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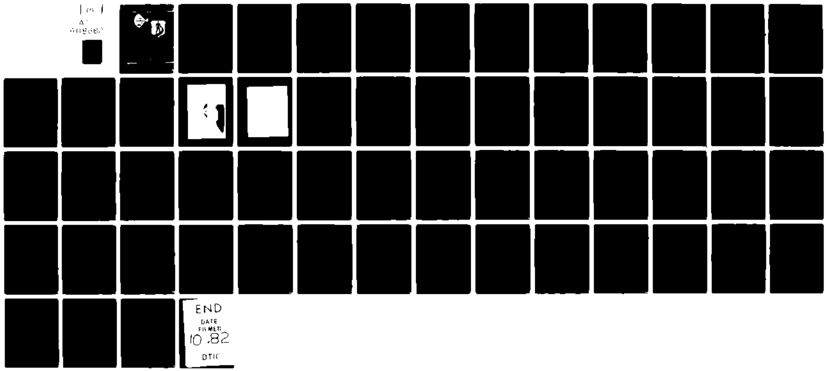

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APPLICATIONS OF SIMULATOR FREEZE TO CARRIER GLIDESLOPE TRACKING INSTRUCTION

July 1982

NAVAL TRAINING EQUIPMENT CENTER
ORLANDO, FLORIDA 32813

AIR FORCE HUMAN RESOURCES LABORATORY
BROOKS AIR FORCE BASE, TEXAS 78235

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Twenty-five experienced F-4 and F-16 Air Force pilots were instructed in carrier landings in the Visual Technology Research Simulator (VTRS). The training was conducted under three instructional conditions, two of which employed the simulator's "freeze" feature. Additionally, two methods of defining errors for carrier glideslope tracking were examined. These experimental training techniques were compared to a conventional training approach where no "freezes" were imposed during the training sequence.

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20. Abstract (Cont'd)

While pilots who were trained under the "freeze" condition developed control strategies that distinguished them from pilots trained by Conventional measures, no differences were found between these groups on rate or extent of learning. In response to a post experimental questionnaire, pilots who were trained under "freeze" conditions indicated that the simulator "freeze" was "frustrating" and added to the overall difficulty of the task. These pilots further reported being more motivated to avoid the "freeze" than to perform the task correctly during training.

A probe technique was used to examine differential transfer in lieu of the more traditional transfer-of-training technique. Although this experimental use of the probe technique was a preliminary effort, it does appear to hold promise for transfer-of-training experiments of this type.

7. Author(s) (Cont'd)

R. G. Hughes
USAF Human Resources Laboratory/OT
Williams AFB, Arizona 85224

G. Lintern
Canyon Research Group, Inc.
Orlando, Florida 32803

D. C. Wightman
Naval Training Equipment Center
Orlando, Florida 32813

R. B. Brooks
USAF Human Resources Laboratory/OT
Williams AFB, Arizona 85224

J. Singleton, LCDR
U.S. Navy

PREFACE

This report is the fourth in a continuing series of cooperative ventures between the Naval Training Equipment Center and the Air Force Human Resources Laboratory. This experiment was carried out on the Navy's Visual Techology Research Simulator (VTRS) in Orlando, Florida, and is the first in this cooperative series to employ the VTRS.

A subject of concern to both the Navy and the Air Force was addressed in the experiment reported here. Issues concerning the implementation of instructional strategies and employment of certain simulator features in line with their instructional value have been addressed in the recent past. The issue addressed in the experiment reported here concerns the instructional value of one common simulator feature, the "freeze" feature. The "freeze" feature allows for a suspension of the simulator task so that a student may be given instructional feedback while freed of the requirement to perform the task. The experiment reported here concerns the "freeze" feature commonly found in flight simulators and whether it should be employed in the training of a complex flight task.

A number of persons contributed to this research. Walter S. Chambers, Stanley C. Collyer, Patricia Daoust and Edward Holler of the Naval Training Equipment Center (Code N-732); Brian Nelson, Daniel Sheppard and Daniel Westra of Canyon Research Group, Inc.; and Jack Davis and Karen Thomley of the University of Central Florida provided technical support.

Twenty-five Air Force pilots from the 56th Tactical Fighter Wing, MacDill Air Force Base, Florida served as subjects in this experiment. They are to be commended for their cooperation. The authors would like to specifically thank Major C.P. Dockery of the 9th Air Force, Shaw Air Force Base, South Carolina and Col. D. McCarter, the Naval Training Equipment Center's Air Force Liaison officer for their valuable assistance in securing the pilots who participated.

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SECTION I

INTRODUCTION

The history of simulation has closely followed the history of aviation. Early trainers were crude, unsophisticated boxes designed to give pilots some semblance of the flying experience and to prepare them to perform procedures important in flight. With the passage of time, aircraft and flight simulators have undergone evolutionary changes. Modern flight simulators are capable of reproducing many of the same conditions that are attainable in the aircraft (Caro, 1977). This refinement in simulator capability is an outgrowth of advances in technology and is due to an increased desire on the part of the simulator design engineer to give the pilot an environment that "feels" as much as possible like the real aircraft. Pilot self-report and subjective assessment were the ruling criteria that drove the development of flight simulators.

Thus the flight simulator has been regarded as an artificial airplane wherein flight tasks could be performed in a safer, cheaper environment. Economy and safety were the specific reasons to substitute flight simulators for aircraft. However recent advances in training technology have increased awareness that the aircraft may not be the best place to begin the process of learning to fly. The simulator, in contrast to the airplane, has the potential to be structured as a learning environment that can facilitate the acquisition of the perceptual and motor skills necessary for aircraft control (Caro, 1976).

Reliance upon an "in-flight" model to dictate the limits of design and use of simulators for pilot training can unnecessarily restrict the potential of simulation to facilitate skill acquisition. Recent research has begun to address the issue of how to enhance the training value of simulation by employing principles of learning and transfer rather than sheer physical fidelity as the guiding criteria (Hughes, 1979). The employment of certain techniques that follow from these principles may lead to simulator conditions that, although objectively unrealistic, can enhance the efficiency of the simulator as a training device.

For example, Hughes, Hannan, and Jones (1979) have explored the use of a record-playback feature for instruction of a complex flight task while Bailey, Hughes, and Jones (1980) have tested the instructional value of backward chaining with a dive bombing task. Lintern (1980) and Hennessy, Lintern, and Collyer (1981) have examined learning with novel and altered visual displays.

Simulators not only offer the promise of permitting learning to proceed more rapidly, but also may permit a higher level of skill attainment. With some specific flight tasks, the benign and predictable simulation environment may permit pilots to quickly perceive critical relationships that can aid their performance in the aircraft but that would never clearly emerge if they practiced only in the aircraft.

These studies represent initial attempts to explore the potential of flight simulators as training devices through the alteration of the display presentation or through the application of principles of learning as training features. This point of view diverges from the artificial aircraft model and requires that relevant learning principles be addressed as the driving force behind the conduct of training in flight simulators.

Of all the instructional options that have been, or might be, built into an aircraft simulator, "freeze" appears to have gained the widest acceptance. "Freeze," in the simulator training context, refers to the suspension of any part or all of the simulated task for instructional purposes. Two uses may be made of this "freeze" feature. First, "freeze" can be employed to suspend some aspect of the flight dynamics (e.g., aircraft roll may be "frozen") so that the trainee may focus his attention upon some other, more critical aspect of the task, prior to attempting the whole task. Another potential use of "freeze" that has high apparent validity is for the instructor to stop the action while explaining errors and strategies to the student. Nevertheless, there must be some concern that the level of assistance provided by the use of "freeze," especially in the latter case, could disrupt retention of the skill (c.f., Snow, 1980) or that the interruption could disrupt its acquisition.

The present study is concerned with the use of the latter, total task suspension "freeze" technique, and how it relates to the specific role of errors in skill acquisition; in particular, whether a "freeze" should be used as an opportunity to instruct the student in the cause and correction of errors or whether it should be used to minimize them. While it is apparent that information about the direction and magnitude of errors can facilitate skill learning (Adams, 1981), there is some concern that frequently committed errors could become embedded in a student's response repertoire (Holding, 1970). Thus approaches that enhance the student's awareness of the nature of the error and those that minimize errors represent extreme positions in the treatment of errors during learning.

The possibility that repetition will embed errors in a student's behavior appears possible in the case of the carrier landing task. For example, a marginal approach, while being severely criticized by the Landing Signal Officer (LSO), can result in a safe landing. Although Navy pilots are consciously and explicitly concerned with technique in making carrier approaches, successful completion of a dangerous task by any means is, in a technical sense, reinforced. This positive reinforcement may partially negate the effects of negative reinforcement from the LSO and from the pilot's own cognitive judgments and could be one of the more potent influences on learning. The natural consequences of errors appear to have a powerful self-correcting influence in perceptual-motor learning, but the natural consequences of errors in carrier approaches may not be sufficiently negative with the required frequency to give full force to this effect.

Given the expanded range of options available for simulator instruction versus in-flight instruction, the questions arise as to whether errors should be permitted, how they should be treated if they are permitted, and how an instructor might intervene to enhance the learning process. The carrier landing task was considered ideal for examining these issues. Control behavior is strictly constrained by the demands of the task, and errors can be specified clearly. Navy pilots and instructors tend to agree that error detection and correction are fundamental to safe and consistent carrier landings.

The present study addressed the issue of how errors should be treated by examining three techniques for teaching the carrier approach task. Specifically, the study addressed the use of the simulator's "freeze" feature to interrupt an otherwise continuous performance whenever an error was detected. One possible advantage of freezing the task in this manner is that it would allow students to attend to instructional feedback without the simultaneous need for them to perform the task. Effectiveness of the feedback might thus be enhanced and so lead to faster learning. Alternatively, interruption of the continuous task might be disruptive and thereby impede learning. The following instructional conditions were created to explore these issues.

"Freeze/Reset." Under the Freeze/Reset condition, the simulator was "frozen" whenever an error was detected. Feedback was given while the "freeze" was in effect. During the "freeze," inside- and outside-cockpit references and cues were maintained as they were when the "freeze" occurred. Before continuing the task, however, the simulator was returned to the appropriate position (vertically) on glideslope with appropriately configured angle of attack and airspeed. At the termination of the "freeze," the student continued the task from the "corrected" position.

"Freeze/Flyout." Under the Freeze/Flyout condition, the actions during the "freeze" were the same as those for the Freeze/Reset condition except that at termination of the "freeze," the student continued the task from the exact point at which it was "frozen." That is, no correction was made.

"Conventional." Under the Conventional condition, students learned the task without use of the "freeze." Instructional feedback was given at the completion of each approach.

In addition to examining these three alternative instructional conditions, the study addressed the manner in which errors were defined. One error criterion was based on displacement from the glideslope while the other was based on both displacement from glideslope and deviation from the optimum rate of descent. The latter criterion is potentially more informative in that a descent-rate error can give advance warning of a displacement error so that earlier corrective action can be taken. The addition of rate information to displacement information has been shown to minimize glideslope tracking errors of experienced Navy pilots (Kaul, Collyer, and Lintern, 1980).

One important methodological issue in transfer-of-training (TOT) research is related to selection of an appropriate training period. Training to a proficiency criterion has often been used, but in a study of differential transfer, the average time for various groups to attain proficiency almost always differs. Thus, training time tends to be confounded with the experimental effects of interest. Fixed training times resolve that problem but selection of an appropriate period can be critical, and necessarily relies heavily on the judgment and experience of the experimenter. Training times could be too short to allow differences to emerge. Alternatively, they could be so long that worthwhile training differences are washed out by subjects attaining a high level of proficiency with even the poorest training conditions. Thus, training times should be extended into, but not beyond, that period in training which shows worthwhile learning differences between instructional methods.

