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ABSTRACT

A systematic study of all fixed wing pilot training programs at the U.S. Army Aviation School was conducted in fiscal year 1968. The objective was to determine whether training might be made more effective through greater use of synthetic flight training equipment and, if so, to specify the main characteristics of appropriate equipment. Secondary objectives were to assist in developing low cost devices for one course and to determine the probably cost-effectiveness of a commercially available device in another. A method was developed which identified specific and differential needs for synthetic equipment in each course and determined suitability of existing equipment to meet those needs. A generalizable, systematic method for determining requirements for synthetic training equipment in existing training programs resulted. (Author)

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Determining Training Device Requirements in Fixed-Wing Aviator Training

Paul W. Caro, Oran B. Jolley,
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April 1972

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HumRRO Division No. 6 (Aviation)
Fort Rucker, Alabama

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The Human Resources Research Organization (HumRRO) is a nonprofit corporation established in 1969 to conduct research in the field of training and education. It is a continuation of The George Washington University Human Resources Research Office. HumRRO's general purpose is to improve human performance, particularly in organizational settings, through behavioral and social science research, development, and consultation. HumRRO's mission in work performed under contract with the Department of the Army is to conduct research in the fields of training, motivation, and leadership.

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

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16. Abstracts

A systematic study of all fixed wing pilot training programs at the U.S. Army Aviation School was conducted in FY 1968. The objective was to determine whether training might be made more effective through greater use of synthetic flight training equipment and, if so, to specify the main characteristics of appropriate equipment. Secondary objectives were to assist in developing low cost devices for one course and to determine the probable cost-effectiveness of a commercially available device in another. A method was developed which identified specific and differential needs for synthetic equipment in each course and determined suitability of existing equipment to meet those needs. A generalizable, systematic method for determining requirements for synthetic training equipment in existing training programs resulted.

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FOREWORD

This report describes the concepts and methodology of a study of fixed wing training device requirements, conducted by the Human Resources Research Organization at the request of the U.S. Army Aviation School. The effort was carried out in 1967-68 as a Technical Advisory Service and built upon methodology, data, and concepts developed in HumRRO Work Units ECHO, ROTOR, and SYNTRAIN.

The major findings and conclusions of this study were reported to the Assistant Commandant, USAAVNS, and the Director, Department of Advanced Fixed Wing Training, USAAVNS, through briefings and a consulting report providing documentation of the details of the study and its findings. The present report is being issued because of the continuing interest which agencies concerned with pilot training device studies have expressed in the methodology used in this study to analyze aviation training device requirements.

This activity and Work Units SYNTRAIN, ECHO, and ROTOR are part of the device research program of HumRRO Division No. 6 (Aviation) at Fort Rucker, Alabama. Dr. Wallace W. Prophet is Director of the Division, and Dr. Paul W. Caro is in charge of training device research for the Division.

Military support for the study was provided by the U.S. Army Aviation Human Research Unit, Fort Rucker. LTC Robert O. Carter is the present Unit Chief.

In developing the information for this study, the cooperation of many persons at USAAVNS, both military and contractor, was necessary. Of special note was the contribution of the Third Army Training Aids Center in constructing the U-21 Ute procedures trainer designed by HumRRO personnel.

Identification of proprietary products in this report is for purposes of research documentation; it does not, in itself, constitute an official endorsement by either HumRRO or the Department of the Army.

HumRRO research for the Department of the Army is conducted under Contract DAHC 19-70-C-0012. Training, Motivation, Leadership Research is conducted under Army Project 2Q062107A712.

Meredith P. Crawford
President
Human Resources Research Organization

SUMMARY AND CONCLUSIONS

MILITARY PROBLEM

Over a period of several decades there has been a significant increase in the complexity of Army aircraft and the Army's aviator mission. During World War II, light, single-engine aircraft were employed principally in aerial reconnaissance roles. By the mid-1960s, helicopters constituted a significant part of the Army's aircraft inventory, and multi-engine reciprocating and turbine-powered aircraft also had been added. The aviation mission had undergone corresponding expansion to meet the requirements of warfare in Southeast Asia. The training required for Army aviators who were destined to fly the more complex aircraft had become a major undertaking. With a requirement to train over 7,000 new aviators each year and to provide advanced training to thousands more, the operation of pilot training programs became extremely costly.

During the 1960s, in support of the Army's growing aviation role, HumRRO Division No. 6 (Aviation) undertook a program of research in the design and utilization of training devices for pilot training. The program included inexpensive, low fidelity mockup devices for procedures training as well as relatively expensive, high fidelity aircraft simulators in which extensive mission-specific training could be conducted. The research program also included the development of techniques to be employed in the study of the cost-effectiveness of such devices when utilized in a specific training program.

In Fiscal Year 1967, two "off-the-shelf" aircraft, the T-42 and the U-21, were added to the Army's inventory of fixed wing aircraft. No training devices were available for either aircraft, and the U.S. Army Aviation School, the agency responsible for training in each, was concerned over the adequacy of existing Army fixed wing training devices to meet training requirements such as those resulting from the introduction of the new aircraft.

Because it was felt that training devices offer great potential for reducing training costs and upgrading the quality of flight instruction, HumRRO was requested to review the T-42 and U-21 training programs and determine the requirements for training devices for them. Where requirements for mockup type devices might be identified, HumRRO assistance also was requested in constructing devices and developing training programs to be used with them.

The various phases of the study were completed by HumRRO Division No. 6, and the findings were reported to the Aviation School during FY 1968 for their operational application as appropriate. While current Army aviation training is geared to lower manpower requirements and its emphasis has shifted more heavily to rotary wing requirements, the training device considerations evaluated in the research remain relevant for both military and some civilian types of flight instruction. This report has therefore been prepared to provide a record of the concepts and methodology that were developed to analyze the various types of training and their differential requirements for training devices and to illustrate their application.

RESEARCH PROBLEM

The two new aircraft which precipitated the Army's interest in new devices had to be viewed in the context of the over-all Aviation School pilot training program. While the aircraft for which training is intended is a major determiner of the content of any training program, consideration also must be given to the skills possessed by the trainee prior to training and to the usefulness, during subsequent operational assignments, of any training received. For example, the T-42 is an aircraft used for undergraduate pilot training only, and is not used operationally by the Army. The U-21, on the other hand, is an operational aircraft, and Army policy limits training in it to relatively experienced aviators.

With the concurrence of the Aviation School, the proposed research was expanded to a systematic study of synthetic training requirements for all fixed wing pilot training programs conducted by the Aviation School. During the course of the study, the scope was further expanded to include the development of cost information relative to a particular training device in the T-42 training program, so that cost-effectiveness data might be used in making a decision on acquiring an off-the-shelf device for that program.

Speaking more generally, the research problem was to develop a method for analyzing training programs in such a way that specific and *differential* needs for training devices could be determined, and the adequacy of available devices for meeting those needs could be evaluated.

APPROACH

To accomplish the requested study, a group of HumRRO aviation psychologists and technicians acquired detailed information on each fixed wing training course—and each phase of each such course—conducted by the Aviation School. Already thoroughly familiar with Army aviation training through years of specialized research in the field, the group reviewed the syllabi of each course, conducted extensive interviews with fixed wing instructor pilots and flight training administrators, observed training activities at the Aviation School at Fort Rucker and at the U.S. Army Aviation School Element at Fort Stewart, and participated, both as pilots and as observers, in a number of training flights. Visits were also made to other pilot training programs and to training device manufacturers.

The research staff also reviewed records to determine the typical flow of trainees through the Army's graduate and undergraduate pilot training program and to determine the prerequisites and typical qualifications of trainees entering each course under study. Available planning documents were reviewed, and future plans of the Army concerning requirements for fixed wing aviators and the conduct of their training were forecast.

In order to be assured that training device requirements defined were directly related to needs of the Army that were relatively stable, the first step in the analysis consisted of

defining the probable training environment of Army aviation. It was defined in the form of a series of assumptions concerning Army aviation fixed wing training as it can be expected to exist for perhaps five years. These assumptions, defined to provide policy guidance for drawing conclusions, were:

(1) The Army Aviation School mission is to provide the following four types of fixed wing flight training to Army Officers, Warrant Officers, and Warrant Officer Candidates.

(a) Contact flight training to trainees who either have no previous aeronautical ratings or have rotary wing ratings only.

(b) Instrument flight training to trainees who either have no previous instrument rating or have rotary wing instrument ratings only.

(c) Twin-engine qualification for trainees who either are fixed wing rated or are undergoing initial entry fixed wing training.

(d) Transition training to a particular tactical aircraft for trainees who are fixed wing, twin-engine, instrument-rated Army aviators.

(2) The initial contact, instrument, and twin-engine qualification phases of fixed wing training will continue to be conducted in aircraft that have been assigned no tactical mission.

(3) Initial fixed wing contact flight training will continue to be conducted in the T-41 or a similar aircraft.

(4) Present Army single-engine tactical fixed wing aircraft are obsolete and will be phased out of the inventory. The tactical missions they perform will be performed by rotary wing or multi-engine fixed wing aircraft in the future.

(5) Instrument flight training and twin-engine qualification will continue to be conducted in the T-42 or a similar nontactical, multi-engine aircraft.

(6) All Aviation School training for multi-engine tactical aircraft will continue to be conducted at one location, thus allowing concentration of appropriate training equipment.

RESULTS

(1) Each fixed wing aviator course, by phase, was analyzed and described in terms of (a) its training objective, (b) the qualifications of its entering trainees, (c) the characteristics of the aircraft in which training was being conducted, and (d) the use, if any, being made of training devices.

Training programs of other military and/or civilian pilot training organizations that were similar were reviewed with respect to their use of training devices. The principal device characteristics which could be used to attain, in whole or in part, the stated objectives of each course were identified.

All known devices which might be judged suitable were reviewed and analyzed, and conclusions were drawn concerning the introduction of devices in each training course which would be expected to lead to more cost-effective pilot training.

(2) In the courses in which T-42 training is conducted, a particular commercially available training device was judged appropriate for use to facilitate the cost-effective attainment of the Army's stated training objectives. At the request of the Aviation School, the cost of training in that device was compared with cost of training in the T-42 aircraft. The cost study approach used was under development at that time by HumRRO in a study of rotary wing training device cost effectiveness.

(3) In the course which conducted training in the U-21, a procedures training device was developed with the assistance of the Third U.S. Army Training Aids Center. Use of this device—a full-scale mockup of the aircraft cockpit—by the Department of Fixed Wing Training reduced requirements for use of the aircraft for procedures training, and thus led to an increase in the amount of flight training time available in the aircraft.

CONCLUSIONS

(1) The majority of existing fixed wing training devices were not optimally suited to existing Army training requirements.

(2) Appropriate use of training devices prior to or early in contact flight training has typically led to reductions in flight-related attrition among trainees, reductions in time required to meet various flight criteria, and improved performance during training.

(3) A particular commercially available device, to be used with a simple extra-cockpit symbolic visual presentation, was judged to be appropriate for use in the Army's initial contact flight training program.

(4) No existing devices were considered optimum to the Army's instrument flight training and twin-engine qualification training requirements. The development of devices with appropriate characteristics would require a considerable period of time.

(5) A particular commercially available device under development, while not optimum, would be suitable for use in fixed wing instrument and twin-engine transition training. Use of this device was projected to be cost effective.

(6) The approach used by the Aviation School for the acquisition and use of relatively sophisticated rotary wing aircraft simulators can serve as a useful model for the design and acquisition of comparable fixed wing training equipment for use in training programs which involve transition to tactical aircraft.

(7) The Aviation School would benefit from the expanded use of procedures training devices in each course involving transition to its more sophisticated aircraft.

(8) The systematic method developed in the research to analyze courses with reference to training device requirements appeared to provide a practical and meaningful approach to determining and differentiating training device needs and evaluating available training device equipment.

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Determining Training Device Requirements in Fixed Wing Aviator Training

THE PROBLEM

The increase, continuing over the past several decades, in the complexity of Army aircraft and of the Army aviator's missions has placed a heavy training requirement on the Army aviation training system. In recent years, this requirement has involved the training of as many as 7,400 new aviators in a single year and the advanced training of additional thousands.

Because of both the complexity and the expense of training aviators to the performance levels and diversity needed for accomplishing Army missions, the U.S. Army Aviation School at Fort Rucker, Alabama, is a major user of synthetic flight training equipment. However, when two "off-the-shelf" aircraft, the T-42 and the U-21, were added to the Army's inventory of fixed wing aircraft in Fiscal Year 1967, no training devices were available for either aircraft. Further, most of the devices being used in other training courses with other aircraft can best be described as "hand-me-downs"—designed to meet training requirements of other services in bygone eras, and at best marginally suited to present Army training requirements. Advances in Army aircraft and the techniques for employing them had not been matched by advances in Army synthetic training capabilities.

Development of improved equipment for Army rotary wing training has been under way since FY 1966. That equipment is known as the Synthetic Flight Training System (SFTS) (1). The SFTS consists of modern synthetic trainers that will enable the Aviation School to implement currently available aviation training technology in their various rotary wing training programs. Comparable equipment for Army fixed wing training is not on hand or under development.

In FY 1968, Aviation School training authorities were concerned not only about the need for training devices resulting from the introduction of the T-42 and U-21 aircraft, but also about the general adequacy of training devices in other fixed wing training courses. Taking the view that training devices offer great potential for reducing training costs and upgrading the quality of flight instruction, the School asked HumRRO to review the T-42 and U-21 training programs to determine the requirements for training devices in these courses and to perform some evaluative and developmental device work.

The research programs which HumRRO Division No. 6 (Aviation) had conducted in support of the Army aviation training mission during the 1960s dealt, in part, with design and utilization of devices for pilot training and had ranged from exploration of inexpensive low fidelity devices for procedures training to design factors for high fidelity aircraft simulators.[1] For example, the Division participated in the development of the SFTS for rotary wing training.

[1] This research was performed primarily under Work Unit ECHO, Synthetic Flight Training Programs and Devices, and Work Unit ROTOR, Design of Rotary Wing Training Devices, and is continuing under Work Unit SYNTRAIN, Modernization of Synthetic Training in Army Aviation.

The requested research related specifically to training devices for the T-42 and U-21 aircraft was completed by HumRRO during FY 1968 and the findings were reported to the Aviation School at that time. While present Army aviation training is geared to lower manpower requirements than in 1968, the concepts and methodology used in this training analysis and device evaluation remain relevant for both military and some civilian types of flight instruction.

This report has therefore been prepared to provide a record of the methods developed for the training analysis, the conceptual approaches used in contrasting the demands of various kinds of training, and the resulting evaluation of the devices then available. No attempt has been made to update the information on status or availability of devices, since the purpose of the report is to describe a methodology for analysis rather than to report the evaluations as such.

RESEARCH OBJECTIVES

The primary objective of the study reported here was to determine whether the effectiveness of the U.S. Army's fixed wing aviator training program might be enhanced through the increased use of synthetic flight training equipment. Where it could be concluded that training effectiveness would be thus increased, the objective included specifying the principal characteristics of appropriate training devices and identifying sources of devices with such characteristics, if available.

On the assumption that procedures training devices would increase the effectiveness of aviator training in the Army's U-21 transition course, a secondary objective was stated for the research, that of assisting the Aviation School in developing relatively low cost devices to be used for U-21 procedures training (earlier HumRRO research with such devices had demonstrated their effectiveness in procedures training). During the course of the study, another objective was added—determining the probable cost effectiveness of introducing a particular commercially available device for use in the Army's fixed wing instrument and twin engine qualification training programs.

APPROACH

The research team organized at HumRRO Division No. 6 (Aviation) consisted of aviation and human factors psychologists and technicians. All of the team members had previous experience with pilot training and training device research in support of Army aviation and were familiar with the training devices development activities of various manufacturers.

To accomplish the primary objective, the study team engaged in a series of activities oriented toward comprehensive analysis of, need for, and availability of training devices. These activities included reviews, by phase, of each fixed wing pilot training program conducted by the Aviation School, identification of considerations pertinent to the use of training devices in each of those programs, and evaluation of all available devices that might be appropriate for use in them.

To meet the supplementary objectives, design concepts and information and human factors support were provided to the Third U.S. Army Training Aids Center at Fort Rucker in developing a procedures training device for the U-21 aircraft, and data provided by the Aviation School and a training device manufacturer were used in developing cost-effectiveness information concerning the use of a commercially available device in the Army's instrument training and twin engine transition programs.

The assumptions and constraints that provided the context for the study are stated in the following subsection, after which the methods used for the analysis of training device needs will be described in some detail. The methods used in meeting the other objectives will then be described briefly but, since this work was not directly a part of the training device needs analysis, details of these supplementary projects will be presented in appendices rather than in the main report.

STUDY ASSUMPTIONS AND LIMITATIONS

By its nature, the conduct of this research required a limited look into the future as well as study of the present. It cannot be concluded, for example, that acquiring a particular training device would be cost effective unless it may be assumed that the requirement for the device is a relatively stable one. Thus, an initial step in the conduct of the study was to state certain assumptions concerning the nature of the Army's fixed wing training requirements. These assumptions then provided guidance of a policy nature for the drawing of conclusions during subsequent study activities.

The assumptions underlying this study were derived on the basis of review of available Army planning documents and discussions of future Aviation School activities with cognizant Army personnel. These assumptions, made with regard to probable training circumstances for a period of perhaps five years, were:

(1) The mission of the U.S. Army Aviation School requires it to provide the following types of fixed wing flight training to Army Officers, Warrant Officers, and Warrant Officer Candidates:

(a) Contact flight training to trainees who either have no previous aeronautical ratings or have rotary wing ratings only.

(b) Instrument flight training to trainees who either have no previous instrument rating or have rotary wing instrument ratings only.

(c) Twin engine qualification for trainees who either are fixed wing rated or are undergoing initial entry fixed wing training.

(d) Transition training to a particular tactical aircraft for trainees who are fixed wing, twin-engine, instrument-rated Army aviators.[1]

(2) The initial contact, instrument, and twin-engine qualification phases of fixed wing training will continue to be conducted in aircraft that have been assigned no tactical mission.

[1] A fifth aspect of the Aviation School fixed wing training mission, that of providing tactical training of the type given in the final phase of the O/WOFWAC, is not included here. It is assumed that training will not be performed when the 0-1 aircraft is phased out (see 4th assumption).

(3) Initial fixed wing contact flight training will continue to be conducted in the T-41 aircraft or in another aircraft of similar configuration, power, and gross weight.

(4) Present Army single-engine tactical fixed wing aircraft are obsolete and will be phased out of the inventory. The tactical missions they now perform will be performed by rotary wing or multi-engine fixed wing aircraft in the future.

(5) Instrument fight training and twin-engine qualification will continue to be conducted in the T-42 aircraft or in another nontactical multi-engine aircraft of similar configuration, power, and gross weight.

(6) All training for multi-engine tactical aircraft for which the Aviation School has responsibility will continue to be conducted at one location, thus allowing concentration of training equipment appropriate to that function.

It was beyond the scope of this research to perform a detailed study and analysis of the potential operational mission requirements which *future* Army Aviation training will support. Therefore, the study is based on projected continuation of present types of training activities and assumes these will be appropriate for future operational mission requirements.

It should be noted also that this report deals only with fixed wing training device requirements of the Aviation School at Fort Rucker and the Aviation School Element at Fort Stewart. The scope of the effort did not permit study of aviation training requirements at non-USAAVNS aviation units—for example, in the training given in the OV-1 at Fort Huachuca; for devices to be used in the maintenance of proficiency on instrument and other flight-related tasks by Army aviators; or in the use of synthetic flight training equipment for the primary or secondary selection of aviator trainees. To be complete, a study of fixed wing training device requirements for the Army should include consideration of such additional factors.

