Research Report 1209

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TRAINING EFFECTIVENESS OF THE CH-47 FLIGHT SIMULATOR

Garvin L. Holman

ARI FIELD UNIT AT FORT RUCKER, ALABAMA

U. S. Army
Research Institute for the Behavioral and Social Sciences

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WILLIAM L. HAUSER
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JOSEPH ZEIDNER
Technical Director

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The training effectiveness of the CH-47 helicopter flight simulator was evaluated in two parts: Part I used a classical two-group transfer-of-training design using aviators undergoing transition training to the CH-47 helicopter, and Part II assessed the training benefits of periodic training of operational CH-47 aviators in the CH-47 flight simulator using a pretest-train-posttest design. Cumulative transfer effectiveness ratios and learning curves are presented for 24 maneuvers taught in the simulator and the
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aircraft. It was concluded that the CH-47 flight simulator is an effective training device for all maneuvers tested except for those, such as hovering maneuvers, that require extensive visual ground referencing at very low altitudes. The simulator was also found to be inadequate for training night operations and terrain flights.

While parts of the report are written for research personnel, the report as a whole is of primary interest to military trainers.

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TRAINING EFFECTIVENESS OF THE CH-47 FLIGHT SIMULATOR

Garvin L. Holman
James A. Bynum, Team Chief

Submitted by:
Charles A. Gainer, Chief
ARI FIELD UNIT AT FORT RUCKER, ALABAMA

Approved By:

Frank J. Harris, Acting Director
ORGANIZATIONS AND SYSTEMS
RESEARCH LABORATORY

Joseph Zeidner
TECHNICAL DIRECTOR

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333

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Department of the Army

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Flight Simulation

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FOREWORD

The Army Research Institute (ARI) Field Unit at Fort Rucker, Ala., provides support to the U.S. Army Center in the area of aviation training research and development. The research reported here was performed with the U.S. Army Aviation Board as a part of the Field Unit's flight simulation research effort. This effort includes research to determine the training device requirements for flight simulation and the testing and evaluation of flight simulators and simulator training programs.

The program of aviation training research and development is responsive to the requirements of Army Project 2Q263743A772, Aircrew Performance Enhancement in the Tactical Environment, and to the Directorate of Training Developments, U.S. Army Aviation Center, Fort Rucker.

CPT Michael F. McGaugh of the U.S. Army Aviation Board managed the operational test in which the transfer-of-training data were gathered. CW3 Joe F. Sefers coordinated the complex daily test activities and contributed his expert knowledge of the CH-47 helicopter and associated training program. CW4 James P. Newhouse planned and coordinated the participation of the U.S. Army Forces Command during the operational test. The instructor pilots of Cargo Branch, U.S. Army Aviation Center, and U.S. Army Forces Command deserve special thanks for their help in conducting the test and in collecting all of the training effectiveness data.

Computer support was given by Shirley Thorpe, Claude Songy, and Barbara Godwin from the Directorate of Combat Developments, U.S. Army Aviation Center, and by Ned Locklar, U.S. Army Aviation Board. Eric Dommasch, Steve Parker, Diana Kozik, and Linda Meredith were responsible for the coding and transformation of all raw data to the computer input format and for the manual analysis of data.

And finally, thanks go to the U.S. Army aviators who participated as subjects in the test, either as aircraft qualification students at Fort Rucker during Part I or as operational aviators in the U.S. Army Forces Command aviation battalions that supported Part II.

JOSEPH ZEIDNER
Technical Director

TRAINING EFFECTIVENESS OF THE CH-47 FLIGHT SIMULATOR

BRIEF

Requirement:

The prototype CH-47 helicopter flight simulator was accepted by the U.S. Army in January 1977 for Development and Operational Tests II prior to setting specifications for production model simulators for field use. The requirement was to plan and conduct training effectiveness experiments reported here as part of the operational testing of the simulator.

Procedure:

The training effectiveness of the CH-47 flight simulator was evaluated in two parts: One determined the transfer of training between the simulator and the aircraft in an institutional setting, and the other determined the simulator's effectiveness in maintaining or increasing combat flying skills in an operational setting. Part I used a classical two-group transfer-of-training design using aviators undergoing transition training to the CH-47 helicopter. Part II assessed the training benefits of periodic training of operational CH-47 aviators in the CH-47 flight simulator using a pretest-train-posttest design.

Findings:

It was concluded that the CH-47 flight simulator is an effective training device for all maneuvers tested except for those, such as hovering maneuvers, that require extensive visual ground referencing at very low altitudes. The simulator was also found to be inadequate for training night operations and terrain flight.

Utilization of Findings:

It was recommended that the prototype CH-47 flight simulator be used in CH-47 transition training and that production models be fielded with the following modifications:

1. Increased field of view in the visual system,
2. Improved chin window display to increase depth cues,
3. Modifications to improve hovering characteristics,
4. A simulated night environment adequate for training, and
5. The capability to train terrain flight operations.

TRAINING EFFECTIVENESS OF THE CH-47 FLIGHT SIMULATOR

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TRAINING EFFECTIVENESS OF THE CH-47 FLIGHT SIMULATOR

INTRODUCTION

This report documents the training effectiveness evaluation of the prototype CH-47C Chinook helicopter flight simulator (CH47FS) in an institutional and a field training program. The CH47FS is a full-mission flight simulator for use in the initial training of aviators to fly the CH-47 aircraft and in maintaining and increasing the combat flying skills of Chinook aviators in the field.

The CH47FS is a ground-based flight simulator composed of the following major subsystems:

- A flight compartment with pilot and copilot training stations (cockpit) and an instructor/operator station,
- A six-degree-of-freedom cockpit motion system,
- A visual system with collimated cockpit displays of the camera-model board type with a forward field of view and a synthetically generated representation of the ground as viewed through the chin window,
- A digital computation system and associated software.

The simulator was designed to provide training in CH-47C helicopter cockpit procedures, aircraft control, contact maneuvers, emergency procedures, sling load operations, confined area operations, pinnacle operations, night flight, and instrument flight procedures.

OBJECTIVES

These evaluations had two objectives:

1. To evaluate the training effectiveness of the CH47FS in a school environment dedicated to the qualification training of aviators to fly the CH-47 aircraft, and

2. To evaluate the training effectiveness of the CH47FS in a field environment dedicated to the maintenance and enhancement of combat readiness skills in operational CH-47 aviators.

METHOD

Part I determined the transfer of training between the CH47FS and the aircraft in a two-group transfer-of-training experiment. The test group consisted of 24 CH-47 Aircraft Qualification Course students selected from six classes used in the study. The test group aviators were trained to a performance criterion in the CH47FS and then trained, as required, to the same criterion in the CH-47 aircraft following the established course of instruction. The control group, composed of those aviators not selected as test students, was given training in the CH-47 helicopter only, following the same course of instruction.

Data collected included a rating of aviator performance on each maneuver performed each time it was practiced and on the time spent on each maneuver. These data were converted to cumulative transfer effectiveness ratios for each maneuver so that the training effectiveness of the simulator could be compared to the training effectiveness of the aircraft.

Part II determined the capability of the CH47FS to train and maintain combat flying skills in a pretest-train-posttest paradigm. The test aviators were 16 CH-47 aviators from operational medium lift helicopter companies. A control group was made up of another 16 CH-47 aviators from the same companies. The test group was administered a detailed inflight test in the CH-47, given periodic training in the simulator for 6 months, allowed to fly only mission-essential flights in the aircraft, and administered a second inflight test at the end of the period. The control aviators were given the same two flight tests and allowed to fly mission-essential flights only.

RESULTS AND CONCLUSIONS

Both evaluations indicated that

1. Some maneuvers could be effectively trained in the simulator in fewer trials or less time than in the aircraft. These maneuvers were most often characterized as procedural, such as four-wheel taxi and deceleration maneuvers.

2. Many maneuvers could be effectively trained in the simulator in approximately the same number of trials or length of time as in the aircraft. Examples of these maneuvers are general airwo , two-wheel taxi, and steep approach maneuvers.

3. Several maneuvers could not be trained as effectively in the simulator or required more trials or time than in the aircraft. These maneuvers were characterized as being conducted, in whole or part, very near the ground at low speeds. Examples of these maneuvers are all hovering maneuvers, shallow approach,

confined area operations, and external load operations. It is believed that the training difficulties were due to the limited field of view, infinity focus display of the visual system, inadequate depth cues in the chin window display, and, perhaps, inadequate aerodynamic simulation of hovering or inadequate motion cueing while hovering.

Night flying operations could not be trained in the simulator due to inadequate visual simulation of the night environment. This is considered a serious limitation, especially for training combat readiness skills. It is anticipated that future combat will require a great deal of night flying, and it is believed that training in night operations should be conducted in a simulator to the maximum extent possible.

Operational units are also required to train in terrain flight operations, especially nap-of-the-earth flight. The prototype simulator does not have a terrain flight capability, because this requirement was not stated in the original device requirement for the CH47FS.

RECOMMENDATIONS

It is recommended that the prototype CH47FS located at Fort Rucker, Ala., be used in the CH-47 Aircraft Qualification Course in a course of instruction designed to take advantage of all the training capabilities of the simulator.

It is recommended that the production models of the CH47FS be designed to eliminate deficiencies and limitations identified in this transfer-of-training study. Design improvements should include the following:

1. Increased field of view in the visual system,

2. Improved chin window display to present more depth cues,

3. Modification of the aerodynamic and/or motion cueing equations to improve hovering characteristics as needed,

4. A simulation of the night environment adequate for training, and

5. The capability to train terrain flight operations.

It is recommended that as many of the above improvements as feasible be retrofitted to the prototype CH47FS.

BACKGROUND

Although many improvements have been made in U.S. Army helicopter flight training, the most important part of the student's instruction is still performed in an aircraft under the direct supervision of an instructor pilot. This method is extremely costly in terms of time required on the flight line by both student and instructor and in terms of flying hour costs in today's sophisticated aircraft.

These costs became more apparent during the late 1960s when the Army experienced a rapid expansion of its aviation assets. A huge increase in the cost of aviation training accompanied this period of expansion, clearly indicating the need for economical synthetic flight training systems that could reduce the requirement for use of operational helicopters.

To fulfill this need, in July 1967 the Army approved a qualitative materiel requirement for development of a synthetic flight training system. Concept formulation was initiated by awarding feasibility study contracts in December 1967. The results of these studies led to a recommendation that development be initiated. Technical characteristics were presented at the Technical Characteristics In-Process Review on 12 September 1968 and approved on 27 November 1968.

A contract was awarded on 22 June 1973 for the construction of a camera-model visual system operational flight trainer simulating the CH-47C (Chinook) aircraft. Factory testing of the prototype flight simulator included evaluation flights by qualified CH-47 instructor pilots from the U.S. Army Aviation Center and development testing by engineers from the U.S. Army Electronics Proving Ground and from the Naval Training Equipment Center. A preliminary acceptance test was performed at the factory during September 1976, and a decision was made on 24 September 1976 to transport the flight simulator to Fort Rucker. The Government's final acceptance test was conducted by Project Manager Training Devices at Fort Rucker during the period 3-15 January 1977.

The operational test of the CH-47 flight simulator began on 17 January 1977 by authority of U.S. Army Training and Doctrine Command as stated in the Letter of Execution dated 26 November 1976. The test was completed on 8 August 1977. The training effectiveness studies were conducted by the U.S. Army Aviation Board and the U.S. Army Research Institute Field Unit at Fort Rucker.

DESCRIPTION

The CH-47 flight simulator (CH47FS) is a ground-based flight simulator designed to provide training for CH-47C helicopter cockpit procedures, aircraft control, contact maneuvers, emergency procedures, external load operations, confined area operations, pinnacle operations, night flight, and instrument flight procedures.

The simulator system consists of the following major subsystems:

- Flight compartment

  --Trainee station for pilot and copilot (cockpit), and
  --Instructor/operator station (IOS);

- Six-degree-of-freedom cockpit motion system;

- Visual simulation system

  --Camera-model image generation system,
  --Synthetic terrain and ground symbol generator, and
  --Infinity image-display systems mounted on cockpit;

- Digital computation system and associated software.

Flight Compartment

The operational flight trainer's (OFT) flight compartment interior, shown in Figure 1, contains a replica of the pilot and copilot positions forward of aircraft station 95, the instructor/operator's station, and an observer's position. A doorway through the rear bulkhead provides for entry into the compartment. Cooling of the trainee and instructor areas is provided by a single air conditioner located outside the simulated cockpit enclosure on the motion platform.

The trainee station, in the forward portion of the flight compartment, is a replica of the pilot and copilot positions forward of aircraft station 95. The controls, indicators, and panels operate in the same way and have the same appearance as those in the aircraft described in TM 55-1520-227-10, Operator's Manual for the CH-47B and CH-47C helicopters. Controls that are not functional have been physically retained to maximize simulator fidelity for the trainee. However, the aft portion of the center console contains the instructor pilot/trainee problem control panel. Space for the control panel was provided by removing the very high frequency (VHF) emergency transmitter and high frequency (HF) communication control panels and by relocating the troop commander's communication control panel. The trainee seats are vibrated individually to simulate the continuous and periodic oscillations and vibrations, including vibrations representing progressive malfunctions, experienced by the crew during

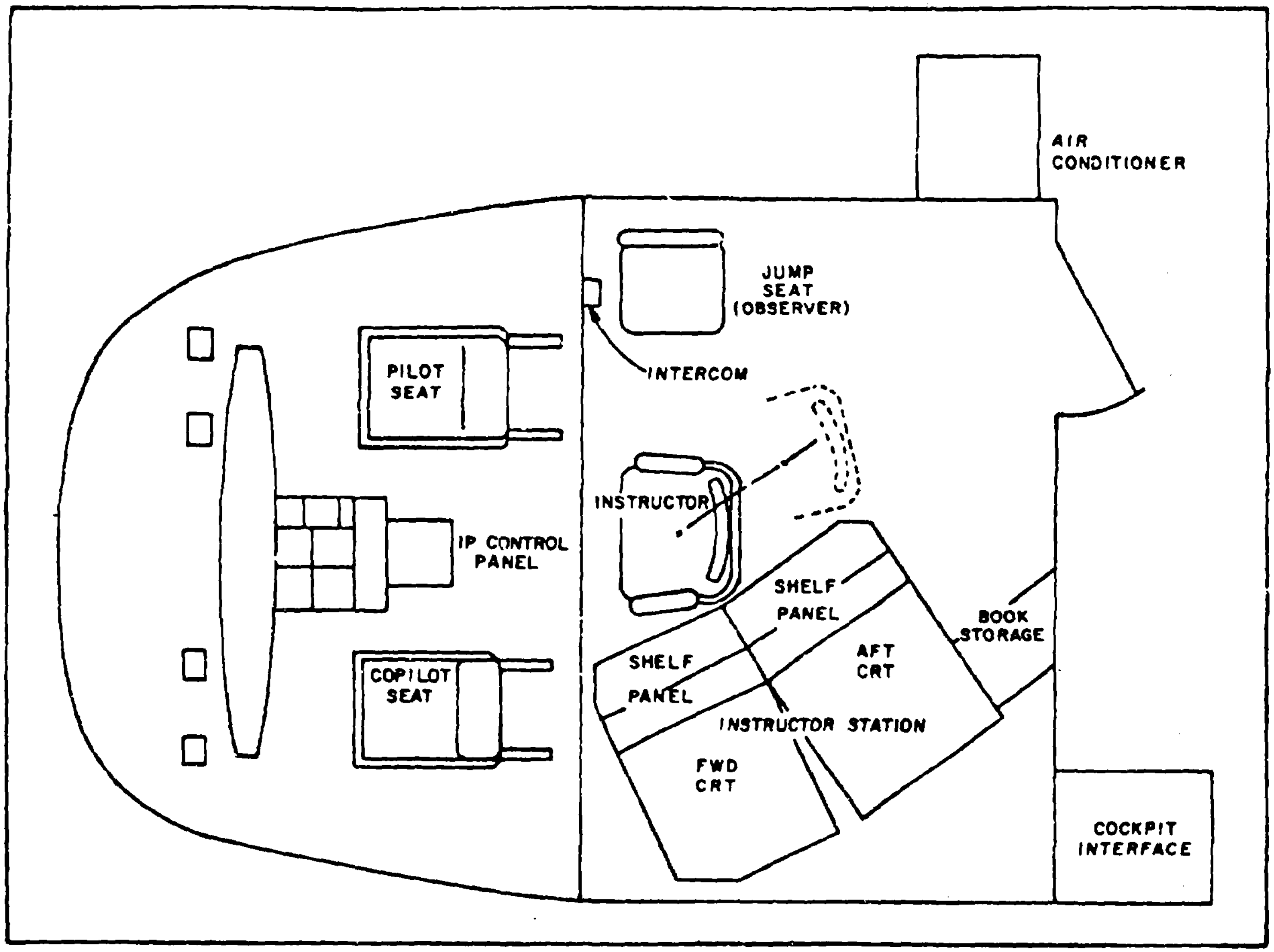


Figure 1. Simulator flight compartment layout.

normal and emergency flight conditions and maneuvers. Seat vibration is isolated from the remainder of the flight compartment by means of damping elements in seat mounting construction. Four loudspeakers provide aural cue sounds with characteristics of location, frequency, and amplitude simulated within limits of safety.

The instructor station is located in the instructor area, aft of the cockpit, in the flight compartment. It provides information and controls with which the instructor can effectively monitor and evaluate student performance and control the training problem. The controls are located on a sloping control panel below two cathode ray tube (CRT) displays which are mounted side by side with their longer display surface dimension vertical. The instructor is also able to operate from either trainee station by using the problem control panel on the center console.

Motion Subsystem

The flight compartment is mounted on a six-degree-of-freedom motion subsystem consisting of a moving platform assembly driven and supported from below by six identical 48-inch hydraulic actuators. The motion subsystem is capable of providing pitch, roll, yaw, lateral, longitudinal, and vertical movement, either independently (without simultaneous motion in any other degree of freedom) or in any combination desired to produce real-time dynamic motion cues.

Simulation includes the motion due to changes in aircraft attitude as a result of flight control and the rotor operation, rough air and wind, and changes in aircraft weight and center of gravity, as well as effects of buffet, blade stall, blade imbalance, blades out of track, and touch down impact.

The simulation program causes the motion subsystem to respond to aerodynamic forces and movements within the mechanical limits of the system. All motions except pitch are imperceptibly washed out to the neutral position after the computed accelerations have reached zero. Pitch attitude is maintained as necessary to simulate sustained longitudinal acceleration cues. Acceleration onset cues are scaled as large as possible to utilize fully the motion capabilities of each degree of freedom.

Ground Conditions. The motion subsystem provides the indicators appropriate to motion of the aircraft on an apron, taxiway, and runway. The motion is a random, low-frequency, low-amplitude, multidirectional oscillation with reasonably abrupt application. The amplitude of oscillation is varied to reproduce the irregularities of unimproved or unprepared surface. The subsystem reproduces the longitudinal effects that are due to abrupt braking applications and the lateral effects that are due to asymmetric braking.

Takeoff and Landing. During ground taxi, the ground performance of the motion subsystem is as described above. Transition to flight is indicated by abrupt cessation of the random oscillation. The motion subsystem provides the indications of takeoff and maintains an attitude appropriate for hover. Appropriate motion effects occur as a result of changes in simulated accelerations during transition to flight. During the landing phase, appropriate longitudinal, vertical, and low-frequency vibration effects occur as in the helicopter. The motion subsystem reproduces the landing impact according to the existing aircraft attitude and vertical and sideslip velocities. If the vertical momentum is greater than the absorption capabilities of the landing gear, landing bounce will be simulated. Pitching and rolling effects of single- or multi-gear contact are reproduced and the magnitude of the bounce will depend on the current landing weight. The longitudinal and pitching effects of brake application are simulated.

Normal Flight. The motion subsystem simulates the complex and repeated cues occurring during the maneuvers associated with airwork. The introduction of varying degrees of turbulence produces the appropriate motion effects of severe yaw and roll, rapid climb or descent, and variations in airspeed. Superimposed upon the background motion, the motion subsystem provides characteristic periodic oscillations up to 5 cycles per second. In addition, continuous higher frequency vibrations are simulated through the seat shaker mechanism in lieu of the motion system.

Abnormal Flight. The motion subsystem reproduces the effect of rotor out-of-track and rotor out-of-balance malfunctions. The motion simulated includes the effect of momentary incorrect control inputs as well as conditions appropriate to stabilization augmentation system (SAS) modes and malfunctions. Hydraulic failure resulting in abnormal control configurations will result in appropriate motion cues. High-speed characteristics and trim changes cause appropriate effects in the motion subsystem. Effects of sling load oscillations are also appropriately reflected into the motion simulation.

Visual Subsystem

The visual subsystem is a camera-model image generator that provides a full-color television image in the forward-looking window displays. The chin window displays are provided by a synthetic terrain generator (STG).

The camera-model image generator consists of a 24 x 56 foot three-dimensional terrain model viewed by a television camera and optical probe mounted on a movable gantry. Servomechanisms on the gantry position the camera and probe in accordance with the position and attitude of the simulated aircraft. The model board is vertically mounted to minimize floor space requirements and has scales of 1:400 and 1:1,500.

The 1:400 scale model is a replica of the east side of Hanchey Army Heliport and represents a gaming area of approximately 0.5 x 1.6 nautical miles (nm). It simulates the detail needed for taxi work and low-altitude hovering. The 1:1,500 scale board contains Goldberg stagefield and the surrounding terrain as would be seen in southeast Alabama during spring. The gaming area of 1:1,500 scale model is 5.75 x 11.75 nm and is used for the training of tasks requiring a larger geographical area such as general airwork; contact maneuvers; and pinnacle, confined area, and external load operations. The instructor controls a special effects generator that introduces sky, cloud, haze, and limited visibility effects into the displayed scene. Day, dusk, and night light conditions are also simulated.

The synthetic terrain generator used for the pilot's and copilot's chin window displays provides a special ground symbol and a terrain representation consisting of a regular checkerboard pattern of alternating green and brown squares in correct perspective for each trainee eyepoint. Each green or brown square is 7 feet on a side. The checkerboard pattern is itself a 392-foot square composed of 3,136 colored squares in a 56 x 56 array. Beyond the checkerboard pattern is continuous green terrain, and beyond the horizon, white sky.

The special ground symbol is a 7 x 42 foot white-black-white trio of rectangles that can be used as a ground reference point for sling load operations or to represent model board features such as the pinnacle landing area, confined landing areas, or landing areas on the stagefield. Whenever the simulated helicopter is within a 0.7 nm radius of a symbol location, and between 10 and 200 feet above the ground reference plane, the STG ground symbol and terrain pattern are automatically computed and displayed; beyond this range the synthetic terrain display is either in or above clouds. The identity of the special ground symbol and the location and orientation of the symbol and its surrounding terrain pattern are controlled by the computer as a function of the training mode selected by the instructor and the flight of the simulated helicopter.

The visual images generated by the camera-model and synthetic terrain systems are displayed via closed-circuit television to both the pilot and copilot simultaneously in their forward and chin window displays. The entire display is collimated, i.e., viewed at infinity. The total field of view visible by movement of the head is approximately 48° horizontal and 36° vertical on the forward windows, and 45° down and 25° outboard in the chin windows.

Computation Subsystem

The computation subsystem consists of a dual computer with associated memory and peripheral units. The operational software consists of an executive program and real-time simulation programs. The real-time simulation programs, in conjunction with the appropriate hardware, provide simulation of flight performance, power plants and engine-related systems, aircraft accessory systems, radio communication and navigation equipment, atmospheric conditions, flight control systems, and malfunctions. The executive program includes computer diagnostics, a daily operational readiness check program, and a test exercise program.

EVALUATION

General Method

The training effectiveness of the CH47FS was evaluated in two parts: One determined the transfer of training between the simulator and the aircraft in an institutional setting, and the other determined the simulator's effectiveness in maintaining or increasing combat flying skills in an operational setting.

Part I was a two-group transfer-of-training experiment. The experimental group consisted of 24 CH-47 transition class students selected from six classes used in the experiment. The control group consisted of those students not selected as experimental subjects. The experimental group was trained to a performance criterion in the CH47FS and then trained, as required, to the same criterion in the CH-47 aircraft; the control group was trained in only the CH-47 aircraft. The data collected were trial-by-trial recordings of the maneuver being performed, the time spent on that maneuver, and the proficiency of the student on each trial. The simulator training could then be compared with the aircraft training for savings.

Part II assessed the training benefits of periodic training of operational CH-47 aviators in the CH47FS. The data gathered were flight test scores of aviators before and after they received 6 months of periodic simulator training compared to flight test scores of aviators who received no simulator training.

PART I
INSTITUTIONAL TRAINING

Subjects

The experimental group consisted of 24 student aviators, 4 from each of the six CH-47 transition classes that participated in the evaluation. Before training began, the classes were administered a newly modified version of the Flight Aptitude Selection Test (FAST) and the Bennett Mechanical Comprehension Test. Recent and total flight experience as well as these tests were used to match the subjects for the two groups. The 35 Army aviators not chosen from the six classes as experimental subjects were the control group aviators.

Instructor Pilots

In preparation for these training evaluations, six CH-47 instructor pilots (IPs) spent 3 weeks learning to operate the simulator and practicing teaching in the device. The first 2 weeks were spent in a formal instructor/operator course conducted by the simulator manufacturer. The last week was spent practicing teaching in the CH47FS the maneuvers spelled out in the Flight Training Guide. Four of the IPs were from the U.S. Army Aviation Center (USAAVNC) and were engaged in teaching CH-47 transition courses. The four USAAVNC IPs also trained other USAAVNC IPs to operate and instruct in the CH47FS. Two of the IPs were from Forces Command (FORSCOM) units and were engaged in combat readiness flying (CRF) training.

Independent Variables

The major variable in this experiment was the use of the CH47FS in the course of instruction (COI) of CH-47 transition training. The control group was trained to fly the CH-47 in a COI developed over several years with a nominal flying time of 30 hours (U.S. Army, 1975). The COI is split into two phases of approximately 15 hours each--a basic phase and an advanced phase. In the basic phase the usual aircraft procedures and maneuvers are taught. These include preflight and postflight inspections, cockpit procedures, taxiing, hovering, various takeoff and landing maneuvers, general airwork, and emergency procedures. The advanced phase includes training in confined area and pinnacle operations, external and internal load operations, slope operations, water operations, and emergency procedures. Between the basic and advanced phases there is a checkride; at the end of the advanced stage, there is the final aircraft qualification checkride.

The COI used with the experimental group was the same as that used with the control group except that the instruction was conducted in the CH47FS rather than in the aircraft. Because of design limitations, internal load, slope, and water operations could not be performed in the simulator. The checkride given between phases was accomplished in the simulator and again in the aircraft. This basic phase checkride was the first time the experimental aviators had flown in the CH-47 aircraft. The advanced phase of training was then conducted in the simulator and the final checkride given in the simulator. This was followed by an identical checkride in the aircraft. Those maneuvers that could not be performed in the CH47FS and those maneuvers not performed satisfactorily on the last checkride were then trained in the aircraft and the CH-47 qualification checkride was given. Thus, the experimental group took three more checkrides than the control group.

