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Research Report 1561

Transfer-of-Training Study of Emergency Touchdown Maneuvers in the AH-1 Flight and Weapons Simulator

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June 1990

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES

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For this report, researchers conducted a transfer-of-training study to investigate the effectiveness of the AH-1 Flight and Weapons Simulator (FWS) as a training device for the reacquisition of skills on five emergency touchdown maneuvers (ETMs). Twenty aviators assigned to operational aviation units served as subjects. All aviators received initial checkrides in the aircraft and the FWS and were assigned to one of two groups on the basis of their checkride scores. The control group (n=10) received training to proficiency in the aircraft on each of the five maneuvers and a second checkride in the FWS. The experimental group (n=10) received training to proficiency in the FWS on each of the five maneuvers followed by similar training in the aircraft. Analysis of the initial checkride scores indicated that the aviators' skills were deficient on the ETMs prior to the study. They required extensive training to reach proficiency in the FWS but relatively little training to regain proficiency in the aircraft. Prior training in the FWS reduced the number of practice trials and the amount of flight training time required to reach proficiency in
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the aircraft. However, training in the existing FWS alone is insufficient for reacquisition of ETM skills to a standard of aircraft proficiency. In view of the prohibition on practice of ETMs in the aircraft, it is recommended that the Army initiate a product improvement program for the FWS. Keywords:
Attack helicopters, Aircrew training, Backward transfer, Continuation training, Flight simulation; Pilot performance measurement. (SDW)

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Transfer-of-Training Study of Emergency Touchdown Maneuvers in the AH-1 Flight and Weapons Simulator

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FOREWORD

The Army Research Institute Aviation Research and Development Activity (ARIARDA) was asked by the Directorate of Training and Doctrine (DOTD), U.S. Army Aviation Center (USAAVNC), Fort Rucker, Alabama, to conduct training transfer research on the effectiveness of flight simulators. This work was initiated under a Memorandum of Agreement between ARI and DOTD, USAAVNC, dated 15 March 1984, and was part of the task entitled "Techniques for Enhancing Aviation Unit Combat Readiness."

The Army has made a significant investment in the development and acquisition of motion-based, visual flight simulators for its rotary wing aircraft. As training resources have become scarce and the competition for those resources has become intense, training in high-fidelity flight simulators has been viewed as a cost-effective alternative to flight training in aircraft. Simulator systems have been developed for the AH-1, CH-47, AH-64, and UH-60 aircraft systems. The focus of this research was the AH-1 Flight and Weapon Simulator (FWS).

The primary function of the Army's flight simulators is to sustain aircrew skills in operational aviation units. However, little empirical data exist to document the training effectiveness of these simulators or to guide the development of programs of instruction that will utilize flight simulators in the most effective manner. ARIARDA developed a research plan designed to generate the empirical data required to decide how best to employ Army flight simulators in the training and sustainment of flying skills among operational aviators.

This report presents results of an experiment that investigated the transfer of training conducted in the FWS on emergency touchdown maneuvers (ETMs). The transfer-of-training experiment determined the degree to which ETM training conducted in the FWS transfers to the AH-1 aircraft, provided estimates of the current ETM proficiency level possessed by operational aviators, determined the rate at which operational aviators reacquire the proficiency required to perform the ETMs in the aircraft, and determined the level of ETM skill transfer from the aircraft to the FWS (backward transfer).

These results were briefed to the Deputy Chief of Staff for Operations and Plans, Training Directorate (DAMO-TR), USAAVNC Command Group, and Directorate of Training and Doctrine. Other briefings to operational personnel were done over a period of approximately 6 months, beginning in January 1988. These briefings produced a renewed emphasis on the conduct of flight simulator training and initiated additional interest for a further examination of flight simulator effectiveness and, in particular, gunnery training. This information will be useful in developing efficient and cost-effective training strategies that employ flight simulators.

EDGAR M. JOHNSON
Technical Director

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TRANSFER-OF-TRAINING STUDY OF EMERGENCY TOUCHDOWN MANEUVERS IN THE AH-1 FLIGHT AND WEAPONS SIMULATOR

EXECUTIVE SUMMARY

Requirement:

This report describes research conducted to assess the extent to which training in the AH-1 Flight and Weapons Simulator (FWS) transfers to the AH-1 aircraft. The research was conducted by the U.S. Army Research Institute Aviation Research and Development Activity, Fort Rucker, Alabama, and is part of a broader program of research aimed at assessing the effectiveness of the Army's flight simulators for training aviators assigned to operational aviation units.

The Army has made a significant investment in the development and acquisition of motion-based, visual flight simulators for its rotary wing aircraft. As training resources have become scarce and the competition for those resources has become intense, high-fidelity flight simulators have been viewed as cost-effective alternatives to flight training in aircraft. Simulator systems have been developed for the AH-1F, AH-64A, CH-47D, and UH-60 aircraft systems. The AH-1 FWS has been deployed to operational aviation units and the U.S. Army Aviation Center at Fort Rucker, Alabama. The other three flight simulator systems are currently in various stages of the fielding process.

The primary training function of the Army's flight simulators will be to support aircrew training conducted in operational aviation units. However, little empirical data exist to evaluate the operational training effectiveness of these simulators or to aid in the development of programs of instruction that utilize flight simulators in the most effective manner.

The primary objective of the transfer of training experiment was to determine the degree to which emergency touchdown maneuvers (ETMs) skills reacquired in the FWS transfer to the AH-1 aircraft. In addition to the primary objective, the study was designed to assess:

- the aviators' initial level of skill on the ETMs in the aircraft,

- the rate at which aviators acquire skills on the ETMs in the FWSs, and
- the rate at which aviators reacquire skills on the ETMs in the aircraft.

Procedure:

A transfer-of-training paradigm was used to meet the objectives of the research. Twenty AH-1 aviators assigned to operational units were administered a checkride in the aircraft and an identical checkride in the FWS. The aviators were then assigned to one of two groups, control or experimental, based on performance during the initial aircraft checkride. The control group subjects received training to proficiency on the ETMs in the aircraft followed by a second checkride in the FWS. Concurrently, the experimental group subjects received training to proficiency on the ETMs in the FWS followed by training to proficiency in the aircraft.

The training effectiveness of the FWS for reacquiring ETM skills was assessed by comparing the performance of the control and experimental groups during their training in the aircraft. In addition, the backward transfer of skills from the aircraft to the flight simulator was assessed by comparing control group performance during the second checkride in the FWS and the final two training trials in the aircraft. The following five ETMs were investigated: Standard Autorotation, Low-Level Autorotation, Low-Level High-Speed Autorotation, Right Antitorque Failure, and Dual Hydraulics Failure.

Findings:

On initial checkrides, most aviators were unable to perform the ETMs safely. Despite their poor initial performance, the aviators required relatively little training to regain proficiency in the aircraft. Although aviators in the experimental group required extensive training to attain proficiency in the FWS, this training did enhance their subsequent performance in the aircraft. Prior simulator training reduced the number of practice trials and the amount of total aircraft flight training time that aviators needed to reach proficiency in the aircraft. However, none of the experimental group aviators performed satisfactorily on their first trial in the aircraft following simulator training. Finally, proficiency in the aircraft did not transfer to the FWS. That is, aviators trained to proficiency in the aircraft could not perform satisfactorily during a subsequent checkride in the FWS.

Utilization of Findings

The findings indicate that (a) operational aviators' skills are deficient on the ETMs, (b) the aviators require relatively little aircraft training to regain proficiency, (c) the FWS does not by itself provide a means for training operational aviators to a satisfactory level of aircraft ETM proficiency, and (d) when used in conjunction with aircraft ETM training programs, the FWS can reduce the number of flying hours required to reacquire proficiency. It is recommended that aviation units implement training programs that provide periodic FWS training on the ETMs. It is further recommended that the Army reexamine the current policy prohibiting periodic practice of ETMs in the aircraft. If the Army decides that the current policy should not be changed, it is strongly recommended that a product improvement program for the flight simulator be initiated to increase its effectiveness for ETM training.

TRANSFER-OF-TRAINING STUDY OF EMERGENCY TOUCHDOWN MANEUVERS IN THE AH-1 FLIGHT AND WEAPONS SIMULATOR

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AAA - Army Audit Agency

AGL - Above Ground Level

AHO - Above Highest Obstacle

ANOVA - Analysis of Variance

AQC - Aircrew Qualification Course

ARIARDA - Army Research Institute Aviation Research and Development Activity

ASI - Anacapa Sciences, Inc.

ATM - Aircrew Training Manual

BW - Ball Width

CH47FS - CH-47 Flight Simulator

CMS - AH-64 Combat Mission Simulator

CPG - Copilot/Gunner

CTER - Cumulative Training Effectiveness Ratio

DA - Department of the Army

DES - Directorate of Evaluation and Standardization

DHF - Dual Hydraulics Failure

ETM - Emergency Touchdown Maneuver

FWS - AH-1 Flight and Weapons Simulator

HL - Helicopter Length

HSA - Low-Level High-Speed Autorotation

HSD - Honestly Significant Difference

ICS - Intercommunication System

IERW - Initial Entry Rotary Wing

IP - Instructor Pilot

IPC - Instructor Pilot Course

K - Knots

KIAS - Knots Indicated Airspeed

LIG - Laser Image Generation

LLA - Low-Level Autorotation

MSL - Mean Sea Level

OPR - Overall Performance Rating

GLOSSARY OF ACRONYMS AND ABBREVIATIONS (Continued)

POI	-	Program of Instruction
PPDR	-	Pilot Performance Description Report
RAF	-	Right Antitorque Failure
RPM	-	Revolutions Per Minute
SA	-	Standard Autorotation
SIP	-	Standardization Instructor Pilot
SCAS	-	Stability and Control Augmentation System
TTC	-	Trials to Criterion
UH60FS	-	UH-60 Flight Simulator
USAAVNC	-	U.S. Army Aviation Center

TRANSFER-OF-TRAINING STUDY OF EMERGENCY TOUCHDOWN MANEUVERS IN THE AH-1 FLIGHT AND WEAPONS SIMULATOR

Introduction

Problem

Over the past two decades, the U.S. Army has made a significant investment in the development and acquisition of motion-based, visual flight simulators for its rotary wing aircraft. As training resources have become scarce and the competition for those resources has become intense, high-fidelity flight simulators have been viewed as cost-effective alternatives to aircraft flight training. The Army has purchased flight simulator systems for its AH-1F, AH-64A, CH-47D, and UH-60 aircraft. The AH-1 Flight and Weapons Simulator (FWS) has been fielded and the other three simulator systems are currently in various stages of the procurement and fielding process.

High-fidelity flight simulators may be used to provide skill acquisition and skill sustainment training necessary to maintain combat readiness in operational aviation units and to provide skill acquisition training in courses taught at the U.S. Army Aviation Center (USAAVNC). However, the Army plans to procure more flight simulators for operational aviation unit training than for institutional training. Current plans project the distribution of 7 AH1FWSs, 6 AH-64A Combat Mission Simulators (CMS), 5 CH-47 Flight Simulators (CH47FS), and 15 UH-60 Flight Simulators (UH60FS) to operational aviation units throughout the major commands. In addition, the Army plans to install 2 FWSs, 1 CMS, 1 CH47FS, and 2 UH60FSs at the USAAVNC.

Despite the Army's extensive distribution plan, there is little empirical evidence that flight simulators will satisfy aviation unit training requirements. In addition, insufficient data exist to help guide the development of flight simulator training programs so that operational aviation units can derive optimal training benefits when utilizing simulators.

The Army Audit Agency (AAA) noted this situation on two different occasions. In 1982, an AAA report concluded that there were insufficient data to justify either the number of flight simulators scheduled for purchase or the Army's plan for dispersing simulators to aviation units (U.S. Army Audit Agency, 1982). The AAA recommended that the Army initiate a program of research to compile the data needed to address these issues. In 1985, the AAA conducted a follow-up audit of the Army's flight simulation program, with similar results. The AAA criticized the Army for failing to obtain the research data needed to justify the planned acquisition and deployment of flight simulators to operational units (U.S. Army Audit Agency, 1985). The use of flight simulators for institutional training was not an issue.

The central issue in both the 1982 and 1985 audits was the lack of empirical data to support the fielding of flight simulators to operational aviation units. The AAA questioned decisions to procure a large number of motion-based, visual flight simulators for use in operational aviation units without first (a) identifying unit aviators' training needs, and (b) demonstrating that training conducted in flight simulators provides the most cost-effective method of satisfying those needs.

Prior to the AAA reports, Orlansky and String had adapted a systems analysis methodology to examine and compare alternative training strategies on the basis of simulator characteristics and the costs incurred for each alternative (see Orlansky, 1984; Orlansky and String, 1977, 1981). In 1977, Orlansky and String presented a model for analyzing the cost effectiveness of flight simulator systems. They cited several examples of research that investigated the effects of variables such as level of fidelity, amount of simulator training, and the presence of motion on the cost-effectiveness of simulators.

Orlansky and String (1977) concluded that flight simulators can be used to train pilots and other crew members on a wide variety of flight related skills, but that previous research can provide only limited guidance for the current acquisition and use of flight simulators. To exercise the cost-effectiveness model for current and future flight simulators, it is necessary to determine the effectiveness of flight simulators for accomplishing specific training objectives and to describe the specific learning that occurs in the flight simulators. Subsequent research has attempted to address these issues.

Flight simulator research. The Army has sponsored research designed to investigate the training effectiveness of several of its flight simulator systems including the CH47FS (Holman, 1979), UH60FS (Luckey, Bickley, Maxwell, & Cirone, 1982), and the AH1FWS (Bridgers, Bickley, & Maxwell, 1980). However, the primary purpose of each of these studies was to determine the effectiveness of the respective flight simulator when incorporated into an established program of instruction (POI) for institutional training. In fact, operational tests of the UH60FS (Luckey et al, 1982.) totally neglected the issue of training effectiveness in the operational aviation unit environment.

Holman (1979) conducted a controlled study of the CH47FS's effectiveness for maintaining flying skills over a period of 6 months. The subjects were 32 qualified and current CH-47C pilots assigned to operational aviation units. Sixteen subjects, assigned to the experimental group, each received 30 hours of training in the CH47FS over a 6-month period in addition to an average of 45.2 hours of mission essential flying in the CH-47C aircraft. None of the 16 subjects assigned to the control group received training in the CH47FS during the test period, but they flew the CH-47C aircraft on mission support flights for an average of 58.0 hours per subject. All subjects received pretest and post-test checkrides on 35 flight tasks in the aircraft. Holman reported that the simulator trained group showed improvement from their pretest checkride scores during the posttest checkride, but there was no significant difference between the two groups on the posttest checkride scores. Holman attributed the improved posttest checkride scores for the experimental group to simulator training alone and concluded that the CH47FS is effective for the maintenance of flight skills.

