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DEGRADATION OF LEARNED SKILLS

Static Practice Effectiveness for Visual Approach and Landing Skill Retention

by
Thomas E. Sitterley

May 1974

Prepared under Contract No. NAS9-13550

The Boeing Aerospace Company
Seattle, Washington

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ABSTRACT

The effectivess of an improved static retraining method was evaluated for a simulated space vehicle approach and landing under instrument and visual flight conditions. Experienced pilots were trained and then tested after 4 months without flying to compare their performance using the improved method with three methods previously evaluated. Use of the improved static retraining method resulted in no practical or significant skill degradation and was found to be even more effective than methods using a dynamic presentation of visual cues. The results suggested that properly structured open-loop methods of flight control task retraining are feasible.

FOREWORD

This report summarizes an experimental study accomplished as part of a program designed to investigate the degradation of learned skills as applicable to spaceflight tasks. The research reported here was begun in July 1973 and was completed in March 1974 for the NASA Lyndon B. Johnson Space Center under Contract NAS9-13550. The study was initiated by Dr. William E. Fedderson, Performance Section Head, Biomedical Research Division, Life Sciences Directorate. Dr. Fedderson was the NASA Project Monitor throughout the study.

The Boeing Program Manager and Principal Investigator was Dr. Thomas E. Sitterley. The author gratefully acknowledges the extensive assistance of Mr. Verle E. Helsel who was technical leader for advanced training method development, to Mr. Stephen Gough for his contribution in flight simulator computer operations, and to Mr. Allen Fukushima for his engineering assistance in simulator, terrain model, and visual systems operation.

Report D180-17875-1, Flight Control and Procedures for Simulated Visual Approach and Landing - Self-Paced Training Package, describes the training materials develped for this study. Previous research in this program of the investigation of degradation of learned skills was covered in Report D180-15080-1, Degradation of Learned Skills - A Review and Annotated Bibliography, Report D180-15081-1, Degradation of Learned Skills - Effectiveness of Practice Methods on Simulated Space Flight Skill Retention, and Report D180-15082-1, Degradation of Learned Skills - Effectiveness of Practice Methods on Visual Approach and Landing Skill Retention.

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1. INTRODUCTION

There has been considerable involvement in the evaluation and optimization of methods for maintaining or retraining skilled performance in recent years. In a series of studies for NASA which began in 1970, elements of pilot skill degration, as a function of time without practice and as a function of time without practice and as a function of retraining methods, were evaluated. These elements involved both emergency procedures (combination of cognitive and discrete psychomotor tasks) and flight control (primarily continuous psychomotor tasks). The results showed that both procedural and control skills deteriorated unacceptably after 1-4 months of inactivity (Sitterley and Berge, 1972). As expected, a fundamental difference in skill degradation was evidenced between procedural and continuous control tasks, with procedural tasks degrading unacceptably in a much shorter period of time. This difference was further highlighted by the finding that static rehearsal (review of manuals, checklists, photographs) countered procedural degradation while dynamic warmup practice (practice on actual equipment) appeared necessary for the retention of control skills.

In a following study, essentially the same types of retraining techniques were evaluated for a more complex and operationally oriented piloting task (Sitterley, Zaitzeff, and Berge, 1972). Improvements were made in the static rehearsal refresher training which enhanced trainee involvement in the tasks. In addition, a new retraining technique called dynamic rehearsal was used. It featured the continuous dynamic presentation of all pertinent visual and information elements of the tasks as they occurred in the simulated cockpit environment, but without any direct control interaction on the part of the pilot.

The results of this second study showed that static rehearsal significantly reduced degradation but did not totally reinstate performance on the flight control tasks without the addition of dynamic warmup practice. On the other hand, dynamic rehearsal prevented degradation for all categories of tasks. The primary difference between static and dynamic rehearsal was the inclusion of a more complete representation of the visual flight environment with dynamic rehearsal. From separate analyses of flight phases, Sitterley, et al (1972), found that the benefits of the dynamic rehearsal method were most strongly apparent for the highly visual (VFR) portions of the flight. Relatively small improvement was found over the static rehearsal method for the instrument flight phase.

It was postulated that the integration or coordination of far field perceptual cues, which were so well reinforced by the dynamic rehearsal method, was the critical element of the retraining. Further, Sitterley et al (1972) suggested that the primary skill retention problem was related to the maintenance of the visual/perceptual elements of the flight control skills. Certainly, manual control performance did degrade; however, with highly experienced pilots, the basic skill of integration of discrete control elements into a smooth, coordinated response was more resistant to degradation. Consequently, it would appear appropriate to concentrate on enhancing the reinforcement of the understanding of the mission profile and flight operations in relation to the out-the-window visual environment and perceptual cues.

The retraining method with the greatest enhancement potential and cost benefit is static rehearsal. Since the dynamic rehearsal method was so successful, the major potential for enhancement will primarily involve improvements in open-loop simulator techniques. While development and operation of such an open-loop trainer is less costly than a dynamic closed-loop device, it is still associated with significant weight, space, power, and cost penalties. On the other hand, the static rehearsal method is inherently less costly in terms of hardware, software, and operation. While the static rehearsal method failed to completely eliminate skill degradation, it did significantly reduce degradation from the no practice levels. The fact that it did so well as a retraining method, even in its relatively unrefined state, suggests that significant improvements in static retraining effectiveness are possible.

Improvements in static rehearsal retraining can be made in three principal areas. First, more pictorial information along the flight path should be included. In the Sitterley and Berge (1972) study, for example, only eight points in the flight were depicted. Three of them were under IFR conditions and did not require instrument and far field visual cue integration. More visual representations of altitude and line up before reaching the flare point were apparently necessary. Second, pictorial representations of off-nominal flight paths appear required to permit comparisons with the normal flight profile in order to give pilots the basis for recognizing poor performance. This very important approach was used for the dynamic rehearsal method. Third, more active pilot involvement with the static pictorial information is required to reinforce and strongly establish the critical perceptual cues of the visual environment. This involvement can be obtained by requiring specific responses from the pilot while he uses the static rehearsal training materials.

If improvements in the content, format and use of static rehearsal methods are successful, the total retraining system costs can be reduced to a fraction of that required for dynamic display retraining methods. Further, costs of initial skill acquisition and ground training may be reduced by making more effective use of considerably less flight simulator/trainer time than currently employed.

Purpose

The purpose of this study, therefore, was: 1) do develop an advanced static retraining method which incorporated the recommended improvements in content, format, and use; and 2) to evaluate the improved static retraining method by comparing its effectiveness to the previously investigated methods under the same simulated flight conditions.

2. METHOD

Experienced pilots were trained to fly a simulated spacecraft of the H-33 Space Shuttle orbiter configuration through an approach and landing. The simulation and experimental methodology was carefully controlled to duplicate that of a previous study of practice method effectiveness (Sitterley, et al, 1972). Flight control data was measured at the end of training and again at the end of 4 months for comparison to the data of the previous study.

Subjects

Five experienced pilots were selected from Boeing engineering and ground school flight training staffs. As in the previous study, the subject population was required to meet the following criteria: (1) previous formal flight training and experience as a pilot; (2) commitment to no flight activities during the test period; (3) vision 20/30 corrected or better; and (4) under 55 years of age.

The average age of the pilot population was 51.6 years with a range of 50 to 54 years. The experience level of the subjects averaged 7,680 pilot hours with a range of 5,000 to 11,000 hours. They averaged 940 instrument hours with a range of 800 to 1100 hours. The pilots averaged 4.5 years since their last flight with a range of .5 to 9 years.

Task Description

The pilot's task was to control the vehicle from an altitude of 31,400 feet through a descending turn to an approach and landing on a runway. Figure 1 depicts a schematic of the basic flight profile which required approximately 6 min. 45 sec. to complete. The mission description, approach data, and charts are described in the previous study report (Sitterley, et al, 1972) and in the self-paced training package used in this study (Helsel and Sitterley, 1973). Basically, the flight profile assumed that the pilot had just made a successful de-orbit and reentry pass through the transition stage.

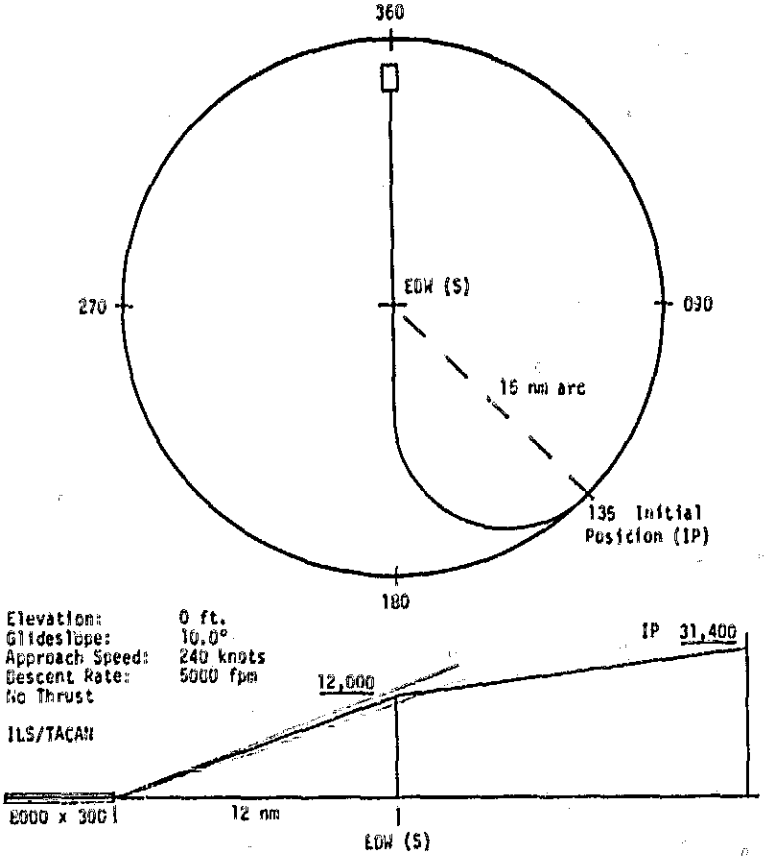


Figure 1: Flight Schematic-Edwards AFB (SIM) Simulation Approach, H-33 Orbiter

The test mission began 15 nautical miles from a simulated Edwards TACAN. The approach and landing were made unpowered. Ceiling was 10,000 feet, overcast, visibility 15 miles; the cloud deck was solid through 35,000 feet. A turning approach descending at about 5,000 feet per minute was made to the TACAN using instruments only (IFR). Energy management was accomplished through judicious use of speed boards at an equivalent airspeed of 240 knots. Stabilization on the localizer and glideslope provided a straight-in approach to the Edwards runway 12 miles from the TACAN. During this portion of the flight, the pilot was required to perform emergency procedures to correct a series of malfunctions in the vehicle's flight control system (SAS Failure Procedure).

