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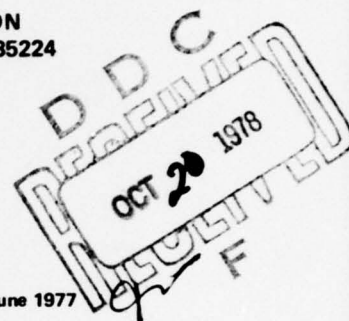
**TRAINING EFFECTIVENESS OF THREE TYPES
OF VISUAL SYSTEMS FOR KC-135
FLIGHT SIMULATORS**

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June 1978
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This final report was submitted by Flying Training Division, Air Force Human Resources Laboratory, Williams Air Force Base, Arizona 85224, under project 1123, with HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235.

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

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The objective of this study was to determine the relative training effectiveness of three generic types of simulator visual systems for application to KC-135 Combat Crew Training School (CCTS): A TV/Model Board system (TV), a Day/Night Color Computer Generated Imagery (CGI) system (Day), and a Night Only/Point Light Source CGI (Night). This study was designed to identify any deficiencies associated with these three systems which might adversely impact training. The comparative effectiveness data for the three visual systems was generated using a transfer-of-training design. Subjects were 30 recent graduates of UPT transitioning into the copilot position of the KC-135. They were divided into three equal groups, each receiving simulator training on one of the three visual systems.		

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Each student received up to eight hours of instruction in the simulator (mean training time: 6.57 hours) with instruction by SAC KC-135 IPs scheduled over a 2-day period. Following simulator training, each student flew two evaluation sorties in the KC-135 aircraft with three to four landings attempted on each sortie.

Simulator Results: All subjects demonstrated an increase in flying skill during simulator training. Comparison of group mean times in the simulator required to meet a specified proficiency criterion did not reveal any differential efficiency (time required to meet proficiency) among the three systems.

Evaluation Flight Results: A comparison of evaluation flight scores revealed that the Night and Day systems trained more effectively than the TV system. The TV system trained less effectively in the final approach glidepath segment of the landing task. No serious deficiencies were identified in the Day and Night system which might adversely affect the quality of training.

Follow on CCTS Training Results: Sixty percent of the simulator trained students received the "Highly Qualified" score on their checkride landings, while only thirty percent of CCTS students normally receive this score. Instructor pilots reported a generally higher skill level from the students who had received simulator training in this study.

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PREFACE

This effort was conducted by the Flying Training Division, Air Force Human Resources Laboratory, Williams AFB, Arizona. The research was completed under project 1123, USAF Flying Training Development, Mr. James F. Smith, Project Scientist, and task 112303, The Exploration of Simulation in Flight Training, Mr. Robert Woodruff, Task Scientist.

This study was conducted in response to an August 1976 statement of technical need from the Simulator Systems Program Office, Aeronautical Systems Division (ASD/SD24), Wright-Patterson AFB, Ohio, and the Strategic Air Command (HQ SAC/XPHS), Offutt AFB, Nebraska. Because of the mutual interests in the study, a joint planning group was organized to oversee the design, planning, and management of the study and its required resources. The three members of this group were Capts Charles Mote (ASD/SD24), Gene Englund (HQ SAC/XPHS), and Jack Thorpe (AFHRL/FT).

The desire to impact pending simulator hardware procurements coupled with the magnitude of the study forced an accelerated research schedule and increased the demands upon a number of people directly or indirectly associated with the execution of the study. It was exclusively due to their extreme dedication and outstanding performance under these severe time constraints that the study was successfully completed and the results made available in time to influence decisions regarding significant hardware expenditures. Four field research teams carried the burden of this effort:

Day Team: (Site: Boeing Aerospace Company, Seattle, Washington)

On-Site Experimenter: Mr. Dean LeMaster

Associate Experimenter: Airman Lois Short

SAC Instructor Pilots:

Maj Harlan Tate, 92 ARS, Fairchild AFB, Washington (Team Chief)

Capt Wally X. Pickard, 905 ARS, Grand Forks AFB, North Dakota

Capt Jim Williams, 9 ARS, Beale AFB, California

Capt Gary L. Curtis, 349 AREFS, Beale AFB, California

Night Team: (Site: American Airlines Flight Academy, Ft. Worth, Texas)

On-Site Experimenter: Capt Bob McFadden

Associate Experimenter: Capt Nick Varney

SAC Instructor Pilots:

Capt Jim Mohan, 19 BMW, Robins AFB, Georgia (Team Chief)

Capt Ron Gordon, 911 ARS, Seymour-Johnson AFB, North Carolina

Capt Rhett Cooper, 301 ARW, Rickenbacker AFB, Ohio

TV Team: (Site: American Airlines Flight Academy, Ft. Worth, Texas)

On-Site Experimenter: Capt Nick Varney

Associate Experimenter: Dr. Delores Tyler

SAC Instructor Pilots:

Capt Jon Benner, 913 ARS, Bardsdale AFB, Louisiana (Team Chief)

Capt Jerry Moynihan, 7 ARS, Carswell AFB, Texas

Capt Rod Wells, 384 AREFS, McConnell AFB, Kansas

In-Flight Evaluation Team: (Site: Carswell AFB, Texas)

Aircraft Commander: Capt William Poston, 93 BMW, Castle AFB, California

Jump Seat Observer: Capt John Clark, 7 BMW, Carswell AFB, Texas

On-Board Experimenter: Capt McFadden/Capt Thorpe/Dr. Tyler

Runway Video Camera Location: Mr. Bill Brubaker, Singer-Link Company (Williams AFB, Arizona)

Ground Experimenter: Capt Varney

The exceptional performance of the twelve Strategic Air Command instructor pilots making up the four field teams is worthy of a special commendation. Each of these pilots demonstrated exceptional talents as members of a scientific research team, adopting the strict rules of the scientist and striving to

achieve the highest level of experimental control. Each demonstrated extraordinary instructor skills in the simulator and keenly perceptive evaluative skills in the aircraft. Throughout the exhaustive experimental schedule, the constant contributions of these research pilots continued to impress everyone associated with the project.

Also worthy of commendation is the exceptional support from the two contractor teams which provided the simulator hardware. At the American Airlines Flight Academy, Mr. Jerry Wynn directed the effort with support from the Simulator Operational Support Branch, especially Mr. Rodney Botts. Expert evaluations of student performance were made by Flight Cpts Pete Singleton and Bill Marpee, and valuable assistance and insight into the training problem was received from Cpts William Cooper and Walter Eskridge. At the Boeing Aerospace Company, Mr. Robert Trask coordinated the effort, relying on the outstanding performance of the Simulator Engineering Branch under the supervision of Mr. Ben Warner and Mr. Bill Kent. Capt Pat Patterson provided excellent evaluations of student performance and Mr. Gale Rhodes accomplished a key technical task by recording simulator parameters onto video tape during student test runs. A special thanks is due Dr. Conrad Kraft for this helpful comments and critiques concerning the organization and conduct of the experiment itself.

Mr. Bill Brubaker, Singer-Link Company, Williams AFB, Arizona, overcame a number of technical obstacles in video tape recording student landings from an isolated runway position. He was able to accomplish this task only because of the capable assistance of Maj Joe Monaghan and Capt Jack Massey, 4235 (SAC), Carswell AFB, Texas, who provided equipment as well as expertise.

A number of other individuals made significant contributions to the project: Capt Bruce Knapp (8AF/DOT), LtCol Jan DeMuth (HQ SAC/XPHS), LtCol Steve Mussleman (HQ SAC/DOTP), Capt Frank Ramsey (15AF/DOT), Majs Jerry Rhyne and Ken Cromwell (93 BMW/DOT), and TSgt Ted Schmalbeck (AFHRL/FT). Significant technical assistance was received from Mr. Michael Cyrus (AFHRL/FT), Capt Barry McFarland (ASD/ENEC), and Mr. Dan Kugel (ASD/SD24).

The heavy administrative workload associated with the conduct of the study and the production of this draft report was borne by Ms. Joann Hill and Ms. Marji Scotten (AFHRL/FT). The AFHRL/FT Research Review Committee made a number of valuable suggestions during earlier drafts of the report which improved its clarity and organization. Dr. Wayne Waag (AFHRL/FT) supervised the final review and assembly of the report, and also contributed significantly to the statistical data analyses.

Special thanks goes to our branch chief Mr. Jim Smith for his staunch support of a project which drained a large portion of his scientific manpower resources for several months.

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TRAINING EFFECTIVENESS OF THREE TYPES OF VISUAL SYSTEMS FOR KC-135 FLIGHT SIMULATORS

I. INTRODUCTION

The technology of flight simulator visual systems is advancing rapidly. Variety and quality have improved, making procurement decisions increasingly difficult. Costs must be considered—not only for the initial acquisition, but for projected operation and maintenance as well. Likewise, the training effectiveness of the system must be considered; that is, the ability of the system to effectively accomplish the training mission required by the user. The present study was designed to provide training effectiveness information for one specific application—three generic types of visual systems being considered for KC-135 Combat Crew Training School (CCTS). One of these systems will be used for transition training of student copilots and upgrading of aircraft commanders in the KC-135 tanker. The three candidate systems considered in this study were the Day/Night Color Computer Generated Image (CGI), Night Only/Point Light Source CGI, and TV/Model Board. For convenience, they are designated Day, Night and TV.

Each of these systems has been used successfully by commercial airlines to train their pilots. Whether each system is equally effective for Air Force training was unknown. For one, the experience level of the learner is different. The Air Force KC-135 student copilot is a considerably less experienced, younger pilot than his airline counterpart upgrading into a Boeing 707. In addition, some Air Force piloting skills are unique, such as in-flight refueling and the flight duties of a crew during an alert.

The present study examined each of the three visual systems to see if they would be effective for use in KC-135 CCTS. This examination took the form of a structured and controlled experiment comparing the training effectiveness of the three systems for a given class of pilots on a given task.

II. METHOD

General Approach

The experiment used a transfer of training design. Subjects were trained on a given visual system in the simulator and then evaluated in the aircraft. The amount of skill carry over, or transfer, was operationally defined as the training effectiveness of each visual system. A comparison of the effective transfer of each system indicates which system is best for a given subject population on a given task. In this experiment, three groups of ten pilots participated, each group being trained using one visual system before proceeding to the aircraft for evaluation.

Since it was beyond the scope of this study to systematically evaluate each visual system across all of the training conditions for which it will probably be used at CCTS, a research strategy was employed which selected the most critical and demanding subject and task variables in order to assess the maximum capabilities of each visual system. The subjects were recent graduates of USAF Undergraduate Pilot Training (UPT) who were transitioning into the copilot crew position in the KC-135. All subjects had been scheduled for CCTS but had not started training. None had previous heavy aircraft or multiengine flying experience nor did any have academic or flight training in the KC-135. It was expected that a less experienced pilot would demonstrate the most skill acquisition during training, thus highlighting any relative differences in training effectiveness of the different visual systems.

The training task was the visual traffic pattern, approach, and landing. This is one of the most visually dependent tasks executed in the KC-135. It is also one of the most difficult tasks performed in the aircraft. It was expected that this task would exercise each visual system to the maximum extent, again accenting the training effectiveness of each system.