Despite the use of a control group, Holman's (1979) conclusion is misleading. First, Holman did not equate the two groups for previous flight experience or flight proficiency; the pretest checkride indicated that the subjects in the experimental group initially were less proficient than subjects in the control group. The differences in performance improvement observed during the second checkride may have been a product of the initial differences in flight skills. Second, the results are confounded by the structured training provided to subjects in the experimental group in the CH47FS but not provided to subjects in the control group. Subjects in the control group did fly the aircraft, but they received no structured training from instructor pilots (IPs) during the test period. The formal training provided to subjects in the experimental group may account for improved performance scores during the second checkride.

Third, subjects in both groups received substantial amounts of flight time in the aircraft during the test period, but the type and amount of flying were not controlled. Most of the maneuvers investigated (e.g., hovering flight, normal takeoff, internal and external loads) are common to all mission support flights accomplished in the CH-47C aircraft. Therefore, the subjects in the experimental group received substantial practice on many of the target maneuvers prior to the second checkride in the aircraft. Fourth, conclusions about the capabilities of the CH47FS to maintain flight skills are unwarranted because Holman did not demonstrate that flight skills degrade in the absence of training over the 6-month period of the study. Evidence from other research (e.g., Ruffner & Bickley, 1983) indicates that contact flight task skills do not degrade significantly over a period as long as one year. Research that addresses skill maintenance through flight simulator training should employ control groups to demonstrate the extent to which skills decay over the period of the research.

AH1FWS research. Bridgers et al. (1980) conducted operational tests of the FWS in two experiments: (a) a transfer of training experiment investigating the effectiveness of the FWS for training 32 POI tasks in the AH-1 Aircrew Qualification Course (AQC), and (b) an experiment investigating the effectiveness of the FWS for maintaining skills on gunnery and contact flight tasks. In the first experiment, student pilots assigned to an experimental group were trained in the FWS to a specified level of proficiency on all tasks included in the POI for the AH-1 AQC. Following training in the FWS, the experimental student pilots received training to the same level of proficiency in the AH-1 aircraft. The control group comprised additional student pilots who received training to proficiency only in the AH-1 aircraft. Bridgers et al. reported positive forward transfer for all of the 32 AQC tasks investigated.

In the second experiment, 12 aviators assigned to operational aviation units were administered a pretest checkride consisting of 3 gunnery and 16 contact flight tasks in the AH-1 aircraft. Subsequently, they were trained on the 19 tasks (mean number of training periods = 6.4 periods[1] in the FWS) and administered a posttest checkride in the AH-1 aircraft. The data indicated that simulator training produced no significant change in gunnery skills but, to some extent, maintained contact flight proficiency. However, all subject aviators experienced the same experimental conditions; that is, the researchers did not employ a control group. Because of the small number of subjects, the lack of experimental controls, and the lack of a suitable scoring system for gunnery tasks, the data supported no conclusions about the effectiveness of the FWS for training conducted in the operational aviation units.

[1]The author did not describe the duration of the training periods; most simulator training periods are approximately 1.5 hours in duration.

Hopkins (1979) conducted a cost and training effectiveness analysis of the FWS using the data obtained during operational tests of the FWS described above (Bridgers et al., 1980). Despite the questionable validity of the operational test data, Hopkins concluded that (a) the FWS provides the opportunity for aviators to fire as many rounds as necessary to maintain a high level of gunnery proficiency, (b) all individual gunnery and most crew gunnery training can be accomplished in the FWS, (c) the instrument flight characteristics of the FWS are outstanding, and (d) the FWS is excellent for conducting emergency procedures training. Even though these conclusions contradict those reached by the investigators who conducted the operational tests, Hopkins recommended that aviation units conduct gunnery, instrument, and basic flight training in the FWS. Furthermore, Hopkins used the Army's annual expenditures of (a) ammunition and (b) training flight time to calculate cost-savings and to justify the purchase and fielding of the FWS.

Lessons learned. The experiments summarized above provided a foundation for future research on the training effectiveness of flight simulators and served as a guide for the research presented in this report. The major lessons learned include the following:

- there is a paucity of empirical data describing the effectiveness of flight simulators for training conducted in operational environments,
- empirical data describing the learning that occurs in flight simulators and the extent to which that learning transfers to aircraft are needed to determine the cost-effectiveness of flight simulators,
- simulator utilization models based on data obtained during institutional training applications do not necessarily generalize when applied to the operational aviation training environment,
- transfer of training experiments should be conducted on relatively small numbers of tasks to control for the generalization of skills between tasks, and
- for the purposes of research, training conducted in both the aircraft and flight simulator should be structured and controlled.

ARIARDA Research Program

In response to the AAA's criticisms of the Army's flight simulation program, Cross and Gainer (1983; 1987) developed a plan for simulator research. The objective of the planned research is to provide systematic performance data for Army managers to use in determining how best to employ flight simulators for training operational aviators. The plan describes two paths for simulator research: (a) a long-term path addressing basic research issues relevant to the design of future flight simulators, and (b) a short-term path addressing issues relevant to the evaluation and optimal use of the family of flight simulators currently being acquired by the Army. The plan emphasizes the need to investigate small groups of tasks within the context of aviation unit training requirements.

Kaempf, Cross, and Blackwell (1989) reported the results from the first two experiments conducted as part of the short-term path. The two experiments were a backward transfer study and a skill acquisition study in the FWS.

Backward transfer experiment. The backward transfer procedure was first described by Adams and McAbee (1961) as a method of evaluating the training effectiveness of flight simulators. The backward transfer experimental design logic is simple. Subjects must be proficient in the aircraft on the tasks of interest but naive with respect to the simulator. Following a demonstration of their proficiency in the aircraft, subjects are administered a checkride in the simulator. The primary assumption is that, during their first exposure to the flight simulator, subjects will attempt to use the same skills that are successful for them in the aircraft. If the aircraft proficient aviators cannot perform the flying tasks successfully in the simulator, the poor performance is attributed to deficiencies in the simulator. The simulator deficiencies may be one or more of three basic types: (a) the cues available in the simulator differ from the ones that aviators employ to fly the aircraft, (b) the control inputs required to fly the simulator differ in some important respect from those required to fly the aircraft, and (c) the simulator requires skills that are not required to fly the aircraft.

The lack of a high degree of backward transfer does not necessarily mean that the simulator has no training value. However, low backward transfer is a clear indication that simulator deficiencies exist that serve to reduce forward transfer and, therefore, the training value of the simulator.

A high degree of backward transfer indicates that pilots possess the skills needed to fly the simulator. However, it cannot be assumed that the skills required to fly the simulator are the same as the skills required to fly the aircraft. In short, a high degree of backward transfer is not necessarily an indication of a high degree of forward transfer.

Kaempf et al. (1989) conducted a backward transfer experiment to (a) investigate the level of fidelity in the FWS, (b) predict the training effectiveness of the FWS for emergency maneuvers, and (c) determine the suitability of the backward transfer procedure for predicting forward transfer of training. Sixteen AH-1 IPs assigned to the AH-1 AQC were administered a checkride in the AH-1 aircraft followed by an identical checkride in the FWS. Both checkrides comprised one trial of each of the eight maneuvers investigated. Comparison of the performance data from the two checkrides indicated that all of the IPs performed poorly in the FWS, even though they were proficient on the maneuvers in the aircraft. The IPs attributed their difficulties in the FWS to deficiencies in the simulator's visual system and to the handling and response characteristics of the flight controls. Kaempf et al. concluded that the FWS has some fidelity deficiencies that degraded the experienced AH-1 aviators' capabilities to perform emergency maneuvers to touchdown in the FWS. They predicted that the forward transfer of training from the FWS to the AH-1 would be low for emergency touchdown maneuvers.

Skill acquisition experiment. The results of the backward transfer experiment raised several issues that were investigated in the subsequent skill acquisition experiment (Kaempf et al., 1989). The primary objectives of the skill acquisition experiment were to determine (a) the rate at which aviators acquire skills in the FWS, and (b) the level of proficiency that aviators can attain in the FWS. Fifteen different maneuvers were investigated including standard contact maneuvers, nap-of-the-earth maneuvers, tactical maneuvers, and the eight maneuvers studied in the backward transfer experiment. Forty operational aviators were divided into four groups of ten. A different set of five maneuvers was investigated with each group. Three groups performed five different maneuvers in the pilot station and one group performed a subset of five maneuvers in the copilot/gunner (CPG) station. The aviators were administered an FWS checkride on their five maneuvers, and then allowed nine practice repetitions of each maneuver in the FWS. Two standardization instructor pilots (SIPs) evaluated each repetition.

The operational aviators demonstrated significant improvement in performance across the 10 training trials on all but four maneuvers. Regression equations derived from the data predict that operational aviators require significant amounts of training in the FWS to reach a satisfactory level of proficiency on all maneuvers investigated. The average number of trials predicted for aviators to reach a satisfactory level of proficiency in the FWS ranged from 9 trials for Manual Throttle Operation in the pilot station to 28 trials for Hovering tasks in the CPG station. Kaempf et al. (1989) concluded that significant differences exist between the FWS and the AH-1 aircraft and that the two should not be considered as interchangeable training devices. Furthermore, they concluded that studies of forward transfer of training are needed to determine the relationship between training conducted in the flight simulator and subsequent pilot performance in the aircraft.

Emergency Touchdown Maneuvers

Another important concern associated with the Army's fielding of motion-based, visual flight simulators is their effectiveness for training skills on maneuvers that are not normally practiced in the aircraft. Some tasks are either too expensive (e.g., weapons related tasks) or too dangerous (e.g., emergency maneuvers) for aircrews to practice in the aircraft. A notable group of these maneuvers is the five emergency touchdown maneuvers (ETM) listed below and described in detail in Appendix A:

- Standard Autorotation (SA),
- Low-Level Autorotation (LLA),
- Dual Hydraulics Failure (DHF),
- Right Antitorque Failure (RAF), and
- Low-Level High-Speed Autorotation (HSA).

In the past, the Army required aviators to develop and maintain proficiency on each of these maneuvers throughout all phases of their training. However, in 1983, the Army determined that greater expense was incurred from ETM training accidents than from accidents that occurred as a result of real aircraft failures. Consequently, in November 1983, the Department of the Army (DA) instituted a 1-year moratorium on the practice of these five maneuvers by aviators in operational units (Department of the Army, 1983). DA instituted a permanent prohibition against practicing the ETMs in 1984 by deleting them from the lists of flight tasks in the Aircrew Training Manuals (ATMs) (Department of the Army, 1984a). Furthermore, DA incorporated the prohibition against ETMs into Army Regulation 95-1: "General Provisions and Flight Regulations" (Department of the Army, 1985).

The exceptions to this prohibition occur within the Initial Entry Rotary Wing (IERW) Course, the Aircraft Qualification Courses (AQCs), and the Instructor Pilot

Courses (IPCs). In accordance with the IERW, AQC, and IPC POIs, student aviators are trained to proficiency and administered flight evaluations on the ETMs. However, under the prohibition, the aviators are not permitted to practice the ETMs in the aircraft following graduation from the AQC.

The prohibition against practicing ETMs clearly has created a training deficiency for Army aviators. Operational aviators have not practiced ETMs in the aircraft either since November 1983 or since they graduated from AQC, and their ability to deal successfully with inflight emergencies has deteriorated.

The Directorate of Evaluation and Standardization (DES) at the USAAVNC has estimated the ETM proficiency of operational aviators by observing their performance upon assignment from operational aviation units to the IPC. Farnham and Rowe (1986) reported the results of checkrides administered to 106 aviators entering the UH-1, AH-1, and OH-58 IPCs. The checkrides comprised 12 maneuvers including 4 that the Army permits in the aircraft:

- Throttle in Governor Mode,
- Engine Failure at Hover,
- Engine Failure at Altitude, and
- High-Speed Engine Failure.

In addition, the checkrides included 8 maneuvers that the Army does not permit in the aircraft:

- Dual Hydraulics Failure,
- Standard Autorotation,
- Low-Level Autorotation,
- Low-Level Low-Speed Autorotation,
- Low-Level High-Speed Autorotation,
- Left Antitorque Failure,
- Right Antitorque Failure, and
- Autorotation with 180° Turn.

Student performance was evaluated on a 6-point subjective rating scale. The lower three scale values (1-3) were verbally anchored to unsatisfactory performance and the higher three scale values (4-6) were verbally anchored to satisfactory performance.

Performance on the permitted maneuvers received an average rating of 4.00 and performance on the prohibited maneuvers received an average rating of 2.97. The majority performance level on each prohibited maneuver was unsatisfactory, except for Dual Hydraulics Failure. For four of the prohibited maneuvers (Dual Hydraulics Failure, Standard Autorotation, Low-Level Autorotation, and Low-Level Low-Speed Autorotation), the majority of subjects required verbal assistance to complete the maneuvers successfully. For the other four prohibited maneuvers (Low-Level High-Speed Autorotation, Left and Right Antitorque Failures, and Autorotation with 180° Turn), the majority of subjects required physical assistance to complete the maneuvers successfully. The authors concluded that operational Army aviators do not possess sufficient skills to perform the prohibited maneuvers satisfactorily.

Anecdotal information suggests that the adverse effects of the ETM prohibition extend beyond performance of the five emergency maneuvers. Aviators have reported that training conducted under extreme emergency conditions prepares them to perform better under normal flight conditions. Aviators contend that, through ETM training, they become more familiar with aircraft handling qualities and flight characteristics, and that mastery of complex emergency conditions instills confidence and positive attitudes. Therefore, although the ETM prohibition may be cost effective, it possibly results in an aviator population that is less proficient in both emergency and normal flight conditions.

An alternative means of acquiring and maintaining ETM proficiency would be valuable. Intuitively, flight simulator training provides the most logical alternative to aircraft training because aviators could practice these maneuvers without endangering themselves or their equipment. However, the effectiveness of flight simulators for training ETMs has not been established.

