pilots group the values may exist.

Capabilities Demonstration for Interested Visitors. ATDs are not used just for training. Occasionally, visiting dignitaries, senior officers, other aircrew personnel or engineering specialists have needs to observe and discuss facets of training programs, devices, aircraft systems, operational characteristics and device or aircraft features. Properly designed, auto-demos could be used to demonstrate aircraft operating characteristics, weapon system capabilities, device capabilities and learning strategies used during training. Auto-demos would ensure that nothing of relevance would be overlooked during the demonstration. In single seat ATDs, automation might be the only way of providing a demonstration. This would be the case, for example, if the visitor's skill level or knowledge was inadequate to allow him to effectively "fly" the ATD alone. Pre-recorded voice messages could be used to ensure appropriate verbal commentary. Special visitor auto-demos might not be required. Those used during normal training operations might be quite adequate, depending upon their content.

Observed Applications

The auto-demo feature was present in several of the ATDs visited in the STRES program (See Table 5). In addition, the Air Force Advanced Simulator for Pilot Training (ASPT) research device has an auto-demo capability.

Utility Information

User acceptance and frequency of use of auto-demo were found to vary significantly among the operational training sites visited during the program. Over the course of the visits, however, a pattern emerged in terms of training contexts and student experience and skill levels that were associated with more frequent use and acceptance of the auto-demo feature. The observations can be summarized as follows:

The training value of an automated demonstration will be greatest when the cues, responses and task performance requirements being demonstrated are new to the student (i.e., they are not highly familiar to him).

The above statement is based on observations of uses of fixed wing ATDs listed in Table 4, and discussions with the instructors and students using these devices. Another way of stating this is that the value of the auto-demo feature appears to lie in applications which involve introducing aircrew members to an aircraft they have not flown before, or to applications of the aircraft and/or its systems that they have not been exposed to before. Thus, it is a fair estimate that the

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Table 5. Surveyed ATDs Equipped With Auto-Demo Feature

Type of Training	Aircraft	Purpose
Undergraduate Pilot Training	T-37	Introduction of UPT students to selected maneuvers. Typically supplemented by verbal commentary from the instructor in the cockpit.
	UH-1	Introduction to, and coaching during instrument takeoff training. Audio tape played to provide instructor commentary.
Transition & Continuation Training	HH-52 H-3	Introduction to instrument takeoff procedures. Used to demonstrate the precise control required for this maneuver in these aircraft. Used at instructor's discretion to introduce auto rotation procedures.
	A-7E	Demonstration of cues, technique and procedures for night carrier landings.
	C-5 DC-10	Feature available on these devices, but not in use during the period covered by this program.

value of auto-demo will be greatest for undergraduate and transition training.

The above conclusion is based on the site visit evidence that auto-demo is used largely where new pilots are being trained, and where relatively new pilots are being transitioned for their initial operational assignment. Related to this was the observation that auto-demo never was used when seasoned pilots were transitioned to different aircraft where mission and task requirements (and cue, task and performance requirements) were highly similar to those in their immediately prior assignment.

Related Research

There is a general lack of empirical research or even controlled observations directly concerned with the instructional efficiency or effectiveness of virtually any instructional support features. This is the case with auto-demo, although three studies were found that dealt with demonstrations.

Hughes, Hannan and Jones (1979) have reported the only known experimental study of the use of auto-demo and record/replay instructional features. Their study was designed to investigate implications of the use of auto-demo and record/replay features in the context of automated instructional approaches to flying training. Fifteen Air Force UPT students were divided into three groups. Training was conducted in the Air Force Advanced Simulator for Pilot Training (ASPT), which simulated the T-37 aircraft. Each student pilot's task was to fly the first two leaves of a cloverleaf in the visually equipped simulator. None had flown the maneuver before.

All of the student pilots received a videotaped introduction to the study, which included a five minute preflight briefing on how to perform the cloverleaf. Each also received an automated demonstration of proper performance of the first two leaves of the cloverleaf maneuver in the simulator. Subsequent training then differed for the three groups of student pilots. One group flew two leaves of the cloverleaf for four blocks of three attempts each. This group received an auto-demo of correct maneuver performance following each block of three attempts. Similarly, a second group received a replay of their most recent attempt at the maneuver following each block of three attempts. A third group (the control group) was given an additional attempt at the maneuver after each block of three trials in lieu of either a replay or a demo.

The performance of all of the student pilots was scored in two ways. An instructor was located in a second, "slaved" simulator cockpit, which provided all instrument readings and out-of-cockpit visual cues available to the students. After each execution of each maneuver for students in all three groups, the instructor rated the maneuver as: unsatisfactory; fair; good; or excellent. Each student was told his

rating after each maneuver. In addition, maneuver performance was scored using an automated performance measurement system.

Results of the study by Hughes, et al. showed that the group that received additional practice instead of either auto-demo or replay did the best. The group that received a replay of their last maneuver attempt did second best, and the group that received the correct performance demonstration came in third. Remembering that students in each group received an instructor rating of their performance after each try at the maneuver, the findings at first suggest that auto-demo and record/replay may have little instructional value. However, both of these instructional features were used in the context of "automated instruction" in which detailed instructor evaluation, guidance and other interaction were excluded. What the findings do show is that in this context, the features investigated showed little promise. What future research should address is the more operationally oriented use of auto-demo and record/replay, where the features are used at the instructor's discretion to correct specific performance deficiencies and where instructor-student interaction is tailored to student learning needs. It also must be noted that other research has indicated that the ASPT simulation may not be well suited for training aerobatic maneuvers. (See Fidelity Volume, Chapter III)

In the context of Navy research with the A-7 Night Carrier Landing Trainer (NCLT), it has been shown that auto-demo has a significant, but non-quantifiable instructional value (Brictson and Burger, 1976). In the study, instructors used auto-demo as an integral part of NCLT training. However, there are no data quantifying the specific contribution that the feature made to overall training effectiveness or efficiency. This application does represent a case, however, where an instructor-flown demonstration was not possible because the NCLT ATD was a single seat configuration. No other method for demonstration was possible.

In the Army's Map Interpretation and Terrain Analysis Course (MITAC), both undergraduate and experienced pilots are presented with the problem of recognizing and correlating map features with real world terrain features during a series of film based exercises. This training is presented to the individual aircrew member, and the pacing of the exercise is controlled to match either the level of instruction or the speed at which the student would experience the cues in the real world (a function of aircraft speed). This course has proved quite successful, and represents the application of this feature in a simple ATD to solve a tactical training problem.

In summary, it must be concluded that additional, operationally oriented research on auto-demo and virtually all other instructional support features is sorely needed.

Design Considerations

There are two basic methods for creating auto-demos. One is to use an ATD's record and replay capability. This method requires that a proficient aircrew member fly the necessary profiles in the desired manner using desired techniques. This method has the advantage that highly proficient crewmembers usually are available. It has the disadvantage that it is difficult, even for highly proficient aircrew members, to fly profiles with the perfection they judge necessary to provide a performance model for the student to pattern after. Also, the lack of well defined criteria for the largest percentage of flying training tasks makes it difficult for instructors to agree on what constitutes acceptable performance. Peer pressure also plays a role in that no pilot wishes to have his "mistakes" recorded for others to observe. Consequently, acceptable demonstrations have proved difficult to develop. Finally, since "no one" flies "perfect" maneuvers in the real world, the need to demonstrate perfection (versus typical performance) must be questioned.

A procedure often used is to draw on the joint capabilities of replay, freeze and fly-out (where the pilot at the controls takes over after a segment of canned maneuvering). The procedure requires that the initial segment of the maneuver for which the demonstration is that being developed be flown and recorded. The ATD is frozen at the point where desired performance is not being achieved by the pilot making the demonstration. The ATD is reinitialized to the beginning of the maneuver segment. The segment is then replayed to a point just prior to where performance was judged unacceptable. The pilot then takes over control manually (i.e., flies-out) and attempts additional segments of the maneuver. The procedure is repeated until the entire mission segment or maneuver is judged acceptable by the pilot. The maneuver then is stored and made accessible for subsequent call up as an automated demonstration.

The second method for creating auto-demos is through the development of customized computer software for each demonstration. This approach has the advantage that system analysts and computer programmers probably can develop and implement mathematically perfect demonstrations. The method has the distinct disadvantage, however, of requiring computer software specialists to create new demonstrations or to modify initial demonstrations following delivery of the ATD. Since highly specialized skills are required, development of automated demonstrations using this method would require either the creation of a new simulator support billet or the need to rely on contract support services. This requires substantial agreement and cooperation between the ATD developer and the user community with respect to identifying and collecting the performance data required to model desired performance. Both manufacturer and user personnel view the direct software approach as the more time consuming and costly of the two methods available. Again, the need for "perfect" demonstrations must be questioned.

Once created, the spectrum of auto-demos must be clearly identified to and accessible by the ATD instructor/operator.

The number of auto-demos and the duration of each also is a design consideration. Each of these factors must be addressed with respect to specific ATD and training program applications. General rules of thumb do not apply.

Incorporating fully synchronized voice audio into an auto-demo capability should be considered from three standpoints. One, it provides a means to present highly standardized and complete instructional information. Second, it provides verbal instructional content to students who may be using an ATD for "extra time" training when a qualified instructor may not be present. Third, it may provide the only means for fully coordinated instructional commentary in cases where the instructor cannot meaningfully observe what the student is observing and doing. An example would be a single place ATD with an out of the cockpit visual system, and a less than adequate presentation (repeater) of the visual scene at the instructor/operator console.

Hughes (1979) correctly observes that present uses of automated demonstrations are highly traditional and rudimentary, where the student sits and passively watches a canned execution of the task. Almost invariably, the canned execution represents "perfect" or text book performance. Hughes also notes that significant research issues remain, for example, in determining the content and use of automated demonstrations. At issue is the need to consider innovative content and uses of auto-demo and to develop sound relationships of this feature to others. For example, consideration should be given to enabling the use of total system freeze during demonstrations. Where this capability has existed, it has been used. Similarly, enabling the use of ground position freeze, parameter freeze and axis lock during the creation of demonstrations may make their development easier.

The capability to terminate an ongoing demonstration and re-initialize the ATD also must be considered from the standpoint of making the most efficient use of training time and in terms of instructor/student acceptance of the feature. Similarly, the capability to stop an automated demonstration and re-initiate it from the beginning must be considered, especially for fairly lengthy demonstrations (e.g., longer than one or two minutes). This provides the ability to "go back and look at it again" without being committed to waiting out the balance of the demonstration. Along the same line, it should be possible to enter an auto-demo at desired points so that it is not necessary to "wait for" the needed element of the auto-demo. Both design factors are needed for user acceptance and use.

From a content standpoint, possible benefits of demonstrating typical student errors and consequences needs more systematic attention. Similarly, possible benefits of demonstrating alternative solutions to a flight or tactical problem need to be addressed to promote coping with

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unexpected conditions. Either of these might also incorporate the use of augmenting cues, such as a flight path predicator or a weapon impact predictor information presented by means of an out of the cockpit visual display system.

RECORD AND REPLAY

Summary

Record and replay makes it possible to recreate a segment of flight just as it was flown, without direct intervention by the student or the instructor/operator. The last five consecutive minutes of flight can be preserved for replay in most current ATDs. It commonly is assumed that record and replay provide a highly detailed and dynamic memory aid. The ability to freeze the ATD during replay is clearly a desired feature for most training applications. The ability to "fly out" of replay also is desirable. Application of the record and replay feature has been limited to more sophisticated ATDs (e.g. OFTs, PTTs, and FMTs). Student proficiency appears to be the primary factor in deciding whether to incorporate record and replay into an ATD. It appears that the greatest training value for record and replay is in cases where the student is not familiar with the specific task (cues and responses) he is learning, and where task loading, timesharing and pacing are problems.

Description

Record and replay is the capability of an ATD to record relevant system parameters and then use these data to present student pilot performance in a review mode. In a typical installation, the last five continuous minutes of performance are recorded. After freezing the ATD, typically using total system freeze, the instructor selects the point in time in the available replay period that he wants replay to be initiated. Typically, the selection is limited to one minute increments. When replay is initiated, the ATD initializes to the conditions prevailing at the replay start point. All events of consequence are reproduced during replay, including the visual scene (if present), motion system operation, primary flight control and display movements, and appropriate sensor display content. The ATD performs as though the student was again flying the replayed segment exactly as it had been flown before. Technically, replay can be accomplished for any segment of flight. Replay of voice communications is possible, but very few existing devices incorporate the capability due to technical difficulties which have resulted in a lack of synchronization between verbal message content and system performance. This has been a handicap because relevant cues are not correlated. Modern digital voice storage, however, offers a solution to this problem.

Replay can be terminated in one of three ways. First, the instructor can freeze the ATD and select a different mode of operation. Second, replay can be de-selected, and the student can resume manual control (i.e., fly out of replay). Third, replay can be allowed to

continue throughout the period for which replay data had been recorded. The ATD can be frozen or manual control assumed following the completion of replay.

The record and replay feature requires substantial two-way communication between ATD controlling software and hardware, and crew station displays and controls. Thus, the record and replay feature is found only in more sophisticated, computer controlled ATDs. ATD hardware and software must be configured to induce changes in the operation of simulated subsystems without any intervention by the student or the instructor.

Related Support Features

The following paragraphs identify relationships to other instructional features.

Automated Demonstration. Automated demonstrations permit an ATD to reproduce a previously recorded segment or phase of flight without direct intervention by the student or the instructor. Record and replay are used in some ATDs to create demonstrations. (See the auto-demo section of this chapter).

Freeze. The freeze feature allows the instructor to suspend some or all device parameters associated with the student's task. This can range from suspending all parameters (total system freeze) through suspending only selected parameters (parameter freeze). (See the freeze section of this chapter).

Where the record and replay feature was observed, total system freeze was used to stop the simulation prior to entering the replay mode and, on many occasions, to temporarily interrupt replay or to terminate replay.

Synthesized Controller. Synthesized speech (i.e. computer generated speech) is a relatively new instructional support technology that, to date, has been incorporated in only a few ATDs. If such a capability were incorporated, for example an automated GCA controller, it is logical that such controllers should operate during replay since they provide guidance information used by the students. (See Chapter VI of this report).

Instructional Values

Historically, replay has been most often used when a student has a performance problem and it is the instructor's judgement that there is little or no training value in continuing practice of the maneuver without personal intervention. The commonly assumed instructional value of record and replay is that it provides a highly detailed and dynamic memory aid. A directly related value is that student task loading is considerably reduced during replay. This provides a better environment

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to work with the instructor to review performance, identify performance problems and resulting errors, analyze causes underlying performance problems, and receive guidance. Total system freeze is a directly related feature that allows replay to be temporarily interrupted for instructional interaction.

A second value for record and replay often cited by instructors was the use of replay to resolve disagreements between the instructor and the student. This use is valuable in cases where the student is temporarily overloaded or distracted and may not recognize that he has a performance deficiency. In this role, replay also can enhance the instructor's credibility as a positive and motivated aircrew trainer.

A review of empirically supported principles of learning indicates that the primary instructional values of record and replay reside in the following instructional principles:

Control cues to make sure that the student is forming proper associations, i.e., responding appropriately to correct cues.

Emphasize differences between correct and incorrect cue forms.

With very complex tasks, instruction in principles yields better results than laying down a detailed drill, while with simpler tasks drill is at least equally effective.

A number of instructors who were interviewed suggested that replaying performance that was well within criteria of acceptance can be motivational by providing positive reinforcement to the student for a job well done. This likely over-statement should be tested empirically. A majority suggested that this use of replay should follow soon after the student works through a performance problem and demonstrates acceptable performance. Others felt that the use of replay should not be limited to this use, alone.

Record and replay was used at the sites visited almost exclusively for pilot and/or copilot training. It is quite possible, however, that replay could be used in a crew training environment as a means to evaluate and improve crew interaction. Voice replay also would be required in this application since many of the indicators of crew interaction hinge on crew communications. This potential need for replay depends on how well individual crewmember responsibilities are defined, how students are trained and evaluated, and how productive replay would be in terms of interactive crew training.

Only one device was surveyed that incorporated a slow motion replay capability. The slow motion replay was at one half real time. The capability was not used because it was "unrealistic". Thus, slow motion replay remains an untried capability for all practical purposes.

Record and replay also holds the potential of providing a set of exercises that can be used to guide standardization and evaluation personnel on the performance that is expected of aircrew members during and at the end of formalized instruction. A similar case can be made for continuation training.

Observed Applications

A number of ATDs observed during site visits incorporated record and replay. All were OFTs or PTTs. Training applications are summarized in Table 6. Operational experience was sampled during training on the following tasks.

Landings and Takeoffs: Based on the survey of operational training sites, record and replay has been used successfully during training for terminal area operations. These tasks include: visual takeoff; instrument takeoff; standard departures; instrument approaches (e.g. VOR); instrument final approach, visual final approach; autorotations; and night carrier landings. The record/replay feature tended to be used more during undergraduate and early transition training because students were least familiar with their tasks at that stage of their training.

Air-to-Air Combat: Record and replay has been used during initial pilot training in air tactics in the Simulator for Air to Air Combat (SAAC). Record and replay reportedly is not used during latter stages of advanced training (e.g. TAC ACES Program), where pilots are more proficient in air combat maneuvering and tactics. This follows since most pilots "know" what is expected and simply need practice late in training.

Utility Information

Two trends were apparent at the sites visited that had ATDs with record and replay. One involved the use of record and replay in relation to student proficiency level and knowledge of the training tasks to be performed. The second involved instructor-to-instructor variability on how often and when they used record and replay.

Interview results showed that record and replay were used more often during training on tasks that were new to the student and were relatively complex for him. In general, the use of record and replay centered on undergraduate pilot training and on the training of new (to the pilot) and relatively complex advanced flying skills, including night carrier landing and air to air combat maneuvering. On the other hand, replay was not used during transition training or continuation training where pilots had a basic understanding of what was required, and unless there was no argument on performance deficiencies. This trend was observed during military and commercial airline training. The same trend was found for the use of automated demonstrations.

Table 6. Surveyed ATDs Equipped With Record and Replay Feature

Type of Training	Aircraft Simulated	Purpose
Undergraduate Pilot Training	T-37/T-38	Used in initial pilot training of various instrument flight procedures, and visual take off and landing.
Transition & Continuation Training	F-4E (SAAC)	Used to demonstrate performance problems and diagnose causes for pilots who are just learning air combat maneuvering.
	A-7E (NCLT)	Used to demonstrate (as Auto Demo) cues, techniques and procedures during night carrier landings. Used to diagnose performance problems. Also used to reinforce well executed approaches and recoveries.
	HH-52 H-3	Used to demonstrate performance problems, diagnose causes and reinforce correct executions of instrument takeoffs, landings and auto-rotations.
	UH-1 CH-47	Same as HH-52 and H-3 above, plus terminal area instrument procedures.

Table 6. (Continued)

Type of Training	Aircraft Simulated	Purpose
	C-5 DC-10 B-747	Feature Available on these devices but not used during the period covered by this program. (Devices were used by highly experienced pilots.)
	E-3A (OFT)	Capability Exists, but not used due to hardware problems.
	E-3A (MT)	Capability exists for replaying portions of tactical mission exercises.
Research & Development	ASPT	Diagnosis and prescription for pilot subjects participating in training research programs.

Instructors were quite consistent in their explanations. Replay is most useful when the student is not aware that he had made an error or is uncertain of the precise cause of his error and resulting performance problem. This situation was most apt to arise when tasks were being initially learned. For example, relevant cues may be missed; students may become disoriented; they may not be able to correctly interpret displays or visual cues; they may not understand flight control, navigation or system operation principles and procedures. In such cases, replay was accepted and used as a meaningful instructional tool. On the other hand, pilots who are more highly experienced and skilled in the tasks to be performed generally are able to identify their own performance deficiencies, diagnose the causes, and take corrective steps without the need for a highly detailed memory and diagnostic aid such as record and replay.

The following principle of use applies for record and replay:

The training value of record and replay will be greatest when the cues, responses and task performance requirements being learned are new to the student.

All of the record and replay capabilities surveyed could replay up to the last five consecutive minutes of flight. The portion to be replayed could be selected in one minute increments. The total five minute span was judged to be quite adequate. In fact, no one was interviewed who had replayed anything approaching five minutes of flight. A frequent comment was that one minute increments of replay often were excessive, and that shorter time increments should be considered in the future. The F-16 ATD will allow replay to be selected in ten second increments.

Related Research

Only one research study was found that investigated the use of record and replay (Hughes, Hannan and Jones, 1979). The study is summarized here; details are presented in the section of this chapter dealing with automated demonstrations.

Hughes et al. had three groups of Air Force UPT student pilots learn to fly the first two leaves of the cloverleaf maneuver in a visually equipped simulation of the T-37 aircraft. One group of students viewed an automated demonstration of the maneuver being performed correctly after each block of three attempts at the maneuver. A second group received a replay of their last attempt after each block of three trials. A third group received one additional trial at performing the maneuver following each block of three attempts in lieu of either a demonstration or a replay. Performance was scored by an instructor in a second, slaved simulator; performance also was measured using an automated performance measurement system.

Results of the study showed that the group that received additional practice instead of either the automated demonstration or replay did the best. The group that received a replay of their last maneuver attempt did second best, and the group that received the correct performance demonstration came in third. The findings at first suggest that the automated demonstration and record/replay features may have little instructional value. However, both of these instructional features were used in the context of "automated instruction" in which detailed instructor evaluation, guidance or other interaction was excluded. What the findings do show is that in this context, the features investigated showed little promise. What future research should address is the more operationally oriented use of automated demonstrations and record/replay, where the features are used at the instructor's discretion to correct specific performance deficiencies and where student-instructor interaction is tailored to student learning needs.

Design Considerations

This section addresses five record and replay design considerations. The first is the number of minutes of flight that needs to be recorded. Hard and fast figures cannot be given. For the applications investigated, a total of five minutes was more then adequate. Instructor consensus was that for most uses, 1.5 to 2.0 minutes probably would be sufficient. However, the amount of replay time to be incorporated into an ATD must be determined on a case by case basis. It may be that for application to crew coordination situations a longer replay capability is appropriate.

The second design consideration is how best to select the point at which replay is to be initiated. The systems surveyed all required the instructor to select replay in one minute increments. Thus, the last one, two, etc. minutes (up to five) could be replayed. A number of instructors commented, however, that one minute "is a long time to replay". Some suggested selecting replay in 30 second increments. The F-16 ATD provides for 10 second increments. Identifying the "best" increment requires further research and operational experience.

An alternative to specific time increments also should be examined. A reasonable alternative is to provide the instructor with a cuing control. Replay then could be started at a determined time prior to when the cuing control was activated (e.g. 20 seconds, or whatever is reasonable for the particular training application). This would allow instructors to relate replay to training events rather than clock time.

Third, voice replay obviously should receive serious consideration for training tasks where voice communication is a significant element of total task performance. Examples include controller messages and crew or team performance. Historically, problems have existed in rapidly initializing to the proper point in recorded voice messages, and in keeping message content synchronized during replay. These problems have stemmed from using magnetic tape technology for storing the

messages. Digital voice recording technology now is available to synchronize voice message content with other cues during replay, particularly vision and motion cues.

The fourth consideration involves the use of freeze together with record and replay. Total system freeze is necessary to stop the simulation while replay is selected. Similarly, total system freeze is necessary to stop replay in order to reinitialize the ATD.

There may be training and user acceptance values in being able to deactivate replay part way through, thereby allowing the student to assume manual control during a "fly out" capability. It is suggested that the capability be designed into ATDs to provide research capabilities as well as potentially enhanced training value.

MANUAL AND PROGRAMMABLE INITIALIZATION

Summary

Every operational flight trainer and full mission trainer surveyed had a capability for initializing/reinitializing aspects of the simulation. The objective of initializing is to position and to some extent configure the ATD with economy of time and effort to support training. Modern ATDs using digital computer technology can be initialized easily. Other, older ATDs sometimes require lengthy manual procedures, such as slewing. In all cases, initializing is geared to initially setting up the simulation for training, or to establishing meaningful conditions (reinitializing) for specialized task training during an ATD session. The feature is central to efficient ATD utilization.

Feature Description

One of the greatest assets of ATDs is that time need not be used unproductively on events of no immediate training value. For example, in an ATD it is not necessary to fly a missed approach profile just to practice final approach and landing. Similarly, it is not necessary to fly the approach and stabilization precontact segments of air refueling to practice hook-up and breakaway. Instead, ATDs can be almost instantaneously initialized to desired conditions for the start of training.

Initialization involves specifying, usually from the instructor/operator console, the parameters of interest and their values. Parameters to be initialized vary with the training applications of the ATD. Parameters most commonly initialized are those that determine the ATD's simulated position with respect to the earth. These include: position (e.g. latitude and longitude); altitude; heading; speed; and attitude. Other factors such as weapons load, ammunition and fuel load also can be initialized. ATDs with out of cockpit visual systems have capabilities for initialization of specific

visual scene characteristics. These include: day, dusk or night scene; ceiling; broken or complete overcast; runway visual range; amount of simulated haze near the ground; intensity of approach, runway and other simulated lighting; and simulated weapon visual effects, such as surface to air missile launches. ATDs used for weapon delivery training also may include capabilities to initialize the weapons carried, distribution, and simulated mounting points. Threat types, locations and other characteristics can also be initalized.

Related Instructional Support Features

Total system freeze was used in each ATD surveyed to stop the simulation during the initialization/reinitialization process. When reinitialization was complete, the ATD was unfrozen so that simulated flight could be undertaken. Total system freeze was discussed earlier in this chapter.

Instructional Values

Being able to quickly initialize/reinitialize ATDs promotes efficient use of available training time and other assets. A good initialization capability minimizes wasted training time by enabling rapid set-up of training conditions. Time is not required to "fly" the ATD to a desired location, for example, as would be required in the air. Rapid initialization is one of the distinguishing features of ATDs.

Observed Applications

Every operational flight trainer and full mission trainer surveyed during the program had some capability to rapidly initialize the simulation. The pattern of use of the feature was in direct keeping with its assumed instructional support value, i.e. to make the most productive use of available training time. Undergraduate and transition training programs used the capability to provide for repeated practice on more complex tasks, such as takeoff and final approach and landing. Transport category programs used the feature to "skip over" unproductive cruise phases of missions. Air combat simulations (including one observed during a prior research program) used initialization to quickly establish initial conditions for attacker and adversary aircraft after each engagement.

Utility Information

ATDs built more than five years ago tended to incorporate dedicated controls for initializing. Some required the operation of several different controls, including: slewing controls to   reposition ATD; and separate control inputs for desired altitude, speed, etc. Some required that the desired ATD heading be established in the ATD cockpit using primary flight controls prior to setting up the initialization.

Newer devices, and several older ones, incorporated dedicated controls (usually pushbuttons) that instructors/operators use to select one of several programmed combinations or sets of initial conditions. These controls can be reprogrammed off line.

Several modern ATDs provided instructors/operators with lists of combinations of initialization options displayed on console CRT displays. The desired combination is selected by making a keyboard entry. This approach is much like the dedicated controls approach, but provides two added advantages. One advantage is that the values of the initialization parameters can be spelled out on the CRT display as a memory aid to the instructor. The second is that more option combinations usually can be made available. The initialization options can be reprogrammed off line.