Dependent Variables

The CH-47 transition course was divided into 32 separate gradable tasks or maneuvers. During daily training, each time a maneuver was performed, the IP recorded a grade for that performance on an experimental data form designed for this study. A sample form appears in Figure 2. For each maneuver the IP recorded an evaluation of that maneuver on a 12-point scale, the time spent on the maneuver, and a rating of subtasks associated with the maneuver. Maneuvers performed during checkrides were rated the same way except that the time spent on each maneuver was not recorded.

The 12-point scale used to evaluate each maneuver was based on a scale by Reid (1975). The rating scale actually encompassed 13 points, since a maneuver demonstrated by the IP was coded as a zero. Varying degrees of "unsatisfactory" performance were rated 1 through 3, "fair" was rated 4 through 6, "good" was rated 7 through 9, and "excellent" was rated 10 through 12. See Figure 3 for definitions of each of the rating codes. Performance level 6 was considered the minimal acceptable level of skill and was the criterion level toward which training was aimed.

Thirty of the 32 graded maneuvers were also divided into subtasks, and the performance of these subtasks was evaluated. Figure 2 also lists the subtasks with the maneuvers on the experimental data form. Each subtask was rated on the basis of performance being (a) near perfect, (b) error present but within acceptable standards, or (c) error present and beyond acceptable standards. The acceptable standards, defined by the Flight Training Guide, were well known to the IPs and students.

The evaluations of the subtasks also interacted with the overall evaluation of the maneuver. If performance of any subtask exceeded the acceptable standard of error, the entire maneuver was judged unsatisfactory and a rating of 1, 2, or 3 was assigned. If performance on all subtasks was within the acceptable standards, a rating of 4 or higher could be given. To obtain a rating of 6, the criterion level of performance, the maneuver had to be performed within all acceptable standards without any verbal coaching from the IP. This was taken to mean that the student knew how to perform the maneuver and required only more practice to achieve higher proficiency. The minimum criterion level of performance required in transition training was a 6 because the student's performance could continue to improve after the present course with a minimum of need for an IP. Maneuvers performed more smoothly and more precisely were given higher ratings. For a maneuver to be rated 9, most of the subtasks had to be performed within the standards expected of an instructor pilot, usually one-half the normal standards. To earn a 10, a maneuver had to be performed entirely within IP standards.

01.	PREFLIGHT	
	TRAINING TIME	
02.	POST FLIGHT	
	TRAINING TIME	:

03.	GEN AIRWORK	
	AIRSPEED	HIGH LOW
	ALTITUDE	HIGH LOW
	ANGLE OF BANK	EXCS VARY
	HDG/GRD TRK	LEFT RIGHT
	TRIM	LEFT RIGHT
	TRAINING TIME	:

STU ______________________ IIN ______

IP ______________________ IIN ______

DATE ______________________

TRAINING TIME ________ . ________

FLIGHT TIME ________ . ________

DAY/NIGHT SIM/ACFT

04.	CPT RNP/SHTDWN				
	PROPER USE	NO	NO	NO	NO
	COMPREHENSION	NO	NO	NO	NO
	TRAINING TIME	:	:	:	:

05.	TAXI (4 WHL)				
	GROUND SPEED	SLO FST	SLO FST	SLO FST	SLO FST
	SWIVEL & SAS	SW SAS	SW SAS	SW SAS	SW SAS
	POWER STEERING	POOR	POOR	POOR	POOR
	TRAINING TIME	:	:	:	:

06.	TAXI (2 WHL)				
	SPEED	SLO FST	SLO FST	SLO FST	SLO FST
	LIMITATIONS	CTRL LDGR	CTRL LDGR	CTRL LDGR	CTRL LDGR
	TECHNIQUE	THRST CYC	THRST CYC	THRST CYC	THRST CYC
	TRAINING TIME	:	:	:	:

07.	TAKEOFF TO HOVER				
	DRIFT	EXCESS	EXCESS	EXCESS	EXCESS
	HEADING	LFT RT	LFT RT	LFT RT	LFT RT
	CONTROL USE	LIM ABRPT	LIM ABRPT	LIM ABRPT	LIM ABRPT
	TRAINING TIME	:	:	:	:

08.	HOVERING FLIGHT				
	ALTITUDE	LO HI	LO HI	LO HI	LO HI
	HEADING	LFT RT	LFT RT	LFT RT	LFT RT
	DRIFT	EXCESS	EXCESS	EXCESS	EXCESS
	TRAINING TIME	:	:	:	:

09.	LNDG FROM A HOVER				
	DRIFT	EXCESS	EXCESS	EXCESS	EXCESS
	HEADING	LFT RT	LFT RT	LFT RT	LFT RT
	CONTROL USE	LIM ABRPT	LIM ABRPT	LIM ABRPT	LIM ABRPT
	TRAINING TIME	:	:	:	:

10.	NORMAL TAKEOFF				
	AIRSPEED	SLO FST	SLO FST	SLO FST	SLO FST
	RATE OF CLIMB	LO HI	LO HI	LO HI	LO HI
	ACCELERATION	LO HI	LO HI	LO HI	LO HI
	HDG/GRND TRK	LFT RT	LFT RT	LFT RT	LFT RT
	TRAINING TIME	:	:	:	:

11.	TRAFFIC PTRN				
	ALTITUDE	LO HI	LO HI	LO HI	LO HI
	AIRSPEED	SLO FST	SLO FST	SLO FST	SLO FST
	GROUND TRACK	LFT RT	LFT RT	LFT RT	LFT RT
	TRAINING TIME				

12.	DECELERATION				
	ALTITUDE	LO HI	LO HI	LO HI	LO HI
	AIRSPEED	SLO FST	SLO FST	SLO FST	SLO FST
	HEADING	LFT RT	LFT RT	LFT RT	LFT RT
	DECEL/ACCEL	EXCS VARY	EXCS VARY	EXCS VARY	EXCS VARY
	TRAINING TIME	:	:	:	:

13.	SAS OFF FLIGHT				
	THRUST	UNDR OVER	UNDR OVER	UNDR OVER	UNDR OVER
	CYCLIC	UNDR OVER	UNDR OVER	UNDR OVER	UNDR OVER
	PEDALS	UNDR OVER	UNDR OVER	UNDR OVER	UNDR OVER
	MANEUVER #				

14.	NORMAL APRCH				
	ENTRY ALT	LO HI	LO HI	LO HI	LO HI
	ENTRY AIRSPD	SLO FST	SLO FST	SLO FST	SLO FST
	ENTRY POINT	ERLY LATE	ERLY LATE	ERLY LATE	ERLY LATE
	APRCH ANGLE	UNARC OVARC	UNARC OVARC	UNARC OVARC	UNARC OVARC
	GROUND TRACK	LFT RT	LFT RT	LFT RT	LFT RT
	CLOSURE RATE	SLO FST	SLO FST	SLO FST	SLO FST
	TERMINATION	SHRT LONG	SHRT LONG	SHRT LONG	SHRT LONG
	TERMINATION	RUGH LIM	RUGH LIM	RUGH LIM	RUGH LIM
	TRAINING TIME	:	:	:	:

15.	MAX TAKEOFF				
	ATTITUDE/ACCEL	LO HI	LO HI	LO HI	LO HI
	POWER SETTING	LO HI	LO HI	LO HI	LO HI
	HDG/GRND TRK	LFT RT	LFT RT	LFT RT	LFT RT
	CONTROL USE	BRKS THRST	BRKS THRST	BRKS THRST	BRKS THRST
	AIRSPEED	SLO FST	SLO FST	SLO FST	SLO FST
	TRAINING TIME	:	:	:	:

16.	STEEP APRCH				
	ENTRY ALT	LO HI	LO HI	LO HI	LO HI
	ENTRY AIRSPD	SLO FST	SLO FST	SLO FST	SLO FST
	ENTRY POINT	ERLY LATE	ERLY LATE	ERLY LATE	ERLY LATE
	APRCH ANGLE	UNARC OVARC	UNARC OVARC	UNARC OVARC	UNARC OVARC
	GROUND TRACK	LFT RT	LFT RT	LFT RT	LFT RT
	CLOSURE RATE	SLO FST	SLO FST	SLO FST	SLO FST
	TERMINATION	SHRT LONG	SHRT LONG	SHRT LONG	SHRT LONG
	TERMINATION	RUGH LIM	RUGH LIM	RUCH LIM	RUGH LIM
	TRAINING TIME	:	:	:	

17.	SHALLOW APRCH				
	ENTRY ALT	LO HI	LO HI	LO HI	LO HI
	ENTRY AIRSPD	SLO FST	SLO FST	SLO FST	SLO FST
	ENTRY POINT	ERLY LATE	ERLY LATE	ERLY LATE	ERLY LATE
	APRCH ANGLE	UNARC OVARC	UNARC OVARC	UNARC OVARC	UNARC OVARC
	TRACK	LFT RT	LFT RT	LFT RT	LFT RT
	AIRSPEED	LO HI	LO HI	LO HI	LO HI
	DECELERATION	INSUF EXCES	INSUF EXCES	INSUF EXCES	INSUF EXCES
	TOUCH DOWN	SLO FST	SLO FST	SLO FST	SLO FST
	TERMINATION	SHRT LONG	SHRT LONG	SHRT LONG	SHRT LONG
	TERMINATION	RUGH LIM	RUCH LIM	RUGH LIM	RUCH LIM
	TRAINING TIME	:	:	:	

DAILY GRADE SHEET

USAAVNBD Form 13
24 January 1977

Figure 2. Data collection form.

RECONNAISSANCE AND CONFINED AREA OPERATIONS

18. HIGH RECON								
ALTITUDE	LO	HI	LO	HI	LO	HI	LO	HI
AIRSPEED	SLO	FST	SLO	FST	SLO	FST	SLO	FST
CNFND AREA PLN	POOR		POOR		POOR		POOR	
TRAINING TIME	:		:		:		:	
19. APRCH & LNDG								
ENTRY ALT	LO	HI	LO	HI	LO	HI	LO	HI
ENTRY AIRSPD	SLO	FST	SLO	FST	SLO	FST	SLO	FST
ENTRY POINT	ERLY	LATE	ERLY	LATE	ERLY	LATE	ERLY	LATE
APRCH ANGLE	UNARC	OVARC	UNARC	OVARC	UNARC	OVARC	UNARC	OVARC
CLOSURE RATE	SLO	FST	SLO	FST	SLO	FST	SLO	FST
TERMINATION	POOR		POOR		POOR		POOR	
TRAINING TIME	:		:		:		:	
20. TAKEOFF								
PLANNING	POOR		POOR		POOR		POOR	
TAKEOFF ANGLE	SHLW	STEEP	SHLW	STEEP	SHLW	STEEP	SHLW	STEEP
ATTITUDE	LO	HI	LO	HI	LO	HI	LO	HI
TRAINING TIME	:		:		:		:	

EXTERNAL LOAD OPERATIONS

21. BRFNG/HK CHK								
BRIEFING	POOR		POOR		POOR		POOR	
HOVER OVERLOAD	CONT	TEAM	CONT	TEAM	CONT	TEAM	CONT	TEAM
HOOK UP	CONT	TEAM	CONT	TEAM	CONT	TEAM	CONT	TEAM
TRAINING TIME	:		:		:		:	
22. TKOFF & FLGHT								
ANGLE	LO	HI	LO	HI	LO	HI	LO	HI
ATTITUDE	LO	HI	LO	HI	LO	HI	LO	HI
CRUISE SPEED	SLO	FST	SLO	FST	SLO	FST	SLO	FST
A/C CONTROL	POOR		POOR		POOR		POOR	
TRAINING TIME	:		:		:		:	
23. APRCH & LNDG								
CLOSURE RATE	SLO	FST	SLO	FST	SLO	FST	SLO	FST
TERM TO HOVER	LO	HI	LO	HI	LO	HI	LO	HI
VERT DESCENT	DRFT	RUGH	DRFT	RUGH	DRFT	RUGH	DRFT	RUGH
TRAINING TIME	:		:		:		:	
24. STNDRD AUTOROT								
ENTRY ALT	LO	HI	LO	HI	LO	HI	LO	HI
ENTRY AIRSPD	SLO	FST	SLO	FST	SLO	FST	SLO	FST
ENTRY POINT	ERLY	LATE	ERLY	LATE	ERLY	LATE	ERLY	LATE
ROTOR RPM	LO	HI	LO	HI	LO	HI	LO	HI
DESCENT AIRSPD	SLO	FST	SLO	FST	SLO	FST	SLO	FST
100 FT RQMTS	SLO	ALIGN	SLO	ALIGN	SLO	ALIGN	SLO	ALIGN
DECEL ALT	LO	HI	LO	HI	LO	HI	LO	HI
DECEL	INSUF	ABRPT	INSUF	ABRPT	INSUF	ABRPT	INSUF	ABRPT
INTL THRST ALT	LO	HI	LO	HI	LO	HI	LO	HI
TERM POINT	SHRT	LONG	SHRT	LONG	SHRT	LONG	SHRT	LONG
TOUCH DOWN	HARD	N HI	HARD	N HI	HARD	N HI	HARD	N HI
TRAINING TIME	:		:		:		:	

PINNACLE OPERATIONS

25. HIGH RECON								
ALTITUDE	LO	HI	LO	HI	LO	HI	LO	HI
AIRSPEED	SLO	FST	SLO	FST	SLO	FST	SLO	FST
PNCL AREA PLN	POOR		POOR		POOR		POOR	
TRAINING TIME	:		:		:		:	
26. APRCH & LNDG								
ENTRY ALT	LO	HI	LO	HI	LO	HI	LO	HI
ENTRY AIRSPD	SLO	FST	SLO	FST	SLO	FST	SLO	FST
ENTRY POINT	ERLY	LATE	ERLY	LATE	ERLY	LATE	ERLY	LATE
APRCH ANGLE	UNARC	OVARC	UNARC	OVARC	UNARC	OVARC	UNARC	OVARC
CLOSURE RATE	SLO	FST	SLO	FST	SLO	FST	SLO	FST
TERMINATION	POOR		POOR		POOR		POOR	
TRAINING TIME	:		:		:		:	
27. TAKEOFF								
TAKEOFF ANGLE	SHLW	STEEP	SHLW	STEEP	SHLW	STEEP	SHLW	STEEP
AIRSPEED	SLO	FST	SLO	FST	SLO	FST	SLO	FST
HEADING	LFT	RT	LFT	RT	LFT	RT	LFT	RT
TRAINING TIME	:		:		:		:	
28. EMER PROC/LDG								
PROCEDURE	USE EMERGENCY PROCEDURES GRADE SHEET							
A/C CONTROL								
AREA								
TRAINING TIME								
29. INST FLIGHT								
PROCEDURES	POOR		POOR		POOR		POOR	
A/C CONTROL	POOR		POOR		POOR		POOR	
UNUS ATT REC	POOR		POOR		POOR		POOR	
TRAINING TIME	:		:		:		:	

AIRCRAFT ONLY OPERATIONS

30. INT LOAD OPER								
IMPROPER	L SEC	WINCH	L SEC	WINCH	L SEC	WINCH	L SEC	WINCH
TRAINING TIME	:		:		:		:	
31. SLOPE OPER								
CONTROL:	LTN	ABRPT	LTN	ABRPT	LTN	ABRPT	LTN	ABRPT
ASCENT/DESCENT	DRFT	HDG	DRFT	HDG	DRFT	HDG	DRFT	HDG
TRAINING TIME	:		:		:		:	
32. WATER OPER								
APPROACH	POOR		POOR		POOR		POOR	
TAXI	POOR		POOR		POOR		POOR	
TAKEOFF	POOR		POOR		POOR		POOR	
TRAINING TIME	:		:		:		:	

Figure 2 continued. Data collection form.

PERFORMANCE ASSESSMENT

	1.	IP had to assume control immediately to avoid crash or collision.
UNSAT.	2.	IP eventually had to assume control as performance deteriorated.
	3.	IP never assumed control but performance was still unsatisfactory.
	4.	Performance rough; IP found that verbal assistance corrected problem, most standards within limits.
FAIR	5.	Performance rough; minimal verbal assistance would correct problem, all standards within limits.
	6.	Performance rough, no verbal assistance needed, practice should improve control touch.
	7.	Performance somewhat smoother than a FAIR; becomes erratic after short time.
GOOD	8.	Performance somewhat smooth but continuously passes through desired state.
	9.	Performance smooth; deviations may last several seconds, most standards within IPC limits.
	10.	Performance very smooth; deviations corrected quickly, all standards within IPC limits.
EXCELLENT	11.	Performance very smooth, deviations are aggressively corrected, all standards within IPC limits.
	12.	No deviations noted; perfect aircraft control.

Figure 3. Twelve-point rating scale used to assess the performance of each maneuver.

Cumulative Transfer Effectiveness Ratios

Cumulative transfer effectiveness ratios (CTER) were used to describe the training effectiveness of the CH47FS. The CTER, as described by Roscoe (1971, 1972), is a measure of the savings realized in learning to operate an aircraft by first training in a training device. The formula for CTERs based on training times is

$$\frac{\text{A/C time control group} - \text{A/C time exp. group}}{\text{Simulator time exp. group}} \quad (1)$$

The formula for CTERs based on training trials is

$$\frac{\text{A/C trials control group} - \text{A/C trials exp. group}}{\text{Simulator trials exp. group}} \quad (2)$$

CTERs were calculated on the basis of both times and trials for the overall training programs and on an individual maneuver basis.

A CTER is a measure of the training efficiency of a training device. A ratio of 1.0 indicates that the training device is as efficient as the actual device; a ratio greater than 1.0 indicates that the training device is more efficient; and a ratio of less than 1.0 indicates that the training device is less efficient. CTERs based on time are of special interest to those doing cost analyses of simulators where the cost basis for both the simulator and aircraft are figured by the hour. In these cases it can be more economical to train in a training device even if its CTER is less than 1.0, as long as its CTER is not lower than the ratio of the simulator cost per hour to the aircraft cost per hour.

CTERs calculated from number of trials are not affected by different time efficiencies of the two training devices. For example, an approach and landing might be practiced in the simulator in 2 minutes, but require 5 minutes in the aircraft because of air traffic control considerations. The CTER calculated from the number of times the maneuver was practiced will be quite different from the CTER based on time spent in practice. Although these time effects must be taken in consideration when designing a training program, they are not as relevant in determining the training effectiveness of a simulator. CTERs based on trials more accurately indicate the training efficiency with which maneuvers are transferred from the simulator to the aircraft and, therefore, the relative training effectiveness of the simulator.

Learning Curves

Learning curves are graphic representations of changes in skill that occur with practice or over time. The learning curves in this paper relate the skills of the students on each maneuver (as measured by their IPs on the 12-point scale) to the number of times (trials) each maneuver was demonstrated or performed. One set of learning curves illustrates the progress on each maneuver by the control group that was trained only in the CH-47 aircraft; the other set shows the progress of the experimental group that trained in both the simulator and the aircraft. There are three curves on each graph for each maneuver. The middle curve on each graph is a plot of the median performance of the group and is based on the 50th percentile scores. The lower curve is based on the 16th percentile; the upper curve, on the 84th percentile scores. These percentile scores were chosen to approximate the mean and plus and minus one standard deviation given distributions of scores that were not normally distributed.

Operational Procedures

Each class of approximately 12 aviators reported to Fort Rucker several days before the start of flight training for administrative purposes. The aviators attended 3 days of ground school in preparation for the flight training. During this time, the class was administered the FAST battery and the Bennett Mechanical Comprehension Test, and individual flight experience data were gathered. On the basis of the test scores and experience data, four students were assigned to the experimental group and eight to the control group so that the groups were matched.

At the start of flight training, both groups spent half a day together in ground school and split the second half day for separate flight training activities. The control group underwent flight training in the CH-47 aircraft according to the program set out in the Flight Training Guide.

The basic phase of flight instruction included preflight inspection, taxiing, hovering maneuvers, takeoff maneuvers, approach-to-landing maneuvers, inflight airwork maneuvers, and basic emergency procedures. During this training the IPs used the experimental data collection forms and recorded for each maneuver student performance on each attempt, performance on the subtasks, and the time spent on the maneuver. The IPs were instructed to train the students to a performance level of 6 on the 12-point scale. This level of skill was considered the criterion for passing all checkrides and an acceptable skill level from which to continue training after completing the course. However, training was rarely stopped at this proficiency level, as discussed in the section on Overtraining. At the end of the basic phase of training a basic phase checkride was administered;

students were required to pass the checkride before entering the advanced phase of training.

The advanced phase included training in confined area, pinnacle, and slope operations, external load and internal load operations, and advanced emergency procedures. The recording of performance data continued throughout the training on all maneuvers. At the completion of advanced training, an aircraft qualification checkride was administered and upon passing it the aviator became a qualified CH-47 pilot. A flow chart summarizing these procedures appears in Figure 4.

The students selected for the experimental group began the basic phase training in the CH47FS. The IPs training them in the simulator followed the same Flight Training Guide and taught the same maneuvers in the same order and to the same criterion level of performance as in the aircraft. At this stage of training, the students and IPs also went to the flight line for training in preflight inspection of the aircraft. The aircraft engines were never started, however, and the aircraft was not flown. As was the case with the control group, the IPs teaching the experimental group recorded performance level and practice time on the experimental data collection forms for every maneuver performed. The IPs were instructed to train all basic maneuvers in the simulator to skill level 6, the criterion level, or until it was obvious that a student would not reach this level of performance in a reasonable amount of time.

At the completion of training the basic phase maneuvers in the simulator, the students were given the basic phase checkride in the simulator. After this checkride a second basic phase checkride was administered in the CH-47 aircraft. Unlike the control group, the experimental group was not required to pass the checkride. This checkride was the first time the experimental group subjects had flown the aircraft.

Regardless of the basic phase checkride scores, the experimental group returned to the CH47FS and continued training on the advanced phase maneuvers. With the exception of internal load, slope, and water operations, the simulator was designed to train all of the advanced phase maneuvers. Again, performance and time data were collected on each maneuver. Upon completion of this phase of training a third checkride, similar to the aircraft qualification checkride, was given in the simulator followed by a fourth checkride in the aircraft. This last checkride was the second time the experimental subjects had flown the CH-47.

At this stage, training in the simulator stopped, and training in the aircraft began. The aircraft training was intended to teach maneuvers that could not be taught in the simulator and that each student had not passed in the last aircraft checkride. Performance and time data were also collected throughout this last phase of training. Training in the CH-47 was followed by the final aircraft

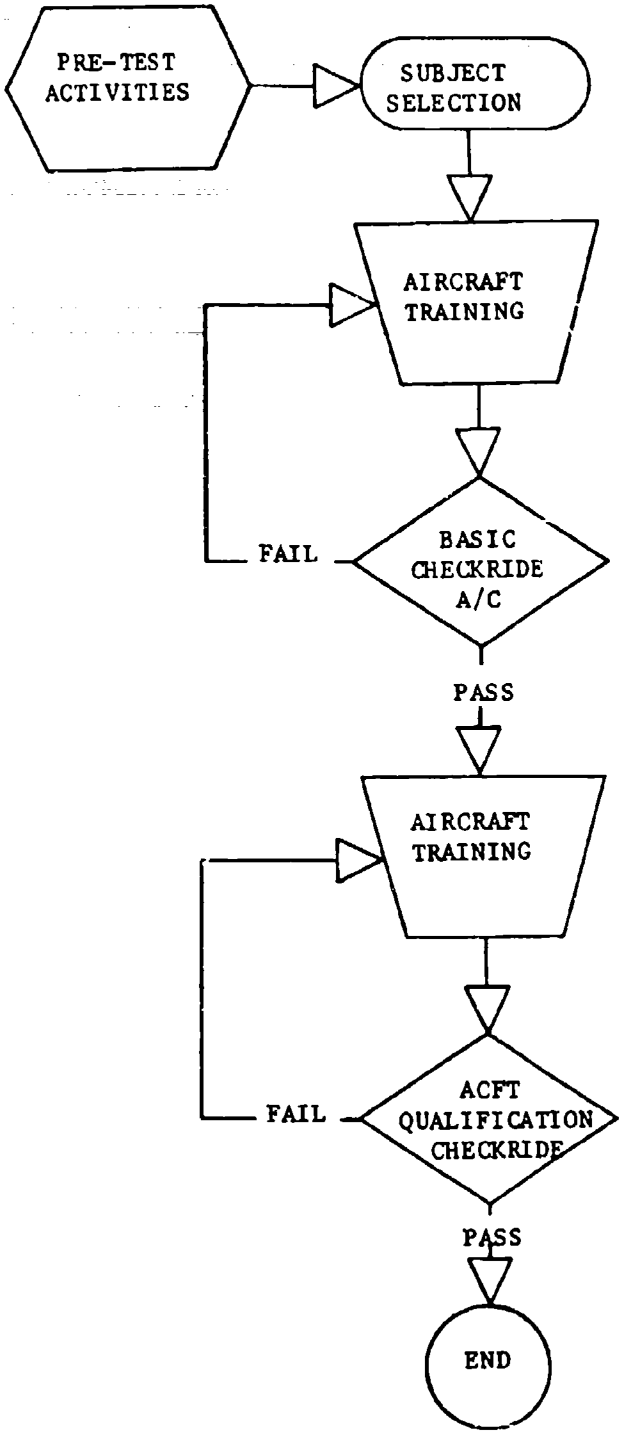


Figure 4. Flow chart of Control Group procedures.

qualification checkride in the aircraft. A flow chart summarizing these procedures appears in Figure 5.

PART I
RESULTS AND DISCUSSION

Learning Curves

Learning curves of all the maneuvers that were taught in both the simulator and the aircraft are presented in Figures 6 through 29. To represent continuity of training, the learning curves of the experimental group in the simulator and in the aircraft are presented on the same graph. For ease of comparison, the learning curves of the control group in the aircraft are presented directly below the experimental group's curves for each maneuver.

Cumulative Transfer Effectiveness Ratios

The CTERs for each maneuver taught in both the simulator and the aircraft appear in Table 1. The table presents CTERs calculated f m the median number of trials spent training in the simulator and the median number of trials to proficiency levels 6 and 8 spent training in the aircraft. The last two sets of CTERs are based on the time spent on each maneuver: The first is based on the total time spent training in the simulator and in the aircraft to performance level 8 for both groups; the second is based on total times used in training each maneuver with no consideration given to the student's proficiency. The last row of CTERs in Table 1 gives the overall CTER for all the listed maneuvers calculated on the basis of the two trials to criterion selected, time to criterion, and total time.