The Present Research

This research is an extension of the research previously reported by Kaempf et al. (1989). Whereas the previous research focused on the identification of simulator deficiencies, this research investigates the effects that FWS training has on subsequent pilot performance in the AH-1 aircraft. Specifically, the research investigates the effectiveness of the FWS for training the five ETMs in an operational aviation unit environment. The specific objectives of the research are noted below:

- estimate the level of ETM proficiency that unit aviators currently possess,
- determine the forward transfer of training from the FWS to the AH-1 aircraft for the five ETMs,
- estimate the amount of training that operational aviators require to regain proficiency on the ETMs,

- verify the results of the previous backward transfer experiment, and
- determine whether the backward transfer measures predict forward transfer of training.

The first three objectives are the primary objectives of this research. However, the backward transfer of training paradigm provided the opportunity to observe the degree to which skills demonstrated in the aircraft transfer to the FWS. Therefore, an analysis of backward transfer is also presented.

The researchers made several assumptions when designing and conducting the research. First, this research focused on the effectiveness of the flight simulator for training individual aviators. Issues concerning crew training were not addressed. Second, the authors assumed that it is necessary to study the training effectiveness of flight simulators for each individual training maneuver. That is, training effectiveness data should be developed for each training maneuver.

Third, a limited number of training maneuvers should be investigated with each group of subjects to control for the generalization of skills between maneuvers. Training provided on one maneuver often facilitates learning on another maneuver. Although the order in which maneuvers should be trained is important when developing the optimal POI, the present research focused on the effectiveness of the FWS to train each maneuver without regard for the order in which the maneuvers were trained. Finally, each training maneuver must be investigated separately for each of the three broad areas of aviation unit training requirements (e.g., skill acquisition, skill enhancement, skill sustainment) to determine whether the training requirements can be satisfied by a flight simulator.

Method

The research was conducted at two sites: Fort Campbell, Kentucky, and Fort Lewis, Washington. Data collection required two weeks at each site; six months elapsed between the data collection efforts at the two sites. The subjects were tested at each site using identical procedures. The procedures employed are discussed below.

Experimental Design

This research employed a transfer-of-training paradigm to address the research objectives identified previously.

Figure 1 depicts the principal steps in the design. All subjects were administered initial checkrides in the aircraft and the flight simulator, and then assigned to one of two groups, control or experimental. The groups were equated in terms of scores received on the initial aircraft checkride. The control group subjects received training to proficiency on the ETMs in the aircraft followed by a second checkride in the flight simulator. Concurrently, the experimental group subjects received training to proficiency in the flight simulator, a second checkride in the flight simulator, and then training to proficiency in the aircraft.

The primary measure of a flight simulator's training effectiveness is the effect that simulator training has on subsequent performance in the aircraft. Consequently, comparing the control and experimental groups' performance

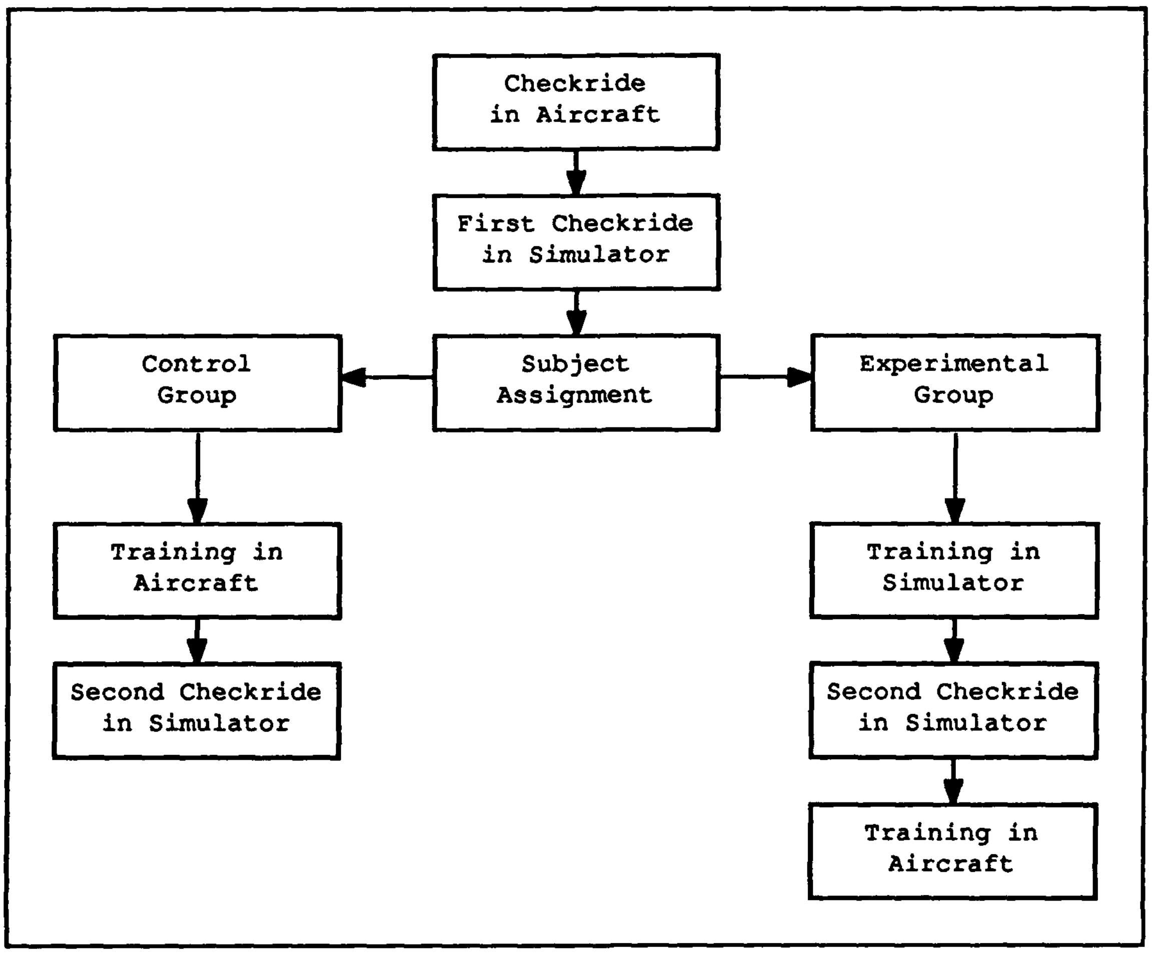

Figure 1. Flow chart of principal steps in experimental design.

during aircraft training provides data describing the flight simulator's training effectiveness for the maneuvers investigated. Furthermore, the other research objectives can be addressed within the transfer-of-training paradigm. The initial checkrides in the aircraft and flight simulator provide estimates of the skill level that aviators maintain on the ETMs. The control group subjects' performance during their second checkride in the flight simulator provides estimates of the backward transfer of skills from the aircraft to the flight simulator.

Equipment

Aircraft. Fully modernized versions (see Figure 2) of the AH-1S, now referred to as the AH-1F, were used to collect all of the pilot performance data in the aircraft. The external wing stores were removed from the aircraft and the overall gross aircraft weight was maintained at approximately 9300 pounds for all flights performed in support of this research. Four different AH-1F aircraft were used during the study at Site 1; three different aircraft were used at Site 2.

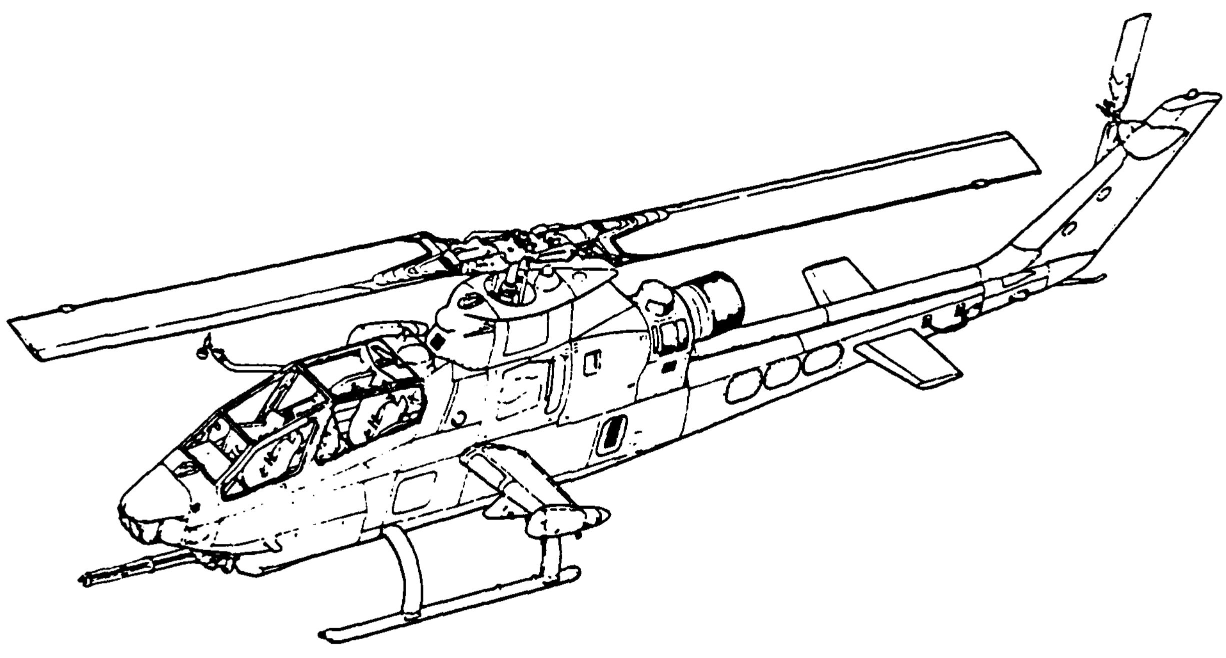

Figure 2. Diagram of AH-1F aircraft.

Flight simulators. Two production model FWSs were employed to collect the pilot performance data. One FWS was located at Fort Campbell, Kentucky, and the other at Fort Lewis, Washington. The FWS is fully described in the Operator's Manual for the AH-1S (Cobra) Flight and Weapons Simulator (Department of the Army, 1984b). The FWS has a pilot cockpit and a CPG cockpit (see Figure 3 and Figure 4), each mounted on a separate six-degree-of-freedom motion platform. An instructor/operator station is located directly behind the crew station in both the pilot and CPG cockpits.

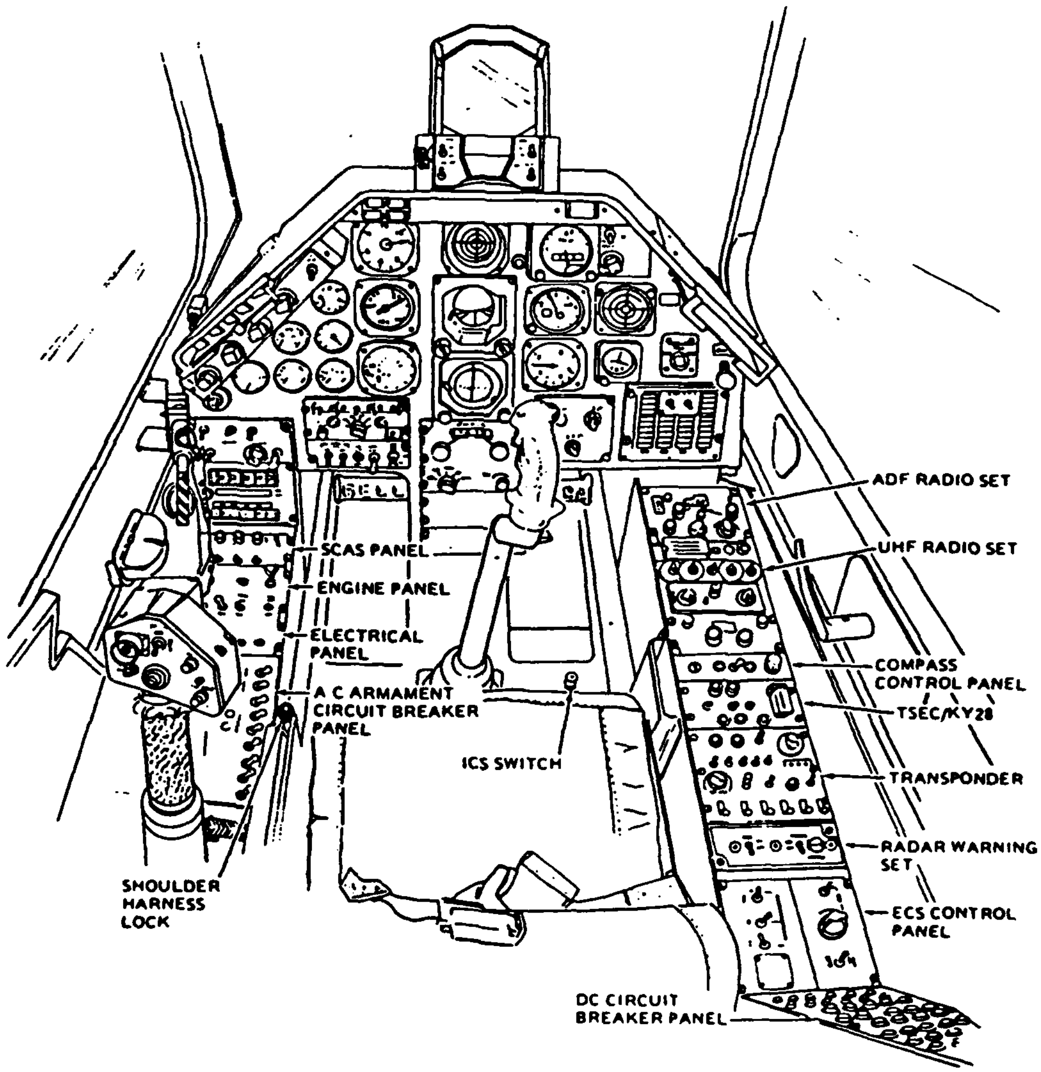

Figure 3. Diagram of FWS pilot station.