After crossing the TACAN station, a complete electrical power failure occurred which required the pilot to perform a corrective procedure

(Subsystem Scan). During the failure, the vehicle was repositioned to one of a standardized set of offsets from the flight path. These offsets, presented in random order, permitted the evaluation of the final visual approach performance from a known starting point for all pilots. Upon power recovery (in 12 seconds), the pilot continued the descent on instruments through 10,000 ft, applying corrective control inputs to return the vehicle to the desired flight path.

The pilot broke out visually at 10,000 ft and was able to use both the instruments and external visual environment to establish the required lineup and glideslope. At 8,000 ft, the on-board terminal navigation system failed, and the pilot was required to perform another corrective procedure. No correction of the failure was possible, forcing the pilot to make the remaining approach and final touchdown under visual conditions (VFR) with only basic vehicle attitude, speed, and altitude information.

Equipment

The experimental test was conducted using the visual flight simulation facilities of the Boeing Aerospace Company in Seattle. This equipment was the same as used in the previous study (Sitterley, et al, 1972) and included the cockpit with associated displays and controls, the visual simulation system, and the computer and simulation control system. The equipment and associated computer software was integrated to provide a highly realistic simulation of a fully aerodynamic Space Shuttle orbiter descent, approach and landing as controlled visually and by instruments from a one-man cockpit.

Cockpit

A one-man cockpit, used for general purpose part-task simulation studies, configured with all displays and controls required to fly the simulated mission was used for both pilot training and retention testing. No attempt was made to duplicate any Space Shuttle cockpit concepts. Figure 2 shows the general cockpit display/control configuration in relation to a simulation pilot.

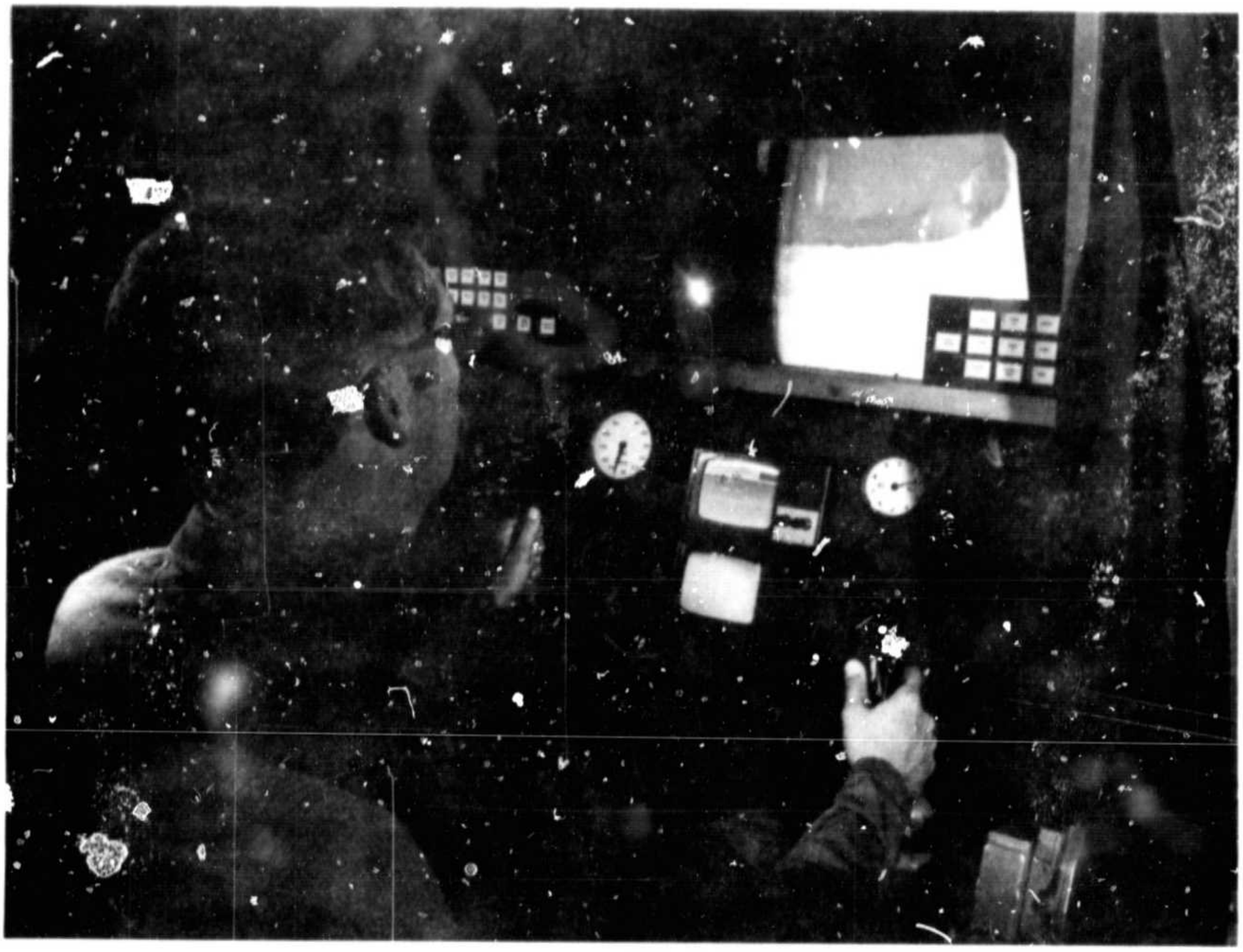


Figure 2: Simulation Cockpit with Pilot

The external out-the-window visual scenes were simulated using a 21-inch, 1029 line T.V. monitor. An infinity optics system provided a field of view of approximately 40 degrees through the centrally located windscreen.

The cockpit displays included electromechanical and cathode ray tube displays for attitude, velocity, altitude, course, and status information. An X-20 type, two-axis, sidearm controller provided proportional rate commands for pitch and roll. Rudder pedals provided displacement commands for yaw. Pitch trim and speed board commands were provided through discrete rate controls.

Visual Simulation System

The external environment seen by the pilot through the electro-optical windscreen display was produced by high resolution television cameras which were computer controlled to "fly" over terrain models. The 1 inch vidicon cameras operated with a 1029 line standard. Each camera was mounted on a rail guided carriage and gimbal system which provided 6 degrees of freedom of motion. The computer controlled carriages and gimbals were digitally positioned over the two terrain models. Precision control was maintained with both positional and velocity feedback signals to an accuracy of 0.001 in. in translation and 3 minutes of arc in rotation.

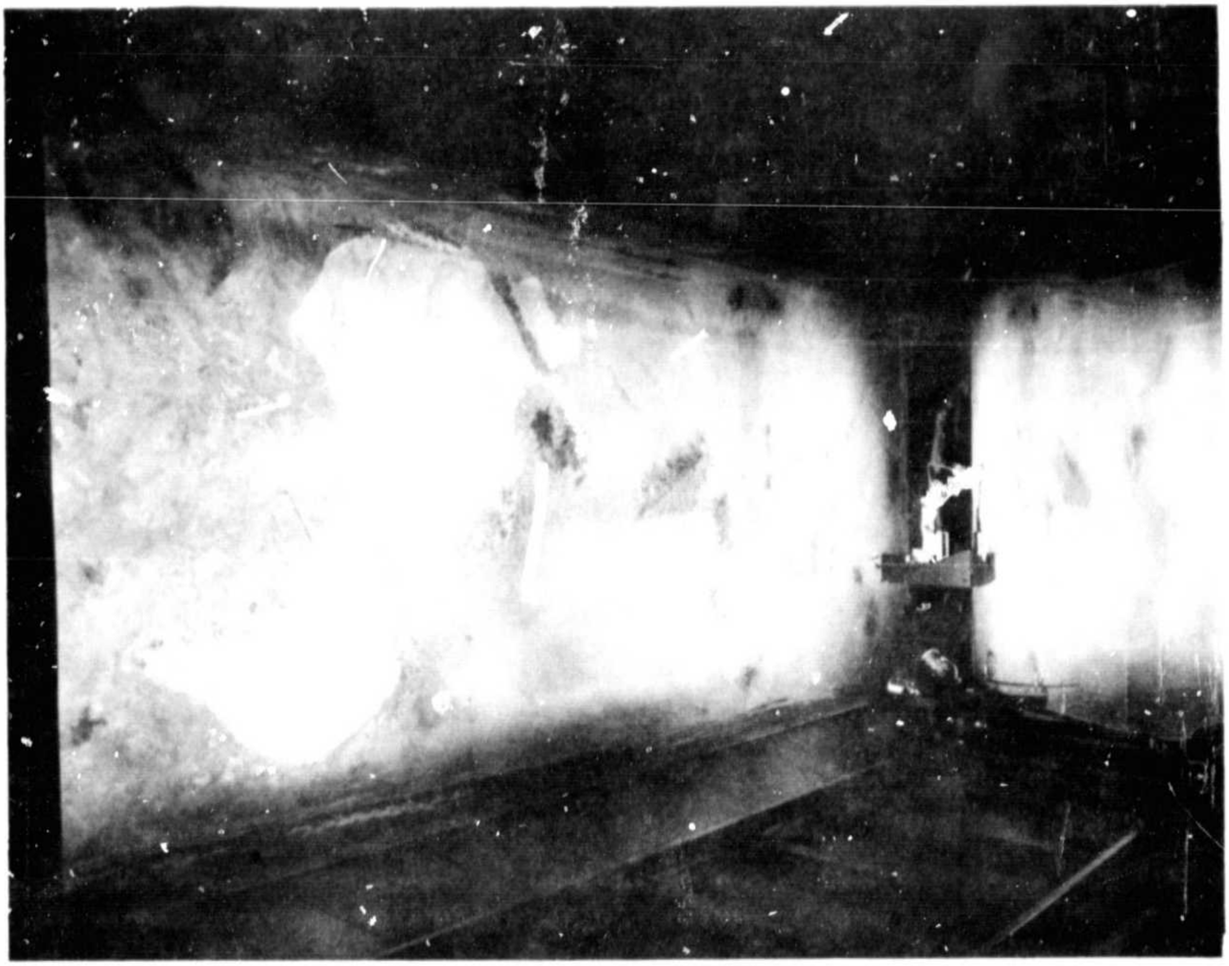


Figure 3: Terrain Model II - Edwards AFB, with Camera Stage and Lighting Mirror

Two scale relief terrain models were used during the visual portion of the approach. These models provided a realistic view of a modified approach to Edwards AFB from an altitude of 10,000 ft to touchdown. Figure 3 depicts Model II of Edwards AFB and one camera/servo system carriage. The model was 11 ft x 24 ft (Scale 1:6250) and provided terrain feature representation to a vehicle altitude of 175 ft. Figure 4 depicts the camera eye view of Model II, approximately 5 miles from the runway threshold.