Pre-experimental work could ascertain the most appropriate training period, but it would require expenditure of a large portion of the experimental resources to obtain a reliable answer. Furthermore, in a study of more than two training conditions, the selected training time may be appropriate for only some of the comparisons. A range of times could be used but would reduce the power of the experiment (i.e., its capability to reveal differences between conditions) to the extent that some of the selected training periods were inappropriate. Training time is a special issue in a study of novel training techniques, such as those considered here where an experimenter has limited experience and meager data to provide guidance.

A probe technique in which learning trials or the experimental conditions are interspersed with test trials on the control condition could avoid these problems. This technique, which appears to have been used only once in applied transfer-of-training research (Smith, Pence, Queen and Wulfeck, 1974) might effectively map the course of learning and thus allow an estimate of the optimum training period for each instructional method. Smith et al. (1974) used a single-trial probe strategy in which training and probe trials alternated. Their strategy was probably not optimum. Presumably an experimental session should be weighted heavily with training versus probe trials to limit dilution of the training effects. Nevertheless probes should be frequent enough to ensure that critical differences are not missed, and sufficient data would be required at each probe to achieve worthwhile stability. Probe methodology would seem to offer distinct advantages for the initial investigation of a novel training method. However, for evaluating savings in relation to a standard instructional paradigm, the traditional transfer-of-training paradigm would still be preferred. In this experiment, the probe technique was employed in an attempt to solve some of the dilemmas faced by transfer of training experimenters. Here probe trials, consisting of performance of the transfer task, were interspersed throughout the training sessions in order to assess the level of proficiency of the trainees as training progressed. Two critical issues surface as a consequence of the use of a probe technique. First, are the probe performances sensitive to the learning that is taking place during the training trials? Secondly, are the probe trials in some way disruptive of the training process? Both of these issues were addressed in the experiment.

SUMMARY OF PRIMARY OBJECTIVES

1. To assess the relative effectiveness of three instructional methods differing in the degree to which each alters the instructional environment following an error.

2. To explore the total task suspension use of "freeze" for instruction of a continuous tracking skill.

3. To examine the effects on learning of two error criteria: displacement only versus displacement and rate.

4. To assess the extent to which the transfer task performance sampled periodically in probe trials is sensitive to what is learned in training trials and what effect, if any, probe trials might have upon learning.

SECTION II

METHOD

Five groups of five experienced Air Force pilots were taught carrier landings in a flight simulator at the Naval Training Equipment Center under a control or one of four experimental training conditions.

Experienced Air Force pilots were sought to avoid the necessity of teaching basic aircraft control skills. These pilots were, however, inexperienced with reference to the specific carrier approach skills that were to be learned in this experiment. Table 1 summarizes the flight experience of the pilots.

APPARATUS

The Visual Technology Research Simulator (VTRS) consists of a fully instrumented T-2C navy jet trainer cockpit, a six-degree-of-freedom synergistic motion platform, a 32-element G-seat, a wide-angle visual system that can project both computer-generated and model-board images, and an Experimenter/Operator Control Station (Collyer and Chambers, 1978). The motion system, G-seat, and model board were not used in this experiment.

VISUAL SYSTEM. The background subtended 50° above to 30° below the pilot's eye level, and 80° to either side of the cockpit. The aircraft carrier image, which was a representation of the Forrestal (CVA 59) was generated by computer and projected onto the background through a 1025-line video system. A carrier wake and Fresnel Lens Optical Landing System (FLOLS) were also generated by this method. Both daytime and nighttime carrier images could be displayed (Figures 1 and 2).

Average delay between control inputs and generation of the corresponding visual scene was approximately 116 msec (calculation of new aircraft coordinates required 50 msec while calculation of the visual scene corresponding to the viewpoint from the new aircraft coordinates required approximately 50 msec and generation of the new scene required 17 msec). An updated aircraft position was computed every 33 msec, but the picture position was updated every 17 msec by extrapolating aircraft position in between each computed aircraft position.

The sky brightness for the day scene was 0.85 fL (foot-lambert) and the seascape brightness was 0.6 fL. The brightest area of the day carrier was 4.0 fL. Except for the horizon, no features were represented in either the sky or sea. The night background luminance was 0.04 fL and the horizon and seascape were not visible. The night carrier appeared as lights of 0.8 fL brightness outlining the landing deck and other features.

TABLE 1. BIOGRAPHICAL DATA ON PILOT SUBJECTS

Subject	1	2	3	4	5	6	7	8	9	10	11	12	13
Group Assignment	(3)	(3)	(1)	(4)	(2)	(5)	(4)	(1)	(5)	(2)	(3)	(4)	(3)
Age	35	35	27	32	33	32	29	37	32	31	33	34	32
Flight Hrs. Aircraft	2030	2363	1233	2050	1900	1680	1250	3040	1500	1825	1500	1956	2700
Simulator	10	470	550	360	300	350	300	450	400	194	210	90	300
Last 30 Days Hrs. Aircraft	15/ F-16	20/ F-16	22/ F-4D	20/ F-16	20/ F-4	20/ F-4D	17/ F-4D	20/ F-4	22/ F-4D	12/ F-16	20/ F-4	24/ F-16	20/ F-16

continued

TABLE 1. BIOGRAPHICAL DATA ON PILOT SUBJECTS (Cont'd)

Subject	14	15	16	17	18	19	20	21	22	23	24	25
Group Assignment	(5)	(2)	(1)	(1)	(4)	(2)	(5)	(4)	(2)	(5)	(1)	(3)
Age	37	38	45	47	43	31	32	36	42	35	39	30
Flight Hrs. Aircraft	2500	3040	3100	5500	3500	2175	2080	2035	5300	1600	2300	1480
Simulator	215	170	150	500	295	200	210	300	350	390	260	250
Last 30 Days Hrs. Aircraft	20/ F-4	25/ F-4	0	15/ F-4	5/ F-4	20/ F-4	18/ F-16	0	15/ F-4D	25/ F-4D	25/ F-4	14/ F-4D

<u>Key to Group Assignment</u>

1) Freeze/Flyout Display
2) Freeze Reset/Displacement
3) Conventional Display
4) Freeze/Flyout Displacement and Rate
5) Freeze Reset/Displacement and Rate

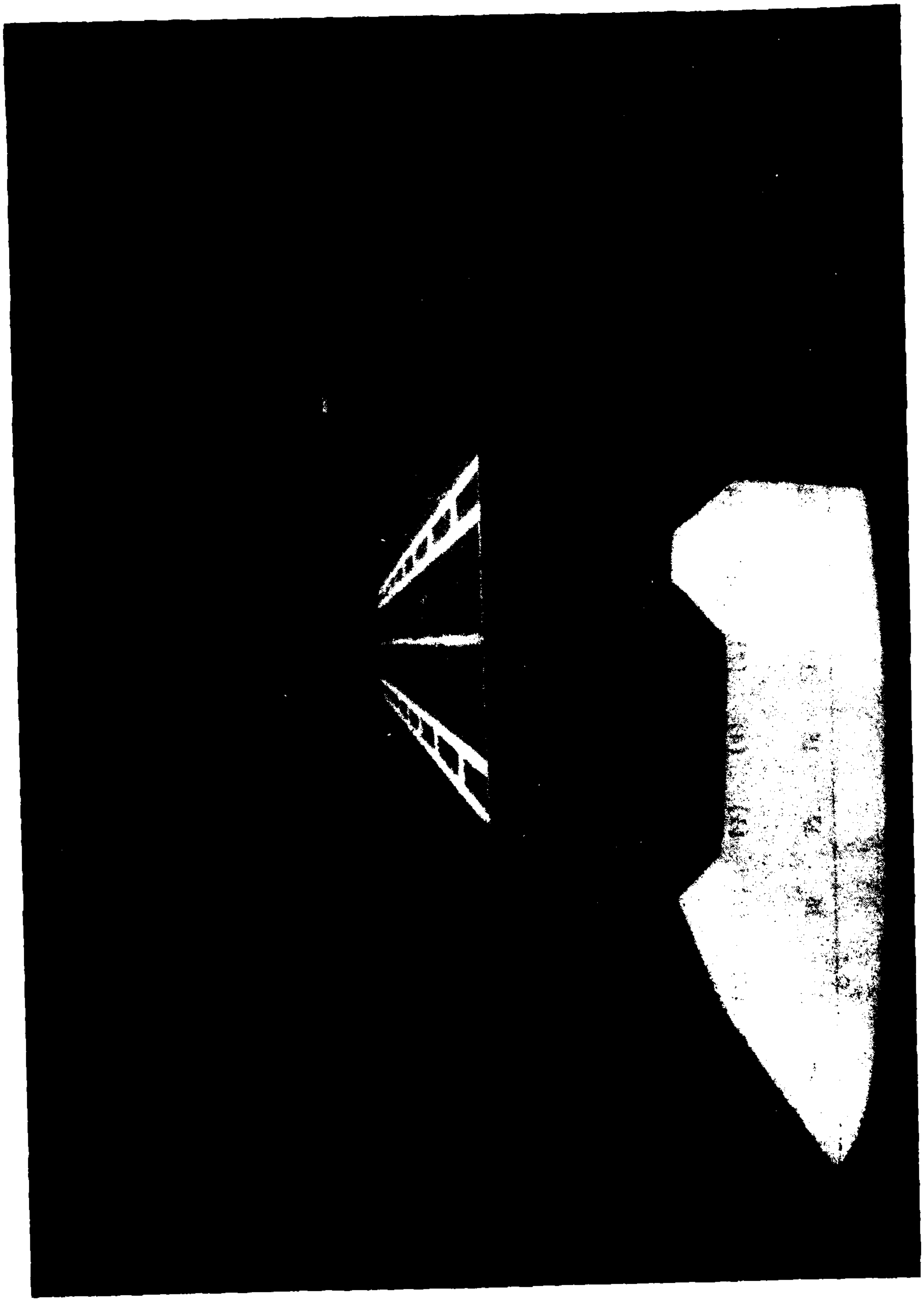

Figure 1. Computer-Generated Image of the Day Carrier, with FLOLS and Portion of Wake.