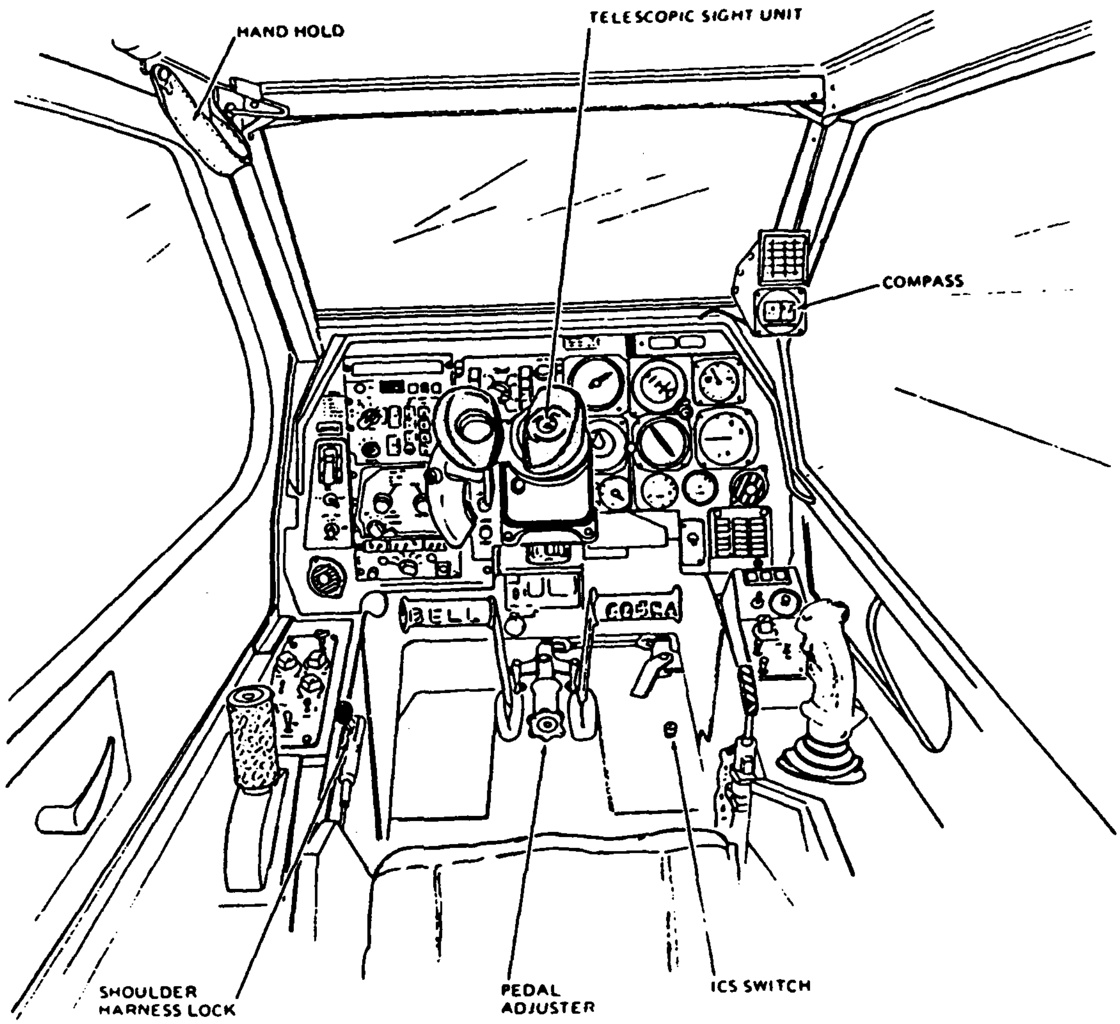

Figure 4. Diagram of FWS copilot/gunner station.

Visual scenes are displayed on two channels (forward and left side) in the pilot station and on a single channel (forward) in the CPG station. Visual scenes are produced by a Laser Image Generation (LIG) system traversing a three-dimensional terrain modelboard that replicates a generic gaming area of approximately 7.3 kilometers by 19.5 kilometers on a scale of 1:1000. The LIG system employs a multicolored laser beam that scans the high-detail modelboard. Scattered and reflected light is picked up by a bank of photomultiplier tubes. The outputs from all of the photomultiplier tubes are added to produce a composite video signal as the gantry duplicates the flightpath of the simulated aircraft.

Maneuvers

Five ETMs (see Table 1) were selected from the AH-1 ATM (Department of the Army, 1984a) for investigation. Descriptions and evaluation guidelines for the maneuvers also were drawn from the AH-1 ATM. Appendix A includes a complete description of each maneuver as performed during this research.

Performance Measures

Gradeslips. Subjective evaluations of pilot performance served as the principal dependent measures in this research. In both the aircraft and the FWS, trained evaluators completed a two-part gradeslip (see Appendix B) for each trial performed during the study. Once completed, the gradeslip provided a record of what the aviator did and how well he did it.

The Pilot Performance Description Record (PPDR), developed by Smith, Flexman, and Houston (1952) and later modified by Greer, Smith, and Hatfield (1962) and by Prophet and Jolley (1969), served as a model for the development of the gradeslip. Smith et al. developed the PPDR to reduce subjectivity present in evaluations of pilot performance and to provide a method for standardizing flight evaluations. Greer et al. demonstrated that overall performance ratings

Table 1

Emergency Touchdown Maneuvers Investigated

Maneuver	ATM Task Number
Standard Autorotation (SA)	3001
Low-Level Autorotation (LLA)	3002
Dual Hydraulic Failure (DHF)	3003
Right Antitorque Failure (RAF)	3004
Low-Level High-Speed Autorotation (HSA)	3005

Note. The following abbreviaiton is used in Table 1: ATM = Aircrew Training Manual.

made with PPDR descriptive scales are more reliable than overall performance ratings made without the PPDR. Versions of the PPDR have been used effectively to evaluate aviator flight performance in a variety of investigations (see Shelnutt, Spears, & Prophet, 1981; Childs, Prophet, & Spears, 1981; Childs, Spears, & Prophet, 1983).

The gradeslips used in this research consist of two parts and are a modification of the gradeslips used in previous studies of simulator effectiveness; their development is fully described by Kaempf et al. (1989). The first part of the gradeslip, completed as the trial was in progress, comprises a series of scales describing detailed performance information during each phase of the maneuver. The descriptive scales represent flight parameters (e.g., altitude, airspeed) considered relevant for evaluating performance on the maneuvers. They are anchored to standards and tolerances established for each parameter by the ATM or the AH-1 Operator's Manual (Department of the Army, 1980). The scales enable the evaluators to indicate quickly how well the subject performed relative to each standard.

The second part of the gradeslip was designed to provide an overall performance rating (OPR) for each practice trial. The primary modification to the earlier gradeslips was the expansion of the OPR scale. Kaempf et al. (1989) employed a 13-point bipolar OPR scale with only one rating point denoting unsatisfactory performance. The scale did not adequately distinguish between the various causes or gradations of unsatisfactory performance. Consequently, data obtained with the scale did not report learning that occurred prior to the aviators attaining proficiency on the maneuver. For the present research, the OPR scale was expanded to 15 points. In addition, a set of descriptive verbal anchors (see Table 2) was developed to guide the evaluator in assigning the OPR. Scale values 1 through 6 are verbally anchored to unsatisfactory performance; scale values 7 through 15 represent various gradations of satisfactory performance.

Subjects

Ten qualified and current AH-1 aviators were selected at each site (N = 20) to serve as subjects for the study. All the aviators were male because of the restriction on females being assigned to combat duties. None of the subjects had performed an ETM in the aircraft since graduation from the AH-1 AQC. Furthermore, 10 of the subjects (6 at Site 1 and 4 at Site 2) had never performed a Right Antitorque Failure because the maneuver was not part of the AH-1 AQC POI when

Table 2

Descriptive Verbal Anchors for the Overall Performance Rating Scale

Scale Value	Verbal Anchor
1	Power recovery/Crash imminent
2	Exceeded aircraft flight parameters
3	Touchdown out of designated touchdown zone
4	Exceeded more than two standards
5	Exceeded two standards
6	Exceeded one standard
7	Satisfactory performance--Low "C"
8	Satisfactory performance--Middle "C"
9	Satisfactory performance--High "C"
10	Satisfactory performance--Low "B"
11	Satisfactory performance--Middle "B"
12	Satisfactory performance--High "B"
13	Satisfactory performance--Low "A"
14	Satisfactory performance--Middle "A"
15	Satisfactory performance--High "A"

they entered the course. All of the subjects had received training on tactical tasks in the FWS during the 12-month period immediately preceding their participation in the research. The subjects reported having practiced an average of 12.4 ETMs (SD = 10.6) in the FWS during the 6-month period immediately preceding the study.

Five subjects at each site were assigned to the experimental group and the other five were assigned to the control group on the basis of their performance during the initial aircraft checkrides. The initial aircraft checkride consisted of one trial for each of the five ETMs. These grades were assumed to represent the aviators' baseline levels of proficiency on the ETMs. For each subject, the five OPR scores awarded during the initial aircraft checkride were added together to obtain a total checkride score. Subjects were then assigned to groups that were equated for total checkride scores. No significant differences existed between the experimental and control groups on the total checkride scores. The mean and standard deviations of checkride scores for the experimental and control groups are shown in Table 3.

Demographic and flight experience information for the subjects in each of the two groups and for the subjects tested at each site are presented in Tables 3 and 4, respectively. The information includes the average score received on a written test requiring knowledge of emergency procedures and standards and the average total OPR score for the initial aircraft checkride. The written test was administered before the study began and comprised 21 questions derived from the AH-1 ATM (Department of the Army,1984a). The questions tested the subjects' knowledge of the procedures and performance standards for the ETMs. A sample of the written test is presented in Appendix C. Tables 3 and 4 report the average number of questions answered correctly.

The experimental and control groups differed significantly only on the mean age of the subjects (t [18] = 2.23, p <.05). Comparisons of the subjects tested at the two sites

Table 3

Demographics and Flight Experience of Subjects in Each Group

	Control (n=10)		Experimental (n=10)	
	Mean	SD	Mean	SD
Age	25.1	1.3	28.2	4.2
Total Flight Hours	476.0	179.6	529.0	49.3
AH-1 Flight Hours	224.0	143.6	287.5	176.1
Months Since AQC	21.8	9.2	22.2	13.0
Test Score	17.4	3.2	16.1	3.3
Checkride Score	15.5	8.3	14.2	8.3

Note. The following abbreviation is used in Table 3: AQC = Aircrew Qualification Course.

Table 4

Demographics and Flight Experience of Subjects at Each Site

	Site 1 (n=10)		Site 2 (n=10)	
	Mean	SD	Mean	SD
Age	26.1	4.2	27.2	2.4
Total Flight Hours	495.0	161.6	510.0	178.6
AH-1 Flight Hours	210.5	128.1	301.0	181.4
Months Since AQC	17.8	9.1	26.2	11.5
Test Score	17.6	3.5	15.9	2.9
Checkride Score	18.8	9.3	10.7	4.4

Note. The following abbreviation is used in Table 4: AQC = Aircrew Qualification Course.

(disregarding group assignment) revealed that the months since AQC (graduation) were significantly greater for Site 2 subjects than for Site 1 subjects (t [18] = 1.81, p <.05) (see Table 3). Furthermore, the subjects tested at Site 2 received significantly lower OPR scores on the initial checkride in the aircraft than these subjects tested at Site 1 (t [18] = 2.50, p <.025).

Evaluators

Evaluator information. Three AH-1 IPs administered all of the checkrides and training conducted in the aircraft. Two of the IPs (Evaluators 1 and 3) were SIPs assigned to DES. Evaluator 1 worked at both sites; he evaluated 142 maneuvers at Site 1 (M OPR = 6.0, SD = 2.6) and 153 maneuvers at Site 2 (M OPR = 4.7, SD = 2.9). Evaluator 2 evaluated 109 maneuvers (M OPR = 7.4, SD = 3.0) at Site 1. Evaluator 3 evaluated 230 maneuvers (M OPR = 5.0, SD = 3.0) at Site 2.

Five rated aviators administered the training and performed all of the evaluations in the flight simulator; four of these evaluators were qualified AH-1 IPs. Evaluators 4 and 5 worked at both sites. Evaluators 6 and 7 worked only at Site 1; and, Evaluator 8 worked only at Site 2. In the FWS, two evaluators assessed subject flight performance and collaborated to derive a single gradeslip for each trial. The pairing of evaluators varied across the FWS training sessions.

Evaluator training. The researchers conducted training sessions to familiarize the evaluators with the rating scales, performance standards, and procedures for employing the gradeslips. Each of the eight evaluators then received six hours of supervised practice in the FWS using the grade-slips to evaluate aviator performance on the ETMs. Each of the three aircraft evaluators received an additional six hours of practice with the gradeslips in the aircraft. The day before data collection began at each site, the researchers conducted another training session with the evaluators to review performance standards and procedures and to ensure that standardized procedures were followed in the aircraft and the FWS.

Data Collection

Data were collected at Site 1 during 2 - 13 February 1987 and at Site 2 during 3 - 14 August 1987. All aircraft evaluations and training were conducted during daylight hours when the weather was fair and the winds were light. The data collection procedures are listed and discussed below:

- perform pretest briefing and administer the written test of ETM procedures and performance standards,
- establish initial condition for each ETM,
- administer initial checkrides in the aircraft and the flight simulator,
- train the control subjects to proficiency on the ETMs in the aircraft and the experimental subjects to proficiency in the FWS and the aircraft, and
- administer a second checkride in the FWS.

The data collection procedures were identical at both sites except as noted in the discussions below.

Pretest briefing and written test. Prior to the initial checkrides, the subjects were thoroughly briefed on the purpose of the experiment and the maneuvers they would be required to perform. Following the briefing, a written test was administered to the subjects. After all subjects completed the test, the questions and the correct answers were reviewed with the subjects.

Initial conditions. The successful performance of each of the five ETMs is heavily dependent upon the aircraft's position, velocity, and trim at the time the pilot commences the maneuver. To control for this source of variability during the aircraft checkrides, the evaluators were instructed to "set up" the aircraft in the manner prescribed for each maneuver prior to relinquishing control to the subject. For each maneuver, the prescribed "set up" conditions were defined in terms of altitude, lateral alignment with the runway, distance from the runway, aircraft airspeed, aircraft attitude, and aircraft trim. Every attempt was made to ensure that the initial conditions were standardized across subjects.

Similarly, during the flight simulator trials, the initial condition sets were established to duplicate as closely as possible the conditions that existed at the time the evaluators relinquished aircraft control to the subjects during aircraft checkrides. Special conditions such as weather, visibility, and turbulence were recreated as closely as possible. Every subject commenced every trial of each maneuver in the simulator under the same conditions prescribed for the aircraft. The initial conditions established in the aircraft and FWS are presented in the maneuver descriptions in Appendix A.

Initial checkrides. Prior to training, all subjects were administered one checkride in the aircraft and one checkride in the flight simulator; the checkrides comprised one trial of each maneuver. The order in which subjects performed the maneuvers was counterbalanced across subjects using a partial Latin Square. Each subject maintained the same order of maneuvers during both checkrides. Subjects were randomly assigned to one of the two aircraft evaluators for the aircraft checkrides; the same pair of FWS evaluators conducted the simulator checkrides for all subjects at each site.