In an earlier report (McGaugh & Holman, 1977) these trials-to-criterion CTER data were presented using a criterion performance level of 6, the level the IPs were requested to use in training as the criterion to stop training on a particular maneuver. For this report the trials-to-criterion CTER data presented in Figure 1 were calculated on the basis of criterion performance levels 6 and 8. All of the maneuvers were trained to a median level of at least 8 in the aircraft. (Using this criterion makes the CTERs more typical of what actually occurred in training.) The change in criterion decreased the CTERs of 5 of the 24 maneuvers and increased the CTERs of 13 of the 24 maneuvers. Further mention of trials-to-criterion CTERs refers to CTERs based on a criterion level of 8.

CTERs based on the time-to-criterion level 8 are presented in the next column of Table 1. These CTERs differ from the trials-to-criterion 8 CTERs to the extent that any individual maneuver could take a different amount of time to perform in the simulator than in the aircraft.

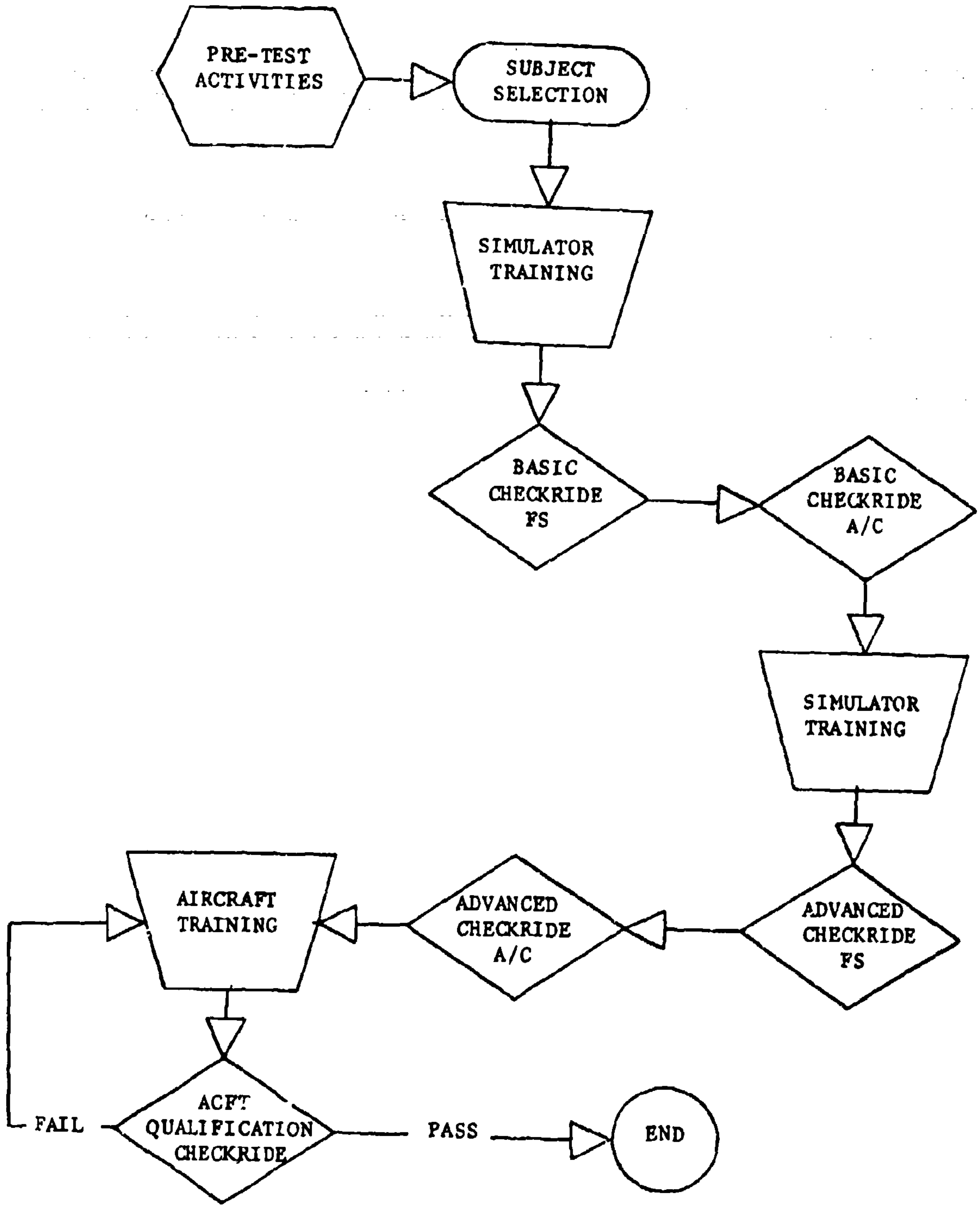


Figure 5. Flow chart of Experimental Group procedures.

Table 1

CUMULATIVE TRANSFER EFFECTIVENESS RATIO (CTER) BY MANEUVER FROM THE CH47FS TO THE CH-47 AIRCRAFT

	CTERs Trials to Criterion		CTERs Time	
Maneuver	Crt 6	Crt 8	Crt 8	Total
General Airwork	.69	1.00	1.08	-.13
Cockpit Runup	1.00	1.50	1.08	1.36
Four Wheel Taxi	1.40	2.80	2.96	1.69
Two Wheel Taxi	1.14	1.00	.81	.75
Takeoff to Hover	.53	.63	.57	.61
Hovering Flight	.58	.79	.73	.57
Landing from Hover	.56	.69	.65	.47
Normal Takeoff	.60	.75	.60	.38
Traffic Pattern	.56	.61	.76	.72
Deceleration	1.00	1.25	1.25	1.08
SAS Off Flight	1.00	1.33		
Normal Approach	.65	.53	.60	.58
Maximum Takeoff	.88	1.25	1.24	.67
Steep Approach	.80	1.00	.98	.80
Shallow Approach	.50	.58	.60	.33
Confined Area Recon	.75	1.00	1.59	.80
Confined Area Approach	.50	.75	.25	-.23
Confined Area Takeoff	.50	.50	.63	.33
External Load Briefing	1.00	.67	.92	.58
External Load Takeoff	.50	.50	1.66	1.62
External Load Approach	.50	.50	.76	.50
Pinnacle Recon	1.00	.50	.71	.09
Pinnacle Approach	.67	.00	-.28	-.43
Pinnacle Takeoff	.67	.33	.26	.06
Overall CTER	.69	.82	.95	.70

Checkride Scores

The mean performance ratings on the final aircraft qualification checkride are presented in Table 2 by subject and by group. The difference between groups is not significant, $t(95) = .55$, $p > .5$. Table 3 presents mean performance ratings by group on the final aircraft qualification checkrides for each maneuver performed on the checkride by at least 85% of the subjects.

Overtraining

One factor that makes the interpretation of the CTERs in Table 1 difficult is overtraining. Overtraining occurred when trials and time were spent in training an aviator to perform a maneuver at a skill level higher than level 6, the criterion performance level. The following examples describe the effects overtraining can have on CTERs.

Consider a hypothetical maneuver that is properly trained to a criterion in both devices and that transfers perfectly from the simulator to the aircraft. The CTER should be 1.0. Assume that it requires 15 trials to learn the maneuver in the aircraft and 15 trials to learn the maneuver in the simulator; and that after simulator training, no further training is required in the aircraft. Putting these figures into equation 2:

$$\text{CTER} = \frac{\text{A/C trials control group} - \text{A/C trials exp. group}}{\text{Simulator trials exp. group}} \qquad (2)$$

$$\text{CTER} = \frac{15 - 0}{15}$$

$$\text{CTER} = 1.$$

As expected, the CTER indicates that the simulator is as good a trainer as is the aircraft.

Given, for example, overtraining of 5 trials in both devices:

$$\text{CTER} = \frac{20 - 5}{20}$$

$$\text{CTER} = 0.75.$$

The resulting CTER gives the erroneous impression that the simulator is not as good a trainer as the aircraft. This is typical of the CTERs reported as total time CTERs in Table 1. The usual case was to overtrain in both devices, as can be seen from the learning curves.

Table 2

MEAN PERFORMANCE RATING ON FINAL AIRCRAFT QUALIFICATION CHECKRIDE BY MANEUVER AND GROUP

Maneuver Name	Mean Ratings	
	Test Group	Control Group
Preflight	8.79	8.59
Postflight	9.33	9.32
General Airwork	8.04	7.88
Cockpit Runup	8.88	8.79
Takeoff to Hover	8.04	8.18
Hovering Flight	8.00	7.71
Landing from Hover	8.25	7.88
Normal Takeoff	8.63	8.21
Traffic Pattern	8.25	8.41
SAS Off Flight	7.92	8.11
Normal Approach	7.75	7.85
Shallow Approach	7.92	7.82
Confined Area Recon	7.63	7.59
Confined Area Approach	7.63	7.09
Confined Area Takeoff	8.29	7.74
External Load Briefing	8.88	8.44
External Load Takeoff	8.33	8.06
External Load Approach	7.63	7.18
Pinnacle Approach	7.83	7.44
Slope Operations	7.38	7.21
Engine Compartment Fire	7.13	7.15

Table 3

MEAN PERFORMANCE RATING ON FINAL AIRCRAFT QUALIFICATION CHECKRIDE BY TRAINEE AND GROUP

Test Group			Control Group		
Trainee	Mean Rating	%	Trainee	Mean Rating	%
500	8.49	70	600	10.09	84
501	10.06	84	601	8.18	68
502	8.75	73	602	9.48	79
503	10.38	86	603	9.79	87
504	7.15	60	604	9.01	75
505	6.53	54	605	9.25	77
506	6.60	55	606	7.88	66
507	6.22	52	607	7.40	62
508	6.70	56	608	8.54	71
509	8.96	75	609	7.60	63
510	9.81	82	611	7.46	62
511	6.13	51	612	7.89	66
512	8.30	69	613	7.66	64
513	8.05	67	614	7.28	61
514	9.23	77	615	7.39	61
515	6.36	53	616	5.71	48
516	7.31	61	617	7.18	60
517	6.29	52	618	6.78	56
518	8.39	70	619	6.77	56
519	9.66	80	622	7.51	63
520	9.68	81	623	7.38	62
521	8.46	71	624	7.37	61
522	7.71	64	625	8.08	67
523	6.68	56	626	7.93	66
			627	5.22	43
			628	6.72	56
			629	8.62	72
			630	9.00	75
			631	6.34	53
			632	8.95	75
			633	6.42	55
			634	9.69	81
			635	7.53	63
			636	7.03	59
MEAN	7.99			7.80	
STANDARD DEVIATION	1.38			1.15	

The trials-to-criterion columns of CTERs were calculated on the basis of total number of trials in the simulator, because it must be presumed that any overtraining here was transferred to the aircraft. The trials counted in the aircraft training were only those needed to reach criterion. The last example recalculated this way:

$$CTER = \frac{15 - 0}{20}$$

$$CTER = 0.75.$$

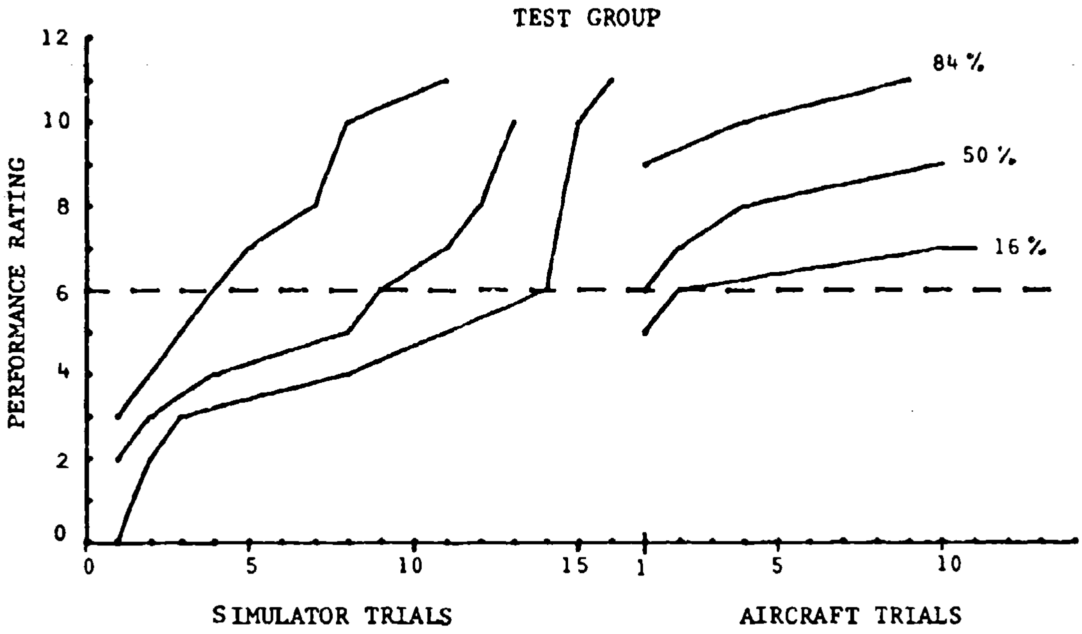
This also gives the impression that the simulator is not as good a training device as the aircraft.

Because, as can be seen from the learning curves, some overtraining occurred with all maneuvers, the total time CTERs in Table 1 are all conservative and lower than they would be had training regularly been stopped at criterion performance. Many of the maneuvers were overtrained in the simulator, and these trials-to-criterion CTERs are lower than would have been the case without overtraining.

General Airwork

General airwork included a number of specific maneuvers such as climbs, descents, and turns. This skill was judged only once each training session and was judged almost every session. Consequently, training on this maneuver exceeded criterion. It was usually rated while flying between stagefields or to other training areas in either the simulator or aircraft.

As shown by the learning curves in Figure 6, general airwork was overtrained in both the simulator and the aircraft. The overtraining makes it difficult to interpret the CTERs for this maneuver. On a trials-to-criterion basis, the CTER is 1.00; on a time-to-criterion basis, it is 1.08. The CTER of -.13, computed on the basis of total times, may be an artifact of overtraining and should not be taken as indicating a lack of training capability in the simulator. Another cause for this large discrepancy is the different amounts of time spent per trial in the simulator and the aircraft doing general airwork. In the aircraft much time was recorded as general airwork while flying from one training location to another. In the simulator, it was not necessary to fly these distances, since the simulator could be repositioned to a new training location. The simulator group averaged 15 minutes per trial while training in the CH47FS and 22 minutes per trial while training in the aircraft.



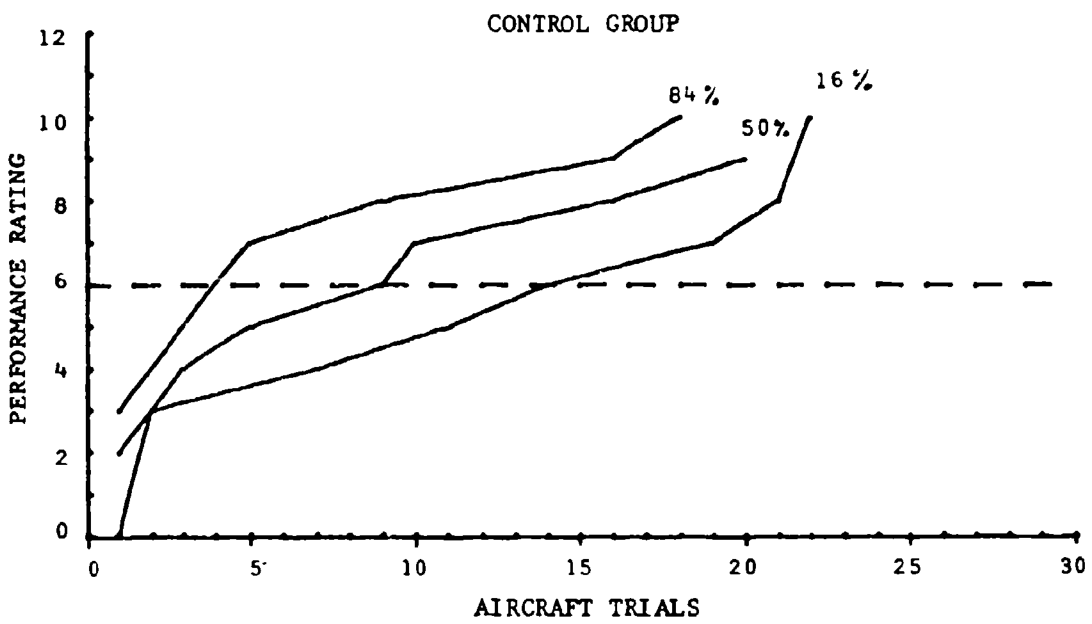


Figure 6. Learning curves for General Airwork.

Cockpit Runup

The trials-to-criterion CTER is 1.50, and the total time CTER is 1.36. These CTERs and the learning curves in Figure 7 indicate that this maneuver was learned more efficiently in the simulator than in the aircraft. It is often the case that when the learning task is procedural in nature, a training device provides a more effective learning environment than the actual device provides. The time-to-criterion CTER is 1.08, considerably smaller than the trials-to-criterion CTER, because more time per trial was taken in the simulator. Additional training in dealing with various runup malfunctions that cannot be practiced in the aircraft accounted for this added time.

Four-Wheel Taxi

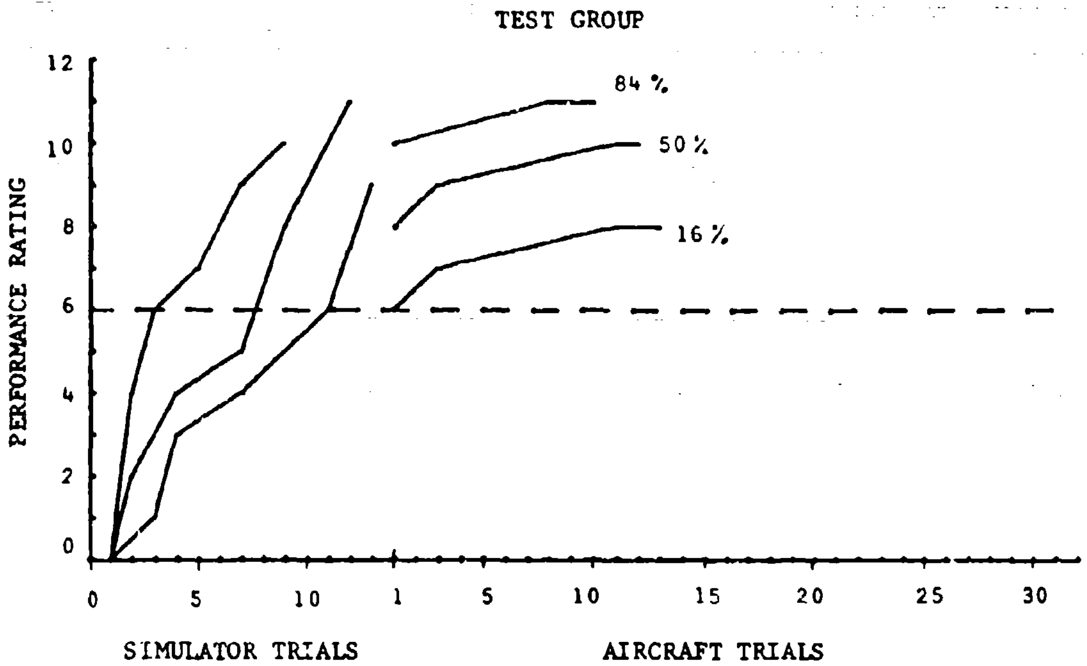
The learning curves for four-wheel taxi in Figure 8 show that this maneuver was quickly learned in the simulator and that this training transferred well to the aircraft. The CTER using trials to criterion is 2.80; using time to criterion, 2.96; and using total time, 1.69. Since there was little overtraining in the simulator on this maneuver, the trials-to-criterion CTER accurately reflects the effectiveness of the trainer. A CTER greater than 1.0 indicates that four-wheel taxiing is trained better in the simulator than in the aircraft. The total CTER time of 1.69, however, is heavily influenced by the overtraining of both groups in the aircraft. As in the case of general airwork, this maneuver was practiced frequently in the aircraft as a matter of necessity even after training could have been terminated.

Two-Wheel Taxi

Figure 9 shows that the learning curves for two-wheel taxi are shallower than those for four-wheel taxi, indicating that the two-wheel taxi maneuver is more difficult to learn than is four-wheel taxi. The learning curves also indicate that the simulator training transferred to the aircraft with no difficulty. The trials-to-criterion CTER is 1.0, indicating that the simulator trains the maneuver as well as the aircraft. The total time CTER of .75 is relatively low and is partially due to overtraining in the aircraft. The time-to-criterion CTER, .81, is also lower because additional time per trial was spent in practice in the simulator.

Takeoff to Hover

The hovering maneuvers were among the most difficult to perform in the simulator. Training on them transferred to the aircraft with less efficiency than on many other maneuvers. The learning curves in Figure 10 clearly illustrate this point and are typical of learning curves generated by many training devices. The simulator group required



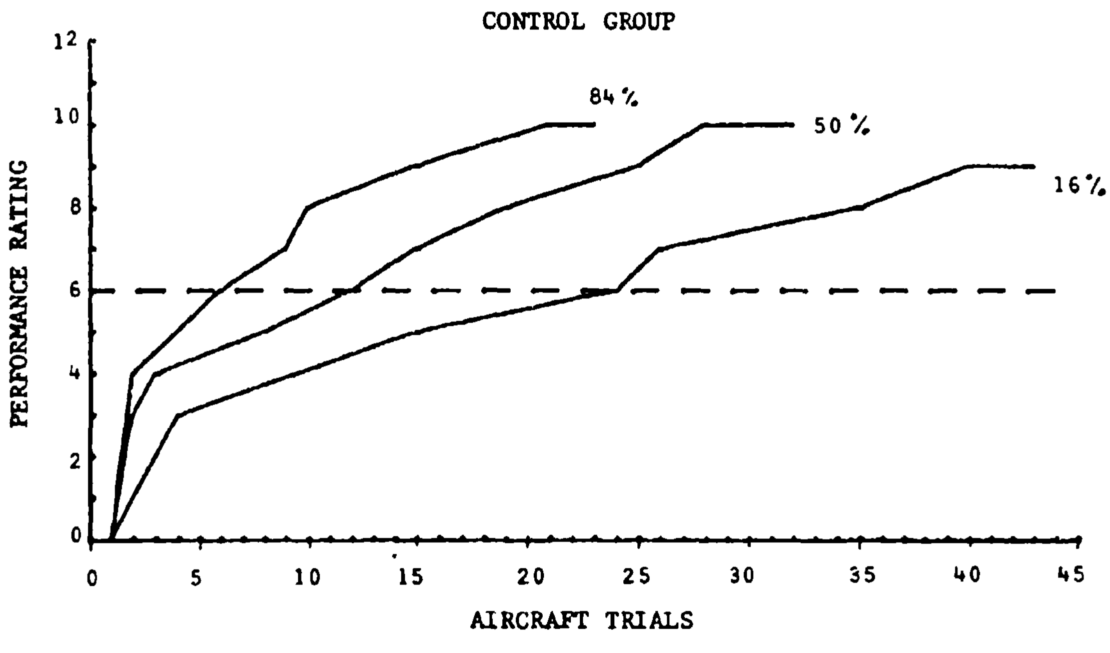


Figure 7. Learning curves for Cockpit Runup/Shutdown.

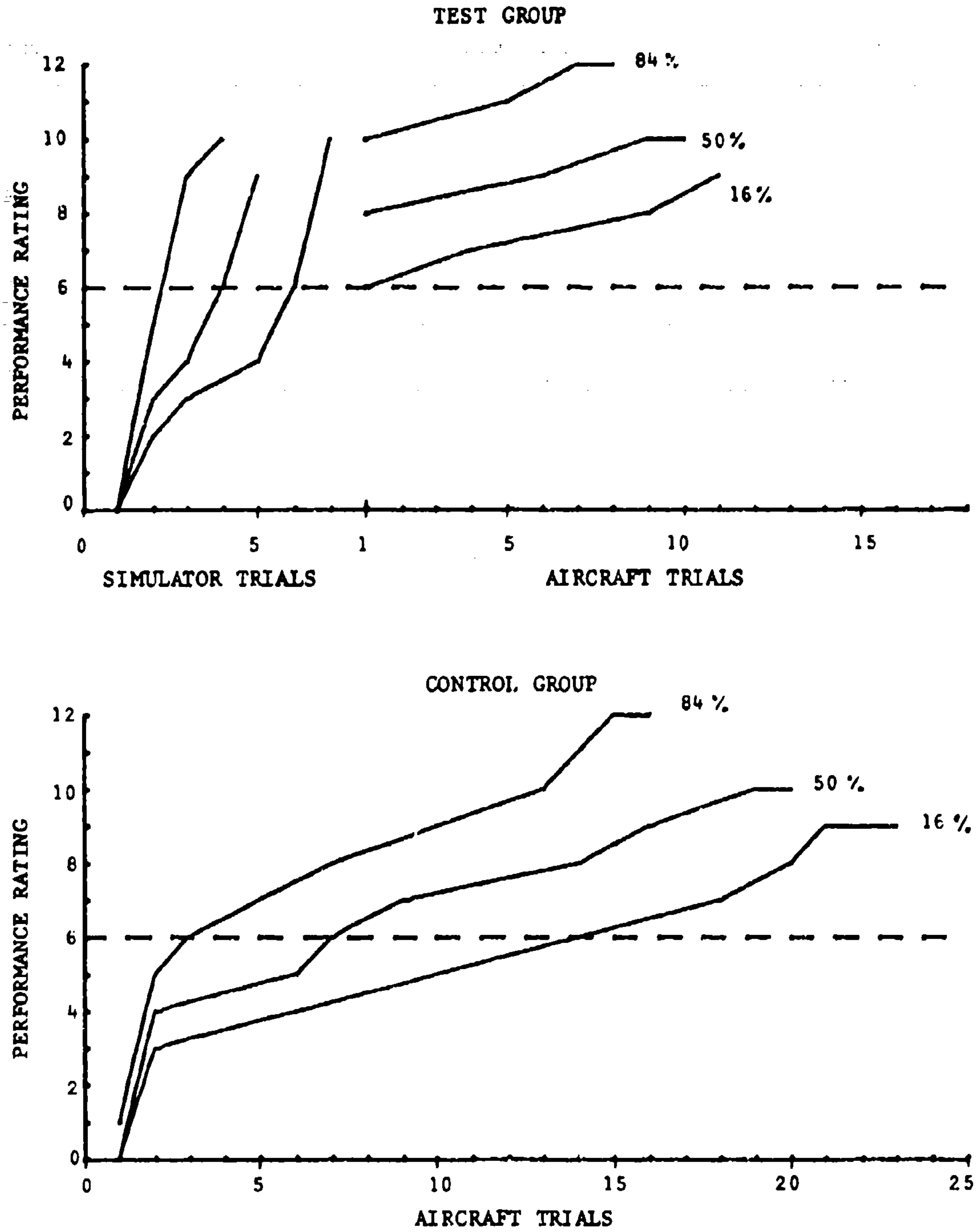


Figure 8. Learning curves for Four-Wheel Taxi.