Instructor/operator consoles using CRT display and keyboard entry systems also can display each initialization parameter, and allow the instructor to input values for each parameter. This approach allows them to create, on line, new initialization options. Most systems designed this way save the initialization values until they are changed by the instructor. This allows instructors to reinitialize to their specially constructed set of conditions with convenience, because they are not required to recreate the conditions for each initialization.

Related Research

No research was found dealing specifically with alternative designs or uses of the ATD initialization feature.

Design Considerations

A careful analysis of ATD training applications must precede attempts to identify which parameters are required for initialization, which sets of parameters are to be combined into initialization option packages, and what the ranges and increments of parameter values should be. General rules of thumb cannot prevail. This follows because initial conditions and condition sets must be geared to training requirements, which vary among training programs.

Many future ATD instructor/operator consoles, including retrofits, will incorporate electronic display technology, together with keyboard or touch panel data entry systems. These technologies are well suited for displaying programmed initialization options to the instructor, and allowing him to select given options or create new ones appropriate to the training objectives being addressed. In addition to providing instructors with initialization option packages to select from, it also is instructionally desirable to enable them to create, at their consoles, additional sets of initial conditions, and to provide the capability for storing them throughout the training session so they can be recalled for repeated use. All programmed combinations of initial

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conditions should be easy to change off line so they can be kept current with changing instructional objectives and practices.

Inputting position initialization information from ATD consoles should involve the use of methods that aircrew members are familiar with. For example, several cases were observed where an instructor wished to initialize the ATD at a particular range and bearing from an established reference point, in this case the end of a runway. The console, however, was designed to accept only latitude and longitude inputs. Thus, it was necessary for the instructor to use supplemental charts and determine latitude and longitude corresponding with the desired range and bearing so that initialization parameters could be updated. Although this certainly was not an impossible task, it was viewed as a nuisance, and should be avoided in the future.

Users of several ATDs with wide angle visual systems recommended that the visual system be automatically blacked out during ATD initialization and reinitialization. Rapid simulated movement of the ATD to different points in space causes rapid movement of visual system imagery. This rapid movement can be quite distracting, making it necessary in some cases to remind pilots in the cockpit to close their eyes or look away from the visual system during reinitialization.

Not every facet of the ATD can be initialized, at least with current technology. For example, it often is necessary to manually reposition throttles, landing gear levers and other cockpit controls, and to re-trim the ATD. Failing to do so can result in very irregular flight performance following initialization. A number of ATD users have found it necessary to develop checklists of manual procedures that must be performed in the cockpit during reinitialization. One reasonable alternative is to provide instructors with electronic display of these memory aids at their consoles.

MANUAL AND PROGRAMMABLE MALFUNCTION CONTROL

Summary

Emergency procedures training is one of the most well accepted uses of ATDs. In most ATDs surveyed, simulated malfunctions and emergency conditions were inserted and removed manually by the instructor/operator. It is technologically possible to program the occurrence of malfunctions to relieve instructors of the insertion/removal task. Properly implemented, the concept has value. Programmed malfunction insertion, however, has not been well received for two reasons. The first is that present implementations cause malfunctions to be inserted at predetermined times during the mission, but mission time may not relate to mission events. Second, some instructors express concern that "word will get out" among students on what malfunctions will occur at specific points during ATD training exercises.

A new approach to automatic malfunction insertion is being tried in an experimental prototype instructor console for a Navy F-14 OFT. The approach allows the instructor to select malfunction and initiating condition pairs from electronically displayed shopping lists. The initiating conditions are mission events, such as weight off wheels or the passing of a geographic reference point. With this system, the instructor also can inhibit an automatic malfunction insertion, and can change initiating conditions during the training exercise. This system will not become operational until late 1980, so its acceptance by instructors remains unknown at this time. However, the console design is intended to unburden instructors from routine tasks so they can concentrate on more important facets of training.

Feature Description

Procedures trainers, operational flight trainers, part task trainers and full mission trainers almost always include the capability to simulate a variety of malfunctions so that training in recognizing and responding to them can be accomplished in a safe, controlled environment. The number of malfunctions that an instructor can present to the student varies with the system being simulated. A typical range is from 60 to several hundred. The number used in training also varies, but typically ranges from 20 to 50, and includes the most critical and common malfunctions that meaningfully can be addressed during available training time.

The most common method of inserting and removing simulated malfunctions is the manual operation of controls by the instructor. The types of controls now in use include: dedicated pushbuttons; programmable pushbuttons; alphanumeric keyboards, where malfunctions are entered and removed based on a number code; and touch panels, where the instructor simply touches a display of options to select the desired malfunction. Most malfunction insertion and removal capabilities also provide the instructor with a memory aid that shows which malfunctions presently are active. Cathode ray tube (CRT) systems frequently provide a displayed list of active malfunctions. Other systems involving pushbuttons illuminate legends showing which malfunctions are active. Cases were observed during the program where CRT displays were added to multi-crew ATDs to provide a central listing of active malfunctions because illuminated malfunction pushbuttons were widely dispersed throughout the simulated cockpit, and instructors experienced difficulty in keeping track of malfunctions inserted by other instructors.

Little creative thought has been given to developing meaningful methods for automatically inserting malfunctions. Time into the mission has been the most common method used in many ATDs. This has proved unworkable because mission time often does not relate to mission events. For example, one ATD was observed where time into the mission did not take freeze into account. If the ATD was frozen so the instructor could work with the student, the malfunction clock kept running. As a result, a new malfunction could occur when the system was unfrozen. If the

reason for freezing the ATD was to work with the student on an existing malfunction, having a new malfunction crop up when the ATD was unfrozen was not welcomed by many instructors. Alternatives to this unworkable and rigid approach are presented in the following section titled Design Considerations.

Related Support Features

Automatic malfunction insertion and removal requires at least a rudimentary automated performance measurement capability. Measurement is required for malfunction insertion because the conditions for initiating the malfunction must be sensed and compared against insertion criteria. Similarly, if the malfunction is to be automatically removed after the student has successfully coped with it, automated measurement is necessary for assessing when the correct procedures have been completed. If the malfunction is to remain in effect (e.g. engine out), then an automated performance measurement system designed to evaluate student performance must know this so that appropriate standards of flight performance can be used.

Instructional Values

It is widely accepted that ATDs provide a safe and controlled learning environment for training adequate response to malfunctions and emergencies that may be encountered in flight. This is the basis for training of malfunction and emergency procedures in ATDs.

One assumed value of automatic malfunction insertion and removal is that it unburdens the instructor from routine tasks, thus freeing his attention and time for more important instructional activities, such as providing guidance and feedback.

A second value involves student self practice. Training practices vary from site to site. However, some training managements encourage students to practice tasks in ATDs whenever ATD time is available, even if instructors cannot be present. In these cases, automatic malfunction insertion can be used to structure training sessions. For example, the student might request that the ATD operator program the ATD to incorporate malfunctions that he does not feel confident in responding to, or that are scheduled to be covered in the next training session. The element of "surprise" or unexpectedness can exist at least with respect to timing. However, the student is provided with the cues that he needs to learn to respond to and still is required to scan for the cues.

Observed Applications

Manual malfunction insertion and removal was observed at all sites visited. Automatic malfunction insertion and removal was not observed at any site visited during the program. Automatic capabilities were observed by program team members during prior programs involving the

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Navy F-14. The following ATDs also will include automatic malfunction insertion: A-10; F-16; B-52; and C-130. Boolean logic will be used at least in the C-130 (and perhaps the others) to cause malfunction insertion.

Utility Information

This section addresses four issues. The first is the preparing of students for productive use of hands-on training in ATDs. The second is ease of use of malfunction features by instructors and device operators. The third is the need for memory aids on malfunctions that already are active. The fourth is alternatives for automatically inserting and removing simulated malfunctions.

Current training practices involving simulated malfunctions assume that only hands-on training will work. This raises the issue of whether students really are prepared to benefit from expensive hands-on training in ATDs. Chapter IV of STRES volume titled Utilization of Aircrew Training Devices, addresses cognitive training and the impact on ATD training. In there the reader will find commentary on the need for preparing students for maximum benefit from hands on training, and will find alternative training methods discussed. For example, it was observed frequently during the program that students were not proficient in identifying cues associated with specific malfunctions at the beginning of ATD training. Better use of ATD time would have resulted if prior study of cues and their meaning had been emphasized.

Instructor/operator convenience and feature ease of use are important issues. If instructors do not care to use an available feature because it is troublesome or requires special attention, then the feature typically will be ignored. Ease of use of manually inserted/removed malfunctions can be improved in several ways. First, the malfunctions must be clearly identified. ATDs were observed where this was not the case. This particularly was true with programmable pushbuttons used for insertion/removal. The pushbuttons were not labeled (since their function was changeable). Instructors either relied on device operators to remember what button operated what malfunction, wrote notes as reminders, or simply did not use the programmable controls.

Memory aids are required to remind the instructor of malfunctions already inserted. This was found to be particularly true in multi-crew ATDs where several instructors were involved. Keeping track of what malfunctions already had been inserted required a memory aid, which in most cases was a CRT display.

Automated malfunction insertion/removal was not used for reasons previously cited. However, this rejection may be due to the ways malfunctions are inserted automatically in present ATDs. Advanced designs incorporating more operationally meaningful insertion/removal logics should overcome these problems.

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Related Research

Only one research study was identified that addressed manual or automated malfunctions. The report (Semple, Vreuls, Cotton, Durfee, Hooks and Butler, 1979) acknowledged the present shortcomings of manual and automated malfunction insertion, and presented alternative initiating conditions. The initiating conditions they identified as potentially valuable centered on mission events (rather than mission time). These included weight off wheels, flap retraction or extension, and the passage of geographic points. Their design also allowed instructors to select initiating conditions, and override initiating conditions selected at the beginning of the training session.

Design Considerations

A distinction must be made between manually controlled malfunction insertion/removal and automation of this task. From the student's standpoint, training to deal with various malfunctions should be treated as any other training objective. In other words, training management determines what malfunctions are worth training for, and training in ATDs should focus on these requirements. Too often, however, malfunctions are inserted to "increase the student's workload", without any specific training end-product in mind. This use of malfunctions may be beneficial, but, at best, it is unstructured and is left to individual discretion. A better approach would be to treat malfunction training objectively. For example, members of the survey team noted that malfunction performance required during standardization and evaluation tests sometimes was not practiced during training. Thus, students were subjected to "final exams" where they were required to perform procedures not incorporated into their hands-on training. This reflects poor training management. A well designed instructional support system would keep track of malfunctions that were responded to correctly, those requiring additional practice, and those required at the end of training.

Memory aids are required. ATD designs should acknowledge this by providing instructor/operators with memory aids showing what malfunctions already have been activated.

AUTOMATED CUING AND COACHING

Summary

Automated cuing and coaching are not common in present ATDs. Their assumed instructional values center on the promptness and accuracy of guidance and feedback information provided to the student, and the unburdening of instructors through automation. Similarly, automated cuing and coaching systems can provide feedback and guidance to students when an instructor may not be present. The systems require good automated performance measurement because automated measurement is used

to determine what messages should be given to the student and the timing of their delivery. Automated cuing and coaching systems can be disruptive to the student if prompts and guidance messages occur too frequently. This suggests the need to be able to deactivate the system, and further suggests the desirability of decision logics designed to keep the frequency of cuing and coaching messages within acceptable bounds.

Feature Description

A cuing message is one that prompts the student by identifying a performance deficiency. An example is: "check your altitude." A coaching message directs the student's behavior through verbal instruction. An example is: "return to flight level 150".

A programmed mission scenario is required so that desired performance is defined clearly. An automated performance measurement (APM) system and additional decision logics also are required for determining message content and timing. An APM capability is needed to sense when student performance is less than what is required for the task he is learning. For example, departures from desired speed, course, heading or altitude must be sensed. (This raises the issue of performance tolerance bands that are acceptable for different stages of training. Further research is needed on this issue.) When differences are found, system logics are needed to identify the appropriate message content to be transmitted to the student. Typically, a cuing message would be transmitted first. Performance monitoring would continue; if the performance deficiency was not corrected, then the appropriate coaching message would be transmitted to the student. If the performance deficiency continued, either the ATD could be frozen or the instructor could be alerted so that he could intervene.

Three technologies are available for creating the messages to be transmitted to the student. One is audio tapes. The system searches a tape file for the appropriate message, and then plays the message to the student via the ATD intercom. The second is digitally stored speech. This technology provides much faster message delivery than is possible using tapes. The third technology is computer generated speech. Computer generated speech is relatively new but is readily understandable. Further design improvements are being made to make computer generated speech sound less machine-like. This digital technology is well suited to automated cuing and coaching messages because the messages involved usually are brief, and computer memory requirements are well within reason. Also, changes in message content are easily accomplished.

The issue of which messages should be built into an automated cuing and coaching system must be addressed on a case by case basis depending on the training being provided and student learning problems during training. The analysis should begin by identifying typical performance problems that occur and go unattended by the student. Commonalities

among the performance problems then should be identified so that the smallest possible set of cuing and coaching messages can be identified. Draft messages then should be developed and reviewed for clarity and brevity. Finally, the automated cuing and coaching system should be tried out in an operational training setting before its design is finalized.

Related Support Features

Relationships of automated cuing and coaching to other instructional support features are summarized below.

Programmed Mission Scenarios. A programmed (i.e. pre-specified) mission scenario is required so that a baseline of desired performance exists. The programmed scenario can be as simple as an ILS profile, or can involve an entire mission plan depending on the training requirements being addressed.

Automated Performance Measurement. An automated performance measurement capability is needed to sense specific performance deficiencies so that correct cuing and coaching messages can be transmitted to the student. (See Chapter IV of this report)

Instructional Values

Assumed instructional values for automated cuing and coaching center on the promptness and accuracy of information provided to the student, and the unburdening of instructors through automation. Similarly, such systems can provide feedback and guidance to students when an instructor may not be present.

It is not uncommon for instructors or console operators to be distracted temporarily with other tasks when a student's performance begins to degrade. Automated cuing and coaching can get around this problem and make sure that feedback and guidance are provided to the student in a timely manner. Also, at a number of training facilities, students are encouraged to use ATDs on their own to practice tasks. Frequently, an instructor is not present. Thus, automated information may be all that is available to the student.

Present applications of automated cuing and coaching have centered on basic (undergraduate) flight and navigation task training. In the future, it may be possible to incorporate these capabilities into procedures task training. Automated measurement of student performance of normal procedures and emergency procedures is advancing. With this capability, it should be possible in the future to provide automated cuing and coaching assists for procedures training.

Observed Applications

Only one application of automated cuing and coaching was observed. The application involved initial entry rotary wing pilot training on instrument procedures. An automated measurement system monitored the following parameters: heading, glidepath, altitude, airspeed, bank angle, pitch angle, trim, vertical velocity, and turn rate. Cuing messages were brief and consisted of: check heading, check altitude, etc. Coaching messages provided guidance to the students. Typical coaching messages were: adjust heading to return to course; and adjust power to return to glide path. The messages were stored on magnetic tape and were presented aurally to students. The instructor had the option of turning the system off, selecting individual parameters to be monitored for message generation, or selecting all simultaneously. A symbol appeared on the instructor's pictorial flight profile display each time the system transmitted a cuing or coaching message. This information was available for use during debriefing. Use of the automated cuing and coaching system was at the instructor's discretion. It is not known how frequently it was used. A number of student pilots reported, however, that they felt the messages were valuable during their training.

A second application was reported by Semple (1974). Undergraduate navigator training was investigated in a new Navy communication and navigation training device. The device incorporated a display panel that presented cuing messages to the students. A tone accompanied each message. This cuing system was found to be so disruptive to students that it was deactivated. It must be noted that this application involved cognitive skill training rather than flight control training. Also, in this application it was not possible to selectively eliminate some of the cuing messages. Additionally, in this case, messages were displayed in printed form, which might have contributed to their lack of acceptance. It also is known that the messages occurred too often and that the simulation was not frozen when performance obviously was deteriorating and instructor involvement was required. In other words, automated decision logics were very rudimentary and not workable in this early application.

Utility Information

With only two observed applications, it is difficult to make solid statements on the use of automated cuing and coaching for the broad spectrum of aircrew training. In one observed application, use of the feature varied considerably from instructor to instructor, which was to be expected because of lack of instructor training on potential values and limits. Some instructors and operators indicated that the feature was used "quite often" by students who came in to practice on their own, but they could not quantify the amount of use. The observed system used audio tape recorded messages. Some difficulty was experienced initially with the mechanical reliability of the tape system. This problem eventually was overcome. In the second application, poor design and

implementation made clear a number of design characteristics to avoid, but precluded determining meaningful, positive guidelines.

Related Research

No systematic research was found that addressed the instructional values of automated cuing or coaching. Similarly, none was found dealing with performance tolerance bands that should be used to trigger messages during various stages of skill acquisition or retention training.

Design Considerations

Again, with only two observed applications, it is difficult to make solid design recommendations. The following guidelines are presented for consideration. They are based largely on a "common sense" approach and must be subjected to test and evaluation.

Computer speech generation is a new but workable technology. It is reasonable to use this technology as the means for creating cuing and coaching messages, particularly because of the timeliness of the messages that can be generated.

Automated cuing and coaching systems can inundate students and instructors with messages. It is necessary, therefore, to make it possible for instructors/operators to selectively activate the messages, rather than force the messages on them.

It also is probable that the use of looser performance tolerances early in training to trigger cuing and coaching messages is desirable. This could serve to reduce the number of messages transmitted to the student during early training when his abilities to perform may be significantly less than what is expected of him at the conclusion of training. However, there presently are no guidelines for determining these tolerances. Further research is needed.

ATD-MOUNTED AUDIO VISUAL MEDIA

Summary

Slide/tape presentations of instructional information have been used for many years by commercial airlines as a complement to guidance provided by instructors in classrooms and cockpit procedures trainers. The U.S. military now is beginning to use these media to provide systematic instruction and detailed procedural information to aircrew members in ATDs. The goals are to provide structured procedural guidance, complete information, and to do so in a context where pilot trainees actually can perform and practice the procedural steps that are required. Additionally, system operational information can be presented and reviewed. Typically, the presenting of pictorial information and procedural steps has been through projections at the cockpit windscreen.

Verbal information has been presented via a tape recording. Such systems have been well received. They allow structured training not only when an instructor is present, but also when students are in a CPT or OFT without an instructor.

Feature Description

Two types of audio visual presentations were observed during the program. Current technology used slides and accompanying audio type presentations. Older technology applications were 16 millimeter motion picture presentations with sound. With either medium, the content of what is presented is of primary importance; the medium is simply a means of conveying the message. In this regard, video tape and video disk technology must be considered as media alternatives.

Related Support Features

Audio visual media are not directly related to any other instructional support features.

Instructional Values

Two instructional values commonly are assumed. The first is consistency and completeness of the information presented. Details are not overlooked, and standardization of instruction is promoted. The second is an efficiency value. With cockpit-mounted audio/visual training media, it may not be necessary for an instructor to be present. For example, after an initial presentation and question/answer period, students may benefit from independent study and practice using audio/visual presentations as a source of guidance and as a baseline for performance assessment and feedback.

Observed Applications

Two applications of audio/visual presentations of procedural training information were observed during the present program, although the authors have observed others during prior programs. In the STRES program, applications were observed at United Airlines Boeing 747 transition training program, and the Navy's E-2 transition training program.

At United, a B-747 CPT serves as the classroom for transitioning captains and copilots. The CPT also is used extensively for transitioning flight engineers, although these pilots also receive classroom training. United's B-747 CPT program is centered around a windscreen audio/visual (slide/tape) presentation of procedural, system and flight operations information. An instructor is present during United's CPT training. The audio/visuals provide supporting pictorial and text information to provide primary instruction. It was observed that instructors frequently interrupted the media presentations to amplify on points previously found not to be clear, review information

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with the transitioning pilots, and to present and explain points that were new (i.e. the media presentations were outdated or incomplete in some respects). Pilot responses to this approach to training were highly favorable for several reasons: 1) instruction was highly personalized since the typical student to instructor ratio was two or three to one; 2) abstract information (i.e. system design and functioning) could be clarified through direct system operation following audio/visual instruction; 3) an instructor was present to amplify on and clarify information as well as answer questions, making the instruction highly individualized; and 4) the pacing of instruction was flexible (within limits) to pilot needs. Navy instructors voiced similar viewpoints with respect to E-2 training. Additionally, the Navy site surveyed also allowed and encouraged pilots to use available CPTs (and other ATDs) on a time available basis, even though instructors were not present. In this instance, providing structured training through cockpit-mounted audio/visual media was useful to the students, especially because structure to the training was provided even though an instructor might not be present.

Utility Information

The value (utility) of ATD-mounted audio/visuals has been described in the preceding part of this section.

Related Research

No research was found that dealt with the effectiveness or efficiency of ATD-mounted audio/visual media. The general effectiveness of such media commonly is assumed, however, in many other applications. Also, efficiency is assumed because of favorable student to instructor ratios. Prior experience shows, however, that both effectiveness and efficiency are under the control of the instructor. If he forces the pace of instruction in keeping with the media pace, then some pilots will be "left behind" because of a lack of understanding of what was presented. Obviously, this is counterproductive and undesirable, although it happens. On the other hand, if the pace of instruction is too slow, lack of student attention can result, and key points can be missed. This, too, can lead to lack of training effectiveness. The issue is to design and evaluate each training (audio/visual) module so that assurance is available that the module is, indeed, geared to the learner audience. Finally, instructor training becomes involved. Most instructors have the technical knowledge required to amplify upon or explain further what has been shown through audio/visual media. However, some are prone to telling "war stories", which can lead to instructional inefficiencies and learner boredom.

Design Considerations

The technical correctness of any audio/visual presentation is a product of the thoroughness and technical knowledge of those who prepare it. The attention getting value of the presentations remains an art

form (although budget also can be a factor). Without question, a team of experts should be used to develop the technical content of any audio/visual presentation. A team is required so that all important technical content is identified. A qualified instructional technologist, however, should direct how the information is sequenced, presented and evaluated. The technologist also should have a demonstrated capability to implement scripts, visuals and feedback systems since all of these factors are critical to information transfer, performance (learning) assessment and user acceptance.

One problem was observed with cockpit audio/visuals during program site visits, and the problem was independent of the user acceptance of the media. It was observed that instructors often had to interrupt audio/visual presentations to review materials and answer questions. With slide/tape media, backing up a presentation for replay is cumbersome because it is necessary to separately back up the slides and the tape, and then re-synchronize them. Typically what was done was to provide the instructor with printed text of the script. Although this was observed to have worked well, it leaves the problem of re-synchronizing the backed-up slides with the audio tape. This problem could be overcome by using video tape or video disc recordings, although they may be more difficult (costly) to update.

CHAPTER IV

MONITOR AND EVALUATE PERFORMANCE

FUNCTION DEFINITION

This chapter addresses two instructional functions (monitor and evaluate) because one supports the other in inseparable ways. Evaluation is a classic decision function. It is determining the relations between observed performance and required performance through systematic and careful comparisons. Monitoring is the observing or gathering of relevant performance information to use in the decision process. Performance is the observable behavior of the student aircrew member and/or observable system responses that result from his actions. Performance observations can be made directly by the instructor, or indirectly by means of computer-based automated performance measurement systems.

RELATED FUNCTIONS

The reader is directed to the following chapters of this report that address functions directly related to monitoring and evaluating performance.

Chapter V,   Control and Individualize Training

Chapter VIII, Instructor/Operator Console
               Design and Location

Chapter IX,   Instructor/Operator Training

The reader also is referred to Chapter VIII of the utilization report, which deals with assessing ATD training effectiveness and includes a section on performance measurement for effectiveness assessment purposes.

INSTRUCTIONAL SUPPORT FEATURES ADDRESSED

The instructional features addressed in this chapter are:

Automated performance measurement

Automated performance alerts

Annunciators and repeater instruments

Closed circuit television

AUTOMATED PERFORMANCE MEASUREMENT

Summary

Automated performance measurement (APM) for training is the computer-based application of technology to monitoring, recording, processing and displaying objective, quantitative information that describes student performance and assists in diagnosing student learning problems. APM systems have been fairly common in research simulators for over ten years. These APM systems typically are not suited for operational training, however, because they have been tailored for research use and frequently produce performance data that require subsequent statistical processing. An APM system designed for use in training must perform all statistical and other processing of performance data in real or near-real time so that students and instructors are provided with useful, concise and timely performance feedback information.

Practically all automated measurement capabilities in existing ATDs or ATDs soon to be delivered are best described as performance monitoring and data collection systems. These capabilities allow instructors to select tolerance bands (e.g. +/- 100 feet) around various performance parameters (e.g. altitude). The performance monitoring capability then monitors for cases that exceed the tolerance bands values, and records out of tolerance conditions for subsequent display at the instructor's console or for hard copy printouts. Such rudimentary performance monitoring capabilities have been used effectively to drive automated performance alerting systems and automated cuing and coaching systems. However, they have found little acceptance for performance evaluation and learning problem diagnosis during training. In other words, such systems are not used by instructors. One reason is that the volume of data produced by such systems often is overwhelming and very difficult to integrate and interpret. A second possible reason is that instructor training has not addressed the use of such data.

Recent APM research suggests yet another reason why outputs from parameter monitoring capabilities are frequently not used. It now is an accepted fact in the APM research and development community that aircrew performance measurement is a multi-variate issue. This means that performance is best described by analysis of how many different performance dimensions simultaneously change with respect to each other, rather than how they change individually. Determining these relationships and developing rules for weighting and combining many individual parameters into a new, statistically defined performance score requires the use of sophisticated statistical procedures. It is not surprising, therefore, that providing instructors with what is basically raw performance data has not proved helpful for evaluating and diagnosing the student's progress in training.

APM for training still requires experimental development work for each application. Discussions with one of the respected researchers in the training APM field revealed the following. He would be quite unwilling to prepare an APM system specification unless the specification clearly required a measurement development and refinement process. In this process, actual student performance data would be collected, analyzed and used to refine the initial APM system so that it would produce a minimal set of valid and usable measures of performance. Automated measurement of human performance is complex, the measures are interactive, and the technology has not yet been thoroughly developed.

Feature Description

Automated performance measurement (APM) for training is the computer-based application of technology to monitoring, recording, processing and displaying objective, quantitative information that describes student performance and assists in diagnosing student learning problems. Modern APM systems operate in real time or near-real time so that student performance information is quickly available for feedback to instructors and students.

It is necessary to distinguish automated performance measurement systems from automatic data monitoring and recording systems. Automatic data monitoring and recording systems sample the values of parameters (e.g. altitude or the position of a particular control) and also may monitor for cases that exceed tolerance band values that have been set for the parameters. Automatic monitoring and recording systems then simply store and/or display this information either for subsequent statistical analysis or for visual examination by instructors and students. The few "automated measurement systems" that are found in existing ATDs actually are automated monitoring and recording systems. They collect and display rather rudimentary data forms. No data processing (i.e. transforming, weighting, combining and scaling) is provided. All of these functions are left to the instructor who must perform them subjectively. Four such "automated measurement systems" were observed during program site visits. One was a part of an F-15 OFT; a second was part of a U.S. Coast Guard helicopter OFT; the third was part of an Army rotary wing OFT; and the fourth was incorporated into a Navy F-14 OFT. None of these systems was used. (See the Utility Information part of this section.)