METHODS USED TO ANALYZE TRAINING DEVICE NEEDS

Review of Fixed Wing Training

Initial preparation for the analysis of training device requirements consisted of reviewing all training documents associated with fixed wing training at the Aviation School. These documents included lesson plans and syllabi, class schedules, student grade folders, and all available planning documents. The research staff visited each training location to observe the training being conducted, and interviewed instructional and administrative personnel and students concerning the nature of that training. The staff members familiarized themselves with each fixed wing aircraft if they were not already sufficiently knowledgeable; this process included completing transition requirements for two training aircraft.

Visits were made by the research staff to several locations where comparable pilot training programs were being conducted. These included Navy, Air Force, and civilian agencies.

On the basis of analyses of the information thus obtained, a description was prepared for each fixed wing training course, by phase, conducted by the Aviation School. These descriptions were organized for easy comparison across courses to facilitate the identification, if any, of common training requirements. The organization consisted of separate but parallel descriptions of each course according to (a) its training objectives, (b) assessment of the skills and knowledges possessed by the students prior to training, (c) description of the aircraft in which training is conducted, and (d) identification of any training devices used in the course.

Identification of Training Device Considerations

Two principal activities, conducted concurrently, provided the bases for determining whether training devices could contribute to the effectiveness of the conduct of the courses under study.

(1) Practices in training programs other than those at the Aviation School were determined.

(a) All other known training programs were reviewed to determine whether training devices were being used in them, and if so, to obtain descriptions of those devices. While the previously mentioned visits to Navy, Air Force, and civilian training agencies were useful in accomplishing this activity, it was found that information related specifically to training device usage could be obtained efficiently by telephone contact.

(b) A literature search was made to identify studies which had evaluated the effectiveness of training devices in various pilot training programs. To supplement the literature survey, persons were contacted who were known by the research staff to be engaged in research on training device design and utilization, and their opinions concerning the adequacy of various training devices were solicited.

(2) The characteristics of devices required to support each Army fixed wing training program were identified. The approach used was based upon concurrent HumRRO research which has been reported elsewhere (2). It consisted of the systematic analysis of stimuli and responses involved in the performance of those skills for which training was intended.

The procedures employed were those associated with conduct of an equipment-device Task Commonality Analysis (TCA). These procedures identify task elements of criterion performance in the operational equipment. Inasmuch as the TCA procedures were then under development,[1] the analyses conducted in the present study were largely informal. Nevertheless, they provided a basis for the identification of characteristics of training devices which could be expected to contribute to the effectiveness of each course under study.

Evaluation of Available Devices

The Task Commonality Analysis procedures also were employed to evaluate the suitability of existing devices for the fixed wing courses under study. While these

[1] They have since been reported in HumRRO TR 70-7 (2).

procedures were, again, informal because they were still under development at that time, they provided the means for identifying the stimulus-response components of the devices. They were used for each pilot training device currently in the Army's inventory, regardless of whether it was being used for the course under study, as well as for each non-Army device that was judged even remotely suitable.

Based upon the evidence thus assembled, conclusions were drawn concerning training device requirements for each fixed wing course, by phase, conducted by the Aviation School. These conclusions are reported as part of the separate section of this report which presents the review resulting from the analysis activities.

SUPPLEMENTARY RESEARCH

Cost-Effectiveness Analysis

One of the conclusions resulting from the main analysis was to the effect that a particular device then under development by a training device manufacturer would be suitable for use in the Army's fixed wing instrument and twin-engine transition training programs. Following discussion with the Aviation School, that conclusion resulted in two further activities:

(1) Relevant portions of the TCA data were made available through the Aviation School to that manufacturer to enable him to modify the cockpit portion of his device to more closely resemble the training aircraft.

(2) A study was conducted to determine the impact that introduction of that device could be expected to have upon training costs in the Aviation School's program.

The procedures used in the cost study were being developed by HumRRO in another research project and subsequently have been reported elsewhere (3). They involved computation of all costs that could be attributed to the conduct of instrument and twin-engine transition training in the course separately for the flight and the synthetic flight training portions. Based upon these data, estimates were developed of annual costs and possible savings associated with selected combinations of flight and synthetic flight training.

These computations were supplied to the Aviation School for use in considering possible adoption of the device. They are presented in Appendix A; the methods used for the computation are described elsewhere (3) in greater detail.

Development of Low-Cost Procedures Trainers

As the study verified the assumed requirements for a procedures training device in the U-21 transition course, its development was undertaken in conjunction with the Third U.S. Army Training Aids Center. Specifications for the device were developed by HumRRO, based upon previous HumRRO research (4, 5, 6, 7, 8), and all construction was accomplished by Training Aids Center personnel.

Upon completion of the development and check out of the U-21 procedures trainer, the study staff developed a training program for use with it. The trainer was then

delivered to the Aviation School and incorporated into the U-21 transition training program. The trainer and the program for its use are described in Appendix B.

A REVIEW OF TRAINING DEVICE CONSIDERATIONS IN FIXED WING FLIGHT TRAINING COURSES

This section presents the analysis of training device needs and the evaluation of available devices that was produced in 1968. No effort has been made to update details of information on training courses or device availability or to review the conclusions for current applicability, because the primary purpose of reproducing the review here is to illustrate the application of the concepts and methods developed in the study. Presenting a fully current statement—as of 1968—for operational use was accomplished by submitting this review to the Aviation School at the time the analysis was completed. To the extent that the assumptions about Army aviation are still applicable, and to the extent that there are not newly available training devices or equipment that would supersede those analyzed, the conclusions can be considered to be current.

PRIMARY CONTACT TRAINING (O/WOFWAC, Phase A)[1]

Description of the Phase

Phase Objective. The objective of the primary contact phase of the Officers and Warrant Officers Fixed Wing Aviators Course (O/WOFWAC) is to train commissioned officers, warrant officers, and warrant officer candidates in the basic flying techniques required to fly fixed wing aircraft.

All flight training in this phase is conducted under visual flight rules. The content of the course is limited to training the aviator to perform normal day and night take-off and landing operations; traditional coordination exercises (e.g., stalls and eights around pylons), forced landings, and day cross-country navigation. The flight training consists of 50 hours of dual instruction and solo practice, and the graduate has skills approximately comparable to those required for the award of a civilian private pilot license.

Trainee Qualification. This is an initial entry flight training course, and trainees accepted for it typically have no prior aeronautical ratings or experience. To be eligible, commissioned officers and warrant officers must meet the requirements for Army aviation flight training, as established by AR-611-110 (9), and warrant officer candidates must have successfully completed the Warrant Officer Indoctrination Training Preflight Course.

Training Aircraft. The aircraft used in Phase A is the T-41, a light, four-place, high-wing, single-engine aircraft that has been assigned no tactical mission in the Army.

[1] At the time of publication of this Technical Report, the Officer/Warrant Officer Fixed Wing Aviator Course had been discontinued.

The T-41 also is used as a primary flight trainer by the U.S. Air Force. Its civilian version is the Cessna 172E.[1] Its flight controls and aerodynamic characteristics are similar to those of other light aircraft typically used in civilian private pilot training programs.

Present Training Devices. Six hours of synthetic flight training are given, using the 1-CA-1, a 1946-vintage fixed wing basic instrument trainer. The device training program consists of familiarization with the device and an introduction to instrument flight techniques. The use of the 1-CA-1 during the primary contact phase is intended to facilitate subsequent instrument flight training rather than as an aid to Phase A flight training.

Training Device Considerations

Review of Training Devices Used in Similar Training Programs

Primary contact flight training in the O/WOFWAC is comparable to civilian private pilot training, to primary contact rotary wing training at the U.S. Army Primary Helicopter School (USAPHS), and to corresponding phases of other initial entry military flight training programs. A variety of training devices have been used from time to time in such training. Some of the devices (e.g., the 12BK-1 Landing Trainer, 10, and basic instrument training devices similar to those currently used in Army instrument flight training programs, 11) have been of little or no positive training value. Others (e.g., the School Link and the Whirlymite Helicopter Trainer) have resulted in significant reductions in the amount of flight training required to reach criterion performance in the air (12), and to significant reduction in flight-related attrition among trainees (13).

It is the consensus of personnel who are familiar with the aviation training literature and have relevant primary flight training experience, that appropriate use of properly designed synthetic flight training devices prior to or early in such training can lead to reductions in flight-related trainee attrition and in the time required to meet various flight criteria, as well as to improvements in performance during training. Each of these benefits was demonstrated in an Army training environment during the experimental use by HumRRO of the Whirlymite Helicopter Trainer in primary contact rotary wing training at the USAPHS (14). Similar improvements in flight training efficiency probably would result from the use of an equally suitable device in other primary contact flight training programs.

Characteristics Needed in Devices for Primary Training

The transfer of flight skills from a synthetic device to an aircraft is dependent upon the degree to which the tasks to be performed in the device correspond to the tasks to be performed in the aircraft—that is, the degree of task or psychological fidelity of the simulation. Psychological fidelity is limited by physical or engineering fidelity—that is, by the extent to which the device looks and responds like the aircraft or aircraft type being simulated. The degree of engineering fidelity required to provide the necessary psychological fidelity for a particular training application depends upon the specificity of the tasks to be trained.

[1] Identification of proprietary products in this report is for purposes of research documentation; it does not, in itself, constitute an official endorsement by either HumRRO or the Department of the Army.

For example, where the training to be provided consists of learning to operate a specific high-performance aircraft within close tolerances in an operational environment, a high degree of engineering fidelity in the device would be needed, so that specific, detailed tasks could be learned and related to unique aircraft characteristics. On the other hand, where the training to be provided consists of learning to operate any one of a general type of low performance aircraft safely while performing a limited number of relatively simple maneuvers to generally relaxed tolerances, a much lower degree of engineering fidelity in the device is indicated.

In the former case, *quantitatively*[1] accurate reproduction of all or nearly all physical characteristics of the aircraft is required in order that specific skills may be learned for subsequent transfer to the aircraft; this requirement is for accuracy in the simulation of *amount* and *rate* of change. In the latter case, the training requirement is only for the development of general, non-aircraft-specific skills, so *qualitative* rather than quantitative fidelity of reproduction of engineering characteristics is required. That is, the trainer must consistently reproduce responses which are of like quality to those of the aircraft; this requirement is for accuracy in the *direction* of change.[2]

In the case of a primary contact flight training device, the tasks being learned do not dictate a requirement for a high degree of engineering fidelity. The development of a high level of skill in flying the T-41 is of no particular value since the T-41 is not a tactical aircraft. The maneuvers performed in the T-41 in this and in the following phase of training are relatively simple and are performed to generally relaxed tolerances. The major objective of the training is to provide a base upon which specific and detailed flight skills can be built, rather than to build such skills in flying a nontactical aircraft. Only qualitative engineering fidelity of simulation of the T-41 is required in order to provide the degree of psychological fidelity needed to assure adequate transfer of primary flight skills.

A training device to be used as a primary contact synthetic flight trainer, then, should have the following characteristics:

(1) Flight and Engine Dynamics. The exact aerodynamic and engine characteristics of the T-41 or of any other specific aircraft do not have to be faithfully reproduced in a primary contact flight training device. It is necessary only that all responses of the device to pilot control input be qualitatively similar to corresponding responses of the training aircraft. It is important, however, that all significant parameters of the engine and flight dynamics be incorporated in the device's design; that is, the simulation must be qualitatively complete. Power-on stalls, for example, can be practiced in a synthetic flight trainer only if the mathematical model used in the flight dynamics simulation contains terms for longitudinal velocity and true airspeed.

(2) External Visual Reference. Obviously, an external visual reference is necessary for the performance of contact flight maneuvers. A real-world representation

[1] Throughout the remainder of this report, the terms "qualitative fidelity" and "quantitative fidelity" will be used in the general meanings described here.

[2] A review of recent research related to fidelity of simulation and transfer of training may be found in reference 15.

consisting of a high-fidelity, closed-loop visual attachment would be desirable, but such displays are so costly that they probably could not be justified on a cost-effectiveness basis, for use with a primary contact flight training device. It has been demonstrated that a "display" of relatively low fidelity—even an inexpensive symbolic display—can lead to much useful training.

In the study reported by the University of Illinois (12), and in another in a high school aviation training program (16), useful training in contact flight maneuvers has been obtained using a "visual display" consisting only of a horizon reference line on a homogeneous field; it has sufficient psychological fidelity to enable trainees to acquire the skills needed to control aircraft attitude during contact flight. In other research, somewhat more elaborate symbolic displays (a projected runway silhouette which changes shape in relation to simulated aircraft attitude and altitude, 17) have facilitated the development of aircraft landing skills. Such simple visual displays can be used in any appropriately configured synthetic training device—one with a clear windscreen that permits viewing of the external reference from the trainee's seat.

(3) Cockpit Motion. The primary purpose of a simple, symbolic visual display, as described, is to provide the trainee with attitude control cues in relation to an external reference—the relative angles between the vertical, horizontal, and lateral axes of the trainer and the horizon. In order to vary these angles, motion must be represented either in the visual display or in the cockpit. Simulation engineering personnel indicate that motion of the cockpit generally is feasible. From the training standpoint, cockpit motion has other advantages as well. For example, it makes the training task appear more "realistic" to the trainee and thus enhances his motivation to use the device. Cockpit motion—preferably in the pitch, roll, and yaw dimensions—is considered to be an essential characteristic for a primary contact flight training device.

Evaluation of Available Devices

Army Devices

The two available Army fixed wing synthetic flight trainers, the 1-CA-1 and the 2-B-12A, were examined to determine whether either might be useful in primary fixed wing contact flight training. The 2-B-12A was not considered satisfactory because it has incomplete aerodynamics and engine simulation, does not have clear windscreens, and has no motion.

The 1-CA-1, with modification, could be used as a minimally acceptable primary contact training device. It has a satisfactory motion platform, and it probably could be modified to provide a reasonable view of an outside reference. Its aerodynamic and engine simulation, while more complete than that of the 2-B-12A, is not as complete as would be desired but would permit performance of many primary contact flight maneuvers.

Non-Army Devices

Only one training device, known to be in existence or under development, was appropriate for use in the Army's primary contact fixed wing training phase. This device is the General Aviation Trainer, Model 1 (GAT-1), which is built by the Link Group, General Precision System, Incorporated.

The GAT-1 meets the flight dynamics and cockpit motion requirements outlined above for a primary contact flight trainer. Its aerodynamics model is the Cessna 150, and all significant flight characteristics of that aircraft are simulated in a qualitatively realistic manner. It has a three-axis motion system which simulates pitch, roll, and yaw cues. Although it incorporates no visual display, it provides extra-cockpit visibility approximately comparable to that of a light, single-place aircraft. At the time of the study, the GAT-1 was being used as a contact and instrument primary flight trainer in a training program at Greene Central High School, Greene, New York (16). A simple visual display, consisting of a horizon line on a homogeneous field, was being used with the GAT-1 in this high school flight training program.

ADVANCED CONTACT TRAINING (O/WOFWAC, Phase B)

Description of the Phase

Phase Objective. The purpose of advanced contact is to train officers, warrant officers, and warrant officer candidates to perform advanced contact flight maneuvers such as chandelles; lazy eights; power-off approaches; barrier, short field, and road strip take-offs and approaches; and night navigation. The flight training in this phase consists of approximately 20 hours of dual instruction and 30 hours of solo practice. All flight training is conducted under visual flight rules.

Trainee Qualification. Successful completion of O/WOFWAC Phase A is the only trainee qualification requirement for this phase.

Training Aircraft. The training aircraft, as in Phase A, is the T-41.

Present Training Devices. Six hours of synthetic flight training are given in Phase B, using the 1-CA-1 device. The training is a continuation of the training given in the 1-CA-1 during Phase A, and its purpose is to facilitate the instrument flight training given during a subsequent phase of the course rather than primarily to aid in the development of advanced contact flight skills.

Training Device Considerations

Training Devices Used in Similar Training Programs

No synthetic flight training devices are known to be in use elsewhere to provide either fixed wing or rotary wing advanced contact flight training.

The term "advanced contact training" is used here within the specific context of the O/WOFWAC—the portion of training in which the trainee's experience level is increased from his 50th hour of flight experience to 100 hours. At much higher levels of experience synthetic flight trainers are used in training programs involving advanced contact maneuvers. Several commercial airlines, for example, use highly sophisticated training devices, or aircraft simulators, in jet transition training courses for airline pilots (18). The trainee characteristics and training considerations in such programs are unlike those of O/WOFWAC Phase B, and such programs are not considered advanced contact flight programs for the purposes of this report.

Characteristics Needed in Devices for Advanced Training

Performance of advanced contact flight maneuvers requires reference to objects and details in the real-world, extra-cockpit environment. The training consists largely of maneuvering the aircraft in close proximity to external objects (e.g., barriers and objects within confined areas) and performing advanced maneuvers. These maneuvers are performed to tolerances only slightly more restrictive than those acceptable for the performance of primary maneuvers during Phase A. No particular significance is placed upon the development of skill in the T-41 *per se* since it is a nontactical aircraft.

For these reasons, the tasks to be performed during Phase B dictate that a synthetic flight trainer should simulate the external visual scene to a relatively high degree of fidelity, but qualitative fidelity of the simulation of the aircraft itself would be acceptable.

The flight and engine dynamics and cockpit motion characteristics of a device that might provide such training are similar to those identified as device requirements for the Primary Contact Phase. The characteristics required for an external visual reference, however, would be much more elaborate because many of the maneuvers must be performed in physical proximity to real-world objects. The use of a simple, extra-cockpit symbolic visual display, such as would be appropriate for attitude control tasks, probably would be of negligible training value during this phase. Rather, a relatively high fidelity pictorial representation which changes as a function of simulated aircraft attitude and altitude is necessary.

A recent review of visual simulation technology conducted by HumRRO indicated that the present state-of-the-art will not permit the fabrication of a high-fidelity visual display appropriate for all advanced contact flight training maneuvers. The resolution required to evaluate a landing area and negotiate a barrier, for example, cannot be provided in an open-loop visual display at the present time.

Evaluation of Available Devices

No synthetic flight training devices that could be expected to enhance the efficiency of advanced contact flight training in the O/WOFWAC are known.

INSTRUMENT FLIGHT TRAINING (O/WOFWAC, Phase C)

Description of the Phase

Phase Objectives. The objectives of this phase are to qualify trainees in the operation of twin-engine aircraft, and to qualify them for the award of an Army Instrument Card (Standard) in accordance with current Federal Aviation Administration standards and applicable Army regulations.

The flight training portion of this phase consists of 10 hours of twin-engine qualification training, of which 30 minutes is solo, and 50 hours of instrument dual instruction, all of which is conducted under simulated or actual instrument conditions. Twin-engine qualification training precedes instrument training.

Trainee Qualification. Successful completion of O/WOFWAC Phase B is the only trainee qualification for this phase.

Training Aircraft. All inflight training for this phase is administered in the twin-engine T-42 aircraft. This aircraft was acquired by the Army for training purposes only and has been assigned no tactical mission. It is not considered to be a high-performance aircraft, and it presents no significant control problems under routine or emergency conditions that are not common to other, light, twin-engine aircraft with similar power and type of engine. Further, there are no on-board systems whose operations present unique twin-engine training requirements. So far as could be determined from interviews with T-42 pilots, there are no unique, dangerous aerodynamic characteristics in this aircraft. The T-42 is sold commercially as the Beechcraft Baron.

Present Training Devices. Approximately 20 hours of synthetic instrument flight training are given during Phase C. The device used is the 2-B-12A, a stationary device procured to meet an Army-wide instrument trainer requirement for the 1960-65 time frame. A design requirement for the device was that it provide qualitative simulation of a light, single-engine, relatively low performance aircraft. While no specific aircraft was identified as the design basis for the 2-B-12A, it was modeled generally after the U-6 Beaver, the aircraft which was the Army's instrument training aircraft during the 1960-65 time frame.

As noted earlier, each trainee receives 12 hours training in Device 1-CA-1 during Phases A and B. The purpose of present synthetic training in Phases A, B, and C is to facilitate trainee performance during the instrument qualification portion of Phase C.