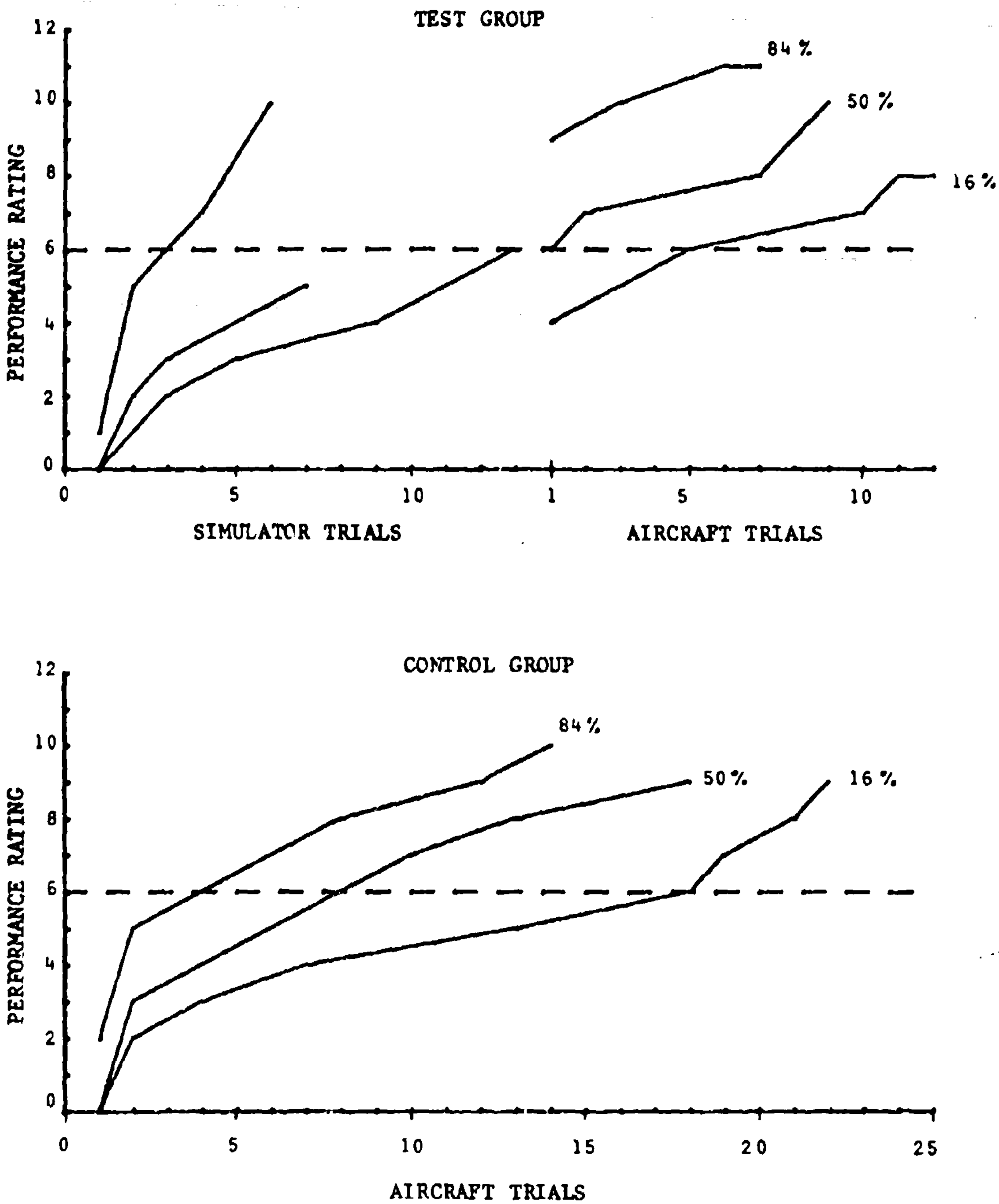


Figure 9. Learning curves for Two-Wheel Taxi.

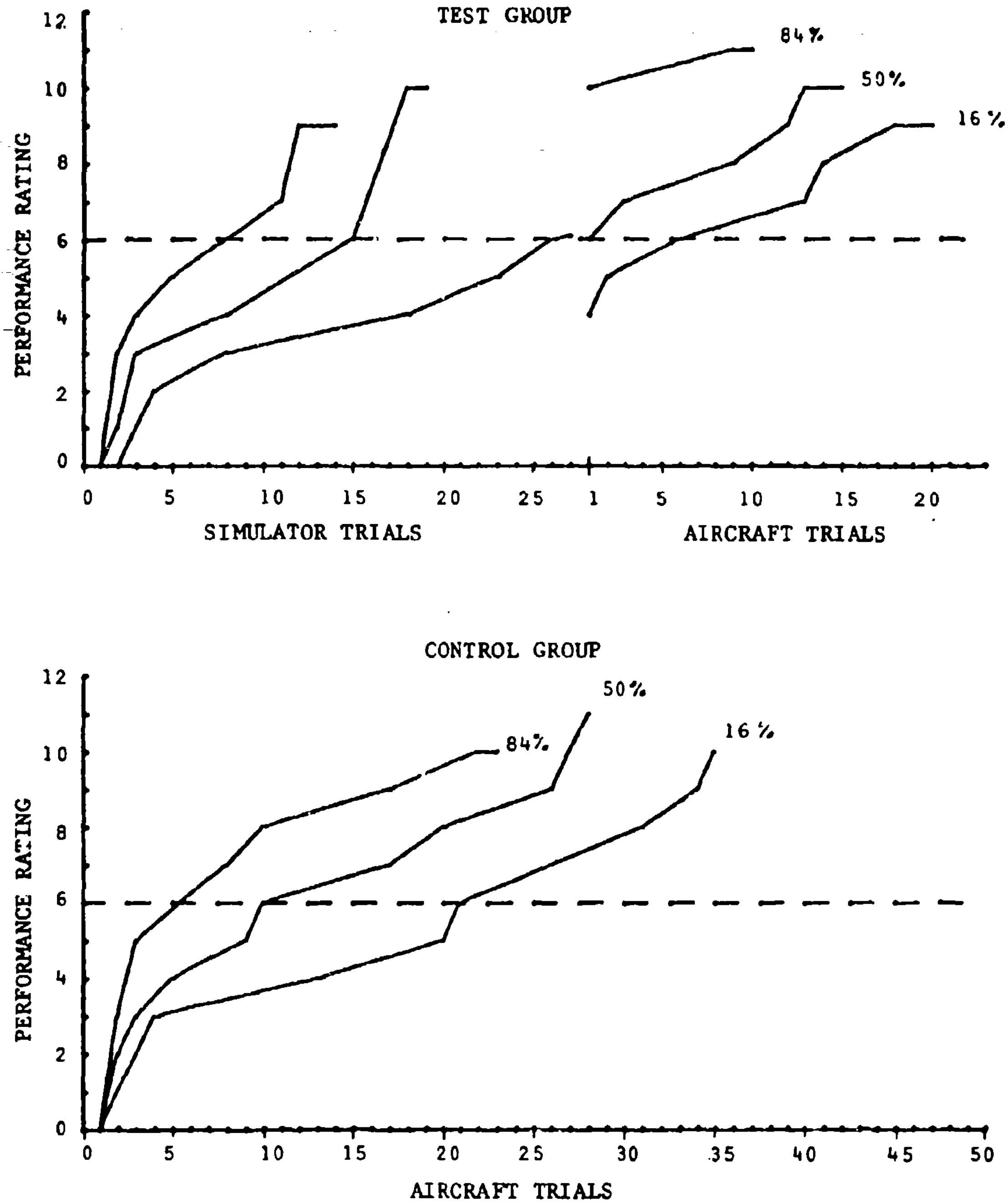


Figure 10. Learning curves for Takeoff to Hover.

more trials than the aircraft group to reach median criterion performance (15 trials versus 10) in their respective devices. When the simulator group started training in the aircraft, the group's performance dropped well below its rating established at the end of simulator training. These two findings are what one would expect of the transfer of training of complex tasks from a training device to the actual situation and are indicated by CTERs of less than 1.0. The trials-to-criterion CTER for takeoff to hover is .63; the time-to-criterion CTER, .57; and the total time CTER, .61.

Hovering Flight

The learning curves in Figure 11 for hovering flight indicate the difficulty of training this maneuver in the simulator and the drop in performance in transferring to the aircraft. The trials-to-criterion CTER is .79; the time-to-criterion CTER, .73; and the total time CTER, .57.

Landing From a Hover

The trials-to-criterion CTER is .69; the time-to-criterion CTER, .65; and the total time CTER, .47. The learning curves for landing from a hover in Figure 12 reflect these CTERs in the increased training required in the simulator. The training effectiveness of these three hovering maneuvers is virtually identical, and each CTER indicates that the simulator is more difficult to hover than the aircraft. It is difficult to determine why this is the case, but it is believed to be due to the limited field of view, the infinity focus presentation of the visual system, and an inadequate simulation of hovering aerodynamics or motion cueing.

Normal Takeoff

The learning curves of the normal takeoff in Figure 13 are similar to those of the hovering maneuvers. The trials-to-criterion CTER is .75; the time-to-criterion CTER, .60; and the total time CTER, .38. The trials-to-criterion CTER is similar to the hovering maneuver CTERs. This, of course, is due to the similarity of the maneuvers and the requirement for similar visual fields. The time-to-criterion CTER is lower because more time per trial was spent on this maneuver in the simulator attempting to perform it well. The very low total time CTER is due to overtraining of both groups in the aircraft.

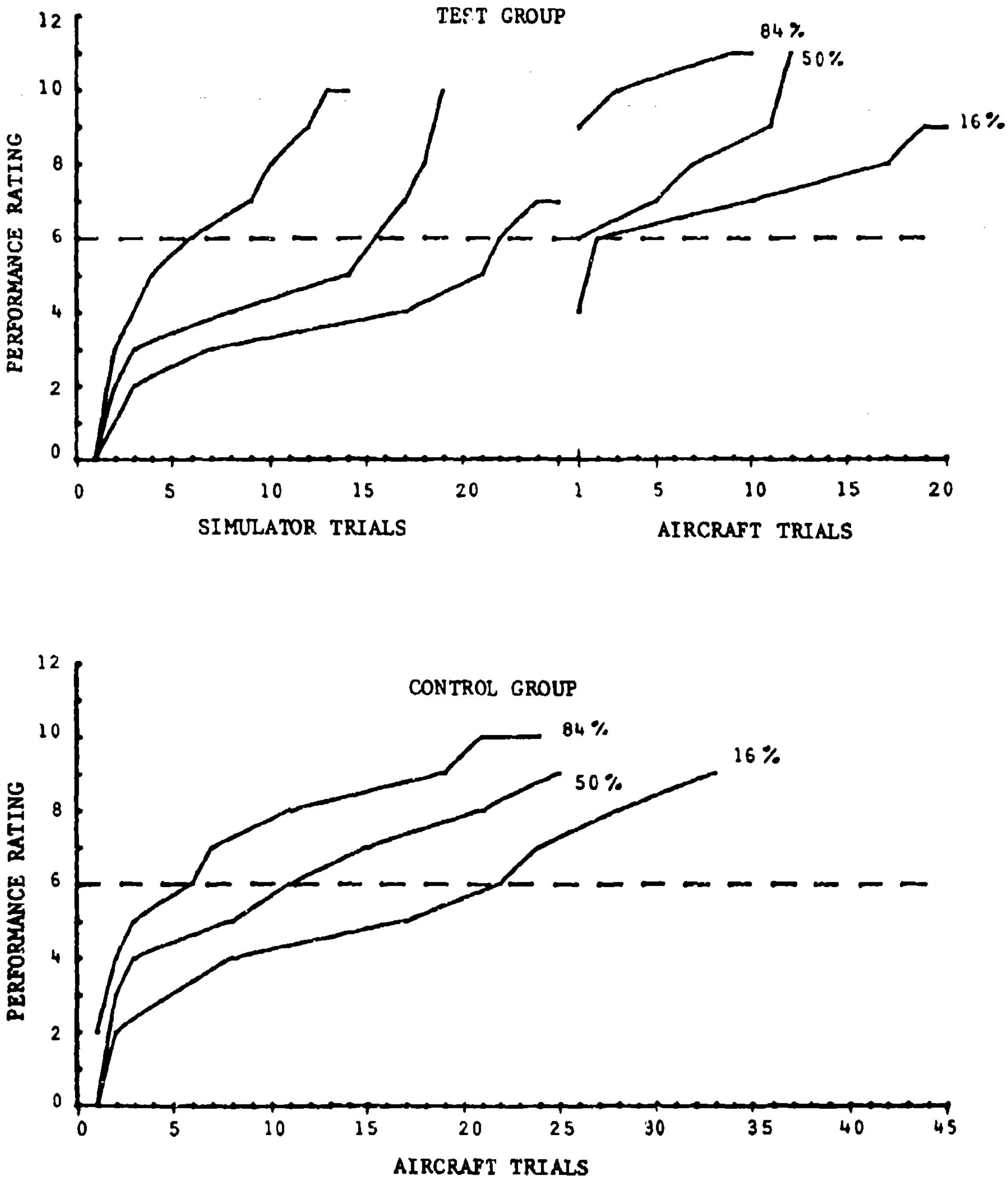


Figure 11. Learning curves for Hovering Flight.

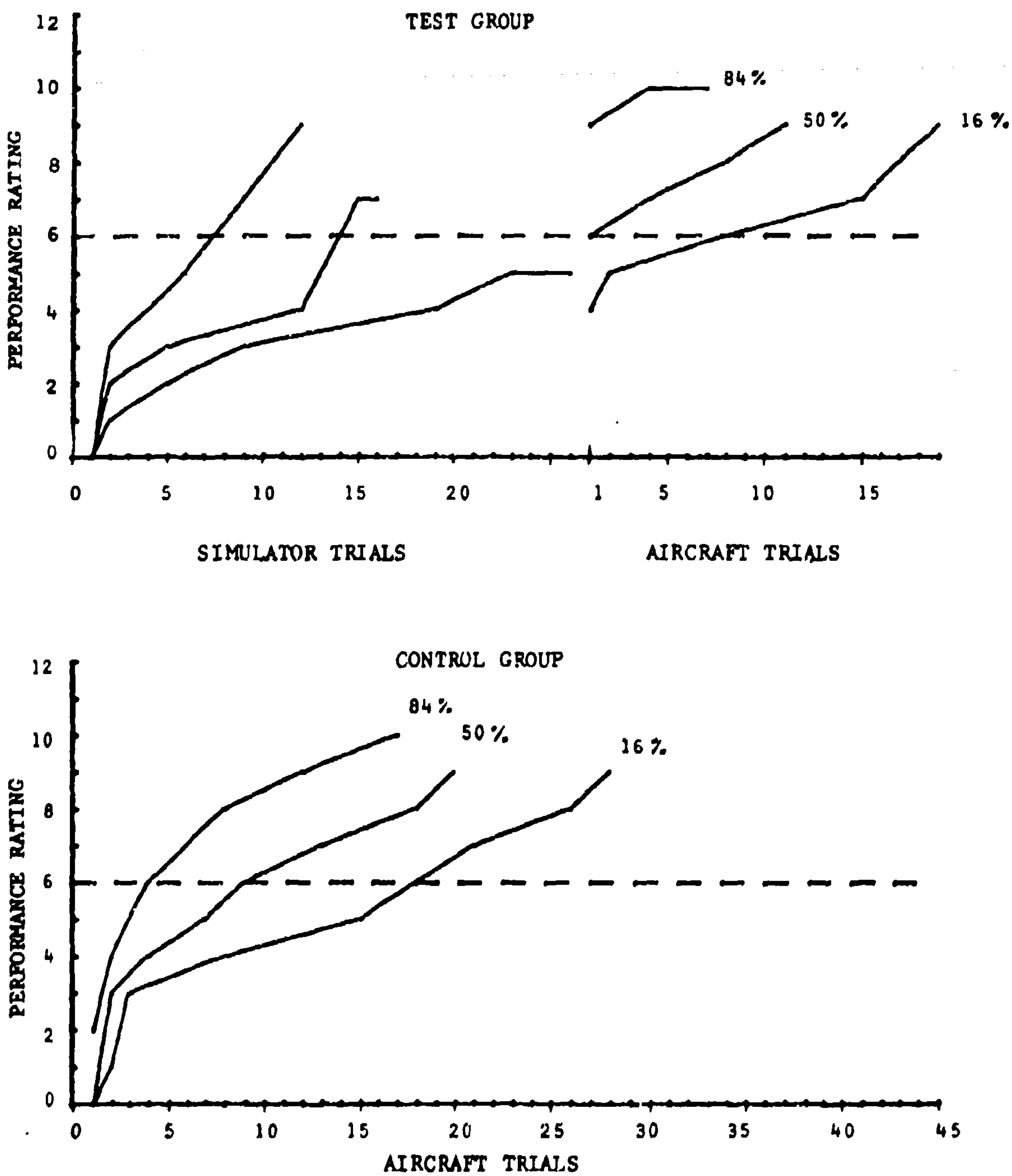


Figure 12. Learning curves for Landing from Hover.

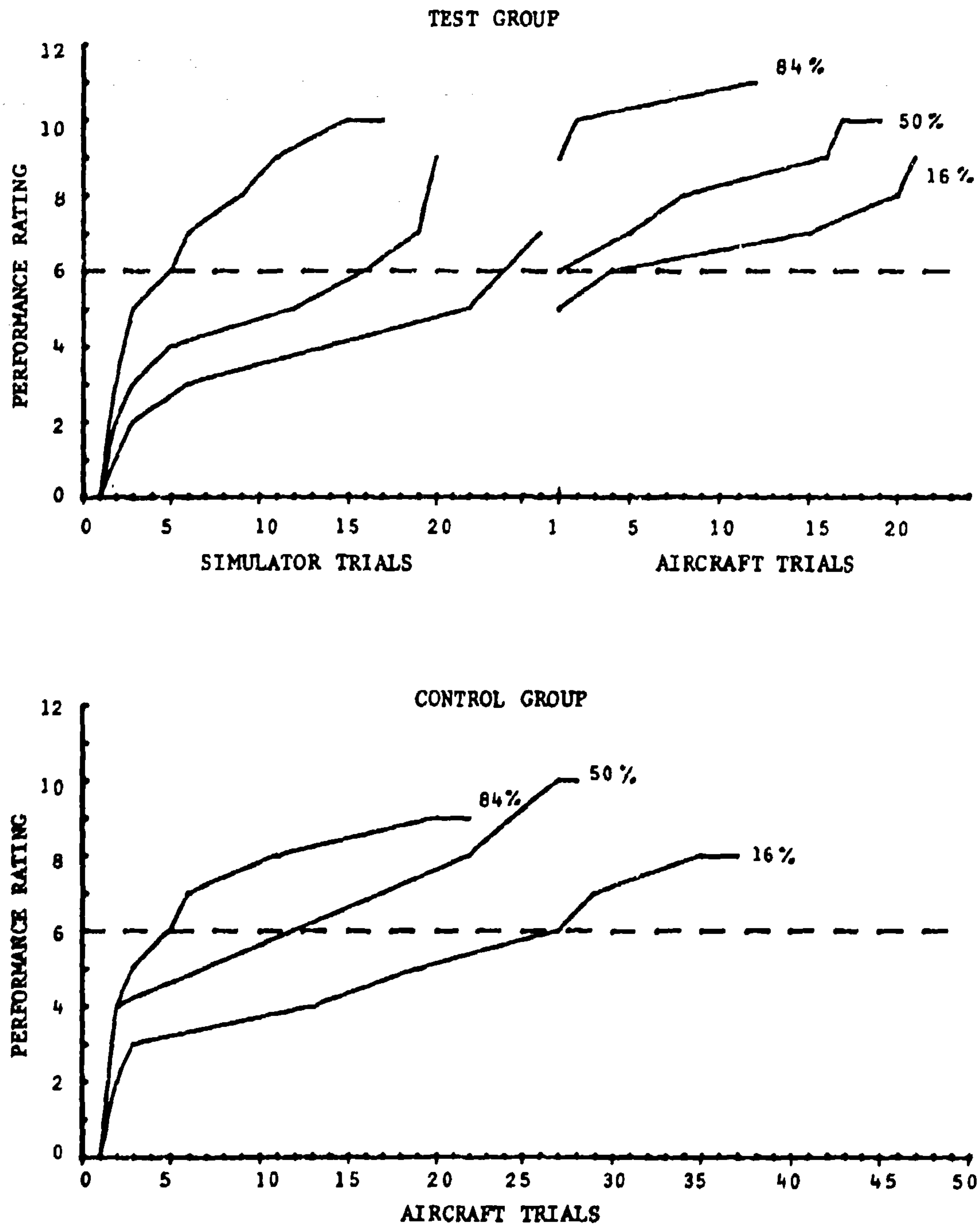


Figure 13. Learning curves for Normal Takeoff.

Traffic Pattern

The learning curves for traffic pattern in Figure 14 indicate that traffic patterns are more difficult to perform in the simulator than in the aircraft. This is due to the lack of any side window visual in the simulator. The CTERs reflect this difficulty, with values of .61 for trials to criterion, .76 for time to criterion, and .72 for total time. If the simulator had a side visual system, one could expect CTERs close to 1.0 for this maneuver. The time-to-criterion CTER is higher because shorter times per trial were spent in the simulator. With no side visual, the patterns were flown using ground features for orientation and were much shorter than those learned flying the aircraft alone.

Deceleration

The deceleration learning curves in Figure 15 show that the deceleration maneuver is learned more efficiently in the simulator than in the aircraft. The trials-to-criterion CTERs are 1.25, and the total time CTER is 1.08. These results are characteristic of a training device that is more effective than the actual device.

SAS Off Flight

SAS off flight is another maneuver with a high trials-to-criterion CTER of 1.33. The learning curves for SAS off flight in Figure 16 show that each group's median performance was similar and that there was little decrement in median performance in transferring from the simulator to the aircraft. SAS off flight was evaluated while doing general airwork and SAS off emergency procedures. SAS off flight was not attempted while doing low-altitude ground reference maneuvers such as hovering. The CH47FS did not simulate this condition with enough fidelity, nor was it controllable enough to be of training value. The main problem seemed to be the narrow field of view of the visual system. CTERs based on time could not be calculated, because time data were not collected for this maneuver.

Normal Approach

The learning curves for normal approach in Figure 17 indicate that this maneuver was somewhat more difficult to learn in the simulator than in the aircraft. The transfer from the simulator to the aircraft was accomplished with only a small decrement in performance. The trials-to-criterion CTER is .53; the time-to-criterion, .69; and the total time CTER, .58. A CTER of about .5 means that the training device is not as effective as the actual device.

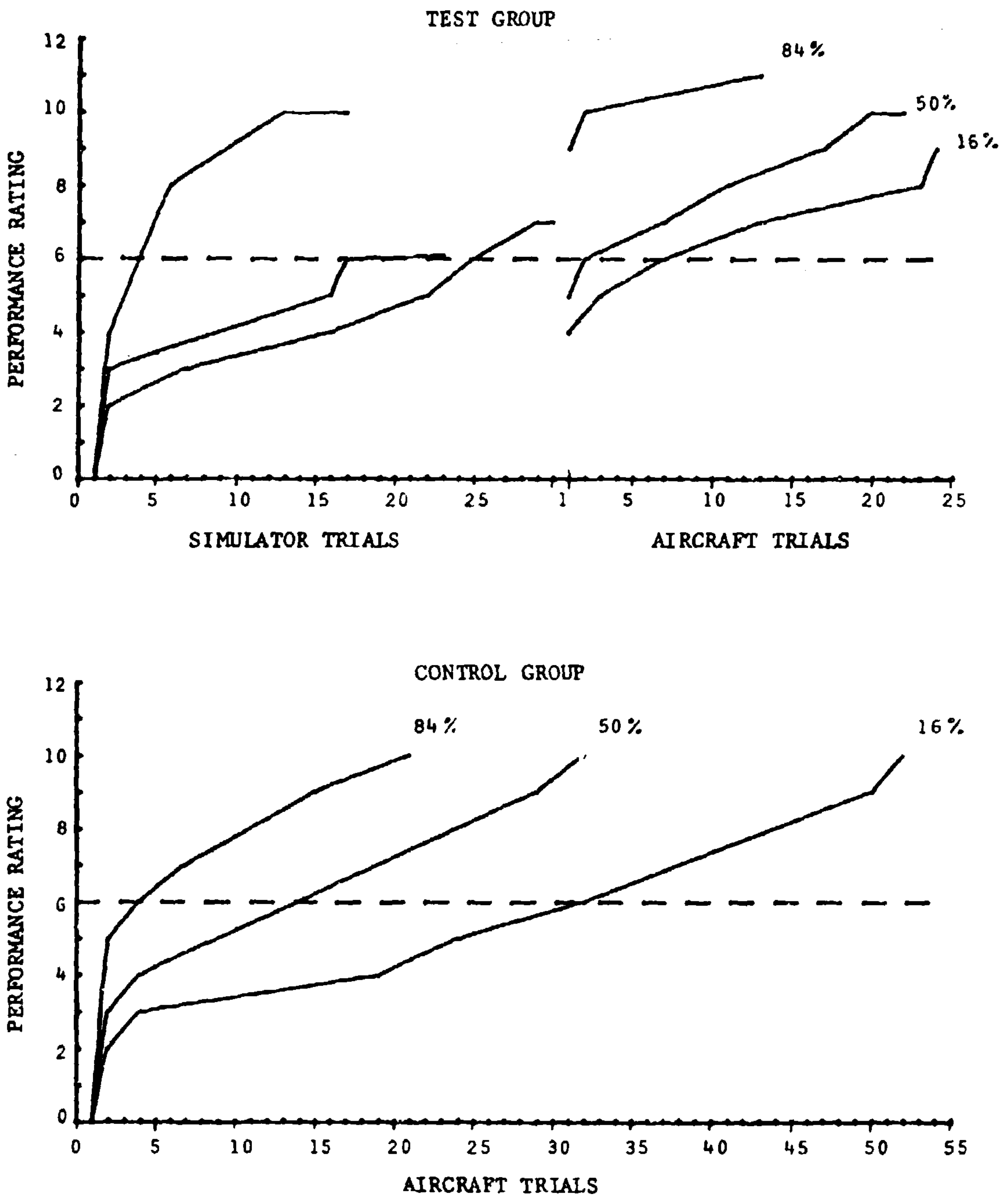
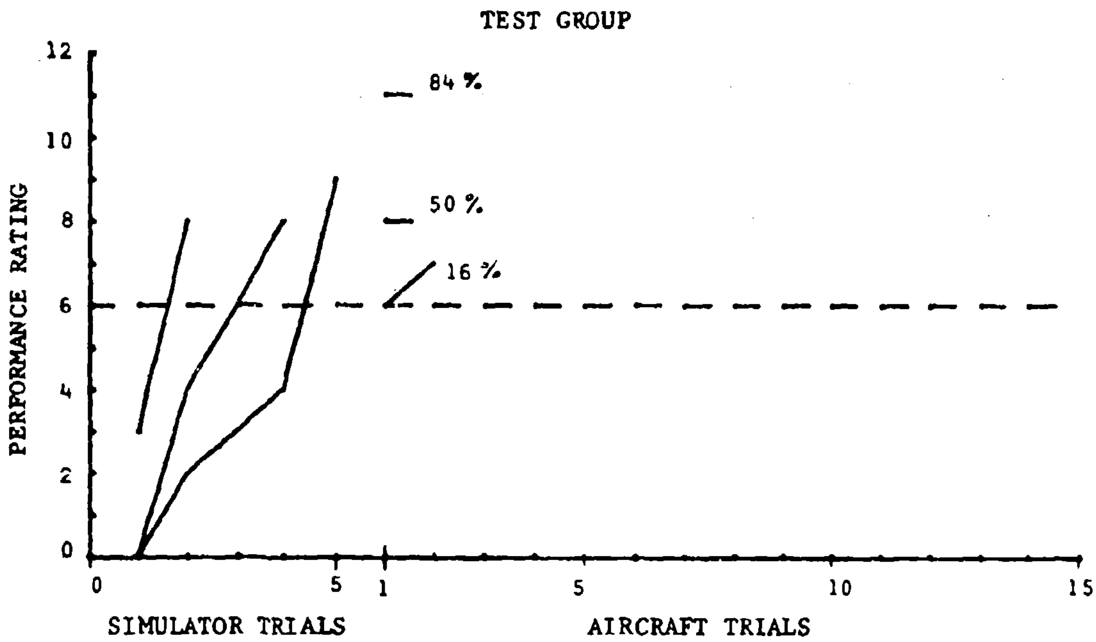


Figure 14. Learning curves for Traffic Pattern.