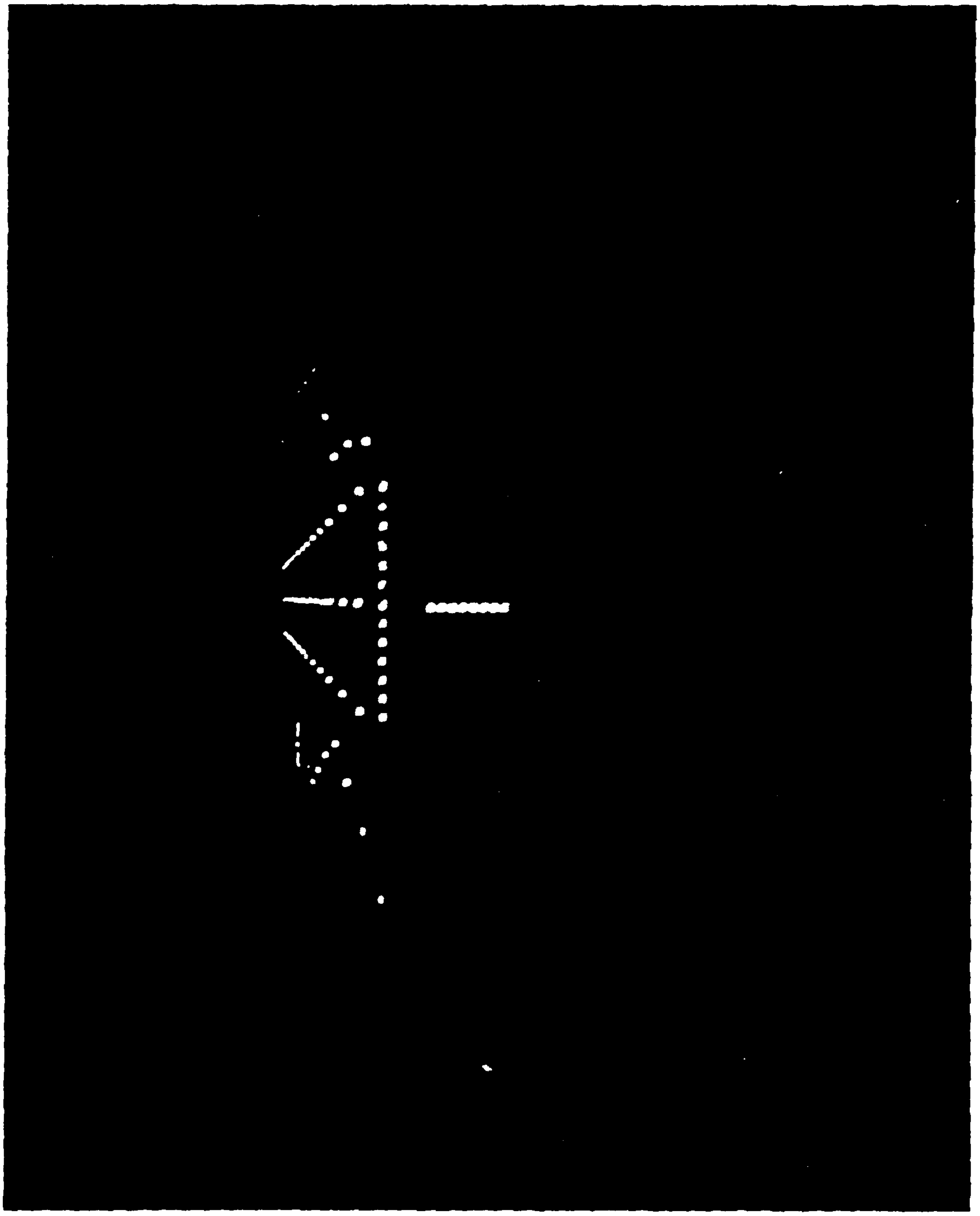

Figure 2. Computer-Generated Image of the Night Carrier, with FLOLS.

FRESNEL LENS OPTICAL LANDING SYSTEM. The configuration of the FLOLS is shown in Figure 3. In contrast to a carrier FLOLS, which is generated by incandescent lights and can therefore be much brighter than other parts of the carrier, the simulated FLOLS was generated by the same system as the carrier image. It was therefore only as bright as the brightest areas of the ship (e.g., the white lines on the landing deck). To compensate for its lower relative brightness, the FLOLS was enlarged by a factor of 4.5 when the distance behind the ramp was greater than 2250 ft. From 2250 ft., the size of the FLOLS was linearly reduced until it attained 1.5X its normal size at 750 ft. It remained that size throughout the remainder of the approach. The FLOLS was centered 414 ft. down the landing deck and 61 ft. to the left of the centerline. It was set at a nominal 3.5° glideslope and with a lateral viewing wedge of 52°.

SIMULATOR CONFIGURATION. The simulator was initialized with the aircraft at 9000 ft. from the ramp, on the glideslope and centerline, and in the approach attitude and configuration (hook and wheels down, speed brake out, 15 units angle-of-attack (AOA), and power at 83%). The T-2C is normally landed with full flaps, but flaps were at half extension for this experiment to more closely simulate approach speeds of typical fleet aircraft. Fuel was set at 1320 lbs. to give 10,000 lbs. gross weight. A landing trial was flown from the initial condition to wire arrestment or, in the case of a bolter, to 1000 ft. past the carrier.

The carrier was set on a heading of 360° at 5 knots. Environmental wind was set at 349.5° with a velocity of 20.1 knots. This combination of carrier speed and environmental wind produced a relative component of 25 knots down the landing deck.

Turbulence was used to increase the difficulty. The turbulence model buffeted the simulator computed aircraft model with a random forcing function.

PERFORMANCE MEASUREMENT. VTRS has the capacity to assess performance at 30 Hz for three classes of measure. First, aircraft position can be determined throughout the approach. Secondly, aircraft control surface activity can be measured throughout the approach for elevator, aileron and rudder displacement. Finally, aircraft control position data can also be collected in order to determine throttle, control stick and rudder pedal activity throughout the approach.

For each of these categories of measure, specific measures such as Root Mean Square (RMS) error, absolute error, and percent time within a predefined tolerance band may be collected throughout the course of an approach. In addition, these measures can also be collected for any predefined segment (or segments) of the approach (e.g., 1500 ft. to touchdown).

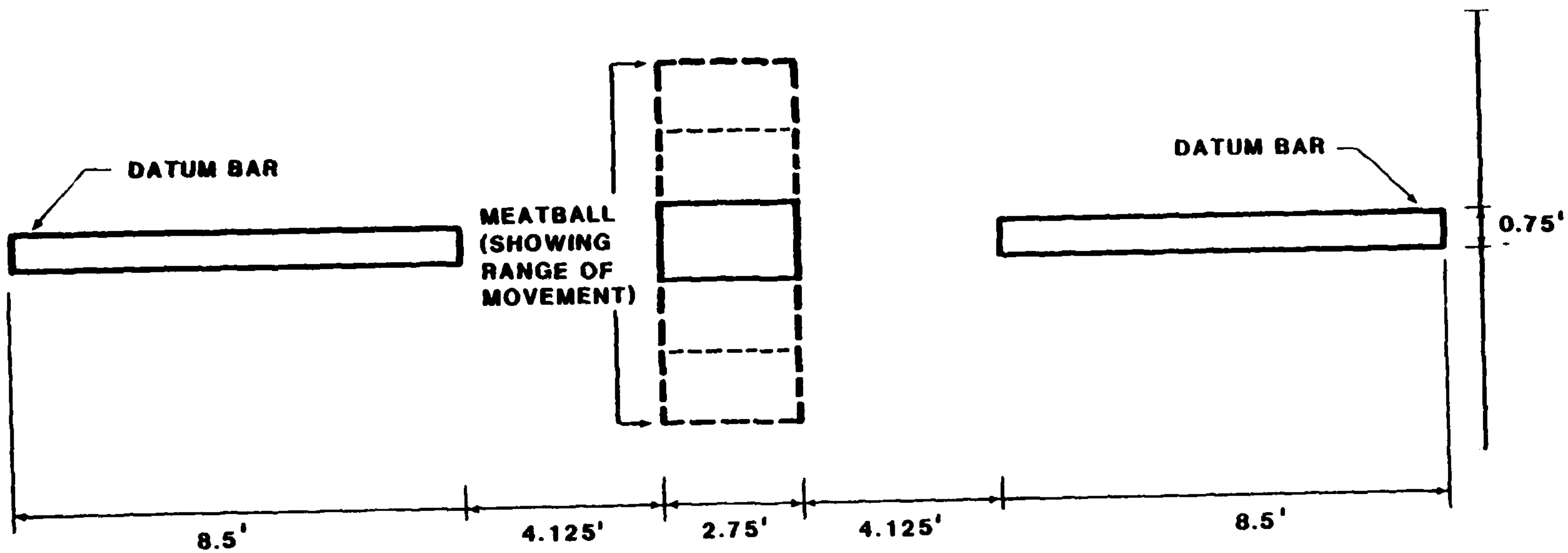

Figure 3. Configuration of FLOLS Simulation, Showing Datum Bars and Meatball. (Dimensions Shown are in Ft.).

Aside from continuous measures of glideslope performance, up to two separate snapshot measures may be collected at any point on the approach. This snapshot can contain any of the classes of measures deemed important.

The capacity also exists for collecting touchdown performance data from which a measure of success of the landing may be calculated.

FREEZE AND RESET FEATURES. The simulator has the capacity to suspend the ongoing simulation either manually, by the use of the "freeze" button located on the console, or the "freeze" feature may be instigated automatically based upon a specified error being committed by the trainee. Regardless of how the "freeze" is initiated, three actions are possible following the suspension of the simulation. First, the simulator may be reset to a corrected initialization point and the trainee can begin to fly from that point. Secondly, the current simulator state may be restored and the trainee can continue the task from that point. Finally, the simulator may be set to some other, entirely different, initial condition and the trainee can be required to perform some other task. The first two of these post "freeze" actions were employed here as experimental training conditions. These training conditions and the criteria for defining an error are described below.

TRAINING CONDITIONS. Two experimental training procedures were used in the experiment. For both procedures the simulator was frozen during the approach if the pilot's vertical deviations from the glideslope exceeded specific criteria. Under one procedure, known as Freeze/Reset, when the simulator was frozen, the pilots were advised on how they had incurred their vertical error and were then reset to the glideslope with the simulator in its optimum approach attitude. Longitudinal distance from the carrier and lateral distance from the extended centerline of the landing deck were not changed. Pilots continued their approach from the reset position. Under the other procedure known as Freeze/Flyout, pilots were advised on how they had incurred their vertical error and how to correct it once they were released. They then continued their approach from the position and attitude in which the simulator had been frozen.

Two experimental training conditions were derived for each Freeze procedure by applying two different criteria.

DISPLACEMENT ERROR CRITERION. This criterion "froze" the system if

$$\theta_i \geq \theta_c \qquad (1)$$

where θ_i = angular displacement of the aircraft from the 3.5° glideslope,

$\theta_c = 0.5625 - r(0.3125 \times 10^{-4}),\ 0 \leq r \leq 6000$

and

r = range in feet from the carrier ramp.

This algorithm linearly increased the criterion in meatball units from 1.0 at 6000 feet from the ramp to 1.5 at the ramp. "Freezes" did not occur beyond 6000 feet from the carrier or past the ramp.

DISPLACEMENT AND DESCENT RATE ERROR CRITERION. The second error criterion would result in a "freeze" if vertical deviation from the 3.5° glideslope, descent rate error, or some combination of the two was excessive. "Freezes" would occur:

if $$|M_i| \geq \theta_C \qquad (2)$$

for $M_i = \theta_i + 0.5625\,\dot{\theta}_C^{-1}$,

$\dot{\theta}_i$ = angular rate of displacement in degrees/second from the glideslope,

$\dot{\theta}_C = 0.405 - (0.49 \times 10^{-4})\,(r + r_K)$,

and r_K = 524 feet, the distance from the carrier ramp to the FLOLS origin.

This algorithm established a criterion that was a weighted sum of the previously described displacement criterion and a descent rate error limit that decreased linearly from 600 fpm at 6000 feet from the ramp to 200 fpm at the ramp.

"Freezes" were not permitted within 10 seconds of restarting the approach after a previous "freeze." In addition, a "freeze" would not occur if, at the end of this 10-second period, the subject was outside of the performance criterion but was decreasing the error.

In the fifth training condition, designated the Conventional, the simulator was not "frozen" during the approach but the subjects were given feedback as to their error (equivalent to that given the Freeze/Flyout. group) at the end of each trial.

PROCEDURE

Two subjects arrived at the simulation facility each day, Monday through Thursday, during the experiment. They viewed a video tape on carrier landings which described the FLOLS and carrier landings. They were then given detailed instructions by a Navy LSO on carrier landing techniques. This instructional period lasted approximately 45 minutes. When convenient, subjects were given this preliminary instruction in pairs, but the remaining experimental work was undertaken with only one subject in attendance except that subjects were occasionally permitted to monitor the performance of others from outside the simulator if they had entirely completed their experimental work. Subjects were assigned to training conditions as they arrived at the simulator facility in accordance with a predetermined sequence that ensured the number of subjects having been trained with each condition remained approximately equal throughout the experiment.