Training Device Considerations

Training Devices Used in Similar Training Programs

Synthetic flight training devices are widely used in both fixed wing and rotary wing instrument training programs. Each military service uses them, as do most civilian flying schools. Most flying schools use single reciprocating engine aircraft for instrument flight instruction, and consequently most instrument training devices are modeled after single-engine aircraft.

An example of a more recently developed instrument training device is Device 2B21, a multiple cockpit instrument synthetic flight trainer which was developed by the U.S. Naval Training Devices Center (NTDC) for a Navy training requirement. The 2B21 simulates the pilot station of the T-28B aircraft, the tandem-seating, single reciprocating engine aircraft used by the Navy as its initial instrument trainer in single-engine training phases of its initial entry pilot training program. The content of this part of the Navy's instrument training program is similar to the instrument portion of the Army's O/WOFWAC Phase C, except that it does not include ILS (Navy aircraft are not ILS equipped). The length of this phase of Navy training is under 30 flight hours, compared with the 50 flight-hour length of the portion of Phase C devoted to instrument training. Twenty-one hours of instruction are given in the 2B21.

The 2B21 is the first instrument flight training device to have all simulation computations performed by a digital computer, although digital computers have been used in more sophisticated flight simulators for a number of years. The 2B21 has a fixed

base (i.e., no motion) and it uses one computer to drive four cockpits. All significant parameters of the engine and aircraft, including sound, are simulated, and the comprehensive simulation of radio communication and navigation facilities provided allows the trainee to perform any navigation operation that could be performed in the T-28B in flight under instrument conditions. A more detailed description of Device 2B21 may be found in NTDC publications (19).

Naval aviation trainees completing the basic and radio instrument training phases proceed to other phases of instruction. Before receiving his wings, each aviator qualifies in an operational type aircraft (i.e., multi-engine, jet, or helicopter) and receives additional instrument instruction in it. Trainees entering the multi-engine program may be compared to Army O/WOFWAC trainees to the extent that both obtain twin-engine ratings during initial entry training and both receive at least a portion of their instrument training in twin-engine aircraft.

Navy multi-engine training is given in the S2-F aircraft. The S2-F also is the aircraft in which additional instrument training is given. The multi-engine transition and instrument training during this phase of Navy training consists of approximately 40 hours of instruction in the aircraft and 21 hours in a synthetic instrument flight training device.

The synthetic instrument flight trainer is the 2B13, a twin-engine device modeled after the S2-F aircraft. The 2B13 is driven by an analog computer, and the simulation of the S2-F is approximate—that is, simulation of the S2-F aerodynamics and engine is qualitative rather than quantitative. The cockpit of the device is similar to that of the aircraft in that all controls and displays required for the training given are present although they are not necessarily identical in location or appearance to corresponding items in the aircraft. Controls for the co-pilot (or instructor) are not provided, a feature reported by Naval training personnel to be a distinct disadvantage. The 2B13 has sound simulation and a two-axis (pitch and roll) motion platform as well as limited ground radio navigation facility simulation. A more detailed description of the 2B13 may be found in NTDC publications (20).

Naval training personnel believe that considerable benefits are derived from use of the 2B13 both as an instrument trainer and as an aid to twin-engine transition. Trainees reportedly often voluntarily schedule themselves for additional training periods to work on problems that are giving them particular difficulty, and flight instructors often accompany trainees to the devices to demonstrate particular maneuvers that may not be demonstrable with equal clarity or safety in flight. No attempts have been made to determine empirically the contribution of 2B13 training to Naval aviator trainee proficiency, nor is it known whether additional training in the aircraft would be required should this device be removed from the training program. Personnel associated with the program are convinced, however, that the device contributes significantly to efficiency of aviator training.

In addition to the 2B13, an S2-F procedures trainer is used in the twin-engine and instrument training phase of Naval training. The device is a system-specific trainer, simulating to a high degree of engineering fidelity the cockpit of the S2-F aircraft and providing quantitative simulation of the aircraft and engines to the extent that practice of all procedures involved in operation of the aircraft on the ground can be accomplished.

Characteristics Needed in Devices

Since the T-42, like the T-41 used in Phases A and B, is a nontactical aircraft, the development of a high level of skill in flying it is not a primary objective of the training. The maneuvers performed in the aircraft are associated with the operation of any twin-engine aircraft and are performed at relatively low skill levels. A high degree of engineering fidelity is not required in a synthetic flight training device in order to provide psychological fidelity of simulation of the generalized task of twin-engine aircraft control. Thus, a training device designed for use in the twin-engine qualification need provide only qualitative fidelity of engineering simulation of the T-42.

In contrast with the objective of the transition portion of Phase C—the development of generalized twin-engine flight skills—the objective of the instrument training portion is to develop highly specific skills to levels required for tactical operations. The flight performance and procedural skill tolerances required are those necessary for operation of any tactical Army aircraft on Federal airways and in tactical environments. Thus, the synthetic instrument training device required for such training must provide a high degree of psychological fidelity of the instrument flight situation. Quantitative fidelity of engineering simulation is required for those aspects of the training that relate to the development of instrument flight skills.

While only qualitative simulation of the T-42 is required for the transition training and aircraft control objectives of Phase C, operation of the aircraft during training necessitates familiarity with the location of certain controls and displays. Certain procedural tasks associated with engine start, run-up, and shut-down, for example, must be performed during each training flight, and, although they typically are learned without undue difficulty early in training, the complexity of these procedures is such that some attention must be devoted to them during the first few training flights. A synthetic flight trainer which provides physical fidelity of simulation of the T-42 cockpit would allow development of the procedural skills associated with operating the T-42.

A training device designed to meet the dual objectives of twin-engine qualification and instrument flight training should have the following characteristics:

(1) Twin-Engine Configuration. The requirement for a twin-engine synthetic flight trainer is based upon two task fidelity considerations. First, practice of the general aspects of uniquely twin-engine tasks (e.g., propeller feathering and single-engine operation) should be provided in the trainer. Second, the trainee's task loading—the number of things he has to do simultaneously—should be similar in the synthetic and in the flight training situations so that the trainee may develop the time-sharing skills required for the coordination of instrument flight related skills. A simplified aircraft control task or a reduced time-sharing requirement in the device would not lead to the same amount of transfer of training as would more comparable trainer tasks.

(2) Flight and Engine Dynamics. The comments on fidelity of simulation of aerodynamics and engine characteristics for a primary contact synthetic flight trainer for Phase A are valid here as well. Since the T-42 is not considered a tactical aircraft, a T-42 simulator or operational flight trainer (OFT) is unnecessary. However, any trainer used in this phase should incorporate all representative twin-engine flight dynamics in order that simulated aircraft responses to pilot control input might be qualitatively similar to corresponding responses of twin-engine aircraft of similar weight and power.

(3) Cockpit Motion. The addition of motion to synthetic instrument flight trainers appears to have a minor but useful effect upon the development of skills in control of the aircraft on instruments, and motion probably is quite useful for the recognition of unusual flight conditions and malfunctions such as loss of an engine. Adding motion to such trainers for beginning instrument trainees might be difficult to justify for the sole purpose of training in aircraft control. However, in view of the value motion may provide for recognizing the onset of unusual conditions and malfunctions, plus the greater trainee acceptance of devices incorporating motion, the cost of a simple motion platform probably is justified. A device that provides qualitative simulation of three-axis motion (pitch, roll, and yaw) probably would be adequate for the training under consideration here, although it should be noted that devices incorporating additional axes of motion (i.e., translational motion) are becoming increasingly popular among major synthetic flight trainer users.

(4) Environmental Simulation. Simulation of the quantitative effects of winds, and so forth is not needed when there is no requirement for precise aircraft flight dynamics simulation. Qualitative simulation of ambient conditions (e.g., wind direction and velocity, atmospheric pressure, turbulence) is a requirement for an instrument flight trainer.

(5) Electronic Aids Simulation. Quantitative simulation of ground electronic navigation aids (i.e., VOR, ILS, ADF, and GCA) and the simulation of the air traffic control system are important requirements. The simulated location of various ground navigation aids must be precise enough to allow the trainee to compute navigation problems. The number of such aids simultaneously represented should be sufficient to provide a realistic navigation task to the trainee without overburdening instructional personnel. The geographic area represented by such simulation should be large enough to allow simulated cross-country flights under instrument conditions

(6) Sound Simulation. The auditory sense is an efficient means of communicating "either-or" or two-category information. Sound intensity changes, frequency shifts, and masking effects are useful aids in aircraft control, particularly in twin-engine aircraft. In a training device designed for the training under discussion, engine sounds are believed to provide potentially useful cues to aircraft control and should be provided. Since recognition of the specific sounds associated with a nontactical aircraft is of limited value, qualitative simulation of T-42 aerodynamic and engine sounds is appropriate in a training device for Phase C.

(7) Cockpit Simulation. To enable the trainee to become familiar with the T-42 cockpit, the location of its controls and displays, and the various procedures (i.e., sequences of activities) he must perform in it, a trainer for Phase C should simulate the cockpit of the aircraft. Since acquiring procedural skills associated with equipment operation depends upon close psychological more than physical correspondence of the training and the criterion task (4)[1] only qualitative engineering fidelity of simulation of the T-42 cockpit is required.

[1] Similar findings were obtained by Wallace W. Prophet and H. Alton Boyd, Jr., in HumRRO Division No. 6 work comparing the effectiveness of a device and a photographic cockpit mockup for procedures training (8).

(8) External Visual Reference. Where flight training is limited to the use of instruments within the aircraft and/or information received via radio, no visual simulation of the out-of-the-cockpit scene is required. For the transition training, however, the use of extra-cockpit visual cues is important. Two sets of cues are involved. One set allows the trainee to orient the aircraft in relation to the horizon, and these cues are particularly useful at altitude during the acquisition of the skills associated with maneuvers such as attitude control during single-engine operations. These cues can be provided by a symbolic visual display such as that provided by a horizon line on a homogeneous field (see the discussion of visual display requirements for a primary training device). The other set of cues allows the trainee to maneuver the aircraft in proximity to the ground (e.g., to perform take-off and landing operations). To provide these cues requires a relatively high fidelity pictorial representation of the extra-cockpit scene which changes as a function of simulated aircraft attitude and altitude.

Since twin-engine transition training consists largely of maneuvering within airport traffic patterns and of landing and taking off from an airport rather than confined or tactical areas, an appropriate visual representation would consist of a simulated three-dimensional airport and surrounding countryside. Visual displays such as this, attached to flight simulators, are currently in use by a number of commercial airlines for familiarizing pilots with the visual cues associated with landing commercial transport aircraft. A synthetic flight training device suitable for Phase C training should be compatible with such external visual displays currently available or under development.

Evaluation of Available Devices

Army Devices

The Army has no training devices intended to aid in twin-engine transition training. Such is not the intent of Device 2-B-12A which is used in this phase of training. Device 2-B-12A has no twin-engine simulation capability and no motion, and cannot be used with a visual display; its aerodynamic and engine simulation is unsatisfactory for Phase C transition training, and its cockpit and sound characteristics do not correspond even qualitatively to those of the training aircraft.

All present synthetic training included in O/WOFWAC is intended to assist trainees in the development of instrument flight skills rather than to aid in transition training. Trainees receive up to 12 hours in Device 1-CA-1 during the Primary and Advanced Contact Phases, and 21 hours of synthetic instrument training in Device 2-B-12A during Phase C. The extent to which training in these devices transfers to the inflight situation is subject to empirical determination. Such a determination has not been made by the Army, and it was outside the scope of the present study. It is likely, however, that some negative transfer is resulting from the present requirement that trainees at a relatively low skill level learn to fly the single-engine 2-B-12A while simultaneously learning to fly the twin-engine T-42.

Device 1-CA-1 has long been considered obsolete by the Army, and the Aviation School has stated that Device 2-B-12A is unsatisfactory so far as accomplishment of the School's fixed wing instrument flight training requirements is

concerned.[1] Discussions with simulation engineering personnel at NTDC and at several simulator manufacturers indicate that existing Army trainers cannot be modified efficiently to incorporate the desired characteristics, even to provide appropriate flight dynamics and twin-engine simulation.

Non-Army Devices

Several devices being used by other services incorporate (or could be modified to incorporate) the desired characteristics, although none of them were being manufactured at the time of the study. Two such devices were checked out—the previously described Multi-Engine Instrument Trainer, Device 2B13, and its predecessor, Twin-Engine Instrument Flight Trainer, Device 2F25. Both are Navy devices. It was determined through the Army Participation Group at NTDC that neither device was available to the Army.

One device, the Link GAT-2, with most of the characteristics and which probably could be used satisfactorily in the Aviation School's twin-engine transition and instrument training was under development. A presentation on this device had been made to Aviation School personnel by Link representatives during September 1967. Analysis during this study indicated that the two areas of discrepancy between the GAT-2 and the requirements for a synthetic twin-engine instrument flight training device were that it had only two axes of motion, and its cockpit was not configured like the T-42. Based upon the information available from Link Group, all other required device characteristics were included, making the GAT-2 the most suitable known device for use in Phase C.

The lack of the third axis of motion—yaw—probably would reduce the effectiveness of the GAT-2 for single-engine training, although the effects of yaw are simulated in all instruments in this device. The fact that the GAT-2 cockpit is not configured specifically like the T-42 is less of a drawback, since familiarity with the T-42 cockpit configuration itself can be obtained through the use of a system-specific cockpit procedures trainer. Such is the procedure followed by the Navy, where synthetic instrument flight training is conducted in the 2B13, and familiarity with the training aircraft's cockpit is provided through use of a procedures trainer for that aircraft.

TACTICAL FLIGHT TRAINING (O/WOFWAC, Phase D)

Description of the Phase

Phase Objectives. The two main objectives of the final phase of the O/WOFWAC are to qualify trainees in the operation of the 0-1 aircraft, and to develop trainee skills in the employment of the 0-1 under tactical conditions for stability operations.

Training oriented toward the first objective is conducted by the Department of Fixed Wing Training, and it familiarizes the trainee with the 0-1 to the extent that the advanced flight maneuvers learned during Phase B can be performed proficiently in it. The training consists of 20:45 hours of dual instruction and 7:15 hours of solo practice.

[1] Message, AASAFW 9-509, Commandant, USAAVNS, to USCONARC, 20 Sep 67. Subject: Type Classification of Fixed Wing Instrument Trainer, 2B12A.

Training oriented toward the second objective is conducted by the Department of Tactics, and it consists of 8:30 hours of dual instruction and 18:30 hours of solo practice. The training includes low-level navigation, evasive maneuvering, contour flying, external load delivery, area and route reconnaissance, aerial conduct of fire, and tactical radio procedures. The final portion of this training consists of operating within a simulated tactical environment as part of a fixed wing aviation platoon. All training during Phase D is conducted under visual flight rules.

Phase D is the final phase of the Army's initial entry fixed wing aviator training program. Graduates of this phase are awarded aviator wings, and in the case of warrant officer candidates, warrants. Initial assignment of the newly qualified aviators is to operational units or to graduate level aviator courses at the Aviation School.

Trainee Qualification. Successful completion of O/WOFWAC Phase C is the only trainee qualification for this phase.

Training Aircraft. All flight training during Phase D is conducted in the 0-1 Bird Dog airplane—a light, two-place, tandem-seat, high-wing, tail-wheel, single-engine aircraft that is employed tactically by the Army. It is similar in configuration and power to the Cessna 180. Its flight controls and aerodynamic characteristics are similar to those of other light aircraft of similar configuration found in civilian aviation. The 0-1 also is used tactically as a light observation aircraft by the U.S. Air Force and the U.S. Marine Corps.

Present Training Devices. No synthetic flight training devices are employed during Phase D.[1]

Training Device Considerations

Training Devices Used in Similar Training Programs

The content of the 0-1 transition training portion of Phase D closely parallels the content of Phase B, Advanced Contact Training. As indicated in the Phase B description, no synthetic flight training devices are known to be in use elsewhere to provide advanced contact flight training.

Unlike the T-41 and the T-42 used in prior phases, however, the aircraft used in Phase D is a tactical aircraft. The development of a high level of skill in flying the 0-1 is a training objective, because graduate aviators will fly this aircraft in tactical environments where mission accomplishment is dependent in large part upon proficient aircraft handling under possibly degraded and probably stressful conditions.

Where high levels of proficiency in the handling of a specific tactical aircraft are required, aircraft simulators—synthetic flight training devices which simulate to a high quantitative degree of engineering fidelity the characteristics of a specific make and model aircraft—often are used in transition training programs. All Air Force tactical jet and multi-engine aircraft transition training programs, for example, make use of such devices. For relatively unsophisticated, low-performance aircraft such as the 0-1, however, aircraft simulators have never been developed, probably because one system-specific

[1] Synthetic training devices that are used to simulate a tactical environment during Phase D, such as hand grenade simulators and ground burst simulators, are not considered to be synthetic flight training devices for the purpose of this report.

simulator for the 0-1 would cost approximately as much as 50 0-1 aircraft. An additional consideration probably has been that the hourly operating cost of aircraft simulators typically equals or exceeds the hourly operating cost of 0-1 type aircraft.

The tactical flight training requirements in the O/WOFWAC are similar to the tactical flight training requirements that exist in the Tactics Phase of the Officer/Warrant Officer Rotary Wing Aviator Course (O/WORWAC). Both courses provide training in visual aerial observation and reconnaissance, target acquisition, target identification, aerial fire adjustment, and navigation at low level by reference to features of the surrounding terrain. At present, no synthetic flight training devices are in use for such training in the Tactics Phase of O/WORWAC, nor are such devices known to be in use in other training programs elsewhere.

It should be noted that certain tactical training requirements are being met in part through the use of training devices in other training programs. For example, training in the delivery of guided missiles is provided in Air Force training programs by Device GAM 85 (Bull Pup simulator) and in the Tactics Phase of O/WORWAC by Device M-22 (SS-11 simulator). The requirement for such training does not exist in O/WOFWAC Phase D.

Characteristics Needed in Devices

While the 0-1 is a tactical aircraft and relatively high aircraft control skill levels are needed for its effective employment, it is unsophisticated and forgiving when compared with most other Army tactical aircraft, and it is relatively inexpensive to operate. A device which simulated the specific characteristics of the 0-1 to a highly quantitative degree of engineering fidelity undoubtedly could be used in the transition training portion of Phase D to accomplish some of the training involved—particularly if the device incorporated a high fidelity, closed-loop representation of the extra-cockpit visual scene—but the development and procurement of such a device could hardly be justified in view of the relative ease with which the desired 0-1 aircraft control skills are being acquired using only the aircraft itself.

Several problems in 0-1 transition training result from the differences in configuration between it and the two other aircraft each trainee previously has flown. In the T-41 and the T-42, for example, the throttle is operated by the right hand and the control wheel by the left; the situation is reversed in the 0-1. A training device designed to acquaint trainees with the cockpit configuration of the 0-1 could be of benefit with this training problem. Such a device could be a procedures trainer such as is used by the Navy in its S2-F program or as that used in the Aviation School's Mohawk Transition Course described elsewhere in this report. The relative simplicity of cockpit procedures in the 0-1, however, suggests that the contribution to training efficiency of an 0-1 procedures trainer may not be justifiable from a cost-effectiveness standpoint unless a low-cost procedures trainer, such as a photographic mockup, were used.

Another problem in 0-1 transition training results from the difference in forward visibility between the 0-1 and the T-41 or T-42 during certain maneuvers. The landing attitude of the 0-1, for example, is somewhat more nose high than that of the other two aircraft, and during early flights trainees often misjudge their proximity to the ground because of reduced forward visibility. To provide adequate training in the visual cues associated with landing an 0-1 would require a training device with an external visual

reference such as that described for transition training in the T-42 aircraft, that is, a relatively high fidelity pictorial representation of an airport scene which changed as a function of simulated aircraft attitude and altitude

0-1 ground handling, particularly high speed taxiing associated with landing, presents problems to the O/WOFWAC trainee. Some ground handling accidents that occur during Phase D could be prevented through appropriate training. A direct approach to this problem would consist of the use, as a "taxi training device," of non-airworthy 0-1 aircraft with reinforced main gear struts and with wings modified to reduce their lift characteristics. Nonflyable aircraft have been used as ground handling training devices with considerable success throughout most of the history of aviation training (21).