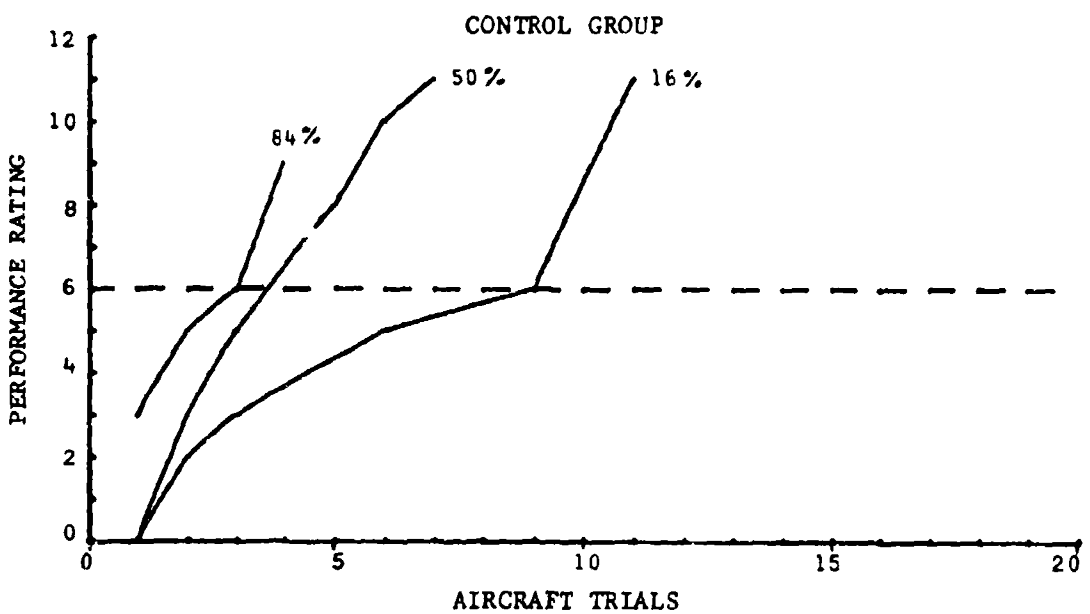


Figure 15. Learning curves for Deceleration.

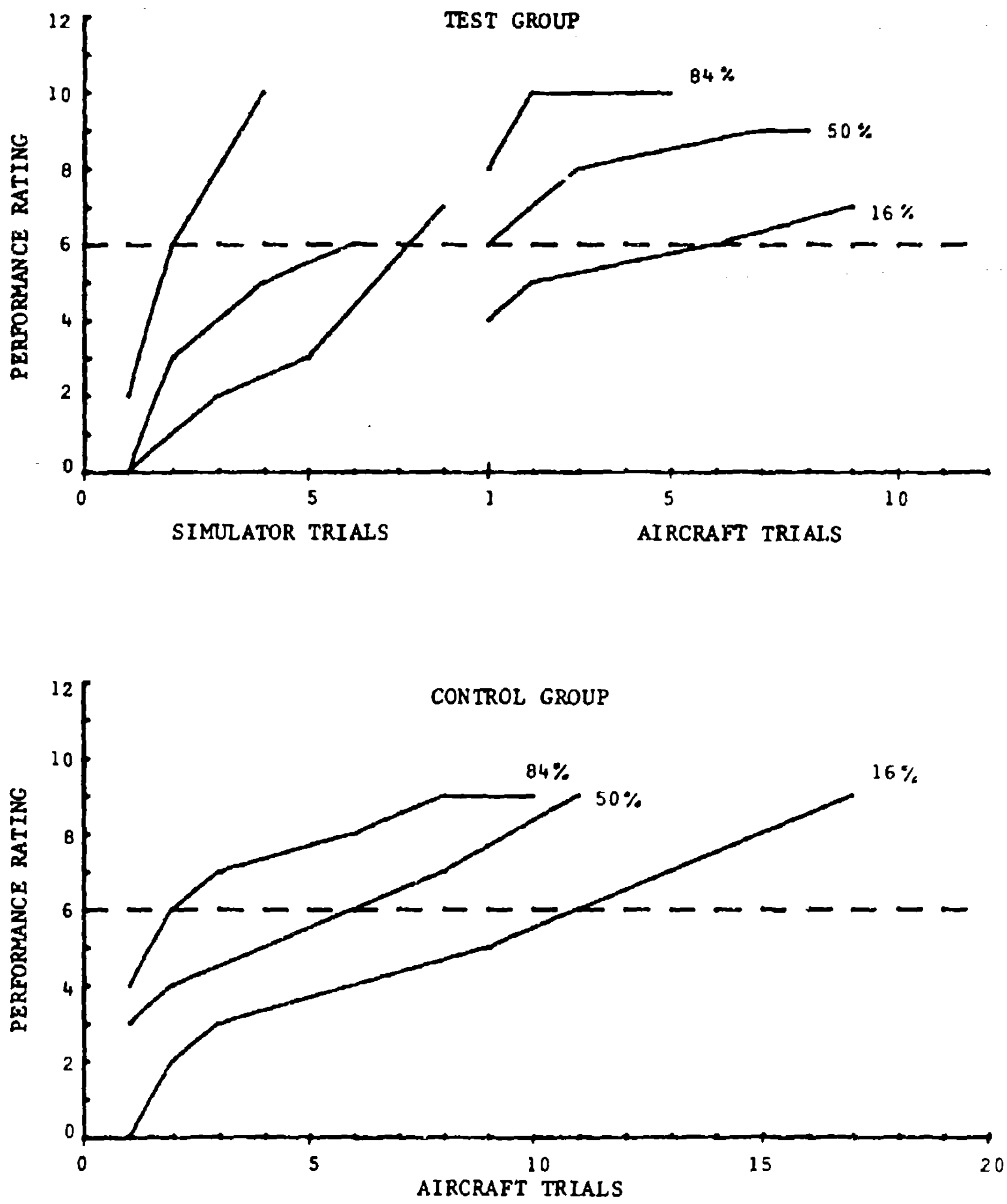


Figure 16. Learning curves for SAS Off Flight.

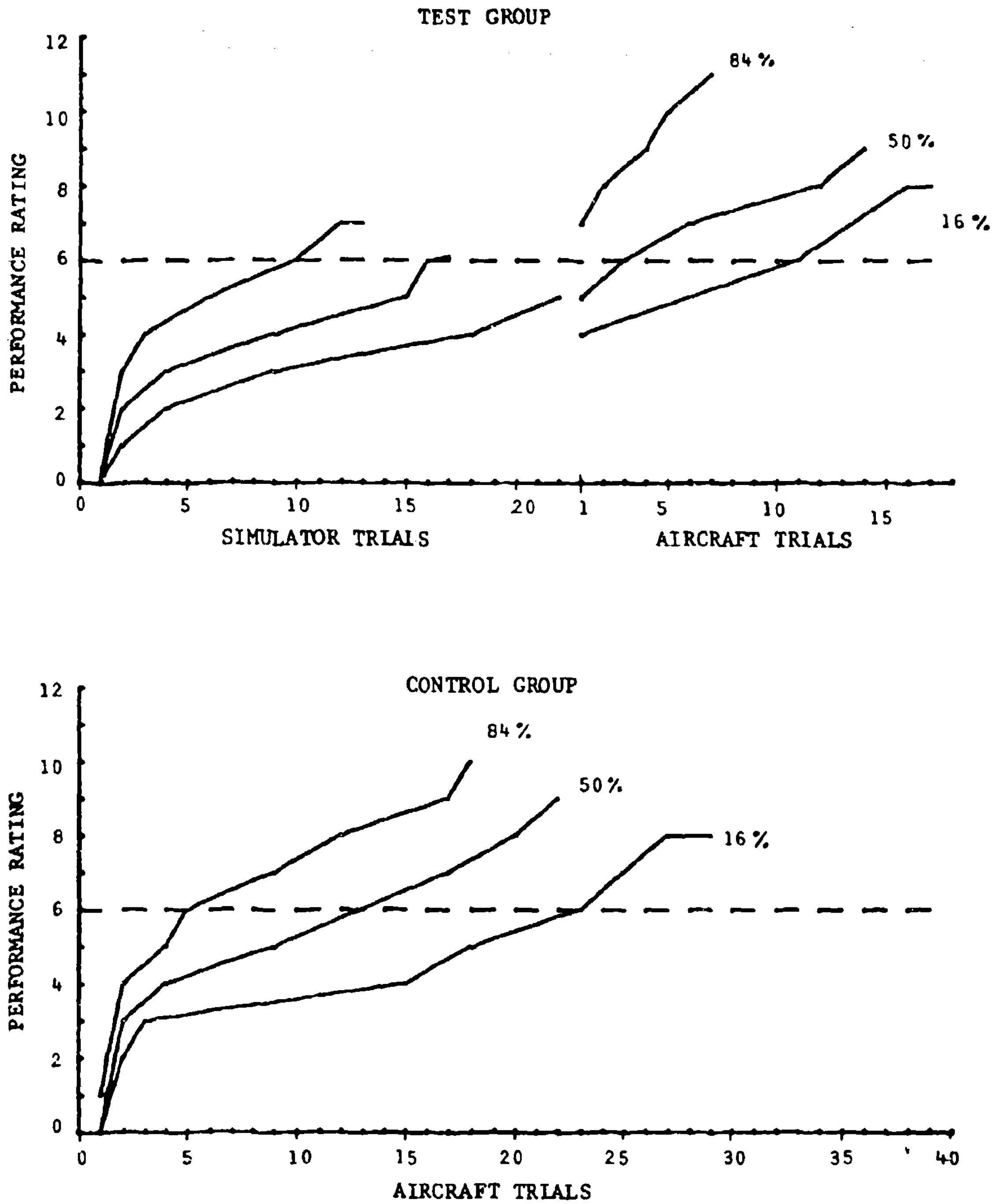


Figure 17. Learning curves for Normal Approach.

Maximum Takeoff

The learning curves for maximum takeoff in Figure 18 indicate that this maneuver was learned more quickly in the simulator, but that there was some decrement in performance when transferred to the aircraft. The net result is a trials-to-criterion CTER of 1.25 and a time-to-criterion CTER of 1.24. The low total time CTER of .69 is due to overtraining in the aircraft. It is believed that the training transfer of the maximum takeoff is greater than that of the normal takeoff because the maximum takeoff is more a procedural maneuver that depends less on external visual cues for a prolonged period while close to the ground.

Steep Approach

The steep approach is another example of good transfer of training from a training device to the actual situation. The learning curves in Figure 19 show that it is slightly more difficult to learn this maneuver in the simulator, and that when transferred to the aircraft there is a small decrement in performance followed by a rapid improvement. The trials-to-criterion CTER is 1.00; the time-to-criterion CTER, .98; and the total time CTER, .80.

Shallow Approach

The learning curves for shallow approach in Figure 20 are similar to those for the hovering maneuvers. The shallow approach requires more training in the simulator and transfers to the aircraft with a decrement in performance. The trials-to-criterion CTER is .58; the time-to-criterion CTER, .60; and the total time CTER, .33. The difference in training transfer observed between the shallow approach and the steep approach is attributed to the longer time spent near the ground in the shallow approach. When near the ground, the importance of the visual system field of view and focus is close to that required for the hovering maneuvers.

Confined Area Reconnaissance

In the opinion of the IPs, it is difficult to perform a confined area reconnaissance in the simulator because of the lack of side vision capability. Because of this difficulty, the IPs did not attempt to teach this maneuver to 8 of the 24 subjects in the simulator. Despite this difficulty, the learning curves in Figure 21 indicate improved performance with practice and strong transfer to the aircraft. The trials-to-criterion CTER is 1.00; the time-to-criterion CTER, 1.59; and the total time CTER, .80. The higher time-to-criterion CTER is due to less time per trial being used in the simulator. With no side vision, the maneuver was a simple overflight at low altitude, requiring

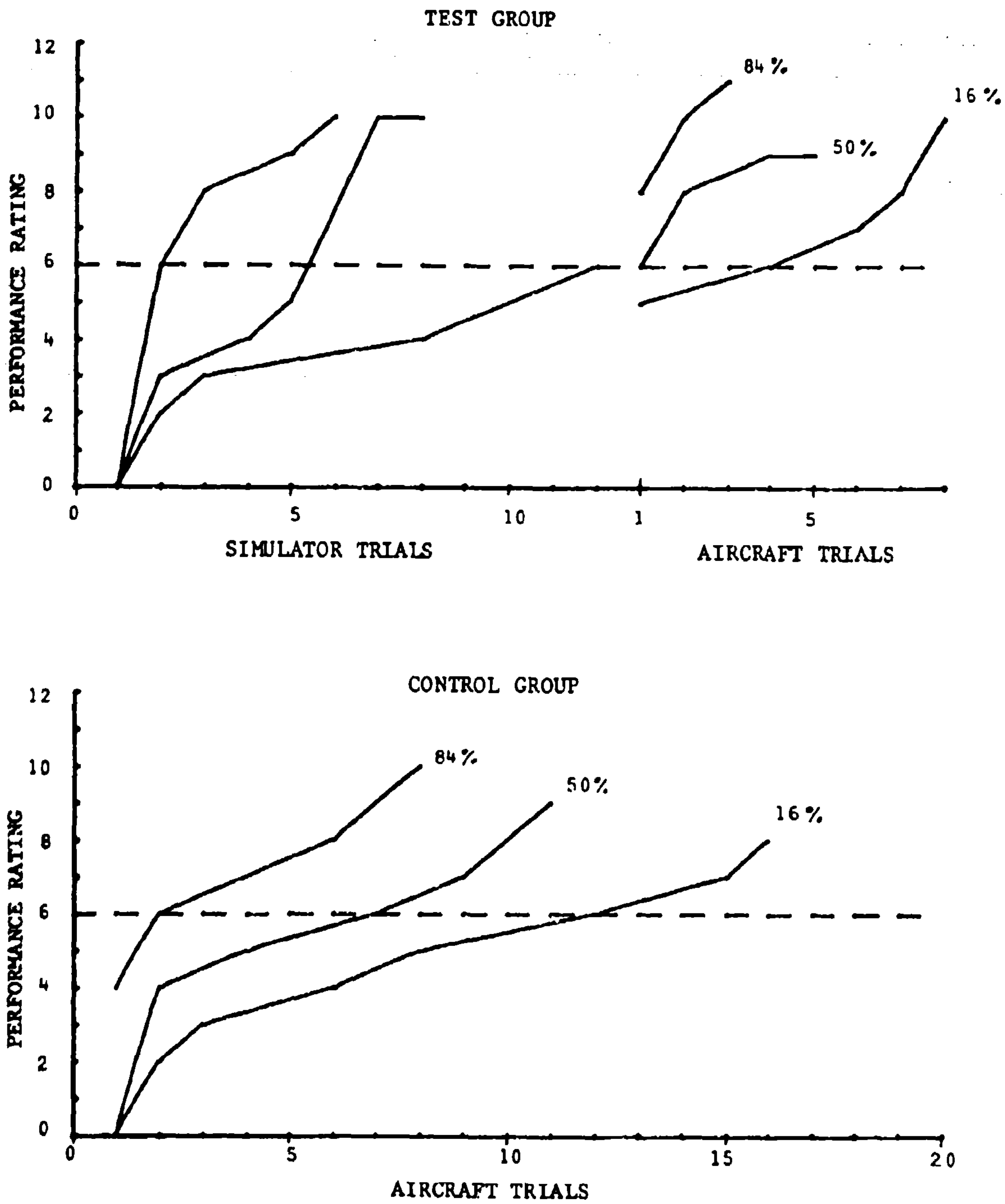


Figure 18. Learning curves for Maximum Takeoff.

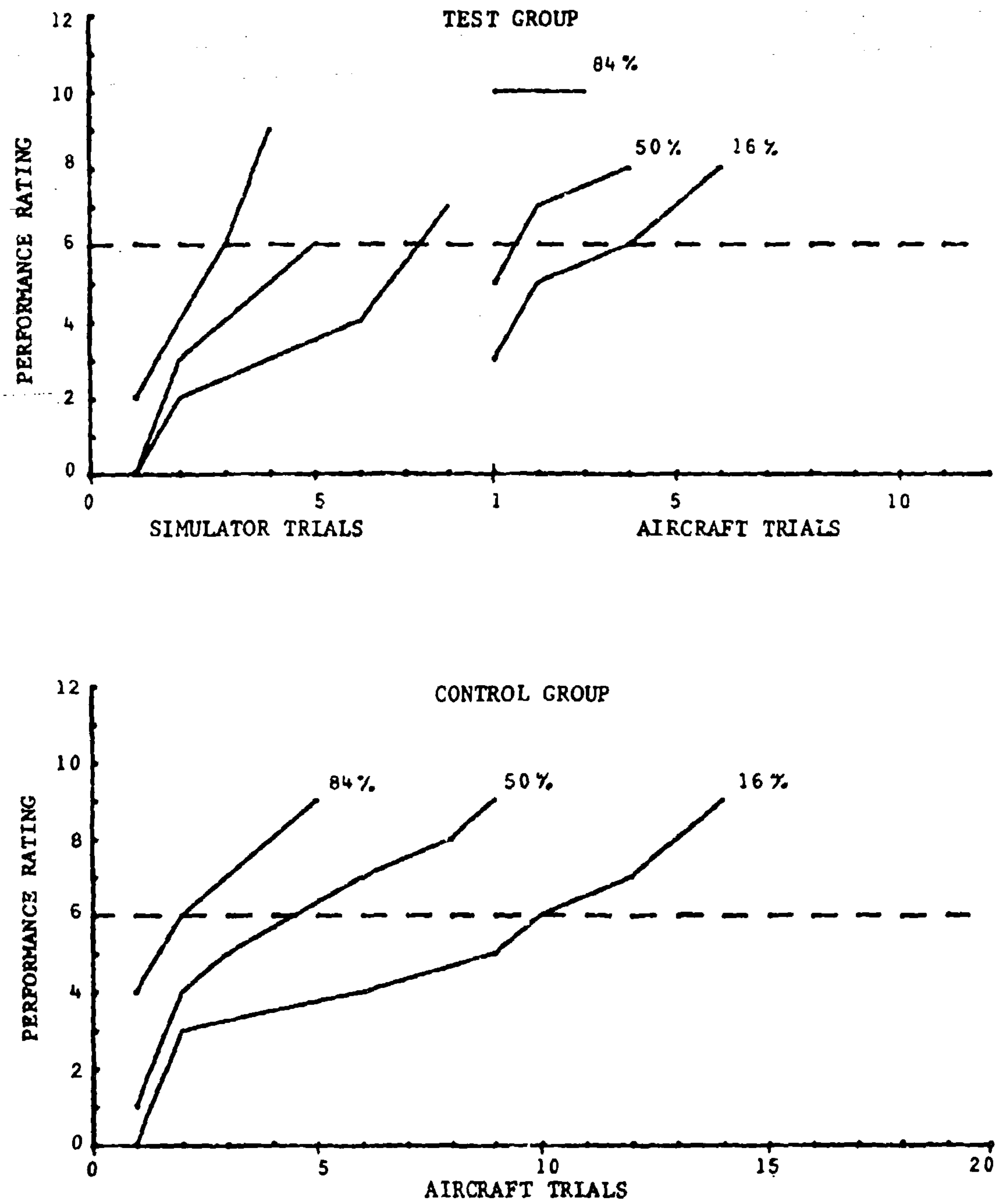


Figure 19. Learning curves for Steep Approach .

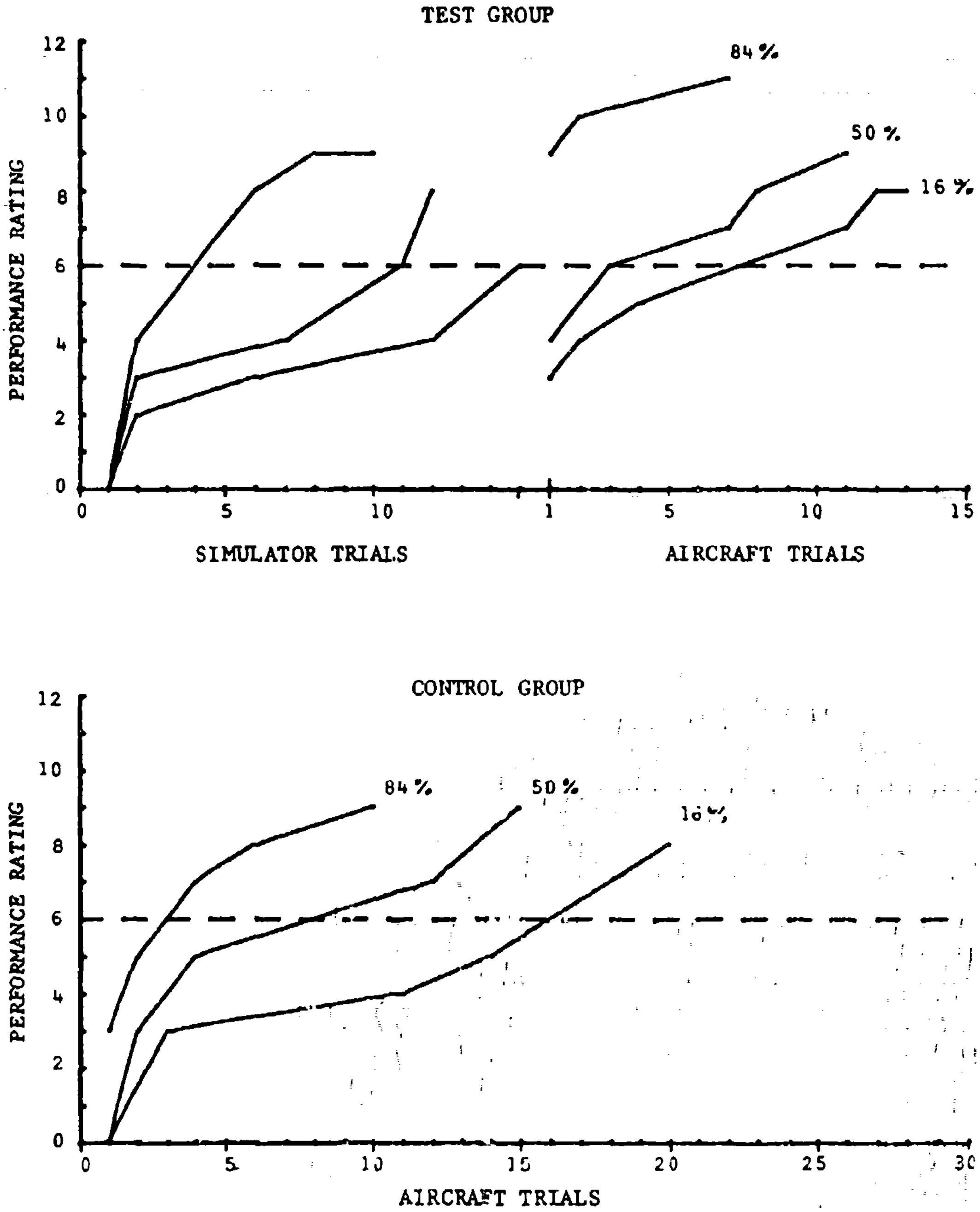


Figure 20. Learning curves for Shallow Approach.