Figure 4: Camera View of Approach to Edwards AFB Model

Model I provided the detailed representation of the runway for pilot's eye altitudes of 200 ft to 20 ft (Scale 1:200). The 11 ft by 90 ft model is depicted in Figure 5 along with its camera/servo system. During pilot training and performance testing, the Model I approach lights and adjacent terrain were replaced with dry lake bed features, scaled and contrast matched to Model II.

Figure 5: Terrain Model I - Runday, and Camera/Servo System

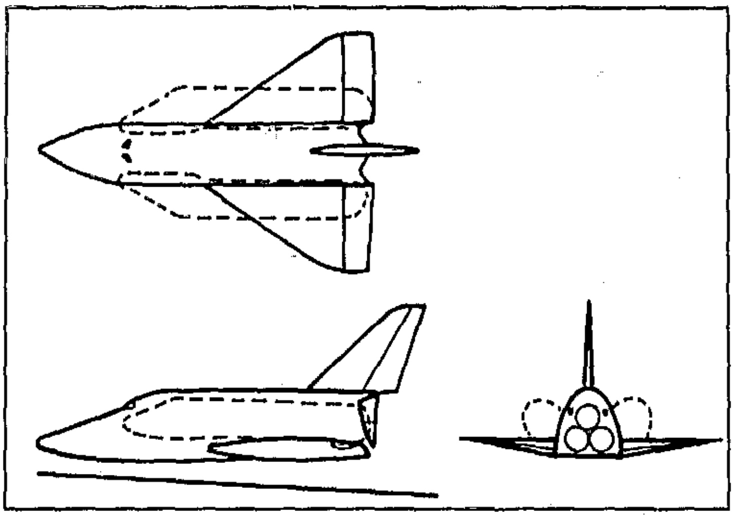
The visual transition between the two models occurred when the vehicle passed through an altitude of 300 ft. The landing model camera stage was synchronized with the vehicle's flight while the other camera stage was still flying. Visual transition was accomplished by computer controlled video fade-in/fade-out of the two TV camera/terrain model systems.

Computer System

Simulation of the flight vehicle aerodynamics, flight control and cockpit information display, and visual simulation system control were accomplished using an XDS 930 digital computer operated in conjunction with a Varian 662i digital computer, a Sanders ADDS 900 graphics display system, and analog to digital and digital to analog conversion equipment. The mathematical model which described the dynamic flight of the H-33 orbiter vehicle and the flight environment was programmed for real time solution on the main digital computer. The model provided a relatively sophisticated description of the vehicle including aerodynamics forces and moments, dynamic pressures, and the flight control system, as well as the flight environment in terms of wind accelerations, velocities, shear, and gusts. Figure 6 depicts the general characteristics of the H-33 vehicle.

Input commands from the pilot in the cockpit and programmed environmental conditions were used to compute the vehicle attitude, position and velocity information. This information was sent as operation commands to each axis of the servo system which oriented the high resolution TV cameras over the scaled terrain models. The resulting video signal was then processed and fed to the large high resolution TV display in the cockpit. Simultaneously, vehicle attitude, position, and movement data was processed for display on the cockpit instruments.

Throughout each simulation flight, the specified flight performance data was collected and stored. At the end of each flight, the 32 flight performance measures were printed along with pilot's names, session and flight numbers, and corresponding experimental conditions, After each set of five flights, block summary data and standard deviations were printed.



		TOTAL VEH	BODY
LENGTH	FT	157	135
WIDTH	FT	95	25
HEIGHT	FT	61	27.5
LANDED WEIGHT	LB	240,000	–
FIXED SURFACES		WING	FIN
AREA EXPOSED	SQ FT	2,900	855
CHORD--AT FUS	FT	68	36.7
AT TIP	FT	15.5	14.7
SWEEP–LE	DEG	55	47
TE	DEG	-5	21.8
ASPECT RATIO		1.846	1.33
TAPER RATIO		0.178	0.38
DIHEDRAL	DEG	5	–
CONTROL SURFACES		ELEVONS–TOTAL	RUDDER–TOTAL
AREA TO HINGE LINE	SQ FT	620	292
CHORD–ROOT	FT	13.6	12.8
TIP	FT	10.0	4.9
SPAN (EACH)	FT	34.8	34.8

Figure 6: H-33 Space Shuttle Orbiter General Characteristics

Procedure

The experimental procedure was identical to that previously used (Sitterley, et al, 1972) and was broken down into three general phases. The first phase included the initial briefing and training of the test subjects to perform the flight control and procedure tasks. This phase concluded with qualification testing of the pilots. The second phase was the 4 month retention interval. During this 4-month period of the subject's absence from the simulated space mission and normal flying, the advanced static retraining materials were developed. The third phase involved retraining the subjects using the new self-paced training package and carrying out retention testing of the subjects.

Pilot Training

All pilot test subjects completed flight and procedure training in the same manner as in the previous study. The five pilots were introduced to the task and provided with copies of the original flight control and procedure manual. They then attended a ground school briefing and cockpit familiarization. Following the ground school, the pilots received IFR and visual flight and landing practice, procedure task training, and full mission flights with emergency procedures.

All pilots were trained and qualified on both the flight control and procedure tasks according to the criterion previously used: essentially asymptotic performance levels. The desired goal was for touchdowns 2000 feet down the runway with sink rates of 4 to 6 feet per second, on centerline, gear down, and yaw and bank angles near zero. Unsatisfactory performance was defined by any of the following: sink rates greater than 12 feet per second, touchdown short or wide of the runway, landing gear up, and yaw or bank angles greater than 10 degrees at touchdown.

The flight control tasks required an average of 60.8 landings per pilot to train to proficiency, with a range of 51-75 landings. In terms of simulator training time, the pilots required an average of 5 hours at the controls to reach qualification. The pilots completed slightly more part mission flights (VFR only) than previously used, which resulted in more landing practice in slightly less total flight time.

An average of 140 procedure task trials were required for each pilot to reach qualification (86 to 197). The time expended for ground school briefing and procedure task training averaged 3.1 hours per pilot (as compared to 2.8 hours in the previous study). The average total training time per pilot amounted to 8.1 hours over 5.4 sessions (as compared to 8.8 hours over 5.3 sessions in the previous study).

Upon completion of training and collection of the training qualification performance test data, all training materials were recovered from the pilots. The pilots were informed that they were entering the 4 month retention interval phase. During the retention interval, they were not to return to the simulator laboratory, discuss the simulated flight, or perform any piloting functions in other flight simulators or actual aircraft. The pilots were told they would be contacted regarding their retention test schedule two weeks before the end of the retention interval.

Training Data Analysis

This study was designed to evaluate the efficiency of an improved static retraining method and compare it with the methods previously investigated (Sitterley, et al, 1972). During the course of the previous study, significant, individual differences in basic flight skills were detected between the subjects. In order to equate initial performance between the original retraining method groups, the subjects had been assigned to groups by skill level using a matched groups design. The five pilots in the present study likewise demonstrated noticeable differences in performance. However, it was no longer possible to use a matched groups design as subject assignment to the original retraining method groups was already established.

In this study, the training qualification performance of the pilots assigned to the new method group (Group IV: Improved Static Retraining) was compared with the performance of the three previous groups (Group I: No Practice, Group II: Static Rehearsal, Group III: Dynamic Display) using a subjects nested within groups analysis of variance design. A total of 32 ANOVA's were performed, one for each of the flight control measures. These analyses used the absolute error data for flight control performance. As procedure task performance was not of interest in this study, no procedure task data was analyzed.

The probability of significant differences between-groups and subjects nested within groups is depicted in Table 1 for each of the 32 performance measures obtained during pilot training. In addition, the average performance of the current Group IV subjects for each measure is listed as well as the grand mean for the first study (Ss in Groups I to III) and grand mean for the current study (Ss in Groups I to IV). Inspection of the performance means indicated that the new subjects achieved a high degree of proficiency at the end of training and performed comparably to those trained in the previous study.

The ANOVA results in Table 1 show that no significant differences were detected between the four treatment groups for any performance measure. While the null hypothesis that no differences exist cannot be proved, inspection of the data and the absence of detectable differences suggests that the current subjects were suitably and comparably trained. As with the previous study, significant subjects within groups differences were detected for most of the flight performance measures.

Improved Static Retraining Method Development

The improved static retraining method was developed to meet the concept of a self-paced retraining package which could be used effectively with little or no supporting training equipment. Development of the retraining package was accomplished in six iterative phases: 1) definition of requirements and flight phases;. 2) specification of behavioral objectives; 3) story boarding of task requirements and sequence; 4) definition of detailed task requirements, 5) formatting and layout of training materials; and 6) production of the training package.

Well defined phases which the pilot could use to continuously visualize his present position with respect to the runway were used to provide a

TABLE 1: Pilot Performance and Analysis of Variance Results (F Ratio) at Completion of Training

		PERFORMANCE MEASURE	NEW GROUP MEAN	GRAND MEAN		ANOVA SOURCE	
				FIRST STUDY	CURRENT STUDY	GROUPS	SS WITHIN GROUPS GROUPS
TACAN	1	ALTITUDE ERROR (FT)	235	357	327	0,576	3.573***
	2	LATERAL ERROR (FT)	527	665	631	0.415	3.667***
	3	HEADING ERROR (DEG)	2.5	1.5	1.8	2.052	1.570
	4	VELOCITY (KTS)	243	245	245	0.994	1.471
	5	DESCENT RATE ERROR (FT/SEC)	10,6	12,0	11,7	0.498	2.041**
	6	INTEGRATED VELOCITY ERROR (KT-SEC)	1002	971	978	0.794	6.922***
FLARE	7	ALTITUDE ERROR (FT)	275	223	236	0.464	3.219***
	8	LATERAL ERROR (FT)	86	100	96	0,555	4.766***
	9	HEADING ERROR (DEG)	1,1	1.2	1.2	0.236	1.191
	10	VELOCITY (KTS)	230	230	230	0.068	3.448***
	11	DESCENT RATE ERROR (FT/SEC)	14,2	13.7	13.8	0,188	5,295***
	12	INTEGRATED VELOCITY ERROR (KT-SEC)	1005	905	885	1.824	1.822**
	13	INTEGRATED ALTITUDE ERROR (FT-SEC)	37,171	38,944	38,501	0,204	1,248
	14	INTEGRATED LATERAL ERROR (FT-SEC)	73,582	70,367	71,171	0,120	0.726
THRESHOLD	15	ALTITUDE ERROR (FT)	64	45	50	0,561	3.801***
	16	LATERAL ERROR (FT)	24	26	26	0,297	3,774***
	17	HEADING ERROR (DEG)	0.6	0.7	0.7	0,188	2.351***
	18	VELOCITY (KTS)	192	189	190	0.841	3.911***
	19	DESCENT RATE ERROR (FT/SEC)	11.0	8.8	9.4	0,318	2,277***
	20	INTEGRATED VELOCITY ERROR (KT-SEC)	567	607	597	0,547	4.162***
	21	INTEGRATED ALTITUDE ERROR (FT-SEC)	4124	3232	3455	0,621	3.224***
	22	INTEGRATED LATERAL ERROR (FT-SEC)	1069	1297	1240	0.359	3.818***
TOUCHDOWN	23	LATERAL ERROR (FT)	26	21	22	0,210	3,992***
	24	DOWN RANGE ERROR (FT)	1125	945	890	0,726	2.173**
	25	HEADING ERROR (DEG)	0.6	0.5	0.6	0,194	1.097
	26	VELOCITY (KTS)	157	162	160	1.295	7.452***
	27	DESCENT RATE (FT/SEC)	8.2	7.2	7.5	0,752	1.663*
	28	BANK ANGLE (DEG)	1.0	0.8	0.9	1,063	1.821**
	29	PITCH ANGLE (DEG)	11,4	10.8	10.9	0.833	10.369***
	30	INTEGRATED VELOCITY ERROR (KT-SEC)	672	560	588	0.876	5.470***
	31	INTEGRATED ALTITUDE ERROR (FT-SEC)	392	235	275	1.334	3.584***
	32	INTEGRATED LATERAL ERROR (FT-SEC)	283	195	217	1.081	2.590***