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It is important to note that this study was a hardware evaluation. Instructional strategies and training techniques were not investigated. Several important components of the overall training scheme were held constant. The simulator syllabus was standardized for all subjects and closely followed. The instructional techniques available to the simulator instructor pilot (IP) were precisely defined and monitored. The visual environments presented by each visual system were not changed to optimize training for the particular pilot experience level or task being studied. The visual environments which were used were those which had been created by the contractor or manufacturer to be the most faithful reproduction of the airdromes specified.

Subjects

Thirty pilots transitioning into the copilot crew position in the KC-135 aircraft participated as subjects in this study. Each pilot was a recent graduate of UPT and had been scheduled to attend KC-135 CCTS, but had not started training. The average age was 25 years, with the range extending from 23 years to 28 years. No pilot had previous flying experience in a large multiengine aircraft. However, some had piloting time in addition to UPT: seven pilots had logged over 100 hours in light aircraft with the most experience being 700, 725, and 1,200 hours; two other pilots had helicopter time from prior service in the Army (1,800 hours and 2,100 hours); a third pilot had 60 hours in sailplanes; a fourth had 25 hours in an F-4 fighter.

The 30 subjects came from two CCTS classes of 15 pilots each. The first class (K77-008, Training Session I) participated in early January 1977. The second class (K77-009, Training Session II) participated in early February 1977. Each class was divided into three groups of five subjects each, and each group was assigned to one of the three visual systems, making a total of 10 subjects per visual system for the overall experiment. The 10 subjects trained on the Day system are referred to as the Day Group. Similarly, the Night and TV Groups were trained on the Night and TV systems, respectively. Individual subjects within groups are designated as D1 through D10, N1 through N10, or TV1 through TV10.

For administrative purposes all subjects reported initially to CCTS, Castle AFB, California, before departing to their respective on-site simulator training locations. No instruction about the KC-135, either academic or flight, was given during this brief period at Castle AFB.

Instructors

Nine SAC KC-135 IPs conducted all of the simulator instruction. They were formed into three teams of three IPs each, one team for each visual system, with two members of the team being designated as principal instructors and one member performing the duties of the team chief.

The instructional strategy developed for use in the simulator is best described as a team approach. For each training session, each IP team instructed five subjects. IP1 instructed the first and fourth, IP2 instructed the second and fifth, and the team chief instructed the third. Each instructor remained with his subject for the total training session and was the primary source of instruction in the cockpit. However, during much of the training, the team chief and often the other IP sat in on the cockpit sessions and assisted the IP. (When the team chief instructed, either IP1 or IP2 assisted, and often both participated in instruction.) This assistance was in the form of helpful comments to the subject, an assessment of the subject's major problem areas, and suggestions of different instructional approaches which might help solve these problems. The team members met frequently in conference with the research staff to analyze subject weaknesses and devise strategies for strengthening these weak areas. In accordance with the experimental procedures, the research staff monitored the progress of training and insured that all data were collected and recorded.

Simulators

In this report "simulator" is used to mean a simulator equipped with one of the three visual systems. Training was accomplished in Boeing 707 aircraft simulators rented from commercial flight training sources (the Day system from the Boeing Aerospace Company, Seattle, Washington, and the Night and TV Systems

from the American Airlines Flight Academy, Ft. Worth, Texas). Commercial sources were used because of the nonavailability of government-owned KC-135 flight simulators equipped with the visual systems of interest. Engineering calculations of various hardware and software response parameters (lags and interactions, for example) were not available and an attempt to collect them was unsuccessful. The simulators were used in the same configurations and with the same calibrations normally used by the contractor during commercial pilot training, with the same fine tuning of the devices by each company's senior pilots and simulator engineering staff.

The configuration of the visual system field-of-view (FOV) for this study required a forward FOV for the instructor and a forward and side FOV for the subject, since the pending procurement would have side windows for the student. The Day and Night systems were available with side windows on either the left or right. The TV/Model Board system, however, was only available with a left side window. The current technology does not yet allow a single television probe to reproduce the forward, as well as the side FOV with an acceptable picture. Therefore, two model boards and two probes were used for the study, one probe facing forward and one probe facing to the side. The system that was used could only reproduce the left FOV. Therefore, the Day, Night, and TV systems were standardized for left FOV presentation, requiring left seat subject training and left-hand traffic patterns. Accordingly, left-hand traffic patterns were flown in the aircraft to evaluate training transfer except in cases where conflicting traffic or local rules forced right-hand patterns. Each system was installed on a device which simulated the commercial airline version of the Boeing 707 aircraft equipped with high thrust fan-jet engines. Due to differences between the 707 and the KC-135 tanker, an assessment was made by CCTS and Strategic Air Command Headquarters personnel on the possible negative transfer effects which could occur from training on a 707 and flying a KC-135. The major recommendations were to change the airspeed indicator in the 707 simulator (a mach/airspeed combined instrument) to a drum pointer indicator of the type used in the KC-135 and to replace the flight director in the simulator with the Collins FD 109 used in the KC-135. The flight director was modified as recommended using a Collins FD 105 (identical to the FD 109 except for its slightly smaller size), but the airspeed indicator modification was not accomplished due to the nonavailability of parts. The differences between the simulator and aircraft were explained to the subject at the start of simulator training. A similar briefing was given prior to the first aircraft sortie, emphasizing differences which could affect performance if not observed, e.g., fuel flow indicator calibrations, which could cause an incorrect thrust setting if not read properly.

Each simulator had two pilot positions (a left seat and right seat), a navigator/flight engineer station located behind the right pilot's seat, an observer's chair behind the left pilot's seat, and a simulator operator's console at the rear of the cabin. The console served as the experimenter station and was occupied during all simulator periods by an on-site experimenter. It was from this position that the elapsed times of various elements of the training were kept, instructor and subject protocols recorded, the execution of the syllabus monitored, and the overall supervision of the experiment carried out.

Because of the training emphasis on flying the approach and landing with primarily visual references, the cockpit and visual environments were modified in the following ways: The subject's instrument landing system (ILS) was turned off (the IP's ILS remained operating to assist him instruct and evaluate subject performance); the subject's radio altimeter was masked; the subject's ILS marker beacon lights (outer, middle, and inner markers) were masked and the IP's marker lights were blocked from the subject's view; and visual approach slope indicator (VASI) lights were taken out of the visual model. Approach strobe lights were left in the visual model.

The visual environment used during simulator training was different for each visual system, partly due to the type of model each system was capable of creating and partly due to the types of models available in each system. Table 1 describes each of the models used.

Each simulator was equipped with a 3 degree-of-freedom motion platform for cockpit motion cues. The motion platform was operational for all training periods.

Table 1. Characteristics of Visual Models

Airdrome Modeled	Day System	Night System	TV System
	Grant County Airport, Moses Lake, Washington	Dulles International Airport	A Standard "Anytown USA" Airdrome; Not Modeled After Any specific Airdrome
Runway Characteristics	Runway 32R Standard Category II 13,500' X 300' No VASIS Approach Strobes on	Runway 36R Standard Category II 12,000' X 200' No VASIS Approach Strobes on	Runway 35L Standard Category II 11,600' X 200' No VASIS Approach Strobes on
Major Ground Cues	Standard Airdrome Features Large Hangar on Left of Touchdown Area Surrounding Area Made of Large Fields, a Lake, and Road Lines	Lights and Shading Used to Create Airdrome Features Intersecting Runway With Moving Traffic 12,000' Parallel Runway	Standard Airdrome Features Industrial Area 2 Miles Off End of Runway 5,000' Parallel Runway to Right of 35L Accurately Scaled Trees Buildings, and Ground Texture
Other	Visibility Set at 35NM to Reduce Raster Detail No altitude Limit	Northern Hemispheric Constellations Modeled No Altitude Limit	Altitude Restricted to 1,900' AGL and Below

Simulator Training

Upon arrival at the simulator site, subjects were given a general overview of the study and the schedule for the training. Rules for proper crew rest during the experiment were explained. The next day was used for subject familiarization at the simulator building and for crew rest. The following day was the start of the 2-day simulator training session. Prior to the first simulator period the IP prebrief was given, presenting technical information required to fly the simulator and the aircraft (see Appendix A).

Each subject was scheduled for 2 days of simulator training 4 hours of instruction each day, but the subject could complete the simulator training in less time if he met certain proficiency criteria prior to the end of the eighth hour. These proficiency criteria are discussed in a later section.

Simulator periods were scheduled according to the study syllabus prepared for this experiment (Appendix B): a 1.0-hour introductory period and two 1.5-hour periods on Day 1; and, two 1.5-hour periods, and a final 1.0-hour period on Day 2. This schedule was designed so that the three daily periods were each separated by a 1.0- to 1.5-hour rest period. Normally each subject was on-site 8 to 9 hours per day.

The daily scheduling of the training sessions at each contractor site was dependent upon device availability. All Night training (January and February) and the January Day training was accomplished between 0800 and 1600 hours. Some of the February Day sessions went late into the evening. All of the TV training (January and February) was conducted between 1600 and 2400 hours since the full-time use of two TV/Model Boards could not be accommodated during normal commercial pilot daytime training periods.

Syllabus. The major element in the syllabus was the teaching of the landing task. The landing task began with initialization of the simulator on base leg, 1,000' above ground level (AGL), at 135 knots indicated airspeed (KIAS), 50% flaps, gear down, and trimmed for straight-and-level flight. At this point, the subject assumed control and flew the base leg, picked a turn point, made a left-hand level turn onto final approach, maintained level flight aligned with the runway centerline until intercepting the glide path,

began a descent, followed the glide path down to the flare point, flared, held a proper landing attitude, and touched down. The IP then directed the student to apply power and rotate the simulator. The simulator was then reinitialized back to the base leg starting point. At this point, the IP normally offered critique and instruction while the simulator was stationary. He then established the initial base leg conditions and the subject began a new landing task. Instruction was also given during the landing task itself. Each task took approximately 3 minutes, unless position freeze was used to halt the simulator in mid-approach for instruction.

Each training period followed the syllabus as shown in Appendix B. The first period was flown without winds or turbulence. These two atmospheric conditions were introduced at some point during the second period, the exact point being at the discretion of the IP. For the remaining periods a wind condition was introduced on all landings. Three wind conditions were used: a 15-knot left crosswind, a 15-knot right crosswind, and a 15-knot headwind. Each condition was presented with the same approximate frequency. A random chart was used to select the wind condition on each landing. Wind direction was announced to the subject prior to the beginning of each landing task.

Each subject received a maximum of 8.0 hours of the time in the simulator, of which 7.25 hours were used for training and the final .75 hour for evaluation. Every subject received the final evaluation period, although he could finish training in less than 7.25 hours if he attained proficiency early.

Proficiency. A subject was considered proficient in the landing task when he was able to accomplish five successive unaided landing tasks within the parameters shown in Table 2. By unaided, it was meant without verbal or physical inputs by the IP or team chief to assist the subject in performing the landing. Momentary excursions outside the performance standards in Table 2 were allowed at the discretion of the IP.

Table 2. Performance Standards for an Unaided Landing^a

Landing Task Element	Parameter	Norm	Acceptable Tolerance
Base Leg	Altitude	1,000' AGL	900'–1,100' AGL
	Airspeed	135 KIAS	130–145 KIAS
Final Turn	Altitude	1,000' AGL	900'–1,100' AGL
	Airspeed	135 KIAS	130–145 KIAS
Final Approach Prior to Descent	Altitude	1,000' AGL	900'–1,100' AGL
	Airspeed	135 KIAS	130–145 KIAS
Final Approach on Glide path	Airspeed	135 KIAS	130–145 KIAS
	Glide path	0 Deviation	± 1 Dot on Glidescope
	Ground Track (Centerline Alignment)	0 Deviation	± 1 Dot on Localizer
Touchdown	Bank (At Touchdown)	0°	±3°
	Touchdown Point	1,000' ^b	0' to 3,000' ^b
	Touchdown Point (Lateral)	Nosewheel on Centerline	Centerhalf of Runway

^a Any unsafe control input or aircraft condition was considered out of tolerance, and the landing was not counted toward proficiency.