After preliminary instruction, subjects were familiarized with the controls of the simulator. They were then given a brief flight of approximately two minutes before they commenced their carrier landing training. The training sequence consisted of 24 approaches to the day carrier on the afternoon of their first day at the simulator facility, and 24 approaches to the night carrier on the morning of the second day. The two 24-trial blocks were divided into six-trial sub-blocks, the first four trials of which were flown under the appropriate training condition. The last two trials of each sub-block were used as probe trials to assess the progress of learning, and were flown under the control condition. The LSO gave no instructions during or following probe trials. Subjects were given a ten minute rest after the twelfth trial of each 24-trial block.

PERFORMANCE MEASUREMENT AND DATA ANALYSIS

Position, attitude, and state of the simulated aircraft and elevator, throttle, aileron and rudder control positions were sampled at 30 Hz. The simulator position, attitude, and state variables were used to derive performance measures for glideslope and AOA tracking. The control position variables were used to derive control activity measures. The continuous measures were derived for non-overlapping 1500-foot segments of the approach.

Repeated measures analyses of variance were applied to root mean square (RMS) glideslope and RMS AOA errors and to flight control activity measures. In addition, multiple discriminant analyses were applied to the probe data to find linear combinations of scores that maximally discriminated the instructional treatments.

SECTION III

RESULTS

TRAINING TRIALS

LEARNING EFFECTS. Several learning trends are apparent and show up as reductions in RMS error for glideslope (See Appendix A, Table A1) and AOA (Table A2), and as reductions in activity of elevator (Table A3) and ailerons (Table A5). There was comparable reduction in throttle activity (Table A4), while average rudder pedal activity (Table A6) showed no reliable effects. Figure 4 shows a consistent trend towards reduction in number of "freezes" (with a reversal in transitioning from Day to Night approaches) in the experimental conditions. This also indicates a steady improvement in glideslope control throughout the experiment.

EXPERIMENTAL TREATMENT EFFECTS. Only RMS glideslope error scores showed any statistically reliable effect of experimental training conditions (Table A1). Glideslope errors of the Freeze/Reset groups were lower than for other groups, an unsurprising result in view of the fact that errors were constrained and frequently zeroed by the experimental manipulation. This suggests that "freezes" occurred frequently enough to reduce error and thereby validates the experimental manipulation to some extent.

PROBE TRIALS

LEARNING EFFECTS. While error scores and control activity tended to decrease throughout probe trials, these trends were generally reliable only for the final segment (last 1500 feet) of the Day approaches (session 1) with measures of RMS glideslope error (Table A7), RMS AOA error (Table A8), and elevator and aileron control activity (Tables A9 and A11). In contrast to other measures, the reductions in aileron control activity were statistically reliable over all four 1500-foot approach segments for both Day and Night conditions. RMS glideslope error and aileron control activity showed a sharp increment in the transition from Day to Night approaches (which coincided with the break between sessions 1 and 2).

EXPERIMENTAL TREATMENT EFFECTS. Univariate analyses showed no reliable instructional treatment effects between probe-trial measures of RMS glideslope error, RMS AOA error and control activity. Tables A7 to A12 summarize the tests of statistical reliability for these measures. Thus neither instructional technique nor the method of determining error appeared to have any clear effect on learning.

In a further effort to seek a relationship between instructional techniques and learning, stepwise discriminant analyses were applied to the six measures of Tables A7 to A12. The analyses were restricted to the data of the final approach segment (1500 to 0 feet) because they showed the most consistent learning trends. Data from the first pair of probe trials

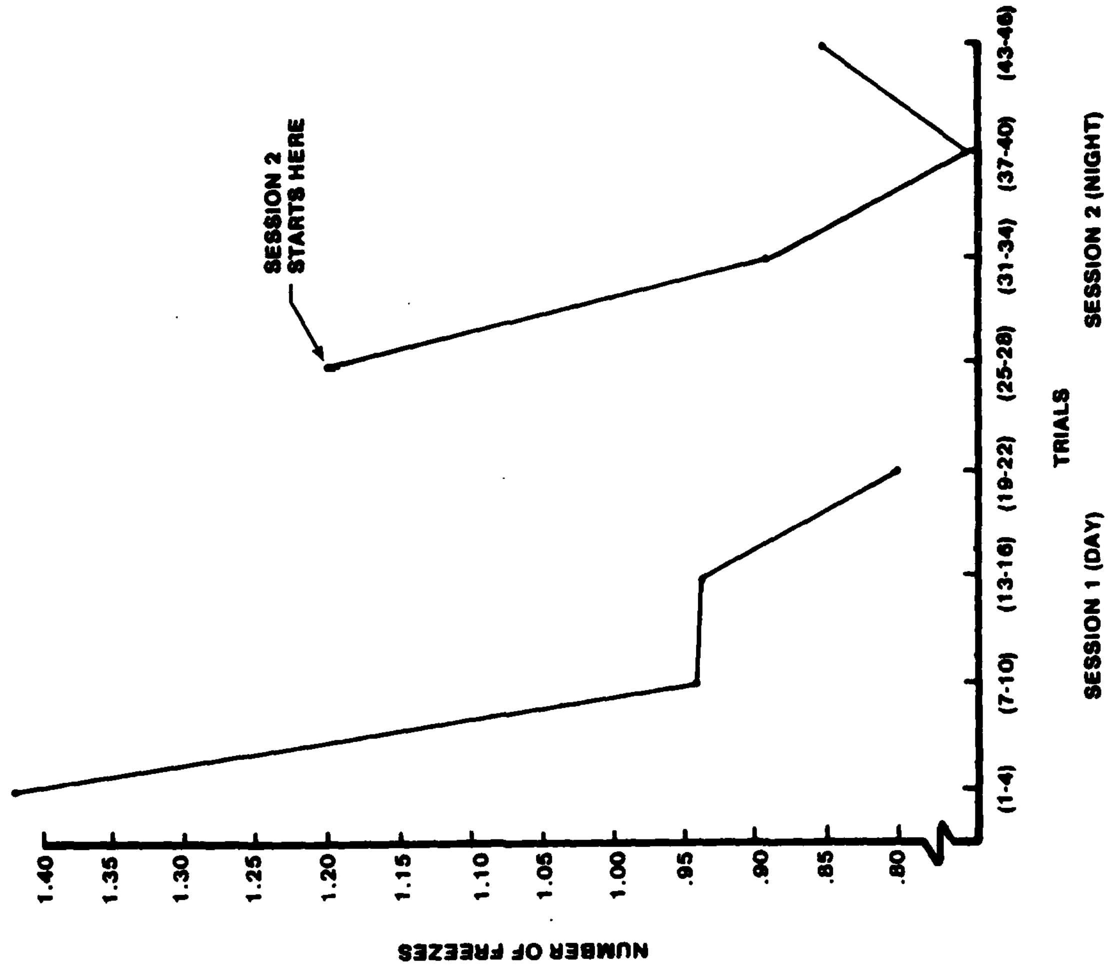

Figure 4. Freezes per Trial Averaged Across Freeze Conditions and Across 4-Trial Blocks of Training Trials.

were not included because they did not appear to follow the pattern of later probe trials, and because it was considered that differences due to learning might not have become established at that point. Pairs of probe trials were used to define dependent measures so that the numbers of dependent measures entered into the discriminant analyses were 18 (three probe pairs by six measures) for the day analysis and 24 (four probe pairs by six measures) for the night analysis. Day and night trials were analyzed separately to improve the ratio of subjects to dependent measures. Nevertheless, the analyses did not conform to the normal constraints (the size of the smallest group should exceed the number of variables, the total number of subjects should be two to three times the number of dependent measures (Tatsuoka, 1970)) and should be considered as purely exploratory.

The cumulative proportion of total dispersion accounted for by the discriminant function of the Day data was 86% and the average correct classification of subjects into groups (using the jackknifed procedure) was 36% (expected chance value of 20%). The overall approximate F ratio was statistically reliable at $p<.01$. Aileron control activity for the third and fourth probe trials contributed most to the separation of the groups on the first canonical variable. The trend was towards smoother aileron control inputs for pilots in the Conventional (no-"freeze") condition.

The cumulative proportion of the total dispersion accounted for by the discriminant function of the Night data was 94% and the average correct classification of subjects into groups was 68%. The overall approximate F ratio was statistically reliable at $p<.01$. Pedal control activity at the sixth and seventh probe pairs, throttle control activity at the fifth probe pair and aileron control activity at the sixth probe pair contributed most to separation of the groups on the first canonical variable. The trend was towards smoother throttle and aileron control inputs for pilots in the Conventional group, and for higher throttle activity for both Freeze groups that used the Displacement-only criterion.

PROBE METHODOLOGY

Means of RMS glideslope errors and of aileron control activity in the final 1500 feet of the approach were examined for disruptive effects of transitions between training and probe trials (Figures 5 and 6). This segment was chosen for analysis because it showed the strongest and most consistent learning trends in both training and probe trials. The glideslope measure was examined because the experimental manipulations were intended to impact glideslope tracking. Aileron control activity was also examined because of the strong and consistent learning effects that were demonstrated with this measure.

There were no consistent differences between probe trials for the experimental groups and the trials for the Conventional groups that were in the probe locations. Nor were there consistent differences between first and second probe trials, between first and second training trials following a probe, or between training trials prior to and subsequent to a probe, that would suggest any disruption resulting from transitions between training and probe trials.

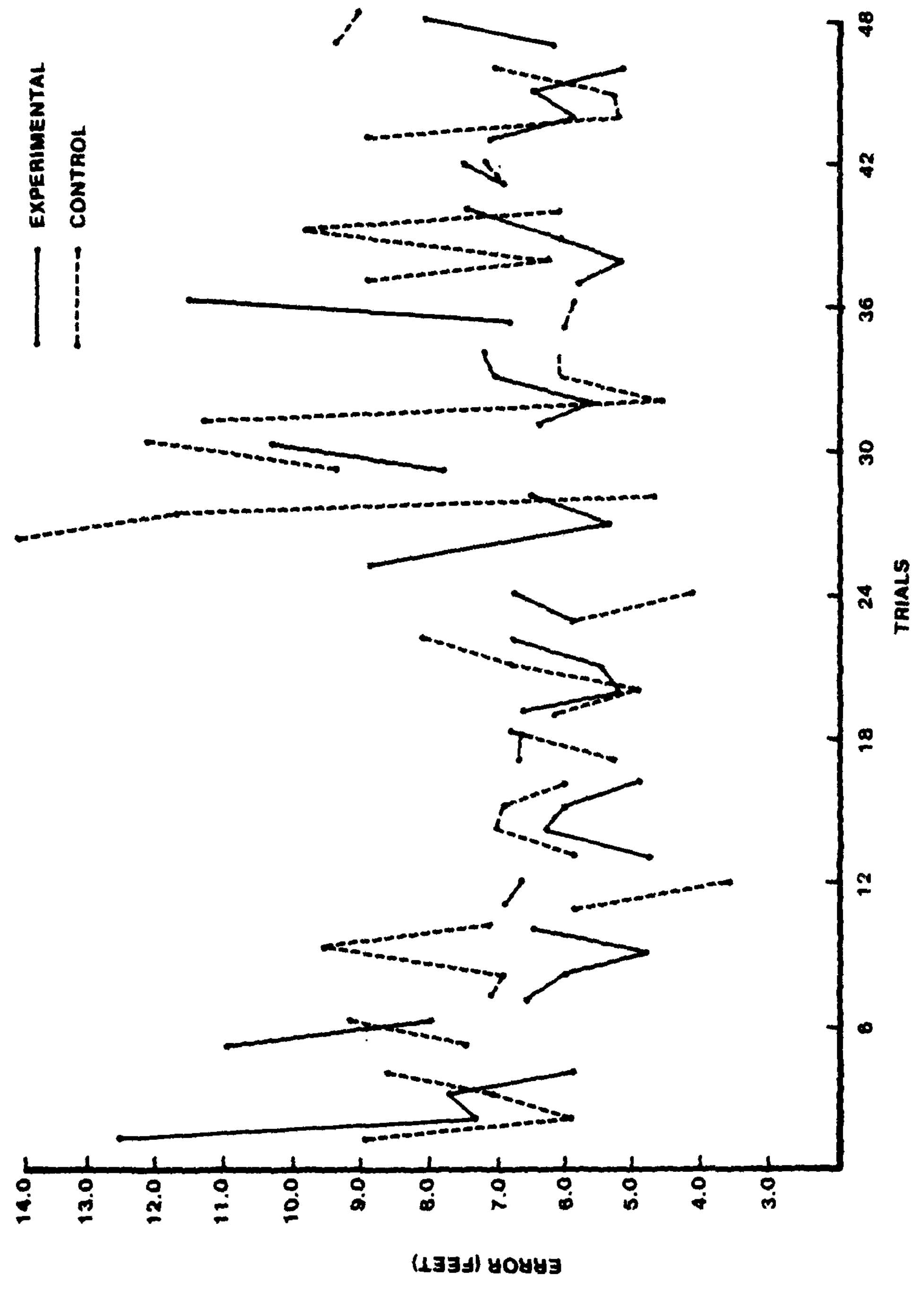

Figure 5. Means of RMS Glideslope Error.