Immediately after each trial, the evaluators assigned OPR scores on the 15-point scale. The evaluators were instructed to judge whether overall performance on the trial was satisfactory. If not, the evaluator referred to the gradeslip's descriptive scales (Table 2) and awarded an appropriate OPR score between 1 and 6. If the evaluator judged that overall performance was satisfactory, he awarded an OPR score of 7 or greater using the "A", "B", and "C" anchors.

The researchers planned to conduct the aircraft checkrides prior to the simulator checkrides. However, poor weather at Site 1 prevented any flying on Day 1 of data collection. Consequently, all checkrides in the FWS were conducted at Site 1 on Day 1 and all checkrides in the aircraft were conducted on Day 2. At Site 2, all aircraft and flight simulator checkrides were completed on Day 1 of data collection. Each subject at Site 2 completed the aircraft checkride prior to the simulator checkride.

Training to proficiency. Subsequent to the initial checkrides, the control group began training to proficiency in the aircraft only, and the experimental group began training to proficiency in the simulator followed by training to proficiency in the aircraft. The control group subjects were randomly assigned to aircraft evaluators; the experimental group subjects were assigned to aircraft evaluators on the basis of the evaluators' availability as control group subjects completed training.

During the first training sessions, the subjects practiced all five ETMs. The number of training trials conducted in both the aircraft and the flight simulator depended upon performance on the individual maneuvers. Rather than receiving a fixed amount of training, all subjects received training on each maneuver until they attained a criterion level of proficiency. The criterion was defined as two consecutive trials of a maneuver, completed during the same training session, on which the subject received OPR scores of 7 or greater. Once a subject reached the performance criterion for a maneuver, he no longer practiced that maneuver.

The researchers instructed the evaluators to train the subjects as rapidly as possible and allowed the evaluators to exercise their judgment as IPs to determine the best method of training each subject. The researchers recommended that four or more consecutive trials of a single maneuver be avoided. However, the researchers did not control the order in which maneuvers were trained or the number of training trials attempted during a session.

Several procedural differences existed between the training conducted in the aircraft and in the flight simulator. First, subjects were observed by the same evaluator during all training conducted in the aircraft; in the flight simulator, the pair of evaluators observing a subject was not held constant across all training sessions. Second, during training in the aircraft, the evaluators did not establish the initial "set up" conditions prescribed for the aircraft checkrides before relinquishing control to the subjects, but allowed the subjects to fly the aircraft throughout the entire traffic pattern. In contrast, all trials attempted in the flight simulator during both training and checkrides began with the initial condition sets. Third, the experimental group's first training session in the aircraft was treated as a checkride. The evaluators required the subjects to complete one trial of each maneuver in the same order that the subjects completed their initial checkrides. The evaluators began instructing the subjects after completion of the first trial of all five maneuvers.

Second FWS checkrides. All subjects received a second checkride in the FWS. Each control group subject received the second simulator checkride no later than 4 days after completing aircraft training. Each experimental group subject received this checkride no later than 1 day after completing simulator training and before beginning aircraft training. For all subjects, the first and second simulator checkrides were identical in the content and order in which the maneuvers were performed.

Grading Procedures

During the aircraft maneuvers, the evaluator occupied the CPG station (front seat) and the subject occupied the pilot station (back seat). To the extent possible without compromising safety, the evaluator completed the descriptive scales of the gradeslip during the maneuver. The evaluator completed the remaining descriptive scales as soon as the aircraft landed. The evaluator then reviewed his entries on the descriptive scale and assigned an OPR for the maneuver prior to takeoff for the next maneuver.

During the flight simulator maneuvers, two evaluators observed and evaluated aviator performance. One evaluator operated the flight simulator and evaluated the subjects' performance from the console operator station in the pilot cockpit. The second evaluator occupied the CPG station and was responsible for monitoring the flight controls and flight parameters. Both evaluators completed separate gradeslips for each flight simulator maneuver. Following each maneuver, the evaluators collaborated to produce a consensus gradeslip for data analysis. The collaboration included discussions between the evaluators, reference to the gradeslips they had completed individually, and observation of as many maneuver "replays" as needed to ensure that the gradeslips were completed accurately. Subjects were disconnected from the intercom system (ICS) while the evaluators discussed their assessments of the subjects' performance. However, the subjects were able to observe visually any maneuver "replays" initiated by the evaluators.

Results and Discussion

The data collection effort required 117 flight hours in the AH-1F, 214 flight hours in the FWS, and 20 aviators to serve as subjects for two weeks each. These resources were expended equally between the two sites. In the aircraft, 99.6 flight hours were expended to train the aviators and 17.4 flight hours were expended to conduct the checkrides. The evaluators assessed a total of 632 training trials in the aircraft for both groups. Training the experimental group in the flight simulator (759 training trials) required 184 FWS flight hours; conducting the checkrides required 30 FWS flight hours.

The data from the descriptive scales provide detailed information about subject performance during each phase of the maneuvers investigated. In future research, these data may be of value in determining the critical parameters for each maneuver and the effect that prior simulator training has on these parameters. However, preliminary analyses of the descriptive data obtained during this research indicated that:

- the data distributions do not meet the assumption of normality for multivariate analyses,
- the data do not meet the multicollinearity assumption required for multivariate analyses, and
- the sample size is too small for appropriate analyses.

Therefore, the OPRs for each trial served as the principal depenaent measure in the analyses. To compare the performance of the two groups or performance between the two sites, the OPR scores were analyzed using mixed design Analysis of Variance (ANOVA) with either Groups (2) and Maneuvers (5) or Sites (2) and Maneuvers (5) as the two factors. These ANOVAs treated the Maneuvers factor as a repeated measures factor and the Group and Site factors as between subjects factors (see Winer, 1971). To compare the experimental group's performance in the FWS with its performance in the aircraft, the OPR scores were analyzed using a two-factor (2 Training Devices x 5 Maneuvers) ANOVA with repeated measures on both factors. Similarly, to compare the performance of the subjects on their first and second checkrides in the aircraft, the OPR scores were analyzed using a two-factor (2 Checkrides x 5 Maneuvers) ANOVA with repeated measures on both factors. Significant ANOVA effects were further analyzed using Tukey honestly significant difference (HSD) tests (Tukey, 1953) to identify the significant differences between the levels of a factor or cells in an interaction.

Differences in Aviator Performance: Site 1 vs. Site 2

The aviators tested at Site 2 were initially less proficient on the ETMs than the aviators tested at Site 1, as shown by the significantly lower OPR scores on both the initial checkride in the aircraft (F [1, 18] = 6.27, p <.025) and the initial checkride in the flight simulator (F [1, 18] = 12.75, p <.005). The Site 1 aviators received average OPR scores of 3.76 and 2.94 on the initial aircraft and flight simulator checkrides, respectively. The Site 2 aviators received average OPR scores of 2.14 and 1.82 on the initial aircraft and flight simulator checkrides, respectively. In addition, the aviators at Site 2 (M = 5.66 trials) required significantly more (F [1, 18] = 9.44, p <.01) training trials to reach proficiency in the aircraft than the aviators tested at Site 1 (M = 2.98 trials).

Differences in Aviator Performance: Aircraft vs. Simulator

The initial checkrides in the aircraft and the FWS provide estimates of the ETM proficiency maintained by operational aviators. Table 5 presents the mean and standard deviation of the OPR scores for each maneuver performed during the initial checkrides in both the aircraft and the flight simulator. The mean scores reflect unsatisfactory performance (OPR less than 7; see Table 2) for all five

Table 5

Mean Overall Performance Rating for Each Maneuver Performed During the Initial Checkrides (N = 20 per maneuver)

	Aircraft		Simulator	
Maneuver	Mean	SD	Mean	SD
Standard Autorotation	2.2	2.2	2.9	2.0
Low-Level Autorotation	2.8	2.9	2.6	2.2
Dual Hydraulics Failure	4.1	2.8	2.6	2.0
Right Antitorque Failure	2.4	2.2	2.1	1.8
Low-Level High-Speed Autorotation	3.1	2.6	1.8	1.0

maneuvers in both devices; performance was rated as satisfactory on only 13% and 7% of the maneuvers attempted during the initial aircraft and simulator checkrides, respectively.

Low ratings awarded during the initial checkrides reflect the severe difficulties the aviators had in performing the maneuvers. Table 6 presents frequency distributions for the OPR scores collapsed across all five maneuvers for the initial aircraft and simulator checkrides. Performance on 55% of the aircraft checkride maneuvers received ratings of 1; performance on 66% of the aircraft checkride maneuvers received ratings less than 4. That is, during the initial aircraft checkrides, the evaluators

Table 6

Frequency Distributions for OPR Scores Awarded During Initial Aircraft and Simulator Checkrides (*N* = 20 subjects, 5 maneuvers)

	Aircraft		Simulator	
OPR Score[a]	Frequency	Cum. %	Frequency	Cum. %
1	55	55.0	44	44.0
2	0	55.0	23	67.0
3	11	66.0	11	78.0
4	9	75.0	15	93.0
5	4	79.0	0	93.0
6	8	87.0	0	93.0
7	5	92.0	3	96.0
8	3	95.0	2	98.0
9	4	99.0	2	100.0
10	1	100.0	0	100.0

Note. The verbal anchors for the OPR scale are presented in Table 2. The following abbreviations are used in Table 6: OPR = Overall Performance Rating; Cum. % = Cumulative percentage.

[a]No OPR scores greater than 10 were awarded.

initiated power recoveries on the majority of maneuvers attempted because the subjects put the aircraft into a dangerous configuration. Similar poor performance was observed during the initial simulator checkrides; 44% of the maneuvers received ratings of 1 and 78% received ratings less than 4.

Frequency distributions of the OPR scores awarded for performance on training trials in the aircraft and flight simulator are presented by maneuver in Tables 7 and 8, respectively. In all cases, at least half of the training trials received OPR scores of less than 7. The positively skewed frequency distributions reflect the improved performance that occurred as training progressed and are an artifact of the experimental procedures. Each aviator terminated training on a maneuver after reaching proficiency; that is, after receiving OPR scores greater than 6 on two consecutive training trials of that maneuver. For most subjects, the OPR scores reflect unsatisfactory performance on the majority of training trials in both the aircraft and the flight simulator. Very few OPR scores were awarded in the B and A range (scores of 10-15).

The frequency distributions in Tables 7 and 8 indicate that reaching the criterion level of proficiency on all maneuvers was more difficult in the flight simulator than in the aircraft. The experimental group required more training trials to reach proficiency in the simulator (M = 60.9 TTC) than either the control group (M = 36.4 TTC; t [18] = 2.85, p <.05) or the experimental group (M = 15.0 TTC; t [9] = 10.31, p <.005) required to reach proficiency in the aircraft. A higher proportion of training trials conducted in the simulator received OPR scores less than 7 (M = 80.5%) than in the aircraft (M = 64.3%).

Backward Transfer

After training to proficiency in the aircraft, the control group provided an opportunity to study the backward transfer of skills from the AH-1F to the FWS. Figure 5 presents the group mean OPR for each maneuver on the last two aircraft training trials on each maneuver and the second FWS checkride. For all maneuvers, a significant decrement in performance occurred between performance on the last two trials in the aircraft and performance during the second FWS checkride (F [1,9] = 301.99, p <.001). No significant differences between maneuvers or significant interactions were observed.

Table 7

Frequency Distributions for OPR Scores Awarded During Aircraft Training Trials ($\underline{N}$ = 20)

OPR Score	SA f	SA Cum %	LLA f	LLA Cum %	DHF f	DHF Cum %	RAF f	RAF Cum %	HSA f	HSA Cum %
1	43	28.5	28	25.9	14	13.3	43	25.6	23	23.0
2	0	28.5	0	25.9	0	13.3	0	25.6	0	23.0
3	6	32.5	3	28.7	9	21.9	7	29.8	5	28.0
4	14	41.8	8	36.1	11	32.4	17	39.9	7	35.0
5	8	47.1	14	49.1	7	39.1	20	51.8	6	41.0
6	23	62.3	7	55.6	17	55.3	28	68.5	9	50.0
7	13	70.9	8	63.0	12	66.7	21	81.0	8	58.0
8	11	78.2	11	73.2	10	76.2	6	84.6	12	70.0
9	20	91.3	13	85.2	10	85.7	9	90.0	11	81.0
10	6	95.3	7	91.7	9	94.3	9	95.2	7	88.0
11	6	99.3	1	92.6	4	98.0	6	98.8	4	92.0
12	1	100.0	7	99.1	1	99.0	0	98.8	6	98.0
13	0	100.0	1	100.0	1	100.0	1	99.4	2	100.0
14	0	100.0	0	100.0	0	100.0	1	100.0	0	100.0
15	0	100.0	0	100.0	0	100.0	0	100.0	0	100.0
TOTAL	151	---	108	---	105	---	168	---	100	---

Note. The verbal anchors for the OPR scale are presented in Table 2. The following abbreviations are used in Table 7: OPR = Overall Performance Rating; SA = Standard Autorotation; LLA = Low-Level Autorotation; DHF = Dual Hydraulics Failure; RAF = Right Antitorque Failure; HSA = Low-Level High-Speed Autorotation; f = frequency; cum % = cumulative percentage.

Table 8

Frequency Distributions for OPR Scores Awarded During Flight Simulator Training Trials (n = 10)

OPR Score	SA f	SA Cum %	LLA f	LLA Cum %	DHF f	DHF Cum %	RAF f	RAF Cum %	HSA f	HSA Cum %
1	33	22.6	32	20.9	34	24.8	60	40.3	54	31.0
2	24	39.0	63	62.1	18	38.0	16	51.0	47	58.8
3	18	51.4	2	63.4	8	43.8	1	51.7	11	64.4
4	15	61.6	15	73.2	17	56.2	17	63.1	18	74.7
5	9	67.8	5	76.5	16	67.9	6	67.1	6	78.2
6	14	77.4	6	80.4	19	81.8	17	78.5	11	84.5
7	9	83.6	9	86.3	5	85.4	5	81.9	9	89.7
8	8	89.0	10	92.8	6	89.8	2	83.2	13	97.1
9	7	93.8	6	96.7	6	94.2	1	83.9	2	98.3
10	6	97.9	3	98.7	4	97.1	6	87.9	2	99.4
11	1	98.6	1	99.3	4	100.0	8	93.3	0	99.4
12	2	100.0	1	100.0	0	100.0	3	95.3	1	100.0
13	0	100.0	0	100.0	0	100.0	3	97.3	0	100.0
14	0	100.0	0	100.0	0	100.0	4	100.0	0	100.0
15	0	100.0	0	100.0	0	100.0	0	100.0	0	100.0
TOTAL	146	---	153	---	137	---	149	---	174	---

Note. The verbal anchors for the OPR scale are presented in Table 2. The following abbreviations are used in Table 8: OPR = Overall Performance Rating; SA = Standard Autorotation; LLA = Low-Level Autorotation; DHF = Dual Hydraulics Failure; RAF = Right Antitorque Failure; HSA = Low-Level High-Speed Autorotation; f = frequency; cum % = cumulative percentage.