^b Past runway threshold.

As the subject approached proficiency during a training period, the IP normally announced an "in-cockpit break" and he and the team chief left the cockpit for a brief conference with the experimenter. If the IP and team chief agreed that the subject was nearing the desired proficiency level, they returned to the cockpit and began to unobtrusively count successive landing tasks which were completed within the allowable tolerances. No instruction was given during the landings, although IP critique and instruction were permitted between task repetitions while the simulator was being reset. If a landing was completed within the tolerances listed in Table 2, the IP discretely signaled the experimenter who recorded the event on the experiment log. If five successive landings were successfully completed, the IP initiated a "full stop" following the touchdown on the fifth landing. The subject was declared proficient and the session was terminated. The final evaluation was scheduled for a later time and the subject returned at that time to complete the final .75-hour period.

Two variations to this procedure could occur. If there was insufficient time remaining in a given period to attempt five landings, the testing for proficiency could be deferred to the next period. Secondly, if the beginning of the count was followed by a deterioration in the student's performance, the IP could elect to resume his instruction during the landing task and defer the count to a later time.

Following completion of the simulator training sessions each subject traveled from the simulator site to Carswell AFB, Texas, for the aircraft evaluation portion of the study.

Evaluation Flights

Each subject flew on two KC-135 aircraft flights scheduled on successive days. Five subjects were on board each flight which lasted approximately 3.0 to 3.5 hours. For example, subjects N1 through N5 flew on the first two flights, E1 and E2. Each subject flew a minimum of three approaches and landings per flight (except as noted later).

The flight schedule was designed to minimize the time between the subject's final simulator period and his first evaluation flight, given a number of scheduling constraints such as CCTS class start dates, weekend flying schedules, and aircraft availability. The final schedule was the best overall reduction of idle days for the maximum number of subjects.

Two KC-135 senior pilots served as evaluators on all 12 aircraft flights. The aircraft commander was from the CCTS Standardization and Evaluation Division and was highly experienced in evaluating the performance of student copilots. The other evaluator was a senior squadron pilot familiar with the Carswell AFB area. He occupied the jump seat during the aircraft flights and was designated as the jump seat observer (JSO). Also on board were IPs from the simulator teams: one IP was on board for E1, two for E2, and three for E3 through E12. One experimenter flew on each flight and at least two experimenters and one IP monitored the progress of the flight from the ground. Prior to the first of the two evaluation flights, the aircraft commander briefed the five subjects on the flight profile, how he would give control of the aircraft to each of them, and how and when he would resume control of the aircraft. He briefed the differences between the 707 simulator and the aircraft in terms of thrust, control loading and response, lags, aerodynamic characteristics, and proper flight parameters (e.g., airspeed, altitude, etc.).

The crew, research staff, and subjects were transported to the aircraft and the subjects were given the appropriate safety briefings. Each subject was permitted to quickly inspect the cockpit upon entering the aircraft, but was not allowed to sit in either pilot's seat to observe cockpit height above the ground. Each subject remained seated in the rear of the aircraft for the takeoff and throughout the flight, except when he flew the aircraft. The subject first entered the cockpit during the crosswind or early downwind portion of the pattern, took his position in the left seat and was helped with his harness and seat adjustment by the JSO. He wore a standard headset although it remained disconnected. Communication between aircraft commander and the subject was accomplished by loud talking. Proceeding downwind, the aircraft commander permitted the subject to become comfortable and observe the predominant terrain features and location of the runway. He then let the subject fly the remaining portion of the downwind leg to get the feel of the controls. The aircraft commander took the plane for the turn to base, established 1,000' AGL

altitude and the proper airspeed for the given aircraft weight (marked on a white card on the console separating the two pilots) and trimmed the aircraft for straight-and-level flight. He then gave the aircraft to the subject and pointed out the runway. The subject flew the final approach, flared, and landed the aircraft. He then advanced the throttles under the direction of the aircraft commander and rotated the aircraft at which time the aircraft commander took control.

The flight crew did not aid the subject in any way while he was making his approach and landing. No instruction was given. The aircraft commander did make control inputs when, in his judgment, the aircraft was getting too far out of tolerance. In such cases, this input was recorded on the performance data card and was considered in the subject's score. For all flights, the subject's ILS and radio altimeter were turned off.

After each subject flew three approaches, the next subject moved into the left seat. If sufficient fuel remained after the fifth subject had completed his three approaches, subjects were rotated back into the cockpit one by one to fly an additional landing.

Except for the approaches made on E11 and a few approaches made on other evaluation flights, all approaches were left-hand patterns. On E11, flown at Blytheville AFB, Arkansas, only right-hand patterns were allowed and all 15 patterns were flown with right turns to final.

Following their second flight, subjects were debriefed on their performance and permitted to ask questions about the study. The flight crew discussed the general performance of the subjects and suggested ways they might improve their performance. The subjects then returned to Castle AFB to begin CCTS academics.

Evaluation Flight Location. Table 3 shows the location and subject composition of each pair of flights. All flights were initially scheduled to be flown at Carswell AFB, but poor weather forced E1 and E2 to be flown at Barksdale AFB, near Shreveport, Louisiana. The remaining flights in Training Session I (E3-E6) were flown at Carswell AFB.

Table 3. Evaluation Flight Location and Subject Composition

Flight	Location (AFB)	Subjects
Training Session I		
E1	Barksdale	N1, N2, N3, N4, N5
E2	Barksdale	
E3	Carswell	TV1, TV2, TV3, D1, D2
E4	Carswell	
E5	Carswell	TV4, TV5, D3, D4, D5
E6	Carswell	
Training Session II		
E7	Carswell	N6, N7, N8, D6, D7
E8	Barksdale	
E9	Carswell	N9, N10, D8, D9, D10
E10	Carswell	
E11	Blytheville	TV6, TV7, TV8, TV9, TV10
E12	Carswell	

As seen in Table 3, all five E1-E2 subjects were from the Night group. Their performance appeared to be outstanding when compared with the performance of Day and TV group subjects on E3-E6. The question that immediately surfaced was whether their performance was in some way attributable to the Barksdale flying environment, rather than to their particular visual system training. The runway at Barksdale is highlighted by flat, undeveloped, uncluttered terrain of homogeneous colors. Carswell, on the other hand, is approached over a populated, hilly area with many buildings surrounding the base and a large plant facility on one side of the runway. The flight crew and research staff considered the Carswell runway more difficult to see than the Barksdale runway. In addition, the Barksdale VASI lights remained on during the E1 and E2 landings in spite of attempts to get them turned off. These lights provide visual glideslope information by indicating high or low glideslope attitudes by their color. Since it was not known whether the good performance of the Night group on E1-E2 was attributable in part to the Barksdale runway environment and VASI lights, two flights in Training Session II with Day and TV group subjects were scheduled to return to Barksdale (E8 and E11) to try to make this determination. Weather forced E11 to be moved further east to Blytheville AFB, which is similar to Barksdale; i.e., the terrain is flat and the runway easily detectable. VASI lights remained on for E8 and E11. The remaining Training Session II flights were flown at Carswell. Specific features of the Carswell, Barksdale, and Blytheville runways are given in Table 4.

Table 4. Features of Carswell, Barksdale, and Blytheville Runways

Base	Runway	Length	Width	ILS	VASI
Barksdale	14	11,754'	300'	—	2.5°
Blytheville	18	11,600'	300'	2.5°	2.5°
Carswell	35	12,000'	300'	2.5°	2.75°
	17	12,000'	300'	—	2.75°

Data Collection

Several types of data were collected throughout the study. Examples of the Student Background Questionnaire, Simulator Usage Log, Student Progress Record, and the Data Card are given in Appendix C.

The major data collection tool was the Data Card. It was used to score performance on the landing task in the simulator, as well as in the aircraft. The card is a combination of a graphic representation of the ground track of the landing task, flight parameters recorded from flight instruments, and letter scores on the segments of the landing task itself. The landing task was divided into five such segments: (a) base leg, (b) turn to final, (c) final approach prior to descent, (d) final approach glide path, and (e) flare, landing attitude, and touchdown. Each segment and its scoring are described in Appendix C.

Two other descriptions of performance in the aircraft were collected. Following each landing, the aircraft commander re-entered the traffic pattern and proceeded to the base leg start point. As soon as he had re-entered the pattern, traffic and communications permitting, he would give a segment-by-segment oral evaluation of the landing. This evaluation was recorded on an in-cockpit tape recorder and later transcribed. It was transmitted over the aircraft intercom and could not be heard by the subject.

A video tape recording of the landing, from a ground camera site, was used to support this evaluation. The camera location was approximately 50 yards off the side of the runway in the touchdown zone (approximately 1,000' from the runway threshold). The camera followed the aircraft from the base leg starting point all the way to touchdown. A narrative description of the landing was broadcast by the JSO over a discrete UHF radio frequency and dubbed onto the audio channel of the video tape. This description could not be heard by the subject.

These narrated video recordings were extremely valuable in reconstructing specific problem areas of various subjects. They were often reviewed by the aircraft crew following the flight. Subjects were not invited to review these tapes.

Missing Data. A few data items were not collected. Due to technical difficulties, the on-board cockpit tape recorder did not record aircraft commander evaluations on E1 and E2. The video taping of landings was not accomplished on E1. For E2-E12, occasionally a video equipment malfunction resulted in a landing task not being recorded. All the data cards, however, were recovered for each rater and every landing.

Letter Scores. Four major categories of accomplishment were used to describe subject performance on landing segments: E = Excellent; G = Good; F = Fair; and U = Unsatisfactory. In addition to these categories, four gradations were used: Fair Minus (F-), Fair Plus (F+), Good Minus (G-), and Good Plus (G+). Word pictures for these eight scores are given in Table 5. These descriptors were anchored against pilot skill levels which were defined in conjunction with the raters. The Fair category was defined as the average skill of a student copilot who was approximately halfway through CCTS. The Good category was defined as the average skill of a CCTS copilot graduate, which was the proficiency objective of the simulator training. The Excellent category was reserved for performance which equalled that of an accomplished pilot with substantial experience in the KC-135.

Table 5. Word Picture Definitions of Letter Scores

Score	Numerical Equivalent	Word Picture
E	7	As good as an accomplished pilot; very accurate on all parameters; no error; no area of criticism; no followup instruction required; high degree of skill demonstrated.
G+	6	Slightly better than G; represents the skill level of the upper 10% of CCTS copilot graduates.
G	5	Proficient; the skill level of the average CCTS copilot or the new pilot in the squadron; could have some minor variations in performance or rough edges but on the average is at this point.
G-	4	Approaching proficiency but not yet consistently performing at the G level; momentary deviations outside desired parameters; characteristic of lower 10% of CCTS copilot graduates.
F+	3	Slightly better than fair; improving but still rough; some parameters could be within or approaching the G-/G ranges, but overall performance is still too variable.
F	2	This is the category characteristic of the CCTS Student copilot performance, the average student copilot halfway through CCTS; many rough areas; parameters can generally be held within large tolerances, but only with considerable variability.
F-	1	Barely able; initial stage of skill acquisition; poor; weak; many parameters significantly out of tolerance.
U	0	Unable to perform task or Dangerously outside of parameters; unsafe or Seriously deficient in areas of airmanship, judgment, decision making, or performance under stress.