*$p < 0,10$
**$p < 0,05$
***$p < 0,01$

meaningful framework for the retraining task. The first step in developing the self-paced training package was, therefore, to divide the flight profile into flight phases with definite beginning and end points. The flight phases were selected consistent with a constant set or family of control actions (Figure 7). Beginning and end points for each phase were selected which permitted rapid recognition of obvious instrumentation information status or change.

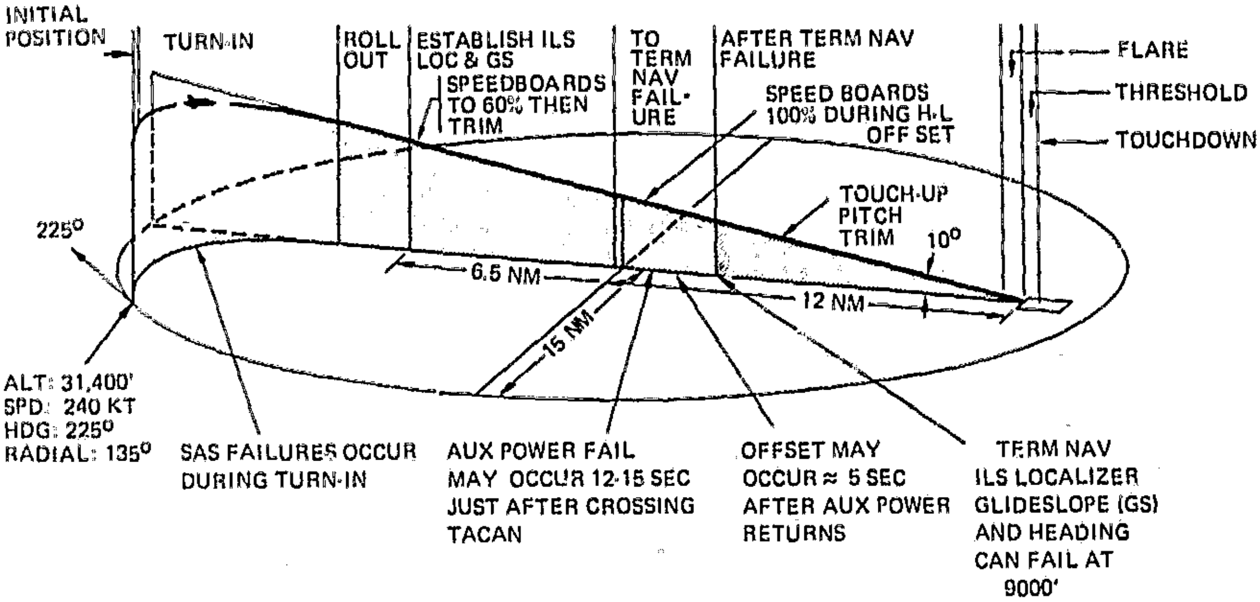


Figure 7: Flight Profile Broken into Flight Phases

After the basic flight phases were established, preliminary specific behavioral objectives were defined for each phase. These objectives stated: 1) what the pilot had to do, 2) the specific conditions under which he was expected to do it, and 3) satisfactory performance criteria. These objectives were updated later as a result of the detailed task requirements definition. They served as the basis for defining the basic training requirements and the identification of the critical visual cues. An overlying purpose of the specific behavioral objectives in final form was to convey to the pilots exactly what was expected of them during each phase and to provide them with a self-test covering the mission requirements and performance.

The flight profile and preliminary specific behavioral objectives were used to define critical information cues and cockpit photo requirements. These requirements included the specific photos for each phase as well as photo frequency (every 5 to 15 sec) required to capture the changing instrument environment cues needed by the pilot. A series of cockpit photos were then taken of a near perfect and selected off nominal flights to provide adequate coverage of situations to which the pilots were expected to successfully respond. These photos were storyboarded and analyzed to see if they met the content requirements of the specific behavioral objectives (Figure 8)

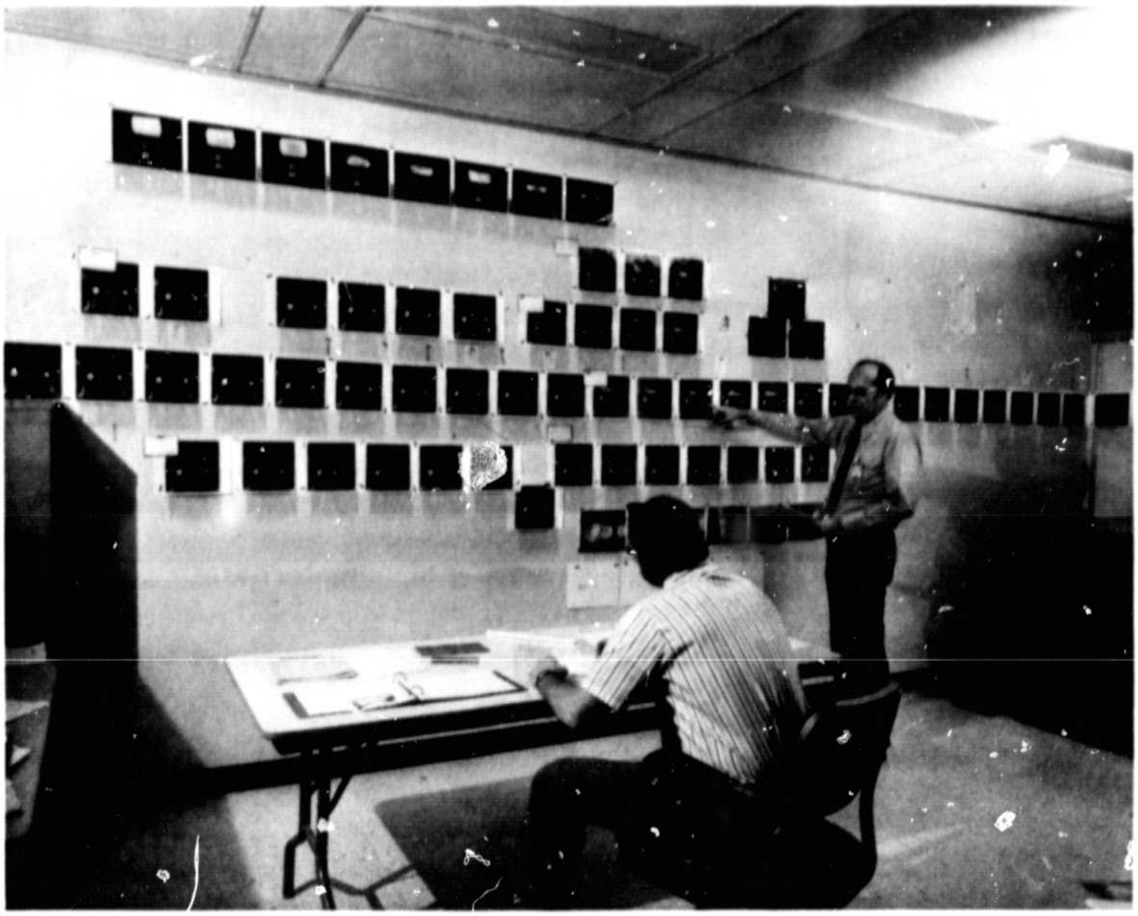


Figure 8: Cockpit Photo Storyboard of Flight Phases for Off-Nominal Flights

Using the storyboard as a guide for the definition of the detailed task requirements, the critical information and instruments were then identified with phase of flight. A detailed breakdown of all primary and secondary information requirements was prepared by instrument and flight phase. The resulting matrix provided immediate visibility of all display and control elements to be covered in the retraining. Using this matrix as a starting point, iterative analyses of the tasks in each phase were made to identify: 1) input information requirements, 2) pilot actions, and 3) outputs for significant and critical tasks. As a result of this ongoing analysis process, the definitions of the flight phases were updated.

The analyzed pilot training data was used in the training requirements definition process to provide useful information in further identifying flight control problem areas. Some of these problems were also identified from the results of the previous study. The major problem areas are summarized as follows:

A. Forgetting the basic cockpit layout and operational nomenclature of display symbology.

B. Forgetting the flight phase sequences and the corresponding correct speed, heading, attitude, etc., for each phase.

C. Forgetting correct display patterns for specific roll angle and flight path off-set conditions.

D. Forgetting the cues used after transition from IFR to VFR for final approach and touchdown.

Based upon the task requirements analysis and specification of critical problem areas, the specific behavioral objectives were updated. Additional cockpit photographs were taken where required to support the training process and a graphical representation of important display symbology was prepared to reinforce recognition of off-nominal flight path conditions. The general mission requirements and associated specific piloting task requirements for flying the spacecraft from the initial position to touchdown provided the "design to" goal for the retraining package. Each portion of the retraining had to contribute to one or more of the task objectives. Repetition and variety was used to emphasize key information and retain student interest.

Once the retraining requirements were established, the general format of the training package was established in book form. The book format was used to readily organize the illustrations and text of the training package. The overall philosophy was to move from the general to the specific: first, to re-familiarize the pilots with the purpose, general vehicle characteristics, and the flight missions; and second, to provide detailed cockpit familiarization, emergency procedures and flight training. The package was designed so that the pilots could repeat those portions of the course in which they were weak.