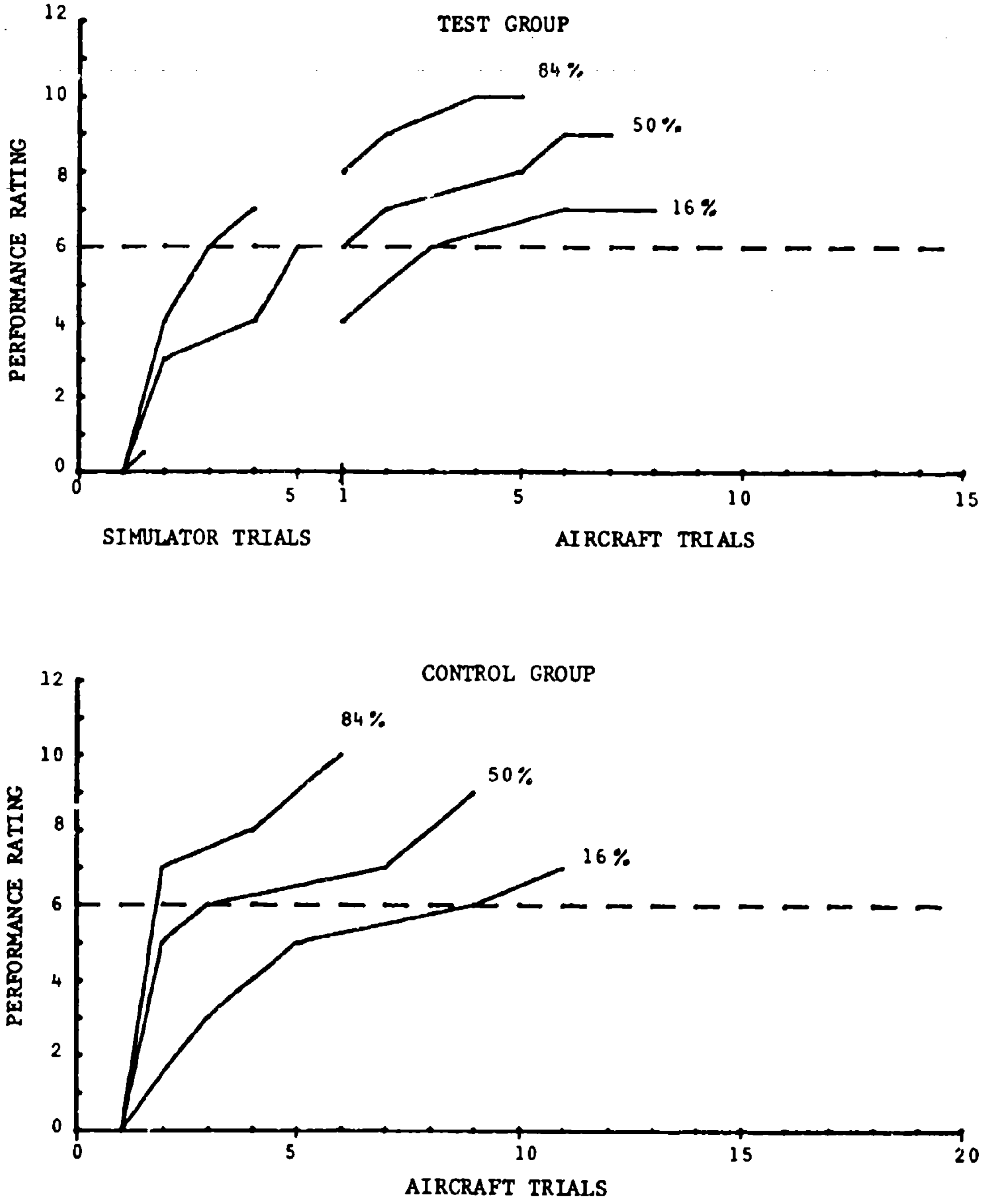


Figure 21. Learning curves for Confined Area Reconnaissance.

an average of only 3.7 minutes compared to 5.2 minutes for the control group.

Confined Area Approach and Landing

The confined area approach and landing was another maneuver the IPs believed to be too difficult to do in the simulator to result in effective training. Although all the simulator students practiced this maneuver, most did not get enough training to reach criterion. The learning curves for confined area approach and landing in Figure 22 reflect this and also show that both groups learned the maneuver rapidly in the aircraft. This being the case, there is doubt that the simulator had any training effect at all. The trials-to-criterion CTER is .75; the time-to-criterion CTER, .25; and the total time CTER, -.23.

It is not clear which aspect of the simulator is responsible for this difficulty. It could be either the visual system, as is suspected in hovering maneuvers (as the last stage of the confined area landing is), or the simulation of the confined area itself. The time-to-criterion CTER is much lower than the trials-to-criterion CTER because extra time per trial was spent in the simulator. A short circling approach is used in the aircraft, whereas in the simulator a long straight-in approach is required because of the lack of side vision.

Confined Area Takeoff

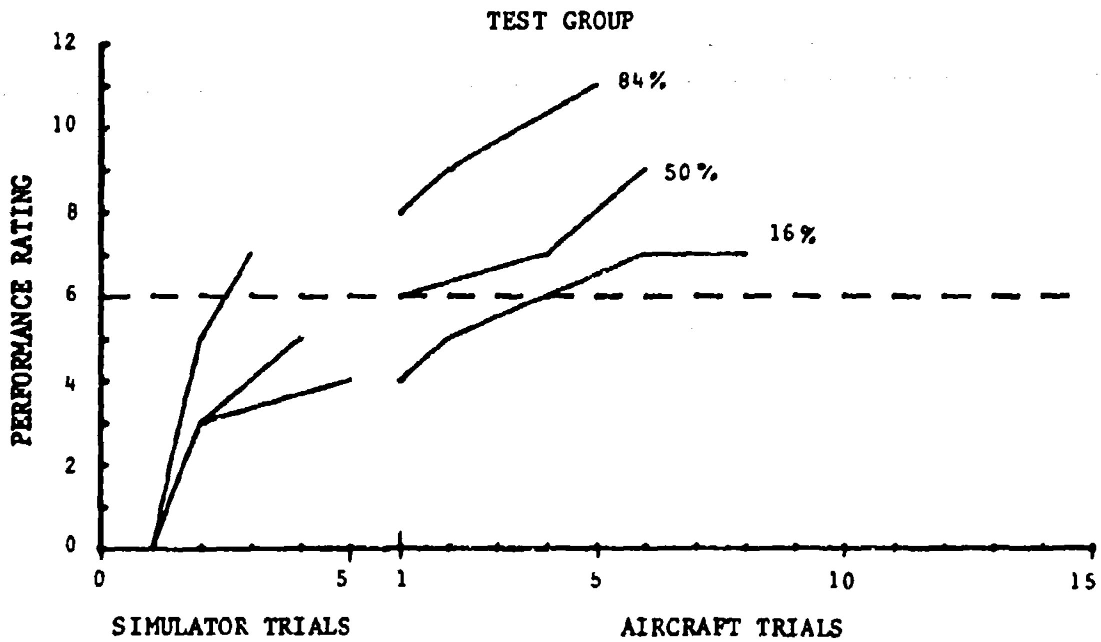
The learning curves for this maneuver in Figure 23 indicate that it, like the preceding two maneuvers, is learned quickly. The trials-to-criterion CTER of .50, the time-to-criterion CTER of .63, and the total time CTER of .33 are also difficult to interpret.

External Load Briefing and Check

The learning curves for external load briefing and check in Figure 24 indicate that this maneuver is quickly learned in both the simulator and the aircraft. The trials-to-criterion CTER is .67; the time-to-criterion CTER, .92; and the total time criterion, .58. The higher time-to-criterion CTER is due to the time efficiency of the simulator, and the lower total time CTER is due to overtraining in the aircraft.

External Load Takeoff and Flight

The learning curves for external load takeoff and flight in Figure 25 indicate that this maneuver is more difficult to learn in the simulator than in the aircraft. The difficulty is probably due to the general problem associated with all hovering maneuvers. The



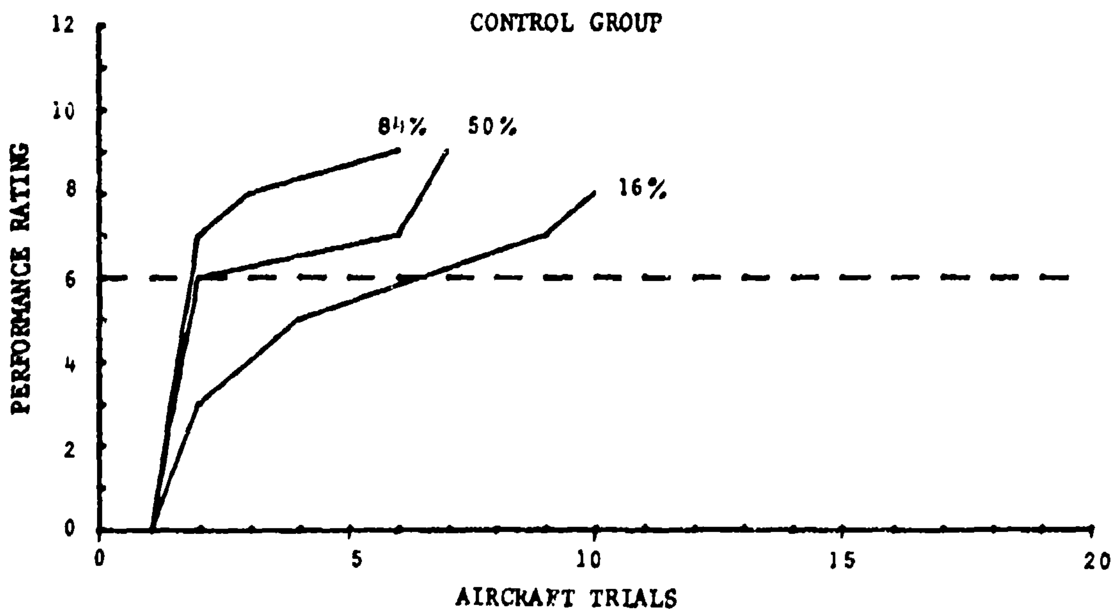


Figure 22. Learning curves for Confined Area Approach and Landing.

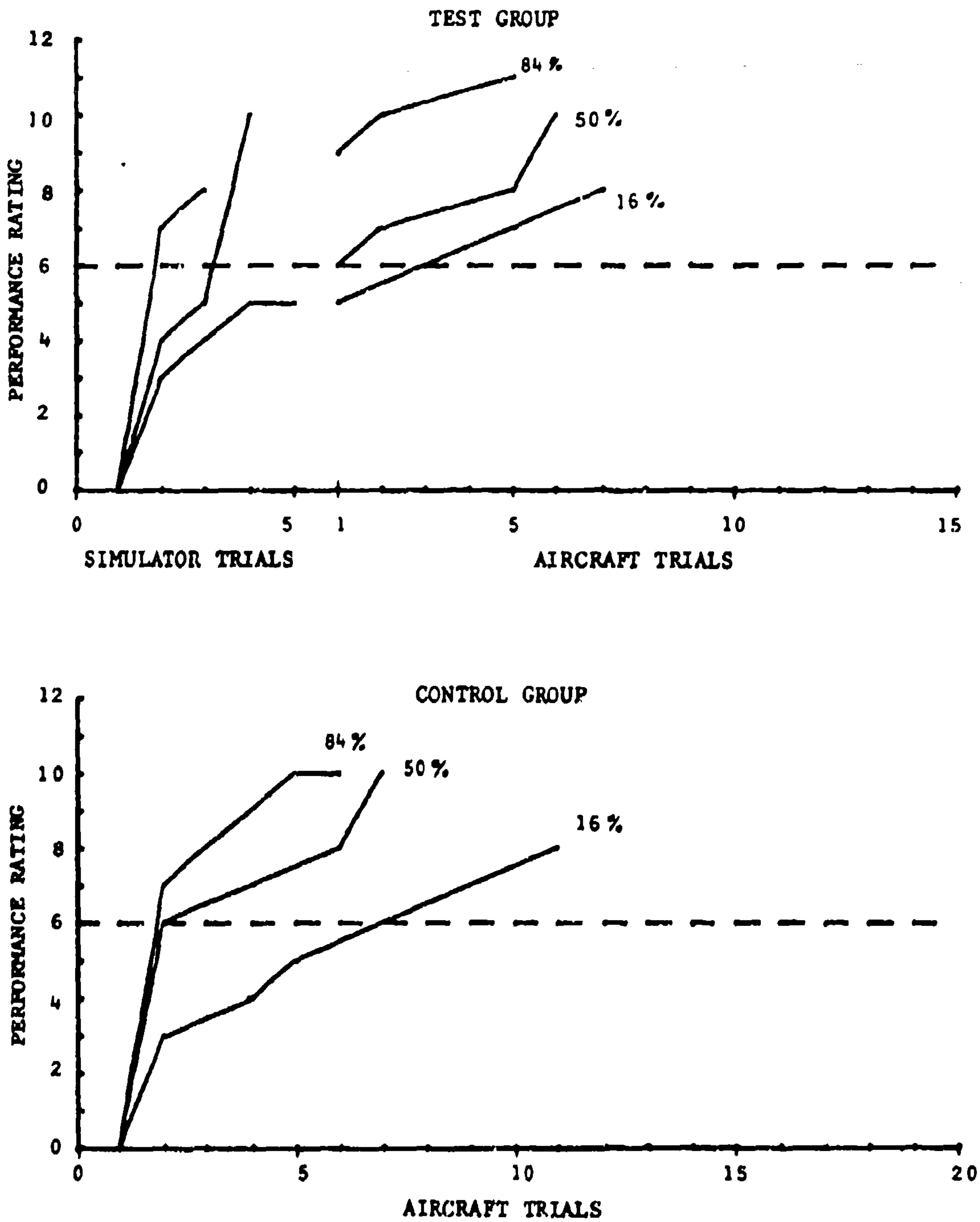
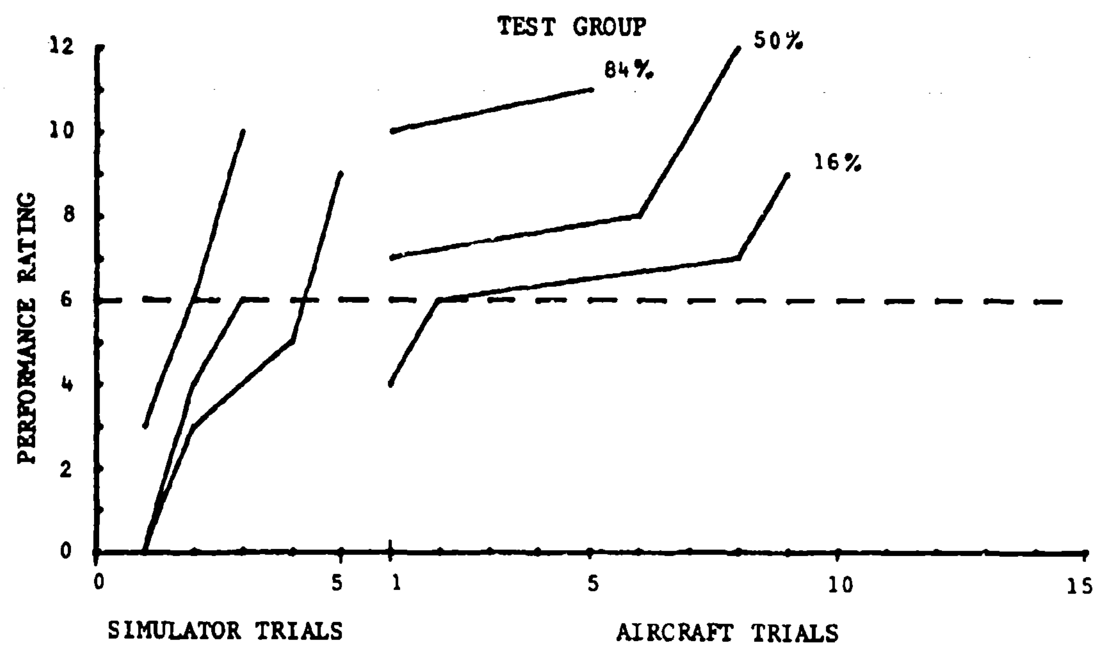


Figure 23. Learning curves for Confined Area Takeoff.



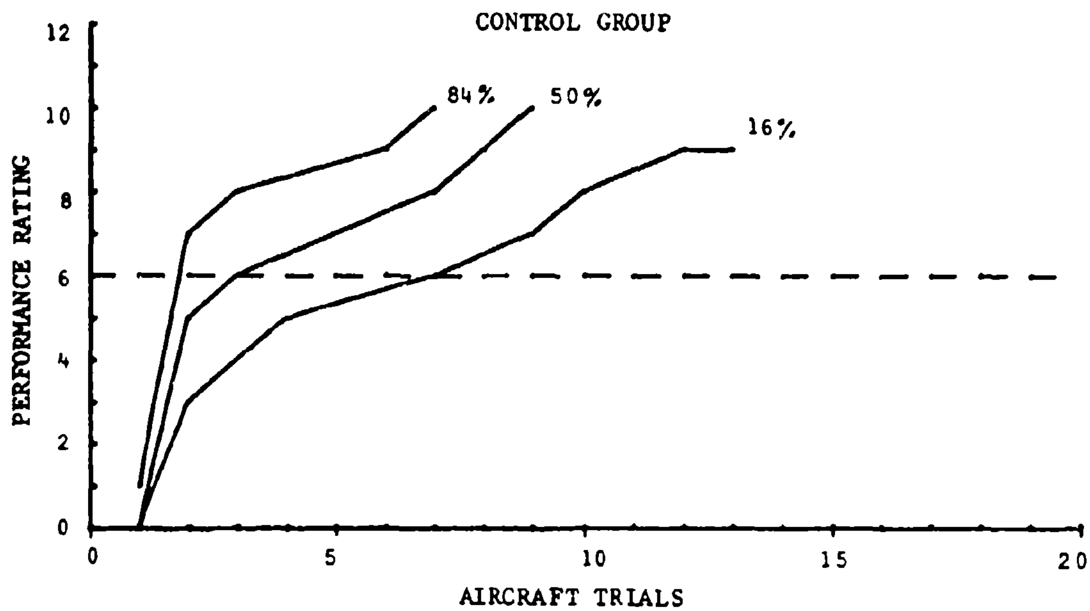


Figure 24. Learning curves for External Load Briefing and Check.

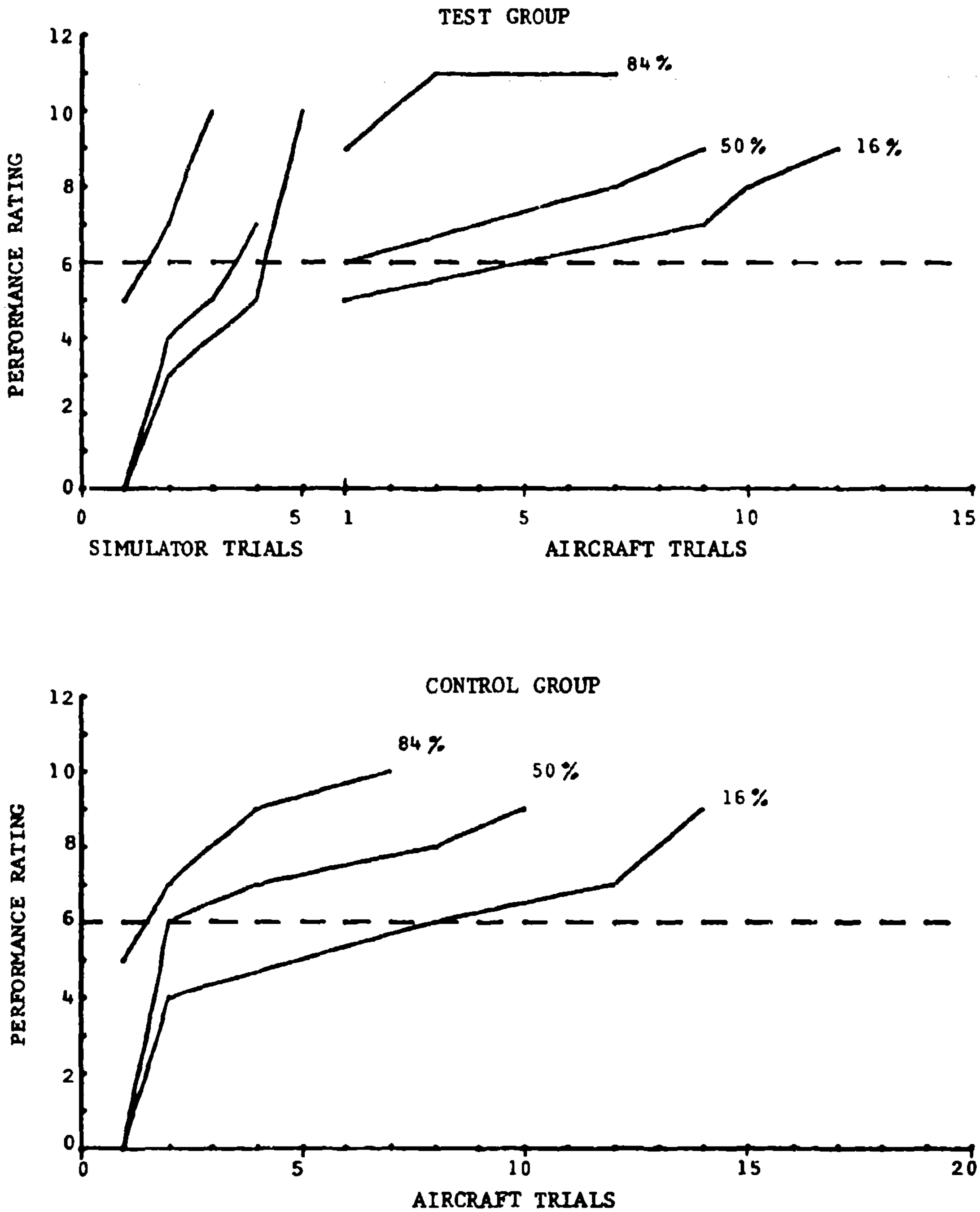


Figure 25. Learning curves for External Load Takeoff and Flight.

trials-to-criterion CTER of .50 is similar to the CTERs for other hovering maneuvers. The time-to-criterion CTER is 1.66, and the total time CTER is 1.62. The former is due to the time efficiency of the simulator, and the latter to less time spent per trial in practicing this maneuver.

External Load Approach and Landing

The learning curves for external load approach and landing in Figure 26 are almost identical to those for takeoff and flight. The trials-to-criterion and total time CTERs are each .50, and the time-to-criterion CTER is .76. Again, the problems seen here are those seen in other hovering maneuvers.

Pinnacle Reconnaissance

The IPs believed that the limited visual field of the simulator precluded any effective training of pinnacle reconnaissance. Therefore, 4 of the 24 students in the simulator group were not trained on this maneuver in the simulator. However, the learning curves in Figure 27 do not support the IPs' belief, but indicate that the maneuver is quickly learned in both the simulator and the aircraft. As was the case with the confined area approach and landing, which was learned in very few trials, it is difficult to determine the actual training effectiveness of the simulator. The trials-to-criterion CTER is .50; the time-to-criterion CTER, .71; and the total time CTER, .09. The very low total time CTER is due to overtraining in the aircraft.

Pinnacle Approach and Landing

The learning curves for pinnacle approach and landing in Figure 28 are similar to those for the pinnacle reconnaissance in that the maneuver is learned quickly in both simulator and aircraft. As in the hovering maneuvers, the simulator students were handicapped visually at the end of the approach. The trials-to-criterion CTER is .0; the time-to-criterion CTER, -.28; and the total time CTER, -.43. This is the only maneuver with a trials-to-criterion CTER of .0. Even though the maneuver was learned quickly in the simulator, the maneuver still took as many trials to reach performance level 8 in the aircraft as it did when trained in the aircraft alone. The lower time-to-criterion and total time CTERs are due to the longer average time spent by the experimental group on each simulator and aircraft trial.

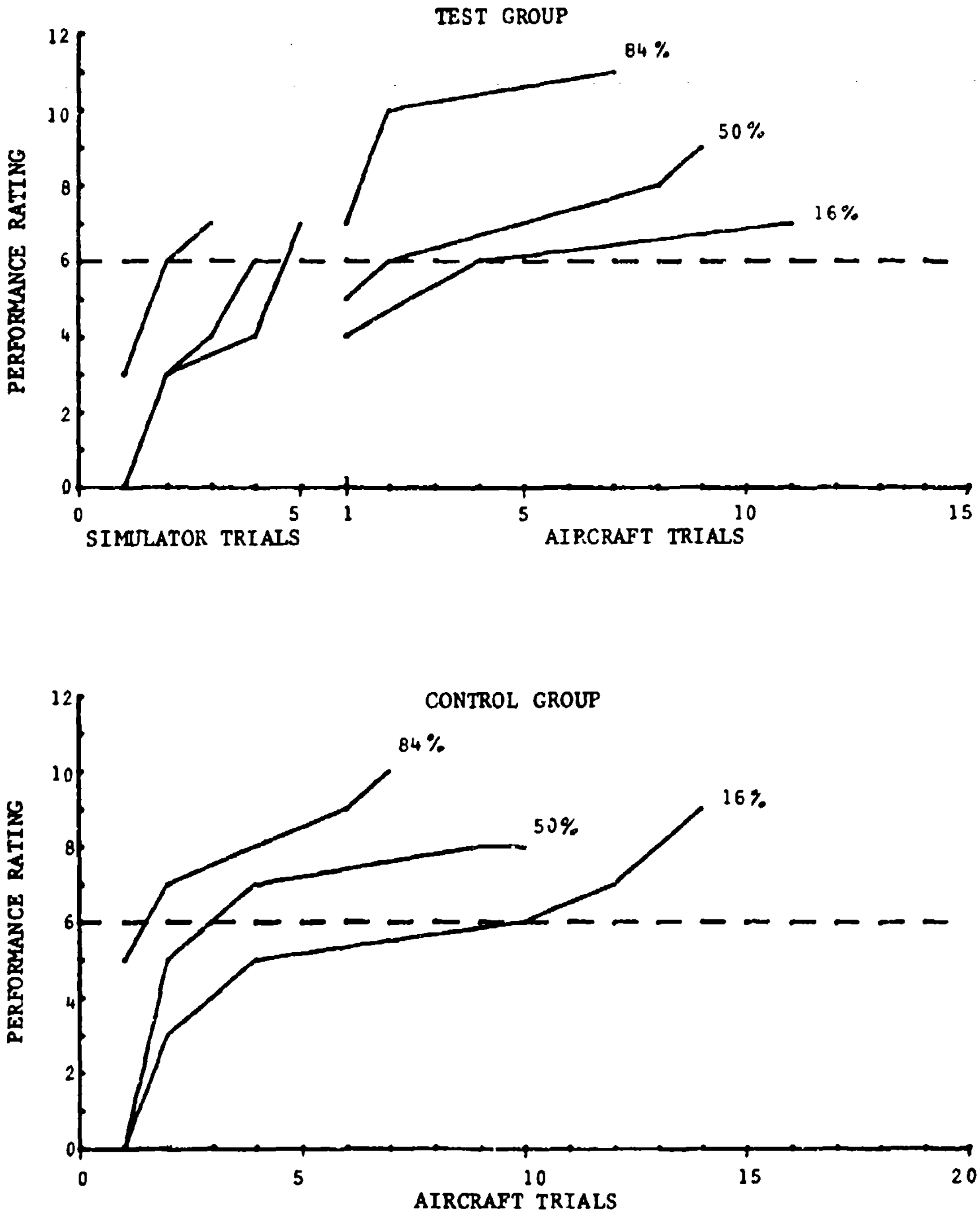


Figure 26. Learning curves for External Load Approach and Landing.