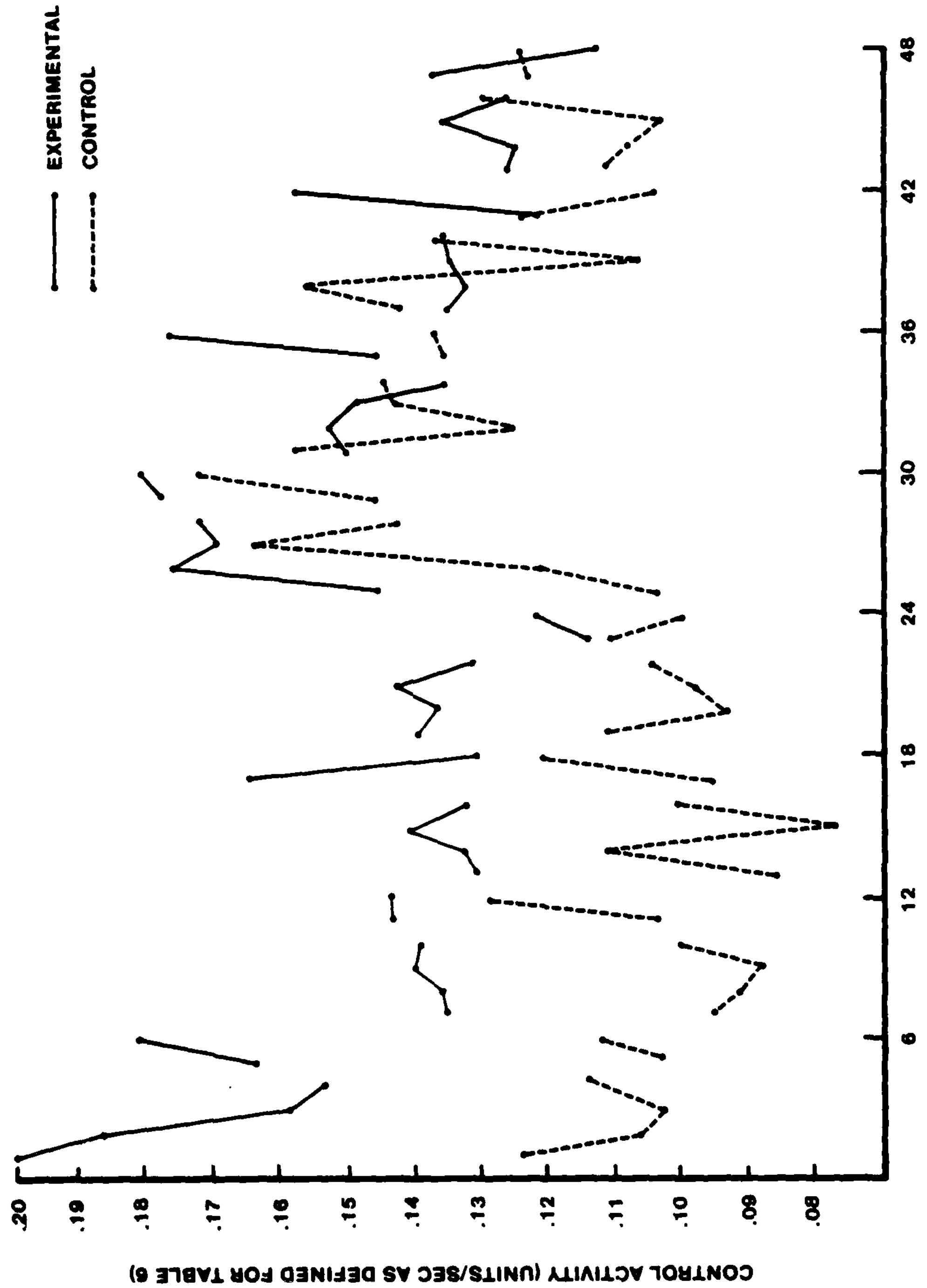

Figure 6. Means of Aileron Control Activity.

QUESTIONNAIRE RESPONSES

Descriptive data based on pilot responses to the paper-and-pencil questionnaire are given by individual item in Appendix B. The results are summarized below.

ON THE GENERAL ROLE OF ERRORS IN TRAINING. Pilots generally disagreed that "errors served little purpose" and also disagreed with the notion that "students may actually learn the errors they commit" (Item 12). Pilots also disagreed with the contention that "instructional methods that allow errors to occur are inefficient" (Item 14). Instead, pilots in the study pointed to error recognition as a basis for the development of correct performance (Item 18). Errors were seen as helping the student to focus on the critical elements of task performance (Item 13), as well as exposing the student to out-of-tolerance situations which may, under later conditions, result from factors such as adverse weather, visibility/ceiling limitations, etc. (Item 15). On the issue of whether correct performance is best thought of as resulting from a process of eliminating errors or from a process of shaping desired responses, pilots were undecided (Item 17).

ON THE INSTRUCTIONAL USE OF THE FREEZE FEATURE. Pilots agreed that it was easier to attend to the LSO's feedback while the simulator was "frozen" than while trying to listen and fly the aircraft at the same time (Item 3). Pilots also agreed that use of the "freeze" aided development of error recognition (Item 5) but were undecided as to whether it might significantly decrease the overall time required to learn the landing task. On the negative side, pilots indicated that the occurrence of the "freeze" early in training was "frustrating" (Item 8). In fact, pilots in the Freeze/Reset condition indicated that they were more motivated by "trying to avoid the "freeze" than by trying to fly the task correctly" (Item 7). Pilots in the Freeze/Flyout condition tended to respond in somewhat the opposite manner. Regardless of the "freeze" condition to which subjects were assigned, all indicated that regaining control of the simulator following a "freeze" significantly added to the difficulty of the flying task (Item 2) and that the difficulty increased the closer the occurrence of the "freeze" to the terminal portion of the task (Item 2).

In general, the questionnaire data indicated that pilots perceived errors as contributing positively to training, that the present use of the "freeze" feature was in some instances aversive, and that it served to add to the difficulty of learning the task in the simulator despite the fact that the "freeze" made it easier to attend to feedback from the LSO. So far as being able to potentially reduce the time needed to learn the task, pilots perceived the present application of the "freeze" to have little value.

SECTION IV

DISCUSSION

Learning appeared to be limited to the final 1500 feet of the approach; an observation that suggests that the experienced Air Force pilots used in the experiment were able to perform the early part of the task with strategies similar to those used in normal landings. Only in the last part of the approach, where the altitude tolerances became very small, did the pilots appear to develop new techniques. This probably reduced the effectiveness of the expermental manipulation since it appears to have offered limited opportunity to "freeze," and to process errors subsequently during the "freeze," in that part of the approach that required new learning. Thus, the results did not clearly bear on the hypotheses relating to the treatment of errors when they occur and the procedure for defining the error criterion.

Nevertheless, the Freeze/Reset condition did result in smaller errors in the final approach so that a modified hypothesis, that the magnitude of errors permitted in training will affect learning, can be examined by contrasting the probe performances of the Freeze/Reset groups with the probe performances of the Conventional and Freeze/Flyout groups. This hypothesis varies slightly from the original one that postulated effects of differential treatment of errors when they occurred.

The notion that learning will proceed more quickly if students can practice with fewer or smaller errors has intuitive appeal. As noted previously in this report, Holding (1970) has suggested that frequently committed errors could become embedded in a student's response repertoire and thereby impede progression to asymptotic behavior. Lintern and Roscoe (1980) have suggested that training might benefit from manipulations that converge quickly on desirable control behavior. In addition, a criterion-setting process might be postulated where students who become used to performing with few errors endeavor to acheive similar standards even under more difficult conditions. Given the popularity of these notions, it seems noteworthy that there is no suggestion in the data that the reduced errors during Freeze/Reset training resulted in any differential rate of learning or terminal level of probe performance. While some instructional strategies that promote more accurate learning behavior do assist skill acquisition (e.g., Lintern, 1980), it would appear that they do so by means other than their error-limiting function.

There is some evidence, albeit insubstantial, that "freeze" had some adverse effects on performance during probe trials; in particular, that subjects training under the "freeze" conditions exhibited higher control activity. Pilot comments support the view that the "freeze" may be aversive and that some applications of the "freeze" (e.g., the Freeze/Reset) may change the nature of students' motivation in performing the task. That one or more of these processes can affect perceptual-motor acquisition is indicated by the work of Payne and his associates (Payne, 1970; Payne and Artley, 1972; Payne and Dunman, 1974; Payne and Richardson, 1972). Thus while there is no evidence that the use of "freeze" can facilitate learning, there is some suggestion that it can disrupt the integrity of the task and thereby impede learning on some aspects of the skill. In summary, the implications of the data for instructional procedures are that attempts to enhance performance during learning will not necessarily facilitate skill acquisition, while injudicious use of the "freeze" function may disrupt it.

From a methodological standpoint, the study is significant in that it supports the use of the probe technique as an alternative to the more traditional transfer-of-training methodology in the preliminary investigation of instructional treatment effects. In the present case, the probe technique proved to be sensitive to learning effects as well as to subtle performance differences which transferred from training trials to the subsequent probe (criterion) trials.

The main methodological issues explored by examining the probe data were in relation to possible disruptive effects from frequent transfer between training and control conditions. There was no evidence of any disruptive effects, although this conclusion must be tempered with the observation that learning effects were minimal. The probe methodology could be valuable in a learning experiment, and its further examination with data that show a strong learning trend would be useful. Stability of the probe trials was similar to stability of similarly located control trials. The question of how many probe trials are necessary might best be answered by a power analysis (Hays, 1963) and would require data that show some worthwhile differences between groups. Nevertheless this preliminary analysis of the probe technique suggests that it could be useful in future studies of skill acquisition.

SECTION V

RECOMMENDATIONS

Caution should be exercised when using the flight simulator's "freeze" feature during the performance of a continuous control task such as that involved in the approach to landing task. Other tasks to which this advice might also apply are aerial refueling training and weapons delivery training.

The fact that an instructional technique may result in better trainee performance during training should not be the sole criterion for its implementation. While an effective instructional technique can be expected to aid and improve learning performances, better performance on an instructional task does not necessarily lead to improved performance on the criterion task.

The probe methodology is recommended as an alternative to the traditional transfer-of-training paradigm, especially for exploratory studies where training effectiveness may vary not only as a function of instructional approach but also as a function of amount of training.