True APM systems for aircrew training applications represent an emerging technology. Recent developments in computer technology have accelerated APM research and development, but automated human performance measurement technology issues still require considerable clarification (Vreuls and Wooldridge, 1977; and Waag and Knoop, 1977).

APM systems for training must be designed to support specific training objectives. Thus, the specific design of an automated performance measurement system will depend on its training application. General characteristics can be described, however, and one such set of

characteristics is how individual measures need to be defined. Based on recent APM training research, it appears that each measure must be defined in terms of the five determinants described below (Vreuls and Wooldridge, 1977).

> Measure Segment. This is any portion of a maneuver or mission for which student performance or system performance is relatively constant or follows lawful relationships from beginning to end, and for which the beginning and end can be defined unambiguously. Measure segments can overlap or can be one-time events. The measure segment must be defined by explicit, unambiguous measurement start/stop logic. This has proved to require sophisticated, innovative logic designs.

> State Variable. A state variable is any quantifiable index of: 1) vehicle states in any reference plane (e.g. bank angle); 2) student physiological states (e.g. heart rate); or 3) control device states (e.g. control stick or switch positions).

> Sampling Rate. This is the temporal frequency at which a state variable (parameter) is recorded or examined by an automated measurement system.

> Desired Value. In many cases, a state variable by itself is of little measurement use. Frequently it is necessary to compare the state variable with a desired value to obtain an error or deviation score. Desired values can be determined analytically or experimentally.

> Transformation. A transformation is defined as a mathematical treatment of the error/deviation score. Transformations can be as simple as just the state variable's value or its absolute value, or may include computations of out of tolerance conditions, measures of central tendency, variability, frequency content or departures from norms. Common transforms are shown in Table 7.

Measurement transforms also do the job of summarizing vast numbers of measurement samples into something that is instructionally manageable. For example, if the state variable being measured was angle of attack, and it was sampled twice per second during a three minute interval (e.g. during final approach to landing), 360 measure samples would result. A measure transform that computed the variability of differences between desired angle of attack versus observed angle of attack, averaged across the entire measurement segment, would result in only one number. Such a transformation could be obtained by computing the standard deviation of angle of attack deviation values. Thus, transformations make automated performance measurement data manageable, among other things. (The example also points out the need for developmental research of APM capabilities, because it would be analytically impossible to establish an acceptable value for such a

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Table 7. Common Measure Transforms

Time History Measures
        Time on target
        Time out of tolerance
        Maximum value out of tolerance
        Response time, rise time, overshoot
        Frequency domain approximations
                Count of tolerance band crossings
                Zero or average value crossings
                Derivative sign reversals
                Damping ratio

Amplitude-Distribution Measures
        Mean, median, mode
        Standard deviation, variance, range
        Minimum/maximum value
        Root-mean-squared error
        Absolute average error

Frequency Domain Measures
        Autocorrelation function
        Power spectral density function
                Bandwidth
                Peak power
                Low/high frequency power
        Bode plots, fourier coefficients
                Amplitude ratio
                Phase shift
        Transfer function model parameters
                Quasi-linear describing function
                Cross-over model

measure, and it still is necessary to establish experimentally whether such "unusual" measures in fact are good performance descriptors.)

APM research has shown that some measures contribute more to the total description of student performance than do others. The research also has shown that, individually, various measures may not be useful for discriminating between "good" and "poor" performance, but when they are properly weighted and combined, the resulting measure set, collectively, is quite useful for discriminating between performance differences (Waag, et. al., 1975). The extent to which various automated performance measures must be weighted and/or combined to become useful for training purposes remains a research issue. The need to do so has been demonstrated, however, for basic instrument flight maneuver training (Vreuls, et al., 1976) and for one versus one air combat maneuvering training (Kelly, Wooldridge, Hennessy, Vreuls, Barnebey, Cotton, 1979). It is fairly certain, therefore, that at least some future ATD APM systems will require sophisticated, near-real time statistical processing of multiple as well as individual measures in order to provide instructors and students with valid, usable performance scores.

Automated measurement of procedural performance, such as the performance of checklist items, also is an emerging technology, and may not be seen in operational applications for at least five years. Automated measurement of performance of procedural sequences requires very complicated computer logics which only now are being developed for training applications (Semple, et al., 1979). A number of newly acquired ATDs will incorporate procedure monitoring capabilities, however (e.g. F-16, A-10, F-5, B-52 and C-130). These systems will display (on either cathode ray tubes or hard copy printouts) the actual sequences in which procedures are peformed. It will be the instructor's responsibility to determine whether or not the procedural sequences and timing were acceptable.

Related Support Features

Some form of automated performance measurement is essential for the use of the instructional support features described below. The level of APM sophistication required for each feature varies significantly, as noted.

Automated Adaptive Training (AAT). AAT is training in which the problem, the cues or the task are varied automatically as a function of how well the student performs. Automated performance measurement is necessary for AAT systems to determine how well the student is performing and to identify specific performance strengths and deficiencies so that subsequent training can be tailored automatically to the student's needs. It is believed that AAT systems for aircrew training will require highly sophisticated automated measurement capabilities. (See Appendix B of this report.)

Computer Managed Instruction (CMI). CMI systems that are capable
of tracking the student's achievement of training objectives require
automated measurement system inputs if the CMI systems are to be
automated. The level of measurement system input to the CMI system
can be quite rudimentary and can indicate simply that a particular
training objective either has or has not been achieved (i.e. a
yes-no input). The system measurement requirements for making the
yes-no decision, however, may be fairly extensive, depending on the
training objectives that are involved. (See Chapter VII of this
report for additional discussion of CMI systems.)

Automated Performance Alerts. Automated performance alerts are
signals provided to instructors and/or the students indicating that
some facet of the student's performance has exceeded accceptable
limits. Automated measurement is required if such alerts are to
occur automatically. The sophistication of the measurement that is
required depends on nature of the alert and what is required to
trigger it. An automated alert that indicates simply a departure
from an assigned altitude poses minor requirements on an automated
performance measurement system. An automated alert indicating
improper primary flight control technique, on the other hand,
requires considerably more complex measurement. (See the next
section of this chapter for further information on automated
alerts.)

Automated Cuing and Coaching. Like automated alerts, these
instructional support capabilities require automated measurement as
the triggering mechanism. And, as with automated alerts, the
complexity of the measurement capability required to operate
automated cuing and coaching capabilities depends entirely on the
nature and complexity of the task being trained. (See Chapter III
of this report for additional information on automated cuing and
coaching.)

Instructional Values

To a great extent, the instructional values of automated performance
measurement are the same as the values of measurement in general. The
general values of measurement are to provide decision making data to
policy makers, technology managers, scientists, training managers,
instructors, and operational commanders. The right kinds of human
performance data are useful in guiding decisions about doctrine,
strategy, tactics, personnel selection, training, training device and
curriculum design, skill maintenance, proficiency advancement, and
operational readiness.

Values offered by automated performance measurement for aircrew
training include: precision; objectivity; standardization; improved
record keeping (e.g. for trend information); and the capability to
measure considerably more facets of human performance simultaneously.

The need for improved aircrew performance measurement capabilities, including automated performance measurement, has been recognized for some time (e.g. Smode and Meyer, 1966; and Department of Defense, 1968). However, it only has been recently that the operational environment has come to recognize the need for improved measurement (Waag and Knoop, 1977). The needs are even more pressing now because of severe budgetary constraints and fuel realities. These factors imply needs for improvements in aircrew training efficiency and effectiveness, skill maintenance and operational readiness. Improved efficiencies require improved measurement. Responsiveness to these needs is reflected in continuing automated performance measurement development programs in the Air Force, Navy and Army.

Observed Applications

The automated measurement systems observed during this program are best described as performance monitoring and recording capabilities rather than true automated performance measurement systems. Performance monitoring and researching capabilities monitor whether tolerance bands (e.g. +/- 5 degrees) around various performance parameters (e.g. heading) are exceeded. Cases that exceed tolerance band values are recorded for subsequent display at the instructor's console or for hard copy printout.

Four such performance monitoring and recording capabilities were observed; one was incorporated into an Army rotary wing OFT; the second was part of a U.S. Coast Guard helicopter OFT; the third was part of an Air Force F-15 OFT; and the fourth was part of a Navy F-14 OFT. The first device was used primarily for basic pilot training. The second, third and fourth devices were used for transition and continuation training.

Utility Information

None of the performance monitoring and recording systems surveyed during the program was used during routine training operations. Many of the monitoring/recording capabilities shared the following shortcomings:

Set-up of the capability was time consuming and required frequent changes. For example, monitoring how well a pilot maintained altitude during cruise required one tolerance band setting; checking to see whether a minimum altitude was exceeded during an instrument approach required making a tolerance band change. Such manual changes to the system are a nuisance to instructors. Therefore, they do not make them. If they do not make the changes, the performance monitoring capability produces irrelevant, meaningless data. This is one reason such systems are not used.

The data that could be produced were overwhelming in volume and were difficult to interpret. Lack of appropriate instructor training may have contributed to the problem. However, recent automated performance measurement reasearch suggests another reason why such

outputs are not useful. It now is an accepted fact in the APM research and development community that performance measurement is a multi-variate issue. It has been found that aircrew performance is best described in terms of how a number of different performance measures change individually. What this says is that aircrew performance is as complex as instructors always have said it is, and simplistic (one measure at a time) approaches to measurement simply cannot be used to get a practical handle on the complexity of aircrew member and total weapon system performance.

Related Research

Practically all APM work has been done in the context of automated meausrement research and development. Exceptions include the development of APM capabilities for aircraft control-display research (e.g. Monroe, Vreuls and Semple, 1968) and aircrew training research (e.g. Waag and Knoop, 1977; and Kelly, M. et al., 1979). Even these applications have focused on research tasks rather than operational performance assessment applications. Exceptions exist, of course. McDonald, Smith, Evans, Baer and Nelson (1979) have reported the development and test of limited APM capabilities for the F-15 OFT. Semple et al. (1979) report the design of a limited, experimental prototype automated performance measurement and scoring capability for a Navy F-14 OFT. This prototype system will be used, in part, for *performance measurement development work* in an operational (transition and continuation) training setting. Povernmire, Russell and Schmidt (1977) also have reported a study in which rudimentary types of automated measures were explored to determine U.S. Coast Guard helicopter pilot proficiency. All of the studies cited above have dealt with individual aircrew member (usually pilot) performance. Only one program is known to be addressing APM for the much more difficult task of assessing crew (*versus individual*) performance. This program involves measurement of Air Force C-5 crew performance.

The studies cited above (and other, related studies) have focused on the following issues, all of which are relevant to developing a workable APM technology base:

How should measures be defined in terms of *computer software and associated logics?*

Which automated measures validly describe aircrew performance? For example, which measures actually discriminate between obviously "good" and "poor" performance?

What are the best ways to weight and combine individual measures to better describe and predict total pilot performance?

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Which measures and combinations of measures are most useful to instructors for diagnosing student learning and performance problems, in order to speed up learning?

Which measures and combinations of measures are useful in automated diagnosis of student learning problems, quantifying proficiency levels, and prescribing subsequent training (i.e. automated adaptive training applications)?

Which automated measures found to be useful in training research and development will be useful in day-to-day training operations?

How can technology developed for automated measurement of flight performance be used to measure the performance of sequences of procedural events (e.g. checklists)?

Which automated measures (and weighted combinations of measures) correlate highly with skilled instructor evaluations (i.e. which measures will be perceived as valid by instructors)?

How should APM data be presented/displayed to instructors and students?

The issues identified above are numerous and broad ranging. In addition, the number of aircrew tasks involved is great; and the range of pilot skill levels to be assessed covers the spectrum from undergraduate through operationally ready. With these points in mind, there should be little surprise that APM research, which has been undertaken seriously only within the past decade, has not led to the resolution of many aircrew measurement needs. The following paragraphs highlight research findings that are representative of the present state of the art. The reader is reminded that this is an area requiring considerable additional research and development.

Methods for defining automated measures of flight performance are fairly well accepted, and are made up of the five measure determinants previously described in the section titled: Feature Description. Defining unambiguously computer logics for automatically starting and stopping measurement remains an intricate and sometimes illusive task. McDonald et. al. (1979), for example, reported that relatively simple automated measures of pilot performance during a standard instrument departure correlated highly (r = .75) with instructor ratings of pilot performance. However, automated measurements of performance during TACAN approachs or ILS final approaches were either uncorrelated or negatively correlated with instructor ratings. McDonald et al. attribute the latter findings to the fact that their automated measurement system started measuring performance at inappropriate times because pilots do not fly the text book approaches their measurement system was patterned after.

It is relatively easy to measure many facets of pilot performance simultaneously with computer based measurement systems. This can result in a "measure overload." The issue then becomes one of identifying which of the candidate (experimental) measures best describe performance, and which do not. Multi-variate statistical procedures have proved to be valuable tools in this process. It has been shown, for example, that initial candidate measure sets containing 30 or so measures can be reduced to about 10 measures with no apparent loss in measurement precision (e.g. Kelly, M. et al., 1979). Appendix B deals with this issue in greater detail. Occasionally, the unexpected also is demonstrated. For example, Vreuls, Obermeyer, Goldstein and Norman (1975) showed that approximately 40% of student performance variance was accounted for by measures of primary flight control (e.g. control stick) inputs in a task involving basic instrument flight maneuvering.

APM research using multi-variate statistical procedures also has shown that not all measures contribute the same (i.e. have the same weight) to describing pilot performance. This is not an unexpected finding, since instructors often note that one or more facets of performance are more important than others in accomplishing various flying tasks. In automated performance measurement systems, however, it is necessary to know fairly precisely just how much weight should be assigned to individual measures. Again, multi-variate statistical techniques can be of considerable value in determining appropriate weights based on analysis of representative samples of actual performance data (See Appendix B of this report). In lieu of having empirically determined performance weights to use, some researchers have assigned weights to different performance measures based on expert opinion (e.g. McDonald, et al., 1979). The problem is that such weights may not be valid, and may distort performance appraisals (McCauley and Semple, 1980). Considerable further research is needed to determine the relative importance of specific measures for performance description and learning problem diagnosis in the training of the many tasks required in military missions.

Very little is known about designing APM systems specifically for learning problem diagnosis so that automated adaptive training system logics can function most efficiently. Wooldridge, Vreuls and Norman (1977) reported a study that compared several different automated adaptive logics (training strategies). The measurement system they used obviously was quite complex, but was not fully reported by them. The tasks they studied were basic instrument pilot maneuvers, and relatively inexperienced pilots were used as subjects. Although their automated adaptive training logics seemed to operate as designed (which implies that the automated measurement system also was adequate), further research also is required in this area because of the limited nature of the tasks used in research to date.

Waag and Knoop (1977) report that automated measurement methods exist for measuring performance on a variety of Air Force undergraduate pilot training tasks. The measurement system is implemented in the Advanced Simulator for Pilot Training (ASPT) at Williams AFB. Whether these research measurement methods can be applied and used practically in undergraduate pilot training operations has not yet been demonstrated, although they may be. Similarly, Kelly, M. et al. (1979) have reported the development and test of an initial APM capability for measuring facets of one versus one air combat maneuvering performance in the Air Force SAAC simulator at Luke AFB. The Vought Corporation also has been tasked by the Air Force to develop the "Good Stick Index" for test and evaluation in air combat training simulators. Whether any of these new but complex measurement developments prove workable in day-to-day training applications remains to be established. At this point, further developmental research and validation is needed to answer the question.

The issue of applying automated measurement techniques to measuring the performance of sequences of procedural events (e.g. pre-start checklist procedural sequences) is just now receiving attention. In this application, an experimental prototype instructional support system for a Navy F-14 OFT will incorporate limited monitoring, measurement and scoring of procedural performance by a single crewmember. Preliminary indications are that considerable and detailed task analysis must precede the development of computer measurement logics. This is because correct sequences must be determined in detail, and likely alternative sequences (both acceptable and unacceptable) also must be defined so that computer measurement and scoring logics act fairly and do not penalize pilots for using occasional (but acceptable) departures from normal, textbook procedural sequences. Related to this are the complex computer logics required to monitor and track procedural sequence chains, decide on their appropriateness, and measure and score appropriately. Initial research data should become available by early 1981.

The preceding paragraphs of this section certainly have not exhausted the research on this relatively new and highly complex topic. Rather, the intent has been to highlight the kinds of research that have been accomplished and that are under way. The fact that considerable further work is required is recognized by all three services. Because of the complexity of the automated measurement research and development task, the Air Force Office of Scientific Research, with tri-service coordination and support, is sponsoring a program to develop APM standards. One primary goal is to explore ways of making individual APM studies more usable across the services based on more consistent experimental methodologies. Another goal is to provide a mechanism for integrating and interpreting the individual contributions being made to APM by various researchers and organizations. These goals take on additional meaning when it is considered that recent analyses (e.g. Cotton, 1978) show that measurements previously possible only in simulators can be made in flight using airborne computers which are hardware and software compatible with specific ATDs. Implications for

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highly objective training effectiveness and operational readiness assessments are much encouraged by these analyses.

Automated measurement of aircrew member performance in ATDs has proceeded along logical and coordinated paths, but only for a relatively short period of time. Research in this admittedly complex technical area is bearing fruit, which ultimately may be applied in flight.

Design Recommendations

Guidelines for the design of practical, valid and acceptable APM systems are not yet at hand. Human performance is complex and the human's evaluation of another human's performance also is complex. Computer-based systems for assessing and diagnosing human performance just are beginning to evolve. Operational applications of true APM systems basically are non-existent.

APM system design recommendations are, thus, both simple and complex. First, candidate measures must be determined both on the basis of existing operational doctrine (which often reflects the limitations of human performance measuring capabilities), and detailed measurement analyses and subsequent measurement development and validation experiments.

The design, development and validation of workable automated performance measurement systems for aircrew training requires an orderly analytic and experimental process. Discussions with a respected APM researcher revealed that he would not participate in developing an APM specification unless the specification included the requirement for a formal development and validation experimental program. This need will continue until enough experimental and operation experience is gained. These requirements cannot now be met. Appendix B was prepared to present guidance on these and related issues. The interested reader is referred to the appendix for a more detailed discussion of APM system design and validation.

AUTOMATED PERFORMANCE ALERTS

Summary

Automated performance alerts are signals provided to the instructor and/or the pilot being trained indicating that some facet of his performance has exceeded acceptable limits. Automated alerting capabilities require an automated performance measurement system. Their use also requires that training tasks be specified and standardized sufficiently that automated performance measurement is possible. Only one ATD (a helicopter OFT) was observed during program site visits that incorporated any form of automated performance alert. This system produced a symbol on the instructor's electronically generated flight situation (graphic position) display at points along the flight profile where predetermined performance limits were exceeded. Results of a

prior training effectiveness evaluation of a navigator training simulator showed that performance alerts may be disruptive to learning if they are presented directly to the student because of the distraction they can cause. To be acceptable to users, automated performance alerting capabilities must be designed so that the alerts are neither excessive in number nor disruptive to student or instructor activities. If an alerting capability is incorporated into an ATD, the ability to turn the capability on or off at the user's discretion also should be provided.

Feature Description

Automated performance alert signals are intended to enhance the monitoring of student performance by combining the capabilities of an automated performance measurement system with an automated capability intended to complement the instructor (or student's) normal monitoring of performance information provided to him.

The use of automated measurement requires that the training tasks can be specified and standardized sufficiently so that automated measurement is possible. For example, the use of automated alerts in the training of many flight control and navigation tasks requires the measurement system to know which task is being performed by the student so that appropriate measurement criteria can be applied for the alerting function. One method of doing this is through the use of pre-programmed mission scenarios (See Chapter III). Some sophisticated laboratory automated measurement systems (e.g. Vreuls et al., 1975) use complex computer logics to identify the task the student is performing by monitoring the ATD's flight path, various flight parameters and the positions of relevant controls such as navigation radio control settings. Until recently, such logics existed only for a limited spectrum of instrument flight tasks. The Navy is sponsoring the development and evaluation of similar logics for determining when procedural sequences (e.g. engine start and before takeoff checklists) have been initiated and completed. Pursuit of these initial developments will expand automated performance measurement and alerting into the procedures monitoring area. Finally, some performance alerts are relatively easy to generate because they are largely independent of specific tasks being trained. Examples include alerts when airspeed exceeds 250 knots below 10,000 feet of altitude, and when the landing gear is lowered above the placard airspeed.

Alert signals can be presented in a number of ways. Two common ways are: 1) visually at an instructor/operator console or on a special display in the ATD student station; or 2) aurally by means of a tone. Verbal alerting messages using computer generated speech technology also are within the state of the art. (See Chapter VI for a discussion of computer generated speech.)

Alerts were presented visually in the ATDs reviewed in this study. One ATD was Army rotary wing training device 2B24. The second was Navy communication and navigation training device 1D23. In device 2B24, unique symbols were displayed on an instructor's electronically generated flight situation (graphic position) display. Device 1D23 displayed a brief text message directly to the student on a special-purpose display (Semple, 1974). The student was required to depress a button within a short time period after the message was displayed in order to acknowledge it. If he did not, a tone sounded.

Related Support Features

Automated performance alerts are related to the following instructional support feature:

Automated Performance Measurement. An automated performance measurement system is required to activate automated performance alerts. (See the first section of the chapter.)

Instructional Values

The most commonly advanced instructional value is an automated assist to the instructor in monitoring the many channels of information that describe student performance, and in determining whether performance is within acceptable limits on each channel. These are not tasks at which the human excels. Computers, on the other hand, are well suited to monitoring and evaluating many different channels at the same time.

Properly designed, automated performance alerting capabilities can provide feedback to the pilot being trained without the presence of an instructor. However, as discussed previously, excessive alerts can be distracting and disruptive to the learning process. Also, alerts used in this way must specifically identify the student's performance problem (e.g. below glidepath) rather than just indicate "you've done something wrong."

Observed Applications

The only application of automated performance alerts observed during this program was in Device 2B24, the Army UH-1 helicopter operational flight trainer. In this application, performance alerts were displayed visually as unique symbols beside a flight path trace on an electronically generated graphic position display at the instructor/operator's console. The performance alert symbols could be displayed or deleted at the instructor's discretion.

Utility Information

The design of the automated performance alerting capability of Device 2B24 allowed instructors to select whether or not they wanted the

alert symbols displayed. This capability was viewed favorably by instructors. The symbols could be deleted to minimize display clutter. Later, following the flight, the history of the flight could be displayed together with the alert symbols as a debriefing aid. This provided a well accepted memory aid as well as a pictorial index of student performance. For example, fewer performance alert symbols on the display indicated better performance. Use of the display for debriefing was limited, however, when ATD utilization was high. A hard copy capability would have alleviated this problem.

Performance alerts can be distracting. Semple (1974) reported that an alerting capability built into a Navy undergraduate navigator trainer was deactivated after a short period of trial use because it was found to be disruptive to the learning process. In this case, students having difficulty performing navigation tasks were sufficiently busy, that having to respond to a performance alert only aggravated their situation. It is possible that voice alerts might not have been as disruptive. However, frequently occurring voice alerts also may be aggravating. Instructors involved in the study commented, however, that such an automated performance alert capability at their remote consoles could have been of value because each instructor/operator team had to monitor the performance of up to 20 different students and share their time among students who needed help the most.

Related Research

No systematic research on effective designs and uses of automated performance alerts for training is known to exist. Such research should be undertaken to define the applications and limits of this potentially useful instructional tool. The only other known aircrew training study involving automated performance alerts (Semple, 1974) has been discussed in preceding parts of this section.

Design Considerations

Research is needed on many automated alerting design guide issues. The following design considerations are provided in part to guide the needed research.

It appears logical to design automated alerting systems with at least three and possibly more different sets of performance standards. Early in the learning process, many mistakes are made. Indeed, the process of training is, in part, designed to eliminate mistakes by directing performance toward acceptable standards. An alerting system that closely monitors student performance early in training according to standards expected at the conclusion of training surely will inundate the instructor or student with performance alerts. Therefore, the use of performance standards that are appropriate for the student's level of performance during the learning process seems more reasonable. This might require up to three and possibly more sets of performance

standards. Developmental research on performance standards should be an integral part of the design of future performance alerting systems.

Any performance alert should be designed with feedback and guidance goals in mind. An alert that simply says "something is wrong" tells neither the instructor nor the student what is wrong. Without specific feedback, specific guidance cannot be given the student on what facet of his performance he should change. This suggests an alerting system with at least two levels of feedback. The most basic levels would be simply to highlight a performance deficiency. The second level should specifically identify the deficiency so that feedback and guidance can be specific. On the other hand, too much information can be as useless as too little. Further research is required to develop meaningful guidelines on the amount and timing of automated performance alert information.

Computer speech generation technology presently is available as a means of providing performance alert information. This is a "natural" communication medium and one that does not require the student or instructor to monitor special displays providing alert information. However, this medium is untried as an alerting channel. Again, research is required.

ANNUNCIATORS AND REPEATER INSTRUMENTS

Summary

Repeater flight instruments and annunciators that signal the occurrence of an event (such as the change in the positioning of a control) are issues that are relevant mostly for instructor consoles that are remote, where the instructor cannot directly observe student actions and the displays and controls that are at the student's training station. The goal is to provide the instructor with information relevant to his instructing the student and evaluating student actions for the purpose of providing feedback and guidance. Many remote instructor consoles incorporate repeater (actual replica) flight instruments. Electronic display technology makes it possible to create symbolic representations of these displays, and this is being done more frequently. Annunciators (usually illuminated indicators) have been used in the past to inform the instructor of the positions of significant controls. Modern technology makes it possible to present this information on electronically generated displays. Significant questions remain regarding the best combinations of design possibilities to provide the instructor with the flight, control and event information required to instruct the student and evaluate his performance.

Organization of the content of this section departs from the format previously used because of the nature of the information that can be provided. This topic is directly related to instructor/operator console design; therefore, the reader is referred to Chapter VIII of this report.

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Annunciator Displays

Annunciator displays come in many forms. Some are flap or wing sweep mechanical indicators. Others are discrete event indicators. Usually, these are illuminated indicators that light up when an event occurs, such as: gear up; bombing mode control set to ripple bomb; or head up display set to attack mode. In each case, the indicator at a remote instructor/operator console is intended to inform the instructor of critical control positions selected by the pilot being trained. Several shortfalls have been observed during this program regarding the design of annunciator displays. Each is summarized below.

The information provided often is incomplete. Since there is nothing sacred about the skin of an ATD, an alternative worth investigating is the provision for direct instructor observation of student performance, particularly during phases of training where procedures and control positioning are important training objectives. The value of this alternative hinges, of course, on all relevant controls and displays being visible to the instructor.

The information provided can be overwhelming. Too many annunciator displays simply can overwhelm the fundamental human ability to monitor and process information. The situation can be fully aggravated when one stops to consider the hundreds of control positions that the instructor needs to be aware of. The problem is particularly acute when the information is provided in formats and arrangements that are not operationally meaningful to the instructors. Automated performance monitoring could reduce this problem. (See the previous section of this chapter.)