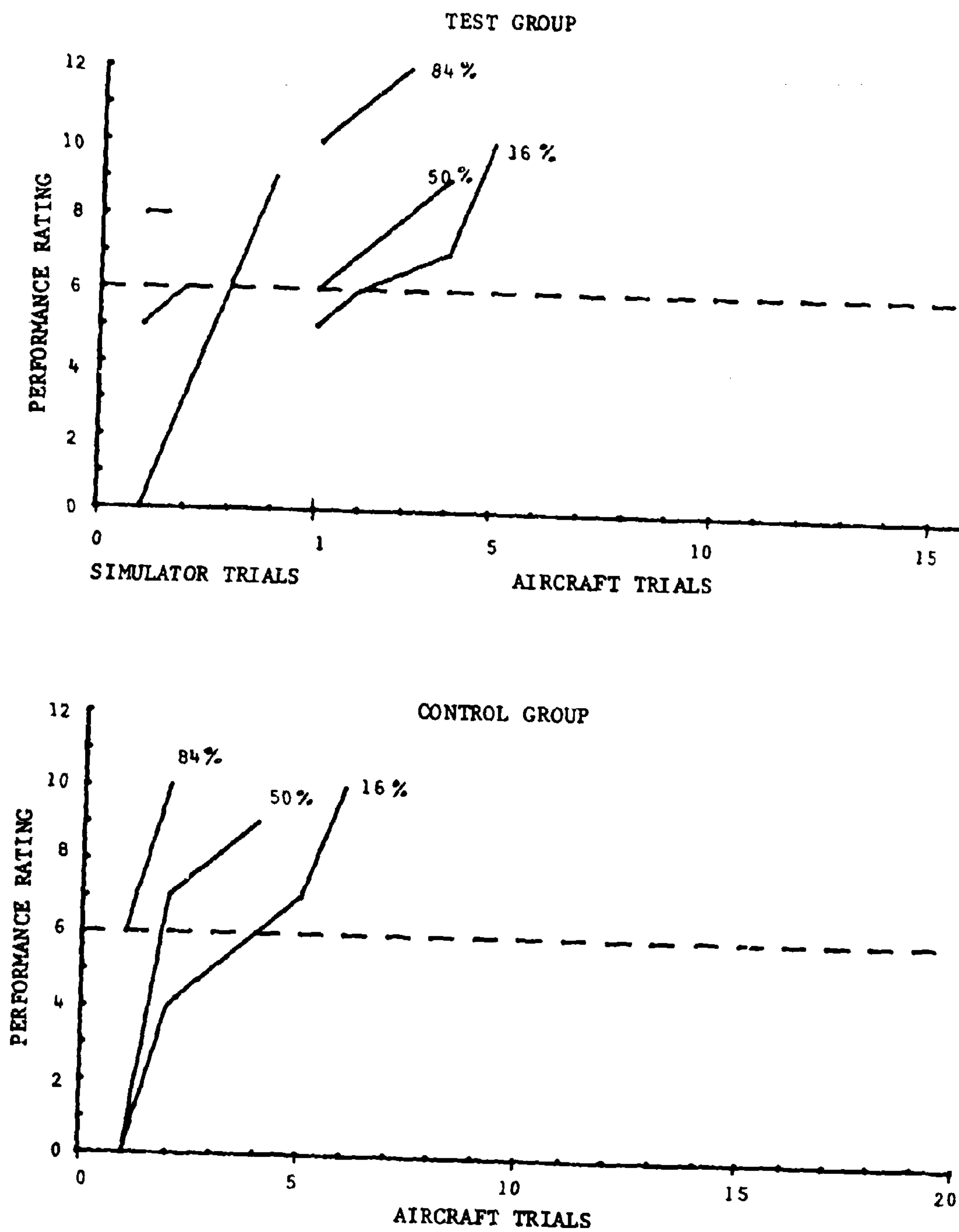


Figure 27. Learning curves for Pinnacle Reconnaissance.

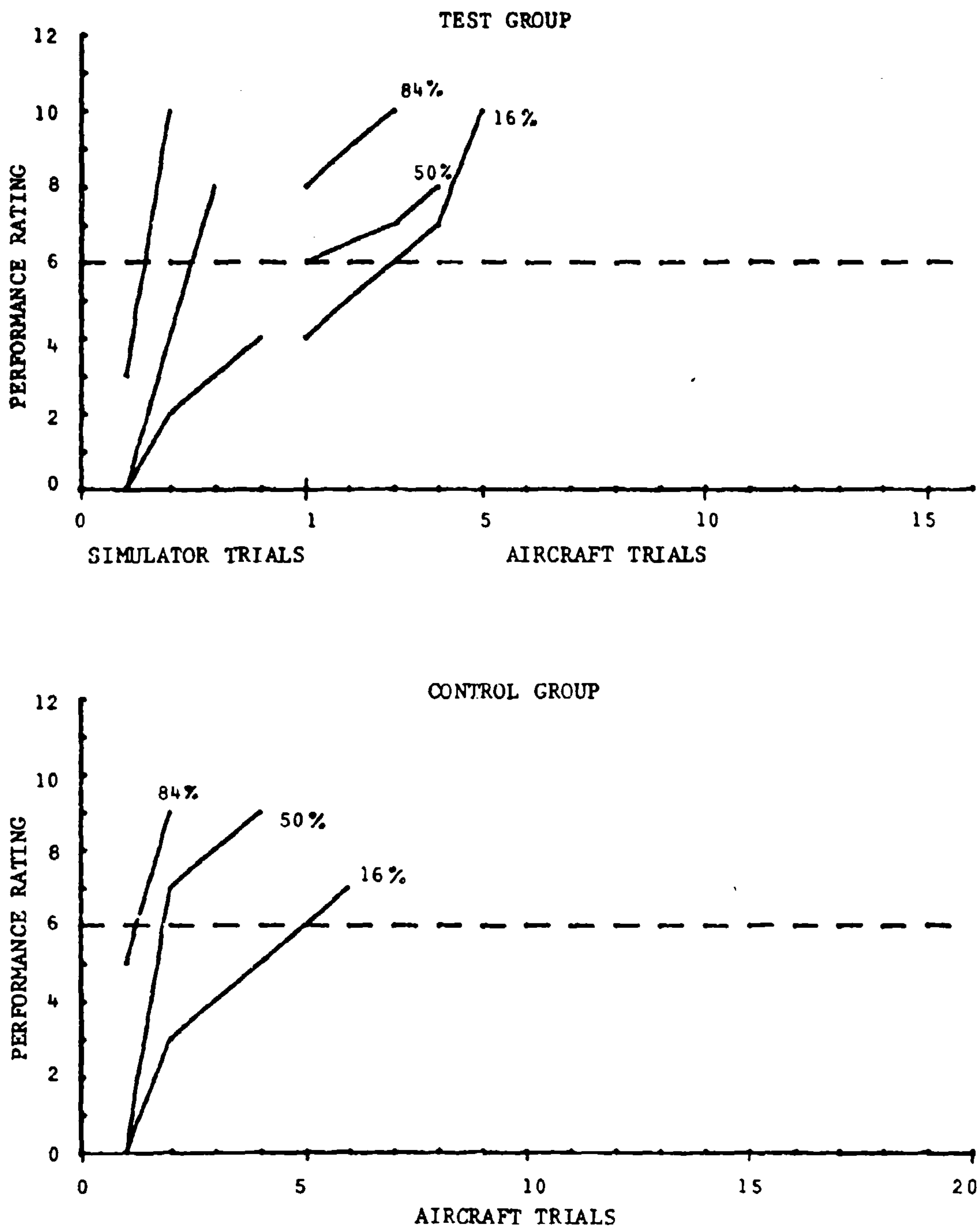


Figure 28. Learning curves for Pinnacle Approach and Landing.

Pinnacle Takeoff

The learning curves for pinnacle takeoff in Figure 29 show this to be another maneuver easily learned in both the simulator and the aircraft. The trials-to-criterion CTER is .33, and the time-to-criterion CTER is .26. The low total time CTER, .06, is due to overtraining in the aircraft.

Overall CTERs

The overall CTERs were computed by using the sums of the individual numbers of trials or time for each criterion or total time column. These CTERs express, for each method of computation, the training effectiveness of the CH47FS if used in a training program, including all of the tested maneuvers listed in Table 1. All of the overall CTERs are conservative because of overtraining.

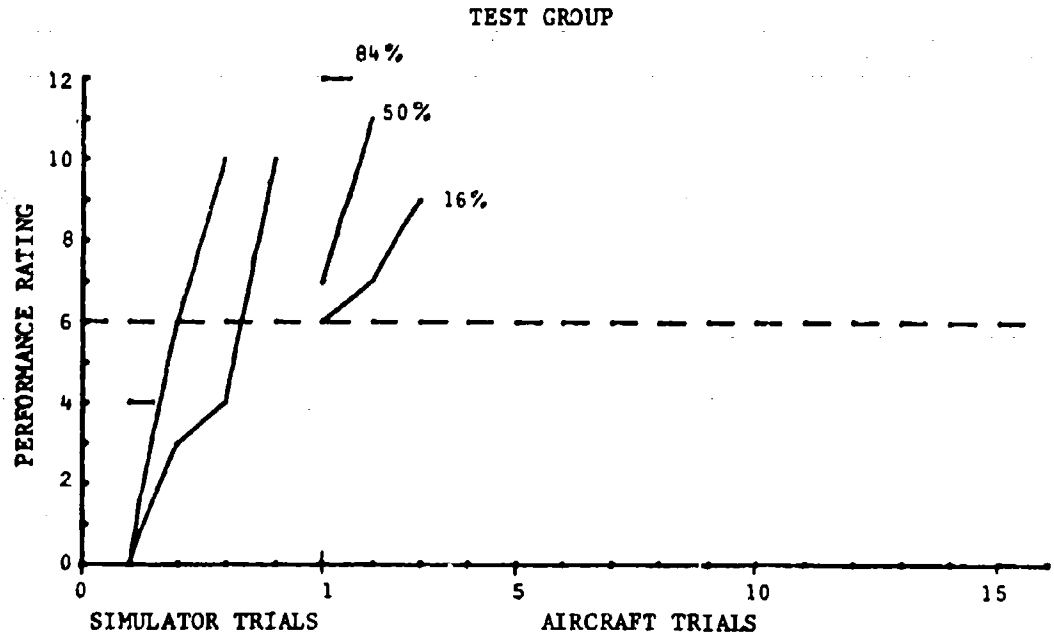
The trials-to-criterion 8 CTER is higher than the trials-to-criterion 6 CTER due to the effect of overtraining on the trials-to-criterion 6 CTER. The time-to-criterion 8 CTER is higher than the trials-to-criterion 8 CTER because of the general time advantage of the simulator over the aircraft. The total time CTER is lower than the time-to-criterion 8 CTER due to overtraining. This comparison points out the desirability of training to a specific performance criterion rather than to a time schedule.

Autorotation

It was planned to evaluate the training transfer of normal autorotations as one of the maneuvers in this study. However, the IPs found autorotations very difficult to perform in the simulator and exposed only 8 of the 24 simulator students to the maneuver. In the aircraft 23 of the 24 simulator students were exposed to an autorotation. In the control group only 25 of the 35 students saw an autorotation. The data are too sketchy to draw conclusions. The IPs suggest that the problem in performing autorotations in the simulator is the same problem that makes the hovering maneuvers difficult--limitations in the visual system. The IPs say that at the end of the autorotation, it is essential that speed, altitude, and rate of closure be determined visually, and that this is impossible in the simulator.

Night Training

The CH47FS was designed to train in three simulated conditions of light: full daylight, dusk, and night. The CH-47 COI calls for training at night, and it was planned to conduct this training in the simulator. However, the instructor pilots and test directors judged the simulation of the night environment inadequate for training, and no night training was attempted.



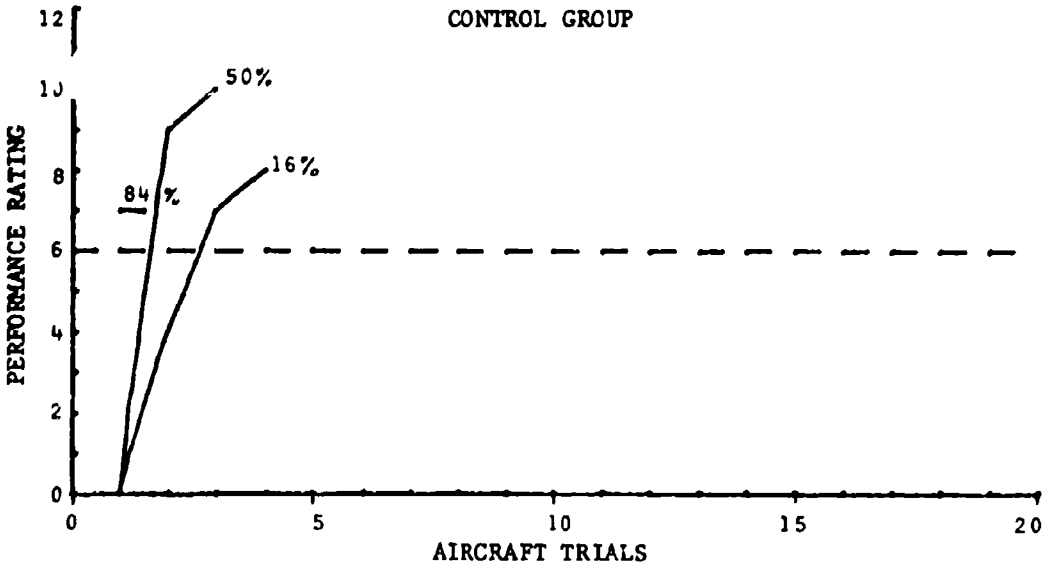


Figure 29. Learning curves for Pinnacle Takeoff.

The night scene was excessively dark and void of contrast to simulate a moonlit night. High contrast features such as light fields with a dark forested background could not be discerned. In addition, cultural lighting and stagefield lighting were not bright enough to be detected at distances suitable for orientation or during an approach to landing. Likewise, the visual scene from ground or hover levels was too dark to perform hovering and external load maneuvers.

Aircraft Qualification Checkrides

Tables 2 and 3 present aircraft qualification checkride scores. There were no significant differences between groups on overall scores or on individual maneuvers. This was expected because the instructors trained the students in the aircraft until the students were prepared to take the final checkride. The exact maneuvers performed in the final checkrides varied from student to student due to limitations in the time available for the test. Table 3 was based upon those maneuvers required of 85% or more of the students.

PART II
COMBAT READINESS FLYING

Method

The objective of this evaluation was to determine experimentally the extent that combat readiness flying skills trained in the CH47FS can be maintained and transferred to the aircraft. The determination was made on the basis of individual maneuvers or tasks performed in both the CH47FS and the aircraft. Such an experimental analysis of the maintenance of proficiency will provide information for decisions concerning improvements in the simulator, improvement of any training program in which the simulator is a part, and a determination of cost effectiveness of the simulator in a combat readiness flying training program.

The method used followed a pretest-train-posttest paradigm. The subject aviators were given an extensive flight test at the beginning of the program, then trained in the CH47FS periodically for 6 months in addition to essential aircraft flying, and then given another flight test. A similar group was given both tests and flew the aircraft, but did not receive CH47FS training.

Subjects

The subjects for this experiment were 32 FORSCOM aviators qualified in and currently flying the CH-47. Sixteen of the aviators comprised the experimental group that received simulator training; the other 16 aviators were the control group. These aviators were selected from two FORSCOM posts, with an equal number of experimental and control subjects coming from each post. The test directors did not have the opportunity to match the experimental and control groups. Company commanders selected the subjects for each group based on unknown criteria.

Independent Variables

The independent variable in this study was the use of the CH47FS in a combat readiness flying (CRF) training program. The 16 control aviators were requested to limit their flying during the 6-month test period to mission-essential flying. Mission-essential flying was defined as flight in a CH-47 essential to the support mission of the unit. They were specifically requested not to fly for training purposes nor to fly other aircraft or flight simulators. These aviators were exempted from meeting required flight hours and from taking required flight tests for the duration of the study.

The 16 experimental aviators were treated the same as the control aviators except that each of these test aviators received 30 hours of training in the CH47FS during the 6-month test period. The training was given in 5-hour blocks once every 4 weeks over 6 of the 4-week cycles. The FORSCOM training representative designed the training program to meet FORSCOM needs. (See Appendix A for the FORSCOM training program.) In addition to receiving 30 hours of direct instruction as pilot, each aviator was exposed to the simulator as copilot for approximately 26 hours while another aviator received the direct pilot training.

Performance Measures

The performance measures used in this evaluation were the ratings given each maneuver performed on the pretraining and posttraining checkrides. These performance ratings were done on the same 12-point scale used in Part I. In addition to checkride ratings, the experimental group was rated on each maneuver practiced in the CH47FS as were the subjects of Part I. Both the experimental and control groups were asked to record all mission-essential flying done in the CH-47 during the test period.

Operational Procedures

The pretest inflight checkrides were administered to all subjects at the beginning of the 6-month study period by their unit standardization pilots under the supervision of the test directors. These data were collected at the field sites and brought to Fort Rucker for analysis. At this point, all subjects began to fly only mission-essential flights and to record their flight experiences.

The aviators chosen to receive training in the simulator came to Fort Rucker every 4 weeks. They trained in the CH47FS in pairs, two pairs per week, for approximately 6 months. Two FORSCOM instructor pilots trained to operate and teach in the simulator by the simulator manufacturer conducted the training. The FORSCOM training representative designed the training program.

Each subject received 5 hours of pilot training in the CH47FS every 4 weeks for a total of 30 hours of training. Throughout the training the IPs recorded the subjects' performance on each maneuver as was done in Part I.

At the completion of training all subjects, control and simulator trained, were given a second checkride identical to the first. Again, these checkrides were supervised by the test directors, and the data were returned to Fort Rucker for analysis. At this time the mission-essential flying records were also sent to Fort Rucker.

PART II
RESULTS AND DISCUSSION

Data presented here are for an experimental group of 15 aviators and a control group of 13 aviators, rather than for groups of 16 each. Military and personal needs required 4 subjects to terminate their participation before taking the posttraining flight test.

During the 6-month test period the simulator group trained in the CH47FS for a mean time of 29.7 hours and participated as copilots for a mean time of 26.4 hours. The mean CH-47 aircraft time for this group was 45.2 hours and for the control group, 58.0 hours. This difference was not statistically significant ($t(26) = 0.27$, $p > .5$).

Overall Test Scores

The flight test scores were transformed by a procedure described by Hays (1967) to weight the score for each maneuver by an estimate of its difficulty. The mean of the simulator group's pretest scores, 47.5, and the mean of the control group's pretest scores, 52.5, were significantly different ($t(26) = 2.3$, $p < .05$). The posttest mean score for the simulator group was 56.7, and for the control group, 53.7, not a significant difference ($t(26) = 1.0$, $p < .4$). The difference between the control group's pretest and posttest scores (52.5 and 53.7) was also not significant ($t(12) = .98$, $p > .5$). The difference between the simulator group's pretest and posttest scores (47.5 and 56.7) was significant ($t(14) = 6.8$, $p < .002$). Table 4 summarizes these data.

Table 4

MEANS AND t-TESTS OF PRETEST AND POSTTEST CHECKRIDE SCORES FOR EXPERIMENTAL AND CONTROL GROUPS

Group	Checkride Pre	Checkride Post	t	df	p
Experimental	47.5	56.7	6.8	14	<.002
Control	52.5	53.7	.98	12	>.5
t	2.3	1.0			
df	26.0	26.0			
p	<.05	<.4			

Of the significant differences found among the overall flight test scores, the pretest and posttest scores of the simulator-trained group were of primary interest. This result indicated that the simulator-trained group improved its performance in flight in the CH-47 as a result of training in the CH47FS. The control group's performance neither improved nor worsened over the 6-month test period. The CH-47 mission-essential flying during the evaluation period maintained this group's flying skill.

The correlation between the aviators' CH-47 flight time during the 6 months of the evaluation and the posttest scores was .12 ($r(27) = .12$) and was not significant. The insignificant correlation between CH-47 flight time during the evaluation period and the posttest checkride scores means that the improvement in performance of the simulator-trained aviators was due to their training and not to experience in the aircraft.

The correlation between the aviators' CH-47 flight time 60 days prior to the pretest and the pretest scores was .37 ($r(27) = .37$, $p < .025$) and was statistically significant. Table 4 shows that the control group scored 6 points higher on the pretest. It is believed that this difference was due to differences in the recent flight experience of the aviators assigned to the control and experimental groups. Those aviators assigned to the control group by their commanders had more recent flight time than those assigned to the experimental group. The significant correlation of .37 between the flight times 60 days prior to the pretest and the pretest scores support this explanation.

Maneuver Test Scores

Tables 5 and 6 present the mean ratings of each maneuver for the control and experimental groups. The pretest and posttest means were tested for significant differences with the correlated t test, and the t value and its significance level were also tabled. The significance levels listed are for the two-tailed t test with alpha set at .05. All probabilities above .05 are considered nonsignificant.

Table 5 compares the mean pretest and posttest performances by the control group on each maneuver. Only two of the tested maneuvers showed any significant changes over the 6-month period. The mean flying time of 58 hours in 6 months was sufficient to maintain existing pilot skills, but not enough to increase them.

Table 6 compares the mean pretest and posttest performance by the experimental group on each maneuver. Seventy-four percent of the tested maneuvers showed a significant improvement. The largest group of maneuvers that showed no improvement was external load operations. It is believed that this was due to limitations in the simulator's visual system. Autorotations did not improve either, probably for the same reason.

The results of Part II agree with those of Part I as to which maneuvers are difficult to train in the CH47FS. Even though these maneuvers are difficult to train in the simulator, there is no evidence of negative training on any maneuver tested.

PARTS I AND II
DISCUSSION

Part I on transition training and Part II on combat readiness flying both show that the CH47FS is an effective training device. For many maneuvers Part I indicates that the CH47FS trains as well as or better than the CH-47 aircraft (CTERs $\geq$ 1.0). Another group of maneuvers can be trained in the simulator with minor increases in the amount of practice required. These maneuvers had CTERs less than 1.0 but greater than 0.7. A third group of maneuvers had CTERs below 0.7. However, CTERs in the range of 0.5 to 0.7 do not indicate that this training device is ineffective. Rather, they indicate that the training device is not as efficient in terms of the number of trials required to learn a particular maneuver as is the actual aircraft.

Table 5

FLIGHT TEST SCORES BY MANEUVER FOR THE CONTROL GROUP

Maneuver	Mean Test Scores Pre	Post	t	p<
Cockpit Runup	7.3	7.9	1.2	--
Taxi (4 wheel)	7.1	7.3	1.0	--
Takeoff to Hover	6.3	7.0	0.8	--
Hovering Flight	6.8	6.6	-0.4	--
Normal Takeoff from Hover	6.9	6.9	0.7	--
Traffic Pattern	6.4	6.5	0.2	--
Normal Approach to Hover	6.5	5.8	1.8	--
Landing from Hover	7.2	6.5	-1.5	--
Normal Takeoff from Ground	6.8	6.3	-0.8	--
Normal Approach to Ground	6.4	6.5	0.2	--
Maximum Takeoff	6.8	6.9	0.3	--
Steep Approach	5.7	6.3	1.6	--
Standard Autorotation	6.2	5.8	-0.6	--
Shallow Approach Single Engine	5.9	5.9	0.0	--
Normal Takeoff w/NBC	6.3	6.4	0.2	--
Traffic Pattern w/NBC	6.3	6.5	1.0	--
Normal Approach w/NBC	6.2	6.0	-0.3	--
Maximum Takeoff w/NBC	6.2	6.4	0.5	--
Standard Autorotation w/NBC	6.2	5.5	-1.1	--
External Load Procedures				
Briefing & Hook Check w/NBC	6.1	5.8	-0.7	--
Takeoff & Flight w/NBC	6.3	6.7	1.0	--
Approach & Landing w/NBC	5.8	6.3	1.7	--
Briefing & Hood Check	6.0	6.3	0.6	--
Takeoff & Flight	6.7	6.8	0.2	--
Approach & Landing	6.3	6.5	0.6	--
Instrument Procedures				
Radio Check	7.2	7.9	1.2	--
Straight & Level Flight	6.8	7.5	2.9	.05
Level Turns	6.7	6.8	0.4	--
Straight Climbs & Descents	6.5	7.0	1.0	--
Approach, GCA	6.3	7.0	2.1	--
Taxi (2 wheel)	5.7	6.5	1.9	--
Cockpit Shutdown	6.8	7.8	2.5	.05
Emergency Procedures				
Engine Failure	5.6	6.6	1.8	--
Low Side Governor Failure	5.4	6.2	1.4	--
Transmission Oil Low	6.3	6.8	0.8	--

Table 6

FLIGHT TEST SCORES BY MANEUVER FOR THE SIMULATOR GROUP

Maneuver	Mean Test Scores Pre	Post	t	p<
Cockpit Runup	6.6	7.8	3.1	.01
Taxi (4 wheel)	6.6	7.2	2.6	.02
Takeoff to Hover	6.6	7.5	2.0	.05
Hovering Flight	6.3	7.3	3.1	.01
Normal Takeoff from Hover	6.3	7.7	4.2	.01
Traffic Pattern	5.7	7.0	3.2	.01
Normal Approach to Hover	5.5	6.7	4.6	.01
Landing from Hover	5.7	7.2	5.0	.01
Normal Takeoff from Ground	5.7	7.1	4.0	.01
Normal Approach to Ground	5.5	6.9	3.2	.01
Maximum Takeoff	5.4	6.9	3.7	.01
Steep Approach	5.5	6.6	2.1	.05
Standard Autorotation	5.1	6.3	1.6	---
Shallow Approach Single Engine	5.6	7.5	2.6	.02
Normal Takeoff w/NBC	5.5	6.3	2.2	.05
Traffic Pattern w/NBC	6.1	7.4	4.0	.01
Normal Approach w/NBC	5.1	6.3	4.9	.01
Maximum Takeoff w/NBC	5.5	6.8	3.3	.01
Standard Autorotation w/NBC	5.2	6.1	1.8	---
External Load Procedures				
Briefing & Hook Check w/NBC	5.7	6.4	1.4	---
Takeoff & Flight w/NBC	6.1	6.5	1.2	---
Approach & Landing w/NBC	5.5	6.2	2.0	---
Briefing & Hook Check	5.8	6.3	1.2	---
Takeoff & Flight	6.3	6.9	2.0	---
Approach & Landing	5.5	6.6	3.9	.01
Instrument Procedures				
Radio Check	7.7	7.4	0.6	---
Straight & Level Flight	6.5	7.3	2.17	.05
Level Turns	6.2	7.1	2.4	.05
Straight Climbs & Descents	6.1	7.3	3.5	.01
Approach, GCA	6.5	6.7	0.7	---
Taxi (2 wheel)	5.4	7.2	4.7	.01
Cockpit Shutdown	7.0	8.3	4.4	.01
Emergency Procedures				
Engine Failure	4.9	7.3	3.0	.01
Low Side Governor Failure	4.9	7.1	3.2	.01
Transmission Oil Low	5.7	6.6	2.9	.01

The maneuvers that produced the lower CTERs were all maneuvers in which a substantial part of the maneuver was spent close to the ground, e.g., all hovering maneuvers, shallow approach, external load, and pinnacle operations. In Part II, the FORSCOM aviators did not increase in proficiency on autorotations and external load maneuvers. It is believed that these difficulties that occur close to the ground are due primarily to limitations in the visual systems.