The similarity between the tactical training requirements of the tactics phases of the O/WOFWAC and the O/WORWAC has been noted above. Both training courses develop skills associated with the visual observation of details in the extra-cockpit environment (e.g., target acquisition, aerial fire adjustment, and navigation at low level by reference to the surrounding terrain). The training device requirements have been specified[1] for a tactics synthetic flight training device for the O/WORWAC. The visual display requirements specified for a rotary wing tactics training device are essentially the same as those required for a tactics training device for O/WOFWAC Phase D, so they will not be repeated here. It should be noted, however, that a technical review of those requirements revealed that a training device meeting them could not be obtained at present because of state-of-the-art limitations.[2]

Evaluation of Available Devices

No synthetic flight training devices that could be expected to enhance the effectiveness of the training being given in O/WOFWAC Phase D are known to be available.

FIXED WING QUALIFICATION COURSE

Description of the Course

Course Objective. The objective of the Fixed Wing Qualification Course (FWQC) is to train rotary wing rated trainees to fly fixed wing observation aircraft and to familiarize them with the tactical employment of such aircraft. All flight training in this course is conducted under visual flight rules, and the course is similar in content to that of Phases A and B of the O/WOFWAC. The flight training consists of 45 hours of dual instruction and 15 hours of solo practice. Graduates of this course are awarded fixed wing aviator ratings and may be assigned to operational units or to graduate level aviator courses at the Aviation School.

[1] Draft Proposed Small Development Requirement, Synthetic Army Aircraft Training System (SAATS), U.S. Army Aviation School, May 1967.

[2] 2nd Ind., Headquarters, U.S. Army Materiel Command, AMC-RD, 30 Nov 67, to Letter, ATOPS-TNG-TSD, USCONARC, 16 June 1967. Subject: Synthetic Armed Aircraft Training System (SAATS).

Trainee Qualification. Commissioned officers and warrant officers who are rated U.S. Army Rotary Wing Aviators are qualified for this course

Training Aircraft. All flight training during the FWQC is conducted in the 0-1 Bird Dog, the same aircraft in which O/WOFWAC Phase D is conducted.

Present Training Devices. No synthetic flight training devices are used in this course.

Training Device Considerations

Training Devices Used in Similar Training Programs

The training conducted in the FWQC is comparable to that conducted in Phases A and B of the O/WOFWAC, and the discussion of training devices used in programs similar to those phases is applicable to the FWQC as well. Trainees in the FWQC, however, are already rated military aviators, and many skills associated with flying—skills which often are described by terms such as "air sense"—already have been developed by them. Characteristically, FWQC trainees reach various training criteria (e.g., solo) more rapidly than do initial entry trainees, and their attrition rates are lower. While training devices used in initial entry training programs would be of similar use in FWQC-type training, the benefits derived in FWQC training would be expected to be less significant.

No synthetic flight training devices are being used in the Rotary Wing Qualification Course, the comparable rotary wing course for previously rated fixed wing Army aviators.

Characteristics Needed in Devices for Qualification Training

The discussion of synthetic flight training device characteristics appropriate for Phase A of the O/WOFWAC is applicable to the FWQC as well. A device having the described qualitative simulation characteristics would be of benefit for the development of rudimentary aircraft control skills; however, unlike Phase A trainees, trainees in this course have relatively little trouble developing such skills without the aid of training devices.

In view of the fact that the 0-1 is a tactical aircraft, the discussion of training device characteristics appropriate for the 0-1 transition portion of O/WOFWAC Phase D is relevant to post-solo training in the FWQC. Again, however, it should be noted that quantitative simulation of the 0-1 could hardly be justified in view of the relative ease with which the desired 0-1 control skills are being acquired using only the aircraft itself for training.

Evaluation of Available Devices

The discussion of the suitability of available Army and non-Army synthetic flight training devices for O/WOFWAC Phase A training is applicable to FWQC training as well. No present Army devices have the required characteristics. One non-Army device, the GAT-1, is considered appropriate, but the rate of development of fixed wing aviator skills of the FWQC trainee would suggest that relatively modest improvements in course efficiency would result from the introduction of such a device in that course.

OV-1 (MOHAWK) AVIATION TRANSITION COURSE

Description of the Course

Course Objective. The Mohawk Transition Course is a graduate-level course conducted by the Aviation School to qualify Army aviators in the operation of Army combat surveillance multi-engine OV-1 Mohawk airplanes. The flight training in this course consists of 46 hours of dual instruction and five hours of solo practice. A graduate of the course must be proficient in the operation of the Mohawk in normal and tactical situations under both visual and instrument flight conditions.

All graduates of this course immediately attend the OV-1 (Mohawk) Aviator Combat Surveillance Familiarization Course at the U.S. Army Combat Surveillance School. The likely assignment for graduates of these courses is to Mohawk operational units in Southeast Asia where they may engage in tactical missions as aircraft commanders.

Trainee Qualification. To qualify for attendance at the Mohawk Transition Course, an officer or warrant officer must be a qualified fixed wing aviator on active duty and must hold a current Army Instrument Card (Fixed Wing). While attendees typically have 500 or more hours' flight experience in fixed wing aircraft, some officers and warrant officers are accepted immediately upon completion of O/WOFWAC.

Training Aircraft. The OV-1 Mohawk is a relatively high performance, twin-engine, turbine-powered, tactical aircraft which has numerous unique aerodynamic characteristics. It has flight control and ejection equipment found in no other Army aircraft. Its various on-board systems have unique operating requirements. The safe operation of the Mohawk during all emergency conditions requires highly specific pilot responses.

Present Training Devices. Three synthetic training devices are used in the Mohawk Transition Course: Device 2-C-9, a cockpit procedures trainer; Device 2-B-12A modified to incorporate an FD 105 flight control system; and Device 9E2A, an ejection seat trainer. Each trainee receives approximately 13 hours' practice in the 2-C-9, 10 hours in the modified 2-B-12A, and one simulated ejection in the 9E2A during Mohawk transition training.[1]

Training Device Considerations

Training Devices Used in Similar Training Programs

Training in the Mohawk may be compared to training in high-performance aircraft by other services (e.g., the Air Force F-111A and the Navy A-7) and by commercial carrier (e.g., the DC-9). The transition training practices of these services and carriers include the use of system-specific flight simulators (sometimes called Operational Flight Trainers) in all current transition training programs for medium- and high-performance aircraft.

[1] Other training devices are used during classroom instruction in this course, e.g., Device 2-A-27B, an engine trainer. These devices have been classified by the Aviation School as maintenance rather than operator training devices.

The simulators used are quantitative facsimiles of the aircraft cockpit, and they provide a high degree of quantitative simulation of all psychologically significant systems, sounds, and engine and flight characteristics associated with a specific make and model aircraft. Most of these simulators have multi-axis motion platforms, and many have visual display attachments which simulate real-world scenes and provide out-of-the-cockpit visual cues appropriate for the performance of many aircraft maneuvers dependent upon visual reference. The quantitative simulation provided by such visual displays is adequate to provide cues appropriate for take-off and landing operations associated with the high-speed, fixed-wing aircraft being simulated.

It has been demonstrated repeatedly that the use of such flight simulators can result in appreciable savings in training costs and in increased pilot proficiency (22). The use of flight simulators to develop skills needed to cope with emergency situations (e.g., loss of an engine on take-off) allows the trainee to acquire needed skills without endangering himself or expensive equipment. The use of similar dynamic flight training devices in Mohawk transition training could result in significant reductions in inflight training requirements while increasing the proficiency of course graduates—particularly their proficiency when inflight emergency situations occur which require prompt, unique pilot responses.

All major U.S. commercial carriers are acquiring flight simulators for the training of their jet aircraft crews. These simulators are designed to meet fidelity of simulation requirements specified by the Federal Aviation Administration. Simulators certified by the FAA as meeting these requirements are being used to provide major portions of the training of commercial pilots transitioning to jet aircraft. Using such devices, the Training Committee of the Air Transport Association has established the goal of complete airplane crew training in simulators alone and the elimination of transitional checkouts in the actual aircraft (23). Similar goals could be considered for the transition training of Army pilots in the Mohawk and similar aircraft.

The military services and commercial airlines that are using flight simulators are also making increasing use of system-specific part-task trainers to supplement them. These devices provide training in part—but not all—of the overall flight training task. The most common example of such a trainer is a device that is used in cockpit procedures training (e.g., the 2-C-9 or the previously described Navy Device S2-F). They simulate to a high degree of psycnological fidelity the environment within which certain procedures associated with flight, such as engine start and run-up, can be practiced. No attempt is made in such devices, however, to simulate aircraft flight control aspects of the flight task.

Characteristics Needed in Devices

Devices used in the Mohawk Transition Course must be system-specific. The graduate aviator will fly the Mohawk in tactical situations, so it cannot be viewed as a training aircraft. Nor is it unsophisticated and forgiving. Rather, it is a relatively high performance tactical aircraft, and all training conducted in it is designed to develop in the trainee high levels of specific operational skills. Such training cannot be provided effectively in general purpose devices that provide only qualitative simulation of the Mohawk.

Some of the required training can be provided effectively in part-task trainers that simulate to a high level of psychological fidelity certain elements of the Mohawk pilot's task. The presently used 2-C-9 is an example of such a part-task trainer. In

addition to this training, however, a whole-task trainer, or flight simulator, is needed to provide synthetic training i the overall flight task and to augment the training otherwise provided in the Mohawk itself.

Such a flight simulator must have the following characteristics:

(1) Engine and Aerodynamic Simulation. The Federal Aviation Administration has published a set of engine and aerodynamics simulation engineering standards and tolerances for the design of commercial simulators (24). A simulator certified by the FAA as meeting these standards and tolerances has a high degree of quantitative fidelity to the simulated aircraft and may be used by a commercial airline for much of the necessary training of its pilots, for one of the semi-annual mandatory checkrides, and for major portions of the other checkride.[1] Similar design requirements exist for Air Force and Navy simulators. These or similar standards and tolerances are also appropriate for use as engine and aerodynamics simulation design requirements for a Mohawk simulator for the Army.

(2) Cockpit Motion. Many of the cues associated with operation of a high-performance aircraft are proprioceptive in nature, that is, they are associated with changes in body position and orientation. The relatively subtle cues associated with acceleration, deceleration, and tilt—the cues that alert highly proficient pilots to out-of-tolerance conditions before they are detected from instrument indications—are in this category, and their simulation requires the physical displacement of the body.

Such is a primary function of the more sophisticated multi-axis flight simulator motion platforms. The cues these platforms provide enable pilots to detect changes in aircraft attitude and speed more rapidly than might otherwise be possible. Motion is particularly useful to experienced pilots who have learned to attend to the more subtle cues associated with the onset of systems malfunctions. Consequently, motion cues must be more faithfully reproduced for them in a training device than for inexperienced pilots such as O/WOFWAC trainees. Because of space limitations, however, only qualitative simulation of motion can be obtained in such platforms.

A simulator for the Mohawk should incorporate a motion platform that provides appropriate psychological cues associated with vibration and with the displacements of the aircraft along the roll, pitch, and yaw axes at a minimum, and possibly along the vertical axis as well. It should be noted that flight simulators under development for the Boeing 747 and the SST will have fore-aft and lateral translation motion in addition to these.

(3) External Visual Reference. The relatively simple cues provided by a symbolic reference such as that described for the Primary Contact Phase of O/WOFWAC would be of little value to an experienced Army aviator undergoing Mohawk transition training. A Mohawk simulator should incorporate a visual display that would enhance the development of skills associated with some of the more critical piloting task requirements such as loss of engine during take-off, landing rollout, and landing.

[1] Subsequent to the study reported here, the FAA changed its requirements with respect to simulator training for air lines pilot transition to allow more extensive use of simulators in certain training programs.

There are several visual displays now available which allow this type of training, but they are expensive to procure and maintain, and they are of limited training value. Other visual systems under development will provide more appropriate and detailed cues for take-off and landing operations when used with flight simulators of the type described here. The characteristics of visual displays that would be appropriate for a Mohawk simulator have been specified elsewhere (25). The procurement of such a display with a Mohawk simulator, or the provision for its later addition, would allow all or almost all Mohawk pilot skills to be developed in a simulator.

Evaluation of Available Devices

Army Devices

The Army currently has no Mohawk flight simulator, and modification of existing Army synthetic training devices to simulate the Mohawk or any of its systems (e.g., turbine engine) has been discouraged during discussions of these devices with simulation engineers. The consensus of these engineers is that a more economical approach would be to develop the required devices "from scratch."

Two of the training devices currently used in the Mohawk Transition Course, Devices 2-C-9 and 9E2A, are system-specific trainers; that is, they provide training in the specific cockpit and ejection procedures that are unique to the Mohawk. The 2-B-12A, however, is not. Even with the FD 105 modifications, this device requires the development of pilot behaviors which are grossly unlike those required in the operation of the Mohawk and which could interfere with aviator performance in the aircraft itself. The use of this device, therefore, cannot provide fully satisfactory training toward the accomplishment of the course objective.

Non-Army Devices

Since the Mohawk is exclusively an Army aircraft, Mohawk simulators or part-task trainers have not been built for other services, agencies, or commercial organizations. There are no system-specific part-task trainers or flight simulators in existence today, other than Devices 2-C-9 and 9E2A, which provide training that could be substituted for training in the Mohawk itself.

U-21 AVIATOR QUALIFICATION COURSE

Description of the Course

Course Objective. The U-21 Aviator Qualification Course is a graduate level course conducted by the Aviation School to qualify Army aviators in the operation of the U-21 Ute in normal, emergency, and instrument flight conditions. The flight training consists of 25 hours of dual instruction, approximately 15 hours of which is conducted under visual flight rules, and the remainder under actual or simulated instrument conditions. Graduates of the Ute course typically are assigned to Southeast Asia where they engage in tactical operations as Ute pilot or co-pilot.

Trainee Qualifications. Commissioned officers and warrant officers who are fixed wing aviator rated and who possess a current Army Standard or Special Instrument Card

are qualified for this course. Some turn-around graduates of O/WOFWAC have been accepted for this course, but the typical trainee has 500 or more hours' experience as a fixed wing aviator.

Training Aircraft. All flight training is conducted in the U-21 Ute aircraft, the military version of the Beechcraft King Air. The Ute is a twin-engine, relatively high performance, turbine-powered, tactical, light transport aircraft. Like the Mohawk, it has unique aerodynamic characteristics and has navigation equipment found in no other Army aircraft. Operation of the Ute during all emergency conditions requires highly developed, specific pilot responses.

Present Training Devices. At the time of this review of fixed wing flight training programs at the Aviation School, each trainee in the Ute course received approximately six hours of synthetic instrument flight training in Device 2-B-12A. The use of this device has since been discontinued. No other training devices were in use at that time.

Training Device Considerations

Training Devices Used in Similar Training Programs

The Ute course is similar to the Mohawk Transition Course, and the comments concerning review of training devices used in programs similar to the Mohawk Transition Course apply to the Ute course as well. Unlike the Mohawk, however, the Ute is not uniquely an Army aircraft. There are civilian training programs designed specifically to qualify aviators in the operation of its civilian version, the Beechcraft King Air.

One of these training programs is operated by Beech Aircraft Corporation at its Wichita, Kansas, facility. Several Army aviators were trained by Beech in this course at the time of the initial procurement of Ute aircraft. One training device is employed in the program—a King Air procedures trainer, used for practice of all King Air ground operating procedures. A high degree of quantitative fidelity of engineering simulation is provided on all systems necessary to practice these procedures. Although the device is not commercially available (the one operated by Beech was built as a part-time project by their personnel), an estimate (not a quotation) of $250,000 was provided by Beech for the manufacture of a similar device for the Army.[1]

Flight Safety, Incorporated, of LaGuardia Airport, Flushing, New York, also operates a King Air transition training program, and a King Air simulator recently has been obtained for use in that program (26). The device simulates to a high degree of quantitative engineering fidelity the cockpit, the flight and engine characteristics, and the sound of the King Air aircraft, and it has a three-axis motion system. The device was built for Flight Safety, Incorporated, by Redifon, Ltd., an English simulator manufacturer. Cost of this device was not available.

Characteristics Needed in Devices

Like the Mohawk, the Ute was procured by the Army for use in tactical environments, and it cannot be viewed as a training aircraft. Also like the Mohawk, it is not an unsophisticated and forgiving aircraft. It is a relatively high performance tactical aircraft, and all training conducted in it must be designed to develop in the trainee high

[1] Personal communication, Jack L. Marinelli, Beech Aircraft Corporation, 22 November 1967.

levels of specific skills. These skills can only be acquired in the aircraft itself or in a synthetic flight training device which simulates quantitatively the specific systems and parameters involved in the aircraft's flight.

The device characteristics specified for effective Mohawk transition training are the same as the characteristics of devices required for effective Ute training.

Evaluation of Available Devices

Army Devices

Training on Device 2-B-12A has been discontinued, and other Army training devices appear to be of little value for use with the Ute.

Concurrent with the present review, and at the request of the Department of Advanced Fixed Wing Training, design specification for a Ute procedures trainer and a program of instruction for use with it were developed by HumRRO. The trainer was constructed for the Department by the Third U.S. Army Training Aids Center at a cost, including material and labor, of approximately $4,300. The device, which is described in Appendix B, provides quantitative dynamic simulation of a number of Ute systems and qualitative simulation of all others which are required for the acquisition of the procedural skills associated with operation of the aircraft on the ground. The device and program of instruction are in use by the Department of Advanced Fixed Wing Training, and training personnel report that trainees who have received procedures training in the device perform exceptionally well in the aircraft.

In addition to the Ute Procedures Trainer, HumRRO Division No. 6, under Work Unit SYNTRAIN, developed the "HumRRO Trainer" for use in connection with the Ute Procedures Trainer and program of instruction described above. The HumRRO Trainer, a two-dimensional paper facsimile of all the displays and controls required for the execution of U-21 procedures, allows the trainee to learn the location and general function of all Ute controls and displays prior to his first period of instruction in the procedures trainer or in the aircraft.

Non-Army Devices

Two non-Army devices for the King Air aircraft, the civilian counterpart of the Ute, have been described above. No other devices are known to exist which might be used in the Ute course.

OTHER FIXED WING COURSES

Fixed wing training courses other than those discussed above were not reviewed in detail during the present investigation. From cursory review, however, it would appear that the content of the other courses presents no new training material. For the most part, the courses differ from those discussed in terms of trainee background (e.g., Regular Army vs. National Guard), rank and amount of experience (e.g., WOCs in the WOFWAC vs. field grade officers in the Fixed Wing Tactics Refresher Course), and aircraft involved (e.g., U-21 vs. U-8). The content of these courses primarily consists of adaptation of the content of courses previously discussed, and, generally, similar training device requirements would be expected to exist.

DISCUSSION

During the survey of fixed wing training device requirements, HumRRO personnel reviewed the objectives and curriculum of each major fixed wing aviator course, and determined the adequacy of existing Army devices with respect to the requirements of these courses. Where Army devices were found to be inadequate or inappropriate, major characteristics of more suitable devices were identified, and the availability of such devices from non-Army sources was determined.

This section of the report summarizes the findings from the review of fixed wing training device requirements with reference to operational considerations and application. Like the review itself, it has not been modified to reflect any changes since 1968 in status of specific courses or availability of specific devices. It should be noted that this discussion is predicated upon the assumptions about training circumstances for the next several years that were set forth in the opening sections of this report.