The self-test was prepared in printed, worksheet format based upon the training objectives. These worksheets were reproductions of various pages of the training package with specific information left blank. The purpose of the self-test was to further reinforce the important information required to successfully fly the mission through the identification of significant flight parameters, display symbology, control actions, and visual cues. Responses were to be recorded on the worksheets from memory if possible, and then completed and verified with reference to the training package.

The complete training package was produced in a printed booklet in order to provide review flexibility. In addition, a sound/slide presentation of a complete flight was prepared using the same photos contained in the printed training package. The slides were presented as a continuous sequence of "stop-action" frames synchronized to the flight time base. The objective of the sound/slide presentation was to provide a final summary review which included time and rate cues for mission events.

Self-Paced Training Package Description

The self-paced training materials consisted of a printed training package in 11 x 17 inch booklet form; 35 mm black and white, and color slides with synchronized audio recording; and a pictorial self-test. The following is a summary of the printed training package, "Flight Control and Procedures for Simulated Visual Approach and Landing - Self-Paced Training Package" (Helsel and Stterley, 1974). The table of contents for the training package is depicted in Figure 9. The "Introduction" section of the course provided the pilots with the objectives for completion of the flight, a description of the H-33 vehicle, and what the desired flight profile was. Other training objectives were provided to help focus the pilot's attention on what was important and what he was expected to do after he had completed the self-paced

I.	Introduction		7
	A.	Objectives	9
	B.	H-33 Space Shuttle general characteristics	10
	C.	Flight profile summary	12
II.	Cockpit familiarization		15
	A.	Identification of functional groups	16
	B.	Instrument group location/description	18
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	C.	Off flight path recognition	58
	D.	High-left offset sequence	61
	E.	8,800 ft. through 800 ft. sequence	67
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Figure 9: Self-Paced Training Package Table of Contents

package. Selected pages from the training package itself, with call outs and specific information missing, were also provided to the pilots as a self-test. These test/work sheets served to correct the student and reinforce his learning in preparation for entering the simulator for the skill retention test.

The H-33 Space Shuttle general characteristics portion of the "Introduction" contained a line drawing of the space shuttle with overall dimensions and weights along with a brief description of the vehicle's characteristics. The flight profile summary contained a plan view, elevation view, and a three-dimensional perspective view of the flight path. Initial position (IP), touchdown and seven (7) phases were defined as well as the location of the TACAN, ILS and runway. The flight path was covered in considerable detail to provide a framework around which the pilot could fill in the required detail as he proceeded through the training package.

The "Cockpit Familiarization" section appeared next to reacquaint the pilots with the cockpit and particularly with the Electronic Attitude Director Indicator (EADI), Multifunction Display (MFD), and the status panels. While the function, range, and units of each instrument was reviewed, the EADI and MFD displays were covered in greater detail because they were unique. The pilots had to remember what the display symbols indicated from their shape and white/grey/black shade. A series of recognition patterns was provided for efficient identification of instruments, controls and status.

"Emergency Procedures" for the stability augmentation system (SAS) and major subsystems were discussed next. The emergency procedures were at this point in the sequence so that when the near perfect flight sequence was covered, the pilot could imagine a SAS or major subsystem failure and mentally trace through the emergency procedure.

"Flight Training" started with a review of a three-dimensional perspective view of the flight profile. The profile contained all important altitude, attitude, position, and velocity information for the initial position, and the beginning and end of each of the seven flight phases ending with touchdown. An abbreviated copy of this three-dimensional perspective flight profile was used in each phase of the near perfect flight sequence to help the student visualize where he was as he reviewed the detail on cockpit instrument panels. This flight profile was repeated for each phase in order to reinforce the flight phase sequence.

The near perfect flight sequence consisted of cockpit photographs at the beginning and end of each flight phase. The instruments that the pilot should observe and what he should do using the controls was listed between these photographs. In addition, special notes were supplied which described in more detail what the student should look for in terms of instrument and visual out-the-window cues. This format allowed the student to see what the cockpit instruments looked like at the beginning and end of each phase, and what he had to observe and do. Next, a series of display symbology recognition patterns for all off-nominal flight path conditions was provided for review. The basic corrective maneuver was also included with each graphical recognition pattern. A series of cockpit photographs which depicted the recovery from a high/left off-set flight path condition was provided following the pattern recognition review. This photographic sequence permitted the pilot to visualize the important display and visual information associated with the most complex corrective maneuver.

The flight training section concluded with two photographic flight sequences. The first, from 8,800 ft to 800 ft, was designed to allow the pilot to visualize the transition from IFR to VFR and to establish the proper mental image of the out-the-window scene. These photographs were taken at 15 second intervals, showing the proper visual image of line-up, altitude, and aim point, to help the pilot arrive at the flare point at the correct distance from the runway. The last sequence was from flare (750 ft) to touchdown. This sequence was photographed at 5 to 12 second intervals to establish a good out-the-window image and instrument/out-the-window eye scan pattern.

The "Summary" section directed the pilot to review several critical portions of the training package a second time. Additional key portions of the training package were listed with recommendations for review if the pilot was unsure of his understanding. The summary concluded with the automatic stop action sequence of 33 cockpit photographs of the entire flight. This slide/sound sequence was presented at a rate which approximated real time.

Retraining and Retention Testing

One week prior to the date the first subject was to be retested, a complete checkout and recalibration of all simulation equipment was accomplished. Cockpit flight control output voltages previously recorded during the training phase were reflown through the computer prior to testing to determine the empirical equivalence of the flight profile, display control operations, and the visual scene camera servo system. Comparisons of the flight performance data recorded during training and the data obtained prior to retention testing as well as the subjective testing flights flown by the experimenter pilots indicated that the simulator was recalibrated to the condition that existed during the training and qualification testing. In addition, the experimenters and laboratory personnel practiced all test operations to ensure that the experimental procedures were consistent with those previously used during training and were performed without error.

Each pilot was scheduled to complete retraining using the new self-paced materials immediately prior to the retention test at the end of the 4 month interval. Only one pilot exceeded the prescribed interval limits (120 days, ± 3 days) and was retested after 129 days.

Immediately prior to returning to the laboratory for formal retraining and retention testing, each pilot was provided with a copy of the self-paced retraining materials for review purposes. This review was self-controlled by the pilots who reported spending an average of 2 hours going over the material. On the day scheduled for retesting, each pilot completed a formal 40 minute review in the briefing room.

This review was self-administered and consisted of: 1) an "open book" self-test covering the important flight control information and requirements, (2) the self-paced training package and photographic flight summary review, and (3) a pictorial 35 mm slide/sound flight profile/operations review. The briefing room was arranged to provide ready access to all of the retraining materials (Figure 10). In addition, a complete photographic sequence of the cockpit during the flight was available for review on the briefing room wall.

The series of 39 slides, depicting the cockpit and out-the-window visual environment, was rear screen projected at full size (Figure 11). Each slide was automatically advanced following the real time sequence of

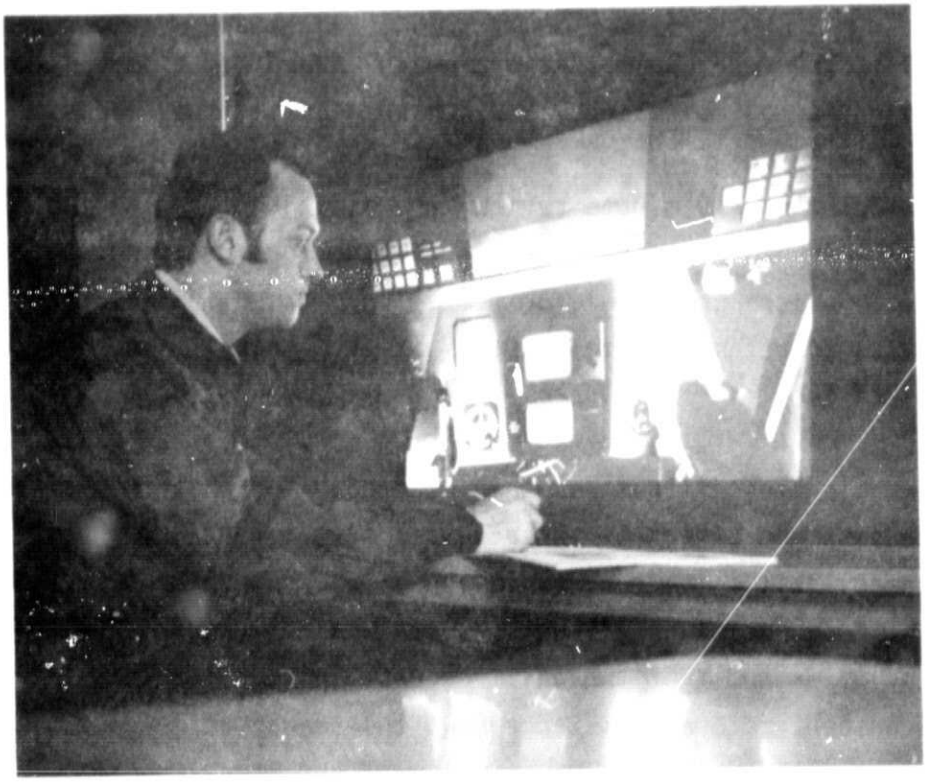

Figure 10: Pilot in Briefing Room Reviewing Self-Paced Retraining Materials

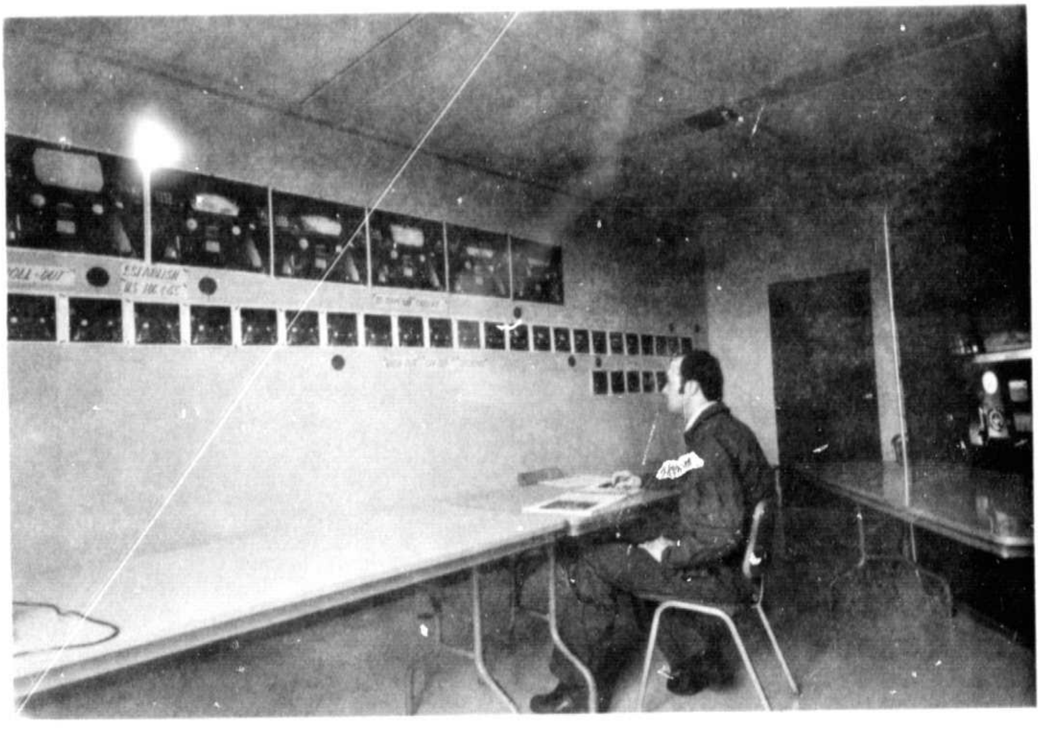

Figure 11: Pilot Watching Rear Projected Cockpit Photograph Sequence of Complete Flight

mission events. The recorded narration, which emphasized critical cues and control events, was automatically synchronized with the slides.