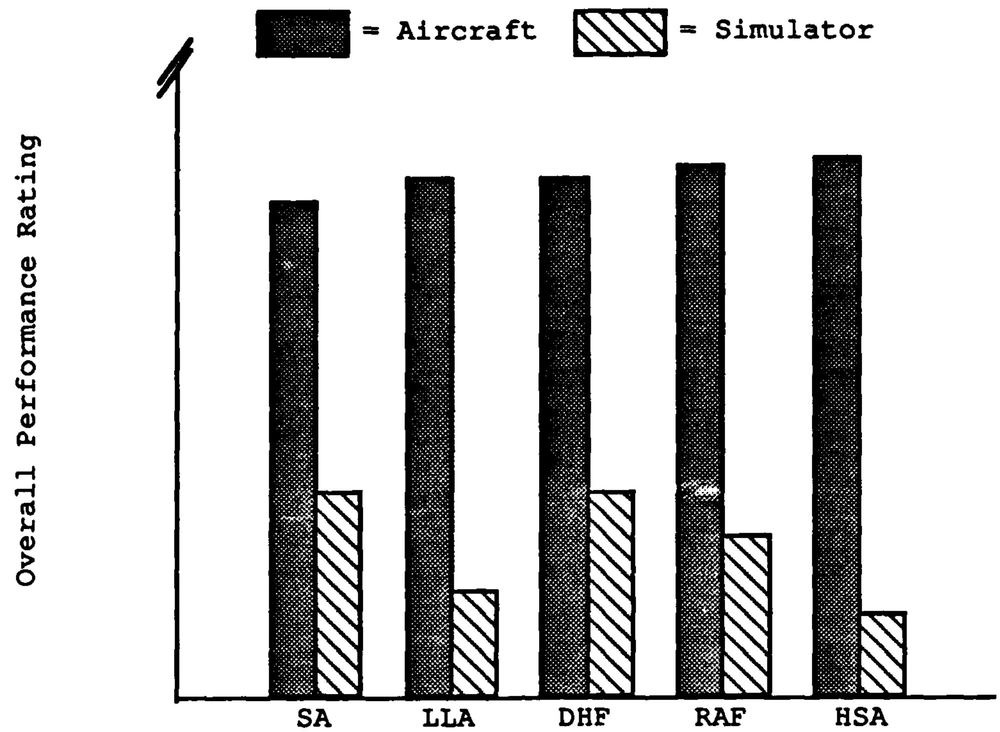

Figure 5. Comparison of performance on each maneuver in the aircraft (mean of the last two trials) and during the second simulator checkride. (The following abbreviations are used in Figure 5: OPR = Overall Performance Rating; SA = Standard Autorotation; LLA = Low-Level Autorotation; DHF = Dual Hydraulics Failure; RAF = Right Antitorque Failure; HSA = Low-Level High-Speed Autorotation.)

The performance decrement observed between the aircraft and the simulator can be quantified as:

$$B = \frac{\sum_{i=1}^{N} \left(\frac{A_i}{S_i}\right)}{N}$$

where:

B = index of backward transfer,
i = subject,
N = the total number of subjects,
A = the mean of the subject's OPR scores for the last two trials of the maneuver in the aircraft, and
S = the subject's OPR score for the maneuver during the second simulator checkride.

This index is the mean ratio of aircraft performance to simulator performance for all subjects in the control group (n = 10) and is calculated separately for each maneuver. A backward transfer index of less than 1 indicates that performance in the FWS was substantially below that in the aircraft. An index value of 1.0 indicates that the subjects performed the maneuver as well on the second checkride in the FWS as during the last two trials in the aircraft. A backward transfer index greater than 1.0 indicates that the subjects performed better in the FWS than in the aircraft.

A standard deviation of the A_i/S_i ratios for all subjects may also be calculated. The standard deviation indicates the variability among subjects in the comparison of performance in the aircraft to performance in the FWS.

Table 9 presents the backward transfer index and the A_i/S_i ratio standard deviation for the five ETMs. For all maneuvers, the backward transfer index is less than 1.0, indicating that the subjects did not perform as well on any maneuver during their second simulator checkride as during their last two trials in the aircraft. A one-factor ANOVA (5 Maneuvers) with repeated measures revealed significant differences between maneuvers for the A_i/S_i ratio (F [4, 36] = 3.06, p <.05). The mean indexes were significantly greater for the SA, DHF, and RAF than for the LLA and HSA.

Table 9

Mean Index and Standard Deviation of Backward Transfer for Emergency Touchdown Maneuvers (n = 10)

Maneuver	B	SD
Standard Autorotation	.430	.350
Low-Level Autorotation	.193	.048
Dual Hydraulics Failure	.402	.259
Right Antitorque Failure	.329	.220
Low-Level High-Speed Autorotation	.157	.067

Note. The following abbreviation is used in Table 9: B = Index of backward transfer.

Forward Transfer of Training

The ultimate measure of a simulator's training effectiveness is the improvement of subsequent performance in the aircraft. Four measures were used to assess forward transfer of training by the experimental group in the present study: trials to criterion (TTC), cumulative training effectiveness ratios (CTER), performance on an aircraft checkride following simulator training, and total aircraft training time required to reach proficiency after flight simulator training. Each measure is discussed in the following subsections.

Trials to criterion. The TTC measure is the number of training trials that an aviator attempted for a given maneuver before reaching the criterion level of proficiency on that maneuver. The researchers established the criterion level of performance for each maneuver as two consecutive trials that were rated as 7 or higher on the OPR scale. The number of TTC was calculated separately for training conducted in the aircraft and in the FWS, and included the trials performed during the initial checkrides.

Table 10 presents, by group, the mean TTC for the five maneuvers trained in the aircraft. Collapsing across maneuvers, the control group (*M* = 5.6 TTC) required significantly

Table 10

Trials to Criterion for Training in the Aircraft

	Maneuver				
Group	SA	LLA	DHF	RAF	HSA
CONTROL (*n* = 10)					
Mean	7.8	3.8	4.3	8.9	3.4
SD	5.4	2.5	3.3	4.5	2.0
EXPERIMENTAL (*n* = 10)					
Mean	3.3	3.0	2.2	3.9	2.6
SD	1.9	2.4	1.0	2.2	1.6

Note. The following abbreviations were used in Table 10: SD = Standard Deviation; SA = Standard Autorotation; LLA = Low-Level Autorotation; DHF = Dual Hydraulics Failure; RAF = Right Antitorque Failure; and HSA = Low-Level High-Speed Autorotation.

more (F [1, 18] = 9.86, p <.01) training to reach proficiency than the experimental group (M = 3.0 TTC). Furthermore, a significant main effect occurred for the Maneuver factor (F [4, 72] = 7.16, p <.001). The aviators required less training to reach proficiency in the aircraft on the RAF (M = 4.9 TTC) and SA (M = 4.5 TTC) than on the DHF (M =8.2 TTC), HSA (M =6.2 TTC), or LLA (M =5.7 TTC). There was no significant interaction between the groups and maneuvers.

Cumulative training effectiveness ratio. The CTER is an index of the degree to which simulator training affects subsequent aircraft training. The CTER reflects the difference in the amount of aircraft training required by the control and experimental groups adjusted for the amount of simulator training received by the experimental group. Roscoe and Williges (1980) provide a thorough discussion of the CTER. In this research, the following formula was used to calculate a CTER for each of the maneuvers investigated:

$$\text{CTER} = \frac{Y_o - Y_x}{X}$$

where:
Y_o = the control group's mean number of trials to criterion for training conducted in the aircraft;
Y_x = the experimental group's mean number of trials to criterion for training conducted in the aircraft; and
X = the experimental group's mean number of trials to criterion for training conducted in the FWS.

Positive CTER values indicate that the simulator has some training value. Negative CTER values indicate that simulator training has a negative impact on performance in the aircraft and increases the requirement for aircraft training. The magnitude of the CTER varies directly with the group difference in aircraft training received and inversely with the amount of simulator training received. A large difference in the amount of aircraft training received by the two groups may be negated if a large amount of simulator training was required to produce that difference. CTER values greater than 1.0 indicate that the simulator is a more effective trainer than the aircraft.

The CTERs computed for each of the five ETMs are as follow:

- RAF = .420,
- SA = .388,
- DHF = .196,
- LLA = .065, and
- HSA = .056.

The CTERs indicate moderate FWS training effectiveness for the RAF, SA, and DHF maneuvers. However, the CTERs indicate that the FWS is not effective for training the LLA or the HSA.

Performance on second aircraft checkride. As described in the Method section, aviators in the experimental group received a second checkride in the aircraft on the ETMs immediately after completing their training in the FWS and prior to beginning their training to proficiency in the aircraft. Across all maneuvers, the experimental group performed significantly better (F [1, 9] = 10.19, p <.05) on the second checkride in the aircraft (M OPR = 5.2) than on the first checkride (M OPR = 2.8). However, despite receiving training to proficiency in the FWS, the experimental group's performance on their second checkride in the aircraft remained unsatisfactory. No data were obtained to determine if FWS training beyond the criterion level of proficiency would have improved aviator performance in the aircraft.

The experimental group's improved performance on the second aircraft checkride might indicate that simulator training improved the subsequent ETM performance in the aircraft. However, this improvement could be caused by the practice that occurred on the initial aircraft checkride. Two analyses were conducted to test this hypothesis.

First, the control group's performance during its second checkride in the aircraft (the first training trial for each maneuver) was compared with their performance on their first aircraft checkride. The control group performed significantly better (F [1, 9] = 12.00, p <.01) during their second aircraft checkride (M OPR = 4.9) than on the initial checkride (M OPR = 3.3). Second, an analysis comparing the control and experimental groups' performance during their second aircraft checkrides disclosed no significant differences between the two groups. These analyses indicate that the performance improvement observed for both groups during the second aircraft checkride may be attributed to learning that occurred during the initial aircraft checkride and, therefore, cannot be attributed to the training conducted in the FWS.

Total aircraft training time. Total flight time to reach proficiency was recorded for each subject's training flights in the aircraft; the flight times were summed to obtain a total aircraft training time for each subject. The total training times for subjects at Site 1 were confounded by operational problems that arose during data collection. These problems included: aircraft maintenance, refueling problems, transit time to and from a remote stagefield, extended taxi times, and an inability to use the same runway each day due to weather and traffic considerations. These problems did not exist at Site 2. Therefore, total training times at Site 2 provide a more realistic estimate of the aircraft training time required for aviators to reach proficiency on the ETMs. At Site 2, the experimental group (M = 3.4 hours per aviator, SD = 1.04, n = 5) required significantly less (t [8] = 6.87, p <.005) training time in the aircraft than the control group (M = 6.7 hours per aviator, SD = .25, n = 5).

Conclusions

The six conclusions drawn from the results of this research are presented below. The first four conclusions deal with the current level of ETM proficiency and the effectiveness of flight simulator training. These results are generalizable for the population of operational aviators. The last two conclusions are technical in nature and deal with this specific sample or with the methodology employed. The six conclusions are followed by a discussion of the research limitations and recommendations, and a statement concerning the utilization of this research.

First, operational aviators are not proficient on any of the five ETMs. This conclusion is based on the unsatisfactory average performance of the subjects during their initial checkride in the aircraft and their lack of ETM procedural knowledge exhibited on the written test. Furthermore, the initial aircraft checkride ratings are conservative estimates of aviator proficiency because the checkrides were conducted under nearly ideal conditions. The weather was always favorable; the aviators knew in advance which maneuver they must perform and they initiated the maneuver themselves. Termination of each maneuver was on a 6000 ft. paved runway. Stress and workload conditions were minimal and a safety pilot was always prepared to take control of the aircraft. Real inflight emergencies do not often occur under such conditions. It seems reasonable to assume that aviator performance would be even poorer under less ideal conditions.

The data indicating the current proficiency of operational aviators are consistent with those reported earlier by Farnham and Rowe (1986). Both sets of data indicate that, in the event of a real emergency, most operational pilots could not safely terminate an emergency maneuver on the ground. In fact, the results of this research indicate that the majority of aircraft and crews may be in jeopardy in the event of an inflight emergency requiring initiation of one of the ETMs (see, for example, the data presented in Table 2 and Table 6).

Second, despite their poor initial performance in the aircraft, operational aviators require relatively little training in the aircraft to regain proficiency on each of the five ETM maneuvers. The subjects who did not receive simulator training required an average of 5.6 trials per maneuver; subjects who did receive simulator training required an average of 3.0 trials per maneuver.

Third, the FWS is moderately effective for training operational aviators to perform the five ETMs evaluated in this research. Although the CTERs indicated substantial training effectiveness for only two maneuvers (Right Antitorque Failure = .420; Standard Autorotation = .388), simulator training enhanced subsequent aircraft training by reducing (a) the number of trials required to reach proficiency on each maneuver and (b) the amount of total flight time needed to train the subjects in the aircraft.

Two factors contributed to the low CTERs: generalization of skills between the maneuvers investigated and the amount of training required in the flight simulator. First, the evaluators preferred to teach the basic autorotation techniques with the SA before progressing to the advanced techniques required for the LLA and HSA. Because the maneuvers have many common components, the subjects acquired many of the skills relevant to the LLA and the HSA while learning the SA. Although the LLA and HSA are more difficult maneuvers, subjects required fewer training trials on the LLA and the HSA than on the SA. This procedure possibly served to mask the simulator's effectiveness for both the LLA and HSA. Second, the low CTERs reflect the extensive amount of training required to reach proficiency in the flight simulator. Subjects received significantly more training on all maneuvers in the flight simulator than in the aircraft.

The CTER provides a measure of the simulator's training effectiveness with respect to the simulator resources expended during training. This measure is appropriate for identifying a cost-effective mix of available training resources that will produce a specified level of proficiency. That is, CTERs are appropriate for determining the least expensive mix of aircraft and simulator training that will produce an acceptable level of proficiency. In this case, the CTER has limited application because the aircraft is not available for training the ETMs; all training on the ETMs, if any, must be accomplished in the flight simulator.