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APPENDIX A.
RESULTS/DATA SUMMARY TABLES

TABLE A1. GLIDESLOPE RMS ERROR (IN FEET): MEANS, STATISTICAL RELIABILITIES (*:$p<.05$, **:$p<.01$), AND VALUES OF ETA SQUARED (η^2): TRAINING TRIALS

Distance From the Ramp (Ft)	6000 - 4500		4500 - 3000		3000 - 1500		1500 - 0	
Means	Day	Night	Day	Night	Day	Night	Day	Night
CONDITIONS								
Freeze/Flyout Displacement	15.3	14.2	13.2	13.5	11.2	10.7	8.9	9.3
Freeze/Flyout Disp & Rate	13.0	13.5	14.4	11.5	10.2	9.1	8.1	8.0
Conventional	16.4	14.7	14.2	15.4	10.5	12.9	7.1	11.9
Freeze/Reset Displacement	13.1	9.7	11.0	11.3	8.6	7.2	4.9	4.9
Freeze/Reset Disp & Rate	8.6	9.1	7.7	8.8	6.7	6.6	4.1	4.2
TRAINING TRIALS								
1-4	14.5	14.3	14.5	14.1	12.4	11.4	8.5	11.0
7-10	14.1	12.1	10.8	10.8	8.4	8.8	6.3	7.1
13-16	13.2	11.4	13.3	11.8	9.2	8.4	5.9	6.3
19-22	12.1	11.1	10.6	11.5	8.4	8.9	6.4	6.5
Reliabilities and η^2	p	η^2	p	η^2	p	η^2	p	η^2
CONDITION								
Day	**	.078	*	.079	*	.055	*	.118
Night	.053	.077	**	.023	--		--	
TRAINING								
Day	--		**	.032	**	.055	**	.030
Night	--		--		*	.023	--	
CT								
Day	--		--		--		--	
Night	--		--		--		--	

TABLE A2. ANGLE OF ATTACK RMS ERROR (IN AOA UNITS): MEANS, STATISTICAL RELIABILITIES (*:p<.05, **:p<.01), AND VALUES OF ETA SQUARED (η^2): TRAINING TRIALS

Distance From the Ramp (Ft)	6000 - 4500		4500 - 3000		3000 - 1500		1500 - 0	
Means	Day	Night	Day	Night	Day	Night	Day	Night
CONDITIONS								
Freeze/Flyout Displacement	.576	.425	.778	.580	.733	.573	1.067	.845
Freeze/Flyout Disp & Rate	.415	.358	.653	.661	.590	.579	.795	.706
Conventional	.370	.355	.482	.437	.423	.407	.695	.701
Freeze/Reset Displacement	.597	.420	.697	.617	.661	.511	.736	.675
Freeze/Reset Disp & Rate	.508	.374	.587	.494	.572	.493	.673	.554
TRAINING TRIALS								
1-4	.562	.476	.727	.634	.671	.591	.905	.829
7-10	.491	.389	.623	.565	.570	.561	.780	.693
13-16	.463	.363	.583	.520	.574	.467	.727	.646
19-22	.436	.322	.623	.473	.560	.427	.792	.622

Reliabilities and η^2	p	η^2	p	η^2	p	η^2	p	η^2
CONDITION								
Day	--		--		--		--	
Night	--		--		--		--	
TRAINING								
Day	**	.022	*	.023	*	.019	.053	.021
Night	**	.033	**	.035	**	.040	**	.035
CT								
Day	--		--		--		--	
Night	--		**	.078	**	.076	--	

TABLE A3. AVERAGE ELEVATOR STICK ACTIVITY (IN UNITS/SEC WHERE RANGE OF CONTROL DISPLACEMENT IS FROM -1 TO +1 UNITS): MEANS, STATISTICAL RELIABILITIES (*:p<.05, **:p<.01), AND VALUES OF ETA SQUARED (η^2): TRAINING TRIALS

Distance From the Ramp (Ft)	6000 - 4500		4500 - 3000		3000 - 1500		1500 - 0	
Means	Day	Night	Day	Night	Day	Night	Day	Night
CONDITIONS								
Freeze/Flyout Displacement	.108	.068	.110	.070	.128	.088	.202	.132
Freeze/Flyout Disp & Rate	.097	.085	.098	.085	.107	.090	.153	.110
Conventional	.071	.086	.067	.083	.075	.089	.127	.141
Freeze/Reset Displacement	.154	.063	.142	.063	.210	.070	.299	.089
Freeze/Reset Disp & Rate	.129	.087	.139	.083	.184	.089	.324	.104
TRAINING TRIALS								
1-4	.143	.079	.134	.078	.169	.090	.253	.127
7-10	.103	.078	.106	.079	.135	.087	.220	.120
13-16	.100	.077	.098	.076	.123	.085	.191	.113
19-22	.091	.079	.096	.076	.117	.083	.188	.106

Reliabilities and η^2	p	η^2	p	η^2	p	η^2	p	η^2
CONDITION								
Day	--		--		--		--	
Night	--		--		--		--	
TRAINING								
Day	*	.044	*	.029	**	.023	**	.015
Night	--		--		--		--	
CT								
Day	--		--		--		--	
Night	--		--		--		--	

TABLE A4. AVERAGE THROTTLE ACTIVITY (IN UNITS/SEC WHERE RANGE OF THROTTLE DISPLACEMENT IS FROM 0 TO +1 UNITS) MEANS, STATISTICAL RELIABILITIES (*:p<.05, **:p<.01), AND VALUES OF ETA SQUARED (η^2): TRAINING TRIALS

Distance From the Ramp (Ft)	6000 - 4500		4500 - 3000		3000 - 1500		1500 - 0	
Means	Day	Night	Day	Night	Day	Night	Day	Night
CONDITIONS								
Freeze/Flyout Displacement	.112	.081	.041	.010	.043	.013	.063	.028
Freeze/Flyout Disp & Rate	.081	.083	.009	.011	.011	.013	.024	.025
Conventional	.081	.081	.008	.008	.010	.009	.019	.022
Freeze/Reset Displacement	.095	.080	.024	.009	.022	.010	.033	.025
Freeze/Reset Disp & Rate	.086	.081	.012	.010	.015	.011	.023	.016
TRAINING TRIALS								
1-4	.087	.081	.012	.009	.015	.011	.031	.022
7-10	.087	.081	.015	.010	.017	.012	.030	.024
13-16	.096	.080	.026	.009	.026	.010	.035	.022
19-22	.094	.082	.023	.010	.024	.012	.036	.023

Reliabilities and η^2	p	η^2	p	η^2	p	η^2	p	η^2
CONDITION								
Day	--		--		--		--	
Night	--		--		--		--	
TRAINING								
Day	--		--		--		--	
Night	--		--		--		--	
CT								
Day	--		--		--		--	
Night	*	.071	--		--		--	

TABLE A5. AVERAGE AILERON STICK ACTIVITY (IN UNITS/SEC WHERE RANGE OF CONTROL DISPLACEMENT IS FROM -1 TO +1 UNITS): MEANS, STATISTICAL RELIABILITIES (*p<.05, **:p<.01), AND VALUES OF ETA SQUARED (η^2): TRAINING TRIALS

Distance From the Ramp (Ft)	6000 - 4500		4500 - 3000		3000 - 1500		1500 - 0	
Means	Day	Night	Day	Night	Day	Night	Day	Night
CONDITIONS								
Freeze/Flyout Displacement	.112	.101	.117	.107	.129	.134	.168	.146
Freeze/Flyout Disp & Rate	.107	.094	.113	.093	.122	.099	.136	.123
Conventional	.071	.083	.073	.090	.079	.103	.100	.112
Freeze/Reset Displacement	.102	.079	.106	.082	.118	.102	.145	.115
Freeze/Reset Disp & Rate	.099	.110	.103	.117	.118	.130	.147	.130
TRAINING TRIALS								
1-4	.111	.104	.111	.108	.132	.128	.163	.150
7-10	.099	.098	.101	.104	.110	.119	.133	.127
13-16	.092	.090	.100	.092	.104	.107	.126	.119
19-22	.090	.090	.098	.095	.105	.112	.132	.112
Reliabilities and η^2	p	η^2	p	η^2	p	η^2	p	η^2
CONDITION								
Day	--		--		--		--	
Night	--		--		--		--	
TRAINING								
Day	**	.032	--		**	.047	**	.050
Night	--		.053	.009	--		**	.044
CT								
Day	--		*	.050	--		--	
Night	--		--		--		--	

TABLE A6. AVERAGE RUDDER PEDAL ACTIVITY (IN UNITS/SEC WHERE RANGE OF PEDAL DISPLACEMENT IS FROM -1 TO +1 UNITS): MEANS, STATISTICAL RELIABILITIES (*:$p<.05$, **:$p<.01$), AND VALUES OF ETA SQUARED (η^2): TRAINING TRIALS

Distance From the Ramp (Ft)	6000 - 4500		4500 - 3000		3000 - 1500		1500 - 0	
Means	Day	Night	Day	Night	Day	Night	Day	Night
CONDITIONS								
Freeze/Flyout Displacement	.063	.049	.058	.046	.061	.051	.074	.064
Freeze/Flyout Disp & Rate	.059	.058	.056	.057	.057	.060	.059	.061
Conventional	.046	.062	.041	.058	.041	.060	.045	.063
Freeze/Reset Displacement	.060	.040	.054	.034	.053	.036	.059	.038
Freeze/Reset Disp & Rate	.058	.061	.056	.056	.057	.057	.060	.056
TRAINING TRIALS								
1-4	.055	.054	.050	.049	.054	.052	.061	.057
7-10	.057	.056	.052	.052	.053	.053	.059	.059
13-16	.060	.053	.057	.050	.054	.054	.059	.056
19-22	.056	.056	.052	.053	.053	.055	.058	.059
Reliabilities and η^2	p	η^2	p	η^2	p	η^2	p	η^2
CONDITION								
Day	--		--		--		--	
Night	--		--		--		--	
TRAINING								
Day	--		--		--		--	
Night	--		--		--		--	
CT								
Day	--		--		--		--	
Night	--		--		--		--	

TABLE A7. GLIDESLOPE RMS ERROR (IN FEET):
MEANS, STATISTICAL RELIABILITIES (*:$p<.05$, **:$p<.01$),
AND VALUES OF ETA SQUARED (η^2): PROBE TRIALS

Distance From the Ramp (Ft)	6000 - 4500		4500 - 3000		3000 - 1500		1500 - 0	
Means	Day	Night	Day	Night	Day	Night	Day	Night
CONDITIONS								
Freeze/Flyout Displacement	14.8	14.2	10.8	12.7	10.0	9.3	7.6	7.4
Freeze/Flyout Disp & Rate	13.0	12.8	11.1	11.1	8.9	9.4	6.6	9.7
Conventional	12.8	15.0	11.3	12.5	8.3	10.1	6.1	8.4
Freeze/Reset Displacement	12.9	11.0	14.9	14.2	10.9	10.7	7.8	8.1
Freeze/Reset Disp & Rate	13.3	11.1	11.8	9.9	8.1	8.8	7.6	7.9
PROBE TRIALS								
5-6	14.7	14.9	12.3	12.9	9.8	10.6	9.3	9.6
11-12	14.3	11.7	11.6	11.7	9.0	10.1	6.3	8.6
17-18	13.1	12.3	13.0	11.3	10.0	8.8	6.7	7.3
23-24	11.3	12.3	11.1	12.4	8.1	9.2	6.2	7.8

Reliabilities and η^2	p	η^2	p	η^2	p	η^2	p	η^2
CONDITION								
Day	--		--		--		--	
Night	--		--		--		--	
PROBE								
Day	--		--		--		**	.082
Night	--		--		--		--	
CP								
Day	--		--		--		--	
Night	--		--		--		--	