The arrangement of annunciators is illogical. Often, annunciators at an instructor console are arranged according to the sequence in which the ATD design engineer thinks they will be used. This sequence often bears little or no relationship to the operational sequences that instructors are used to looking for.

The current trend is toward electronic display of information at instructor/operator consoles. This means that display pages easily could be created showing lists of control events performed. However, this too could result in an information overload, which would be similar to the second shortcoming listed above. Additional research is required on how to effectively display discrete event procedures information (and continuous data showing trend information) on electronic displays. One option is to relegate the task of performed monitoring to an automated performance measurement system, and only display departures from accepted procedural sequences. However, the matter of information display still requires examination.

Repeater Instruments

Repeater instruments displaying flight control information have been used at remote instructor consoles for many years to provide pilot instructors with performance data in formats they are used to. Present technology allows for the presentation of such information using electronically generated displays, rather than actual cockpit instruments. Advantages lie in the area of cost and maintainability. Potential disadvantages lie in providing information in formats that instructor pilots are not highly familiar with. Only one ATD (F-15 OFT) was reviewed during this program that used electroncially generated flight displays. The F-15 instructor pilots interviewed reported that the displays were natural to interpret and use to monitor flight performance.

CLOSED CIRCUIT TELEVISION

Summary

Closed circuit television (CCTV) systems have been designed into several training and research simulators on the premise that student behavior could be monitored better from a remote instructor console or that improved debriefing information could be made available. None of the sytems installed to date has proved workable due to poor image quality, narrow field of view, or poor viewing angles.

Feature Description

CCTV systems incorporated a camera, a TV monitor for real time viewing, and, depending on their design and intended use, a video tape system for post-mission replay. Systems installed to date have been black and white. Most cameras have been positioned to "look over the student's shoulder", and provide images of the student, portions of the forward instrument panel, and portions of the visual scene for visually equipped ATDs. One was designed to video tape scenes of instructor console displays for debriefing use. This was in the Air Force Simulator for Air to Air Combat (SAAC.)

Related Instructional Support Features

CCTV is unrelated to other support features.

Instructional Values

Assumed instructional values fall into two categories. The first assumed value is providing improved monitoring of student bahavior in ATDs that have been designed so that direct instructor observation is not practical. The second assumed value is providing real-time debriefing information.

Observed Applications

Four applications of CCTV were identified during the program. The prototype of Device 2B24, used for initial entry training of UH-1 helicopter pilots, included a CCTV system. Production units did not because of the inadequate field of view. The Air Force Advanced Simulator for Pilot Training (ASPT) incorporates an over the shoulder CCTV system. The Air Force SAAC device incorporates a CCTV system to record display information at the instructor console for later replay during debriefing. The Northrop Corporation's Large Amplitude Simulator/Wide Angle Visual System (LAS/WAVS) device incorporated an over the shoulder CCTV system to allow monitoring of an adversary aircraft and pilot actions during one versus one air combat maneuvering.

Utility Information

None of the CCTV systems identified during STRES was found to be usable. Poor image quality was one reason. Restricted field of view was another. And, over the shoulder views mostly show the student's back, and little of what he is looking at or doing. Although image quality and field of view problems can be overcome, camera location problems may not be easily resolved.

Design Considerations

To date, no ATD has incorporated a CCTV system that was designed to provide a front view of the student, rather than an over the shoulder view. A front view system might provide relevant training information on pilot visual scan patterns and/or hand movements. The possibility exists that such a system could interfere with a simulated out of the cockpit visual scene presentation. However, fiber optics technology offers a means around this potential problem. The training value of this type of system is an experimental question.

CHAPTER V

CONTROL AND INDIVIDUALIZE TRAINING

FUNCTION DEFINITION

Control means to direct or regulate training events. Individualizing training is a special case of controlling, where training is tailored to the student's specific skill levels and learning needs.

RELATED FUNCTIONS

The reader is directed to the chapters of this report listed below that address functions related to controlling and individualizing training. The reader also is referred to Chapter IV of the utilization report for related information on the structuring of ATD training and assessing training effectiveness.

Chapter IV,   Monitor and Evaluate Performance

Chapter VII,   Prepare, Brief and Debrief

INSTRUCTIONAL SUPPORT FEATURES ADDRESSED

Instructional support features addressed in this chapter are:

Automated adaptive training

Programmed mission scenarios

AUTOMATED ADAPTIVE TRAINING

Summary

Automated adaptive training is a complex and developing technology in which instructional objectives and strategies that are implemented as computer software are used to automatically tailor (adapt) instruction to individual student learning needs. The present status of automated adaptive training is reflected in the fact that there appears to be no well established, commonly used definition of the concept with meaningful implications for how adaptive training systems should be conceived and designed. It generally is assumed that automated adaptive training systems will hold the potential to achieve very efficient, highly individualized training while ensuring that all students also achieve specified, measurable skill levels at the conclusion of training. Present research, which has been limited and exploratory in nature, has involved only a sampling of instructional strategies and measurement methods, and has involved only limited instrument flight training tasks. Research conducted to date has not clearly demonstrated any training advantages to automated adaptive training. However,

available findings do suggest potentially fruitful avenues for future research in this new and complex area.

Feature Description

In a general sense, automated adaptive training (AAT) is the computer implementation of learning strategies and objectives with the general goals of individualizing aircrew member training, achieving training efficiencies by focusing instruction on student performance deficiencies, and ensuring that all students also achieve specified, measurable skill levels at the end of training. AAT is defined in this report as training in which cues or tasks are varied automatically as a function of how well the student performs. This definition is adapted from the definition of AAT used by Kelley (1969). Hughes (1979) defines AAT as a technique in which the complexity and/or difficulty of a task is adapted automatically to the skill level of the student. Still others (e.g. Wooldridge, Vreuls and Norman, 1977), who have done research on AAT for aircrew training, offer no specific definition of the term, perhaps because they hoped the results of their work would provide a more empirical basis for defining the concept for aircrew training applications.

The adaptation of learning experiences to student needs probably was used by Socrates. Skilled instructors, today, tailor training to student needs. It is attempts to automate the adaptation of training that are new. Essentially, therefore, AAT systems require the automation of instructor models. Key questions are: 1) what instructor (instructional) strategies and decisions should be automated; 2) how must these be tailored based on differences in student learning styles (Sullivan, Casey and Hebein, 1978); 3) what facets of student performance must be monitored and evaluated so that student performance strengths and learning deficiencies can be objectively and reliably identified, so that subsequent training can be based on them; and 4) how are automated instructor models impacted by the tasks being trained and whether they are individual crewmember tasks or team tasks? These are complex issues and questions. For example, it does not appear totally clear how to train (program) human instructors to be effective, efficient teachers of aircrew members, at least based on program surveys. Additionally, military missions require that aircrew members be able to perform a very wide variety of tasks. Also, AAT systems require highly sophisticated automated performance measurement capabilities (e.g. Wooldridge, et al., 1977), which also are at the forefront of technology. It should be no surprise, therefore, that AAT concepts, definitions, research and initial findings are purely at the exploratory development level, and are not yet ready for application to a majority of day-to-day training needs (McCauley and Semple, 1980).

Related Support Features

AAT is directly related to automated performance measurement.

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4.5 2.8 2.5
5.0
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3.6
4.0 2.0

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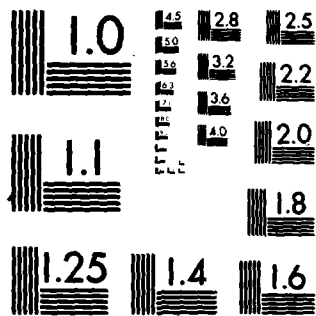
MICROCOPY RESOLUTION TEST CHART
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Automated Performance Measurement (APM). Automated measurement is necessary for AAT systems to determine how well the student is performing and to identify specific performance strengths and deficiencies so that subsequent training can be tailored automatically to the student's needs. It is believed that AAT systems for aircrew training will require highly sophisticated automated measurement capabilities. (See Appendix B of this report.)

Instructional Values

It is assumed that automated adaptive training systems hold the potential to achieve very efficient, highly individualized training while ensuring that all students also achieve specified, measurable skill levels at the conclusion of training (Conway and Norman, 1974).

Observed Applications

Only one system was observed during program surveys that incorporated a capability even approaching AAT. This was Army training device 2B24. At the instructor's discretion, the device could be commanded to automatically increase turbulence and crosswinds during instrument approach and departure training depending on how well the student had performed the previous attempt at the task. This feature of the device was used at the instructor's discretion, and no indications could be obtained on its perceived value. Recent research (Wooldridge, Vreuls and Norman, 1977) suggests that such "problem difficulty" adjustments during initial task learning may interfere with the learning process.

Utility Information

No practical utility information is available because no true applications of AAT were observed during this program.

Related Research

There has been very little experimental research dealing with AAT for aircrew training. Several preliminary AAT systems were placed in the field for evaluation at NAS Chase Field and Luke AFB. The systems were designed for AAT of the GCA maneuver. Although the systems provided well accepted features for training task setup, control and performance feedback, problems with the efficiency of training that could be accomplished with the systems were observed (Puig and Gill, 1975; and Brown, Waag and Eddowes, 1975). The design of these systems was based on concepts developed for feasibility demonstration only (Charles and Johnson, 1971; Charles, Johnson and Swink, 1972; and Charles, Johnson and Swink, 1973). Practically none of the design issues had been researched. Rather, design decisions were based on "best estimates" of training and software specialists. The resulting systems demonstrated a working application of AAT and were shown to have some

appeal based on pilot opinion (Wooldridge, Vreuls and Norman, 1977). No claims were made, however, that the AAT system designs were either optimum or efficient.

The complexity of AAT design and use issues is reflected in a recently reported study (Wooldridge, et al., 1977), which investigated several different experimental adaptive training logics for use in training relatively naive pilots to perform basic instrument flight maneuvers (straight and level flight, climbs and dives, level turns, climbing and diving turns, and GCA). Aircraft weight, center of gravity, turbulence and steady state winds (crosswinds) also were varied. In addition to the AAT logics studied, they also included two control groups of interest. One control group received task training in a random sequence (versus according to a particular adaptive training logic). Two instructors, working from a remote console, also provided "manually controlled" training as a second control condition.

The adaptive training logics studied by Wooldridge et al. were rather complex and were intended to sample the thinking of training researchers at the time. Without pursuing the details of the logics they studied, several findings are important. First, in terms of the amount of time required for students to complete the experimental syllabus, the random presentation of tasks proved to be one of the best instructional strategies. Second, none of the automated instructional strategies was as efficient as of one of the instructors, who apparently disregarded variations in task difficulty (e.g. turbulence, gross weight, etc.) until his students had mastered the basic tasks. Then he exposed them to the various "difficulty" factors.

Results of the study by Wooldridge, et al. are somewhat difficult to interpret because they suggest that not all student groups were trained to the same levels of proficiency. Thus, comparing group performances based on training times is difficult at best. However, the fact that either a good instructor or a random sequence of training events could result in improved training efficiencies (compared with the adaptive logics studied) indicates that AAT technology is not yet ready for operational application, whether the training tasks involve basic instrument flight maneuvers or more complex, operationally-oriented tasks. Further research is needed in this potentially productive area.

Design Recommendations

No AAT system design recommendations can be made based on available operational or experimental evidence. AAT is an area requiring considerable future research.

PROGRAMMED MISSION SCENARIOS

Summary

Programmed mission scenarios can be thought of as non-adaptive training exercises. Programmed scenarios are not modified to reflect changes in student performance. Rather, they consist of highly structured sets of events that often are patterned after the content of existing blocks of instruction. At least one developmental system (an experimental prototype Navy F-14 OFT instructional support system) incorporates a shopping list of task modules that instructors can use to create special programmed missions that can be tailored to specific student needs. The programmed mission scenario feature was used a great deal in one SAC mission trainer for training involving penetration through known high threat environments. In this application, various threats were pre-programmed to occur at meaningful points in the mission.

Feature Description

Programmed mission scenarios are highly structured, programmed sequences of events. Factors that can be programmed include: flight tasks (mission segments); malfunctions; threats; and environmental variables. Usually, a specific chock to chock mission profile is used. However, individual segments of a total mission or specific tasks or maneuvers can be used (Hughes, 1979).

Related Support Features

Programmed mission scenarios are most directly related to the five instructional features identified below:

Recorded briefings. Recorded briefings provide a convenient briefing tool for missions that are programmed. (See Chapter VII)

Automated controllers. Automated voice controllers can be used with programmed mission scenarios, as can "iron pilots" to control adversary aircraft. (See Chapter VI)

Freeze. Total system freeze and flight system freeze can be used meaningfully during programmed missions. (See Chapter III)

Automated performance measurement. Automated measurement requires that a specifiable set of tasks and task sequences be used as the basis for measuring. Programmed missions are one means of providing specifiable tasks and sequences. (See Chapter IV)

Assumed Values

Two insructional values of programmed mission scenarios commonly are assumed. The first is standardization of training, or at least

standardization of practice opportunities. All training, of course, cannot not be relegated to programmed event sequences, since doing so would ignore the need to focus much of training on specific student learning needs. Nonetheless, programmed mission scenarios provide opportunities for the standardization of at least some facets of aircrew training. An example is posing realistic threat problems to aircrew members in a context that will allow them to practice dealing with the threats until acceptable performance is demonstrated.

Programmed missions can provide opportunities for automated performance measurement and student evaluation. This follows since the baseline of performance often is defined by a highly structured scenario. A full mission scenario, however, is not required for automated measurement. The only requirement is that the measurement system must "know", unambiguously, what task is being performed so that it can apply the appropriate measurement algorithms. A programmed scenario is one way of informing the measurement system of what tasks are being performed.

A potential value of programmed scerarios is to enable structured practice opportunities for students who may be using an ATD without an instructor present. In these cases, a device operator could call up/load the programmed mission requested by the student, and the student then could practice the tasks required in the mission.

Observed Applications

Only one application of programmed mission scenarios was observed during program site visits. This was on FB-111 simulation that was used for transition and continuation training. The application involved training on penetration through high threat environments. The mission scenarios were highly realistic and involved known and anticipated threats that aircrew members would encounter in an emergency war order mission.

Utility Information

Instructors and students who had experience with them viewed programmed scenarios favorably. Programming mission events greatly simplified instructor activities at the ATD console because they did not have to manually control each event. Rather, they were able to devote their time to monitoring student performance and providing verbal instruction. Students responded favorably for the same reasons. Several students also pointed out that meaningful threats were not accidentally excluded due to instructor workload or diversion.

Many instructors and students that have not had experience with programmed missions are apprehensive about them. Their apprehensions stem from rigidity associated with programmed events. Their concern centers on the possibility that the situations and cues that students would experience would be too restricted and could lead to safety

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problems during actual flight. Of course, the validity of this concern hinges directly on how the programmed scenarios are designed and used. This apprehension must be acknowledged. However, it also must be acknowledged that relatively few instructors or students have actual experience with programmed missions.

Related Research

The Navy is developing an experimental prototype instructional support system that will complement an existing instructor/operator console on an F-14 operational flight trainer. The Air Force is developing a similar system for the C-5A ATD. Both systems are experimental prototypes, and will not be operational until at least 1980.

The Navy system was designed to meet a number of objectives, which include: automated training involving programmed mission scenarios; adaptive training; and automated measurement of student performance (Semple, et al., 1979). The approach taken was to develop basic sets of task modules which could be used as building blocks to construct programmed missions, or create highly tailored adaptive training exercises. System modes allow instructors to select from pre-programmed missions (pre-programmed sequences of task modules), or to create, within some limits, new task sequences from the instructor console. The latter capability was included to allow tailoring of training exercise content while still taking advantage of the basic values of programmed mission scenarios.

Design Considerations

Programmed mission scenarios should be relatively easy to create and to modify. The basic system design should acknowledge that training requirements change, and it will be necessary to modify programmed scenarios accordingly. This should not be a difficult, time consuming task for operational personnel, and it should not require contractor participation.

Instructors must be made aware of programmed events that are about to occur. This is necessary not only for anticipation, but so they can override (i.e. inhibit) programmed events. For example, if a student obviously is working at capacity for his skill level, then further burdening him with emergencies, threats, or the like would have no instructional benefit. In such cases, instructors must be provided with the option of overriding pending events.

It is desirable that instructors be provided with memory aids that define the sequence of mission events and, when appropriate, the conditions that will initiate the programmed events, This can be done with either a hard copy listing of mission content, or by displaying a mission event listing at the instructor/operator console.

CHAPTER VI

CONTROLLER FUNCTION

FUNCTION DEFINITION

Control means to regulate or direct. Instructors and/or ATD operators often play the roles of air traffic controllers, tactical controllers, or they control the actions of simulated airborne threats. This chapter addresses instructional support feature technology designed to assist ATD instructors in performing the controller function.

RELATED FUNCTIONS

The reader is directed to the following chapters in this report for information related to the controller function:

Chapter III, Instruct

Chapter IV, Monitor and Evaluate Performance

Chapter VIII, Instructor/Operator Console Design/Location

INSTRUCTIONAL SUPPORT FEATURES ADDRESSED

Instructional support features addressed in this chapter are:

Automated controllers incorporating computer generated voice and automated speech understanding technology

Graphic and text readouts of controller information

Computer controlled (iron pilot) threats

AUTOMATED CONTROLLERS

Summary

The automated controller is a relatively new computer based technology. The technology is founded on recent advances that make it possible for computer based systems to understand at least limited amounts of human speech, and to generate speech that can be understood by the human. Automated controller systems incorporate models of the specific operational situations that they control. They also require

automated measurement capabilities that relate actual student performance to desired performance so that controller messages are appropriate to the original incoming message and the operational situation. The combination of automated speech understanding, situation recognition and computer generated speech is becoming a powerful instructional support tool for automated training (although only one operational training system (the Automated Flight Training System, AFTS) currently has these capabilities).

Potential training benefits steming from this new technology lie in three areas: 1) unburdening instructors and/or ATD operators from routine tasks involved in playing controller roles; 2) increasing the timeliness and correctness of controller messages; 3) unburdening instructors from the measurement of verbal task performance, and associated record keeping; and 4) providing a new medium through which students and ATDs can interact with each other in a highly natural manner. As examples of the fourth point, it is technically possible for the student to ask the ATD, "How did I do on that bomb run?" If the system has the necessary performance models and performance measurement capabilities, the ATD computer could respond: "Very well", and provide a detailed performance diagnosis if desired. This technology also opens opportunities for very precise, automated student coaching and cueing. The U.S. Navy, this year, has sponsored a program to investigate the full spectrum of training applications for automated speech technology.

Present (1980) prototype training systems which incorporate computer speech understanding are limited to individual word recognition (IWR) technology. This technology interprets individual words or very short phrases spoken by humans; and requires very precise, stylized speech by the human. Also, IWR technology requires each student to repeat each phrase or word up to 10 times in a speech sampling procedure to "train" the computer to consistently understand what was said.

During the past year, connected speech recognition system technology has surfaced. This technology allows people to speak more naturally, without the stylization constraints required by IWR. Also, connected speech systems seem easier to "train".

With respect to computer generated speech, present technology is quite adequate for creating words and sentences that can be understood by the human. Work continues on ways to make the computer generated speech sound more natural. Finally, much of the technology needed to create the mathematical models and performance assessment capabilities required by automated controllers also exists. However, it still is the case that all such models require experimental testing and fine tuning.

Feature Description

Automated voice controllers are new technology computer based systems that: (1) recognize highly structured, short length statements; (2) relate the statements to specific operational situations; and (3)

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make responses appropriate to the original incoming statement and the operational situation. A typical example involving both speech understanding and speech synthesis might be:

Incoming Communication: From Pilot	"Approach Control - X RAY 1 turning to final"
Situation:	Aircraft X RAY 1 is turning onto the final ILS approach at the correct altitude. Environmental conditions are those selected for the exercise.
Outgoing Communication: From Automated Controller	"X Ray 1 you are cleared to land. Wind now 150 at 20 gusting 27"

In the incoming signal, the automated voice controller system recognizes the standard message content (approach control, ---- turning to final) and the unique content (X RAY 1). The controller model then relates the standard message content to the actual position of the aircraft to generate the response. In the response, unique content (X RAY 1 and wind data) are interlaced with standard content to make up a complete and meaningful message. For example, the wind statement would be different depending on how the simulator environmental control is set.

An automated ground controlled approach (GCA) controller has been successfully applied to an F-4E simulation as an integral part of the Automatic Flight Training System (AFTS) (Swink, Smith, Butler, Futas and Langford, 1975). This instructional application of automated speech technology marked the beginning of a new era of automated controllers for ATDs. While the F-4E AFTS GCA controller required a resident general purpose computer and a disk memory system to provide a limited repertoire of GCA oriented words and phrases, modern microelectronics technology now offers similar capability on 2 to 4 chips with repertoires of up to 200 words. One set of chips converts analog speech into compressed digital data, while the other set works in reverse. The speech conversion to drive the controller is based on recognition of acoustic speech patterns and their conversion to a small number of parameters (normally between 10 and 20).

Synthetic voice-based controllers are expected to be used increasingly for many ATD voice applications with highly structured vocabulary.

Computer speech technology developments in the last seven years have emphasized "applications" rather than the development of basic principles of speech understanding and synthesis. This has resulted in certain system inadequacies at this time. For instance, it is necessary for each person using a system to initially "sign-on" by speaking a series of standard or reference phrases to permit the system to conduct statistical recognition of the speech pattern and measure the duration

between words of the speaker using the system (i.e. to "train" the system). In an ATD environment, this initialization is somewhat time consuming.

Automated speech understanding systems do not always correctly recognize (i.e. understand) the words and phrases spoken to them, even though the systems have been "trained" to recognize the words and phrases involved. It is estimated that 95 to 99% correct recognition rates are possible under ideal speaking conditions (Lea, 1980). Recognition accuracy was found to range from 50 to 97% in a recent field evaluation of a prototype training system incorporating IWR technology (McCauley and Semple, 1980). The average correct recognition rate was 85%. Thus, what presently is achievable is less than what is desired. However, the technology is evolving rapidly, and improved recognition accuracy soon should be achieved. Even presently achievable recognition rates have proved adequate for training and operational applications where limited vocabularies and near ideal speaking conditions exist. (A less than ideal speaking environment is one that is noisy and/or involves multiple speakers.)

Automated speech understanding/computer synthesized speech voice controllers presently have significant limitations. A completely flexible system would have to be able to recognize thousands of words. Current voice controllers can operate efficiently using a vocabulary constrained by 40 to 60 acoustical units. This appears to be adequate for highly structured speech; however, it may be many years (perhaps 20) before a person can interface with a computer through a voice channel and have the computer carry out a series of tasks based on unstructured conversational English. Fortunately, training situations almost always involve a relatively limited subset of language.

Related Support Features

Relationships of automated controller technology with other instructional support features are summarized below. Only the relationship with automated performance measurement is known to exist. Relationships with the remaining features are speculative and deal with possible future uses of automated speech technology.

Automated Performance Measurement. Automated controller systems rely on automated measurement. Automated measurement is needed to: 1) compare the student's communication performance (message content and timing) with what is desired in order to evaluate communication performance; and 2) know where the simulated aircraft is with respect to desired flight profiles so that appropriate controller messages can be generated and transmitted to the student.
(See Chapter IV, Monitor and Evaluate Performance)

Automated Cuing and Coaching. Cuing is the alerting of the student to take an action, either as a corrective measure or in order to adhere to a standard procedure. Coaching is providing instruction

or direction. Computer speech technology offers one means of providing cuing and coaching messages to students, and checking for the students to acknowledge receipt of the message. Automated cuing and coaching also rely on automated measurement. (See Chapter IV, Monitor and Evaluate Performance)

Instructor/Operator Console Design. Using automated controller technology in ATD designs could change or even eliminate certain information display requirements at the instructor/operator console. (See Chapter VIII, Instructor/Operator Console Design and Location)

Instructor/Operator Training. The use of automated controller technology could ease some instructor/operator training requirements because some of their instructional tasks could be automated. (See Chapter IX, Instructor/Operator Training)

Instructional Values

At this time, assumed instructional values of automated controller technology fall into the two areas discussed below. As noted previously, the U.S. Navy recently began looking into the full spectrum of training values and applications for this new and rapidly evolving technology (e.g., Hicklin, Barber, Bollenbacher, Grady, Harry, Meyn and Slemon, 1980; Clark, Halley, Regelson, Slemon and Versteeg, 1979; Breaux and Goldstein, 1975).

It is assumed that automated controllers will unburden ATD instructors and/or operators from routine, instructionally unproductive workload. It is expected that automating the voice control of the student will allow the instructor to use available time more meaningfully. Also, it is a fairly common practice to require or allow ATD operators to perform voice controller functions. Automating controller functions could eliminate the need to provide ATD operators with training on how to function as controllers. Based on a recent analysis (Semple, et al., 1979), it is believed that the following controller tasks could be automated: approach and departure control; ground control; tower; missed approach control; F.A.A. sector control; carrier air traffic control center; marshall control; carrier controlled approach, ground controlled approach, bolter control; and tactical intercept control.

It is assumed that automated controllers will markedly improve aircrew training and performance on tasks where the student must rely heavily on the performance of various controllers in order to be able to do his own tasks well, or where the student acts as a controller for other students during training. Automated controllers, for example, can provide for consistency and correctness of air traffic control communications in accordance with military and F.A.A. procedures. Correct communication procedures often are not adhered to during ATD training. It also was observed during program site visits that a number of older ATDs simply do not provide the instructor or operator with

adequate situation information to use in certain control tasks, such as a GCA final approach. The retrofit of automated controllers could overcome this problem. Also, it was observed that ATD operators often were not adequately trained to function as controllers. Thus, the controller information given to the students often must be questioned in terms of its timeliness and accuracy.

The following learning principles are involved in properly designed automated controllers:

Control cues to ensure that the student is forming the proper associations; i.e., responding appropriately to the correct cues.

Transfer increases as differences between reference (training) and generalization (job) stimuli decreases.

Ensure that the appropriate cues are available continually during the performance of a task.

Observed Applications

No applications of automated speech technology were observed during site visits made in this program. However, several relevant research studies are summarized in the following part of this section titled: Related Research.

Utility Information

Since no applications of automated voice controllers were observed during site visits, no direct utility information is available. However, the next section of this chapter addresses graphic and text readouts of controller information. Since these are the present manual alternatives to automated controllers, the reader is referred to this section for utility information on the alternatives.

Related Research

Five training-related activities involving automated voice controllers technology were identified during the program. Each is summarized below to provide the reader with insights into this evolving area.

The first application of computer speech technology to aircrew training was the prototype AFTS (Swink, et al., 1975). The AFTS application incorporated computer speech understanding (individual word recognition technology), performance models, automated performance measurement, computer generated speech, and an early form of automated adaptive training for F-4E CCT training in GCA and ground attack radar (GAR) weapons delivery. Several inefficiencies were found during prototype test in the areas of performance modeling, performance measurement, and automated adaptive training logics. However, computer

speech technology was found to be sufficiently acceptable that other AFTS, with some modifications, were purchased for use in automated training for A-7 Air National Guard Units in GCA performance. Other AFTS units were purchased by the Greek Air Force.