INITIAL CONTACT FLIGHT TRAINING[1]

Appropriate use of synthetic flight training devices prior to or early in contact flight training has typically led to reductions in flight-related attrition among trainees, reductions in time required to meet various flight criteria, and improved performance during training. Examples of initial contact flight training programs where such benefits were derived include the experimental use of Device DHT-1 at the USAPHS (14), the use of Device 1-CA-2 at the University of Illinois (12), and the use of the General Aviation Trainer Model 1 (GAT-1) at Greene Central High School, Greene, New York (16). The introduction of an initial contact synthetic flight training device with the characteristics described in the review section of this report would be expected to result in similar benefits to the Aviation School's primary contact fixed wing training programs.

One available device—the GAT-1—was found to be appropriately designed for the Army's training requirements, and its use in the Officer/Warrant Officer Fixed Wing Aviator Course (O/WOFWAC), Phase A, and in similar initial contact flight training programs seems promising. The GAT-1 should be used in conjunction with a simple extra-cockpit symbolic visual presentation similar to that used in the training program at Greene Central High School.

The benefit to be derived from the use of the GAT-1 with a symbolic visual display is to a large extent a function of *when* it is introduced in the training cycle. If the trainer is initially used following the first solo flight, for example, many of the skills which can be developed in it will already have been acquired. If it precedes the first period of inflight instruction, on the other hand, maximum opportunity would be afforded for the development of skills for subsequent transfer to the inflight situation. These skills include the performance of climbs and climbing turns, approaches, go-around procedures,

[1] Assumptions 1a, 2, and 3 (see p. 5-6) are relevant to this discussion of initial contact flight training device requirements.

coordination exercises, clearing turns, slow flight, stalls, slips and slipping turns, straight and level flight, glides, and gliding turns.

From an administrative standpoint, the introduction of the GAT-1 in the primary contact flight training program could best be accomplished early during the pre-solo period of instruction. Its use at that time, though not as desirable as use before any inflight instruction, reasonably could be expected to enhance trainee performance in flight, lead to quicker solo, and reduce attrition during the early stages of the course. However, the benefit of such training, regardless of when in the training cycle it may occur, will be limited by the way in which the device is used—that is, the program of instruction (POI). Careful attention to the development and empirical validation of synthetic training POIs and their coordination with inflight training activities is essential.

A limited number of GAT-1s might be procured initially in order that their specific training value under operational training conditions might be evaluated experimentally. Such an evaluation should include technical assistance in the development of objective performance criteria, experimental design, and statistical analyses of data.

INSTRUMENT FLIGHT TRAINING AND TWIN-ENGINE QUALIFICATION[1]

A training device designed to meet the dual objectives of twin-engine qualification and instrument flight training—the objectives of O/WOFWAC, Phase C—should have the charecteristics indicated for such training in the review section of this report. No device with these characteristics is known to be available. Present Army devices used in twin-engine qualification and instrument flight training (2-B-12As) were designed for training requirements no longer existing at the Aviation School, and were procured essentially as interim solutions. These devices are not appropriate for the present training requirements.

The requirement for devices incorporating the characteristics described can be met by (a) developing a fixed wing synthetic flight training facility, the procedure followed by the Aviation School in the development of a USAAVNS subsystem for the SFTS, or (b) purchasing or developing a number of independently operating devices, the procedure more typically followed by the Army in the past. The development of a synthetic training facility has been proposed by HumRRO Division No. 6 (Aviation) as a desirable solution to the Aviation School's synthetic training requirements.[2]

The development of a synthetic flight training facility to meet the fixed wing instrument and twin-engine qualification training requirements of the Aviation School

[1] Assumptions 1b, 1c, 2, and 5 (see p. 5-6) are applicable to this discussion of instrument and twin-engine transition training. It is recognized that some instrument training currently is given in the single-engine U-6, but it is assumed (see Assumptions 4 and 5) that this practice will cease. Until that time, continued use of Device 2-B-12A as a synthetic instrument trainer in courses where the U-6 is the training aircraft would appear justified.

[2] Research done by Paul W. Caro under HumRRO Work Unit ECHO concerning implications of digital computer advances for Army simulation requirements.

again is proposed as a long-term solution to this requirement. A Synthetic Flight Training System with a fixed wing twin-engine instrument training subsystem would provide the Aviation School with training equipment superior to that which could be provided through the procurement of a number of independent training devices. Training technology developed for rotary wing application in the SFTS would be applicable to such a subsystem, and the inherent flexibility of the SFTS approach would provide desirable adaptability to the Aviation School in meeting its future fixed wing, rotary wing, and VTOL training requirements.

It should be noted that the SFTS as presently being procured is amenable to expansion to include fixed wing instrument and twin-engine qualification training modules.

Based upon the Aviation School's experience with the procurement of major flight training devices (e.g., Device 2-B-12A and the SFTS), it is likely that an appropriately designed subsystem of fixed wing training devices which incorporate modern engineering and training technology could not be in operation at the Aviation School in less than five years. It is apparent that a short-term solution to the instrument and twin-engine qualification training device requirement is also needed. The procurement of already developed devices, which would allow bypassing the lengthy device development cycle, could provide an interim solution to the device requirement while the more desirable training facility is being developed.

So far as could be determined during the present survey, no training devices now available have the desired characteristics. One potentially useful commercial device, however, was under development at the time of the review. While not meeting all of the training device requirements (e.g., it has a two- rather than a three-axis motion system), it is judged generally suitable for use at the Aviation School on an interim basis pending development of a fixed wing synthetic flight training system.

This particular device is Link's General Aviation Trainer Model 2 (GAT-2). A presentation on the GAT-2 made to Aviation School personnel by Link Group representatives demonstrated the general compatibility of the proposed GAT-2 with the Aviation School's twin-engine qualification and instrument training device requirement. Members of the Work Unit SYNTRAIN research staff estimate that a 40% to 50% reduction in O/WOFWAC Phase C flight training could be effected through appropriate utilization of the GAT-2 in that course. Limited procurement of the device would permit an experimental determination of its value as a replacement for Device 2-B-12A in the O/WOFWAC Phase C.

At the request of the Assistant Commandant of the Aviation School, HumRRO Division No. 6 undertook development of estimates of costs associated with the introduction of GAT-2 training devices to the Aviation School's fixed wing flight training programs. The information thus developed was made available to Aviation School representatives in February 1968. The information is contained in Appendix A.

In addition to the device development and procurement actions indicated above, system-specific procedures trainers should be developed by the Aviation School for use in conjunction with these devices and with the T-42 aircraft itself. Procedures trainers such as the U-21 Procedures Trainer described in Appendix B and the paper HumRRO Trainer being used with it will provide useful training supplemental to that otherwise provided in

twin-engine qualification training. It should be noted, however, that the effectiveness of these devices is largely dependent upon the use of a highly structured program of instruction such as that developed for use with the U-21 Procedures Trainer and the HumRRO Trainer.

TRANSITION TRAINING[1]

The transition training mission of the Aviation School consists of training twin-engine instrument rated Army aviators in the operation of the Army's twin-engine tactical aircraft, such as the OV-1 Mohawk. The development of high levels of skill is required in order to employ these aircraft and their on-board systems effectively under the hazardous circumstances and the often degraded conditions associated with extended tactical operations. These skill levels can be acquired only in the aircraft itself or in highly sophisticated and realistic flight simulators that can subject aviators to the psychological as well as the physical stresses involved in such operation. The characteristics of devices designed to provide such training are summarized in the review section of this report.

Flight simulators of the complexity described should be developed for use in each of the Aviation School's transition courses, that is, the Mohawk, Ute, and Seminole[2] courses. Such development would be consistent with the policy the Aviation School is pursuing in the development of simulation for the transition training of aviators for two rotary wing tactical aircraft, the UH-1 and the CH-47. Simulators for these aircraft are being developed as part of the SFTS, and transition training for both will be conducted using the Aviation School Subsystem of the SFTS. Fixed wing simulators could be added to this Subsystem alongside or in place of either the UH-1 or the CH-47 trainer modules, or a separate fixed wing simulator SFTS subsystem could be developed specifically for the transition training requirement.

In addition to simulators, system-specific part-task trainers may be expected to make significant contributions to the efficiency of the Aviation School's transition training courses. The development and introduction of a Ute procedures trainer, the use of a Ute paper HumRRO Trainer, and the highly structured program of instruction to go with them are described in Appendix B. A procedures trainer, the 2-C-9, also is in use in the Mohawk Transition Course. Use of these devices and the programs of instruction developed for them should continue, and similar devices and programs should be developed for other Aviation School transition training programs.

Use of Device 2-B-12A with the FD 105 modifications and Device 9E2A probably should be continued until more suitable devices are procured; however, there is no known empirical evidence that the training received on these devices transfers positively to the Mohawk aircraft, and it would be desirable to collect evidence to validate the use of these devices.

[1] Assumptions 1d, 4, and 5 (see p. 5-6) are applicable to this discussion of transition training.

[2] The U-8 (Seminole) Aviator Qualification Course was not included in the study on the assumption that the skill requirements for it are comparable to those of the Mohawk and Ute Aviator Transition Courses which were included.

SIMULATION TECHNOLOGY

Since the advent of digital computer controlled flight simulation equipment several years ago, flight simulation technology has made enormous strides. The increased capability and flexibility of the newer equipment has led to corresponding advances in aviation training technology.

In order to enable Army aviators to keep fully informed of many Army capabilities and potential value of the newer equipment, a systematic program of visits to users of such equipment would be beneficial. Visits by Aviation School personnel involved in fixed wing training programs to other military and civilian agencies conducting pilot training would assist the School in maintaining awareness of such developments and their implications for Army aviation training. Additional benefit would be derived from a program of visits to the major manufacturers of modern flight training equipment and from discussions with representatives of their engineering and research staffs.

SUMMARY OF PROPOSED ACTIONS

1. Initial contact flight training:

a. Procure a limited number of GAT-1 trainers with symbolic visual displays.

b. Investigate the use of the GAT-1 in the Greene High School training program.

c. Determine empirically the training value of the GAT-1 in Army fixed wing primary training.

2. Instrument flight training and twin-engine qualification training:

a. Develop a fixed wing instrument and twin-engine qualification synthetic flight training facility similar to the SFTS being developed for rotary wing synthetic instrument flight training (a long-term solution).

b. Procure a limited number of GAT-2 trainers (a short-term solution).

c. Determine the training value of the GAT-2 in Army fixed wing instrument flight and twin-engine qualification training.

d. Develop procedures trainers, paper HumRRO Trainers, and structured programs of instruction for them for use in twin-engine qualification training.

3. Transition training:

a. Modify the SFTS under development to include simulators for the Army's twin-engine tactical aircraft, or develop a separate fixed wing SFTS subsystem for twin-engine tactical transition training.

b. Continue the use of the available system-specific part-task trainers employed in twin-engine transition courses for tactical aircraft.

c. Develop procedures trainers, paper HumRRO Trainers, and structured programs of instruction for twin-engine transition courses not now employing them.

4. An additional proposal:

A systematic program of visits by Aviation School personnel to other pilot training agencies and to manufacturers of flight training equipment.

LITERATURE CITED

AND

APPENDICES

LITERATURE CITED

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Appendix A

FLIGHT AND SYNTHETIC FLIGHT TRAINING COSTS IN THE OFFICER/WARRANT OFFICER FIXED WING AVIATOR COURSE, PHASE C

INTRODUCTION

The purpose of this Appendix is to present an estimate of the savings that might be expected to accrue from procurement by the U.S. Army Aviation School of the General Aviation Trainer, Model 2 (GAT-2) for use in Phase C of the Officer/Warrant Officer Fixed Wing Aviator Course. HumRRO was asked by the School to develop information related to the cost of flight and synthetic flight training in the course under consideration, in order that such information could be taken into account in the School's decision on possible adoption of the equipment. The present Appendix was prepared in response to that request.

APPROACH[1]

The approach taken was to compute, on an annual basis, the costs which could be attributed to the operation of O/WOFWAC Phase C flight training, to estimate the costs which might reasonably be incurred by the procurement and use of GAT-2 training devices, and to compute from these costs the savings that would result from specific reductions in flight training time due to the increased efficiency of synthetic training using the new device.

Table A-1 indicates the various materials and services which were included in the cost computations and the source of the cost data concerning them. It should be noted that certain costs associated with both flight and synthetic flight training in Phase C are not included. Costs associated with administration of the U.S. Army Aviation Center and the conduct of academic instruction in Phase C were not included because it was assumed that the contribution of such costs to the conduct of flight training would be insensitive to a change in the ratio of flight to synthetic flight training. In addition, costs associated with student transportation, housing the synthetic trainers, operation of the airfields where O/WOFWAC Phase C is conducted, and buildings provided the contractors for administrative purposes were omitted because of the limited personnel resources available to HumRRO during the period of this investigation.

It should be noted that the cost data cited in this Appendix are current as of 31 March 1968. It is probable that data current on any subsequent date will not coincide exactly with all of the costs reported herein.

Although the U.S. Army does not depreciate its property for accounting purposes, that means of representing the annual cost of equipment and facilities was selected for the present calculation. Table A-2 presents the depreciation periods which were adopted. They were judged to be reasonable estimates of the useful life of the items included in

[1] See Reference 3.

Table A-1

Materials and Services Included in the Study and Cost Data Sources

Materials and Services	Cost Data Source
T-42 aircraft Office equipment and furniture Flight clothing and equipment	Supply Division, DOSS, USAAVNS
Buildings Building maintennace Utilities Janitorial Service	Real Property Section, Engineers Division, DCSLOG, USAAVNC
Aircraft spare parts Petroleum, oil, and lubricants Government furnished maintenance equipment[a] Refueling, contract Maintenance, contract	Logistics Management Board, DCSLOG, USAAVNC
Flight training contract Synthetic training contract	Plans Division, G-3, USAAVNC
GAT-2	Link Group, General Precision Systems, Incorporated

[a]Government furnished maintenance equipment consists of 1,213 items supplied to the maintenance contractor. The equipment includes items such as vehicles, furniture, office equipment, tugs, cranes, and special tools. Because of the number and variety of the items involved, they are treated as one item in this Appendix.

Table A-2

Depreciation Periods

Item	Depreciation
Permanent buildings (masonry-steel)	50 years
Temporary buildings (wood)	25 years
Aircraft	10 years
Synthetic trainers	10 years
Furniture	10 years
Office equipment	10 years
Government-furnished maintenance equipment	10 years
Flight equipment	5 years
Flight clothing	2 years

the investigation. Straight line depreciation schedules were used, and the periods involved ranged from 50 years for permanent buildings to two years for flight equipment.

RESULTS

Table A-3 contains a summary of the annual costs associated with the conduct of flight training in Phase C of the O/WOFWAC. These costs total $2,330,020.63. The present annual input to Phase C is 645 trainees, and each trainee receives approximately 60 hours of flight training. The total annual number of training flight hours in Phase C, therefore, is 38,700. Dividing 38,700 flight hours into the $2,330,020.63 annual cost of Phase C flight training in the T-42 yields a flight training hourly cost of $60.21.

Table A-4 contains a summary of the annual costs associated with the conduct of synthetic flight training in Phase C of the O/WOFWAC, assuming the use of 13 GAT-2 trainers. These costs total $154,140.00. With the present annual input to Phase C of 645, and with each trainee receiving approximately 21 hours of synthetic flight training, the total number of hours of such training is 13,545. A computation similar to that performed for flight training yields a synthetic flight training hourly cost of $11.38.

Table A-3

Annual Costs of Phase C Flight Training

1. Aircraft depreciation			$ 188,522.00
2. Flight training cost			
Contract		$658,858.67	
Flight building			
Depreciation	$2,092.71		
Utilities	3,914.76		
Janitorial services	2,801.26		
Maintenance	963.47		
		9,722.20	
Furniture and other equipment			
Depreciation		1,636.48	
Flight clothing			
Depreciation		2,778.70	
Flight equipment			
Depreciation		1,100.82	
			674,146.87
3. Maintenance cost			
Contract		971,370.00	
Spare parts (OMA)		278,253.00	
Spare parts (PEMA)		4,257.00	
Government-furnished maintenance equipment		8,718.76	
			1,262,598.76
4. Petroleum, oil, and lubrication			172,215.00
5. Refueling			32,508.00
			$2,330,020.63

This report provides a discussion of the suitability of the present synthetic flight training device, Device 2-B-12A, for Phase C training. With the 21 hours' synthetic flight training now provided in Device 2-B-12A, 60 hours' flight training is required in the T-42 in order for the trainees to attain sufficient instrument flight proficiency in the T-42 aircraft to pass the final Phase C checkride.

Table A-4

Annual Costs of Phase C Synthetic Flight Training

Trainer depreciation	$ 55,740.00
Trainer operation	78,900.00
Trainer maintenance	19,500.00
	$154,140.00

Because of the more suitable design of the GAT-2, it is believed that training in it will transfer more efficiently to the T-42 aircraft. It is estimated that substitution of 20 hours of appropriate training in the GAT-2 for the training now given in the 2-B-12A will permit an immediate reduction of at least five hours in the length of O/WOFWAC twin-engine and instrument flight training. Further, it is believed that a synthetic flight training program can be developed for use with the GAT-2 which will permit further reduction in the amount of flight training in the T-42 aircraft required to meet the present end-of-phase proficiency requirements.

The cost data cited in this Appendix are based upon specific training conditions—60 hours in the T-42 and 21 hours in the GAT-2. Reducing the amount of flight training or

Table A-5

Annual Costs and Probable Savings Associated With Selected Combinations of Flight and Synthetic Flight Training

Hours of training in the		Annual Cost	Annual Savings
Aircraft	Trainer		
60	21[a]	$2,465,440.63	$ 0
55	20	2,282,751.75	182,688.88
50	25	2,125,275.00	340,165.63
45	30	1,967,798.25	497,642.38
40	35	1,810,321.50	655,119.13
35	40	1,652,844.75	812,595.88
30	45	1,495,368 00	970,072.63

[a]The present Phase C training program, consisting of 60 hours in the T-42 and 21 hours in the 2-B-12A, is included for comparison. For the purpose of this comparison, the cost of synthetic flight training in the 2-B-12A was estimated (not computed) to be $135,450.00, or $10.00 per hour. Except for the first row, all costs and savings shown in Table C-5 are based upon the use of CAT-2 trainers.

increasing the amount of synthetic flight training will result in changes in the hourly cost of these two types of training. Nevertheless, the cited hourly costs can be used as estimates in order to determine the effect upon total training costs of various combinations of T-42 and Gat-2 training.

Table A-5 contains selected combinations of flight and synthetic training that probably could be achieved were the GAT-2 introduced in Phase C. The values selected for this table are not based upon transfer of training data, since no such data exist at the present time. Rather, they represent the opinion of the HumRRO research staff that training programs consisting of the indicated combinations of flight and synthetic flight training can be developed that will achieve the same level of trainee proficiency now being achieved in Phase C. Optimum combinations of flight and synthetic flight training must be determined empirically. To achieve a given flight time reduction may actually require a greater or lesser amount of synthetic flight training than that shown in this table.

COMPUTATION NOTES

Aircraft

Thirty-five T-42A aircraft are required to support Phase C training. Each aircraft cost $53,872.00, and it is depreciated over a ten-year period. Therefore, ($53,872.00 x 35)/10 = $188,552.00, the annual Phase C aircraft cost.

Flight Training

Phase C flight, synthetic, and academic instruction is conducted under a fixed rate contract based on the number of trainees involved. The annual contract cost for flight instruction only for FY 1968 is $358,858.67. This includes salaries of supervisors, instructors, and clerical personnel, Social Security tax, State and Federal Unemployment Insurance, Workmen's Compensation tax, uniform expenses, office expenses, communication services, accountant's fees, and contractors's profit.

Phase C flight training is conducted out of Building 205, Cairns Field. This is the fixed wing flight training building. It houses Headquarters, Department of Advanced Fixed Wing Training, and all fixed wing flight courses.

The area of Building 205 occupied by and charged to Phase C, including a pro-rata share of the lobby, halls, and latrines, is 8,378.28 square feet. This represents 35.22 percent of the 23,785 gross square footage of the building. Total value of the building is $297,091.65, of which 35.22 percent is $104,635.68. The building was depreciated over a 50-year period. Therefore, ($104,635.68)/50 = $2,092.71, the annual cost of the Phase C training building.