After completion of the 40 minute review, the pilot returned to the simulator area and was read a standard set of instructions covering seat and rudder pedal adjustment and simulator operation. The pilot was then allowed a few minutes to refamiliarize himself with the cockpit, the instruments, and control locations.

The first retention test flight was then started. The data from this flight was used to assess the effect of the advanced static retraining on retention of flight control skills. After completion of the retention test flight, the pilot flew four additional flights. Data was collected on all flights and at the end of each flight the only feedback information that the pilot received was descent rate and distance down the runway at touchdown.

The four additional flights in combination with the retention test flight provided a total of five hands-on practice flights. During these flights, the pilot could become more familiar with the dynamics of the vehicle operation, instrumentation and visual cues. Upon completion of the flights, the pilot was allowed a 10 minute break.

At the end of the rest period, the pilot was once again tested on his ability to successfully fly the simulated approach and landing mission. The data from this sixth retention test flight was used to assess the effectiveness of a combination of the advanced, self-paced retraining method and hands-on practice.

3.0 RESULTS

Eleven performance measures were used to evaluate flight control performance. Six of the measures were repeated at four points in the flight, two measures were taken during three flight phases, and two additional measures were taken at touchdown. This provided a total of 32 flight control data measurements which were identical to those used in the previous study (Sitterley, et al., 1972).

Based upon three of these measures, one critical measure of operational significance was derived: landing success; that is, did the vehicle land safely on the runway with a descent rate within the tolerance of the landing gear structural strength. In addition, 26 of the 32 individual performance variables were integrated in a combined flight performance measure to assist in the overall interpretation of the results.

Crash Landing Criteria

In the previous study it was reported that the absence of any type of retention interval practice was disastrous. Each of the five pilots in Method Group I crash landed the vehicle at the end of the four month retention interval as defined by one or more of the crash condition criteria (long/short, wide, or hard). Dynamic warmup practice afforded by the five practice flights reduced the number of crash landings to two. Static rehearsal practice (Group II) also resulted in only two crash landings. The addition of warmup practice to static rehearsal practice eliminated the incidence of crash landings completely. In the previous study, only the dynamic rehearsal (Group III) resulted in no crash landings at the end of the retention interval.

In the current study, no crash landings occurred using the improved static retraining (Group IV). In terms of this practical measure of successful performance, the improved static retraining method equalled the effectiveness of the dynamic rehearsal method of the previous study.

Combined Flight Performance Measure (CFPM)

The CFPM is an expression of overall piloting performance throughout the entire flight in one measure. The measure was determined by equally weighting all of the error performance measures (except heading) at each of the four critical flight control points (TACAN, Flare, Threshold, Touchdown). Heading "errors" (deviations from an ideal course line) were not considered because these were generally less than 2 degrees and were usually indicative of a corrective action taken to decrease the apparent lateral error at the moment. Likewise, pitch and bank angle error at touchdown were not included in the combined measure as the deviations were very small and usually corrective in nature. Thus, of the 32 flight performance measures, 26 were used to derive the CFPM.

A baseline performance level was determined for each measure by its average value in all qualification performance tests. This nominal or "qual" level was used to establish the performance factor or ratio for each data measurement that was taken. That is, the flight performance factor for a data measurement was the actual value measured, divided by the mean of that parameter in all qualification tests of both the previous and the current study. Since the CFPM was evolved to give a picture of the flight overall, all the parameters were given equal weight. The 26 flight performance factors were, therefore, arithmetically averaged to provide the overall combined flight performance measure for each flight.

Overall flight control performance was evaluated using the CFPM for the total flight. Figure 12 depicts the effectiveness of the improved static retraining method (Group IV) in comparison with the methods previously evaluated. As can be seen, the improved static method eliminated virtually all skill degradation. Furthermore, the data show that performance after using the improved method was better than any method previously used.

A tests by methods analysis of variance statistic (ANOVA) with subjects nested within methods was used to analyze differences between groups and performance tests on the combined flight performance measure. The retention

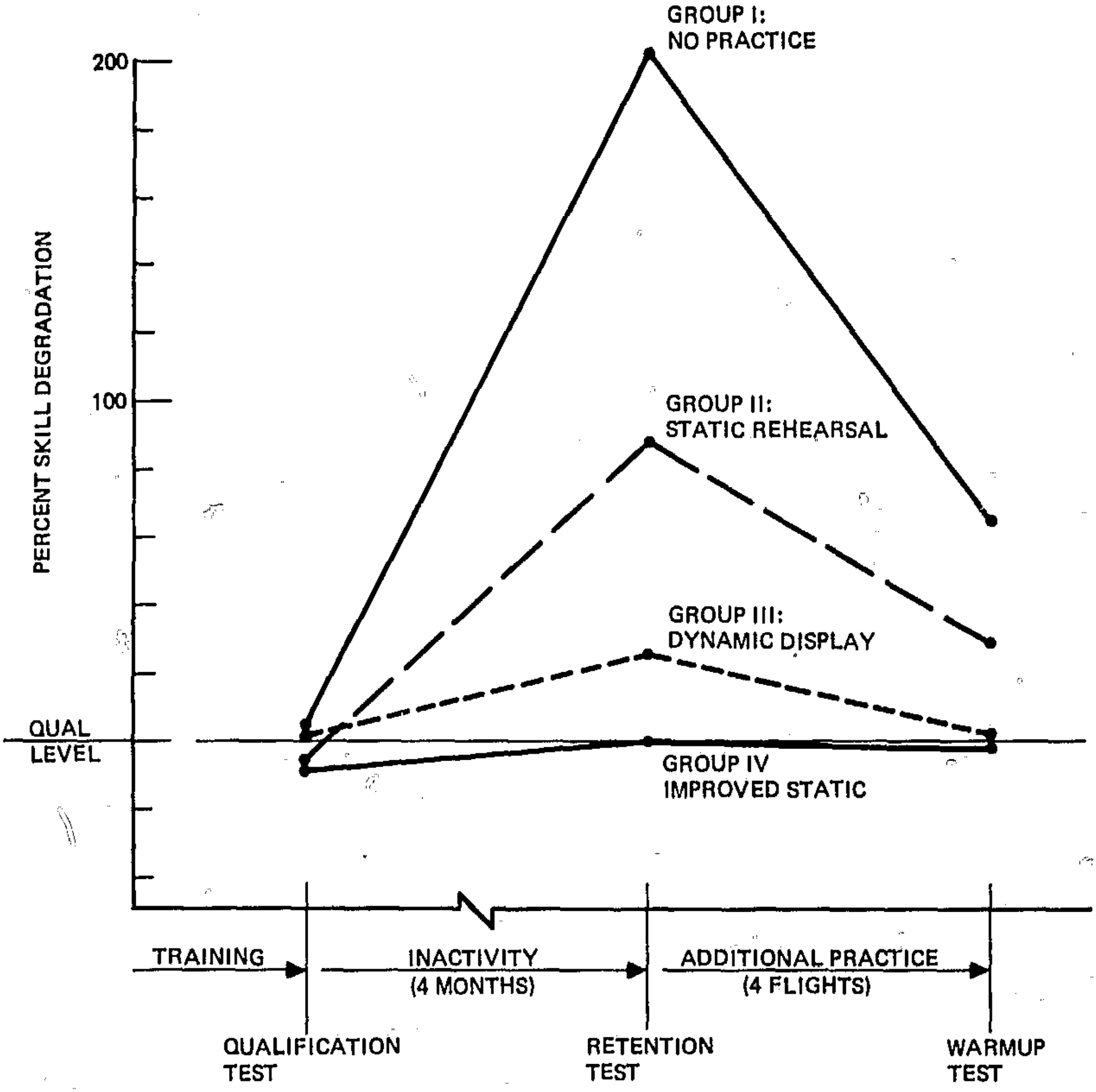

FIGURE 12: Skill Retention with Improved Static Retraining (Group IV) Compared with Previous Methods (Groups I, II, and III). (Based on Combined Flight Performance Measure.)

test data evaluated the effects of no practice, static rehearsal and dynamic display rehearsal for Method Group I, II, and III of the previous study and improved static rehearsal for Method Group IV in the current study. The warmup test data evaluated the effects of the addition of dynamic warmup practice to the training methods used by the four groups.

The results of this analysis are depicted in Table 2 for the overall flight, with significant differences ($p < .01$) detected for both main effects and for the interaction. The significant methods effect indicated that retention performance improved as a function of practice method. The significant tests effect and the methods by tests interaction showed that the benefit of warmup practice was most strongly associated with the groups that had less efficient or no retention training.

TABLE 2: Analysis of Variance Results (F Ratio) for the Combined Flight Performance Measure

MISSION PHASE	SOURCE		
	TESTS	METHODS	T x M
OVERALL FLIGHT	27.26***	6.18***	7.89***
TACAN	10.69***	3.81**	2.56**
FLARE	14.00***	4.08**	4.53***
THRESHOLD	4.39**	3.42**	1.77
TOUCHDOWN	1.63	4.40**	1.35

*p < .10
**p < .05
***p < .01

The data were further analyzed using the Duncan's New Multiple Range Test. As previously reported (Sitterley, et al, 1972), performance of both the no practice group and the static rehearsal group was significantly degraded at the end of the retention interval while the dynamic display rehearsal group showed no significant and little practical degradation. The static rehearsal group performance was significantly better than the no practice group and the addition of dynamic warmup practice significantly reduced the amount of degradation for Groups I and II.

Most importantly, however, was that no degradation was found for the improved static method (Group IV). In terms of the CFPM for overall flight, the improved static method resulted in better performance than the methods previously used.