III. RESULTS

All 30 subjects completed the simulator training and evaluation flight phases of the study. The following analyses examine performance in each of these phases separately.

Simulator Training

The IP progress reports show that training did occur during the 2 days of simulator instruction. For 28 subjects there occurred an improvement in the specific skills required to accomplish the landing task as well as an improvement in the ability to integrate these skills into an overall acceptable piloting behavior. For the remaining two there was an improvement in certain specific skills, but the integration of these skills was often weak or inconsistent.

Four indices of training performance in the simulator were recorded and subsequently analyzed. These included: (a) the number of subjects reaching proficiency, (b) total training time in the simulator, (c) total time flying the simulator (performing the task), and (d) the total number of landing tasks completed in the simulator. These data are summarized in Tables 6 and 7.

Table 6. Number of Subjects Not Reaching Proficiency

Training Session	Experimental Group			
	Day	Night	TV	Total
I	1 (5)	1 (5)	1 (5)	3 (15)
II	2 (5)	3 (5)	4 (5)	9 (15)
Total	3 (10)	4 (10)	5 (10)	12 (30)

Note. — Parentheses indicate the number of subjects trained within the appropriate cell, column, or row.

Table 7. Group Means for Simulator Training Performance Data

Measure	Training Session					
	I			II		
	Day	Night	TV	Day	Night	TV
Total Training Time	6.11	6.06	6.56	6.54	6.93	7.21
Total Flying Time	3.93	3.53	3.89	4.05	4.05	4.28
Total Landing Tasks	57.20	67.40	77.80	81.20	75.60	81.40

In spite of the apparent improvement in overall skill ability, not all of the subjects reached proficiency as defined on page 9. As shown in Table 6, 12 of 30 (40%) did not complete five successive unaided landings within the specified tolerances. Chi-square analyses indicated significantly fewer proficient subjects in the second class ($X^2 = 5.00$, $df = 1$, $p < .05$) although no significant differences among the three groups ($X^2 = .83$, $df = 2$, $p < .50$). An examination was subsequently made of the simulator progress records (IP comments) and in-simulator protocols from the experimenter log to see if specific problem areas could be detected which were associated with the demonstrated lack of proficiency. A summary of these examinations for the Day, Night and TV nonproficiency subjects is provided in Appendix D.

The data for the remaining measures of training performance are summarized in Table 7. Each measure was analyzed by a completely randomized two-factor analysis of variance (visual system X training session). An analysis of the total training time in the simulator revealed a significant main effect for the training session factor ($F(1,24) = 4.66$, $p < .05$). The visual system main effect ($F(2,24) = 1.20$) as well as the interaction ($F(2,24) = .18$) were nonsignificant. An inspection of Table 7 reveals that the total time in the simulator was greater for the second class. For those individuals not reaching proficiency, time in the

simulator was maximum; that is, 7.25 hours. Since the second class had a higher percentage of students not reaching proficiency, the increase in total training time is easily explained. An analysis of the total time spent performing the task revealed a similar trend although the differences were not statistically significant. Main effects for visual system ($F(2,24) = .80$) and training session ($F(2,24) = 3.05$) as well as their interaction ($F(2,24) = .35$) produced no statistically reliable differences.

An analysis of the total number of landings performed yielded a significant main effect for the training session factor ($F(1,24) = 10.72, p < .01$), but non-significant results for the visual system factor ($F(2,24) = 3.00$) and their interaction ($F(2,24) = 2.87$). Despite the lack of statistical significance, there is a trend toward differences. Table 7 shows a decreased number of repetitions for the first class of the Day group despite the fact that time in the simulator was approximately the same as that for the Night group. This was due to an error made in determining the reset coordinates for starting the landing task in the Day simulator. The TV/Model board was the limiting factor in the distance from the runway from which a landing task could be started. The TV probe could move only so far into the corner of the board before it moved off the board entirely. Therefore, the Night and Day reset points were made to match the farthest extended TV reset point to achieve the longest possible standardized pattern. An error had been made in calculating the coordinates for the Day system and the Day landing task was slightly farther out with a longer base leg than the Night and TV landing tasks. This was not detected until after the completion of Training Session I. On the average, D1-D5 flew approximately a 4.0-minute landing task while N1-N5 and TV1-TV5 flew approximately a 3.0-minute landing task. The Day coordinates were corrected for Training Session II and all subjects flew approximately a 3.0-minute pattern. While D1-D5 flew fewer discrete landing tasks, Table 7 shows that their total time flying the simulator (performing landing tasks) compared with their total time in the simulator was greater (64%) than the Session I Night group (58%) or TV group (59%).

An examination of the total number of landing tasks accomplished in the typical 1.5-hour training period dispels any concern that the TV system would not allow as many landing tasks because of the extra time for it to reset itself due to the slow moving gantry. All three systems averaged about 19 landing tasks/1.5-hour period, depending on instructor technique, use of problem freeze and length of between-task critiques.

The insertion of turbulence into the landing task during Period 2 had a detrimental effect on subject performance for all groups. The erratic motion added a new dimension to the control problem that required additional time to master. The introduction of crosswinds had a similar effect. The IPs felt that the addition of the turbulence and crosswind motion component into the overall cockpit motion formula added to the value of the training.

Evaluation Flights

Twelve KC-135 aircraft flights were flown to evaluate transfer of visual system training to aircraft performance. During these flights 209 approaches and landings were attempted and 197 were completed. Twelve ended prematurely with a go-around resulting from traffic conflicts, excessive crosswinds, or other reasons. Twenty-seven subjects made six or more total landings over both pairs of evaluation flights. Three subjects made six approaches over both days, but only five resulted in touchdowns.

Subject performance on each landing was evaluated in two steps. First, data cards were used on board by the JSO and IPs to score each of the five segments of the landing. These segment scores were transformed and combined into composite landing scores, providing a comparison of overall landing performance as well as a segment-by-segment analysis. Second, the narrative evaluations, supported by the video tape recordings of the landings, were used to determine the types of errors the subjects made, thereby suggesting reasons why a particular score was given.

Landing Scores. Each landing was graded (using the data card) by JSO and the IPs on board the aircraft. Raters individually judged each segment of the landing and recorded a segment score on the card. Each score was converted from the rater's letter grade score to its numerical equivalent. The decision to

combine JSO and IP segment scores was made after rank-orderings of daily subject performance indicated a high degree of agreement among these raters. Following each evaluation flight, each rater independently rank-ordered the five subjects according to the skill demonstrated. To assess the degree of inter-rater agreement, the Kendall coefficient of concordance, W , was computed for each evaluation flight. The computed W 's ranged from .76 to 1.00 with an average of .87. All of the coefficients were statistically significant, indicating substantial agreement among the raters. Consequently, the composite segment score for each landing was computed to be the mean of the individual segment scores across all raters. A daily score for each segment was then computed by taking the mean of the composite segment scores for the first three landings. These daily individual segment scores were used as the raw data for all subsequent analyses. They are summarized in Table 8.

Table 8. Group Means for Evaluation Flight Data

Segment	Evaluation Flight					
	I			II		
	Day	Night	TV	Day	Night	TV
Base Leg	4.89	4.86	4.92	5.28	5.38	5.08
Turn to Final	4.13	3.60	3.69	4.43	4.56	3.62
Prior to Descent	4.28	4.66	4.49	4.98	4.85	3.88
Glide Path	3.62	4.11	2.81	4.33	4.44	3.05
Landing	2.70	3.30	2.50	3.65	4.13	2.10

The data were analyzed by a three factor analysis of variance having one between-groups factor (visual system) and two within-groups factors (evaluation flight and maneuver segment). The results of the analysis are presented in Table 9. As indicated, all main effects were statistically significant, as well as two of the first-order interactions.

Table 9. Analysis of Variance Summary Table

Source	SS	df	Ms	F
Between Subjects	161.5519	29		
A	33.4817	2	16.7409	3.5294**
Subj. w/Grp.	128.0702	27	4.7433	
Within Subjects	375.9340	270		
B	9.0134	1	9.0134	8.9963***
AB	8.7603	2	4.3802	4.3719**
B X SwGrp.	27.0523	27	1.0019	
C	140.4278	4	34.0609	36.2602***
AC	14.6726	8	1.8341	1.8968*
C X SwGrp.	104.4278	108	.9669	
BC	1.2902	4	.3226	.5310
ABC	4.8601	8	.6075	1.0000
BC X SwGrp.	65.6137	108	.6075	
Total	537.4859	299		

Note. — Factor A — Visual System.
Factor B — Evaluation Flight.
Factor C — Maneuver Segment.

* $P < .10$.

** $P < .05$.

*** $P < .01$.

The data revealed an overall difference in performance across the three groups trained with the different visual systems. A Tukey's Honestly Significant Difference (HSD) test for pairwise comparisons indicated a significant difference for the Night versus TV comparison ($p < .05$) and also a difference for the Day versus TV comparison ($p < .10$). No differences were found for the Day versus Night comparison. Using the Sheffe's S method, the data from the Day and Night groups were combined and found to be superior to the performance of the TV group ($p < .05$).

The other significant main effects were originally expected and provide support to the validity of the study results. First, the data revealed a significant improvement in performance from the first to the second evaluation flight. Second, the data indicated significant differences in performance across the five segments of the landing tasks. The first three segments require the pilot to maintain straight-and-level flight, execute a level turn, and again maintain level flight until the beginning of the descent. The fourth and fifth segments are considered to be much more difficult since they require the pilot to make his final descent, flare, and touchdown. The data from Table 8 are consistent with this fact and clearly demonstrate a performance decrement in the final two segments of the landing pattern. Likewise, a level turn is considered to be more difficult than maintaining straight-and-level flight, a supposition which is also demonstrated by the data. The correspondence of the data to these expectations provide evidence of the internal validity of the study effort.

To evaluate the significant visual system by evaluation flight interaction, tests for simple main effects were computed. The results indicated a significant effect across the three visual systems on the second evaluation flight ($F(2,27) = 6.56$, $p < .01$), but not the first ($F(2,27) = .79$). Likewise, a significant improvement in performance from the first to the second evaluation flight was obtained for the Day group ($F(1,27) = 9.28$, $p < .01$) and Night group ($F(1,27) = 7.99$, $p < .01$), but not for the TV group ($F(1,27) = .46$). These data are graphically presented in Figure 1.