In addition to the cost of the training building itself, other costs are associated with its use. A percentage of utilities, janitorial service, and maintenance also must be charged to Phase C.

The Engineers Division, DCSLOG, reports that, on a post-wide annual basis, utilities cost $51.51 per person who works or maintains a work area in post buildings. Seventy-six Phase C flight training contractor personnel utilize Building 205. Therefore, $51.51 x 76 = $3,914.76 which is chargeable annually to Phase C for training building utilities.

Janitorial services for Building 205 are provided by a civilian contractor. Two types of services are provided:

(1) On a nightly basis, at a charge of $.017 per square foot of cleanable area.
(2) On a permanent basis.

Building 205 utilizes both services. One full time janitor is provided at a cost of $275.00 monthly. In addition, there is nightly clean-up service costing $.017 x 22,812 square feet of cleanable area in the building, or $387.80 per month for a monthly total of $662.80, or an annual charge of $7,953.60. Since Phase C personnel occupy 35.22 percent of Building 205, the pro-rata annual charge to Phase C is $7,953.60 x .3522, or $2,801.26.

Maintenance of permanent type buildings is computed by DCSLOG on a basis of $115.00 annually per 1,000 square feet of floor space. Phase C occupies 8,378.28 square feet of floor space. Therefore, 8.378 x $115.00 = $963.47 annually for training building maintenance. The government provides the contractors involved in Phase C with sufficient office and classroom furniture and equipment to support training. The flight training contractor has $16,364.75 worth of such equipment in offices and classrooms in Building 205. Depreciated over ten years, this equipment costs $1,636.48 annually.

Each contractor instructor pilot is furnished flight suits, boots, gloves, and flight jacket. The total cost of this clothing is $5,557.40. Depreciated over two years, the annual cost is $2,778.70.

Each contractor instructor pilot is furnished a headset, knee pad, flashlight, and computer. The total cost of this equipment is $5,504.12. Depreciated over five years, the annual cost is $1,100.82.

Maintenance

Maintenance support for the aircraft used in Phase C is provided by a civilian contractor. For FY 1968, the following amounts have been programed by DCSLOG for maintenance support for the 35 T-42A aircraft used in Phase C:

Labor and overhead	$971,370.00
Spare parts (OMA)	278,253.00
Spare parts (PEMA)	4,257.00

The maintenance contractor is provided government equipment to support maintenance for 180 U.S. Army fixed wing aircraft located at Cairns AAF. The equipment includes special tools, office equipment, furniture, vehicles, etc. The total cost of this equipment, estimated by DCSLOG, is $448,501.06.

Thirty-five of these aircraft, or 19.44%, are required to support Phase C flight instruction. Therefore, .1944 x $448,501.06 = $87,188.61, which is chargeable to Phase C flight training. Depreciating this equipment over ten years yields an annual cost of government furnished aircraft maintenance equipment of $8,718.86.

POL

Approximately 38,700 hours of flight time will be flown in FY 1968 in the Phase C flight program. According to current flying hour cost figures prepared by the Logistics and Management Section of DCSLOG, the T-42A hourly POL cost is $4.45. On an annual basis, this amounts to $172,215.00.

Refueling

Refueling services are provided by a civilian contractor. DCSLOG provided cost figures show refueling cost to be $0.84 per hour for the T-42A. On an annual basis, this amounts to $32,508.00 for 38,700 flight hours.

Trainers

The cost of procurement of GAT-2 training devices has been quoted by the manufacturer as $42,500 each.[1] An additional $4,900 has been quoted for on-site

[1] Shipping and installation charges are not included.

installation of the first two of these devices and the training of USAAVNS personnel in their operation and maintenance. Replacement of existing devices with GAT-2s on a 1:1 basis was used as a basis for computation. Therefore, 13 new GAT-2s will be required. The cost of these devices, including initial installation and training of USAAVNS personnel, will be $557,400. Using a depreciation period of 10 years, the annual cost will be $55,740.

Synthetic Flight Training

Synthetic flight training is conducted by a contractor. The cost of that training, obtained from the Plans Division, G-3, USAAVNS, is $78,900 annually.

Trainer Maintenance

The cost of spare parts to be used in maintaining GAT-2 devices has been estimated by the device manufacturer at $1,500 per trainer per year, or $19,500 annually for 13 trainers. Considering the fact that the GAT-2 is a new device and no valid data on spare parts utilization exist, the manufacturer's technical personnel have stated informally that this is likely to be an overestimate of the actual cost.

Appendix B

DEVELOPMENT OF A U-21 PROCEDURES TRAINER

During the course of the Technical Advisory Service to the Department of Advanced Fixed Wing Training, a cockpit procedures trainer for the U-21 Ute was developed. The trainer constitutes the implementation of previous research conducted by HumRRO Division No. 6 (Aviation), HumRRO Division No. 5, and HumRRO Division No. 3 under Work Units TRADER, ECHO, RINGER, and STRANGER.[1]

The trainer is a three-dimensional, full-scale replica of the cockpit of the Ute forward of (approximately) Station 143. It contains operating facsimilies of all Ute aircraft controls and components required to be manipulated by the pilot during the execution of cockpit preflight, engine start and run-up, engine clearing, pretake-off, shutdown, and cockpit post flight procedures.

The trainer may be seen in Figure B-1. It was fabricated by the Third U.S. Army Training Aids Center to specifications developed by the HumRRO research staff. The cost

U-21 UTE Procedures Trainer

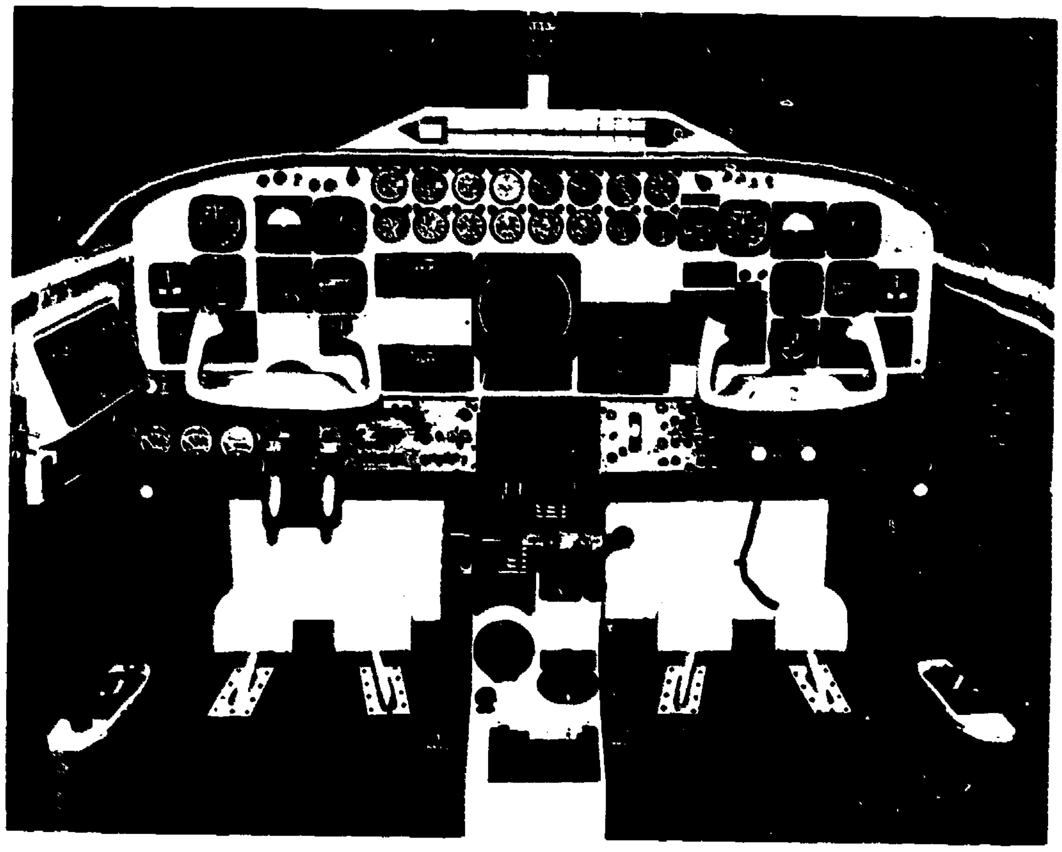

Figure B-1

[1] See References 4, 5, 6, 7, and 8.

of the device, including all parts and labor, was reported to be $4,300. Upon completion of its development and checkout, it was delivered to the Department of Advanced Fixed Wing Training and is being used there in the U-21 Aviator Qualification Course.

A design criterion for the trainer was the activation of all indicators and displays that were used during the execution of the procedures listed. To the extent that such activation was within the capability of the Third U.S. Army Training Aids Center, this was accomplished through the use of electrical signals. Where electrical activation was not practicable, techniques were devised to provide the necessary system dynamics through the trainer instructor or the trainee himself. To this end, the following techniques were employed:

(1) A remote instructor's control box was provided. The box contains switches that permit the instructor to turn indicator lights on the cockpit instrument panel on and off in response to trainee action.

(2) All engine instruments that display information used by the trainee during the procedures for which training is provided are activated by the trainee; that is, he moves instrument dial needles to specified instrument values in response to his own manipulation of the aircraft controls.

No training device is of value without a training program. A program of instruction was developed for use specifically with the procedures trainer. It specifies, in step-by-step detail, the actions required of a trainee and an instructor during Ute procedures training. The program of instruction was delivered to the Department of Advanced Fixed Wing Training along with the trainer.

A research product of HumRRO Work Unit SYNTRAIN, a 4/10 scale paper mockup of the UTE cockpit, called a HumRRO Trainer, also was provided to the Department of Advanced Fixed Wing Training for use in conjunction with the procedures trainer and the program of instruction described above. The HumRRO Trainer is shown in unassembled and assembled form in Figures B-2 and B-3. An Instructor Guide for the U-21 Procedures Trainer was prepared to facilitate the standardized use of the procedures trainer, the paper HumRRO Trainer, and the program of instruction. A copy of the Instructor's Guide is included in this Appendix.

Unassembled HumRRO Trainer

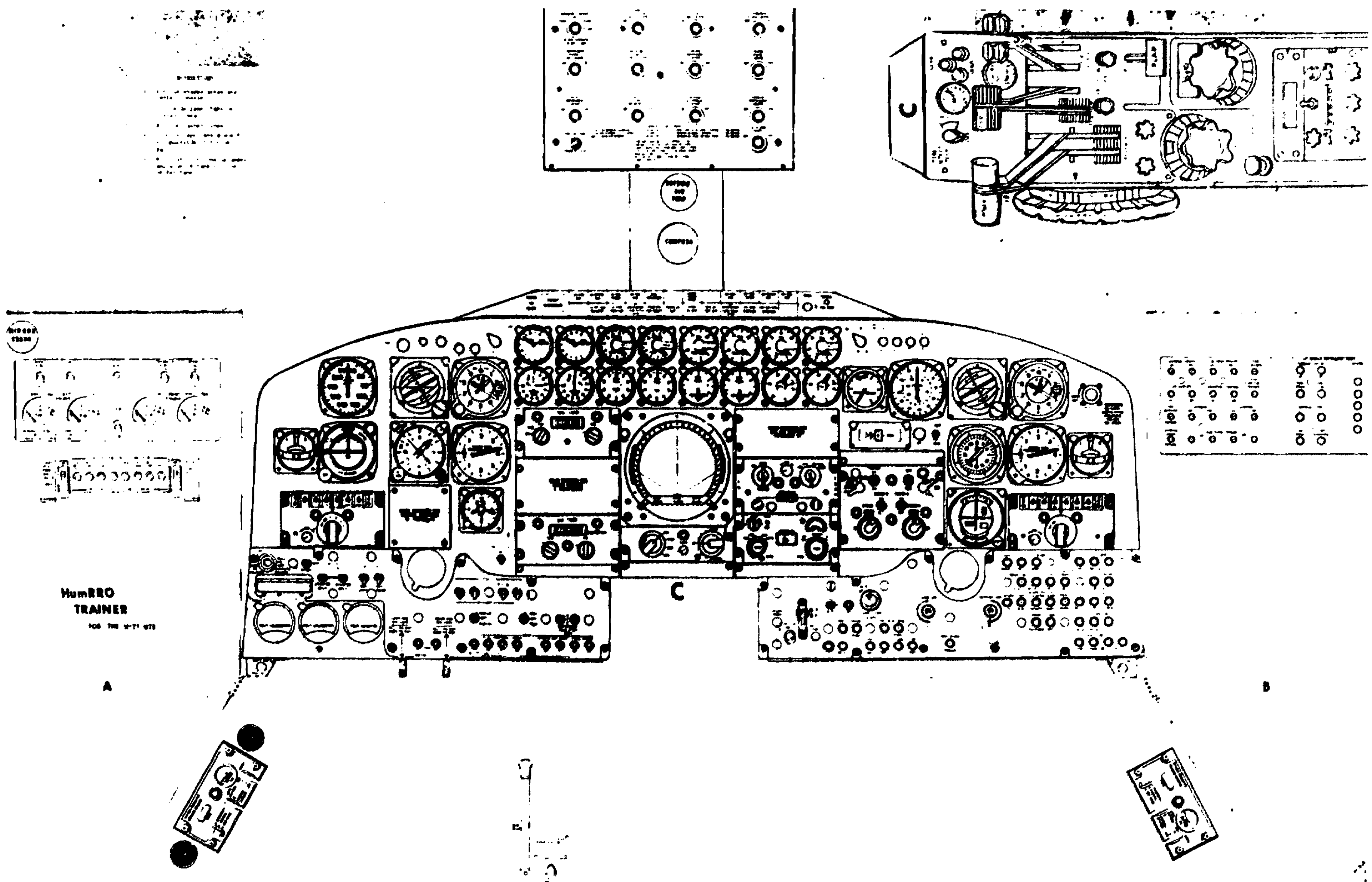

Figure B-2

Assembled HumRRO Trainer

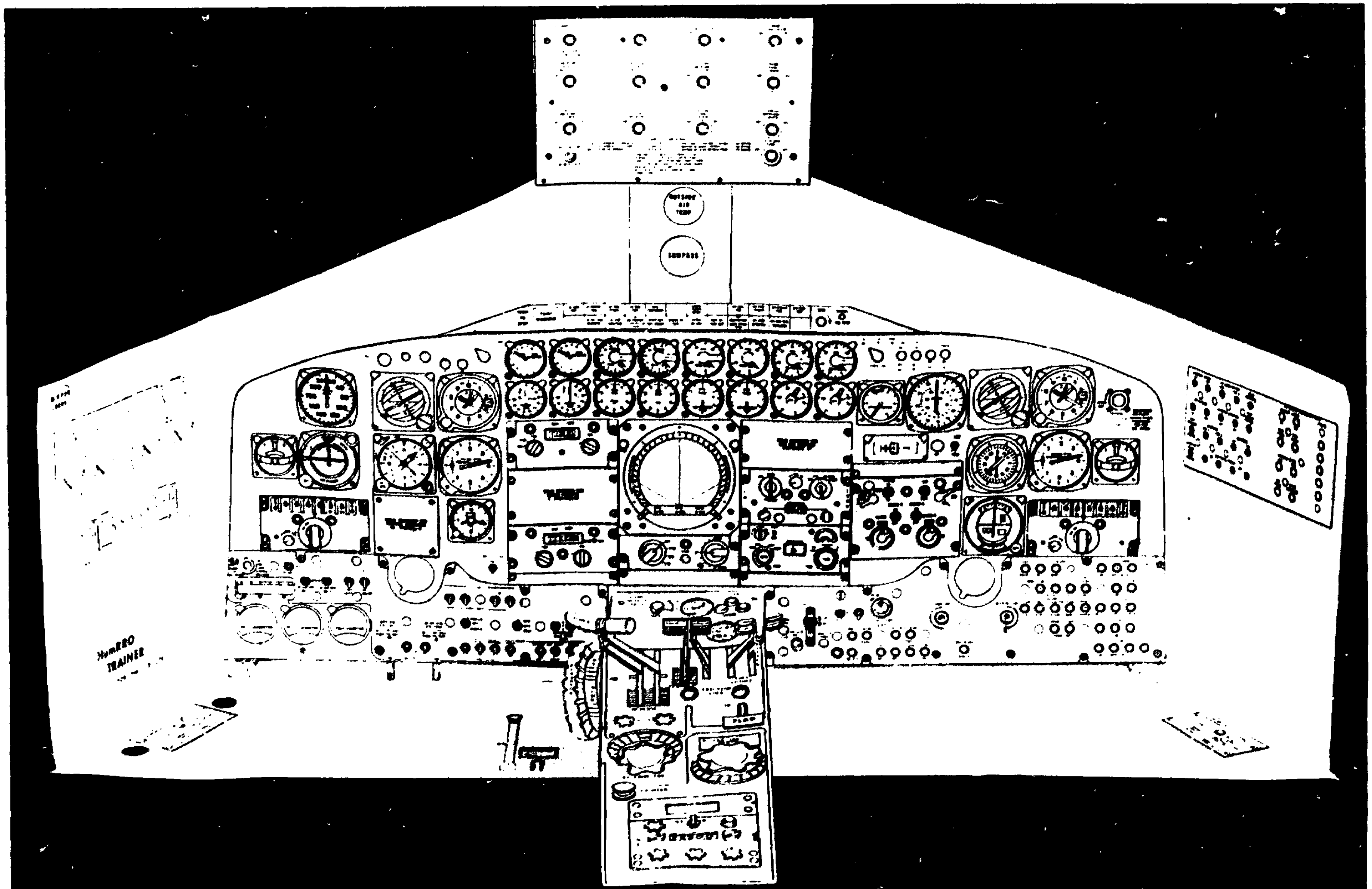

Figure B-3

INSTRUCTOR'S GUIDE FOR THE U-21 PROCEDURES TRAINER

The U-21 Procedures Trainer is a training device designed to facilitate the acquisition of certain procedural skills necessary to the operation of the U-21 Ute. All procedures associated with operation of the U-21 on the ground, e.g., Starting Engines and Engine Shutdown, may be practiced in the trainer.

The U-21 Procedures Trainer Checklist is designed for use in the trainer and as a home study guide in conjunction with the U-21 HumRRO Trainer. Each item number of the Procedures Trainer Checklist corresponds to the aircraft checklist item number found in TM 55 1510-209-10. You will see that some items on the Prorcedures Trainer Checklist have been broken into component steps. Trainee actions entailed by each step must be memorized because these steps are not given in the checklist used in the aircraft.

To be effective, training in the Procedures Trainer must precede training in the aircraft itself. With adequate home study using the Procedures Trainer Checklist and the U-21 HumRRO Trainer, the typical trainee can essentially master these procedures in five trials in the trainer. On the sixth trial (i.e., the first trial in the aircraft), the trainee should be expected to perform the appropriate procedures, using only the aircraft checklist found in the -10, without error. The recommended training technique is to allow the trainee to use the detailed Procedures Trainer Checklist during the first two or three trials in the trainer, thereafter requiring him to perform from memory. The "challenge and reply" method used in the aircraft is appropriate for use in the trainer.

The Procedures Trainer was fabricated at Fort Rucker. Some of the knobs and levers do not operate. The rudder pedals, fresh air vent knob, and ice vane levers, for example, can be damaged should excessive pressure be exerted on them. In order to extend the life of electrical components (e.g., light bulbs), the battery switch should remain in the OFF position when the trainer is not in use.

The column headings on the Procedures Trainer Checklist generally are self-explanatory. You may find it desirable to elaborate upon some of the comments in order to assure trainee understanding.