The Naval Training Equipment Center has sponsored the development of an experimental prototype training device for Navy enlisted personnel precision approach radar controller training. This precision approach radar training system (PARTS) also incorporates individual word recognition speech recognition technology, PAR controller models, automated performance measurement, computer generated speech, and adaptive training logics (Hicklin, Nowell and Petersen, 1978).

The experimental prototype PARTS device recently was evaluated in an operational training environment (McCauley and Semple, 1980). A central issue in the evaluation was to define the capabilities and limitations of isolated word recognition technology for application to automated training of tasks that are highly focused on the content and timing of voice messages. The evaluation involved a transfer of training experiment in which the performance of precision approach radar students trained using PARTS was compared with the performance of comparable students trained using existing, manually controlled training devices.

The authors concluded that computer speech recognition is sufficiently advanced to begin applying it in appropriate (highly defined speech-related) training tasks. Isolated word recognition has some limitations, namely the requirements for speech stylization and extensive speech sampling (computer training). These limitations can be minimized by careful courseware design, emphasizing stylization instruction and speech sampling within a task-oriented instructional context.

McCauley and Semple further concluded that automated speech recognition provides the capability to: 1) simulate a control system that includes verbal advisories or commands, such as air traffic control; and 2) expand the application of computer assisted instruction by voice interaction with the instructional system.

Another set of automated training fuctions, not necessarily related to speech recognition systems, includes adaptive or fixed syllabus control, problem generation, record keeping, and performance feedback to students and instructors. Combining the capabilities of automated speech recognition with other automated training features enables the development of fully automated training systems for speech related tasks. The potential benefits to be derived from well designed automated training systems with speech recognition include cost savings, the reduction of instructor workload, reduction of instructor to student ratios, elimination of training support personnel who are the recipients of the verbal information, increased student interest, enhanced training effectiveness through individualized instruction, and

the systematic manipulation of a wide range of task variables by modeling and simulation.

The Naval Training Equipment Center also has sponsored the development of a prototype automated instructional support system to augment presently available instructional capabilities of the Navy F-14A operational flight trainer. The development program has many instructional goals. One is the development and test of improved automated voice controller models and related automated measurement capabilities for GCA and similar final approaches. The tests are to start in calendar year 1980, with one goal being the test, evaluation and refinement of automated training technologies in an operational setting. The work will be performed at NAS Miramar.

Connected speech recognition system technology is under development by the F.A.A., the Navy and commercial organizations. New connected speech recognition system technology is now under evaluation by the F.A.A. as a means to enable air traffic controllers to communicate by voice with A.T.C. computer systems. The Navy has contracted to establish ways of casting this evolving capability from hardware into software, which can be more easily controlled and tailored to specific training applications. The advantages of connected speech recognition technology are that the speech understanding system component is "much more understanding/forgiving" of voice and inflection departures from what it originally heard during "computer training". In this regard, readers of this report are advised that computer speech technology statements made in this document likely will have become obsolete during the process of printing the report. This is an evolving technology where further breakthroughs will occur, leading to changes in ATD design and use, as well as in weapon system design and effectiveness.

Design Considerations

The design of automated controller models involves two principal considerations. First, the technology of computer speech understanding is improving very rapidly. In fact, many improvements (e.g. connected speech understanding) were occurring as this report was being written. Since these and subsequent improvements could markedly impact system performance and user acceptance of automated controllers, system designers should maintain a continuous awareness of the most current technology that is at their disposal.

A second and important consideration is the design of the operational performance model that drives the controller. Early controller models, for example, were derived from "text book" procedures for performing the maneuvers that were being controlled. In the operational world, pilots seldom fly profiles strictly according to procedures. Human controllers are aware of this and respond accordingly. For example, a pilot may choose to turn to intercept his final approach course at a distance from touchdown and at an altitude that an automated controller has not been programmed to recognize as the

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initial point for a final approach to landing. Two things can result. One is that the controller model may issue spurious commands because it has not correctly recognized initial conditions for the start of the approach. For example, it might command the pilot to fly up to intercept the desired glide path, rather than allowing him to continue in level flight until he intercepts the desired glidepath. Second, the automated performance measurement system that provides information to the controller model also may be "fooled" because of a departure from the procedure it has been programmed to accept as baseline performance. This can provide the controller model with inaccurate information and can result in a poorer score on the approach than actually was earned.

The use of controller models in aircrew training is new. The technology and the "lessons learned" data bases require expansion. It is recommended, therefore, that all automated controller models be evaluated and refined during the development process to ensure that the models function accurately and acceptably before their design is frozen.

GRAPHIC AND TEXT READOUTS OF CONTROLLER INFORMATION

Summary

Many operational flight trainers and full mission simulators provide the instructor with symbolic situation awareness displays showing the simulated aircraft's position with respect to geographic reference points, other aircraft, or desired flight profiles. The types of displays used include: mechanical plotters; electronic displays (cathode ray tube displays); and readouts. The content of this section describes and discusses the advantages and disadvantages of each display type.

Feature Description

To date, instructors have been provided with four types of information displays to use when controlling and/or monitoring the flight of simulated aircraft. Each is discussed below.

Mechanical plotters have been provided at remote (out of cockpit) instructor/operator stations for the past quarter of a century. The underlying notion was that instructors could be provided with relative aircraft position information, and that a paper copy of flight paths could be provided for use during debriefing. In fact, mechanical plotter displays are physically large; they usually have been positioned behind instructors, making their use infrequent and difficult; and problems of obtaining odd-sized paper for them has negated their intended debriefing use. Mechanical plotters are now in use (without paper for debriefing records) primarily to provide instructors with pictorial information on where the simulated aircraft is with respect to known geographic references.

A number of modern digital flight simulators incorporate cathode ray tube (CRT) situation displays at instructor/operator consoles. These displays have been generally easy to interpret. Content of the displays varies with the training application. However, a typical display used to monitor terminal area navigation performance and to vector and otherwise control the simulated aircraft includes: a runway; desired glide slope and localizer paths; relevant navigation aids such as VOR or TACAN stations; approach plate information; missed approach information; natural hazards, such as mountains in the simulated area; and a symbol showing present aircraft position. Often, a trail is produced behind the aircraft symbol to show the last minute or so of its flight path. Similar displays could be developed to show aircraft position in relation to ground based threats.

A second type of electronic display was developed for use in monitoring air intercept performance and for controlling a simulated adversary aircraft from a remote instructor console during one versus one air combat in a Northrop Corporation simulator (Spring, 1976). The central area of a 21 diagonal inch graphics CRT showed a view of the combat training arena as it would appear to an external observer in a third aircraft. The gaming area shown was 20 by 20 miles. A grid of lines was used to represent the ground plane. The lines were spaced at two mile intervals. Ground track lines were superimposed on the grid under each aircraft symbol as an aid in determining relative position and movement. Each aircraft was shown symbolically as a wedge. The aircraft controlled by the instructor had a single vertical tail; the student's aircraft symbol had two tails to distinguish it from the other. Also, the instructor's aircraft symbol was brighter to help distinguish it. Other highlighting and shading techniques also were used to distinguish the two aircraft symbols.

It was found necessary to falsely scale the size of the aircraft symbols. After considerable experimentation, a scale factor was selected that maximized aircraft symbol size by reducing the symbol size to only one half as the symbol went from a one mile to a 20 mile range. This type of scaling was necessary so that the aircraft symbols did not become so small that their orientation and direction of flight could not be perceived.

A vertical column of data along one edge of the display presented flight parameters for one of the aircraft; an identical column along the other edge presented data for the other. Parameters displayed included airspeed, altitude, G loading, azimuth, elevation and throttle position. A row of data across the top edge of the display presented information on the relationship between aircraft (angle off tail, range, and closure rate). Pictorial information could be electronically "tilted" from a top-down view of the engagement through a side view. ' A viewing perspective of about 45 degrees was most frequently used by instructors. The Air Force Simulator for Air to Air Combat incorporates a similar display at the instructor/operator console, as does the Air Force Air Combat Maneuvering Instrumentation (ACMI) system.

A third display type that uses an array of lights was observed on an F-14 OFT console for use in carrier controlled approaches. A performance model determines whether the simulator was on glidepath and on localizer, or not. For example, if the simulated aircraft was above glidepath, an annunciator light labeled "above" illuminated. If the student was well above glidepath, then a second annunciator light labeled "well above" illuminated. The underlying notions are that the instructor/operator can read the illuminated message to the student, and that this information is adequate to control a GCA final approach. The goal is to enable meaningful GCA flight control training without burdening instructors or operators with a complex controller task. In fact, this approach assumes a very simplified role for the GCA controller. Also, trend information on the progress of the approach is almost totally lacking using this display method.

A fourth display method provides written text of controller messages on a CRT display. This method is similar to the method described immediately above. The difference is that the written text approach provides the complete text of the appropriate controller message when the message is required, with the aim of further standardizing training and relieving ATD instructors or operators of specific controller knowledge requirements. As with the first method, the second method, by itself, does not provide adequate trend information. Neither approach can result in a hard copy printout of approach information for use during debriefing.

Both the light array method and the written text method require performance models of desired GCA performance by the student, a measurement system to assess actual performance in relation to what is desired, and controller logic (a controller model) to drive the displays. These are some of the same functional requirements as for an automated controller system, and the same design problems are involved. (See the first section of this chapter)

Related Support Features

Relationships with three other instructional support features are summarized below.

Automated Performance Measurement. Controller information displays that tell the instructor what it is (either generally or specifically) that he is to say as a controller rely on automated measurement. Automated measurement is needed to compare the simulated aircraft's position to desired flight profiles so that appropriate controller messages can be generated. (See Chapter V of this report)

Instructor/Operator Console Design. The type of controller information display that is selected will influence the physical design of the instructor/operator console. Also, if an electronic

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display medium is selected, the possible need to timeshare the display with other uses must be considered. (See Chapter VIII of this report)

Instructor/Operator Training. The type of information displayed will influence instructor/operator training requirements. The use of pictorial (graphic) information may place additional requirements on instructor performance, and therefore training, because of the need to properly interpret and use the available information.

Automated Controller. The use of automated controllers may relieve instructors from the need to actively control the situation. However, the instructor/operator still may desire a graphic display of situational information for trend data. (See the first section of this chapter)

Instructional Values

The assumed instructional value of any graphic or text readouts of controller information is that they will make possible training in an ATD that otherwise would not be possible if the ability for an instructor/operator to act as a controller was absent. Specific principles of instruction are not involved in the design of these · displays.. Electronically generated graphic controller information offers the added possibility of providing hardcopy printouts of the displayed information for use as a debriefing aid. Automated controllers reduce or eliminate the need for instructor training in the controller function.

Observed Applications

Observed applications of the use of graphic and text readouts of controller information during this program are summarized in Table 8. Examination of the relevant research literature and results of site visits during the STRES program indicate that graphic displays and text readouts of controller information have been applied to the following program High Value Tasks:

Landings and Takeoffs. GCA final approach is the most frequent use of graphic or textual readouts of controller information. The Air Force UPT/IFS simulation incorporates a graphic display of final approach information and text displays. A console operator acts as the final controller. Similar graphics displays are incorporated into the Army's Device 2B24 and U.S. Coast Guard ATDs for HH-52 and H-3 rotary wing training. The U.S. Navy's F-14A operational flight trainer incorporates a light matrix array of controller information at a remote instructor/operator console.

Air to Air Combat. The SAAC simulator incorporates a graphic presentation of air combat information. The display is used to monitor the engagement and can be used to control one of the

Table 8. Surveyed ATDs Equipped with Graphic or
Text Readouts of Controller Information

Type of Training	Aircraft	Purpose
Undergraduate Pilot Training	T-37 and T-38 (UPT/IFS)	Vectoring students in the terminal area, and GCA final approach control
	UH-1 (Device 2B24)	Vectoring students in the terminal area, and GCA final approach control
Transition and Continuation Training	HH-52 H-3	GCA final approach control

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adversary aircraft from a remote instructor console. The Northrop Corporation's Large Amplitude Simulator/Wide Angle Visual System (LAS/WAVS) was configured several years ago with a display similar to the one found in SAAC. It was used for the same purposes during an experimental study on the effectiveness of LAS/WAVS for training basic one versus one air combat maneuvering.

Utility Information

Graphic (pictorial) situation displays for approach control and final approach control were well received by ATD instructors and operators who had experience with them. These displays provide situational awareness information that is not available through text and readout displays. The instructors/operators interviewed appeared quite proficient in using the displays to perform their controller functions. In one case (Air Force UPT/IFS), console operators who functioned as controllers were required to have had prior air traffic control (ATC) experience. Concern was expressed, in this case, about the availability in the future of console operators with this experience. Concern was expressed that a considerable training investment would be required to achieve acceptable controller performance from operators without prior ATC experience. In a second case, instructors acted as the controllers. They found the graphic displays at their onboard consoles quite adequate for controlling a GCA final approach. However, it was observed that they did not strictly adhere to standard GCA procedures prescribed by the FAA and the military. In a third case, console operators were given formal training in the controller jobs they performed.

A text readout of controller messages was observed on only one ATD console. This console also incorporated a graphic situation display. The text readouts were not used because all console operators had prior ATC experience and did not need to refer to displayed text for correct message content.

The annunciator light array display of controller information was observed during a different program on a Navy F-14 OFT console. Instructors who had used this display method described several shortcomings. One was a lack of situational awareness. A second was that the display of GCA commands at the console tended to lag and therefore be somewhat untimely. A third problem was observed. This method of providing controller information is very inconspicuous. Often, instructors/operators would be occupied with other tasks at the console and would overlook the information that was being displayed. As a result, at best the controller messages were issued late; at worst they were missed altogether. Similar problems can be anticipated for console displays that present only controller text messages.

The utility of air combat situation displays, like those previously described, depends on more than just the single display, its content and organization. The Northrop Corporation air combat situation display described by Spring (1976) proved effective for monitoring a one versus

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one air combat engagement at a remote instructor console and for controlling the adversary aircraft from the console. In this case, the console also incorporated an electronic display that showed a horizon line, a stylized bowframe of the aircraft being controlled, and an aircraft symbol for the adversary aircraft when it was in a front quarter field of view. Also, at the instructor's discretion, the display could be switched to show the same information for the simulated aircraft being flown by the student. In either case, a forward, out of the cockpit visual scene was simulated. The instructor could select whether he wanted the scene as viewed from the aircraft he was controlling, or from the cockpit from the student's simulator cockpit. Using the combat situation display in conjunction with the other electronically generated forward looking display, instructors were able to control the adversary aircraft from the console in very demanding maneuvers, including rolling scissors. The point is that aircraft situation displays, by themselves, may be inadequate for controlling a highly maneuverable threat aircraft remotely from an ATD console.

The controls available to the instructor also were critical to this use of the displays described by Spring. Pitch and roll rate inputs were made through a desk top mounted controller. Controller inputs were highly processed so that the end result was flying using control stick steering, rather than conventional inputs. When the stick was released, the adversary would indefinitely continue the maneuver established by the pitch and roll altitude at the time of stick release. Simple throttle and speed brake controls also were available to the instructors. The control-display system made it possible for instructors flying from the console to realistically maneuver the simulated threat aircraft. A similar configuration on the McDonnell Douglas MACS air combat simulator also is reported to be usable.

The Air Force SAAC simulator console incorporates tactical situation display content similar to that described above. However, only one CRT display is available, and instructors must switch continuously back and forth between the tactical situation display content and other display content. The SAAC joystick control used to control the adversary provides no control feel, making it very easy to grossly overcontrol the adversary aircraft from the console. As a result of these combined factors, instructors report that it is very difficult to control an adversary aircraft from the SAAC instructor's console.

Apparently the SAAC displays are adequate for monitoring progress of one versus one and two versus one engagements. SAAC I/O console features and capabilities are continuously being modified and improved. In one recent improvement, the "view from the cockpit" mode automatically switches to a straight ahead view when the adversary is in the forward area, and automatically switches to the 360 degree tactical situation mode when he is not.

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Related Research

No experimental research studies were found dealing directly with the design or the training use of displays in satisfying the controller function.

Design Considerations

The design of controller information displays hinges on what the displays are to be used for and their intended method of use. For example, a CRT display that would allow the control of a simulated flight enroute or in the terminal area probably should present the following information, depending on the specific application: a plan (downward looking) view of the area being flown over; easily distinguishable symbols for each simulated aircraft being controlled; altitude, speed and heading for each controlled aircraft; the communication frequency that the simulator is tuned to; the navigation frequency that has been selected; airways corridors showing acceptable tolerance limits; natural and man made hazards; relevant radio navigation aids and their operational range; and the runway. A display used to control a GCA final approach, on the other hand, must present separate displays of desired glidepath and course, and at least the approach end of the runway. Lines on either side of the desired glideslope or course show maximum tolerable flight path departures and also appear to assist instructors in performing the GCA controller role. Range markings also should be displayed.

An electronically generated line showing the actual flight path often is useful for debriefing. However, flight path traces can result in considerable clutter. The instructor/operator should be provided with three easily selected trace options: no trace; a short (one to two inch) trace; and the full flight path trace. With these options, the instructor can tailor display content to his needs, yet still call up the entire trace history at the completion of the flight to make a hard copy of the display content for debriefing. If a hard copy capability is desired, it is important to design the display system with a buffer memory to retain the displayed image data while the hardcopy printout process takes place. Otherwise, the ATD would have to be frozen while the hard copy is made. Interviews during the program revealed that hard copy systems that require the use of ATD freeze are not used, while systems incorporating a buffer memory are used.

Display clutter is to be avoided. Larger displays, such as 18 to 21 diagonal inch CRT displays provide considerable display area for presenting controller information. However, display content should be limited to the minimum consistent with the ability to control the flight.

The need for color is another consideration. Color should be used only when it is a necessary code to enable instructors to distinguish among the information symbols presented. The UPT/IFS controller display

allows for the simultaneous terminal area control of four ATD flights. It is a black and white system, and no problems were noted that would require color coding for their solution.

The need for dedicated controller displays must be considered. It is becoming common practice to use CRT displays to present many different kinds of information at ATD consoles. If other information, such as malfunction selection, must be accessed during the period of aircraft control, then it may be desirable to dedicate a separate display for controller information so that the process of controlling is not continuously interrupted. As a workable alternative, several ATD instructor/operator consoles were observed (e.g. Army Device 2B24) where a small portion of the CRT display, usually along the bottom edge or at a corner, was dedicated to the display of relevant information, including: preselected malfunction options; environmental options such as ceiling height, runway visible range, and turbulence level to serve as memory aids; and preselected initial conditions for reinitializing the ATD.

Because of the differences in the information that must be displayed, it often is necessary to use one display format for enroute or approach control, and a different format for GCA. This means switching from one display format to the other as the flight progresses and controller information needs change. The simulated area covered by each display should "overlap" so that the position of the simulated aircraft always is known by the controller, even when changing from one display to the next. One ATD instructor/operator console observed during the program (Air Force UPT/IFS) had a "gap" between the geographic areas used for approach control and GCA displays. The result was that when the aircraft symbol reached the limit of the approach control display, the GCA display format could be called up, but a period of time lapsed until the aircraft symbol "flew" into the area covered by the GCA display. This was found to be highly objectionable. Also, there is no technical reason for designing displays in this manner. The ATDs surveyed all required operator action to switch from one controller display to the next. Future designs should provide instructor/operators with the option to select automatic changeover as a function of aircraft position or manual changeover.

One ATD investigated during the program incorporated a capability to store in the computer approximately 100 minutes of graphics display information. At the completion of the training session, this data base could be accessed to recreate graphics display information for debriefing. Instructors reported that this capability was used relatively frequently. This Army ATD (Device 2B24) was used for initial entry rotary wing pilot training.

Little experience is available on the value of displaying the text of controller voice messages on controller displays. The one system observed that was capable of this was relatively new (UPT/IFS); also, the console operators interviewed all had prior experience in air

traffic control. It appears reasonable to at least consider this design option if relatively inexperienced personnel are to act as controllers. The approach assumes, of course, that a computer based model can be developed that accurately identifies controller message content and timing. If this can be assumed, it would be reasonable to take the next step and display the content of correct student responses to allow for improved student feedback. Additionally, if accurate controller messages can be provided for visual display, the option of using computer generated speech to transmit the messages directly to the student should be considered (Semple et al., 1979).

Mechanical plotters are not recommended as a means of presenting controller information. Electronic display technology is much better suited to this application.

The approach of providing GCA controller information by means of an array of annunciator lights that simply indicate whether the student is high, low, left, etc., is not recommended. No trend information is provided, and such displays are inconspicuous and often ignored at critical times. A far better approach would be to incorporate an automated GCA controller. (See the first section of this chapter)

The design of situation displays for the control from a remote console of an adversary aircraft during air combat maneuvering or for the monitoring of air combat is an evolving art. For example, modifications are continuously being made to console displays of the SAAC simulator to improve these capabilities. Also, the design of the controls used to maneuver the simulated adversary may be as important as the design of the associated displays. The reader is referred to the second topic (Feature Description) in this section for design recommendations. All that can be said safely is that any such design must be flexible and changeable, and should be subjected to hands-on evaluation and refinement exercises before the design is frozen.

COMPUTER CONTROLLED ADVERSARIES

Summary

Computer controlled adversaries frequently are referred to as "iron pilots". They are computer models that control the flight path and actions of an adversary aircraft based on the tactical relationship of the agressor aircraft and the adversary. Iron pilots have been used in visually equipped air combat simulators (e.g. the Air Force SAAC; Northrop Corporation's LAS/WAVS, and NASA's Differential Maneuvering Simulators). Properly designed, they can unburden the instructor from controlling the adversary and provide realistic adversary maneuvering. When combined with an automated performance measurement capability, summary information can be generated describing engagement final outcome, offensive/defensive times for each aircraft, time in gun envelope, time in missile envelope and similar performance information.

Feature Description

The original adaptive maneuvering logic was developed under a NASA contract and implemented in NASA's air combat device, the Differential Maneuvering Simulator. The capability of this first iron pilot was unrealistic because it had perfect information about the attacker. For example, the computations did not take into account factors such as restricted field of view due to simulated aircraft wings or fuselage geometry. Also, the computations were nearly instantaneous, whereas human pilot decision making requires some interval between visual input, mental processing, decision making and response action.

A version of the original advanced maneuvering logic was implemented in the SAAC. As expected, the original system was found to be unrealistic and was judged to have little training value (Kelly, Brown, Van Arsdall and Lee, 1979). Subsequent developmental work has resulted in a much more realistic iron pilot that now is used extensively for control of the adversary aircraft.

A less sophisticated iron pilot is described by Spring (1976). The system described by Spring was developed for use in a transfer of training experiments involving training on one versus one basic air combat maneuvering in the Northrop Corporation's Large Amplitude Simulator/Wide Angle Visual System (LAS/WAVS). The purpose of the iron pilot was to unburden instructors from having to continuously control the adversary aircraft, which was done from a remote console, and to provide repeatability of adversary aircraft actions during training. A library of canned adversary flights was tried initially as a means of meeting these goals. This approach was abandoned, however, because adversary flight·profiles, being canned, remained unchanged regardless of student pilot actions. Instructor pilots involved in the program felt that the canned flight profiles would be of little if any training value. (The validity of this instructor attitude was not tested experimentally.)

The iron pilot developed for use in the LAS/WAVS involved simulated autopilot loops around the F-4J mathematical model used for direct control of the simulated adversary. Autopilot adversary control was developed for three maneuvers: head-on engagement, high yo yo, and barrel roll attack. The autopilot maneuvering characteristics were programmed from instructor descriptions of how the adversary should respond to attacker maneuvering. The desired autopilot maneuvering capability was selected by depressing one of three push buttons. In addition, instructors at the console also could select a "normal" adversary reaction, or a harder turning version of each autopilot adversary.

Two additional adversary control modes were provided. One was a control stick steering mode that gave instructors semiautomatic control of the adversary by allowing pitch rate, roll rate and throttle inputs. When the stick was released, the adversary would indefinitely continue the maneuver established by the pitch and roll attitudes at the time of

stick release. For technical reasons unique to LAS/WAVS, the control stick steering mode was limited to maneuvers that did not exceed 85 degrees of bank or 60 degrees of pitch. The capability allowed instructors to establish adversary turns and make adjustments to the turns without having to continuously control the adversary. The remaining mode was direct manual control, which required continuous hands-on flying. It was possible to switch among the three modes (autopilot, control stick steering, and manual control) during an engagement. This capability was used extensively.

Related Support Features

Computer controlled adversaries are related to the following instructional support feature:

> Graphic Displays of Controller Information. These displays provide the capability to monitor an automatically controlled engagement, and provide information for semiautomatic or manual control during a simulated engagement. (See the preceding section of this chapter)

Instructional Values

Three primary values are associated with computer controlled adversaries. One is the repeatability of the behavior of the adversary. Adversary actions are consistent and predictable (by instructors) during training. This provides a more consistent baseline against which to evaluate student performance and diagnose learning problems. The second value is the unburdening of the instructor during training so that he can concentrate on student performance, and provide more meaningful and timely guidance and feedback. The third value is the lessening of specialized instructor skills that must be developed to continuously control a simulated adversary aircraft from a remote console.

Computer controlled adversaries that operate with selectable levels of simulated pilot skill hold considerable potential for air combat training. Easier adversaries could be used earlier in training when the student is learning the fundamentals of air combat maneuvering. As the student's skill levels increase, more difficult adversary reactions could be selected. In this manner, the challenge provided to the student would be in keeping with his abilities to perform, rather than overwhelming him. The progressive approach to adversary capabilities could hasten the learning process. This was the rationale behind the "normal" and "difficult" autopilot adversaries developed for the Northrop LAS/WAVS simulation. Instructors in LAS/WAVS used both difficulty levels for the training of transitioning students.

Observed Applications

The use of an iron pilot capability in the Air Force SAAC device was discussed with instructors during this program. Team members

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participating in the STRES program also were involved in the experiment to evaluate the effectiveness of basic air combat maneuvering training in the Northrop LAS/WAVS device, which incorporated autopilot adversaries.

Utility Information

The original iron pilots, as discussed previously, were "too good". They were unrealistic because they operated on perfect information that is not available to the human pilot, and their decisions were made almost instantly. This made the first iron pilots virtually unbeatable. They had little training value for these reasons. When iron pilots are designed to provide realistic maneuvering, they are well received by instructors and are used extensively. This was the case in the Northrop Corporation study discussed previously. Interviews with SAAC instructors also indicated that the "detuned" and more realistic iron pilot now programmed in the SAAC device is used extensively and is viewed by many SAAC instructors as being one of the best instructional support features of the device.

Related Research

No research was identified that investigated the design of iron pilots for training or the effects on student performance of training involving iron pilots versus human controlled adversaries. Work to date on the development and refinement of iron pilots as training aids has been done on the basis of expert judgement rather than empirical research or verification.