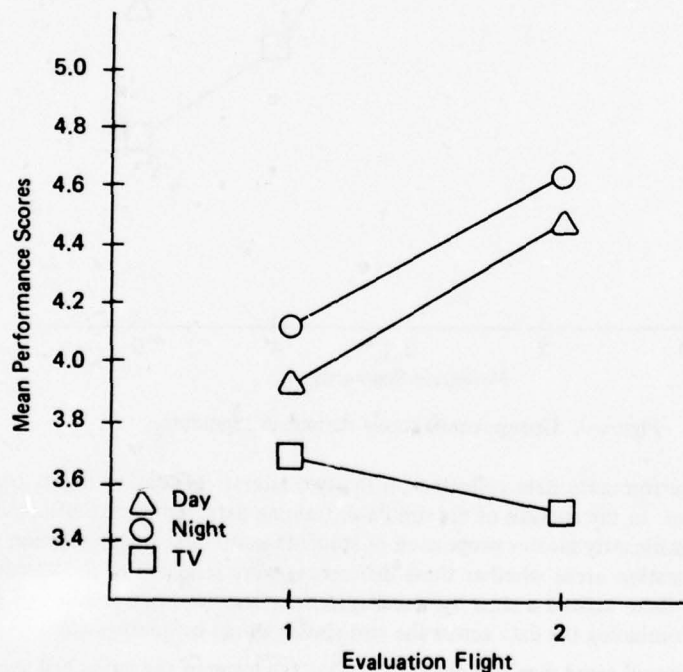


Figure 1. Group means across evaluation flights.

Simple main effect tests were also computed for the visual system by maneuver segment interaction. No differences in performance across the three groups were obtained for Base Leg ($F(2,27) = .04$), Turn to Final ($F(2,27) = 1.18$), and Final Approach Prior to Descent ($F(2,27) = 1.04$) segments of the landing. Differences did emerge for the Final Approach Glide Path ($F(2,27) = 5.79, p < .01$) and Flare, Landing Attitude, and Touchdown ($F(2,27) = 5.92, p < .01$) segments. Significant differences across the five segments were obtained for all three groups – Day ($F(4,108) = 10.36, p < .01$), Night ($F(4,108) = 6.15, p < .01$), and TV ($F(4,108) = 22.22, p < .01$). These data are graphically summarized in Figure 2.

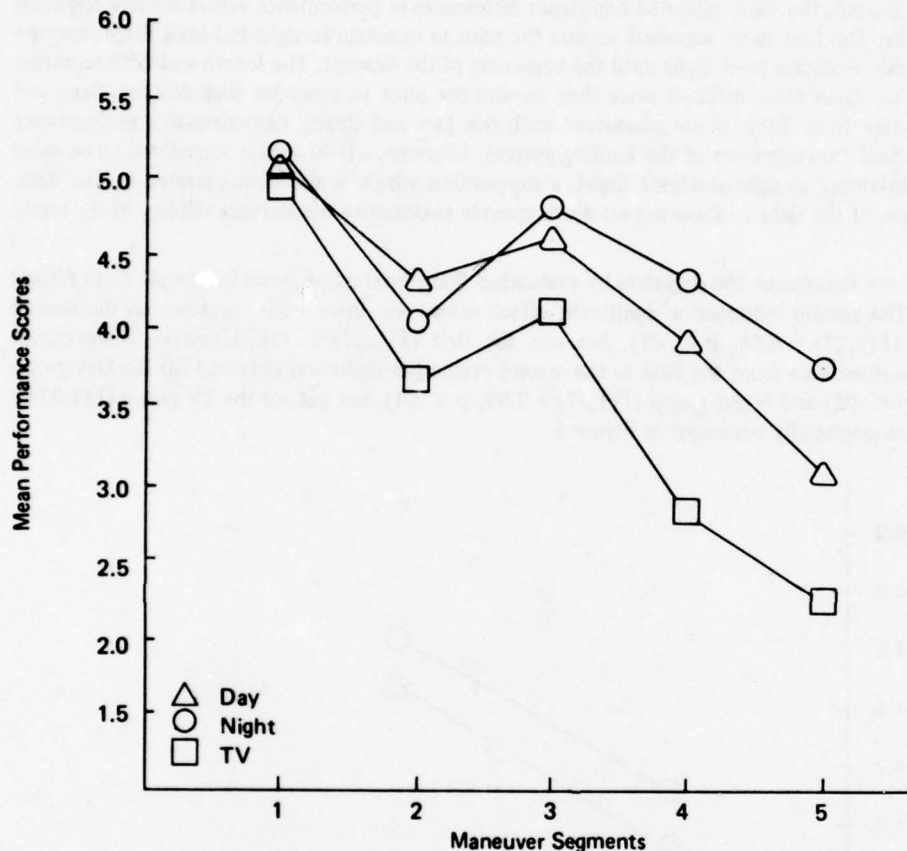


Figure 2. Group means across maneuver segments.

The analysis of the performance data collected on the two aircraft evaluation flights combined the subjects from the two classes. In the analysis of the simulator training data, significant differences emerged between these classes. A significantly greater proportion of students in the first training session reached the proficiency criteria. The question arose whether these differences were reflected in the transfer data and, more importantly, whether there existed a class by visual system interaction. In the event of a significant interaction, the validity of combining the data across the two classes would be questionable.

For each subject an overall score was computed by taking the mean of the individual segment scores across the two evaluation flights. These data are summarized in Figure 3. A completely randomized two-factor analysis of variance (visual system X training session) was computed. The results indicated significant main effects for the visual system factor ($F(2,24) = 4.07, p < .05$) and the training session factor

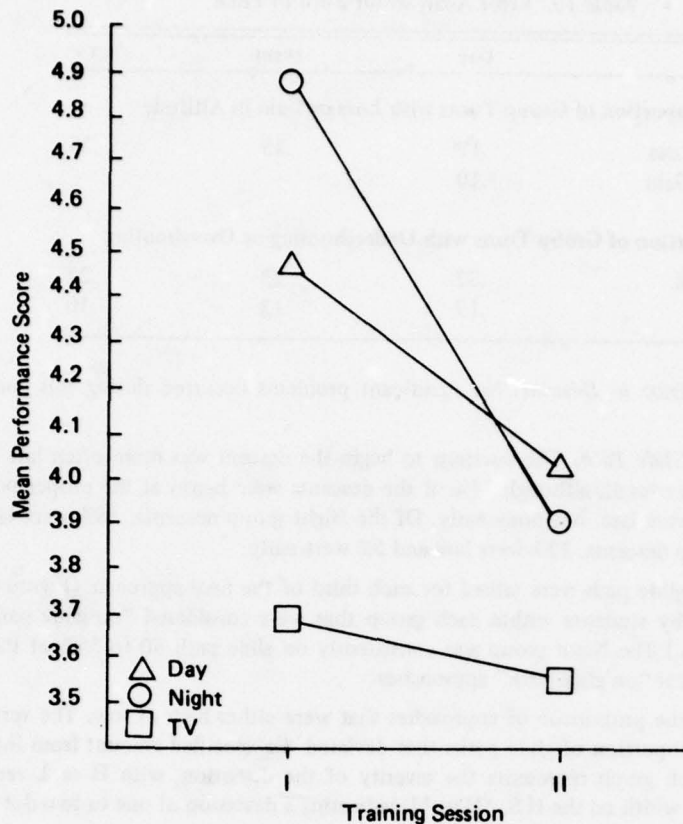


Figure 3. Group means across training sessions.

($F(1,24) = 5.06$, $p < .05$) but not for their interactions ($F(2,24) = 1.04$). As shown in Figure 3, subjects in the first class performed significantly better. Calculations of omega-squared indicated that the training session further accounted for 10.08% of the total variance of the dependent measure while the visual system factor accounted for 15.25%.

Frequencies and Types of Errors. The aircraft commander narrative evaluation combined with the video tape records were used to perform an error analysis on the types and frequencies of errors on each of the segments. This analysis identifies the specific causes for the scores reported in the previous section. Of special interest was whether there were any trends among groups that could be indicative of a visual system weakness.

1. **Base Leg.** There were very few problems with maintaining straight-and-level flight on the base leg. There were no apparent differences between groups.

2. **Turn to Final.** Table 10 shows the proportion of turns where altitude control problems and roll-out problems occurred.

Altitude was not maintained on approximately 29% of the turns made by all subjects. For the majority of these turns the loss or gain was in the 100' to 150' range. The Day group experienced both losses and gains, while the Night and TV groups experienced only losses in altitude. Alignment with the runway centerline upon rolling out was a problem on 40% of all turns. Undershooting occurred about twice as often as overshooting for all three groups.

Table 10. Error Analysis for Turn to Final

	Day	Night	TV
Proportion of Group Turns with Loss or Gain in Altitude			
Altitude Loss	.17	.35	.25
Altitude Gain	.10	—	—
Proportion of Group Turns with Undershooting or Overshooting			
Undershot	.32	.23	.27
Overshot	.17	.12	.10

3. *Final Approach Prior to Descent.* No significant problems occurred during this portion of the landing.

4. *Final Approach Glide Path.* The decision to begin the descent was more often late (22%) than early (7%) for the subjects overall, although 71% of the descents were begun at the proper point. Of the Day group descents, 22% were late, but none early. Of the Night group descents, 18% were late and 15% were early. Of the TV group descents, 27% were late and 5% were early.

Deviations from the glide path were tallied for each third of the final approach. (Figure 4 shows the proportion of approaches by students within each group that were considered "on glide path" for each third of the final approach.) The Night group was consistently on glide path 50 to 55% of the time. The Day and TV groups had fewer "on glide path" approaches.

Figure 4 also shows the proportion of approaches that were either high or low. The vertical axis of each graph indicates the proportion of glide paths that deviated the specified amount from the glide path. The horizontal axis of each graph represents the severity of the deviation, with H or L representing a deviation less than one dot width on the ILS, *H or *L indicating a deviation of one to two dot widths, and **H or **L indicating more than two dot widths of deviation.

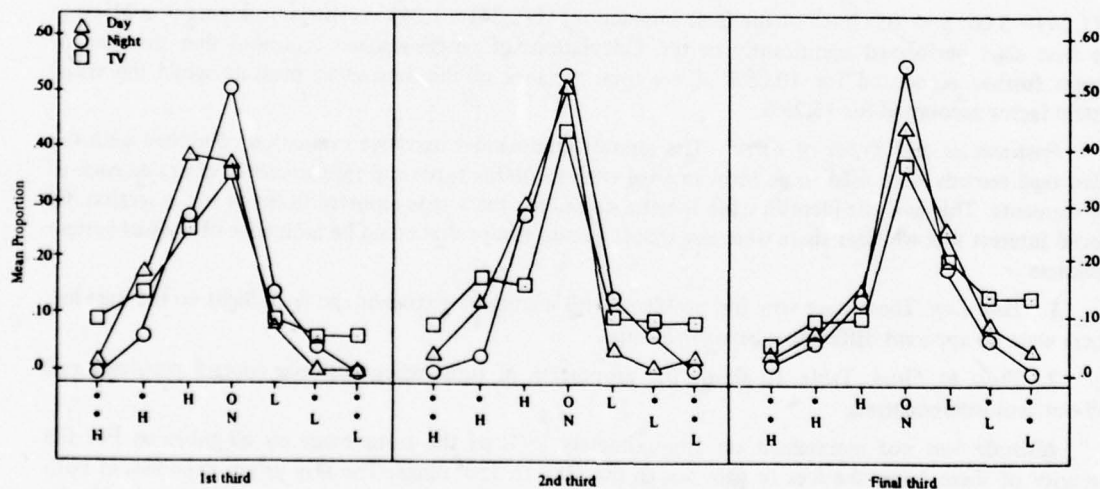


Figure 4. Glide path deviation.