DISTRIBUTION LIST

2 DIR OASD MANPOWER (PPEGR)
1 CHF DEF NUC AGCY ATTN DOC LIB BR
1 DIR WSEG WASH., D.C. 20305
1 DIR OASD MANPOWER & RESERVE AFFAIRS
1 OFC OF THE ASST SEC OF DEF (M&E) (OAA) ATTN M BIEGEL
2 COMDR FLD COMD DEF NUC AGCY SANDIA BASE ATTN FCTG7
2 NASA SCI & TECH INFO FACILITY COLLEGE PARK MD
1 CINC US EUROPEAN COMD ATTN SUPPORT PLANS BR J3
1 CINC USA PACIFIC ATTN G3 CDC APO SAN FRAN 96610
1 CG US ARMY JAPAN APO 96343 SAN FRAN ATTN G3
10 CG USA FORCES SOUTHERN COMD ATTN SCARCD C/
1 CG USA ALASKA ATTN ARACD APO 98749 SEATTLE
2 CG US ARMY EUROPE APO 09403 NY ATTN OPNS DIV
1 CO ARMY TRANS RES COMD FT EUSTIS ATTN TECH LIB
1 CG USA AD COMD ENT AFB ATTN ADGPA COLO
6 CG 1ST ARMY ATTN DCSOT FT MEADE MD
1 CG 3RD ARMY ATTN DCSOT FT MCPHERSON
2 CG SIXTH ARMY PRES OF SAN FRAN ATTN AMOPS-T7
1 CG EUSA ATTN AG-AC APO 96301 SAN FRAN
1 CLIN PSYCHOL SERV DEPT OF NEUROPSYCHIAT WALTER REED GEN HOSP
1 DIR HEL APG MD
1 CG USA CDC EXPERIMENTATION COMD FT ORD
2 ENGNR PSYCHOL LAB PIONEERING RES DIV ARMY NATICK LABS NATICK MASS
1 TECH LIB ARMY NATICK LABS NATICK MASS
2 INST OF LAND CBT ATTN TECH LIB FT BELVOIR VA
1 REDSTONE SCIENTIFIC INFO CTR US ARMY MSL COMD ATTN CHF DOC SEC ALA
1 CO FT HUACHUCA SPT COMD USA ATTN TECH REF LIB
2 CG US ARMY CDC EXPERIMENTATION COMD FT ORD
1 SIXTH USA LIB DEPOT BLDG M 13 14 PRES OF SAN FRAN
1 PLNS OFCR PSYCH HOQTRES USACDCEC FT ORD
5 CG FT ORD ATTN G3 TNG DIV
1 DIR WALTER REED ARMY INST OF RES WALTER REED ARMY MED CTR
2 DIR WRAIR WALTER REED ARMY MED CTR ATTN NEUROPSYCHIAT DIV
1 CO HQ ARMY ENLISTED EVAL CTR FT BENJ HARRISON
1 TECH LIB BOX 22 USACDC EXPERIMENTATION COMD FT ORD
1 HUMAN FACTORS TEST DIV (AOHZ) USAF HOSP EGLIN AFB
1 CO FRANKFORD ARSNL ATTN SMUFA-N6400/202-4 PA
3 6TH RGN USARADCOM FT BAKER
1 4TH ARMY MSL COMD AIR TRANSPORTABLE SAN FRAN
1 PERS SUBSYS DIV CREW SUBSYS DRCT AERO SYS DIV WRIGHT-PAT.
1 DIR ARMY BD FOR AVN ACCIDENT RSCH FTRUCKER
2 CO PICATINNY ARSNL DOVER N J ATTN SUMPA VCI
1 LIB DEF SUPPLY AGCY CAMERON STA VA
2 CO USA CDC AG AGCY FT BENJ HARRISON IND
1 REF M MS IS NASA ALA
1 CO USA CBT DEVEL COMD TRANS AGCY FT EUSTIS
1 CO ARMY CDC INF AGY FT BENNING
1 CO ARMY CDC ARMOR AGY FT KNOX
8 USA CDC SPEC WARFARE AGENCY FT BRAGG
1 CO US ARMY CDC AVN AGCY FT RUCKER
3 CO USA CDC CBT SUPPORT GP FT BELVOIR
3 CO USA TNG CTR (FA) ATTN AKPSITC-TT FT SILL
1 CG USA TNG CTR & FT LEONARD WOOD ATTN ACOFS G3
1 CG USA INF CTR ATTN AJIGT-T FT BENNING
1 CG USA TNG CTR INF ATTN ACOFS G3 FT DIX
1 CG USA TNG CTR ATTN ACOFS G3 FT JACKSON
1 CG USA TNG CTR INF ATTN ACOFS G3 FT LEWIS
1 CG USA TNG CTR INF & FT ORD ATTN ACOFS G3
49 CG USA TNG CTR INF ATTN ACOFS G3 FT POLK
5 CO USA MED TNG CTR ATTN DIR OF TNG FT SAM HOUSTON
20 CG USA AD CTR ATTN G3 FT BLISS
1 CG USA TNG CTR INF ATTN ACOFS G3 FT CAMPBELL
3 LIB ARMY WAR COLL CARLISLE BKS
1 COMDT COMD + GEN STAFF CO FT LEAVENWORTH ATTN ARCHIVES
1 DIR OF MIL'T PSYCHOL + LDRSHP US MILIT ACAD WEST POINT
1 US MILIT ACAD WEST POINT ATTN LIB
1 COMDT ARMY AVN SCH ATTN DIR OF INSTR FT RUCKER
2 COMDT ARMY SECUR AGY TNG CTR + SCH FT DEVENS ATTN LIB
1 COMDT INDSTR COLL OF THE ARMED FORCES FT MCNAIR
2 COMDT NATL WAR COLL FT LESLEY J MCNAIR ATTN CLASSF RECORDS BR LIB
1 STIMSON LIB MED FLD SERV SCH BROOKE ARMY MED CTR FT SAM HOUSTON
3 COMDT THE ARMOR SCH ATTN DOI FT KNOX
1 COMDT ARMY ARMOR SCH FT KNOX ATTN WEAPONS DEPT
1 LIB USA ARMOR SCH FT KNOX
1 COMDT USA CHAPLAIN SCH ATTN DOI FT HAMILTON
1 COMDT ARMY CHEM CORPS SCH FT MCCLELLAN ATTN EDUC ADV
1 COMDT USA FIN SCH ATTN CHF DOC DEV LIT PLN DIV DDDI IND
1 USA FINANCE SCH FT BENJ HARRISON ATTN EDUC ADV
4 COMDT ADJ GEN SCH FT BENJ HARRISON ATTN EDUC ADV
1 COMDT USAIS ATTN EDUC ADV FT BENNING
1 COMDT USAIS ATTN AJIIS-D-EPRD FT BENNING
1 HQ US ARMY ADJ GEN SCH FT BENJ HARRISON ATT COMDT
1 LIB ARMY QM SCH FT LEE
1 COMDT USA QM SCH FT LEE ATTN EDUC ADV
1 COMDT ARMY TRANS SCH FT EUSTIS ATTN EDUC ADV
1 CO USA SEC AGY TNG CTR & SCH ATTN IATEV RSCH ADV FT DEVENS
1 COMDT USA MIL POLICE SCH ATTN PLNS &PROG ODOI FT GORDON
2 COMDT US ARMY SOUTHEASTERN SIG SCH ATTN EDUC ADV FT GORDON
1 COMDT USA AD SCH ATTN DOI FT BLISS
1 CO USA ORD CTR & SCH OFC OF OPS ATTN AHBN-O APG MD
5 ASST COMDT ARMY AIR DEF SCH FT BLISS ATTN CLASSF TECH LIB
3 CG USA FLD ARTY CTR & FT SILL ATTN AVN OFCR
1 COMDT DEF INTELL SCH ATTN SIGAS DEPT
1 COMDT ARMED FORCES STAFF COLL NORFOLK
1 COMDT USA SIG CTR & SCH ATTN DOI FT MONMOUTH
1 COMDT JUDGE ADVOCATE GENERALS SCH U OF VA
1 DPTY COMDT USA AVN SCH ELEMENT GA
1 DPTY ASST COMDT USA AVN SCH ELEMENT GA
1 USA AVN SCH ELEMENT OFC OF DIR OF INSTR ATTN EDUC ADV GA
1 EDUC CONSLT ARMY MILIT POLICE SCH FT GORDON
6 COMDT USA ENGR SCH ATTN EDUC ADV AHBBES-EA FT BELVOIR
2 COMDT USA SCH EUROPE ATTN EDUC ADV APO 09172 NY
1 OFC OF DOCTRINE DEV LIT & PLNS USA ARMOR SCH ATTN AHBAAS-DM
1 COMDT ARMY AVN SCH FT RUCKER ATTN EDUC ADV
5 CG USA PRIM HELICOPTER CTR/SCH & FT WOLTERS ATTN ATSPH-DOT
1 DIR OF INSTR US MIL ACAD WEST POINT NY
1 DIR OF MILIT INSTR US MILIT ACAD WEST POINT
1 USA INST FOR MIL ASSIST ATTN LIB BLDG 1ST2808 FT BRAGG
4 USA INST FOR MIL ASSIST ATTN COUNTERINSURGENCY DEPT FT BRAGG
1 COMDT DEF MGT SCH FT BELVOIR
2 COMDT USA MSL & MUN CTR & SCH ATTN CHF OFC OF OPS REDSTONE ARSNL
2 COMDT US WAC SCH US WAC CTR ATTN AJMCT FT MCCLELLAN
2 HQ ABERDEEN PG ATTN TECH LIB
1 CO USA INTELL CTR & SCH ATTN DIR OF ACADEMIC OPS FT HUACHUCA
1 CO USA INTELL CTR & SCH ATTN DIR OF DOC & LIT FT HUACHUCA
1 COMDT USA C&GSC OFC OF CHF OF RESIDENT INSTR FT LEAVENWORTH
1 COMDT USA CA SCH ATTN OFC OF DOCTRINE DEVEL LIT & PLNS FT BRAGG
1 COMDT USA CA SCH ATTN DOI FT BRAGG
1 COMDT USA CA SCH ATTN EDUC ADV FT BRAGG
1 COMDT USA CA SCH ATTN LIB FT BRAGG
1 COMDT USA SCH & TNG CTR ATTN ACOFS G1 TNG DIV FT MCCLELLAN
1 COMDT USA SCH & TNG CTR ATTN ACOFS G3 PLNS & OPS DIV FT MCCLELLAN
10 COMDT USA INST FOR MIL ASSIST ATTN DOI FT BRAGG
1 LIBN USAIS FT BENNING
8 COMDT USA FLD ARTY SCH ATTN DOI FT SILL
1 COMDT USA ARTY SCH ATTN EDUC SERVICES DIV FT SILL
1 COMDT USA ARTY SCH ATTN EDUC ADV FT SILL
1 COMDT USA TRANS SCH ATTN DIR OF DOC & LIT FT EUSTIS
1 COMDT USA TRANS SCH ATTN LIB FT EUSTIS
2 USA INST FOR MIL ASST ATTN EDUC ADV FT BRAGG
1 COMDT USA C&GSC ATTN ATSCS-DJ (SPWAR)
1 COMDT ARMY QM SCH OFC DIR OF NONRESID ACTVY ATTN TNG MEDIA DIV VA
1 COMDT USA ARTY SCH ATTN LIB FT SILL
1 CG USA SCH & TNG CTR ATTN ACOFS G3 FT GORDON
1 DIR OF GRAD STUD & RSCH ATTN BEHAV SCI REP USAC&GSC
1 COMDT USA AD SCH ATTN AKBAAS-DL-EA FT BLISS
1 COMDT USA AD SCH HIGH ALTITUDE MSL DEPT FT BLISS
2 DIR BRGD + BN OPNS DEPT USAIS FT BENNING
1 DIR COMM ELEC USAIS FT BENNING
1 DIR ABN-AIR MOBILITY DEPT USAIS FT BENNING
2 DIR COMPANY TACTICS DEPT USAIS FT BENNING
1 CG USA SIG CTR & SCH ATTN ATSSC-DP-COB FT MONMOUTH
1 CG USA SIG CTR & SCH ATTN ATSSC-EA FT MONMOUTH
1 SECY OF ARMY, PENTAGON
1 DCS-PERS DA ATTN CHF C+S DIV
1 DIR OF PERS STUDIES & RSCH ODCSPER DA WASH DC
1 CO FOREIGN SCI + TECH CTR MUN BLDG
2 ACSFOR DA ATTN CHF TNG DIV WASH DC
1 CG USA MAT COMD ATTN AMCRD-TE
1 CHF OF ENGNRS DA ATTN ENGTE-T
1 HQ ARMY MAT COMD R+D DRCTE ATTN AMCRD-RC
2 CG ARMY MED R+D COMD ATTN BEHAV SCI RES BR
1 US ARMY BEHAVIOR & SYS RSCH LAB ATTNCRD-AR ARL VA
1 OPO PERS MGT DEV OFC ATTN MOS SEC (NEW EQUIP) OPOMO
1 PROVOST MARSHAL GEN DA
1 DIR CIVIL AFFAIRS DRCTE ODCSOPS
1 OFC RESERVE COMPON DA
2 CG USA SEC AGCY ARL HALL STA ATTN AC OF S G1 VA
12 ADMIN DOC ATTN: TCA (HEALY) CAMERON STA ALEX., VA. 22314
1 CO US ARMY MED RES LAB FT KNOX
1 CG ARMY ELECT COMD FT MONMOUTH ATTN AMSEL CB
1 CHF OF R+D DA ATTN CHF TECH + INDSTR LIAISON OFC
1 CO USA CDC MED SERV AGCY FT SAM HOUSTON
2 CG ARMY MED R+D COMD ATTN MEDDH-SR
1 USA BEHAVIOR & SYS RSCH LAB ATTN CRD-AIC ARL VA
1 COMDT USA CBT SURVEIL SCH & TNG CTR ATT ED ADV FT HUACHUCA
1 COMDT USA CBT SURVEIL SCH & TNG CTR ATTN ORG DOC & NEW EQUIP ARIZ
2 TNG & DEVEL DIV ODCSPERS
1 COMDT USA CBT SURVEIL SCH & TNG CTR ATTN 1ST CBT TNG BDE ARIZ
1 CAREER MGT BR ATTN R DETIENNE CAMERON STA ALEX VA
1 USA LIB DIV-TAGO ATTN ASDIRS
1 PRES ARMY ARMOR BD FT KNOX
1 PRES ARMY MAINT BD FT KNOX
2 PRES ARMY AVN TEST BD FT RUCKER
2 PRES ARMY ARTY BD FT SILL
1 CG CONARC ATTN COL E M HUDAK ATIT-SA FT MONROE
15 CG CONARC ATTN ATIT-SIM FT MONROE
2 CG CONARC ATTN LIB FT MONROE
1 CO ARMY CBT DEVEL COMD MILIT POLICE AGY FT GORDON
1 USA ARCTIC TEST CTR CHF INSTR & TEST METH DIV SEATTLE
1 CHF USA AD HRU FT BLISS
1 CHF USA ARMOR HRU FT KNOX
1 CHF USA AVN HRU FT RUCKER
1 CHF USA INF HRU FT BENNING
1 CHF USA TNG CTR HRU PRES OF MONTEREY
1 CG 2D ARMORED DIV FT HOOD ATTN DIV AVN OFCR
6 CG 4TH ARMORED DIV ATTN DCSOT APO NY 09326
4 CO 2D ARMORED CAV REGT APO 09693 NY