Fourth, training to proficiency in the flight simulator alone does not prepare an aviator to deal safely with an inflight emergency. Most experimental group aviators did not perform satisfactorily during their first exposure to the aircraft after simulator training. Performance in the aircraft immediately following training in the simulator replicates the situation that occurs during an inflight emergency. Currently, all ETM training is conducted in the simulator and the only opportunity that an aviator has to perform an ETM in the aircraft is during an actual emergency. At that time, the aviator has only one opportunity to accomplish the maneuver successfully.

Simulator training on the ETMs does enhance performance and training conducted subsequently in the aircraft. However, ETM proficiency in the aircraft cannot be achieved without practice in the aircraft. In the flight simulator, aviators learn the techniques and procedures for the ETMs, but the training does not provide the skills necessary to complete the maneuvers successfully in the aircraft. In support of this conclusion, the IPs who evaluated the aviators in the aircraft reported that the experimental group subjects were very mechanical in their piloting techniques. Furthermore, these subjects consistently experienced difficulty estimating the appropriate altitudes for initiating critical maneuver segments during their first aircraft practice trials. The IPs reported that the experimental group required a few practice trials to gain a "feel" for the aircraft and to eliminate these problems.

Fifth, significant differences in flight proficiency exist between the aviators assigned to different locations. The aviators at Site 1 consistently performed better than the aviators at Site 2. These proficiency differences possibly may be attributed to differences in the times since the aviators graduated from the AQC. The AQC was the last opportunity that any of the subjects had to perform the ETMs in the aircraft. On the average, aviators tested at Site 1 graduated from the AQC 8.4 months after those aviators tested at Site 2. Therefore, the Site 2 aviators had a longer period for their ETM skills to decay. Although this explanation probably does not totally account for the differences between sites, no data were collected to support or refute other hypotheses.

Finally, the backward transfer data obtained in the present study support the results obtained previously (see Kaempf et al., 1989). The backward transfer of skills from the aircraft to the FWS was low. This indicates that the skills required to perform the five ETMs successfully in the aircraft are not the same as those required in the FWS. The backward transfer indexes predicted moderately positive transfer for three maneuvers (SA, DHF, and RAF) and poor forward transfer for the LLA and HSA. Although the CTER for the DHF (.20) was somewhat less than predicted by the backward transfer index (.40), the CTERs calculated for the other four maneuvers were consistent with the predictions of the backward transfer indexes.

These results confirm that relatively inexpensive backward transfer studies may be employed to identify the training tasks that should be investigated in forward transfer-of-training research. However, the predictive utility of the backward transfer procedure is limited until further research is conducted. The training maneuvers investigated in this research represent those with moderate and low forward transfer. Future studies should attempt to identify maneuvers with high forward transfer.

Limitations

Two major limitations to the generalizability of this research should be noted. First, the generalizability is limited because a single method of instruction was used during training in the FWS. The simulator's instructional support features and technical capabilities make possible a number of different approaches to training. The effectiveness of simulator training is, to a large degree, a product of the training methodology employed. The training methodology employed during this research (as described in the Method section) was not derived empirically, but was selected because of recommendations from subject matter experts. Although the results indicate that this method of simulation training did enhance pilot performance in the aircraft, it may not be the optimal method for training ETMs in the FWS.

Second, the generalizability is limited because this research does not address the capability of the FWS for sustaining proficiency on the ETMs; it only addresses the extent to which operational aviators can reacquire proficiency on the ETMs through FWS training. Whereas the research evidence indicates that the FWS is only moderately effective for reacquiring proficiency on the ETMs, it is possible that the FWS may be very effective for maintaining proficiency over time. Skill sustainment research is required to demonstrate the rate at which ETM proficiency decays and the effect that simulator training may have on that decay. Previous research indicates that proficiency on contact tasks does not begin to decay until 6 to 12 months after complete abstention from flying (see Ruffner & Bickley, 1983). ETMs were not investigated in that research. Skill sustainment research is required to determine the effect that simulator training has on the rate of ETM skill decay over various time intervals.

Recommendations

Three recommendations are presented on the basis of the results of this research. First, Army aviation units should require that aviators receive periodic instruction on the ETMs in the FWS. The instruction should include development of the fundamental skills required to perform each maneuver and practice performing each maneuver both in the stagefield environment and in high workload environments (e.g., during weapons engagement).

Second, Army aviators currently are unable to perform ETMs satisfactorily. Proficiency may degrade further as the prohibition against practicing ETMs continues. The research data suggest that operational aviators cannot perform ETMs satisfactorily on their first attempt, but that very little practice in the aircraft is required to regain satisfactory proficiency. It is recommended, therefore, that the policy prohibiting periodic practice of ETMs in the aircraft be reexamined. If Army officials decide that the practice of ETMs should remain prohibited, it is recommended that an FWS product improvement program be initiated to increase its effectiveness for ETM training.

The third recommendation is that additional research should investigate (a) the rate and amount of skill decay on flight maneuvers over a period of 12 months and (b) other parameters that may affect the FWS's effectiveness for training operational aviators.

Utilization

The costs of training resources (i.e., ammunition, flight hours, availability of aircraft, logistics) has dramatically increased the Army's dependence on flight simulators for training that was previously accomplished in aircraft. This dependence on simulation characterizes training conducted in operational aviation units and in the various courses conducted at the USAAVNC. Most Army aviators are required to accomplish a portion of their annual flight requirements in a flight simulator. Furthermore, the trend toward substituting training in a flight simulator for training in an aircraft is likely to continue as aircraft resources become more expensive and simulator technology becomes more advanced.

The Army has not based the deployment or utilization of flight simulators on empirical training effectiveness data that relate to the acquisition or sustainment of individual aviator's flying skills. In fact, individual unit commanders retain the responsibility for incorporating flight simulators into their unit's training programs. Therefore, there are differences in the ways that aviation units utilize flight simulators, even when two or more aviation units use the same simulator site. Tradeoff decisions between the utilization of aircraft and flight simulators must be based on empirical demonstrations of the simulators' effectiveness for specific training requirements. Empirical data can provide a sound basis for determining (a) which maneuvers should be trained in the flight simulator, (b) how much training on each maneuver should be accomplished in the flight simulator, and (c) how much additional training should be accomplished in the aircraft. Management can use these data to develop programs of instruction that achieve their training goals and maximize the utilization and effectiveness of the training resources available.

This research represents an initial step toward empirically defining the effectiveness of the FWS for satisfying the training requirements of operational aviation units. The data may be used to develop programs of instruction that provide an optimal mix of aircraft and simulator training. The data provide estimates of the amount of training required for aviators to reach proficiency in the aircraft and the flight simulator as well as estimates of the forward transfer of training. In addition, the training effectiveness data may be used to determine the cost-effectiveness of the FWS.

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APPENDIX A

DESCRIPTIONS OF FIVE EMERGENCY TOUCHDOWN MANEUVERS

Emergency Touchdown Maneuvers

The following five emergency touchdown maneuvers were investigated in this research:

- Standard Autorotation,
- Low-Level Autorotation,
- Dual Hydraulics Failure,
- Simulated Right Antitorque Failure, and
- Low-Level High-Speed Autorotation.

A description of each of these maneuvers is presented in this appendix.

During all trials for each of the emergency touchdown maneuvers, the evaluators took control of the AH-1F aircraft or initiated power recoveries only when the subjects entered an unsafe condition. The evaluators allowed the subjects to terminate all maneuvers in the FWS unless damage to the flight simulator was imminent. For all maneuvers, the following environmental conditions were established in the flight simulator:

- unlimited visibility,
- ceiling of 2000 feet, and
- winds equivalent in magnitude and direction to those in effect at the airfield on that day.

Standard Autorotation

The Standard Autorotation was performed in the aircraft and the FWS as described in Task 3001 of the AH-1 ATM (Department of the Army, 1984a). The following parameters were established in the flight simulator and the aircraft on each trial prior to relinquishing the flight controls to the subject:

- Position in the gaming area = 1-mile final approach to the stagefield,
- Altitude = 800 feet above ground level (AGL) at the stagefield,
- Airspeed = 100 knots indicated airspeed (KIAS), and
- Heading = aligned with runway approach heading.

After taking the flight controls on a long final approach to the stagefield, the subject maintained the specified airspeed, heading, and altitude until reaching a point from which he could terminate a Standard Autorotation on the stagefield. The subject then initiated the Standard Autorotation and continued the maneuver to the ground.

Low-Level Autorotation

The Low-Level Autorotation was performed in the aircraft and the FWS as described in Task 3002 of the AH-1 ATM (Department of the Army, 1984a). The following parameters were established in the flight simulator and the aircraft on each trial prior to relinquishing the flight controls to the subject:

- Position in the gaming area = 2-mile final approach to the stagefield,
- Altitude = 100 feet above the highest obstacle (AHO),
- Airspeed = 100 KIAS, and
- Heading = aligned with the runway approach heading.

After taking the flight controls on a long final approach to the stagefield, the subject maintained the specified airspeed, heading, and altitude until reaching a point from which he could terminate a Low-Level Autorotation on the stagefield. The subject then initiated the Low-Level Autorotation and continued the maneuver to the ground.

Dual Hydraulics Failure

The Dual Hydraulics Failure was simulated in the AH-1F aircraft by engaging the aircraft's force trim as described in Task 3003 of the AH-1 ATM (Department of the Army, 1984a). However, the FWS simulated a complete dual hydraulics failure. The following parameters were established on each trial in the aircraft and the flight simulator prior to relinquishing the flight controls to the subject:

- Position in gaming area = downwind leg of the stagefield traffic pattern,
- Altitude = 800 feet AGL at the stagefield,
- Airspeed = 100 KIAS, and
- Heading = aligned with the reciprocal of the runway approach heading.

The following procedures were followed in the aircraft and the FWS. The subject took the flight controls on the downwind leg of the traffic pattern and stabilized the heading, altitude, and airspeed at the specified values. The evaluator then inserted the malfunction by activating the force trim in the aircraft or by inserting Malfunction Number 653 (Dual Hydraulics Failure) in the flight simulator. The subject was required to complete the traffic pattern and execute an approach and landing at the stagefield. Prior to attempting the first trial in the FWS, all subjects observed a prerecorded demonstration of the stagefield traffic pattern to identify significant landmarks.

Right Antitorque Failure

The Right Antitorque Failure was performed as described in Task 3004 of the AH-1 ATM (Department of the Army, 1984a). The following parameters were established in the flight simulator and the aircraft on each trial prior to relinquishing the flight controls to the subject:

- Position in the gaming area = 2-mile final approach to the stagefield,
- Altitude = 500 feet AGL at the stagefield,
- Airspeed = 80 KIAS, and
- Heading = aligned with runway approach heading.

After taking the flight controls on a long final approach to the stagefield, the subject stabilized the airspeed, heading, and altitude at the specified values and then applied up to one ball width of right pedal, not to exceed a deviation of 10° of aircraft heading. At that time, the evaluator fixed the pitch of the tail rotor by locking the pedals of the aircraft or by inserting Malfunction Number 755 (Tail Rotor Fixed Pitch) in the FWS. The subject was required to complete the approach and execute a landing to the stagefield.

Low-Level High-Speed Autorotation

The Low-Level High-Speed Autorotation was performed in the aircraft and the FWS as described in Task 3005 of the AH-1 ATM (Department of the Army, 1984a). The following parameters were established in the flight simulator and the aircraft on each trial prior to relinquishing the flight controls to the subject:

- Position in the gaming area = 2-mile final approach to the stagefield,
- Altitude = 100 feet AHO,
- Airspeed = 130 KIAS, and
- Heading = aligned with runway approach heading.

After taking the flight controls on a long final approach to the stagefield, the subject maintained the specified airspeed, heading, and altitude until reaching a point from which he could terminate a Low-Level High-Speed Autorotation on the stagefield. The subject then initiated the Low-Level High-Speed Autorotation and continued the maneuver to the ground.

APPENDIX B

GRADESLIPS FOR EMERGENCY TOUCHDOWN MANEUVERS

Gradeslips

A separate gradeslip was developed to record pilot performance on each of the five Emergency Touchdown Maneuvers. The development and implementation of these gradeslips is discussed in the section titled Performance Measures. A sample of each of the gradeslips is presented in this appendix in the following order:

- Standard Autorotation,
- Low-Level Autorotation,
- Dual Hydraulics Failure,
- Right Antitorque Failure, and
- Low-Level High-Speed Autorotation.