The most obvious limitation in the visual system is the limited field of view (48^{o} x 36^{o}). It seems that many of the visual cues normally used for hovering maneuvers are more than 24^{o} from the centerline of the aircraft or 18^{o} below the horizon. These cues may not be required for hovering maneuvers, as is shown by the fact the aviators did learn to perform them, but are available in the aircraft and do aid performance.

A more subtle limitation in the visual system is the infinity focus CRT display in the cockpit. Through the use of a beam-splitter and a curved mirror, the CRT display is made to cover a 48^{o} visual angle and is focused at infinity. A near object seen in this system does not have all the usual depth cues present to indicate how close the object is to the viewer. Because both eyes see the same scene delivered by the CRT, there is no stereoscopic disparity present. Since the scene is focused at infinity, there is not the appropriate angle of eye convergence or lens accommodation. The result is that near objects appear to be farther away and larger than they should (Gregory, 1973). This discrepancy in depth perception may also be partially responsible for difficulties in hovering and in judging distances properly when close to the ground at the end of a landing approach.

The difficulties in judging depth in the visual display are especially critical in the chin window display. The chin window display presents a checkerboard pattern through an infinity focus CRT display to represent the ground and to provide additional cues during an approach or while hovering. Drift cues are represented by movement of the pattern across the display as if each square of the display was a square on the ground 7 feet on a side. The only depth cue available in the display is the size of the square. None of the expected monocular depth cues such as texture gradients, overlapping of objects, or size of familiar objects are present. As in the main display, there are no cues for stereoscopic disparity, eye convergence, or lens accommodation. This results in difficulties in judging height, rate of closure, and rate of drift. These cues are essential to performing all maneuvers close to the ground, such as the landing approaches and hovering maneuvers found to be difficult to perform in the CH47FS.

Another source of difficulty in performing and training hovering maneuvers could be the aerodynamic simulation of hovering. Experienced CH-47 aviators criticized the simulator on this point as well as on control feel (McGaugh & Holman, 1977). Without further study it is impossible to determine whether or not the hovering aerodynamic equations and/or control dynamics require revision. It is possible that aviators would describe difficulties they have in flying the CH47FS as difficulties in control feel or simulator flight characteristics when the actual problem is in some other system. For example, an aviator might find that he is overcontrolling the simulator and complain that the controls are too sensitive or the simulator is too reactive when the actual problem is a delay in visual feedback caused by lags in the visual system. This is a possibility, because there are noticeable lags in the model board visual system (McGaugh & Holman, 1977).

The source of difficulty could also be in the motion-cueing equations. These equations transform the output of the aerodynamic simulation into control signals that activate the hydraulic motion system. Inadequate motion cueing could also result in problems in hovering and comments about control feel and response.

A second major problem with the CH47FS is its inability to train maneuvers during night conditions. The visual simulation of the night environment is too dark and void of contrast to allow night training. Production models of the CH47FS without adequate night simulation will not meet the training needs of FORSCOM aviators (McGaugh & Holman, 1977).

The CH47FS was not designed to perform water operations, slope operations, internal load procedures, or nap-of-the-earth (NOE) flight. The operational and training requirements of FORSCOM CH-47 aviators have since changed to include NOE flight. Although the prototype CH47FS cannot be faulted for not having an NOE capability, the production models must include it to satisfy the training needs of FORSCOM (McGaugh & Holman, 1977).

RECOMMENDATIONS

It is recommended that the prototype CH47FS located at Fort Rucker be used in the CH-47 Aircraft Qualification Course (AQC). To obtain the maximum benefit from the CH47FS, it is recommended that a minimum of time be spent training the hovering type maneuvers with the low CTERs in the simulator. The limited simulator time should be spent training those maneuvers with the highest transfer to the aircraft. Table 7 presents a proposed outline for the AQC. The flight hours listed in Table 7 should not be used as required training times, but merely as guides for planning. All training should be conducted to a performance criterion to insure maximum efficiency of training in both the CH47FS and the aircraft. The outlined course is based upon the assumptions that each class will consist of 12 students, that the course will remain 7 weeks in length, and that a new class will start midway through each class in residence.

Table 7

RECOMMENDED AIRCRAFT QUALIFICATION COURSE OUTLINE

TRAINING DAY	TRAINING ACTIVITY		PILOT FLIGHT HOURS	
	CH47FS	CH-47	CH47FS	CH-47
1-10	Cockpit Procedures and Basic Maneuvers (Taxi, Takeoffs, Approaches, Traffic Patterns, SAS Off, Basic Emergency Procedures)	Pre-flight Inspection Procedures	13	
11-16		Basic Maneuvers		7
17		Basic Checkride		1.5
18-25		Advanced Maneuvers (Sling Loads, Confined Area & Pinnacle Operations, Night Flight, Night Sling Loads, Advanced Emergency Procedures		8.8
26-29	IFR Procedures & Advanced Emergency Procedures		5.2	
30-31		Advanced Maneuvers		2.2
32		Aircraft Qualification Checkride		1.5
			18.2	21

It is recommended that the production model simulators be designed to overcome deficiencies and limitations identified in this transfer-of-training study. These design improvements should include

1. Increased field of view in the visual system,

2. Improved chin window display to present more depth cues,

3. Modification of the aerodynamic and/or motion cueing equations to improve hovering characteristics as needed,

4. A simulation of the night environment adequate for training, and

5. The capability to train terrain flight operations including NOE techniques.

It is recommended that as many of the improvements in the above paragraphs as are economically feasible be retrofitted to the prototype CH47FS.

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APPENDIX A

FLIGHT TRAINING GUIDE FOR CH-47 FLIGHT SIMULATOR
TRANSFER OF UNIT FLYING TRAINING TEST

1. GENERAL. This flight Training Guide is established to provide guidance during the Operational Test II of the CH47FS.

a. Purpose of test: To experimentally determine the extent that unit flying skills learned in the CH47FS will be maintained and transferred to the aircraft.

b. Location: Fort Rucker, Alabama

c. Duration: Approximately six months

2. MANEUVERS AND PROCEDURES. The schedule of maneuvers and procedures contained herein is provided to insure the proper pacing of the aviators participating in the CH47FS test. Emphasis should be placed on preparation, briefing, and debriefing to insure that SFTS flight time is used to the best advantage.

3. GENERAL REQUIREMENTS. While performing all maneuvers and procedures, the aviators will comply with the checklist (CL) and operator's manual (-10) for the CH-47C helicopter. For amplification of maneuvers and procedures consult AR 95-1, AR 95-63, FM 1-5, FM 1-51, operator's manual and CL for CH-47C, TC 1-28, TC 1-39, DOD FLIP, and Flight Training Guide for CH-47 Aviator Qualification Course.

4. DESCRIPTION OF TRAINING.

a. During the test each aviator will fly a total of 30 hours in the CH47FS. This 30 hours will be flown at 5 hours per month for a 6 month period.

b. Each aviator will be administered a checkride in the CH-47 aircraft prior to flying the CH47FS. At the conclusion of the 30 hour test, another checkride will be given for comparative purposes. Both checkrides should conform as closely as possible to the written profile.

5. FLIGHT HOURS.

a. This test consists of a total of 30:00 hours in the CH47FS as indicated on the following page:

VFR		12.5 hrs
BASIC MANEUVERS	5 hrs	
ADVANCED MANEUVERS	7.5 hrs	
INSTRUMENT		10 hrs
BASIC MANEUVERS	5 hrs	
ADVANCED MANEUVERS	5 hrs	
OTHER		7.5 hrs
NIGHT FLIGHT	2.5 hrs	
FLIGHT WEARING A PROTECTIVE MASK (NBC)	2.5 hrs	
TACTICAL NAVIGATION AND INSTRUMENT FLIGHT	2.5 hrs	
TOTAL		30 hrs

FLT PERIOD: 1 FLT TIME: 2.5 hrs TOTAL FLT TIME: 2.5 hrs

1. Instructor Pilot's briefing

2. Demonstrate and practice

   a. Before-starting engine check
   b. Starting engine check
   c. Ground operational check
   d. Taxi check
   e. Taxi (four wheel)
   f. Before-takeoff check
   g. Takeoff to hover
   h. Hover check
   i. Normal takeoff from hover
   j. Level turns
   k. Local area orientation
   l. Climbs and descents
   m. Climbing and descending turns
   n. Normal approach to hover
   o. Landing from hover
   p. Engine shutdown check
   q. Steep approach

3. Debriefing

FLT PERIOD: 2 FLT TIME: 2.5 hrs TOTAL FLT TIME: 5.0 hrs

1. Instructor Pilot's briefing

2. Review as required

3. Demonstrate and practice

   a. Hovering flight
   b. Normal takeoff from ground
   c. Decelerations
   d. Traffic patterns
   e. Before landing check
   f. Normal approach to the ground
   g. After landing check
   h. Taxi (two wheel)
   i. Simulated maximum performance takeoff
   j. Emergency procedures

      (1) Normal engine beep trim failure

(2) Engine shutdown without the gas producer or condition lever operative

4. Debriefing

FLT PERIOD: 3	FLT TIME: 2.5 hrs	TOTAL FLT TIME: 7.5 hrs

1. Instructor Pilot's briefing

2. Review as required

3. Explain and practice

   a. SAS off flight
   b. Shallow approach to running landing
   c. Single engine running landing
   d. Autorotation
   e. Emergency procedures

      (1) Fuel boost pump failure
      (2) Generator failure
      (3) Engine failure (with or without fire)
      (4) Go around with one engine inoperable
      (5) Engine failure on takeoff
      (6) Single transformer rectifier failure

4. Debriefing

FLT PERIOD: 4	FLT TIME: 2.5 hrs	TOTAL FLT TIME: 10 hrs

1. Instructor Pilot's briefing

2. Review as required

3. Explain and practice

   a. High, low, and ground reconnaissance
   b. Confined area operations
   c. Pinnacle and ridgeline operations
   d. Confined area operations with internal loads
   e. Pinnacle and ridgeline operations with internal loads
   f. Emergency procedures

      (1) Thrust control rod magnetic brake failure

(2) Transmission chip detector caution light
(3) Longitudinal cyclic speed trim system failure
(4) Single SAS failure (while operating with one SAS on)
(5) Engine shutdown with the APU inoperative

FLT PERIOD: 5	FLT TIME: 2.5 hrs	TOTAL FLT TIME: 12.5 hrs

1. Instructor Pilot's briefing

2. Review as required periods 1-5

3. Explain and practice

   a. External load operations
   b. Confined area operations with external loads
   c. Pinnacle and ridgeline operations with external loads
   d. Emergency procedures

      (1) Engine failure at a hover
      (2) Emergency descent
      (3) Crosswind autorative landing

4. Debriefing

FLT PERIOD: 6	FLT TIME: 2.5 hrs	TOTAL FLT TIME: 15.0 hrs

1. Instructor Pilot's briefing

2. Explain and practice night flight

   a. Taxiing
   b. Takeoff to hover
   c. Hovering flight
   d. Landing from hover
   e. Normal takeoff
   f. Climbs and descents
   g. Level turns
   h. Climbing and descending turns
   i. Traffic patterns
   j. Normal approach
   k. Simulated maximum performance takeoff
   l. Steep approach

m. Autorotation
n. SAS off flight
o. External load operations
p. Confined area operations
q. Pinnacle and ridgeline operations

3. Debriefing

FLT PERIOD: 7	FLT TIME: 2.5 hrs	TOTAL FLT TIME: 17.5 hrs

1. Instructor Pilot's briefing

2. Explain and practice instrument flight

   a. Straight and level flight
   b. Level turns
   c. Straight climbs and descents
   d. Climbing and descending turns
   e. Decelerations
   f. GCA approach

3. Debriefing

FLT PERIOD: 8	FLT TIME: 2.5 hrs	TOTAL FLT TIME: 20.0 hrs

1. Review as required Period 7

2. Instructor Pilot's briefing

3. Explain and practice instrument flight

   a. Instrument check
   b. Instrument takeoff
   c. Timed turns
   d. Compass turns
   e. Emergency panel
   f. Unusual attitude recovery
   g. SAS off flight

4. Debriefing

FLT PERIOD: 9	FLT TIME: 2.5 hrs	TOTAL FLT TIME: 22.5 hrs

1. Instructor Pilot's briefing

2. Review as required period 7 and 8

3. Explain and practice instrument flight

   a. ADF orientation and tracking
   b. Enroute navigation
   c. ATC procedures
   d. Holding using ADF
   e. ADF approach
   f. Missed approach procedures
   g. Review emergency procedures as required

4. Debriefing

FLT PERIOD: 10	FLT TIME: 2.5 hrs	TOTAL FLT TIME: 25.0 hrs

1. Instructor Pilot's briefing

2. Review as required periods 7, 8 and 9

3. Explain and practice night instrument flight

   a. VOR orientation and tracking
   b. Holding using VOR
   c. IFR communications failure
   d. VOR approach
   e. ILS approach
   f. Review emergency procedures as required

4. Debriefing

FLT PERIOD. 11	FLT TIME: 2.5 hrs	TOTAL FLT TIME: 27.5 hrs

1. Instructor Pilot's briefing

2. Explain and practice flight wearing a protective mask (NBC)

   a. Taxiing
   b. Takeoff to hover
   c. Hovering flight
   d. Landing from hover
   e. Normal takeoff
   f. Climbs and descents
   g. Level turns

h. Climbing and descending turns
i. Traffic patterns
j. Normal approach
k. Simulated maximum performance takeoff
l. Steep approach
m. SAS off flight
n. Confined area operations
o. External load operations
p. Autorotation
q. ADF approach

3. Debriefing

FLT PERIOD: 12	FLT TIME: 2.5 hrs	TOTAL FLT TIME: 30.0 hrs

1. Instructor Pilot's briefing

2. Review as required periods 1 thru 11

3. Explain and practice Tactical Navigation and Instrument Flight

   a. Flight planning procedures
   b. Corridor approach
   c. Spiraling approach
   d. Missed approach

4. Review emergency procedures as required

5. Debriefing

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1 HQDA (DAPC-PAS-A)
1 HQDA (DUSA-OR)
1 HQDA (DAMO-ROR)
1 HQDA (DASG)
1 HQDA (DA10-PI)
1 Chief, Consult Div (DA-OTSG), Adelphi, MD
1 Mil Asst. Hum Res, ODDR&E, OAD (E&LS)
1 HQ USARAL, APO Seattle, ATTN: ARAGP-R
1 HQ First Army, ATTN: AFKA-OI-TI
2 HQ Fifth Army, Ft Sam Houston
1 Dir, Army Stf Studies Ofc, ATTN: OAVCSA (DSP)
1 Ofc Chief of Stf, Studies Ofc
1 DCSPER, ATTN: CPS/OCP
1 The Army Lib, Pentagon, ATTN: RSB Chief
1 The Army Lib, Pentagon, ATTN: ANRAL
1 Ofc, Asst Sect of the Army (R&D)
1 Tech Support Ofc, OJCS
1 USASA, Arlington, ATTN: IARD-T
1 USA Rsch Ofc, Durham, ATTN: Life Sciences Dir
2 USARIEM, Natick, ATTN: SGRD-UE-CA
1 USATTC, Ft Clayton, ATTN: STETC-MO-A
1 USAIMA, Ft Bragg, ATTN: ATSU-CTD-OM
1 USAIMA, Ft Bragg, ATTN: Marquat Lib
1 US WAC Ctr & Sch, Ft McClellan, ATTN: Lib
1 US WAC Ctr & Sch, Ft McClellan, ATTN: Tng Dir
1 USA Quartermaster Sch, Ft Lee, ATTN: ATSM-TE
1 Intelligence Material Dev Ofc, EWL, Ft Holabird
1 USA SE Signal Sch, Ft Gordon, ATTN: ATSO-EA
1 USA Chaplain Ctr & Sch, Ft Hamilton, ATTN: ATSC-TE-RD
1 USATSCH, Ft Eustis, ATTN: Educ Advisor
1 USA War College, Carlisle Barracks, ATTN: Lib
2 WRAIR, Neuropsychiatry Div
1 DLI, SDA, Monterey
1 USA Concept Anal Agcy, Bethesda, ATTN: MOCA-MR
1 USA Concept Anal Agcy, Bethesda, ATTN: MOCA-JF
1 USA Arctic Test Ctr, APO Seattle, ATTN: STEAC-PL-MI
1 USA Arctic Test Ctr, APO Seattle, ATTN: AMSTE-PL-TS
1 USA Armament Cmd, Redstone Arsenal, ATTN: ATSK-TEM
1 USA Armament Cmd, Rock Island, ATTN: AMSAR-TDC
1 FAA-NAFEC, Atlantic City, ATTN: Library
1 FAA-NAFEC, Atlantic City, ATTN: Hum Engr Br
1 FAA Aeronautical Ctr, Oklahoma City, ATTN: AAC-44D
2 USA Fld Arty Sch, Ft Sill, ATTN: Library
1 USA Armor Sch, Ft Knox, ATTN: Library
1 USA Armor Sch, Ft Knox, ATTN: ATSB-DI-E
1 USA Armor Sch, Ft Knox, ATTN: ATSB-DT-TP
1 USA Armor Sch, Ft Knox, ATTN: ATSB-CD-AD
2 HQUSACDEC, Ft Ord, ATTN: Library
1 HQUSACDEC, Ft Ord, ATTN: ATEC-EX-E-Hum Factors
2 USAEEC, Ft Benjamin Harrison, ATTN: Library
1 USAPACDC, Ft Benjamin Harrison, ATTN: ATCP-HR
1 USA Comm-Elect Sch, Ft Monmouth, ATTN: ATSN-EA
1 USAEC, Ft Monmouth, ATTN: AMSEL-CT-HDP
1 USAEC, Ft Monmouth, ATTN: AMSEL-PA-P
1 USAEC, Ft Monmouth, ATTN: AMSEL-SI-CB
1 USAEC, Ft Monmouth, ATTN: C, Facl Dev Br
1 USA Materials Sys Anal Agcy, Aberdeen, ATTN: AMXSY-P
1 Edgewood Arsenal, Aberdeen, ATTN: SAREA-BL-H
1 USA Ord Ctr & Sch, Aberdeen, ATTN: ATSL-TEM-C
2 USA Hum Engr Lab, Aberdeen, ATTN: Library/Dir
1 USA Combat Arms Tng Bd, Ft Benning, ATTN: Ad Supervisor
1 USA Infantry Hum Rsch Unit, Ft Benning, ATTN: Chief
1 USA Infantry Bd, Ft Benning, ATTN: STEBC-TE-T
1 USASMA, Ft Bliss, ATTN: ATSS-LRC
1 USA Air Def Sch, Ft Bliss, ATTN: ATSA-CTD-ME
1 USA Air Def Sch, Ft Bliss, ATTN: Tech Lib
1 USA Air Def Bd, Ft Bliss, ATTN: FILES
1 USA Air Def Bd, Ft Bliss, ATTN: STEBD-PO
1 USA Cmd & General Stf College, Ft Leavenworth, ATTN: Lib
1 USA Cmd & General Stf College, Ft Leavenworth, ATTN: ATSW-SE-L
1 USA Cmd & General Stf College, Ft Leavenworth, ATTN: Ed Advisor
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: DepCdr
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: CCS
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: ATCASA
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: ATCACO-E
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: ATCACC-CI
1 USAECOM, Night Vision Lab, Ft Belvoir, ATTN: AMSEL-NV-SD
3 USA Computer Sys Cmd, Ft Belvoir, ATTN: Tech Library
1 USAMERDC, Ft Belvoir, ATTN: STSFB-DQ
1 USA Eng Sch, Ft Belvoir, ATTN: Library
1 USA Topographic Lab, Ft Belvoir, ATTN: ETL-TD-S
1 USA Topographic Lab, Ft Belvoir, ATTN: STINFO Center
1 USA Topographic Lab, Ft Belvoir, ATTN: ETL-GSL
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: CTD-MS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATS-CTD-MS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-TE
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-TEX-GS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-CTS-OR
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-CTD-DT
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-CTD-CS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: DAS/SRD
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-TEM
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: Library
1 CDR, HQ Ft Huachuca, ATTN: Tech Ref Div
2 CDR, USA Electronic Prvg Grd, ATTN: STEEP-MT-S
1 HQ, TCATA, ATTN: Tech Library
1 HQ, TCATA, ATTN: AT CAT-OP-Q, Ft Hood
1 USA Recruiting Cmd, Ft Sheridan, ATTN: USARCPM-P
1 Senior Army Adv., USAFAGOD/TAC, Elgin AF Aux Fld No. 9
1 HQ USARPAC, DCSPER, APO SF 96558, ATTN: GPPE-SE
1 Stimson Lib, Academy of Health Sciences, Ft Sam Houston
1 Marine Corps Inst., ATTN: Dean-MCI
1 HQUSMC, Commandant, ATTN: Code MTMT
1 HQUSMC, Commandant, ATTN: Code MPI-20-28
2 USCG Academy, New London, ATTN: Admission
2 USCG Academy, New London, ATTN: Library
1 USCG Training Ctr, NY, ATTN: CO
1 USCG Training Ctr, NY, ATTN: Educ Svc Ofc
1 USCG, Psychol Res Br, DC, ATTN: GP 1/62
1 HQ Mid-Range Br, MC Det, Quantico, ATTN: P&S Div

1 US Marine Corps Liaison Ofc, AMC, Alexandria, ATTN: AMCGS–F
1 USATRADOC, Ft Monroe, ATTN: ATRO–ED
6 USATRADOC, Ft Monroe, ATTN: ATPR–AD
1 USATRADOC, Ft Monroe, ATTN: ATTS–EA
1 USA Forces Cmd, Ft McPherson, ATTN: Library
2 USA Aviation Test Bd, Ft Rucker, ATTN: STEBG–PO
1 USA Agcy for Aviation Safety, Ft Rucker, ATTN: Library
1 USA Agcy for Aviation Safety, Ft Rucker, ATTN: Educ Advisor
1 USA Aviation Sch, Ft Rucker, ATTN: PO Drawer O
1 HQUSA Aviation Sys Cmd, St Louis, ATTN: AMSAV–ZDR
2 USA Aviation Sys Test Act., Edwards AFB, ATTN: SAVTE–T
1 USA Air Def Sch, Ft Bliss, ATTN: ATSA TEM
1 USA Air Mobility Rsch & Dev Lab, Moffett Fld, ATTN: SAVDL–AS
1 USA Aviation Sch, Res Tng Mgt, Ft Rucker, ATTN: ATST–T–RTM
1 USA Aviation Sch, CO, Ft Rucker, ATTN: ATST–D–A
1 HQ, DARCOM, Alexandria, ATTN: AMXCD–TL
1 HQ, DARCOM, Alexandria, ATTN: CDR
1 US Military Academy, West Point, ATTN: Serials Unit
1 US Military Academy, West Point, ATTN: Ofc of Milt Ldrshp
1 US Military Academy, West Point, ATTN: MAOR
1 USA Standardization Gp, UK, FPO NY, ATTN: MASE–GC
1 Ofc of Naval Rsch, Arlington, ATTN: Code 452
3 Ofc of Naval Rsch, Arlington, ATTN: Code 458
1 Ofc of Naval Rsch, Arlington, ATTN: Code 450
1 Ofc of Naval Rsch, Arlington, ATTN: Code 441
1 Naval Aerospc Med Res Lab, Pensacola, ATTN: Acous Sch Div
1 Naval Aerospc Med Res Lab, Pensacola, ATTN: Code L51
1 Naval Aerospc Med Res Lab, Pensacola, ATTN: Code L5
1 Chief of NavPers, ATTN: Pers-OR
1 NAVAIRSTA, Norfolk, ATTN: Safety Ctr
1 Nav Oceanographic, DC, ATTN: Code 6251, Charts & Tech
1 Center of Naval Anal, ATTN: Doc Ctr
1 NavAirSysCom, ATTN: AIR–5313C
1 Nav BuMed, ATTN: 713
1 NavHelicopterSubSqua 2, FPO SF 96601
1 AFHRL (FT) William AFB
1 AFHRL (TT) Lowry AFB
1 AFHRL (AS) WPAFB, OH
2 AFHRL (DOJZ) Brooks AFB
1 AFHRL (DOJN) Lackland AFB
1 HQUSAF (INYSD)
1 HQUSAF (DPXXA)
1 AFVTG (RD) Randolph AFB
3 AMRL (HE) WPAFB, OH
2 AF Inst of Tech, WPAFB, OH, ATTN: ENE/SL
1 ATC (XPTD) Randolph AFB
1 USAF AeroMed Lib, Brooks AFB (SUL–4), ATTN: DOC SEC
1 AFOSR (NL), Arlington
1 AF Log Cmd, McClellan AFB, ATTN: ALC/DPCRB
1 Air Force Academy, CO, ATTN: Dept of Bel Scn
5 NavPers & Dev Ctr, San Diego
2 Navy Med Neuropsychiatric Rsch Unit, San Diego
1 Nav Electronic Lab, San Diego, ATTN: Res Lab
1 Nav TrngCen, San Diego, ATTN: Code 9000–Lib
1 NavPostGraSch, Monterey, ATTN: Code 55Aa
1 NavPostGraSch, Monterey, ATTN: Code 2124
1 NavTrngEquipCtr, Orlando, ATTN: Tech Lib
1 US Dept of Labor, DC, ATTN: Manpower Admin
1 US Dept of Justice, DC, ATTN: Drug Enforce Admin
1 Nat Bur of Standards, DC, ATTN: Computer Info Section
1 Nat Clearing House for MH–Info, Rockville
1 Denver Federal Ctr, Lakewood, ATTN: BLM
12 Defense Documentation Center
4 Dir Psych, Army Hq, Russell Ofcs, Canberra
1 Scientific Advsr, Mil Bd, Army Hq, Russell Ofcs, Canberra
1 Mil and Air Attache, Austrian Embassy
1 Centre de Recherche Des Facteurs, Humaine de la Defense Nationale, Brussels
2 Canadian Joint Staff Washington
1 C/Air Staff, Royal Canadian AF, ATTN: Pers Std Anal Br
3 Chief, Canadian Def Rsch Staff, ATTN: C/CRDS(W)
4 British Def Staff, British Embassy, Washington
1 Def & Civil Inst of Enviro Medicine, Canada
1 AIR CRESS, Kensington, ATTN: Info Sys Br
1 Militaerpsykologisk Tjeneste, Copehagen
1 Military Attache, French Embassy, ATTN: Doc Sec
1 Medecin Chef, C.E.R.P.A.–Arsenal, Toulon/Naval France
1 Prin Scientific Off, Appl Hum Engr Rsch Div, Ministry of Defense, New Delhi
1 Pers Rsch Ofc Library, AKA, Israel Defense Forces
1 Ministerie van Defensie, DOOP/KL Afd Sociaal Psychologische Zaken, The Hague, Netherlands