Figure 4 shows that the Day group tended to be high for the first two thirds of the glide path and then low on the final third. The Night group was higher on the first two thirds but fairly balanced on the

final third, with fewer extreme deviations (**H and **L). The TV group tended to be higher on the first third, more balanced on the second third, and considerably low on the final third, with substantially more extreme deviations than the other two groups. Across the entire length of the glide path, 4% of the Day glide path/thirds had extreme deviations, less than 1% of the Night thirds had extreme deviations, and 14% of the TV thirds had extreme deviations.

5. *Flare, Landing Attitude, and Touchdown.* The flare was a problem on 35% of the Day, 35% of the Night, and 58% of the TV landings. This included flaring high, low, or not at all. Each group had a moderate portion of skips, bounces, and firm touchdowns (Day 25%, Night 23%, TV 32%).

For 20% of the Day landings, the aircraft commander had to make a control input, ranging from a blocking action on the yoke to prevent the aircraft nose from raising too high to a deliberate aileron input to neutralize wind rock. Control inputs were made on 13% of the Night landings and 27% of the TV landings. The aircraft commander had to take the aircraft from the subject due to deteriorating circumstances (approaching the outer limits of tolerances) on 10% of the Day landings, 8% of the Night landings, and 12% of the TV landings.

CCTS Training Performance

The progress of subjects participating in the study was monitored throughout CCTS. After arriving at CCTS, the subjects began a 5-week academic block of instruction with no opportunity to fly the aircraft. When they did go to the flight line, they had to transition from the left seat (as trained in this study) to the right seat. Each pilot flew as part of a crew on nine training sorties, one check ride, and one solo sortie. During all of this flying the student made about 20 landings. On the check ride given at the end of training, students were evaluated as being Highly Qualified, Qualified, Qualified with Additional Training, or Unqualified. All subjects participating in the study were rated Qualified or Highly Qualified. The breakdown according to group is presented in Table 11.

Table 11. Final CCTS Check Ride Evaluations

Evaluation	Day	Night	TV
Highly Qualified	9	5	4
Qualified	1	5	6

Thus far, the results have focused on a comparison of performance among the three groups trained with different visual systems. Since the study did not have a control group without simulator training, it seemed necessary to compare the present subjects' performance with CCTS student copilots from other classes. One source of comparison was the judgment of the aircraft commander who conducted the evaluation flights. Comparing subject performance on the evaluation flights with the skill levels of the typical student, it was his judgment that the majority of the experimental subjects performed at a skill level comparable to a CCTS student copilot well along in CCTS training. Further, several of the subjects consistently executed the landing task as well as the average CCTS copilot graduate, and, on a number of occasions, individual landings were executed on a skill level equaling an experienced KC-135 command pilot. This observation was supported by the other IPs on board the aircraft and on the ground.

An additional source of comparison comes from the final check ride evaluations of students from other classes. Data were compiled from the seven classes preceding the two experimental classes and the first class thereafter. The two categories, Qualified with Training and Unqualified, were combined due to the small number of students receiving these evaluations. The resulting data are presented in Table 12. As shown, 60% of the pilots in the two experimental classes received a Highly Qualified evaluation, whereas only 30% of students in the other eight classes received this rating. A chi-square test indicated these differences to be statistically significant ($X^2 = 10.12$, $df = 2$, $p < .01$).

Table 12. Check Ride Comparison with Other Classes

Evaluation	Study Classes		Other Classes
Highly Qualified	18	(60%)	38 (30.4%)
Qualified	12	(40%)	78 (62.4%)
Not Qualified	0		9 (7.2%)

IV. DISCUSSION

Four topics are addressed in this section: (a) the transfer effectiveness of the simulation training, (b) the relative efficiency of the simulation training across the three visual systems, (c) the relative effectiveness of the simulation training across the three visual systems, and (d) the effective utilization of visual simulation in operational training.

Transfer Effectiveness of Simulation Training

The results clearly demonstrate the transfer effectiveness of the training provided in the study. This conclusion is supported by the subjective opinion of the IPs as well as performance on the final CCTS evaluation check ride. In the eight other classes used for comparison, 30 percent received a final evaluation of Highly Qualified. For the two classes participating in the present study, 60 percent were rated at this level. Despite these figures, care must be exercised in their interpretation. Since these evaluations represent terminal performance at the end of training, there is no information reflecting time to proficiency. Consequently, the usual measures of transfer effectiveness are not available.

During CCTS, each student accomplished approximately 20 landings in the aircraft. During the experimental training, each student accomplished approximately 73 landings in the simulator and six landings in the aircraft. Since the number of landings accomplished on the two evaluation flights represent a sizeable proportion (30 percent) of the total accomplished in CCTS, a precise estimate of the effects solely attributable to the simulation training is not available. Despite this confounding and the lack of time to proficiency information, the data clearly indicate that transfer of training did occur. Subjects in the two experimental classes who received the simulator pretraining did perform significantly better than students from other classes. It is only the magnitude of these effects that remains undetermined.

Relative Efficiency of Visual Simulation Training

The training efficiency of a training device can be measured by the time needed to train a specific task. The total training time for each group (Table 7) is one index of the efficiency of each visual system. These data do not show any statistically reliable differences between visual systems. The difference between the shortest and longest mean times to train the landing task was only 33 minutes. However, this table uses 7.25 hours as the total time for subjects who did not achieve proficiency. If each subject had been allowed to take as much time as needed to satisfy the proficiency criterion, more definitive trends might have appeared. Using the "Estimated Time to Proficiency" from Appendix D with 3 hours estimated for N6, these times can be projected, if only roughly. The resulting group means are still nonconclusive: 6.63 (Day), 7.10 (Night), and 7.48 (TV). The difference between the Day and TV is 51 minutes. This could be indicative of a trend, but remains a very small amount of time.

Even if the results had indicated a more dramatic difference in training efficiency, it would be difficult to speculate on the impact of such a finding. Since the simulator is a training device and an integral part of a training system, it is the efficiency of the overall system which is of real concern. The efficiency of each component of the system is dependent upon other components in the system and, therefore, the

efficiency of the simulator will be dependent on how it is used, where it is sequenced into the training syllabus along with other training devices (including the aircraft, which is also a training device), how often it is used and for how long, how it is viewed by the user (IP, as well as the student), and many other factors. Had one of the visual systems shown a marked lack of efficiency under the conditions of this study, it could be argued that a simple rearrangement in the simulator schedule or a revised sequencing of simulator and aircraft sorties would adequately remove the deficiency. Therefore, the final statement of trainer efficiency must be made within the context of the total training system after each component is studied.

Relative Effectiveness of Visual Simulation Training

While efficiency concerns the time to train a task in the simulator, effectiveness reflects the impact of that training upon subsequent performance in the aircraft. The data, presented in Table 8, with the supporting statistical analyses, indicated that the subjects in the Day and Night groups performed significantly better than those in the TV group. These performance differences were reflected primarily in the last two segments of the landing task, the Final Approach Glide Path and Flare, Landing Attitude, and Touchdown. Furthermore, the differences among groups were statistically significant only on the second evaluation flight. The Day and Night groups' performance improved on the second evaluation flight whereas the performance of the TV group remained approximately the same. The reason behind the failure of the TV group to improve their performance on the second flight is unknown. It may be speculated that the training provided by the TV system was not sufficient to enable the student to profit from his initial three landings in the aircraft. In other words, the entry skill level of these students may have been in the lower end of the learning curve where no improvement in performance is often observed.

The error analyses of segment performance indicated that the base leg did not present any significant problems, probably since the aircraft commander had already established the aircraft in a steady state and the subject simply had to maintain it. Similarly, while subjects had altitude and centerline problems in the turn, these problems were not major. For the majority of these errors, the subjects realized they were out of tolerance and proceeded to make the proper corrections.

The final approach glide path was consistently the most difficult area of performance. The subject had to rely on the runway picture and an approximate rate of descent reference from the vertical velocity indicator as his primary cues. As shown in Figure 4, the Night group was "on glide path" 50 to 55 percent of the time, while the Day group was "on glide path" 37 to 50 percent and the TV group was "on glide path" 35 to 42 percent. The Day and TV groups were on glide path more in the middle third of the approach than the first or final third, while the Night group was more accurate on the final third of the glide path.

All three groups tended to be high rather than low on the first third of the approach (Figure 4). For the second third, the Day group remained almost exclusively high while the Night and TV groups were more balanced. For the final third the Night groups remained approximately balanced, but the Day group went low and the TV group was even lower. What is most striking in Figure 4 is the proportion of critical deviations in excess of two dot widths (**H and **L) especially in the final third of the approach. The Night group had very few critical deviations, followed closely by the Day group. The TV group had a substantial number of critical deviations, especially in **L (in excess of two dots low) during the final one-third of the approach.

In the final segment, many flares were started too high, and a number were started too late, with the aircraft impacting the runway without establishing a landing attitude. The higher percentage of poor flares for the TV group (58 percent) is mostly from the higher percentage of high and low final glide paths. This carried over to skips, bounces, and firm touchdowns.

The aircraft commander had to take the aircraft from the subject's control on about the same number of landings for all groups. This action was precipitated by the aircraft approaching the outer limits of tolerances, for example excessive wing rock close to the ground, too low on final approach, or a firm touchdown and bounce into an airborne condition. Counting these occasions with other aircraft

commander inputs (preventing the yoke from coming back too far, an aileron input to level the wings, etc.), the Night group had fewer total aircraft commander inputs (13 percent) than the Day group (20 percent) or TV group (27 percent).

Effective Utilization of Visual Simulation

There is evidence to suggest that how a training device is used often accounts for more training output (efficiency, as well as effectiveness) than the hardware characteristics of the device. Sophisticated hardware refinements of a device might result in only token increases in training effectiveness, whereas simple innovations in the use of the device might substantially increase its effectiveness. Some of the observations made by the research and instructor staff concerning such applications are presented below.

For the task trained in this study, the 1.5-hour training period seemed to be too long. A 1.0-hour period probably would have been more beneficial to the training objective. Reports of mental fatigue were received from some subjects. Eye fatigue was also reported, partly due to the type of optics used to display the visual model. Occasionally eye discomfort was caused by the instant change in brightness when the Day simulator reset itself. Visual system manufacturers should consider a less drastic light intensity change when designing the reset function in their devices.

The sequencing of training devices in a curriculum should be based on a scheme matching the device or media to the learner's state of preparedness to learn. The progression from a textbook to the learning center, a cockpit procedures trainer, a part-task trainer, a simulator, and finally the airplane, should have some rationale and be empirically tested for a given task and student population. Eddowes (1974) describes such a training strategy.

In the present study a cognitive pretraining technique of the type being investigated by Edwards (1978) might have reduced the overall simulator training time. In his current study, Edwards shows pictures of various landing attitudes and aircraft positions taken from the cockpit prior to the student's aircraft flight. The objective is for the student to learn the visual discrimination skills he needs to land the aircraft before he goes to fly. A similar set of materials might have been useful to demonstrate the correct runway picture to subjects before they entered the simulator, thus saving expensive simulator time and optimizing instructor and student efforts. The sequencing of the aircraft should also be carefully studied in the overall curriculum design. The aircraft, like the other components of the training system, should be introduced to the student at that point where it optimizes its training benefit.

One instructional technique which was used successfully in the simulator was problem freeze. Problem freeze was used frequently to stop the simulator in mid-approach and point out aspects of the landing picture to the student. The instructor could select various parameters for freezing and leave others alone. For example, on short final, position freeze, and altitude freeze were used. The instructor could then pivot the simulator as if it were on a ball and show the student nose low and high attitudes, improper alignment and, by moving the airplane vertically with altitude freeze off momentarily, he could show high and low glide path conditions. Likewise, the insertion of crosswinds and turbulence was also considered beneficial to the simulator training.