TABLE A8. ANGLE OF ATTACK RMS ERROR
MEANS, STATISTICAL RELIABILITIES (*:$p<.05$, **:$p<.01$),
AND VALUES OF ETA SQUARED (η^2): PROBE TRIALS

Distance From the Ramp (Ft)	6000 - 4500		4500 - 3000		3000 - 1500		1500 - 0	
Means	Day	Night	Day	Night	Day	Night	Day	Night
CONDITIONS								
Freeze/Flyout Displacement	.59	.38	.61	.59	.76	.59	1.07	.71
Freeze/Flyout Disp & Rate	.43	.43	.66	.73	.59	.57	.70	.83
Conventional	.35	.31	.45	.39	.45	.39	.60	.61
Freeze/Reset Displacement	.51	.43	.77	.77	.63	.66	.87	.70
Freeze/Reset Disp & Rate	.55	.42	.70	.53	.54	.50	.90	.55
PROBE TRIALS								
5-6	.53	.40	.67	.65	.67	.57	1.14	.68
11-12	.51	.42	.66	.59	.57	.58	.72	.74
17-18	.43	.37	.62	.58	.56	.52	.80	.65
23-24	.47	.37	.62	.58	.56	.49	.65	.65

Reliabilities and η^2	p	η^2	p	η^2	p	η^2	p	η^2
CONDITION								
Day	--		--		--		--	
Night	--		--		--		--	
PROBE								
Day	--		--		--		**	.073
Night	--		--		--		--	
CP								
Day	--		--		--		--	
Night	--		--		--		--	

TABLE A9. AVERAGE ELEVATOR STICK ACTIVITY (IN UNITS/SEC WHERE RANGE OF CONTROL DISPLACEMENT IS FROM -1 TO +1 UNITS): MEANS, STATISTICAL RELIABILITIES (*:p<.05, **:p<.01), AND VALUES OF ETA SQUARED (η^2): PROBE TRIALS

Distance From the Ramp (Ft)	6000 - 4500		4500 - 3000		3000 - 1500		1500 - 0	
Means	Day	Night	Day	Night	Day	Night	Day	Night
CONDITIONS								
Freeze/Flyout Displacement	.099	.071	.108	.070	.126	.082	.195	.121
Freeze/Flyout Disp & Rate	.101	.089	.104	.090	.11	.099	.169	.147
Conventional	.066	.073	.065	.074	.071	.081	.132	.130
Freeze/Reset Displacement	.105	.066	.136	.066	.179	.077	.282	.115
Freeze/Reset Disp & Rate	.139	.089	.147	.087	.193	.097	.348	.123
PROBE TRIALS								
5-6	.117	.074	.143	.075	.164	.086	.269	.127
11-12	.098	.083	.104	.082	.127	.094	.225	.14
17-18	.101	.077	.105	.076	.129	.085	.205	.116
23-24	.093	.077	.096	.076	.124	.084	.2	.126

Reliabilities and η^2	p	η^2	p	η^2	p	η^2	p	η^2
CONDITION								
Day	--		--		--		--	
Night	--		--		--		--	
PROBE								
Day	--		--		--		*	.01
Night	--		--		--		--	
CP								
Day	--		--		--		--	
Night	--		--		--		--	

TABLE A10. AVERAGE THROTTLE ACTIVITY (IN UNITS/SEC WHERE RANGE OF THROTTLE DISPLACEMENT IS FROM 0 TO +1 UNITS): MEANS, STATISTICAL RELIABILITIES (*:p<.05, **:p<.01), AND VALUES OF ETA SQUARED (η^2): PROBE TRIALS

Distance From the Ramp (Ft)	6000 - 4500		4500 - 3000		3000 - 1500		1500 - 0	
Means	Day	Night	Day	Night	Day	Night	Day	Night
CONDITIONS								
Freeze/Flyout Displacement	.103	.081	.035	.010	.038	.013	.053	.025
Freeze/Flyout Disp & Rate	.081	.080	.008	.008	.009	.010	.024	.027
Conventional	.079	.079	.008	.007	.009	.009	.016	.017
Freeze/Reset Displacement	.083	.080	.012	.009	.013	.010	.036	.027
Freeze/Reset Disp & Rate	.084	.092	.014	.010	.016	.012	.027	.020
PROBE TRIALS								
5-6	.084	.081	.012	.009	.015	.011	.031	.025
11-12	.086	.090	.015	.01	.016	.012	.032	.024
17-18	.093	.08	.023	.008	.024	.010	.039	.022
23-24	.082	.079	.011	.009	.013	.010	.024	.022

Reliabilities and η^2	p	η^2	p	η^2	p	η^2	p	η^2
CONDITION								
Day	--		--		--		--	
Night	--		--		--		--	
PROBE								
Day	--		--		--		--	
Night	--		--		*	.022	--	
CP								
Day	--		--		--		--	
Night	--		--		--		--	

TABLE A11. AVERAGE AILERON STICK ACTIVITY (IN UNITS/SEC WHERE RANGE OF CONTROL DISPLACEMENT IS FROM -1 TO +1 UNITS): MEANS, STATISTICAL RELIABILITIES (*:$p<.05$, **:$p<.01$), AND VALUES OF ETA SQUARED (η^2): PROBE TRIALS

Distance From the Ramp (Ft)	6000 - 4500		4500 - 3000		3000 - 1500		1500 - 0	
Means	Day	Night	Day	Night	Day	Night	Day	Night
CONDITIONS								
Freeze/Flyout Displacement	.104	.095	.118	.101	.137	.128	.162	.145
Freeze/Flyout Disp & Rate	.11	.116	.117	.123	.125	.142	.133	.158
Conventional	.068	.085	.068	.091	.08	.109	.109	.133
Freeze/Reset Displacement	.089	.096	.096	.102	.115	.125	.147	.160
Freeze/Reset Disp & Rate	.097	.110	.105	.120	.113	.134	.14	.140
PROBE TRIALS								
5-6	.104	.107	.113	.114	.127	.133	.159	.174
11-12	.091	.109	.098	.119	.113	.146	.138	.156
17-18	.093	.089	.098	.097	.114	.117	.14	.133
23-24	.088	.096	.094	.098	.103	.115	.115	.125

Reliabilities and η^2	p	η^2	p	η^2	p	η^2	p	η^2
CONDITION								
Day	--		--		--		--	
Night	--		--		--		--	
PROBE								
Day	*	.019	**	.024	*	.026	**	.059
Night	*	.023	**	.031	**	.032	*	.044
CP								
Day	--		--		--		*	.063
Night	--		--		--		--	

TABLE A12. AVERAGE RUDDER PEDAL ACTIVITY (IN UNITS/SEC WHERE RANGE OF PEDAL DISPLACEMENT IS FROM -1 TO +1 UNITS): MEANS, STATISTICAL RELIABILITIES (*:p<.05, **:p<.01), AND VALUES OF ETA SQUARED (η^2): PROBE TRIALS

Distance From the Ramp (Ft)	6000 - 4500		4500 - 3000		3000 - 1500		1500 - 0	
Means	Day	Night	Day	Night	Day	Night	Day	Night
CONDITIONS								
Freeze/Flyout Displacement	.057	.051	.057	.045	.065	.051	.073	.064
Freeze/Flyout Disp & Rate	.058	.062	.056	.057	.057	.062	.056	.067
Conventional	.042	.054	.038	.052	.038	.052	.046	.059
Freeze/Reset Displacement	.051	.042	.047	.037	.048	.040	.055	.044
Freeze/Reset Disp & Rate	.058	.062	.056	.058	.058	.058	.062	.060
PROBE TRIALS								
5-6	.053	.055	.052	.049	.058	.053	.066	.067
11-12	.053	.056	.051	.052	.053	.056	.059	.059
17-18	.056	.054	.051	.05	.053	.054	.057	.056
23-24	.051	.051	.049	.048	.049	.049	.052	.051

Reliabilities and η^2	p	η^2	p	η^2	p	η^2	p	η^2
CONDITION								
Day	--		--		--		--	
Night	--		--		--		--	
PROBE								
Day	--		--		--		--	
Night	--		--		--		--	
CP								
Day	--		--		--		--	
Night	--		--		--		--	

APPENDIX B

MEANS AND STANDARD DEVIATIONS OF INDIVIDUAL ITEMS OF THE QUESTIONNAIRE: FREEZE/RESET AND FREEZE/FLYOUT CONDITIONS.

SYMBOLS: FREEZE/FLYOUT = O; FREEZE/RESET = Δ

1) Use of the freeze feature may be used to significantly decrease the overall training time required to learn the landing task.

1--------------2----------Δ-O-3--------------4--------------5

Strongly Disagree — Neutral — Strongly Agree

$\bar{X}$ = 2.8, σ = 1.32 — $\bar{X}$ = 2.9, σ = 1.10

2) Regaining control of the simulator following a freeze significantly added to the difficulty of the flying task in the simulator (when responding, consider each of the following phases of the maneuver separately):

(a) "IN THE MIDDLE" (first 1/3)

1--------------2----O----Δ---3--------------4--------------5

Strongly Disagree — Neutral — Strongly Agree

$\bar{X}$ = 2.2, σ = .79 — $\bar{X}$ = 2.6, σ = 1.07

(b) "IN THE GROOVE" (second 1/3)

1--------------2--------------3Δ/O--------------4--------------5

Strongly Disagree — Neutral — Strongly Agree

$\bar{X}$ = 3.1, σ = 1.1 — $\bar{X}$ = 3.1, σ = 1.1

(c) "IN CLOSE" (5-10 seconds from the ramp)

1--------------2--------------3--------Δ-----4---O---------5

Strongly Disagree — Neutral — Strongly Agree

$\bar{X}$ = 3.7, σ = 1.49 — $\bar{X}$ = 4.2, σ = .92

(d) "AT THE RAMP"

1--------------2--------------3--------------4--------------5

Strongly Disagree | Neutral | Strongly Agree

$\bar{X} = 4$ $\sigma = 1.49$ | $\bar{X} = 4.5$ $\sigma = .97$

3) It was significantly easier to attend to the LSO's feedback while frozen than while trying to listen and fly the aircraft at the same time.

1--------------2--------------3--------------4--------------5

Strongly Disagree | Neutral | Strongly Agree

$\bar{X} = 3.6$ $\sigma = .70$ | $\bar{X} = 3.8$ $\sigma = 1.14$

4) Improvements in performance were highly correlated with a decrease in the number of freezes.

1--------------2--------------3--------------4--------------5

Strongly Disagree | Neutral | Strongly Agree

$\bar{X} = 3.5$ $\sigma = .85$ | $\bar{X} = 3.5$ $\sigma = .85$

5) Using the freeze feature to explicitly identify pilot errors during the "training" trials made it easier to detect errors on "test" trials when no feedback was given and when no freezes were in effect.

1--------------2--------------3--------------4--------------5

Strongly Disagree | Neutral | Strongly Agree

$\bar{X} = 3.4$ $\sigma = 1.35$ | $\bar{X} = 3.5$ $\sigma = 1.08$

6) Compared with the usual practice of giving detailed feedback at the conclusion of a task, providing feedback immediately following an error is more effective.

1--------------2--------------3--------------4--------------5

Strongly Disagree | Neutral | Strongly Agree

$\bar{X} = 3.3$ $\sigma = 1.16$ | $\bar{X} = 3.5$ $\sigma = .97$

7) In learning the task, I was more motivated by trying to avoid a freeze than by trying to fly the task correctly.