DATE ____________ STUDENT ____________

TRIAL # ____________ IP ____________

STANDARD AUTOROTATION

ENTRY

ALTITUDE: TOO LOW [ ] — -100 — -80 — -60 — -40 — -20 — **1000' MSL** — +20 — +40 — +60 — +80 — +100 — TOO HIGH [ ]

AIRSPEED: TOO SLOW [ ] — -10 — -8 — -6 — -4 — -2 — **100K** — +2 — +4 — +6 — +8 — +10 — TOO FAST [ ]

PROPER TECHNIQUE: **YES** [ ] NO [ ]

DESCENT

ROTOR RPM: TOO LOW [ ] **GREEN** TOO HIGH [ ]

TRIM: LEFT [ ] — 1.7BW — 1.0BW — .5BW — **0 TO .2 BW** — .5BW — 1.0BW — 1.7BW — RIGHT [ ]

AIRSPEED: TOO SLOW [ ] — HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD — TOO FAST [ ]

DECELERATION

AIRSPEED AT 100': TOO SLOW [ ] — -5 — -4 — -3 — -2 — -1 — **70K** — +2 — +4 — +6 — +8 — +10 — TOO FAST [ ]

ALTITUDE: TOO LOW [ ] — HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD — TOO HIGH [ ]

AMOUNT: TOO LITTLE [ ] — HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD — TOO MUCH [ ]

PITCH/PULL

INITIAL ALTITUDE: LOW [ ] — 5 — 6 — 7 — 8 — 9 — **10-15 FEET** — 16 — 17 — 18 — 19 — 20 — TOO HIGH [ ]

INITIAL AMOUNT: TOO LITTLE [ ] — HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD — TOO MUCH [ ]

TECHNIQUE: TOO SLOW [ ] — HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD — TOO ABRUPT [ ]

HEADING: LEFT [ ] — 5° — 4° — 3° — 2° — 1° — **IDEAL** — 1° — 2° — 3° — 4° — 5° — RIGHT [ ]

TOUCHDOWN

HEADING: LEFT [ ] — 5° — 4° — 3° — 2° — 1° — **IDEAL** — 1° — 2° — 3° — 4° — 5° — RIGHT [ ]

TOUCHDOWN ATTITUDE: LEVEL [ ] — HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD — TAIL LOW [ ]

CUSHION: TOO LITTLE [ ] — HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD — TOO MUCH [ ]

LANDING: — HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD — TOO HARD [ ]

GROUND SLIDE: — **0-2 HL** — 2.5HL — 3.0HL — 3.5HL — 4.0HL — 4.5HL — TOO MUCH [ ]

GROUND TRACK: LEFT [ ] — HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD — RIGHT [ ]

OVERALL PERFORMANCE RATING

UNSATISFACTORY		SATISFACTORY		
Crash	No Crash	C	B	A
1 2 3	4 5 6	7 8 9	10 11 12	13 14 15

DATE ____________ STUDENT ____________

TRIAL # ____________ IP ____________

LOW-LEVEL AUTOROTATION

ENTRY

ALTITUDE: TOO LOW [ ] -25 -20 -15 -10 -5 **100' AHO** +5 +10 +15 +20 +25 TOO HIGH [ ]

AIRSPEED: TOO SLOW [ ] -10 -8 -6 -4 -2 **100K** +2 +4 +6 +8 +10 TOO FAST [ ]

PROPER TECHNIQUE: **YES** NO [ ]

ROTOR RPM: TOO LOW [ ] **GREEN** TOO HIGH [ ]

TRIM: LEFT [ ] 1.7BW 1.0BW .5BW **0 TO .2 BW** .5BW 1.0BW 1.7BW RIGHT [ ]

DECELERATION

AIRSPEED AT 100': TOO SLOW [ ] -5 -4 -3 -2 -1 **70K** +2 +4 +6 +8 +10 TOO FAST [ ]

ALTITUDE: TOO LOW [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD TOO HIGH [ ]

AMOUNT: TOO LITTLE [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD TOO MUCH [ ]

PITCH/PULL

INITIAL ALTITUDE: TOO LOW [ ] 5 6 7 8 9 **10-15 FEET** 16 17 18 19 20 TOO HIGH [ ]

INITIAL AMOUNT: TOO LITTLE [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD TOO MUCH [ ]

TECHNIQUE: TOO SLOW [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD TOO ABRUPT [ ]

HEADING: LEFT [ ] 5° 4° 3° 2° 1° **IDEAL** 1° 2° 3° 4° 5° RIGHT [ ]

TOUCHDOWN

HEADING: LEFT [ ] 5° 4° 3° 2° 1° **IDEAL** 1° 2° 3° 4° 5° RIGHT [ ]

TOUCHDOWN ATTITUDE: LEVEL [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD TAIL LOW [ ]

CUSHION: TOO LITTLE [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD TOO MUCH [ ]

LANDING: HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD TOO HARD [ ]

GROUND SLIDE: **0-2 HL** 2.5HL 3.0HL 3.5HL 4.0HL 4.5HL TOO MUCH [ ]

GROUND TRACK: LEFT [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD RIGHT [ ]

OVERALL PERFORMANCE RATING

UNSATISFACTORY		SATISFACTORY		
Crash	No Crash	C	B	A
1 2 3	4 5 6	7 8 9	10 11 12	13 14 15

DATE ______________ STUDENT ______________

TRIAL # ______________ IP ______________

DUAL HYDRAULICS FAILURE

DOWNWIND

ALTITUDE: TOO LOW [ ] -100 -80 -60 -40 -20 | 1300' MSL | +20 +40 +60 +80 +100 [ ] TOO HIGH

AIRSPEED: TOO SLOW [ ] -10 -8 -6 -4 -2 | 100K | +2 +4 +6 +8 +10 [ ] TOO FAST

GROUND TRACK: LEFT [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD [ ] RIGHT

TRIM: LEFT [ ] 1.7BW 1.0BW .5BW | 0 TO .2 BW | .5BW 1.0BW 1.7BW [ ] RIGHT

TURN FINAL

BANK ANGLE: SHALLOW [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD [ ] STEEP

GROUND TRACK: LEFT [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD [ ] RIGHT

AIRSPEED: TOO SLOW [ ] -10 -8 -6 -4 -2 | 80K | +2 +4 +6 +8 +10 [ ] TOO FAST

TRIM: LEFT [ ] 1.7BW 1.0BW .5BW | 0 TO .2 BW | .5BW 1.0BW 1.7BW [ ] RIGHT

APPROACH

GROUND TRACK: LEFT [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD [ ] RIGHT

CONSTANT ANGLE: SHALLOW [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD [ ] STEEP

RATE OF CLOSURE: TOO SLOW [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD [ ] TOO FAST

TRIM: LEFT [ ] 1.7BW 1.0BW .5BW | 0 TO .2 BW | .5BW 1.0BW 1.7BW [ ] RIGHT

TOUCHDOWN

AIRSPEED: TOO SLOW [ ] -10 -8 -6 -4 -2 | 80K | +2 +4 +6 +8 +10 [ ] TOO FAST

LANDING: HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD [ ] TOO HARD

TOUCHDOWN POINT: TOO SHORT [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD [ ] TOO LONG

GROUND TRACK: LEFT [ ] HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD [ ] RIGHT

HEADING: LEFT [ ] 5° 4° 3° 2° 1° | IDEAL | 1° 2° 3° 4° 5° [ ] RIGHT

OVERALL PERFORMANCE RATING

UNSATISFACTORY		SATISFACTORY		
Crash	No Crash	C	B	A
1 2 3	4 5 6	7 8 9	10 11 12	13 14 15

DATE ____________________ STUDENT ____________________________

TRIAL # ____________________ IP ____________________________

RIGHT ANTITORQUE FAILURE

ENTRY

ALTITUDE	TOO LOW	-100	-80	-60	-40	-20	1000' MSL	+20	+40	+60	+80	+100	TOO HIGH
AIRSPEED	TOO SLOW	-10	-8	-6	-4	-2	80K	+2	+4	+6	+8	+10	TOO FAST

GROUND TRACK	LEFT	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD	RIGHT

APPROACH

ANGLE	SHALLOW	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD	STEEP
RATE OF CLOSURE	TOO SLOW	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD	TOO FAST
GROUND TRACK	LEFT	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD	RIGHT

THREE FEET

ALTITUDE	TOO LOW	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD	TOO HIGH
AIRSPEED	TOO SLOW	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD	TOO FAST
GROUND TRACK	LEFT	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD	RIGHT
TOUCHDOWN POINT	TOO SHORT	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD	TOO LONG

TOUCHDOWN

THROTTLE REDUCTION	TOO LITTLE	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD	TOO MUCH
COLLECTIVE	TOO LITTLE	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD	TOO MUCH
LANDING		HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD	TOO HARD

HEADING ON TOUCHDOWN	LEFT	5°	4°	3°	2°	1°	IDEAL	1°	2°	3°	4°	5°	RIGHT
HEADING ON SLIDE	LEFT	5°	4°	3°	2°	1°	IDEAL	1°	2°	3°	4°	5°	RIGHT

OVERALL PERFORMANCE RATING

UNSATISFACTORY		SATISFACTORY		
Crash	No Crash	C	B	A
1 2 3	4 5 6	7 8 9	10 11 12	13 14 15

DATE ____________ STUDENT ____________

TRIAL # ____________ IP ____________

LOW-LEVEL HIGH-SPEED AUTOROTATION

ENTRY

ALTITUDE	TOO LOW	-25	-20	-15	-10	-5	100' AHO	+5	+10	+15	+20	+25	TOO HIGH
AIRSPEED	TOO SLOW	-10	-8	-6	-4	-2	130K	+2	+4	+6	+8	+10	TOO FAST
PROPER TECHNIQUE	YES		NO										

DESCENT

ROTOR RPM	TOO LOW	GREEN		TOO HIGH					
TRIM	LEFT	1.7BW	1.0BW	.5BW	0 TO .2 BW	.5BW	1.0BW	1.7BW	RIGHT
AIRSPEED	TOO SLOW	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD							TOO FAST

DECELERATION

AIRSPEED AT 100'	TOO SLOW	-5	-4	-3	-2	-1	70K	+2	+4	+6	+8	+10	TOO FAST
ALTITUDE	TOO LOW	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD											TOO HIGH
AMOUNT	TOO LITTLE	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD											TOO MUCH

PITCH/PULL

INITIAL ALTITUDE	LOW	5	6	7	8	9	10-15 FEET	16	17	18	19	20	TOO HIGH
INITIAL AMOUNT	TOO LITTLE	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD											TOO MUCH
TECHNIQUE	TOO SLOW	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD											TOO ABRUPT
HEADING	LEFT	5°	4°	3°	2°	1°	IDEAL	1°	2°	3°	4°	5°	RIGHT

TOUCHDOWN

HEADING	LEFT	5°	4°	3°	2°	1°	IDEAL	1°	2°	3°	4°	5°	RIGHT
TOUCHDOWN ATTITUDE	LEVEL	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD											TAIL LOW
CUSHION	TOO LITTLE	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD											TOO MUCH
LANDING		HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD											TOO HARD
GROUND SLIDE							0-2 HL	2.5HL	3.0HL	3.5HL	4.0HL	4.5HL	TOO MUCH
GROUND TRACK	LEFT	HOW SATISFACTORY? (CIRCLE ONE) POOR 1 2 3 4 5 6 GOOD											RIGHT

OVERALL PERFORMANCE RATING

UNSATISFACTORY		SATISFACTORY		
Crash	No Crash	C	B	A
1 2 3	4 5 6	7 8 9	10 11 12	13 14 15

APPENDIX C

TEST OF PROCEDURES AND STANDARDS FOR EMERGENCY TOUCHDOWN MANEUVERS

Appendix C presents a copy of a test that was administered to all subjects three days prior to their initial checkride in the aircraft. All questions were drawn from the AH-1 Aircrew Training Manual (Department of the Army, 1984a) and tested the subjects' knowledge of the procedures and standards for the emergency touchdown maneuvers. The purpose of the test was to ensure the subjects were knowledgeable about the procedures and standards before attempting to perform the maneuvers in the aircraft.

TEST OF PROCEDURES AND STANDARDS

Note. This test consists of questions that are designed to assess your knowledge of the procedures and standards for the five emergency touchdown maneuvers. All questions were derived from the appendix to the AH-1 Aircrew Training Manual (FC 1-213). Questions 1 - 18 are fill-in-the-blank questions. Please read each question carefully and write your answer in the appropriate space to the left of the question number.

_______ 1. If the traffic pattern altitude for downwind is 800 feet (MSL), what is the correct entry altitude (MSL) for a Standard Autorotation?

_______ 2. What is the correct entry airspeed (KIAS) for a Standard Autorotation?

_______ 3. What is the correct altitude (AGL) to apply initial pitch during a Standard Autorotation?

_______ 4. What is the correct entry airspeed (KIAS) for a Low-Level Autorotation?

_______ 5. What is the correct entry altitude (above the highest obstacle at point of entry) for a Low-Level Autorotation?

_______ 6. What is the correct altitude (AGL) to apply initial pitch during a Low-Level Autorotation?

_______ 7. What is the correct entry airspeed (KIAS) for a Low-Level High-Speed Autorotation?

_______ 8. What is the correct entry altitude (above the highest obstacle in flight path) for a Low-Level High Speed Autorotation?

_______ 9. What is the correct altitude (AGL) to apply initial pitch during a Low-Level High-Speed Autorotation?

_______ 10. What is the correct airspeed (KIAS) for the base-leg of a traffic pattern during an Antitorque Malfunction?

_______ 11. What is the minimum touchdown airspeed (KIAS) for a Dual Hydraulics Failure?

_______ 12. When performing a stuck pedal maneuver, in which direction (Right or Left) will the nose of the aircraft turn if the throttle is rolled off and the collective setting remains unchanged?

_______ 13. When performing a stuck pedal maneuver, in which direction (Right or Left) will the nose of the aircraft turn if the throttle is rolled on and the collective setting remains unchanged?

_______ 14. When performing a stuck pedal maneuver, in which direction (Right or Left) will the nose of the aircraft turn if the collective is pulled up and the throttle setting remains unchanged?

_______ 15. When performing a stuck pedal maneuver, in which direction (Right or Left) will the nose of the aircraft turn if the collective is lowered and the throttle setting remains unchanged?

_______ 16. What is the maximum allowable airspeed (KIAS) during a Dual Hydraulics Failure?

_______ 17. What is the appropriate airspeed to reach on the turn-to-final during a Dual Hydraulics Failure?

_______ 18. What is the maximum out-of-trim condition (degrees of heading) to be established on final for a stuck right pedal setting?

Note. Items 19 - 21 are multiple choice questions. Please read the questions and answers carefully. Then, select the answer that you think is most correct and write the appropriate letter in the blank to the left of the item number.

_______ 19. What is the correct order of control inputs to enter a Standard Autorotation?

(a) First, apply aft cyclic, then retard the throttle to the engine-idle stop, and then reduce the collective to the full down position.

(b) Simultaneously lower the collective, retard the throttle to the engine idle-stop, and apply aft cyclic.

(c) First, reduce the collective to the full down position, then retard the throttle to the engine-idle stop, and adjust the pedals to maintain trim.

(d) First, retard the throttle to the engine-idle stop, then apply aft cyclic, then reduce the collective to maintain rotor RPM within limits.

_______ 20. What is the correct order of control inputs to enter a Low-Level Autorotation?

(a) First, apply aft cyclic, then retard the throttle to the engine-idle stop, and then reduce the collective to the full down position.

(b) Simultaneously lower the collective, retard the throttle to the engine idle-stop, and apply aft cyclic.

(c) First, reduce the collective to the full down position, then retard the throttle to the engine-idle stop, and adjust the pedals to maintain trim.

(d) First, retard the throttle to the engine-idle stop, then apply aft cyclic, then reduce the collective to maintain rotor RPM within limits.

_______ 21. What is the correct <u>order</u> of control inputs to enter a <u>Low-Level High-Speed Autorotation</u>?

(a) First, apply aft cyclic, then retard the throttle to the engine-idle stop, and then reduce the collective to the full down position.

(b) <u>Simultaneously</u> lower the collective, retard the throttle to the engine idle-stop, and apply aft cyclic.

(c) First, reduce the collective to the full down position, then retard the throttle to the engine-idle stop, and adjust the pedals to maintain trim.

(d) First, retard the throttle to the engine-idle stop, then apply aft cyclic, then reduce the collective to maintain rotor RPM within limits.