Although little data are available, it is widely believed that simulators can be more effectively utilized if students are trained to proficiency before they are advanced to the aircraft. The data collected in the present study permitted a comparison of performance in the aircraft between those who did and did not reach proficiency in the simulator. Eighteen subjects were considered proficient while 12 were not. For each subject, the mean score across the two evaluation flights was used as an estimate of performance in the aircraft. A t-test indicated performance of the "proficient" group to be somewhat better ($t = 1.82$, $df = 28$, $p < .10$). Although these results are not striking, they do provide evidence in support of the proficiency advancement concept.

V. CONCLUSIONS

The three visual systems, evaluated in this study, were successful in increasing the skill level of student copilots during a 2-day training period. When compared with other student copilots, the simulator trained students performed at a higher skill level at CCTS.

A detailed examination of the training efficiency of each visual system did not uncover any reliable differences between systems. However, the Day and Night systems trained more effectively than the TV system, as evidenced by reliably higher evaluation flight scores for Day and Night subjects. Neither the Day nor Night system was more effective than the other. The TV system trained less effectively in the final approach glide path segment of the landing task, with proportionately more extreme deviations from the glide path, especially with very low glide slopes in the final one-third of the approach. The Day group also tended to be low in the final one-third of the approach, but not to the extent of the TV group. The TV group had substantially more problems with the flare, believed to be due in part to glide path deviations just prior to flaring.

Based on the data collected during this study, it is considered that the two computer-generated imagery systems will provide more effective training for KC-135 CCTS. No serious deficiencies were identified in the Day or Night systems which might adversely affect the quality of training.

REFERENCES

- Eddowes, E.E. *A cognitive model of what is learned during flying training*. AFHRL-TR-74-63, AD-A000 046. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, July 1974.
- Edwards, B.J. *Transfer of visual discrimination pretraining to an undergraduate pilot training landing task*. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, in press.

APPENDIX A: INSTRUCTOR PILOT SIMULATOR PREBRIEF TO SUBJECTS

SIMULATOR PRELIGHT BRIEFING INSTRUCTIONS

The formal preflight briefing will be given during a half-hour period before the first simulator hour of the day. There may be exceptions to this due to scheduling adjustments. This briefing is designed to acquaint the subject with the content and conduct of the training, the basics of flight in the simulator, and the specifics of the landing task.

Brief the items in the order they occur in the attachment. Spaces have been left between many of the items for the team members to add specific information. The team chief will conduct a brief seminar with the IP's and experimenter(s) prior to the first simulator day to derive the specifics of the task.

1 Atch
Briefing Format

BRIEFING FORMAT

1. CONDUCT OF TRAINING

- a. Left seat training: Right seat instructor - unlike copilot training at CCTS.
- b. Multiple repetitions of a landing task - specialized training.
- c. No intent to teach copilot procedures - SAC procedures eliminated.
- d. Research environment - note-taking, data collection, quiet, standardization.
- e. Asking questions during training permissible - includes preflight brief, flight and debrief only.
- f. Performance measurement during training
- g. No questions during evaluation - these are assessments of quantity/quality of learning.
- h. Strict timing control - start on time, stop on time, always be in place five minutes before scheduled start time for all phases of training.

2. CONTENT OF TRAINING

- a. Open the syllabus and explain it to the subject

DESCRIBE: Content of each period
Length of period
Periodic data collections

QUESTIONS: Answer "what" but not "why" questions

- b. Approximately 8 hours of simulator training and evaluation

DESCRIBE: Simulator environment - quiet except for engine sound, front and side visual displays
Long sessions - rest periods as required

QUESTIONS: Do not answer questions concerning rating scales on evaluations

- c. Two KC-135 evaluation flights at Carswell AFB, TX

DESCRIBE: Similarity of task to be flown in aircraft
When flights in A/C will be flown

QUESTIONS: Do not answer

3. BOEING 707-123 SIMULATOR

a. Brief basic cockpit layout using chalkboard and/or wall charts in the briefing room.

DESCRIBE: Seating arrangement & adjustment
Instrument panel - important instruments, crosscheck
Collins 108 Flight Director
Brief Specifics, Fuel flow, RPM, throttle use

SPECIFICS: A/S bug, no precession ADI, IVSI.

b. Describe the visual display field-of-view

DESCRIBE: Visual system. All - front and left window, runway environment independent window for right seat, runway size

NOVOVIEW: Point lite source nite environment, horizon glow, blind spot, airdrome layout, apparent depth.

TV CAMERA: Model board w/camera sweeping, daytime, blind spot, airdrome layout, basic ground references, altitude restriction

DAY CGI: Computer imagery, day color, angular shapes, ground & runway texture, apparent depth, r/w layout

4. BASICS OF FLIGHT IN THE SIMULATOR

a. Difference between jet trainer and heavy airplane

1. Smaller angles of bank - 18° bank not to exceed 30° in turn to final.

2. Power to control pitch - explain "Pendulum" effect.

3. Relatively "sluggish" controls - move pressure than T-38, slower response.

4. Throttles right hand, yoke & trim with left hand - unlike fighter type flying, throttle alignment, span of right hand

5. Tendency toward using rock/dutch roll due to using area of momentum

6. Greater lead points, patience after inputs.

7. Trim wheel - noise, electric from yoke
8. Fuel Flow - approximate throttle movement to obtain FF changes
9. Arm rest
- b. Performance characteristics of the simulator
 1. Relate simulator characteristics to KC-135
 - (a) Fanjet response in sim different than A/C
 - (b) Motion response to varying inputs.
 - (c) Approximate bank and pitch angles
 - (d) Slightly more response in simulator over A/C
5. THE LANDING TASK
 - a. Diagram the landing task on the chalkboard and explain the elements of the task.

Draw graphic depiction on board and highlight the segmentation of the total task.

Where to begin (a/c position in relation to r/w)
 - b. Table brief how to fly the landing task. *Brief winds during period 1 desired.
 1. Control movements
 2. Specific parameters (altitude, airspeed, ground track).
 3. Visual references - location of r/w aim point in windscreen
 - ground points
 - lead points
 - peripheral cues in left window
 4. Composite crosscheck
 5. Performance standards - altitude, A/S, bank, tdzn limits
 6. Stress VFR
6. QUESTIONS FROM SUBJECT
 - a. Document questions and answers

APPENDIX B: STUDY SYLLABUS

PERIOD 1

F11	FAMILIARIZATION (COCKPIT)	60 MIN 5 min
	1. The subject will be familiar with the following: a. Strap-in and seat adjustment b. Basic flight instrumentation c. Yoke controls d. Throttles e. Trim control f. Engine instruments	
F12	FAMILIARIZATION (FLIGHT CHARACTERISTICS)	20 min
	1. The subject will fly the simulator and become familiar with the following: a. Simulator characteristics during straight and level flight, turns of 15⁰-30⁰ bank to headings based on ground references, shallow descents, low approaches. No landings. b. Trim control during flight	
	2. Special Requirements: a. Freeze may be used. b. Maximum altitude for familiarization is 1500' AGL.	
D11	DEMONSTRATION	5 min
	1. The instructor will demonstrate the landing task one time.	
	LANDING TASK (PRACTICE)	15 min
	1. The subject will fly the landing task beginning from the primary reset (PR) point until the time expires.	

2. Special Requirement:

- a. Freeze may be used.
- b. No wind.

LT12 LANDING TASK (EVALUATION) 15 min

1. The subject will fly three landing tasks beginning at the PR point.

2. Special Requirement:

- a. Freeze may NOT be used.
- b. No wind.
- c. Performance measurement data will be taken by the IP, TC, and Experimenter (machine).
- d. No talking while performing LT: critique between tasks permissible.

PERIOD 2

LT21 LANDING TASK (PRACTICE) - NO EVALS 1.5 hrs

1. The subject will practice the landing task beginning from the PR point until the time expires.

2. Special Requirement:

- a. Freeze may be used.
- b. No wind until IP calls for it. Begin turbulence at 1/2 notch.
- c. Increase turbulence to 1 notch on IP request.

PERIOD 3

LT31 LANDING TASK (PRACTICE/EVALUATION) 1.5 hrs

1. The subject will practice the landing task beginning from the PR point until the time expires.

2. Special Requirements:

- a. Freeze may be used during performance measurement.

- b. Wind will be introduced and varied between conditions no later than the beginning of this period with 1 notch turb.
- c. Performance measurement will be taken on three landing tasks (by the IP, TC, and experimenter machines)

PERIOD 4

LT41 LANDING TASK (PRACTICE) 1.5 hrs

1. The subject will practice the landing task beginning from the PR point until the time expires.
2. Special Requirement:
 - a. Freeze may be used.
 - b. Wind will be varied between conditions with 1 notch turb. Turb off 1/2 mile on final.
 - c. A demonstration of the landing task may be flown in the last 30 minutes if the subject has not flown at least one unaided landing task by this time.

PERIOD 5

LT51 LANDING TASK (PRACTICE) 1.5 hrs

1. The subject will practice the landing task under varying wind conditions until the time expires.
2. Turb off 1/2 mile on final.

PERIOD 6

LT61	LANDING TASK (PRACTICE)	60 MIN 15 min
	1. The subject will practice the landing task for 15 minutes.	(Eliminate the 15 min practice if already reached proficiency)
	2. The subject will take the checkride, regardless of proficiency attainment, during the last 45 minutes.	

PERIOD 7

LT62

LANDING TASK (CHECKRIDE)

45 min

1. The subject will fly two landing tasks with no performance measurement with wind and turb.
2. The subject will fly five landing tasks with performance measurement by the IP, TC, CIP, and Experimenter (machine).
3. Special Requirements:
 - a. Freeze may not be used during the five measured trials.
 - b. Wind will be varied between conditions.
 - c. THE CHECKRIDE MAY OCCUR EARLIER, BASED ON ACTUAL ATTAINMENT OF PROFICIENCY.

APPENDIX C: DATA COLLECTION FORMS AND PROCEDURES

Several forms were created for collecting the different types of data. Figure C1 shows the questionnaire used to document subject experience. Figure C2 shows the experimenter log maintained at the experimenter station to record the length of each landing task and interim critique. Subject and IP protocols, significant remarks, wind conditions, and other important items were recorded to document the history of each simulator period. Figures C3 and C4 show the two page test pilot progress record. The IP made an entry after each simulator period summarizing the training that occurred during the period and any problems encountered by the subject.

FOR RESEARCH PURPOSES ONLY

STUDENT BACKGROUND SHEET

ASDS 4001
Class 008

NAME _____

Subj # _____

AGE 25

Flying Background (Pilot, Nav, etc. - designate)

<u>Aircraft</u>	<u>Hours</u>
<u>C-150</u>	<u>36</u>
<u>T-37</u>	<u>90</u>
<u>T-38</u>	<u>120</u>
_____	_____
_____	_____

Total Hours: 246

Other Special Experiences or Qualifications: None

FOR RESEARCH PURPOSES ONLY

Figure C1. Student background questionnaire.