Design Considerations

Three design recommendations are warranted based on experience gained with iron pilots in the SAAC device and the Northrop LAS/WAVS device. The first is that adversary actions controlled by the iron pilot models must be realistic. The second is that iron pilots with selectable "skill levels" should be developed so that adversary responses can be adjusted to student pilot skill levels during training. The third recommendation is to incorporate very fundamental or basic adversary maneuvering capabilities, such as simple turning maneuvers, to be used early in basic air combat training. This capability was used extensively in the Northrop Corporation study discussed previously. With respect to this, the control stick steering concept used by Northrop also was used extensively to make adjustments to adversary turning responses.

The iron pilot maneuvering logic programmed in SAAC has one notable deficiency that should be overcome in future applications. The SAAC is capable of simulating two versus one air combat engagements. The iron pilot logic in SAAC is programmed to respond only to the closest aircraft. As a result, for example, if the iron pilot adversary is attacking one's wingman, the other pilot can simply fly close to the

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iron pilot adversary to make it react to him, allowing the wingman to escape. This is not realistic, and allows "simulator wise" pilots to defeat the intent of the training being provided.

CHAPTER VII

PREPARE, BRIEF AND DEBRIEF

FUNCTION DEFINITIONS

Three instructional functions and their related support features are addressed in this chapter. Each function is defined below.

Prepare means working out beforehand the details of what is to be trained and how it is to be trained during a period of ATD instruction. For the purposes of this program, prepare focuses on individualized, proficiency advanced training where the instructor is required to make training content decisions as a matter of routine.

Brief means giving final training session instructions to the student, coaching him through the events of the mission in advance, questioning him to determine his readiness for upcoming training, and providing remedial instruction in weak areas. In short, it is cognitive (mental) pre-training.

Debrief means to review with the student the training events that occurred during an ATD session with the goals of evaluating performance, providing verbal instruction to aid the student in overcoming performance deficiencies, and providing positive feedback for tasks performed well.

RELATED FUNCTIONS

The reader is directed to the chapters listed below that deal with functions related to preparing, briefing and debriefing. The reader also is directed to Chapters VIII and IX of the utilization report for related information on assessing and maintaining ATD training effectiveness.

Chapter IV,   Monitor and Evaluate Performance

Chapter V,   Control and Individualize Training

INSTRUCTIONAL SUPPORT FEATURES ADDRESSED

The instructional features addressed in this chapter are:

Computer managed instruction

Recorded briefings

Automated performance measurement

Instructor console station displays

Hard copy printouts of performance information

The balance of this chapter is organized differently from preceding chapters due to the differing nature of the materials covered. Separate sections deal with each function (prepare, brief and debrief). Sub-sections address relevant instructional support feature technology. Automated performance measurement and instructor/operator console design are discussed in detail in Chapters IV and VIII respectively.

PREPARE FUNCTION

Summary

Computer managed instructional (CMI) systems hold future promise for assisting in preparing ATD training session content. CMI systems compare a student's training history with a standard training syllabus made up of lists of clearly defined tasks. Student performance is measured, and tasks are identified where acceptable performance has and has not been achieved. Individualized training then is developed and scheduled. Improved operational readiness, training efficiency, and reduced instructor administrative workload are assumed benefits. Computer management of ATD instruction is just coming into being. Therefore, practically based design and use information remains scarce.

Computer Managed Instruction

CMI systems can be designed to perform many functions. Their general function is a tool in the management of instruction so that training is efficiently directed toward desired outcomes on an individual student basis. In a general sense, CMI systems compare a student's training history with a standard training syllabus. The syllabus consists of a list of clearly defined tasks the student is required to perform, together with criteria of acceptable performance. The CMI system measures (either automatically or from manual inputs) student performance on each task performed, and identifies those tasks the student can perform and those he still cannot. System software then composes an individualized set of instructional tasks to be trained during subsequent training sessions. Sophisticated systems can schedule subsequent training based on training asset availability, and predict a training completion date.

CMI systems can be designed to control, or manage various sized units of instruction. They may range from entire blocks of instruction, made up of a number of training tasks requiring the same or different devices, to individual training tasks. A CMI capability that could be used to highly individualize training in ATDs would have to deal with the measurement, assessment and scheduling of training at a very precise task level. This is necessary so that the tasks trained within a

particular block of time could be tailored precisely to student learning needs.

Related Support Features

Computer management of ATD training is related to the following instructional support features addressed in this report:

Automated Performance Measurement. An automated performance measurement capability is one means that can be used to inform the CMI system of the acceptability of student performance on a task by task basis. (See Chapter IV) Alternately, a comparable instructor entry is required.

Automated Adaptive Training. Automated adaptive training is computer controlled training in which the problem, cues or tasks are varied as a function of how well the student performs. Such systems determine which tasks the student has and has not yet mastered, and can make detailed changes to training content within a training session. (See Chapter V)

Instructional Values

Four instructional values often are discussed for computer management of aircrew ATD training. The first is CMI's support of operational readiness by ensuring that all tasks are trained to accepted and standardized criteria of performance. A second value is improved training efficiency, because ATD training is focused on overcoming performance deficiencies, rather than less productive lock step training where training time continues to be spent on tasks which already have been mastered. Third, many assume it to be beneficial that students can progress through training at their own pace. Thus, both fast and slow learners can be accommodated while ensuring that all master the required tasks. It must be recognized, however, that self-paced proficiency advancement through training programs also can mean that the pipeline must be able to accept newly trained or transitioned pilots whenever they complete training. Administratively, this can pose problems. One solution to this problem used in other training contexts has been to provide those who finish minimum couse requirements early with additional, "enrichment" training on tasks that are job related but are not part of the training syllabus or typically are not trained to high levels of proficiency (McCauley and Semple, 1980). This is a productive use of training time, and is a method for controlling graduation dates while taking advantage of self-paced, proficiency advanced training. Finally, CMI systems can relieve instructors of time consuming administrative details involved with scoring and tracking student progress and proficiency on a task by task basis.

The following learning principles are involved in properly designed and used ATD computer managed instructional systems:

Ensure that relevant subordinate capabilities have been thoroughly learned before counting on them to support the learning of more advanced capabilities.

Objectively measure the frequency and types of errors throughout training.

Even a partial CMI capability may benefit training effectiveness and efficiency. Semple, Vreuls, Cotton, Durfee, Hooks and Butler (1979) have described a prototype instructional support system that tracks student progress in achieving acceptable performance for a number of aircrew tasks. The system, presently being constructed, does not use this information to create subsequent training exercises. However, the design calls for a capability to provide instructors and students with a listing of tasks that have been mastered, and those yet requiring mastery. It is expected that providing even this level of information will enable more efficient tailoring of instruction to student needs, although the tailoring would be done "manually".

Observed Applications

No computer managed instructional systems designed specifically for aircrew training were observed during program site visits. However, a number of observations were made during this and prior programs that bear on future designs and uses of these systems. The observations are summarized below.

Instruction in ATDs usually is designed to be administered in blocks. The length of blocks vary, but usually range from one to four hours in duration. The length of the block often is selected for ease of administration. Training to be addressed in each block of instruction is defined, but the level of definition often is marginally adequate at best. On the other extreme, one site was visited where highly detailed training objectives were specified for each one-hour block of instruction. The objectives consumed 15 to 20 pages of written description. Although this level of detail may be desirable for instructor training, it was proving unworkable in day to day operations.

It has been observed in a number of cases that specific training tasks or objectives intended for a block of instruction often are not attempted due to training time running out. Training thus missed may or may not be addressed in subsequent blocks of instruction. Frequently, record keeping is quite informal, and on occasion it was observed that the student is the one tasked with keeping track of which training he has and has not received. Consequently, in some cases, there is no assurance that tasks intended to be trained in the ATD even were attempted.

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A properly designed computer managed instructional system can be used to keep track of which tasks have been attempted by the student, and which of these he has and has not mastered. This information then can be used, together with appropriate computer decision logics, to tailor content of the next block of instruction to individual student needs. As discussed previously, some systems also can be designed to schedule subsequent training for each student in keeping with his needs and the availability of instructional assets. These capabilities of computer managed instructional systems can assist in easing the administration of training while also tailoring training to individual needs, which might be cumbersome if done manually. (See Chapter V of the utilization report for addition information on sequencing and scheduling ATD training.)

Utility Information

Utility information is not available because no applications of CMI were observed during the program that dealt specifically with aircrew ATD training.

Related Research

No experimental research, as such, was identified that dealt specifically with the evaluation of alternative designs or uses of CMI for ATD training. Two computer information management systems are being developed and implemented, however, that are related. The Air Force Operations Resource Management System (AFORMS) is being developed to provide commanders, unit schedulers and training officers with timely information for critical resource allocation decisions. AFORMS performs a number of functions. One will be to keep track of and provide information for scheduling the events to be trained during flight sorties. In this respect, AFORMS shares a commonality with ATD CMI systems in that master listings of unit level flight training requirements must be maintained, together with current information on the meeting of each requirement by individual aircrew members. Requirements to be met during subsequent flights then can be determined and scheduled on an individual aircrew member basis.

The U.S. Navy is implementing an Aviation Training Support System (ATSS). The overall objectives of ATSS are directed toward maintaining personnel readiness in the face of economic restrictions, manpower competition, and increasing weapon system sophistication. ATSS involves a variety of training applications, including fleet readiness training. A CMI subsystem directs student learning activities and manages and tracks the performance and progress of students through self-paced, individualized training exercises (Naval Weapons Center, 1978).

Design Recommendations

Specific design recommendations are difficult to make for ATD computer managed instructional systems. For one, these usually are very

complicated systems. Second, no actual experience has been gained to date using CMI systems for aircrew training. Therefore, the following recommendations are general. They are adapted from Semple, et al. (1979).

The master task listing against which student progress is measured must be specific. This is no small job. For example, specific normal and emergency procedures that are to be trained must be separately identified so that tracking and planning of training can be done precisely. Similarly, maneuvers to be trained must be specifically defined. Semple, et al., for example, identified nine different approaches to shore based facilities for a Navy program they analyzed. These included: Hi-TACAN A, Miramar; Random Radar Vector to Hi-TACAN A initial approach fix; and random radar vector to GCA pickup, MCAS, Yuma. Other flight tasks were similarly defined so that student performance on each could be readily determined. Precision is necessary to individualize training in ways that promote efficient use of training time and other assets.

A second general requirement appears to be flexibility of use. It takes fairly sophisticated computer logic to review a list of tasks yet to be trained, and construct a meaningful ATD training exercise from the list. The U.S. Navy is sponsoring work to develop such logics for the detailed level of planning discussed above. Until such logics are developed and verified, it is necessary to rely on instructor participation in individualizing training session content. This can be accomplished by making available to him the listings of tasks trained and yet to be trained that are available within CMI systems.

Finally, task lists and computer logics that use them must be relatively easy to modify. This is necessary because training requirements frequently change, and computer systems supporting training must be correspondingly kept up to date.

A final issue is the size of the training program needed for CMI to be economically advantageous. Smaller programs may not be worth the computing and software investments. In such cases, "manual" tailoring of instruction may be more practical. The minimum program size issue was not addressed during STRES.

BRIEFING FUNCTION

Recorded Briefings

Much aircrew training in ATDs now is provided in organized blocks of instruction. Commonly, instructors brief students before each ATD session. Many times, the only preparation the student goes through for the ATD session is the pre-session briefing. Often, tasks to be trained, performance standards expected, and the sequence in which events will occur are not clearly understood by the student when he enters the ATD. Other times, students use ATDs for self instruction,

and guidance on what they should do during self-instruction sessions would be beneficial. Recorded briefings, with accompanying, supporting text, hold promise for improving the efficiency of ATD training sessions, whether or not an instructor is present, because task description, coaching and related study information could be thoroughly studied by students prior to their training in ATDs. Automated briefings also can play significant roles during automated demonstrations (See Chapter III) by providing tailored instruction and commentary that is in direct keeping with the demonstration.

Discussion

Recorded briefings are succinct, well organized, clearly stated, recorded messages dealing with the content and performance expectations of structured ATD training sessions. They may be used by instructors in lieu of portions of individual briefings, or they may be used by students for more systematic study of task requirements to be addressed during the ATD training session. Supplemental, but brief text may also be desirable so students can review details of tasks and performance expectations confronting them. Recorded pre-session briefing, together with accompanying text dealing with performance details, offer good potential for improved standardization and efficiency of highly structured ATD training.

Recorded pre-session briefings were used at two training sites visited. They were used in conjunction with automated demonstrations in an Army initial entry rotary wing training program. It was not possible to determine with any accuracy how often the recorded briefings were used. Some instructors used them fairly regularly; others hardly at all. Their use was left to the instructor's discretion, and general use guidelines were not issued. It was pointed out, however, that experienced pilots using the simulators to practice instrument flight before check rides also used automated instrument flight demonstrations and accompanying recorded briefings. One commercial airline also provided recorded briefings for in-simulator use by flight engineers who were using the simulators during off-hours to practice instrument flight skills. In this application, qualified instructors often were not available. The recorded briefings dealt with simulator operation, aircraft performance data, and flight control techniques.

Since recorded briefings assume that the training content of the ATD session is defined, this feature is related to programmed mission scenarios and automated demonstrations (See Chapter III of this report). Training content does not need to be under computer control, however, as would be the case with automated demonstrations or programmed scenarios. Rather, a device operator or instructor could work from a printed mission scenario that details task sequences and requirements making up the training session.

Many hours often are spent by instructors and students reviewing training events, contingency plans and safety considerations before training flights are undertaken. The method being used is cognitive (mental) pre-training. The method is essential not only for safety of flight, but also for productive use of training resources. The use of recorded ATD session briefings and related summary text information also involves cognitive pre-training. Actual hands-on experience, then, becomes more practice oriented than discovery oriented. This is the primary assumed instructional value of recorded briefings.

DEBRIEFING

The instructional features addressed in this section are dealt with in detail elsewhere in this volume. Therefore, this chapter has been organized around known and possible roles that each feature can play in support of debriefing. Crossreferencing is used to direct the reader to detailed information on the individual features addressed.

Role Of Automated Performance Measurement

Summary. A properly designed automated performance measurement (APM) system should be a valuable debriefing aid because of the objectivity and completeness of the performance information that can be made available to the student and instructor. Unfortunately, most existing APM systems are so poorly designed as to be useless. The amount of detail they present is overwhelming, and the performance details often cannot be related to specific mission events. Automated measurement and scoring of discrete event procedures (i.e. switch positioning procedures) is on the horizon, but not yet available operationally. However, a number of new ATDs will display procedural event sequences on CRT displays for instructor review and evaluation (e.g., C-130, B-52, F-16 and A-10). It is believed by experts in the field that a useful APM system would provide summary score (grade-like) outputs separately for each task trained. Additional performance details could be obtained from the system at the instructor or student's discretion. Prototypes of such APM systems are being developed for field test. (See Chapter IV of this report)

Discussion. Presently, instructors make notes during training to serve as memory aids during debriefing and for completing grade forms. A well designed APM system could complement or replace the need to take notes. Grade forms that typically are used identify training tasks in rather global ways. For example, grades often are required for "approach and landing", but specifics of the particular type of approach and final approach flown (e.g. TACAN approach to an initial approach fix, followed by a GCA final approach with no flaps) are not called out. An APM system needs to know such specifics so that it can measure and score appropriate performance dimensions. Details of tasks trained could easily be made available to instructors.

Physical design and location of the APM display will affect its training value and use during debriefing. If performance information is displayed electronically at an instructor's console CRT display, problems may arise because the console cannot be tied up for debriefing due to the demands of a subsequent training session that is about to start. Hard copy printouts can be used to overcome this problem, if the printout process also does not tie up the console or the display.

One instance was observed during the program where relatively simple, but meaningful automated measurement information was output on a line printer. However, the line printer was nowhere near the instructor/operator console; in fact, it was in the ATD computer complex. Needless to say, it was not used for training.

Role Of Computer Managed Instruction

Summary. Computer managed instructional (CMI) systems can be designed to perform many instructional management functions. One function is keeping track of which training objectives have and have not been met by each student and aiding in determining the instructional content of the next ATD training session. One goal of CMI systems is to individualize training in order to make the most efficient use of training assets. CMI system output can be used during debriefing to identify for the student the specific training objectives he achieved during the session and to be addressed in his next ATD session. This information should be useful in assisting him to prepare for the next session. (See the section of this chapter addressing the prepare function.)

Discussion. CMI systems have not yet been applied to aircrew ATD training. It appears, however, that they soon may be. One of the assumed advantages of CMI is that it will enable tailoring of ATD training to student learning needs during a particular session. Thus, it may not be possible for students or instructors to refer to printed syllabi and other course description documents to identify the content of the next ATD session. It would appear reasonable, therefore, to interrograte the CMI system during debriefing to identify the instructional content of the next ATD session so that the student can prepare properly.

Role Of Console Displays

Summary. A number of modern military ATDs incorporate graphic displays of flight profile and related information at instructor consoles. Some have capabilities for making hard copy printouts of display content. Where such capabilities exist they have been used during debriefing, particularly for undergraduate and transition training.

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Discussion. Three ATD training systems observed during program site visits provided the capability of replaying, in real time, flight profile performance in relation to desired courses. Two were rotary wing training devices; the third was a UPT/IFS complex. These systems provided a downward view where flightpath history was displayed in relation to ground references. One other system displayed history of air combat profiles from several different perspectives. A similar system was used in a research study of air combat maneuvering training. Several new ATDs will incorporate this feature (e.g. B-52 and C-130). In most cases, instructors commented that graphic displays of flight profile histories were useful during debriefing because they provided detailed, easy to understand memory aid information. A problem that frequently made it impossible to use such displays was the press of time, where the console was needed for other training uses.

One potential solution to the time problem is to provide for remote, off-line replay capabilities. Only one prototype system was identified that had a remote replay capability. The remote replay reportedly was not used, but no records were kept, and it is totally unclear why this was the case. The U.S. Navy is developing an automated instructional support system that will include remote replay. The system will not be ready for operational try out until late 1980, however, so potential benefits remain speculative. The Air Force Simulator for Air-to-Air Combat (SAAC) incorporated a TV taping system to record graphic flight profile data from an instructor console display. Technical difficulties precluded its use. However, pilots seem to be "picture oriented" people. Further work is required to determine whether graphic flight profile information in fact benefits aircrew member training; the assumption obviously is that it will.

Role Of Hard Copy Printouts

Summary. Hard copy printouts of performance information are used by instructors for debriefing where the capability exists, and where printouts are designed for convenient access.

Discussion. As discussed initially in this section, printouts of detailed, numerical automated measurement data are not used. This is because present measurement systems are early generation capabilities, and provide little if any usable data. One air combat manuvering simulator system (SAAC) was observed where simple, yet meaningful performance data were available via printout. The data dealt with time within firing envelopes, number of weapon strikes, and related information. In this case, however, the hard copy printer was so physically remote from the instructor's console that it was not used. This emphasizes the need for convenience.

The ability to obtain a debriefing hard copy of graphic flight profile information was viewed favorably by instructors. Where the capability existed, it was used by many. One ATD produced performance

alert symbols overlaying flight profile data. This, too, was viewed favorably as a debriefing aid.

It is necessary to incorporate a display buffer capability for hard copy printout. With a buffer, hard copy print-outs can be made while the display is used for a different purpose. Without a buffer, the entire simulation may be tied up while a hard copy printout is made. This virtually precludes making hard copy printouts during an ATD training session, because neither instructors nor students want to halt (freeze) training just to get a hard copy performance printout.

Discrete event (i.e. switchology) procedures measurement capabilities are just beginning to mature. It is unclear at this time just how much procedural detail will be useful during debriefing. It is possible to inundate students and instructors with hard copy of procedural detail. This approach surely will make such information unusable. How to best design procedural hard copy printouts remains to be investigated.

CHAPTER VIII

INSTRUCTOR CONSOLE DESIGN AND LOCATION

SUMMARY

This chapter is presented in two parts. One deals with instructor console design, and emphasis is placed on consoles that are located remotely from the student's work station. References are made to detailed design guidelines presented in earlier chapters of this report. The second part deals with the issue of where the instructor's station should be located (at or near the student's station versus at a remote location) from the standpoint of how the student likely would benefit from each alternative.

CONSOLE DESIGN

Introduction

It is quite difficult to provide generalized guides on how to design ATD instructor consoles without reference to specific ATD training applications and without a reasonable analysis of instructor and operator tasks that the console is to be designed to support. Preceding chapters in this report provide design guidelines for a number of individual instructional support features. The reader is advised also to review this information with respect to console design. Large design information gaps exist, however, on how to effectively combine a number of individual instructional features, displays and related controls into a single console configuration. This is particularly the case when multiple instructors and multiple device operators must work effectively as team at the console. Additional research is needed to develop guides for the design of large, complicated, multi-crew consoles.

Remaining sections of this chapter deal with design features often overlooked when designing instructor stations, particularly those that are remote from the student's workstation; a number of console design issues that are of concern because of recent trends; and recommendations for prototype console evaluation before committing to production.

Overlooked Features

A number of console features seem to be overlooked frequently during design. Some are at the nuisance level, but they are presented here with the intent of eliminating such nuisances in the future.

Instructor consoles frequently do not have adequate work space for the routine paperwork required during ATD sessions. There seems never to be adequate surface workspace or convenient storage space for maps, charts, syllabi, grading forms and guides, and the like. Existing human engineering criteria should be applied in this respect.

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The communication and navigation radio frequencies that the student has tuned to in the ATD cockpit seldom are displayed at instructor consoles. As a consequence, the instructor frequently must contact the student on the ATD intercom to seek communication and navigation information. A positive forward step would be to display selected communication and navigation frequencies at the instructor's console.

Instructor information needs from repeater cockpit instruments may be different from the student's needs. Cases were observed where electronic repeater displays (typically attitude director displays and head up displays) at the instructor's console were slaved to modes selected by the student in the ATD. Thus, steering command information, lead computing site information and similar items were not accessible to the instructor unless the student selected them, although their access could have assisted the instructor in evaluating and guiding student learning in how to use various (e.g. degraded) display modes. In other words, what the instructor needs to see at his console should not be limited by what the student chooses to see in the simulator.

Virtually every ATD remote instructor's console surveyed lacked plugs for extra headphones, so that other instructors, including instructor trainees, could listen-in conveniently to conversations between the ATD instructor and the student. Extra headphone plugs also prove valuable when visitors are touring ATD facilities.

No ATD surveyed displayed at the instructor's console information on the status of ATD support systems, such as hydraulics, electrical and air conditioning. Whether this information needs to be displayed must be decided on a case by case basis depending on the tasks that console instructors and operators are to perform at the console. At issue is the tasks that are assigned to ATD instructors. If they are to monitor ATD systems, then their displays and training must address these issues.

Issues of Concern

An issue of continuing concern is that the aircrew instructor's ATD job seems to have escaped needed detailed analysis. This issue is discussed in Chapter IX, Instructor/Operator Training, in the context of an Instructional System Development (ISD) approach to ATD instructor training. The same issue is of concern with respect to console design, because consoles are pieces of equipment meant to support men in the doing of their jobs. It is only reasonable, therefore, to start with a thorough knowledge of the tasks and performance the instructor's job requires so that consoles can be designed to support these requirements. It probably is the case that at least some ATD manufacturers take the instructor's tasks, sequences, workloading and coordination requirements into account when they design ATD instructor consoles. What is needed, however, are improved guidelines for relating instructor task requirements to console design characteristics so that what results will be more predictably workable.

Related to the above issue is a driving technology force in ATD console design. Electronic displays, such as cathode ray tube displays (CRT), are showing up in increasing numbers in ATD instructor consoles. By themselves, they are not bad; in fact, electronic displays provide many advantages, as discussed previously in this report. However, the age-old goal of simplicity of design and operation is easily endangered by unrestrained use of this technology. Given a highly versatile display medium such as the CRT, literally hundreds of pages of information can be created for display. The technology to do the programming is available. The technology to guide the programming cannot be drawn solely from site visits involving older technology devices or the existing ATD research literature. Thus, a lingering concern among many training specialists is that instructor workload, training requirements and device acceptance will suffer unless research is directed toward developing meaningful guides for capitalizing on new console technology without being captured by it. Air Force research now is beginning to address this issue.

Taking a somewhat different view point, concern also is evident in the training community that instructor consoles that are located remotely from the student workstation may not provide instructors with needed student performance information, or may provide it in forms that are difficult to use. One issue of concern is how best to display for the instructor the many hundreds of discrete event procedures (e.g. switch positions and sequences) that students perform. Individual annunciator lights showing discrete switch positions can be so numerous as to be overwhelming to the instructor. Also, the annunciators, at least in many present applications, often do not display events in natural sequences. Rather, the instructor is required to learn patterns of annunciator illuminations in order to be able to critique student procedural performance and provide guidance. An alternative is to display discrete procedural event sequences using electronic display technology. This is being done in a number of new ATDs (e.g. B-52, C-130, A-10 and F-16). However, this also can result in a burdensome instructor monitoring and evaluation task. An additional alternative is to rely on an automated performance measurement system to monitor procedures performance, and alert the instructor only to discrepancies in desired performance. The issue of how best to display discrete event procedural performance information remains an important issue to be resolved.

A further issue of concern is the nature of ATD visual scene information needed at a remote instructor's console to enable productive training. The fidelity volume (pages 54 and 55) for example, discusses the possibility that one versus one air combat training was not possible in one Air Force ATD for students unfamiliar with the tasks, because their instructors did not have adequate visual information on student performance or the adversary's performance. This factor probably made ATD instruction impossible, which could explain why experience in the ATD resulted in no improvement in airborne performance. Research is

required on this issue, because the costs of mass-produced failures should be measured in more than just dollars.

Recommendations

This section has presented several specific recommendations for research that are not repeated here. In addition to the above recommendations, it also is recommended that research be undertaken to develop design guides, particularly for more complicated instructor consoles, so that their utility and acceptance can be ensured. In addition, until programatic research is completed, it is recommended that instructor console prototypes be developed and evaluated before designs are frozen. Related to this, it is recommended that prototype designs and evaluations be well documented so that lessons learned from them are available for future use.

CONSOLE LOCATION

Introduction

The issue of where the ATD instructor's console (and hence the instructor) should be located physically with respect to the student has been dominated by perceived needs for exact physical correspondence between the ATD cockpit (student workstation) and the aircraft cockpit. Typically, if the instructor can be present in the aircraft cockpit, he can be present in the ATD cockpit. If not, then ATD designs have relegated instructors to remote console locations. Thus, the issue has been and largely remains a physical system fidelity issue rather than a training issue. Site visit survey results showed that instructors strongly preferred whatever arrangement it was that they already had. Careful analysis of this trend, in combination with several recent ATD design trends, strongly suggests an underlying instructor desire to be able to see what the student is doing so that he can better provide training feedback and guidance.

Considerations for Onboard Console Location

A number of multi-crew ATDs were observed where instructor stations were at the student workstation because this is the case in the aircraft. In these cases, instructors strongly favored onboard instructor station locations. A number indicated that they did not known how instruction could be accomplished in any other way. When these devices incorporated remote operator consoles, the functions of the remote consoles typically were to support communication, navigation or electronic warfare training activities. Control of the training simulation, however, could be accomplished from onboard instructor stations.