Similar results were obtained when performance during each flight phase was evaluated. The four flight phases were: 1) Start to TACAN (IFR); 2) TACAN to flare (VFR); 3) flare to threshold (VFR); and 4) threshold to touchdown (VFR).

Figure 13 depicts performance as measured by the CFPM as a function of flight phase. The CFPM data for each flight phase were analyzed using the same ANOVA as for the overall flight; these results are also shown in Table 2. As with the overall flight CFPM, the use of the improved static method eliminated skill degradation for all flight phases. It is important to note that for the IFR phase (TACAN) the improved method was considerably more effective than the dynamic display method. As can be seen, the CFPM showed the same overall results in terms of method selection as did the frequency of crash landings: improved static retraining was superior to the previous methods.

Individual Flight Control Performance Measures

Two basic analyses of each of the flight control data measurements were also performed. The first analysis compared performance at the end of training (qualification test) with performance using the improved static retraining method at the end of the 4 month interval (retention test) and after five hands-on practice flights (warmup test). The second analysis compared performance on the three tests using the improved static method with the performance data collected in the previous study. For both analyses, the analysis of variance (ANOVA) statistic was used to evaluate the results obtained from each of the 32 performance measures.

The results of the first analysis, assessing the effectiveness of the improved static method for countering skill degradation, is depicted in Table 3. Included in the table is the mean performance achieved by the five subjects on the three tests for each performance measure and the

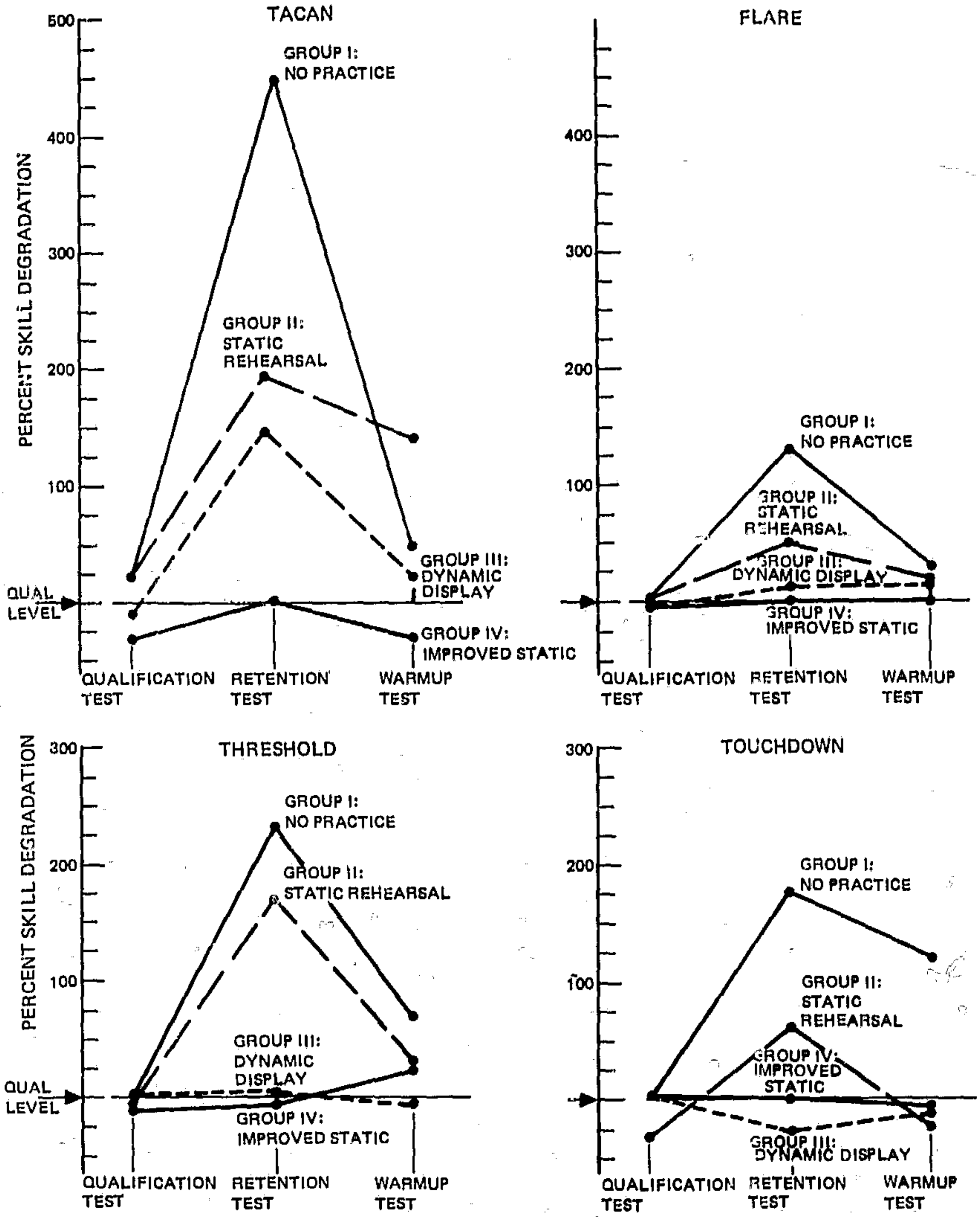

FIGURE 13: Skill Retention with Improved Static Retraining (Group IV) Compared with Previous Methods (Groups I, II, and III) for Four Critical Flight Phases. (Based on Combined Flight Performance Measure.)

TABLE 3: Improved Static Method-Pilot Performance and Analysis of Variance Results for Skill Retention Tests

PERFORMANCE MEASURE			PERFORMANCE TEST MEANS			ANOVA	
			QUAL	RETENTION	WARMUP	F RATIO	P
TACAN	1	ALTITUDE ERROR (FT)	144	227	150	0.566	
	2	LATERAL ERROR (FT)	310	205	271	0.481	
	3	HEADING ERROR (DEG)	1.6	1.5	1.8	0.081	
	4	VELOCITY (KTS)	243	240	242	0.397	
	5	DESCENT RATE ERROR (FT/SEC)	4	6	6	0.415	
	6	∫ VELOCITY ERROR (KT-SEC)	714	1498	818	3.494	<.10
FLARE	7	ALTITUDE ERROR (FT)	178	160	256	0.568	
	8	LATERAL ERROR (FT)	51	57	141	3.198	<.10
	9	HEADING ERROR (DEG)	1.6	2.0	1.8	0.095	
	10	VELOCITY (KTS)	234	237	230	1.101	
	11	DESCENT RATE ERROR (FT/SEC)	21	8	10	2.456	
	12	∫ VELOCITY ERROR (KT-SEC)	959	940	893	0.045	
	13	∫ ALTITUDE ERROR (FT-SEC)	29.5K	50.8K	39.1K	2.296	
	14	∫ LATERAL ERROR (FT-SEC)	116.7K	159.5K	106.7K	4.396	<.10
THRESHOLD	15	ALTITUDE ERROR (FT)	35	22	67	2.853	
	16	LATERAL ERROR (FT)	32	56	60	0.837	
	17	HEADING ERROR (DEG)	.7	1.3	1.0	0.552	
	18	VELOCITY (KTS)	192	186	186	0.387	
	19	DESCENT RATE ERROR (FT/SEC)	9	5	9	0.604	
	20	∫ VELOCITY ERROR (KT-SEC)	564	520	664	0.470	
	21	∫ ALTITUDE ERROR (FT-SEC)	3037	1760	2478	0.670	
	22	∫ LATERAL ERROR (FT-SEC)	1096	858	2093	3.142	<.10
TOUCHDOWN	23	LATERAL ERROR (FT)	37	21	18	2.029	
	24	DOWN RANGE ERROR (FT)	871	919	969	0.027	
	25	HEADING ERROR (DEG)	.6	1.8	1.5	1.103	
	26	VELOCITY (KTS)	160	187	167	12.806	<.01
	27	DESCENT RATE (FT/SEC)	10	9	9	0.206	
	28	BANK ANGLE (DEG)	0.8	1.8	1.6	1.346	
	29	PITCH ANGLE (DEG)	11	8	11	6.166	<.05
	30	∫ VELOCITY ERROR (KT-SEC)	639	218	515	5.940	<.05
	31	∫ ALTITUDE ERROR (FT-SEC)	280	332	275	0.054	
	32	∫ LATERAL ERROR (FT-SEC)	277	136	269	0.726	

•P < .10
••P < .05
•••P < .10

associated results of the repeated measures ANOVA. As can be seen by inspection of the data in Table 3, little practical or significant degradation occurred in performance when the improved static retraining method was used.

Of the seven measures for which strong trends or significant test differences were detected, only four were associated with degradation on the retention test (Measures 6, 14, 26 and 29). Of these four, the lower pitch angle (measure 29) on the retention test was complemented by the higher touchdown velocity (measure 26) which resulted in a satisfactory descent rate (measure 27).

Each of these performance measures were also subjected to the analysis of variance statistic to evaluate the effectiveness of the type of refresher training on skill degradation. A two factor (retraining methods by performance tests) experimental design with repeated measures on the test factor (subjects nested within groups) was used for this second analysis.

When compared with the retraining methods used in the previous study, the improved static method resulted in very high performance. Table 4 depicts the mean performance for each measure as a function of practice methods used in the previous study (Groups I, II, and III) and the current study (Group IV). Inspection of the data reveals that the improved static method did as well as the best previous method on most of the performance measures. The results of the second series of ANOVA's are depicted in Table 5. Similar to the comparable analysis performed in the previous study, this analysis failed to detect significant differences for most of the individual measures due to the small sample size.