DATE 7 Feb IP 2 S TIME 1820 5 SESSION

REMARKS:

LT 1	<u>3</u> MIN	<u>10</u> SEC	REMARKS: Winds: L-306; got high on glideslope then brought A/C down too fast on short final
	crit <u> </u> min	<u>32</u> sec	
LT 2	<u>3</u> MIN	<u>14</u> SEC	REMARKS: Winds: R-026; better approach (descent point) then got way low on short final
	crit <u> </u> min	<u>58</u> sec	
LT 3	<u>3</u> MIN	<u>17</u> SEC	REMARKS: Winds: H-346
	crit <u> </u> min	<u>0</u> sec	Came in too low - trouble with flare
LT 4	<u>3</u> MIN	<u>14</u> SEC	REMARKS: Winds: H-346
	crit <u> </u> min	<u>28</u> sec	
LT 5	<u>3</u> MIN	<u>18</u> SEC	REMARKS: Winds: R-026
	crit <u> </u> min	<u>25</u> sec	Pumping yoke
LT 6	<u>3</u> MIN	<u>18</u> SEC	REMARKS: Winds: H-346
	crit <u> </u> min	<u>22</u> sec	Pumping yoke; landed on right side
LT 7	<u>3</u> MIN	<u>05</u> SEC	REMARKS: Winds: L-306
	crit <u> </u> min	<u>32</u> sec	GP low; is always on right side during GP and landing
LT 8	<u>3</u> MIN	<u>10</u> SEC	REMARKS: Winds: R-026
	crit <u> </u> min	<u>30</u> sec	Landed on far left with IP help
LT 9	<u>3</u> MIN	<u>11</u> SEC	REMARKS: Winds: L-306; Balloon in flare;
	crit <u> </u> min	<u>11</u> sec	landed on far right; no crosswind correction; rudder problem.
LT 10	<u>3</u> MIN	<u>15</u> SEC	REMARKS: Winds: R-026
	crit <u> </u> min	<u>28</u> sec	Landed on left; low GP; rudder control problem

TIME OUT continued

66
REMARKS:

Figure C2. Experimenter log.

STUDENT _____

STUDENT PROGRESS RECORD
DAY 1ASDS 4001
28 Dec 76

PERIOD 1 (1 hour) (Weak areas, problems, instructor comments. Describe student entry level skills.)

Showed early signs of being one of the better subjects. No real problems. He is almost always in the tolerances already. A little slow to reduce power at start descent point causing A/s to increase slightly. Flare/landing attitude picture is excellent for this level. Very smooth on controls - trims well. Overall G.

PERIOD 2 (1.5 hours) (Weak areas, problems, instructor comments. Describe progress.)

Had the no-wind task wired. Winds and turbulence were introduced after approximately 30 min. Has a tendency to fight the turbulence. Overcontrol some this period. Overall F+.

PERIOD 3 (1.5 hours) (Weak areas, problems, instructor comments. Describe progress.)

Improvement this period - slight overcontrol still - getting lined up sooner. Needs to use sidewindow more in turn. Subject was getting tired last half of period. Overall G-.

Figure C3. Student progress record - page 1.

DAY 2

<u>PERIOD 4 (1.5 hours)</u> (Weak areas, problems, instructor comments. Describe progress.) Subject continues to progress. The remaining problem is feel of the A/C. The light just hasn't come on yet. Inputs this period were much smaller than last period, which is good. The picture is there - he just needs to fine-tune A/C control inputs. Overall G-.
<u>PERIOD 5 (1.5 hours)</u> (Weak areas, problems, instructor comments. Describe progress.) Continues to hold pressure rather than trim off. Has T-38 control technique of constantly moving the yoke. Last three approaches for proficiency. Overall G-.
<u>FINAL PERIOD</u> (Including evaluation. Describe student's exit level proficiency.) First five approaches for proficiency. Little problem with high A/s on several approaches. G/s and flare picture were excellent. Overall G.

Figure C4. Student progress record - page 2.

Data Card. The original data card used to evaluate simulator and aircraft performance during Training Session I is shown in Figure C5 and a slightly modified version used in Training II is shown in Figure C6. This 5" X 8" card was a combination of a graphic representation of the ground track of the landing task, flight parameters recorded from the flight instruments, and letter scores on segments of the landing task.

The landing task was divided into five segments: (a) base leg; (b) turn to final; (c) final approach prior to descent; (d) final approach glide path; and (e) flare, landing attitude, and touchdown. Each segment, described in detail below, was composed of subelements which were assigned letter scores (e.g., "Hold Alt ____") and subelements consisting of recorded flight parameters. Each subelement is described below. These subelements, along with other criteria for the successful execution of a given segment, such as proper throttle, rudder, and yoke input techniques, were used to arrive at a letter score for the segment.

ASDS4001

Student	Hour	Run	Date

Roundout Smoothness _____

Technique _____

1000' ---

2000' ---

3000' ---

WVI _____

WVI _____

WVI _____

Centerline Align _____

Hold Alt _____

Begin Descent

Roll Out

Hold Alt _____

Hold Bank _____

Hold Alt _____

Smoothness _____

Roll In

Figure C5. Basic data card.

ASDS4001

Student	Hour	Run	Date

Roundout Smoothness _____

Technique _____

1000' ---

2000' ---

3000' ---

WVI _____

WVI _____

WVI _____

Hold A/S _____

Hold Alt _____

Begin Descent

Roll Out

Hold A/S _____

Hold Bank _____

Hold Alt _____

Smoothness _____

Roll In

Figure C6. Revised data card.

Each segment was considered a composite of the various subelements. A scoring rule was imposed that prohibited any segment score from being higher than the lowest score of its subelements. For example, if "Smoothness" and "Hold Altitude" were scored as Good on segment 2 but "Hold Bank" was scored as Fair, the highest score which could be assigned to segment 2 was Fair. A lower score could be assigned to this segment if one of the unwritten criteria was violated, such as unsatisfactory rudder control during the turn.

The five segments and their subelements are shown below:

1. *Base leg:* The subject was normally given the simulator or aircraft on the base leg after the IP or AC had stabilized the critical flight parameters of airspeed, altitude, and trim. The subject was scored on his ability to maintain straight-and-level flight holding airspeed and altitude during the base leg prior to beginning his turn to final. On the Session I card (Figure C5), the rater gave a letter grade for maintaining altitude ("Hold Alt ____") and a letter grade for the overall performance on the segment. On the Session II card (Figure C6), a letter grade was also given for maintaining airspeed ("Hold A/S ____").

2. *Turn to Final:* The turn to final started with the decision point for beginning the turn ("Roll-In"). The rater marked the roll-in as early or late by checking the appropriate box. If the roll-in was started at the correct point, a mark was made through the solid dot. During the turn, a letter score was given for bank control ("Hold Bank ____"), maintaining altitude ("Hold Alt ____"), and ("Smoothness ____"). On the Session II card, a letter score was also given for maintaining airspeed ("Hold A/S ____"). Upon rolling out, the rater indicated centerline alignment by marking whether the subject undershot (a mark in the left "roll-out" box), overshot (a mark in the right "roll-out" box), or rolled out on centerline (a mark through the solid dot). A letter grade was also assigned for the overall performance during the segment.

3. *Final Approach Prior to Descent:* This segment was the straight-and-level portion of the approach following roll-out prior to the begin descent point. During the simulator sessions and on some aircraft approaches, this period was too brief to score and was left blank. When it was scored, a letter grade was given for maintaining altitude ("Hold Alt ____"), centerline alignment ("Centerline Align ____"), and an overall segment score.

4. *Final Approach Glide Path:* This segment began with the descent decision point and terminated just prior to the flare decision point. The decision to begin the descent was indicated as early or late by a mark in the appropriate box. If the descent was started at the correct point, the rater placed a mark through the solid dot. During the descent, information was collected at three points to assess glideslope and centerline alignment error. These points were approximately 3.5 miles, 2.25 miles, and 1 mile from the runway threshold. At each of these points, the rater recorded the vertical velocity shown on the vertical velocity indicator (VVI), and the glideslope deviation and centerline alignment from the Collins FD 108 Flight Director. The VVI reading was the actual feet per minute shown on the instrument. The glideslope deviation was shown as it appeared on the glideslope indicator (GSI) on the Attitude Director Indicator (ADI) with the dots corresponding exactly with the instrument. Therefore, if the subject was one dot width low on glideslope, a mark was made through the upper dot on the card. High glideslopes were marked against the lower dot. If the proper glideslope was being maintained, a mark was made next to the horizontal line. Centerline alignment was indicated in a similar way, with the degree of error being displayed in relation to dot widths of error from the centerline. However, the mark showing aircraft position corresponded directly with the ground track. So if the aircraft was to the right of centerline, the mark appeared to the right of the data card. An overall letter score was also assigned to performance on this segment.

5. *Flare, Landing Attitude, and Touchdown:* This segment began with the decision to flare and ended with the touchdown. The decision to flare was judged as early, late, or correct and marked accordingly by the rater. The subject's smoothness and technique in flaring and holding the correct landing attitude was assigned letter grades ("Smoothness ____," "Technique ____"). The touchdown point was marked with a cross to indicate the lateral and longitudinal location where the main landing gear touched the runway. The Session I card had a 1,000' calibration mark to show the optimum touchdown point 1,000' from the runway threshold. Two additional distances (2,000' and 3,000') were added to the Session II card (Figure C6). An overall letter score was also assigned to this segment.

APPENDIX D: ANALYSIS OF NONPROFICIENCY SUBJECTS

The following tables show the reasons for nonproficiency of the twelve subjects not reaching the proficiency criteria. Each table shows the segments of the landing task on the left margin and the appropriate subject number across the top margin.

Table D1. Analysis of Non-Proficiency - TV Group

Segment	Subjects			
	TV5	TV7	TV8	TV9
Turn	TV10			
Glideslope	Late Corrections to Glidepath and Centerline	Consistently Held Pressure Rather Than Trim	Usually High; Overcontrol During Last 1/3 Excessive Throttle Control	Consistently High Glidepath Rate of Descent; Low on Short Final
Flare	Control Problems; Difficulty in Deciding Flare Pt.	Pumped Yoke	Overcontrol With Ailerons; Flared High	
Landing Attitude				
Touchdown				
Estimated Time to Proficiency	+ 1.0 hour	+ 1.0 hour	+ 2 hours	+ 1.0 hour
				+ 1.0 hour

Table D2. Analysis of Non-Proficiency - Night Group

Segment		Subjects		
		N3	N6	N8 N10
Turn				
Glideslope				Low on Short Final
Flare	Difficulty With Cross-Wind Control; Wingrock		Problems in All Areas	Wingrock; Poor Aileron Control
Landing Attitude	Crosswind Control; Wingrock;		Of Task	Tendency To Over-Control or Under-Control During Cross-Wind
Touchdown				After 3hr Training Mastered All But Touchdown Touchdown in Crab
Estimated Time to Proficiency	+1.5 hours	Unable to determine	+1.0 hour	+0.5 hour

Table D3. Analysis of Non-Proficiency - Day Group

Segment	Subject	
	D1	D7
Turn		Poor Altitude Control
Glideslope	Low on Last 1/3 of Approach	Poor Centerline Control From Roll-Out to Flare Point Low Last 1/3 of Approach Unable to Perceive Error on Glidepath Until Extremely out of Tolerances, Either High or Low. Consistently Low During Last 1/3 of Approach
Flare		Often Flew Into Runway During Flare
Landing Attitude	Drift	Trouble with Wings Level
Touchdown		
Estimated Time to Proficiency	+ 0.5 hour	+ 0.5 hour + 2.0 hours