Instructor preference for being onboard centered on improved information gathering. For example, advantages cited included being able to observe student instrument scan patterns, visually detect

hesitations in physical movements, better observe crew coordination, and observe how the students used checklists, charts and other technical information. Instructors also indicated improved opportunities to guide students in how to perform their tasks, and provide "fine tuning" feedback on student performance. All of these are valid instructional points.

ATD costs usually are less for onboard instructor stations, because the instructor can observe actual cockpit instruments, controls, and depending on its design, simulated out of cockpit visual scenes. They do not need to be reproduced elsewhere.

Observations suggest that the perceived need for a remote instructor's station does not become strong until training in flight control and mission oriented tasks is begun. Then, if the aircraft excludes the instructor, strong feelings develop that the ATD also should exclude the instructor. However, several interesting exceptions exist.

Two ATDs surveyed included closed circuit television systems so that instructors at remote consoles might see what students were doing. Neither was used because of technical reasons. However, the perceived need for their initial existence suggests that cockpit physical fidelity was being adhered to, but cheated at the same time in order to make direct observations of student behavior possible.

Procedures trainers, even for single seat aircraft configurations, typically allow easy instructor visual and verbal access to students. This type of ATD design is well accepted. The same situation was observed for a weapon system trainer (FB-111). In this case, instructors spoke highly of being able to directly observe and work with the student throughout training. During performance demonstration runs, of course, the instructor did not work directly with the student, but acted as a passive observer. It is easy to argue that single seat ATDs for pilot training should have instructor observation stations in the cockpit for the same reason.

By way of summary, there are many instructional advantages to having the instructor colocated with the student, even if this means a departure from strict adherence to the physical fidelity of the cockpit. However, a strong emotion exists to allow instructors to be colocated only if that is the case in the aircraft, and particularly when flight control and mission training are undertaken.

Considerations for Remote Console Location

Remotely located instructor consoles were used commonly when the ATD simulated an aircraft that could not accommodate an instructor in an observer type position during flight. Thus, most single seat and two seat simulations had remote instructor consoles.

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Instructors using these devices argued strongly that they should not be colocated with the student because this was not possible in the air. A frequently encountered argument was that instructors did not want students to learn to count on an instructor's presence when this would not be possible during flight. The argument that instructors, on some occasions, must not be colocated with students hinges on the physical fidelity issue and, of course, impacts on the design and cost of remote instructor consoles. The argument also side-steps the fact that ATDs are training tools, rather than weapon systems. All training tools should be designed to promote effective, efficient training.

Research Evidence

Only very scant research evidence exists specifically on the issue of instructor station location. Existing evidence favors an onboard location.

The evidence comes from comparing two simulator studies involving the training of pilots unfamiliar with air combat maneuvering (ACM) on one versus one ACM. One study (Payne, et al., 1976) showed that simulator training transferred positively to inflight performance. The simulator they used had a hemispherical dome projection system, so an instructor could be (and was) seated beside the student, even though the aircraft simulated was an F-4. Pohlman and Reed (1978), however, found no inflight benefit from comparable simulator training. The device they used was the Air Force Simulator for Air to Air Combat (SAAC), which also is an F-4 simulation. This device used a direct view visual system with infinity optics. Although the imagery was more realistic (i.e. higher fidelity), instructors were unable to view what the student was seeing or doing. Thus, they could not directly provide guidance or feedback. No training took place in the simulator, and as expected no performance improvement was observed in the air. It is a reasonable possibility that instructors may have to be colocated with students for ATD training on at least some types of tasks, particularly during early stages of learning. If they are not colocated, they may have to be provided with very extensive and costly information at remote consoles in order to provide meaningful training.

The U.S. Army recently procured a training simulator for a two-place attack helicopter. This simulator is unique in that the pilot's station is separate from the gunner's station. Each separate station, however, was designed as a two-seat configuration so that instructors could be present in the simulation during training. This device was surveyed, but before experience with it in training had been gained. A follow-up certainly is warranted.

An Alternative

The Army rotary wing training device described above provides one option. Another alternative is to design ATDs so that instructors can be present when needed, and not present when this is better. For

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example, an instructor's station in a single seat ATD could be located behind and to one side of the student. The instructor, his controls and displays would be quite unobtrusive. Yet, he could observe student performance directly, and provide guidance and feedback as required. Performance monitoring displays also could be incorporated in a remote console so that the instructor could monitor student performance there during evaluation runs. During these runs, a canopy could be closed around the student's portion of the ATD to promote realism. Also, nothing would be sacrificed in important fidelity areas such as the physical location of cockpit controls and displays.

CHAPTER IX

INSTRUCTOR/OPERATOR TRAINING

SUMMARY

ATD instructors and operators are central to the effective and efficient use of these devices for aircrew training. Part of the instructor and operator's job is knowing how to operate ATDs. A significant part of the instructor's job is knowing how to use ATDs and their capabilities to teach effectively. The program survey showed that a vast majority of instructor training deals with how to do the tasks he is to train, safety, and training-related administrative matters. On the average, only about three hours of formal instruction dealt with how to be a teacher. In virtually all cases reviewed, instructor and operator training on how to operate ATDs was left to informal on the job training. Instructor training on how meaningfully to use ATDs and their instructional features was, again, left almost exclusively to informal on job training with no form of quality control. The STRES report titled Utilization of Aircrew Training Devices addresses the general issue of ATD instructor training in Chapter VI. Numerous other chapters in the Utilization report deal with principles of effective instruction in ATDs. The balance of this chapter deals with instructor training on effective use of ATD instructional support features, and is meant to complement the content of the utilization report.

BACKGROUND

The best of training equipment, by itself, will not produce operationally ready aircrews. The equipment must be used effectively to achieve this goal. Obviously, instructor and operator training is central to the effective and efficient use of ATDs for aircrew training. The fact remains, however, that virtually every Air Force aircrew instructor training program focuses on how to perform the tasks to be trained, safety of flight considerations, and administrative facets of student review and management. These are important issues. However, information gathered during this program suggests that each Air Force instructor pilot receives only about three hours of formal instruction on how to be a teacher. This seems very little when one considers the educational background and training the nation demands of public school teachers, for example.

RECOMMENDATIONS

Better instructor training almost certainly is an area where improved training cost and student performance benefits would result. To date, the aircrew instructor's job has been examined only in general terms. The result has been descriptions of the instructional and administrative functions performed by ATD inst

for ATD design and use based on job function descriptions. To date, however, no one has taken a detailed, task-level look at a spectrum of aircrew instructor jobs to identify specifically what it is they do, what could be done even better, and what task facets are common versus unique to different training applications. In short, the first detailed Instructional System Development (ISD) step has not been taken for the most basic facet of an instructor's job -- i.e. teaching. It is recommended, therefore, that a systematic analysis of ATD instructor tasks be undertaken so that improved instructor training can be objectively related to required job performance.

Analysis, of course, is a means rather than an end; and analyses require a certain time investment. A reasonable question, then, is what can be done until the needed analyses are performed? Some specific guidance is available for instructor training on ATD instructional support feature use. Many sections of chapters of this volume have addressed this issue. For example, guidance is presented on common and potential instructional feature uses. Also, information on observed feature applications has been presented to further stimulate creative thought on how to better use available features in existing ATDs. Finally, utility information sections often present further suggestions, together with the experiences of others with various instructional support features. This information, together with the content of companion STRES reports, can provide a nucleus for instructor seminars or other types of training on how to use many ATD capabilities and features. It is recommended, therefore, that steps be taken to transfer to instructors the information now available to them in this and companion STRES program reports. It is further recommended that Air Force aircrew instructor training be systematically reviewed and revised to better match instructor training with instructor job requirements.

REFERENCES

Breaux, R. and Goldstein, I. "Development of Machine Speech Understanding for Automated Instructional Systems." In 8th NTEC/Industry Conference Proceedings, New Concepts for Training Systems. Naval Training Equipment Center, Orlando, FL, 1975.

Brictson, C. A., and Burger, W. J. Transfer of Training Effectiveness: A7E Night Carrier Landing Trainer (NCLT) Device 2F103. Technical Report NAVTRAEQUIPCEN 74-C-0079-1. Naval Training Equipment Center, Orlando, FL, August 1976.

Brown, J. E., Waag, W. L., and Eddowes, E. E. "USAF Evaluation of an Automated Adaptive Flight Training System." In 8th NTEC/Industry Conference Proceedings, New Concepts for Training Systems. Naval Training Equipment Center, Orlando, FL, November, 1975.

Caro, P. W. Some Factors Influencing Air Force Simulator Training Effectiveness. HUMRRO Technical Report 77-2. Human Resources Research Organization, Alexandria, VA, March, 1977.

Caro, P. W., Pohlmann, L. D., and Isley, R. N. Development of Simulator Instructional Feature Design Guides. Seville Research Corporation Technical Report 79-12. Prepared for Air Force Office of Scientific Research, Bolling AFB, D.C., 1979.

Charles, J. P. Instructor Pilot's Role in Simulation Training (Phase II. Technical Report NAVTRAEQUIPCEN 76-C-0034-1. Naval Training Equipment Center, Orlando, FL, August 1977.

Charles, J. P. and Johnson, R. M. Automated Training Evaluation (ATE). Technical Report NAVTRADEVCEN 70-C-0132-1. Naval Training Device Center, Orlando, FL, March, 1971.

Charles, J. P., Johnson, R. M., and Swink, J. R. Automated Flight Training (AFT) GCI/CIC Air Attack. Technical Report NAVTRAEQUIPCEN 72-C-0108-1. Naval Training Equipment Center, Orlando, FL, 1972.

Charles, J. P., Johnson, R. M., and Swink, J. R. Automated Flight Training (AFT) Instrument Flight Maneuvers. Technical Report NAVTRAEQUIPCEN 71-C-0205-1. Naval Training Equipment Center, Orlando, FL, February, 1973.

Clark, W., Halley, R., Regelson, E., Slemon, G., and VerSteeg, R. Functional Design for Air Intercept Controller Prototype Training System. Technical Report NAVTRAEQUIPCEN 78-C-0182-8. Naval Training Equipment Center, Orlando, FL, 1979.

Connelly, E. M., Bourne, F. J., Leontal, D. G., Migliacco, J. S., Burchick, D. A., and Knoop, P. A. Candidate T-37 Pilot Performance Measures for Five Contract Maneuvers. Technical Report AFHRL-TR-74-88. Air Force Human Resources Laboratory, Advanced Systems Division, Wright-Patterson AFB, Ohio, December, 1974. AD-A014 331.

Conway, E. J., and Norman, D. A. "Adaptive Training: New Directions." In 7th NTEC/Industry Conference Proceedings. Technical Report NAVTRAEQUIPCEN IH-240. Naval Training Equipment Center, Orlando, FL, November, 1974.

Cotton, J. C. "Universal Airborne Approach to Pilot Performance Assessment." Paper Presented at SAE National Aerospace Meeting. San Diego, CA, November, 1978.

Department of Defense. Review of Tactical Jet Operational Readiness Training (U). Office of the Secretary of Defense, Washington, D.C., November, 1968.

Hicklin, M., Barber, G., Bollenbacher, J., Grady, M., Harry, D., Meyn, C., and Slemon G. Ground Controlled Approach Controller Training System Final Technical Report. Technical Report NAVTRAEQUIPCEN 77-C-0161-6. Naval Training Equipment Center, Orlando, FL. 1980.

Hicklin, M., Nowell, L., and Peterson, R. Ground Controlled Approach Controller Training System Training/Functional Design Report. Technical Report NAVTRAEQUIPCEN 77-C-0162-1. Naval Training Equipment Center, Orlando, FL, December, 1978.

Hughes, R. G. "Enabling Features Versus Instructional Features in Flying Training Simulation." In 11th NTEC/Industry Conference Proceedings. Naval Training Equipment Center, Orlando, FL, November, 1978.

Hughes, R. G. Advanced Training Features: Bridging the Gap Between In-Flight and Simulator Based Models of Flying Training. Technical Report AFHRL-TR-78-96. Air Force Human Resources Laboratory, Flying Training Division, Williams AFB, AZ, March, 1979. AD-A068 142.

Hughes, R. G., Hannan, S. T., and Jones, W. E. Application of Flight Simulator Record/Replay Feature. Technical Report AFHRL-TR-79-52. Air Force Human Resources Laboratory, Flying Training Division, Williams AFB, AZ, 1979. AD-A081 752.

Kelley, C. R. "What is Adaptive Training?" Human Factors. Volume 11, Pages 547 - 566. 1969.

Kelly, D. H., Brown, J. E., Van Arsdall, R. S., and Lee, R. D. Final Report: Evaluation of the Simulator for Air-to-Air Combat (SAAC). TAC Project 75A-040U. Tactical Air Command, USAF Tactical Air Warfare Center, Eglin AFB, FL. February, 1979.

Kelly, M., Woolridge, L., Hennessy, R., Vreuls, D., Barnebey, S., and Cotton, J. Air Combat Maneuvering Performance Measurement. Technical Report AFHRL-TR-79-3. Air Force Human Resources Laboratory, Flying Training Division, Williams AFB, AZ, 1979. AD-A077 429.

Lea, W. A. (Ed.) Trends in Speech Recognition. Prentice-Hall, Inc. Englewood Cliffs, NJ, 1980.

McCauley, M. E., and Semple, C. A. Precision Approach Radar Training System (PARTS) Training Effectiveness Evaluation. Technical Report NAVTRAEQUIPCEN 79-C-0042-1. Naval Training Equipment Center, Orlando, FL, 1980.

McDonald, M. J., Smith, B. A., Evans, D. W., Baer, L. H., and Nelson, W. H. F-15 Flight Simulator: Development and Analysis of Computer Scoring Algorithm. Technical Report AFHRL-TR-78-72. Air Force Human Resources Laboratory, Flying Training Division, Williams AFB, AZ, 1979. AD-A067 765.

Monroe, R. D., Vreuls, D., and Semple, C. A. Summary of All-Weather Landing Simulation Studies. FAA Technical Report SRDS RD 68-12. Federal Aviation Administration, Washington, D.C., 1968.

Naval Weapons Center Master Program Plan for the Aviation Training Support System (ATSS). Technical Report TM 3143-3347-77. Naval Weapons Center, China Lake, CA, September, 1978.

Norman, D. "Training Device Developments." Paper Presented at SAE National Aerospace Meeting. San Diego, CA, November, 1978.

Povenmire, H. K., Russel, P. D., and Schmidt, D. "Conservation of People, Planes, and Petroleum Through Optimized Helicopter Simulation." In 10th NTEC/Industry Conference Proceedings: Resource Conservation Through Simulation. Technical Report NAVTRAEQUIPCEN-IH-294. Naval Training Equipment Center, Orlando, FL, November, 1977.

Puig, J. A., and Gill, R. "Evaluation of an Automated Flight Training System." In 8th NTEC/Industry Conference Proceedings, New Concepts for Training Systems. Naval Training Equipment Center, Orlando FL, November, 1975.

Semple, C. A. Training Effectiveness Evaluation: Device 1D23, Communication and Navigation Trainer. Technical Report NAVTRAEQUIPCEN 72-C-0209-2. Naval Training Equipment Center, Orlando, FL, March, 1974.

Semple, C. A., Vreuls, D., Cotton, J. C., Durfee, D. R., Hooks, J. T., and Butler, E. A. Functional Design of an Automated Instructional Support System for Operational Flight Trainers. Report No. NAVTRAEQUIPCEN 76-C-0096-1. U. S. Naval Training Equipment Center, Orlando, FL, January, 1979.

Smode, A. F., and Hall, E. R. An Assessment of Research Relevant to Pilot Training. Biotechnology, Inc., 1966.

Smode, A. F., and Meyer, D.E. Research Data and Information Relevant to Pilot Training. Volume I. General Features of Air Force Pilot Training and Some Research Issues. Technical Report AMRL-TR-66-99, Volume I. Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio, 1966.

Spring, W. G. Experiments to Evaluate Advanced Flight Simulation in Air Combat Pilot Training. Volume 4. Simulation Development and Preparation. Technical Report NOR 76-52. Northrop Corporation, Aircraft Division, Hawthorne, CA, March, 1976.

Sullivan, D. J., Casey, R. J., and Hebein, J. M. Acquisition and Retention of Cognitive Versus Perceptually Oriented Training Materials. Technical Report prepared for U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA, 1978.

Swink, J., Smith, J., Butler, E., Futas, G., and Langford, H. Enhancement of Automated Adaptive Flight Training System (AFTS) for F-4E Weapon Systems Training Set (WSTS): Training Specification. Technical Report NAVTRAEQUIPCEN 75-C-0017-1. Naval Training Equipment Center, Orlando, FL, September, 1975.

USAF, Aeronautical Systems Division Air Force Aircrew Training Devices Master Plan. Technical Report ASD-TR-78-16. USAF, Aeronautical Systems Division, Wright-Patterson AFB, OH, March, 1978.

Vreuls, D., and Goldstein, I. "In Pursuit of the Fateful Few: A Method for Developing Human Performance Measures for Training Control." In 9th NTEC/Industry Conference Proceedings. Technical Report NAVTRAEQUIPCEN IH-240. Naval Training Equipment Center, Orlando, FL. May, 1976.

Vreuls, D., Obermayer, R., Goldstein, I., and Norman, D. Trainee Performance Measurement in Four Instrument Flight Maneuvers. Technical Report NAVTRAEQUIPCEN 74-C-0063-1. Naval Training Equipment Center, Orlando, FL, 1975.

Vreuls, D., and Wooldridge, A. L. "Aircrew Performance Measurement." In Symposium Proceedings: Pproductivity Enhancement: Personnel Performance Assessment in Navy Systems. Naval Personnel Research and Development Center, San Diego, CA, 1977.

Vreuls, D., Wooldridge, A. L., Obermayer, R. W., Johnson, R. M., Goldstein, I., and Norman, D. A. Development and Evaluation of Trainee Performance Measures in an Automated Instrument Flight Maneuvers Trainer. Technical Report NAVTRAEQUIPCEN 74-C-0063-1. Naval Training Equipment Center, Orlando, FL, May, 1976.

Waag, W. L., Eddowes, E. E., Fuller, J. H., and Fuller, R. R. ASUPT Automated Objective Performance Measurement System. Technical Report AFHRL-TR-75-3. Air Force Human Resources Laboratory, Flying Training Division, Williams AFB, AZ, 1975. AD-A014 799.

Waag. W. L., and Knoop, P. A. "Planning for Aircrew Performance Measurement R&D: U. S. Air Force." In Symposium Proceedings, Productivity Enhancement: Personnel Performance Assessment in Navy Systems. Naval Personnel Research and Development Center, San Diego, CA, 1977.

Wheaton, G. R., Fingerman, P. W., Rose, A. M., and Leonard, R. L. Training Techniques and Principles. (Appendix A of Evaluation of the Effectiveness of Training Devices: Elaboration and Application of the Predictive Model). Research Memorandum 76-16. U. S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA, July, 1976.

Wooldridge, A. L., Vreuls, D., and Norman, D. A. An Adaptive Logic Study: A Study of Various Adaptive Logic Efficiencies. Technical Report NAVTRAEQUIPCEN 76-C-0079-1. Naval Training Equipment Center, Orlando, FL, December, 1977.

APPENDIX A

INSTRUCTIONAL SUPPORT FEATURES
INTERVIEW GUIDE

The interview guide presented in this appendix was used to guide interviews conducted during program site visits with respect to ATD instructional support features. An interview guide is a checklist of topics to be addressed. Its purpose is to guide and structure indepth, penetrating interviews. Unlike a questionnaire, which is highly structured, an interview guide does not exclude meaningful avenues of investigation that suggest themselves during the course of data gathering. A primary use of the guide in this appendix was a checklist, which was referred to at the close of each day of interviewing to assure that all relevant topics were covered during each site visit.

INSTRUCTIONAL SUPPORT FEATURE INVENTORY

1. Event Definition and Control

   a. Pre-session audio-visual demonstrations

   b. Simulator initialization procedures

   c. Automated demonstration(s)

   d. Pre-programmed (canned) mission events

   e. On-line programmable mission events

   f. On-line capability for establishing event initial conditions

   g. Auto malfunction/emergency insertion-removal; and capability to add additional malfunctions/emergencies

   h. Manual malfunction/emergency insertion-removal; and capability to add additional malfunctions/emergencies

   i. Dedicated controls (functional groupings)

   j. Keyboards

   k. Joy sticks and related controls

   l. CRT data entry/selection formats (touch panel, other)

   m. Threat control

   n. Environment control (rough air, etc.)

   o. Task difficulty control

   p. Freeze

   q. Reset

   r. Record and replay

2. Event Monitoring

   a. Repeater instruments (functional groupings)

   b. Electronic pictorial/analog display(s)

   c. Other performance and event monitoring displays

   d. Mechanical plotter

e. Closed circuit TV, and record/playback capabilities

f. Other video monitoring capabilities, and record/playback capabilities

g. Hard copy output

3. **Instructor/Operator - Student Communication**

    a. Usual methods of communicating with student work station

    b. Cockpit-mounted alphanumeric displays

    c. Cockpit-mounted responder controls

    d. Computer generated voice

    e. Automated speech understanding

    f. Simulator-mounted audio-visual instructional devices

4. **Automated Support**

    a. Automated performance measurement

    b. On-line performance monitoring and alerting

    c. Automated scoring

    d. Automated learning problem diagnosis

    e. Automated coaching

    f. Automated cuing

    g. Automated performance norm data files

    h. Computer managed instruction

INSTRUCTIONAL SUPPORT FEATURE SURVEY ELEMENTS

1. **Description**

    a. Manufacturer and date

    b. Functional description

    c. Modes of operation

    d. Man-machine interface

e. Representative operating procedures

f. Difficulty of use

g. Factors affecting operability (ease/complexity and time)

h. Planned design changes

i. Desirable design changes

j. Local modifications made and date (hardware and software)

k. Contracted modifications and date

l. Reasons for modifications

m. Perceived benefits from modifications

n. Training evaluations of modifications

o. Surveyor's assessments

2. Training Applications

a. Present training applications (tasks)

b. Training content involved (tasks)

c. Specific student learning and/or performance problems

d. Instructional uses originally designed to support

e. Reasons for additions/deletions to uses

f. Training evaluations performed

g. Planned changes to training that could affect applications

h. Suggestions for other applications

i. Surveyor's assessment

3. Utilization

a. Job performance aids and user assists available

b. Perceived values of the feature

c. Perceived drawbacks of the feature

d. Frequency of use

e. Reliability

f. Procedures and forms to report maintenance problems

g. Factors influencing feature utilization

   (1) Training requirements

   (2) Perceived benefits

   (3) Perceived drawbacks

   (4) Design/implementation

   (5) Schedule considerations

   (6) Instructor training

   (7) Attitudes toward simulation

   (8) Other

h. Characterize impacts of feature on ATD utilization

i. Essentiality

   Cite representative uses of the feature that fall into the
   following categories.

   (1) Highly essential. The feature is required to accomplish
        simulator training.

   (2) Moderately essential. The feature aids in accomplishing
        simulator training, but it would be possible to get along
        without it.

   (3) Marginally essential.   The feature is convenient for
        simulator training, but it would be easy to get along
        without it.

   (4) Totally non-essential.

J. Surveyor's assessments

SURVEY ELEMENTS UNIQUE TO CERTAIN FEATURES

1. Record and Replay

    a. Where is replay accomplished?

        (1) in cockpit

        (2) remote (location and content)

        (3) availability of augmented feedback during replay (e.g., scoring or diagnostics)

    b. How much of the mission can be replayed?

2. Freeze

    a. Can freeze be operated during replay?

3. Video Display

    a. Description (field of view, size, resolution, color, number)

    b. Record/replay capabilities

4. Automated Demonstrations

    a. Capabilities and procedures for constructing/modifying canned scenarios

        (1) On-line (who and how)

        (2) Off-line (who and how)

    b. Difficulties in developing and using canned scenarios

        (1) Development

        (2) Call-up and use

5. Automated Performance Measurement

    a. Descriptive data

        (1) Manufacturer and delivery date

        (2) Add-on to simulator?

        (3) Production or R&D feature/capability?

        (4) Describe any in-house modificiations

(5) Describe any on-going APM R&D

(6) Obtain system and R&D documentation

(7) Identify R&D point of contact (name, organization, telephone)

b. Characteristics

(1) Parameters that can be measured (total set)

(2) How are the parameters designated (procedures)?

on-line

off-line

(3) How are performance tolerances set?

on-line

off-line

(4) How is measurement start and stop designated?

on-line

off-line

(5) Are any mathematical transforms performed?

(6) How and when are the measures displayed?

(7) Utility of measures for quantifying proficiency (criteria used) (use of measurement outputs when completing student grade forms?)

(8) Diagnostic value of the measures

(9) Utility of the measurements for training quality control

(10) Desirable improvements

(11) Other applications

6. **Automated Scoring**

a. Describe/define the combining of measures into scores

b. Describe/define scoring criteria used

c. Describe intended uses of the scores

d. Utility of performance scores for training quality control

e. Use of scores when completing student grade forms

7. Automated Adaptive Training (AAT)

a. Descriptive Data

(1) Manufacturer and delivery date

(2) Add-on?

(3) Production or R&D feature/capability

(4) Describe any in-house modifications

(5) Describe any related R&D activities

(6) Obtain system and R&D documentation .

(7) Identify R&D point of contact (name, organization, telephone)

b. Characteristics

(1) Describe adaptive logic structure(s) used

(2) Describe automated measurement/scoring used

(3) Describe on-site modifications and reasons

(4) Training impacts of modifications

(5) Effects of AAT system on:

(a) Student progress through automated portions of syllabus

(b) Student proficiency

(c) Training quality control (portions of syllabus involved)

(6) Effect of AAT on instructor involvement

(7) Effect of AAT on operator involvement

(8) Student acceptance of AAT

(9) Instructor acceptance

8. Computer Managed Instruction

    a. Descriptive Data

        (1) Name and acronym

        (2) Developer and installation date

        (3) Cognizant organization and symbol

        (4) Obtain documented description of the system

        (5) Training supported (academics, simulator, inflight)

    b. Characteristics

        (1) Describe how it is used (general)

        (2) Input data sources

        (3) Simulator training objectives tracked

        (4) Inflight training objectives tracked

        (5) Utility in determining simulator session training content

        (6) Utility in determining flight training content

        (7) Utility in scheduling simulator sessions

        (8) Utility in scheduling training flights

        (9) Impacts on training quality control

INSTRUCTOR/OPERATOR STATION DESIGN

1. Present configuration

    a. Device designation and type

    b. Linked mode operation?

    c. Location(s) relative to student workstation

    d. Present opportunities for dynamic observation

    e. Functions performed (at each location)

      f. Instructors/operators assigned to each location

      g. Instructor/operator interaction

      h. Ease/difficulty of coordination

      i. Perceived benefits of present configuration

      j. Perceived drawbacks of present configuration

      k. Suggested design modifications (and reasons)

2. General Perceptions and Suggestions

      a. Types of training where direct observation is perceived as necessary

      b. Types of training where direct observation is perceived as desirable

      c. Student skill level impacts on instructor/operator station locations

      d. Device type (CPT, OFT, WST, etc.) impacts on instructor/operator station locations

      e. Perceived general benefits and drawbacks of in-cockpit location

      f. Perceived general benefits and drawbacks of remote location

      g. Advantages/disadvantages of designing student workstations to incorporate an instructor/operator station if it meant that the student's workstation environment might not appear exactly as in the aircraft

3. Background

      a. Interviewee's prior experience with remote and/or in-cockpit instructor stations.