TABLE 4: Mean Performance as a Function of Practice Methods For Individual Flight Control Performance Measures

	PERFORMANCE MEASURE	GROUP I: NO PRACTICE			GROUP II: STATIC REHEARSAL			GROUP III: DYNAMIC DISPLAY			GROUP IV: IMPROVED STATIC		
		QUAL	RET TEST	WARMUP	QUAL	RET TEST	WARMUP	QUAL	RET TEST	WARMUP	QUAL	RET TEST	WARMUP
1	ALTITUDE ERROR (FT)	520	1891	873	390	1884	1321	102	736	118	144	227	150
2	LATERAL ERROR (FT)	137	1637	360	847	884	1101	200	1968	397	310	205	271
3	HEADING ERROR (DEG)	1.1	1.4	1.0	1.4	3.7	2.4	1.5	4.4	2.2	1.6	1.5	1.4
4	VELOCITY (KTS)	243	281	240	242	243	241	246	241	248	243	240	242
5	DESCENT RATE ERROR (FT/SEC)	18	41	9	9	27	13	6	13	16	4	6	6
6	INTEGRATED VELOCITY ERROR (KT-SEC)	720	2709	852	828	1176	1099	1198	1369	1180	714	1498	816
7	ALTITUDE ERROR (FT)	261	458	500	278	397	156	322	183	183	178	160	256
8	LATERAL ERROR (FT)	105	137	105	73	127	70	80	32	109	51	57	141
9	HEADING ERROR (DEG)	.7	1.9	1.2	1.3	.7	1.2	1.4	1.6	1.0	1.6	2.0	1.8
10	VELOCITY (KTS)	231	215	238	227	232	230	234	230	233	234	237	230
11	DESCENT RATE ERROR (FT/SEC)	10	36	7	16	19	20	8	21	15	21	8	10
12	INTEGRATED VELOCITY ERROR (KT-SEC)	637	3505	800	996	1553	1399	898	1556	1242	959	940	893
13	INTEGRATED ALTITUDE ERROR (FT-SEC)	56.8K	89.3K	77.2K	40.6K	106.3K	59.4K	50.3K	59.4K	51.5K	29.5K	50.8K	39.1K
14	INTEGRATED LATERAL ERROR (FT-SEC)	110.0K	172.0K	146.8K	137.9K	197.4K	152.8K	111.0K	137.4K	131.3K	116.7K	159.5K	106.7K
15	ALTITUDE ERROR (FT)	68	72	167	38	69	39	82	60	34	35	22	67
16	LATERAL ERROR (FT)	26	90	52	26	27	37	47	13	26	32	56	60
17	HEADING ERROR (DEG)	.3	1.6	1.0	.4	.8	.6	1.2	.6	.7	.7	1.3	1.0
18	VELOCITY (KTS)	191	154	206	191	151	183	198	181	191	192	186	186
19	DESCENT RATE ERROR (FT-SEC)	10	33	13	12	12	12	12	4	7	9	5	9
20	INTEGRATED VELOCITY ERROR (KT-SEC)	595	1004	342	593	817	716	441	744	577	564	520	664
21	INTEGRATED ALTITUDE ERROR (FT-SEC)	4051	4046	7293	4064	5133	2542	4491	2674	2237	3037	1760	2478
22	INTEGRATED LATERAL ERROR (FT-SEC)	1189	1899	1801	1147	1705	982	1060	541	1245	1096	858	2093
23	LATERAL ERROR (FT)	20	83	24	28	43	32	29	14	54	37	21	18
24	DOWN RANGE ERROR (FT)	1323	4360	2416	695	2708	935	1370	1673	1577	871	919	969
25	HEADING ERROR (DEG)	.2	1.8	.9	.2	1.5	.4	.7	.6	1.2	.6	1.8	1.5
26	VELOCITY (KTS)	161	180	156	168	181	163	164	163	154	160	187	162
27	DESCENT RATE (FT/SEC)	7	35	12	8	22	7	8	7	9	10	9	9
28	BANK ANGLE (DEG)	1.2	3.3	1.6	.4	1.3	2.8	1.3	.5	.7	.8	1.8	1.6
29	PITCH ANGLE (DEG)	11	6	11	11	7	11	10	11	12	11	8	11
30	INTEGRATED VELOCITY ERROR (KT-SEC)	627	733	960	431	554	382	647	360	707	639	218	516
31	INTEGRATED ALTITUDE ERROR (FT-SEC)	377	346	1593	116	299	106	457	295	305	280	332	275
32	INTEGRATED LATERAL ERROR (FT-SEC)	229	451	539	139	308	203	391	147	396	277	136	269

TABLE 5: Analysis of Variance Results (F Ratio) for Individual Flight Control Performance Measures

PERFORMANCE MEASURE			SOURCE		
			TESTS	METHODS	T x M
TACAN	1	ALTITUDE ERROR (FT)	6.047•••	4.274••	0.949
	2	LATERAL ERROR (FT)	2.747•	0.790	1.146
	3	HEADING ERROR (DEG)	2.448•	1.401	0.783
	4	VELOCITY (KTS)	1.830	2.674 •	2.927••
	5	DESCENT RATE ERROR (FT/SEC)	5.479•••	3.061•	2.054•
	6	INTEGRATED VELOCITY ERROR (FT-SEC)	10.886•••	1.629	3.099••
FLARE	7	ALTITUDE ERROR (FT)	0.236	2.342	1.879
	8	LATERAL ERROR (FT)	1.008	1.026	1.833
	9	HEADING ERROR (DEG)	0.278	1.205	0.477
	10	VELOCITY (KTS)	0.300	0.142	0.713
	11	DESCENT RATE ERROR (FT/SEC)	2.701•	0.782	3.479•••
	12	INTEGRATED VELOCITY ERROR (KT–SEC)	12.139•••	1.504	5.760•••
	13	INTEGRATED ALTITUDE ERROR (KT-SEC)	5.801•••	2.427	0.923
	14	INTEGRATED LATERAL ERROR (FT-SEC)	6.748•••	2.476•	0.517
THRESHOLD	15	ALTITUDE ERROR (FT)	0.987	1.187	2.165•
	16	LATERAL ERROR (FT)	0.915	3.522••	2.082•
	17	HEADING ERROR (DEG)	1.036	0.812	1.036
	18	VELOCITY (KTS)	3.578••	0.354	0.710
	19	DESCENT RATE ERROR (FT-SEC)	0.621	3.016•	2.665••
	20	INTEGRATED VELOCITY ERROR (KT-SEC)	3.740••	0.247	1.958
	21	INTEGRATED ALTITUDE ERROR (FT-SEC)	0.248	2.213	2.182•
	22	INTEGRATED LATERAL ERROR (FT-SEC)	1.686	1.708	2.204•
TOUCHDOWN	23	LATERAL ERROR (FT)	0.669	0.775	2.459••
	24	DOWN RANGE ERROR (FT)	2.333	2.189	0.738
	25	HEADING ERROR (DEG)	3.388••	0.813	0.679
	26	VELOCITY (KTS)	4.303••	0.334	0.395
	27	DESCENT RATE (FT-SEC)	6.357•••	2.981	2.788••
	28	BANK ANGLE (DEG)	1.235	0.516	1.259
	29	PITCH ANGLE (DEG)	10.026•••	0.765	1.862
	30	INTEGRATED VELOCITY ERROR (KT-SEC)	0.987	1.316	0.889
	31	INTEGRATED ALTITUDE ERROR (FT-SEC)	1.719	2.142	2.849••
	32	INTEGRATED LATERAL ERROR (FT-SEC)	0.443	0.823	0.627

•$p < .10$

••$p < .05$

•••$p < .10$

4. DISCUSSION AND CONCLUSIONS

The effectiveness of an improved training method was compared in this study with the effectiveness of methods previously investigated (Sitterley, et al, 1972). Whenever new results are evaluated in relation to results previously obtained, the comparability of simulator characteristics, experimental procedures, and test subjects is important to the validity of the results and conclusions. Since both studies required that the test subjects experience the same experimental conditions after relatively long intervals of time, considerable care was exercised to make certain that the experimental conditions could be closely duplicated from the very beginning.

The aerodynamics model and scaling of the electronic flight instruments were held constant by digital computer programs and hardwired circuit cards. High fidelity calibration recordings of all flight control elements of the simulator were used to maintain the empirical equivalence of the display/control operations and the camera servo systems. Detailed experimental procedure checklists for simulator checkout and operation, subject training, data collection, and analysis provided the basis for maintaining close control and repeatability of all experimental procedures, both within and between studies.

Likewise, the test subjects were obtained from the same pilot population using the same selection criteria for both studies. The time required to train to criterion, and the performance at the end of training, amply demonstrated that the pilots in the current study were very comparable to those used in the previous study. It may be assumed, therefore, that the characteristics and fidelity of the simulator and experimental procedures as well as subject selection in the current study provided a close replication of the previous study. As such, results obtained using the advanced static retraining method may be compared with the retraining method results of the previous study with reasonable confidence.

The results of this study showed that use of the improved static retraining method countered skill degradation beyond expectations. After 4 months without practice, the improved static method prevented any significant or practical degradation in flight control performance during the simulated approach and landing. Furthermore, and perhaps most significant, the improved static retraining method appeared to be more effective in countering skill degradation than even the dynamic display method, which was most effective in the previous study.

The previous study demonstrated the substantive requirement for critical visual cue and flight operation reinforcement for skill retention training, and suggested that alternate methods of retraining which do not involve closed-loop interaction with the pilot may be feasible. The present study reconfirms these conclusions. It was also suggested that the important element in effective retraining was the inclusion of a more complete and dynamic representation of the visual flight environment. However, the success of the improved static method in the present study failed to confirm the necessity of dynamic visual cue presentation for retraining. Apparently, the carefully structured visual cues of the improved static method were sufficient to "key" the appropriate pilot responses even though they were presented in a static or still form.

The improved static retraining completely overcame the inadequacies of the original static retraining method by providing a more complete stop action sequence of events which carefully integrated the visual cues, flight profile, cockpit instrumentation, and required control responses. In addition, the improved method provided the comparative basis for recognizing the limits of good performance and the proper recovery from off-nominal situations. It is clear that the systematic identification of retraining requirements and structuring of the course content formed the basis for the current success of static retraining.

However, it is not so clear why the improved static method was more effective than the dynamic display retraining method. With the dynamic display method, the pilot sat in the cockpit and viewed the instruments and out-the-window visual scene throughout the complete flight. While the pilot did not have the capability to interact with the flight situation via the controls, all of the dynamics of instrument operation and visual field were available to him. Certainly, the visual cues, in their proper context, were more complete in the dynamic display method than in the current improved static method retraining. The effectiveness of the improved static method does not, therefore, appear to be related to the total inclusion of all visual cues or to the presentation of the necessary cues in dynamic or motion form.

Apparently the important element was the presentation of those cues or stimuli which assisted the pilots to recall their basic flight experience, both perceptual and control, and to apply it to the characteristics of the current flight problem. The flexibility of the self-paced retraining approach, coupled with the integration of the critical instrument, flight profile, and visual cues were the unique characteristics of the improved static retraining. The graphic self-test further reinforced these characteristics and the learning situation by providing direction to, and interactive involvement with, the retraining materials.

Conclusions

This study confirms the thesis that properly structured open-loop methods of flight control task retraining are feasible. Furthermore, it indicates that these retraining methods do not require a dynamic presentation media to be effective.

Application of the results of this study can have a significant impact on the cost-effectiveness of recurrent and transition flight training. Fuel and aircraft costs are at a premium for flight training. Certainly simulators can and do relieve a significant portion of this burden. However, simulators are still relatively expensive and their widespread availability for training is limited.

Current advancements in the state-of-the-art of training technology may well permit an off-loading of simulator training time similar to that which simulators have provided for flight training. At a minimum, the benefits of improved self-paced training materials should materially enhance the effective utilization of our limited simulator and aircraft training hours.

5. REFERENCES

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