1 CO 3D ARMORED CAV REGT FT LEWIS
1 CO 14TH ARMORED CAV REGT ATTN AVN OFCR APO 09146 NY
1 1ST ARMORED DIV HQ & HQ CO FT HOOD ATTN AC OF S G2
10 CO 1ST BN 63RD ARMOR 1ST INF DIV ATTN S3 FT RILEY
4 CO 1ST BN 64TH ARMOR 3RD INF DIV ATTN S3 APO NY 09031
8 CO 2ND BN 68TH ARMOR 8TH INF DIV ATTN S3 APO NY 09034
1 CO COMPANY A 3D BN 32D ARMOR 3D ARMORED DIV APO NY
1 CO 5TH BN 33D ARMOR ATTN S3 FT KNOX
1 CO 3RD BN 37TH ARMOR 4TH ARMORED DIV ATTN S3 APO NY 09066
2 CALIF NG 40TH ARMORED DIV LOS ANGELES ATTN AC OF SG3
1 55TH COMD HQ DIV ARMY NG JACKSONVILLE FLA
4 CO 150TH AVN BN NJ AIR NG ELIZABETH
1 CG HQ 27TH ARMORED DIV NY AIR NG SYRACUSE
1 TEXAS NG 49TH ARMORED DIV DALLAS
3 CG ARMY ARMOR CTR FT KNOX ATTN G3 AIBKGT
1 CG 3RD INF DIV ATTN ACOFS G3 APO NY 09036
1 CG 7TH INF DIV ATT ACOFS G2 APO SAN FRAN 96207
1 CG 8TH INF DIV ATTN ACOFS G2 APO NY 09111
3 CG 4TH INF DIV (MECH) & FT CARSON ATTN ACOFS G3
1 DA HQS FT CARSON & HQS 4TH INF DIV (MECH) ATT MAJ HARRIS
3 CG 82ND ABN INF DIV ATTN ACOFS G3 FT BRAGG
1 CG XVIII ABN CORPS ATTN ACOFS G3 FT BRAGG
1 CO 197TH INF BRGD FT BENNING ATTN S3
1 CO 1ST BN (REINF) ATTN S3 FT MYER
1 CO HDQTRS 2ND BN 6TH US INF REGT ATTN S3 APO NY 09742
7 CO 3RD BN 6TH INF REGT ATTN S3 APO NY 09742
1 CO 171ST INF BDE ATTN S3 APO SEATTLE 98731
1 CO 1ST BN 39TH INF 8TH INF DIV ATTN S3 APO NY 09034
1 CO 2ND BN 15TH INF 3RD INF DIV ATTN S3 APO NY 09026
5 CG 1ST INF DIV ATTN ACOFS G3 FT RILEY
4 CO 1ST BN (MECH) 52ND INF 198TH INF BDE ATTN S3 APO SAN FRAN 96219
1 CO 4TH BN (MECH) 54TH INF ATTN S3 FT KNOX
1 CO USA PARTIC GP USA TNG DEVICE CTR FLA
2 CONSOL RES GP 7TH PSYOP GP APO 96248 SAN FRAN
2 DA OFC OF ASST CHF OF STAFF FOR COMM-ELCT ATTN CETS-6 WASH
1 CHF MED RES PROJ ARMY HOSP US MILIT ACAD WEST POINT
1 CG MILIT DIST OF WASHINGTON
2 DA USA ADV GP (ARNGUS) RALEIGH NC
1 USA RECRUITING COMD HAMPTON VA
1 DIR ARMY LIB PENTAGON
1 STRATEGIC PLANNING GP CORPS OF ENGNR ARMY MAP SERV
1 CHF OF MILIT HIST DA ATTN GEN REF BR
1 CO USA 10TH SPEC FORCES GP FT DEVENS
1 CO 24TH ARTY GP (AD) ATTN S3 RI
1 CG 31ST ARTY BDE AD ATTN S3 PA
1 CO 49TH ARTY GP AD ATTN S3 FT LAWTON
2 HQS 4TH BN 59TH ARTY REGT ATTN S3 NORFOLK
1 CO 28TH ARTY GP AD ATTN S3 SELFRIDGE AFB
1 HQS 45TH ARTY BDE AD ATTN S3 ARL HTS ILL
1 CO 35TH ARTY BDE AD ATTN S3 FT MEADE MD
1 CG 101ST ABN DIV (AIRMOBILE) ATTN ACOFS G3 APO SAN FRAN 96383
1 CG 1ST CAV (AIRMOBILE) ATTN ACOFS G3 APO SAN FRAN 96383
1 US ARMY GEN EQUIP ATTN TECH LIB FT LEE
1 US ARMY TROPIC TEST CTR PO DRAWER 942 ATTN BEHAV SCIEN CZ
1 CO USAFAAC ATTN S3 FT SILL
10 CG III CORPS & FT HOOD ATTN G3 SEC FT HOOD
30 CO 1ST ARMORED DIV ATTN G3 SEC FT HOOD
30 CG 2D ARMORED DIV ATTN G3 SEC FT HOOD
25 CO 13TH SUPT BGDE ATTN S3 SEC FT HOOD
1 CG USAFAC & FT SILL ATTN AKPSIGT-TNTN
20 CO III CORPS ARTY ATTN G3 SEC FT SILL
15 CO 1ST AIT BGDE ATTN G3 SEC FT BLISS
8 CG USATCI & FT POLK ATTN AKPPO-DCOT
1 RSCH CONTRACTS & GRANTS BR ARO
1 BESD ARO OFC CHF OF R&D WASH DC
1 CHF OF R&D DA ATTN SCI INFO BR RSCH SPT DIV WASH DC
1 CO HQS BN USAFAC & FT SILL ATTN S3
4 CO III CORPS ARTY ATTN S3 FORT SILL
1 CO USRAH ATTN S3 FT SILL
1 CG USAFACFS ATTN AKPSIAG-AS FT SILL
1 EACH PROF OF MILITARY SCI USA ROTC
1 CINC US ATLANTIC FLT CODE 312A USN BASE NORFOLK
1 CINC PACIFIC SCIEN ADV GP (J305) BOX 13 FPO 96610
1 CDR TNG COMMAND US PACIFIC FLT SAN DIEGO
1 CHF BUR OF MED + SURG DN ATTN CODE 513
1 HEAD CLIN PSYCHOL SECT PROFESNL DIV BUR OF MED + SURG DN
5 TECH LIB PERS 11B BUR OF NAV PERS ARL ANNEX
3 DIR PERS RES DIV BUR OF NAV PERS
1 TECH LIB BUR OF SHIPS CODE 210L NAVY DEPT
1 ENGNR PSYCHOL BR ONR CODE 455 ATTN ASST HEAD WASH DC
3 CO + DIR NAV TNG DEVICE CTR ORLANDO ATTN TECH LIB
1 CO FLT ANTI-AIR WARFARE TNG SAN DIEGO
1 CO NUCLEAR WPNS TNG CTR PACIFIC US NAV AIR STA SAN DIEGO
1 CO NAV AIR DEVEL CTR JOHNSVILLE PENNA ATTN NADC LIB
2 US FLT AAW TNG CTR DAM NECK VA
2 CO FLT TNG CTR NAV BASE NEWPORT
2 CO US FLT TNG CTR NORFOLK
1 CO FLEET TNG CTR US NAV STA SAN DIEGO
1 CLIN PSYCHOL MENTAL HYGIENE UNIT US NAV ACAD ANNAPOLIS
1 PRES NAV WAR COLL NEWPORT ATTN MAHAN LIB
2 CO & DIR US ATLANTIC FLT ASW TACTICAL NORFOLK
1 CO NUCLEAR WEAPONS TNG CTR ATLANTIC NAV AIR STA NORFOLK
2 CO FLT SONAR SCH KEY WEST
1 CO FLT ANTI-SUB WARFARE SCH SAN DIEGO
1 CHF OF NAVL RSCH PERS & TNG BR (CODE 458) ARL VA
1 CHF OF NAV RES ATTN HEAD GP PSYCHOL BR CODE 452
1 DIR US NAV RES LAB ATTN CODE 5120
1 DIR NAVAL RSCH LAB ATTN LIB CODE 2029 WASH DC
1 CHF OF NAV AIR TNG TNG RES DEPT NAV AIR STA PENSACOLA
1 CO NAV SCH OF AVN MED NAV AVN MED CTR PENSACOLA
1 CO MED FLD RES LAB CAMP LEJEUNE
1 CDR NAV MSL CTR POINT MUGU CALIF ATTN TECH LIB CODE 3022
1 DIR AEROSPACE CREW EQUIP LAB NAV AIR ENGNR CTR PA
2 OIC NAV PERS RES ACTVY SAN DIEGO
1 NAV NEUROPSYCHIAT RES UNIT SAN DIEGO
2 NAVAL MSL CTR (CODE 5342) PT MUGU CALIF
1 DIR PERS RES LAB NAV PERS PROGRAM SUPPORT ACTIVITY WASH NAV YD
1 NAV TNG PERS CTR NAV STA NAV YD ANNEX CODE [illegible] ATTN LIB WASH
3 COMDT MARINE CORPS HQ MARINE CORPS ATTN CODE AO-1B
1 HQ MARINE CORPS ATTN AX
1 DIR MARINE CORPS EDUC CTR MARINE CORPS SCH QUANTICO
1 DIR MARINE CORPS INST ATTN EVAL UNIT
1 US MARINE CORPS HQS HIST REF LIB ATTN MRS JAUDT
1 CHF OF NAV OPNS OP-01P1
1 CHF OF NAVL OPS OP-039 WASH DC
1 CHF OF NAV OPNS OP-07TL
2 COMDT HQS 8TH NAV DIST ATTN EDUC ADV NEW ORLEANS
1 CHF OF NAV AIR TECH TNG NAV AIR STA MEMPHIS
1 DIR OPS EVAL GRP OFF OF CHF OF NAV OPS OP03EG
2 COMDT PTP COAST GUARD HQ
1 CHF OFCR PERS RES + REVIEW BR COAST GUARD HQ
1 CO US COAST GUARD TNG CTR GOVERNORS ISLAND NY
1 CO US COAST GUARD TNG CTR CAPE MAY NJ
1 CO US COAST GUARD TNG CTR & SUP CTR ALAMEDA CALIF
1 CO US COAST GUARD INST OKLA CITY OKLA
1 CO US COAST GUARD RES TNG CTR YORKTOWN VA
1 SUPT US COAST GUARD ACAD NEW LONDON CONN
1 OPNS ANLS OFC HQ STRATEGIC AIR COMD OFFUTT AFB
1 AIR TNG COMD/XPT RANDOLPH AFB
1 TECH DIR TECH TNG DIV(HRD) AFHRL LOWRY AFB COLO
1 CHF SCI DIV DRCTE SCI + TECH DCS R+D HQ AIR FORCE AFRSTA
1 FAA DRCTE OF PLNS & OPS HQ USAF WASH DC
1 CHF OF PERS RES BR DRCTE OF CIVILIAN PERS DCS-PERS HQ AIR FORCE
1 CHF ANAL DIV (AFPDPL (R) DIR OF PERSONNEL PLANNING HQS USAF
2 CDR ELEC SYS DIV LG HANSCOM FLD ATTN ESMDA/STOP 36 MASS
1 AFHRL/TT ATTN CAPT W S SELLMAN LOWRY AFB
1 HQ SAMSO (SMSIR) AF UNIT POST OFC LA AFS CALIF
2 MILIT TNG CTR OPE LACKLAND AFB
2 AFHRL (HRT) WRIGHT-PATTERSON AFB
1 AMD AMRH BROOKS AFB TEXAS
1 HQS ATC DCS/TECH TNG (ATTMS) RANDOLPH AFB
1 USAF SCH OF AEROSPACE MED ATTN AEROMED LIB BROOKS AFB
1 USAFA DIR OF THE LIB USAF ACAD COLO
1 6570TH PERS RES LAB PRA-4 AEROSPACE MED DIV LACKLAND AFB
1 TECH TNG CTR (LMTC/OP-I-L1) LOWRY AFB
2 CO HUMAN RESOURCES LAB BROOKS AFB
1 COMDT USAF SPEC OP SCH (TAC) EGLIN AFB
1 AFHRL (FT) WILLIAMS AFB ARIZ
1 PSYCHOBIOLOGY PROG NATL SCI FOUND
1 DIR NATL SECUR AGY FT GEO G MEADE ATTN TDL
1 DIR NATL SECUR AGY FT GEO G MEADE ATTN DIR OF TNG
3 CIA ATTN CRS/ADD STANDARD DIST
1 SYS EVAL DIV RES DIRECTORATE DOD-DCD PENTAGON
1 DEPT OF STATE BUR OF INTEL + RES EXTERNAL RES STAFF
1 SCI INFO EXCH WASHINGTON
2 CHF MGT & GEN TNG DIV TR 200 FAA WASH DC
1 BUR OF RES & ENGR US POST OFC DEPT ATTN CHF HUMAN FACTORS BR
1 EDUC MEDIA BR OE HEW ATTN T D CLEMENS
1 NAT'L BUR STANDS BEHAV SCI GP ATTN DR D E ERLICK
1 OFC OF INTERNATL TNG PLANNING & EVAL BR AID WASH DC
1 FAA MED LIB HQ 640 WASH DC
1 DEPT OF TRANS FAA ACQ SEC HQ 610A WASH DC
2 ERIC OE WASH DC
1 CONSOL FED LAW ENFORCEMENT TNG CTR WASH DC
1 SYS DEVEL CORP SANTA MONICA ATTN LIB
2 DUNLAP + ASSOC INC DARIEN ATTN LIB
2 RAC ATTN LIB MCLEAN VA
1 RAND CORP WASHINGTON ATTN LIB
1 GP EFFECTIVENESS RSCH LAB U OF ILL DEPT OF PSYCHOL
2 ELECT PERS RSCH GP U OF SOUTHERN CALIF
1 COLUMBIA U ELEC RES LABS ATTN TECH EDITOR
1 MITRE CORP BEDFORD MASS ATTN LIB
2 SIMULATION ENGR CORP ATTN DIR OF ENGR FAIRFAX VA
2 LEARNING R&D CTR U OF PITTS ATTN DIR
1 WESTERN ELECTRIC CO INC NY
1 HUMAN SCI RES INC MCLEAN VA
2 TECH INFO CTR ENGNR DATA SERV N AMER AVN INC COLUMBUS O
1 CHRYSLER CORP MSL DIV DETROIT ATTN TECH INFO CTR
1 RAYTHEON SERV CO ATTN LIBN BURLINGTON MASS
1 GEN DYNAMICS POMONA DIV ATTN LIB DIV CALIF
1 OTIS ELEVATOR CO DIV ATTN LIB STAMFORD CONN
1 MGR BIOTECHNOLOGY AEROSPACE SYS DIV MS 8H-25 BOEING CO SEATTLE
1 IDA RSCH & ENG SUPT DIV ARL VA
1 SCI & TECH DIV IDA ARL VA
1 HUGHES AIRCRAFT COMPANY CULVER CITY CALIF
1 DIR CTR FOR RES ON LEARNING + TEACHING U OF MICH
1 R M STOGDILL OHIO STATE UNIV
1 EDITOR TNG RES ABSTR AMER SOC OF TNG DIRS U OF TENN
1 U OF CHICAGO DEPT OF SOC
1 HUMAN FACTORS SECT R+D GEN DYNAMICS ELECTRIC BOAT GROTON
1 DIR CTR FOR RSCH IN SOCIAL SYS KENSINGTON MD
3 CANADIAN JOINT STAFF OFC OF DEF RES MEMBER WASHINGTON
3 CANADIAN ARMY STAFF WASHINGTON ATTN GSO2 TNG
2 CANADIAN LIAISON OFCR ARMY ARMOR BD FT KNOX
1 GERMAN LIAISON OFCR ARMY AVN TEST BD FT RUCKER
2 OFC OF ARMED FORCES ATTACHE ROYAL SWEDISH EMBSY DC
3 AUSTRALIAN NAV ATTACHE EMBSY OF AUSTRALIA WASH DC
2 FRENCH ARMY LIAISON OFCR USAAVNC & FT RUCKER
1 BRITISH LIAISON OFCR ARMY AVN TEST BD FT RUCKER
1 OFC OF AIR ATTACHE AUSTRALIAN EMBSY ATTN: T.A. NAVGN WASH, D.C.
2 AUSTRALIAN ARMY ATTACHE EMBSY OF AUSTRALIA ATTN TECH CLK
2 DR B T DODD LRNING SYS LTD SURREY ENGLAND
1 MENNINGER FOUNDATION TOPEKA
1 AMER INSTS FOR RSCH SILVER SPRING
1 AMER INSTS FOR RSCH ATTN LIBN PA
1 DIR PRIMATE LAB UNIV OF WIS MADISON
1 DR E GINZBERG COLUMBIA UNIV SCH OF BUS
3 MATRIX RSCH CO FALLS CHURCH VA
1 EDUC & TNG CONSLT CO LA CALIF
1 DR GEORGE T HAUTY CHMN DEPT OF PSYCHOL U OF DEL

1 GEN ELECTRIC CO SANTA BARBARA ATTN LIB
1 VITRO LABS SILVER SPRING MD ATTN LIBN
1 HEAD DEPT OF PSYCHOL UNIV OF SC COLUMBIA
1 TVA PERS STAFF OFCR KNOXVILLE TENN
1 U OF GEORGIA DEPT OF PSYCHOL
1 U OF UTAH DEPT OF PSYCHOL
1 GE CO WASH D C
1 AMER INST FOR RSCH ATTN LIB PALO ALTO CALIF
1 COLL OF ART. & SCI U OF MIAMI ATTN L L MCQUITTY
1 ROWLAND + CO HADDONFIELD NJ ATTN PRES
1 NORTRONICS DIV OF NORTHROP CORP ANAHEIM CALIF
1 OHIO STATE U SCH OF AVN
1 SCI RSCH ASSOC INC DIR OF EVAL CHICAGO ILL
1 AIRCRAFT ARMAMENTS INC COCKEYSVILLE MD
. DR J A CULLEN DEPT OF SOC & ANTHROP UNIV OF RI
2 OREGON STATE U DEPT OF MILIT SCI ATTN ADJ
1 AMER PSYCHOL ASSOC WASHINGTON ATTN PSYCHOL ABSTR
1 NO ILL U HEAD DEPT OF PSYCHOL
1 GEORGIA INST OF TECH DIR SCH OF PSYCHOL
1 ENGNR LIB FAIRCHILD HILLER REPUBLIC AVN DIV FARMINGDALE N Y
1 LIFE SCI INC HURST TEXAS ATTN W G MATHENY
1 AMER BEHAV SCI CALIF
2 DIR INSTR RESOURCES STATE COLL ST CLOUD MINN
1 COLL OF WM + MARY SCH OF EDUC
1 SO ILLINOIS U DEPT OF PSYCHOL
2 ASSOC DIR EDC TNG PROG ATLANTA GA
1 WASH MILITARY SYS TECH LIB DIV BETHESDA MD
1 NORTHWESTERN U DEPT OF INDSTR ENGNR
1 HONEYWELL ORD STA MAIL STA 806 MINN
1 DR L TWYFORD NY STATE EDUC DEPT ABSTRACT EDITOR AVCR
1 AEROSPACE SAFETY DIV U OF SOUTHERN CALIF LA
1 MR BRANDON B SMITH RES ASSOC U OF MINN
1 DR V ZACHERT RT 1 GOOD HOPE GA
1 J P LYDON DIR JR ROTC SAN ANTONIO TEXAS
1 DR E FOULKE DEPT OF PSYCH UNIV OF LOUISVILLE
2 CHRYSLER CORP DEF ENGR ATTN DR H BERMAN DETROIT
1 DR S ROSCOE ASSOC DIR FOR RSCH INST OF AVN U OF ILL
1 DR C HELM DEPT EDUC PSYCH CITY U OF NY
1 DR E PERKINS PROF OF PSYCH ST CLOUD STATE COLL MINN
1 GEN H P HARRIS (USA RET)PRES THE CITADEL SC
1 DR H SHOEMAKER DIR TNG RSCH GP NY
1 U OF MINN DEPT OF INDUST EDUC ATTN R E KUHL
1 VOC-TECH EDUC PROG PLNNG DEV ATTN W STOCK ST PAUL
1 CHF PROCESSING DIV DUKE U LIB
1 U OF CALIF GEN LIB DOCU DEPT
. FLORIDA STATE U LIB GIFTS + EXCH
1 PSYCHOL LIB HARVARD UNIV CAMBRIDGE
1 U OF ILL LIB SER DEPT
2 U OF KANSAS LIB PERIODICAL DEPT
1 U OF NEBRASKA LIBS ACQ DEPT
1 OHIO STATE U LIBS GIFT + EXCH DIV
1 PENNA STATE U PATTEE LIB DOCU DESK
1 PURDUE U LIBS PERIODICALS CHECKING FILES
1 STANFORD U LIBS DOCU LIB
1 LIBN U OF TEXAS
1 SYRACUSE U LIB SER DIV
1 SERIALS REC UNIV OF MINN MINNEAPOLIS
1 STATE U OF IOWA LIBS SER ACQ
1 NO CAROLINA STATE COLL DH HILL LIB
2 BOSTON U LIBS ACQ DIV
1 U OF MICH LIBS SER DIV
1 BROWN U LIB
1 COLUMBIA U LIBS DOCU ACQ
1 DIR JOINT U LIBS NASHVILLE
2 LIB GEO WASH UNIV ATTN SPEC COLL DEPT WASH DC
2 LIB OF CONGRESS CHF OF EXCH + GIFT DIV
1 U OF PGH DOCU LIBN
1 CATHOLIC U LIB EDUC & PSYCHOL LIB WASH DC
1 U OF KY MARGARET I KING LIB
1 SO ILL U ATTN LIBN SER DEPT
1 KANSAS STATE U FARRELL LIB
1 BRIGHAM YOUNG U LIB SER SECT
1 U OF LOUISVILLE LIB BELKNAP CAMPUS
1 GEORGETOWN U LIB SER DEPT WASH DC
1 LIBS COLO STATE U ATTN DOC LIBN FT COLLINS
1 G E RYAN JAYCOPTERS LTD NY NY
1 SYS ENGR GP RSCH & TECH DIV AFSC OHIO
1 S GRYDE TNG CO-ORDINATOR HONEYWELL INC CALIF
1 M F EASTER SCH OF AVN OHIO STATE UNIV AIRPORT COLUMBUS
1 R E FLEXMAN DIR OF AVN INST UNIV OF ILL
1 LTC GORDON C CONKLIN(USAR RET) SPRINGFIELD VA
1 D E MEYER AFMR LAB BROOKS AFB TEXAS
1 DR A F SMODE DUNLAP & ASSOCIATES CONN
1 W B BONEY ONR ORLANDO FLA
1 DR H KERBER LIFE SCI RSCH DEPT GOODYEAR AEROSPACE CO OHIO
1 G LUDWIG MELPAR INC FALLS CHURCH VA
1 CHF OP TNG BR TNG RSCH DIV BEHAV SCILAB WRIGHT-PATTERSON AFB
1 CO NTDC ATTN CODE 55 ORLANDO FLA
1 DPTY COMDT USA AVN SCH HUNTER ARMY AIRFIELD
1 J CURTIN HUMAN FACTORS DEPT MACDONNELL-DOUGLAS CORP ST LOUIS
1 DR C R KELLEY DUNLAP & ASSOC SANTA MONICA
1 S H COTTON JR SIMULATION ENGR CORP VA
1 R T CHESLOW LOGISTICS MGMT INST WASHDC
1 DR T H GRAY HONEYWELL CALIF
1 DR J H GROSSLIGHT DEPT OF PSYCHOL FLA STATE UNIV
1 DISPLAY SYSTEMS DEPT HUGHES AIRCRAFTCALIF
1 G REID MARTIN CO ORLANDO
1 DR G BRYAN PSYCHOL SCI DIV ONR WASH DC
1 G B POTTER DIR AVN SAFETY DIV UNIV OF S CALIF LA
1 OFC OF SURGEON GEN ATTN AVN SEC DA
1 USA TRANS RSCH COMD ATTN F MCCOURT VA
1 R A MONTY CORNELL AERONAUTICAL LAB BUFFALO
1 DR K P DEGREENE UNIV OF SOUTHERN CALIF LA
1 LRNING RES CTR UNIV OF TENN KNOXVILLE
1 DR L W CURETON SCH OF EDUC UNIV OF TENN
1 LIB EMBRY-RIDDLE AERONAUTICAL INST DAYTONA FLA

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