         (1) As a student (weapon system, device, dates)

         (2) As an instructor (weapon system, device, dates)

DEVICE OPERATIONS

1. Surveyor's Assessments

      a. Instructor status/morale

b. Adequacy of instructor training

c. Problems noted

d. Desirable points noted

e. Implications for other programs

2. <u>Typical Device Operator Characteristics</u>

a. Rank

b. Years in service

c. Number of months at this assignment

d. Duration of this assignment in months

e. Prior device operator experience

f. Operator selection criteria/procedures

g. Continuity in operator staff

3. <u>Device Operator Job Characteristics</u>

a. Hours worked per week, training support activities

b. Hours worked per week, other activities

c. Device utilization activities description

d. Other activities description

4. <u>Device Operator Training</u>

a. Schools attended

b. Factory training for this job

c. Local program for operator training

(1) Topics covered

(2) Program description

(3) Program duration

(4) Role of formal instruction

(5) Role of on-the-job training

(6) OJT supervision

        (7) Criteria for completing training

    d. Perceived value of school training for this job

    e. Perceived value of factory training for this job

    f. Perceived value of local training for this job

    g. Planned changes in operator training program

    h. Suggested changes to operator training program

5. <u>Surveyor's Assessments</u>

    a. Operator status/morale

    b. Adequacy of operator training

    c. Problems noted

    d. Desirable points noted

    e. Implication for other programs

APPENDIX B

GUIDANCE FOR THE DEVELOPMENT OF AUTOMATED
PERFORMANCE MEASUREMENT SYSTEMS

INTRODUCTION

Automated performance measurement (APM) systems require a deliberate development procedure if they are to be useful and accepted. This appendix presents general specifications for APM systems for ATDs and then presents a workable APM development procedure.

Functional Specifications for AMP Systems

The following functional specifications have been developed for users who have need to specify an APM system as part of a new ATD procurement or the retrofitting of existing ATD. They have been developed from recent APM research and development work (See the Related Research section in the APM portion of Chapter III of this report).

Level 1 APM System. (Continuation Training Profiency Assessment)

Purpose. To provide a system that will measure and score the exceeding of criteria prescribed for specific operational flight segments or procedures.

Application. Continuation training proficiency assessment of a pilot who has been qualified previously on the aircraft type or in the ATD in which the assessment is to be performed.

Scope of Measurement. To automatically measure performance on ground referenced, air referenced, and proponent/opponent referenced flight profiles and other specialized missions required by the continuation training curriculum.

Method of Measurement. Monitoring of selected flight and control parameters on a sampled basis, including the monitoring of time related procedural or discrete events (e.g., landing gear lever down, or #1 hydraulic pump not switched off).

Segmentation of Flight Profiles. Each flight profile to be automatically tracked using stop/start logic based on discrete events or change of state of one or more measured parameters to determine the beginning and end of each segment or sub-segment of the profile.

Method of Scoring. Scoring algorithms to be based on exceeding of limits established for the parameters used for measurement in each specific segment of a flight profile. Separate scoring methods are required for flight and control measurement, and time related discrete events chains. The partial scores so obtained should then be combined using empirically derived weighting coefficients into performance scores for the flight segment, overall flight profile, or overall recurrent proficiency assessment as required.

Development of Score Weightings. A primary objective is to arrive
at a minimum set of measures which captures the performance variance
of at least 67 percent of the pilot population used in developing
the performance norms. Initially, the scoring algorithms may be
based on information obtained from highly qualified check pilots who
normally score each specific performance objective. Subsequently,
the scoring algorithms must be refined commensurate with a "test"
group of skilled pilots already endorsed on the specific aircraft
type and maneuvers for which the ATD is used. For scoring a time
related discrete event chain (for example, a hydraulic failure
requiring the isolation of some hydraulic elements), scoring must
take into account whether correct outcome was achieved, the time
taken in arriving at the outcome, and that an optimum discrete event
path through alternative event sequences was taken.

Method of Presenting Scores. By CRT or line printer. The
achieved scores should be broken down to show each partial score and
how it compares to the norm established for the task being assessed.

Compatibility of ATD APM System to the Aircraft. Even though many
ATDs have different flight control characteristics than the
aircraft they represent, a major design objective for the ATD APM
system is to approach equality with the scoring appropriate for
pilot performance in the aircraft.

Development and Validation. This should be an orderly process in
accordance with the steps shown in Figure B-1. The process is
further described later in this appendix.

Level 2 APM System. (Undergraduate and Transition Training Proficency
Assessment)

Purpose. To provide a system that will measure and score
performance when measured against criteria for a specific
undergraduate or transition training program.

Application. Incremental proficiency assessment of a pilot who is
undergoing training (undergraduate or transition) in a specific
simulator (or aircraft) in which the assessment is taking place.
The Level 2 system appliction may include the use of performance
measurement as the primary control element in an automated adaptive
training system which will advance the pilot through a flight
training curriculum in the most efficient manner. (See Chapter V of
this report)

Scope of Measurement. To automatically measure performance on
ground referenced, air referenced, and proponent/opponent referenced
flight profiles and other specialized missions required by the
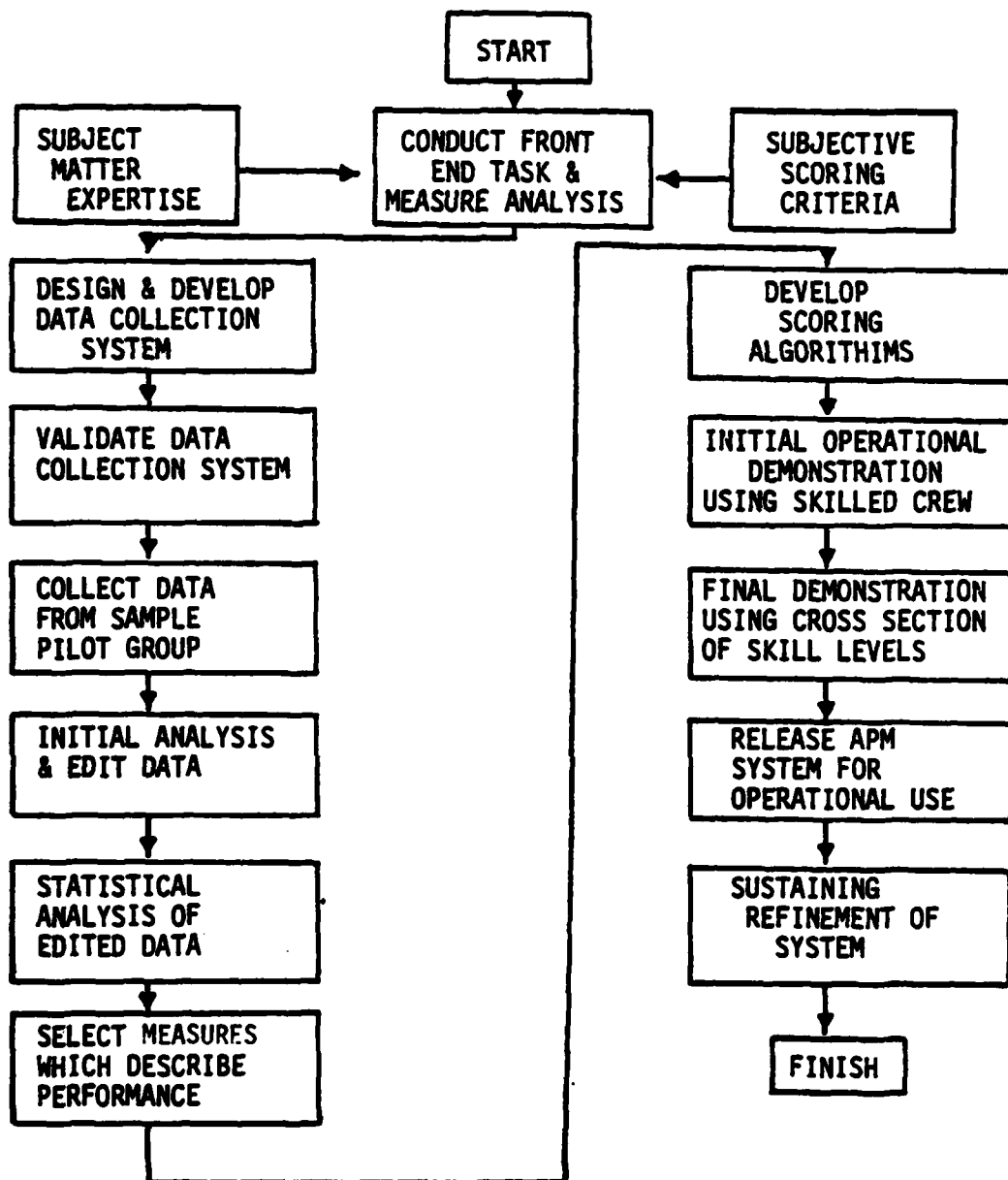training curriculum.

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Figure B-1. Automated Performance Measurement
Design and Development Process

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Method of Measurement. Monitoring of selected flight and control parameters on a sampled basis including the monitoring of time related procedural or discrete events (e.g., gear lever down, or #1 hydraulic pump not switched off). Depending on the automated adaptive training requirements for the measurement system, interactive aerodynamic measurement may be required to describe performance in, say, a climbing turn. Typical aerodynamic parameters measured in climbing turn would be: airspeed, heading, altitude change, angle of attack, side slip, power setting, stick forces, stick displacements, pitch and roll angles, and their rates.

Segmentation of Flight Profiles. Each flight profile to be automatically tracked using stop/start logic based on discrete event or change of state of one or more measured parameters to determine the beginning and end of each segment and sub-segment of the profile.

Method of Scoring. Scoring algorithms to be based on criterion values for critical parameters used in specific segments of each flight profile. Separate scoring methods are required for flight and control measurements, and time related discrete event chains. The "partial" scores so obtained should then be combined using empirically derived weighting coefficients into separate task scores as well as single session scores for diagnostic and evaluation purposes.

Development of Score Weightings. A minimum set of measures which captures the performance variance of at least 67% of the pilot population is a primary objective. Initially the scoring algorithms may be based on information obtained from highly qualified instructor pilots who normally score each specific incremental training objective. Subsequently, the scoring algorithms must be refined commensurate with a representative group of pilots being trained with varying degrees of experience on the training tasks for which the ATD is used. For scoring a time related discrete event chain (for example, a hydraulic failure requiring the isolation of some hydraulic elements) scoring must take into account that the actual correct outcome was achieved, the time taken in arriving at the outcome, and that an optimum discrete event path through alternative event sequence was taken.

Method of Presenting Scores. By CRT or line printer. The achieved score should be broken down to show each partial score and how it compares to training criteria established for that segment of flight.

Compatibility of ATD APM System to the Aircraft. Even though many ATDs have different flight control characteristics than the aircraft they represent, a major design objective for the ATD APM system is to approach the scoring appropriate for pilot performance in the aircraft.

Development and Validation. This should be an orderly process in accordance with the steps shown previously in Figure B-1. The process is further described in the next section of this appendix.

APM DEVELOPMENT PROCEDURE

Prior research has shown that twelve general steps still are required to develop and validate a workable APM system. The steps are presented below. (See the Related Research section of the APM portion of Chapter III of this report.)

1. Detailed front end analysis of the tasks to be measured, including the selection of measures considered by knowledgeable analysts to describe profiency in those tasks.

2. Design and development of a data collection system to be used in the operational environment to establish how the selected measures perform in the real world.

3. Validation of the data collection system to ensure that it produces useable data.

4. Collection of data across a spectrum of aircrew members of varying skill levels to establish a "group" baseline of performance.

5. Initial data "screening" analysis (editing) to eliminate extraneous data which could distort final results.

6. Statistical analysis of the edited data using multivariate statistical techniques.

7. Selection of measures which describe and discriminate observed performance of the "group" (usually the smallest possible set).

8. Empirical development of scoring algorithims to produce single scores for the tasks measured. This requires the combining and weighting of measures from sub-tasks.

9. Initial validation demonstration using instructional and training crews to validate the objectively generated scores.

10. Collection of instructor pilot ratings, APM scores and summary measurement data for a reasonable sample of student and experienced pilots to provide final validation of the system.

11. Release of the system for training use.

12. Continued recording of measurement data for APM research and system refinement.

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All 12 steps presently are required because of the complexity of measuring aircrew performance, and the need to further understand these complexities for useful measurement system development.

MEASUREMENT MODEL

A generalized measurement model simply is a systematic way of defining automated measures that uniquely describe measurements for research or training applications. A workable model that defines each measure in terms of the following five determinants has been shown to be practical (Vreuls and Wooldridge, 1977). Each determinant is defined in Chapter IV of this report. Definitions are summarized below.

1. A measure segment (or task)

2. A state variable

3. A sampling rate

4. A desired value (if required)

5. A data transformation

A segment (or task) is any portion of a flight for which desired behavior or system performance follows a lawful relationship from beginning to end, and for which the beginning and end can be defined unambiguously. Measurement start and stop conditions define a segment. Conditional tests of ongoing performance, such as the following, are required to start and stop measurement:

If (1) Altitude is Greater Than .Or. Less Than 1000 feet
from the initial value,

.And.

(2) Heading is Greater Than 90 degrees .And. Less Than
270 degrees,

Then, start measuring.

A variable is any quantitative index of; 1) vehicle states in any reference plane; 2) personnel physiological states; 3) control device states; or 4) discrete events. A sampling rate is the temporal frequency at which the variable is examined. Often, variables have no utility unless compared to a desired value or a tolerance to derive an error score. Finally, a transformation is any mathematical treatment of the parameter, to include measures of central tendency, variability, scalar values, Fourier transforms, pilot/system transfer functions, etc. Common measure transforms are identified in Table B-1.

Table B-1. Common Measure Transforms

<u>Time History Measures</u>
        Time on target
        Time out of tolerance
        Maximum value out of tolerance
        Response time, rise time, overshoot
        Frequency domain approximations
            Count of tolerance band crossings
            Zero or average value crossings
            Derivative sign reversals
            Damping ratio

<u>Amplitude-Distribution Measures</u>
        Mean, median, mode
        Standard deviation, variance, range
        Minimum/maximum value
        Root-mean-squared error
        Absolute average error

<u>Frequency Domain Measures</u>
        Autocorrelation function
        Power spectral density function
            Bandwidth
            Peak power
            Low/high frequency power
        Bode plots, fourier coefficients
            Amplitude ratio
            Phase shift
        Transfer function model parameters
            Quasi-linear describing function
            Cross-over model

MEASURE SELECTION

The present state of the art requires that measurement development must start with a good analysis, but empirical methods are required to reduce measures to a small, efficient set.

The reduction of analytically defined measures into a set which can be shown (operationally and statistically) to have desired properties is called the measure selection process. The measure selection process is based on multivariate statistical models which are used to evaluate the total set of measures, taken together, and provide measure scaling (weighting) information.

The current measure selection process is based on criteria that the final measure set should represent a comprehensive, yet minimum set of measures which: 1) eliminate redundant forms of information; 2) is sensitive to the skill changes that occur during training; and 3) has performance prediction qualities.

The first step in the development of measures involves specifying candidate performance measures which, in the judgment of the measurement analyst, might contain information of importance for instructors, adaptive logics, or other systems which are to manage training. Examples from the literature can be used along with common task analytic techniques to develop analytic measure specifications.

The next step in the process requires collecting empirical performance data during training to provide a reliable sample for measure selection analyses. Computer measure selection techniques, based on multivariate statistical models, are used to reduce the candidate measures to a final measure set that meets statistical and operational criteria. The outcome of each analysis is evaluated and merged (sometimes subjectively) into a reduced set of measures for each task.

The recommended measure sets then are statistically processed to establish weighting coefficients for each measure (see the following section of this appendix). The weights reflect the relative importance of each measure to training, scale the measures on a common basis, and permit summation of the many measures into one score.

MEASURE SELECTION TECHNIQUES

Reduction of the initial candidate measure set to something that is operationally workable should be based on an analysis of data collected through a trial application of the initial APM system. As a rather large number of measures is typical initially, a number of pilots and repetitions is needed for an adequate statistical sample. The criteria for final measure set selection then must be defined in quantitative, operational form.

But, on what ground should a specific measure be included or excluded for further consideration? After consideration of the needs for measurement in training (Vreuls and Goldstein, 1974), three general criteria are recommended:

1. If two measures provide the same information for a given application, one member of the redundant pair may be discarded.

2. Measures may be discarded if they are not sensitive to performance differences between individuals. The measures retained should be able to discriminate between "good" and "poor" performers, and performance by a student early in training compared with the same performance later in training.

3. Measures also should be retained if they lend themselves to early prediction of operational performance to be achieved by an individual; for example, the performance level to be achieved at the close of training, or the prediction of deficiencies which may be remedied by an appropriate change in training.

If two measures correlate highly, then one of the pair may be removed from the candidate measure set. In fact, it may be necessary to remove such measures for the proper functioning of multivariate statistical analyses used in other measurement selection criteria (see the following sections of this appendix). However, the APM system designer also must ensure that small differences between two imperfectly correlated measures are not important; for example, one subject of a larger group may be sufficiently different that the measures are definitely uncorrelated, but only for him. Further, the problem of specifying the magnitude of the correlation coefficient (degree of relationship) for determining which measures will be considered redundant remains the judgment of the APM system designer. Further research is required.

A multivariate statistical technique, the multiple discriminant analysis, is available to derive a discriminant function made up of a composite weighted sum of measures that hold potential for best differentiating between two or more groups. The computed weightings indicate the relative amounts that each of the measures contributes to the differentiation. If the APM system designer can establish test groups which are known to be different in terms of skill levels, and if test data can be collected, then the multiple discriminant analysis can be used to find the measures within the candidate measure set that maximize the differentiation. The weightings, then, are key to the definition of measure selection criteria. The criteria can be that the measures with the least weights are discarded. Of course, the threshold level for measure weights now must be left to the APM system designer's judgment.

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Specific details of the APM selection criteria used, and the statistics of the selection process, are best presented in terms of the statistical operations needed, which are summarized in the following section.

MEASURE SELECTION BY DISCRIMINANT ANALYSIS

The statistical programs generated to select measurement through discriminant analyses assume that a battery of measures has been taken for each group of subjects. The primary purpose of these statistical computer programs is to identify the measures that best discriminate between groups of known skill differences. For example, a pair of groups may consist of experienced and inexperienced pilots. The statistical procedure eliminates measures that do not contribute to the ability to tell the groups apart.

Computer programs for measure selection based on discriminant analysis iteratively discard candidate measures until a minimum set of statistically defined measures is selected by the APM analyst. The iterative process stops when one of two criteria is met: 1) the total number of remaining measures is less than the minimum number of factors determined through a principal components analysis; or 2) discarding another measure will reduce discrimination to an unacceptable level.

The above procedure is satisfactory unless some of the measures are highly correlated; then the ability of the measure set to differentiate between groups cannot be clearly attributed to either of a pair of correlating measures. The recommended procedure, therefore, first performs a correlation analysis, and one of the pair of highly correlative measures must be discarded. The procedure then is continued (with selected discards) until the measurement analyst is satisfied. Obviously, further research is needed so that automated measures ultimately can be determined without excessive reliance on this complex developmental procedure.

MEASURE SELECTION BY CANONICAL CORRELATION ANALYSIS

Another series of data analysis programs is designed to select measures that relate performance demonstrated at one time in training to that at another time. The basis of the method is a canonical correlation analysis which derives a linear combination of the measures, and maximizes the correlation between the linear combination of one set of measures in relation to another set of measures. If the following linear combinations are formed:

$$Y1 = a_1 x_1 + a_2 x_2 + \ldots a_n x_n$$

$$y2 = b_1 x_1 + b_2 z_2 + \ldots b_n z_n$$

where x and z are the same measures collected at different points in the

training sequence, then canonical correlation analysis determines the coefficients a and·b so that Y1 and Y2 are maximally correlated.

The quantities Y1 and Y2 are factors of their respective data groups. Computer programs generate the factor structure for each set of data which displays the correlation between each measure and factor. The factor which correlates between groups best is also indicated, and it is this factor which is used for measure selection. The measure which correlates least with this factor contributes least to between group correlation.

MEASURE SET SELECTION

The objectives of the previous measure selection processes are to define the set of measures that best discriminated among skill levels and predict performance for each task and operational variation. The results of the discriminant analysis and canonical correlation analyses are brought together to find commonalities and differences in order to recommend measurement which will contain both discriminative and predictive information. Also, it is necessary to determine the weighting coefficients for each measure to reflect the training importance of each measure and to scale each measure on a common basis for possible summation into an overall performance score.

Final measure set selection remains a judgmental procedure based on experience and objective data. If one wishes to use these criteria, minimum measure sets which result from the discriminant analysis can be entered into a student performance data table for each maneuver segment and task variation, such as aircraft weight change or addition of turbulent air. To each table are added any measures produced by the canonical process.

Resulting measure sets are examined to ensure that all aircraft outer loops representing task instruction are present. Measures that appeared infrequently (once or twice for any maneuver segment) may be eliminated if the information they contain is represented by a high correlation (.70 or greater) with another comparable measure that is contained in the set, and/or they have been added to the measurement table by the canonical process and are weakly related (loadings less than .20) to the canonical factors.

Finally, discriminant analysis can be modified to perform an analysis on the recommended measure set. The overall analysis assures that a significant discriminant function is retained. Also, the weights assigned to each measure of the final set are computed. The weights provide scaling information for each measure relative to other measures in the set and coefficients for the linear summation of the measures into a single score.

APPENDIX C

GLOSSARY OF TERMS

AAT - Automated adaptive training, which is a complex and evolving technology in which instructional objectives and strategies that are implemented as computer software are used to automatically tailor (adapt) instruction to individual student learning needs.

ATD - Aircrew training device. These training media include cockpit familiarization and procedures trainers, operational flight trainers, part-task trainers, weapon system trainers and full mission trainers.

AUGMENTATION - Providing information which does not exist in the real world, or an enhancement of naturally occurring information.

AUTO-DEMO - Automated Demonstrations. An instructional feature that permits the standardized presentation of a mission segment or entire simulated flight. All cues of consequence, including the visual scene (if present), motion system, primary flight controls and displays, crew communications and sensor displays, are reproduced for the selected mission segment or maneuver through computer control.

AUTOMATED COACHING - Providing automatically guidance messages to students that are designed to assist the student in correcting a performance deficiency.

AUTOMATED CONTROLLERS - Computer-based systems that use mathematical models to determine controller messages and issue controller messages using computer generated speech.

AUTOMATED CUING - The automated capability to provide performance alerting messages to students when their performance does not meet established standards.

AUTOMATED PERFORMANCE ALERTS - Signals intended to enhance the monitoring of student performance by combining the capabilities of automated performance measurement with automated alerting signal generation for instructors and/or students.

AUTOMATED PERFORMANCE MEASUREMENT (APM) - The computer-based application of technology to monitoring, recording, processing and displaying objective, quantitative information that describes student performance and assists in diagnosing student learning problems.

CCT - Combat crew training.

CCTV - Closed circuit television.

CPT - Cockpit procedures trainer.

CT - Continuation training: training conducted routinely in operational squadrons, or proficiency training conducted periodically.

CUE - In this report, cue means some critical feature which gives important information to a pilot or other aircrew member. There is no commonly accepted definition of cue as used with respect to fidelity.

DIAGNOSE - To determine the reasons underlying less than acceptable performance.

FIDELITY - The extent to which cue and response capabilities in an ATD allow for the learning and practice of specific tasks so that what is learned will enhance performance of the tasks in the operational environment. Also see: physical fidelity; task fidelity; and realism.

FIELD OF VIEW - The dimensions of the area of a visual display which can be seen.

FLIGHT TRAINING MODEL - Patterning the way aircrew training is done in an ATD directly after the way comparable training is done in the aircraft; needlessly imposing limitations on ATD use that stem from the ways aircraft must be used for training.

FREEZE - An instructional support feature that allows simulator parameters to be fixed at values existing when freeze is operated.

IMAGE - The picture or scene created by a simulator visual system which is viewed by a pilot or other aircrew member.

IMAGE QUALITY - Characteristics of the appearance of an image, independent of the scene content of the image.

INITIALIZATION - Initialization involves specifying, usually from the instructor/operator console, the parameters of interest and their values for repositioning and reconfiguring an ATD through computer control.

INSTRUCTIONAL SUPPORT FEATURE - ATD hardware and software capabilities that allow the instructor to manipulate, supplement and otherwise control the student's learning experiences with the intent of promoting the rate at which skills are learned and maximizing the levels of skills achieved.

IRON PILOTS - Computer controlled adversaries, typically used in air combat maneuvering training in ATDs.

ISD - Instructional system development: procedural approaches to the analysis of training requirements and the development of training systems.

MULTI-VARIATE - A number of variables that are combined to provide an indicator of performance.

OFT - Operational flight trainer.

PHYSICAL FIDELITY - The degree of structural or dynamic correspondence of an ATD to the aircraft it represents.

PRACTICE - Deliberate participation in activities for the purpose of learning or mastering skills that depend on the thoughts and motor actions involved in the activities.

PROGRAMMED MISSION SCENARIOS - Highly structured sets of events that are caused to occur automatically, under computer control.

RECORD AND REPLAY - The instructional feature that provides the capability in an ATD to record relevant system parameters and then use these data to present student pilot performance in a review mode in the ATD.

REALISM - The extent to which an aircrew member's experiences in an ATD correspond to experiences as they actually would occur in an aircraft under a given set of conditions. Also see physical fidelity.

RESOLUTION - The smallest separation between two objects in a display which can be detected, usually by the human eye.

RESPONSE - Any motor, perceptual or mental act by a person; generally refers to an element of an overall action as opposed to the overall action itself.

RETENTION - The capacity to remember task requirements and perform accordingly after a lapse of time during which the task has not been practiced.

STRES - Simulator Training Requirements and Effectiveness Study.

TASK FIDELITY - The degree of correspondence of cues and responses accompanying task performance in an ATD to those characteristics of analogous performance in an aircraft.

TRAINING EFFECTIVENESS - The training benefit gained in terms of operational readiness. Also, the thoroughness with which training objectives have been achieved, regardless of training efficiency.

TRAINING EFFICIENCY - The extent to which training resources (including time) are used economically while achieving training effectiveness.

TRAINING OBJECTIVES - Precise statements of the goals of training which set forth the tasks to be performed, the performance standards to be met for each task, and the conditions under which task performance is to be demonstrated.

TRAINING REQUIREMENTS - General statements of job performance skills required for operational proficiency. Also, general statements of job performance skills that require periodic practice in order to maintain proficiency.

TRANSFER OF TRAINING - The use of skills learned in one context (e.g., an ATD) in a substantially different context (e.g., an aircraft). The carry-forward of trained performance to real world applications.

TRANSITION TRAINING - Training for aircrew members transitioning to different operational aircraft.

UPT - Undergraduate pilot training: initial pilot qualification training.

WST - Weapon system trainer.