1--------------2--------------3--------------4--------------5

Strongly Disagree | Neutral | Strongly Agree

$\bar{X} = 2.7$ $\sigma = 1.42$ | $\bar{X} = 4$ $\sigma = .94$

8) The occurrence of the freeze was "frustrating" early in training.

```
1-------------2-------------3-----O------4----Δ--------5
Strongly                    Neutral                  Strongly
Disagree                                                Agree
                   X̄ = 3.5       X̄ = 4.3
                   σ = 1.39      σ = 1.06
```

9) A helpful feature would be to present a "warning" signal (such as an auditory tone) prior to freezing the visual system.

```
1-------------2-------------3-----Δ--O--4--------------5
Strongly                    Neutral                  Strongly
Disagree                                                Agree
                   X̄ = 3.5       X̄ = 3.7
                   σ = 1.58      σ =  .82
```

10) Night approaches were more difficult to learn than the Day approaches.

```
                                O
1-------------2-------Δ------3-------------4-------------5
Strongly                    Neutral                  Strongly
Disagree                                                Agree
                   X̄ = 2.6       X̄ = 3.0
                   σ = 1.35      σ = 1.05
```

11) Errors were more difficult to detect during the Night approaches than during the Day approaches.

```
                                Δ
                                O
1-------------2-------------3-------------4-------------5
Strongly                    Neutral                  Strongly
Disagree                                                Agree
                   X̄ = 3         X̄ = 3
                   σ = 1.15      σ = 1.05
```

12) "Errors serve little purpose, since students may actually learn the errors that they commit."

```
1-------------2----Δ-O------3-------------4-------------5
Strongly                    Neutral                  Strongly
Disagree                                                Agree
                   X̄ = 2.3       X̄ = 2.4
                   σ =  .95      σ = 1.07
```

13) "Errors help the student to focus on the critical elements of task performance."

```
1-------------2-------------3--------O---4Δ------------5
Strongly                    Neutral                  Strongly
Disagree                                                Agree
                   X̄ = 3.7       X̄ = 4.1
                   σ =  .48      σ =  .57
```

14) "Instructional methods that allow errors to freely occur are inefficient, since students spend valuable training time practicing incorrect responses."

```
1-------------2---Δ------O--3-------------4-------------5
Strongly                 Neutral                 Strongly
Disagree                                            Agree
            X̄ = 2.3      X̄ = 2.8
            σ = 1.06     σ = 1.03
```

15) "In committing errors, students learn how to recover from situations which at some later time may be caused not be task-specific errors but by conditions beyond their control (for example, by adverse weather, visibility, turbulence, etc.)."

```
1-------------2-------------3-----------O-4-----Δ-------5
Strongly                 Neutral                 Strongly
Disagree                                            Agree
            X̄ = 3.9      X̄ = 4.4
            σ =  .74     σ =  .52
```

16) "Pointing out 'errors' frustrates students, whereas pointing out what a student is doing 'right' is reinforcing."

```
1-------------2---------O-Δ3-------------4-------------5
Strongly                 Neutral                 Strongly
Disagree                                            Agree
            X̄ = 2.8      X̄ = 2.9
            σ =  .92     σ = 1.1
```

17) "Correct performance results from a process of eliminating errors and not from a process of shaping desired performance."

```
                            O
1-------------2-------------3--Δ-----------4-------------5
Strongly                 Neutral                 Strongly
Disagree                                            Agree
            X̄ = 3.0      X̄ = 3.2
            σ =  .94     σ = 1.03
```

18) "A student's recognition of what is considered correct is dependent upon his being able to recognize what is incorrect (that is, an error)."

```
1-------------2-------------3----------O--4----Δ--------5
Strongly                 Neutral                 Strongly
Disagree                                            Agree
            X̄ = 3.8      X̄ = 4.3
            σ =  .42     σ =  .67
```

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Department of the Navy
Orlando, FL 32813

DMDC (DPMYL) 1
550 Camino El Estero
Monterey, CA 93940

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Ft Sheridan, IL 60037

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Bldg S-237
Naval Air Station Memphis
Millington, TN 38054

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AUSTRALIA

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C/O RAE, APRE
Farnborough, Hants, ENGLAND

LT COL Joseph Birt 2
Aerospace Medical Research Laboratories/HE
Wright-Patterson AFB, OH 45433

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US Army Research Institute
Field Unit
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Fort Harrison, IN 46216

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AD/SAG(A)3
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Whitehall, London SWIA 2HB
ENGLAND

MAJ Charles A. U. Cotton 1
Canadian Forces Personnel
Applied Research Unit
1107 Avenue Road
Toronto, Ontario M5N 2E4
CANADA

Dr. Ralph Dusek 2
US Army Research Institute
for the Behavioral and Social
Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

Mr. E. Elliott 1
SP (N)
Archway South, Old Admiralty Bldg
Spring Gardens
London SWLA 2BE, ENGLAND

Dr. John Ford 1
Naval Personnel Research and
Development Center
San Diego, CA 92152

Dr. K. Gardner 1
Head of APU
Admiralty Marine Technology
Establishment
Queens Road
Teddington, Middlesex, UK

USAFSAM/VN (Dr. Bryce Hartman) 1
Brooks AFB, TX 78235

Dr. D. Hopkin 1
RAF Institute of Aviation and
Medicine
Farnborough, Hampshire
ENGLAND

Mr. Les Innes 1
Behavioral Sciences Division
Defense and Civil Institute
of Environmental Medicine
P. O. Box 2000
Downsview, Ontario M3M
CANADA

Mr. J. James 1
Research Branch
HQ Support Command
RAF Upwood
Huntingdon, Cambridgeshire PE17 1PJ
ENGLAND

Dr. Ed Johnson 1
US Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

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Productivity Development Division
Department of Productivity
Canberra ACT 2600
AUSTRALIA

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CANADA

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D. Psych-A
Department of Defense
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AUSTRALIA

Dr. D. G. Pearce 1
Behavioral Science Division, DCIEM
P. O. Box 2000
Downsview, Ontario M3M 3B9
CANADA

Dr. M. Radomski 2
Associate Chief, Defense and Civil Institute of Environmental Medicine
P. O. Box 2000
Downsview, Ontario M3M 3B9
CANADA

Dr. L. A. Ryder 1
Directorate of Psychology - Air Force
DEFAIR - Russell Offices
Canberra A.C.T. 2600
AUSTRALIA

Dr. H. Wallace Sinaiko 1
Smithsonian Institution
Manpower Research
801 N. Pitt Street
Alexandria, VA 22314

Dr. K. N. Ackles 4
Defense Research and Development
Canadian Defense Liaison Staff
2450 Massachusetts Avenue, NW
Washington, D.C. 20008

Mr. K. W. Tilley 1
ACS(P) (RAF)
Main Building
Whitehall, London SWIA 2HB
ENGLAND

Dr. Martin Tolcott 1
Office of Naval Research
800 N. Quincy Street
Department of the Navy
Arlington, VA 22217

Dr. Martin Wiskoff 1
Navy Personnel Research and Development Center
San Diego, CA 92151

Dr. Russell Brown 1
Defense and Civil Institute of Environmental Medicine
P. O. Box 2000
Downsview, Ontario M3M 3B9
CANADA

IPC Science and Technology Press Limited 1
Westbury House
Bury Street
Guildford, Surrey, GU2, 5AW
ENGLAND

Commanding Officer 1
Canadian Forces Personnel Applied Research Unit
Suite 600
4900 Yonge Street
Willowdale, Ontario MZN 6B7
CANADA

LT COL Dennis J. Armstrong 2
1 Psych Research Unit
Department of Defense (Army Office)
Campbell Park Offices
CANBERRA ACT 2600
AUSTRALIA

The Air Attache (S3B) 1
Embassy of Australia
1601 Massachusetts Avenue, NW
Washington, D.C. 20036

Dr. J. Huddleston 1
Head of Personnel Psychology
Army Personnel Research Establishment
c/o RAE, Farnborough
Hants, ENGLAND

The Naval Attache 1
Embassy of Australia
1601 Massachusetts Avenue, NW
Washington, D.C. 20036

Dr. Jesse Orlansky 1
Science and Technology Division
Institute for Defense Analyses
400 Army-Navy Drive
Arlington, VA 22202

HumRRO/Western Division/Carmel Office 1
27857 Berwick Drive
Carmel, CA 93923

Seville Research Corporation 1
Suite 400
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Pensacola, FL 32505

4444th OPS SQDN (OTD) 2
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TAC/DOOS 1
Langley AFB, VA 23665

34 TATG/TTDI 1
Little Rock AFB, AR 72076

National Aviation Facilities 1
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Library
Atlantic City, NJ 08405

Dr. Donald W. Connolly 1
Research Psychologist
Federal Aviation Administration
FAA NAFEC ANA-230 Bldg 3
Atlantic City, NJ 08405

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Research
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Naval Air Development Center
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Chief of Naval Operations (MPT) 1
OP-115
Attn: M. K. Malehorn
Arlington Annex
Washington, D.C. 20350

Assistant Secretary of the Navy 1
Research, Engineering & Systems
Washington, D.C. 20350

Office of Deputy Chief of Naval 1
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Manpower, Personnel and Training
(OP-01)
Washington, D.C. 20350

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OP-987H
Attn: Dr. R. G. Smith
Washington, D.C. 20350

Chief of Naval Operations 1
OP-596
Washington, D.C. 20350

Chief of Naval Operations 1
OP-593B
Washington, D.C. 20350

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CT 176
Patuxent River, MD 20670

Dr. J. D. Fletcher 1
Defense Adv. Research Projects Agency (CTO)
1400 Wilson Boulevard
Arlington, VA 22209

Commanding Officer 1
Naval Education Training Program and Development Center
Attn: Technical Library
Pensacola, FL 32509

Chief of Naval Education and Training 1
Code 01A
Pensacola, FL 32509

Commanding Officer 1
Naval Aerospace Medical Research Laboratory
Code L5
Department of Psychology
Pensacola, FL 32512

Chief 1
ARI Field Unit
P. O. Box 476
Ft Rucker, AL 36362

Chief of Naval Air Training 1
Attn: Code N2
NAS
Corpus Christi, TX 78419

Chief of Naval Education and Training Liaison Office 1
Human Resource Laboratory
Flying Training Division
Williams AFB, AZ 85224

Commander 1
Pacific Missile Test Center
Point Mugu, CA 93042

Commander 1
Naval Weapons Center
Human Factors Branch (Code 3194)
Attn: Mr. Ronald A. Erickson
China Lake, CA 93555

Officer in Charge 1
Naval Aerospace Medical Research Laboratory
Box 29407
New Orleans, LA 70189

CAPT James Goodson 1
Code L-32
Naval Aerospace Medical Research Laboratory
Pensacola, FL 32512

Mr. James Basinger 1
ASD/YWE
Wright-Patterson AFB, OH 45433

Mr. Don Gum 1
AFHRL/OTT
Wright-Patterson AFB, OH 45433

Mr. Eric Monroe 1
AFHRL/OTR
Williams AFB, AZ 85224

Dr. Thomas Longridge 1
AFHRL/OTR
Williams AFB, AZ 85224

Dr. Kenneth Boff 1
AFHRL/LR
Wright-Patterson AFB, OH 45433

Mr. Brian Goldiez 1
PM TRADE
Attn: DRCPM-PND-RE
Naval Training Center
Orlando, FL 32813

Mr. Robert Wright 1
Aeromechanics Lab (USAAVRADCOM)
Ames Research Center, MS 239-2
Moffett Field, CA 94035

Dr. David C. Nagel 1
LM-239-3
NASA Ames Research Center
Moffett Field, CA 94035

Mr. Will Bickley 1
USARI Field Unit
P. O. Box 476
Fort Rucker, AL 36362

Mr. James L. Copeland 1
NASA Langley Research Center
MS 125-B
Hampton, VA 23365

AFHRL/OTLN 20
Williams AFB, AZ 85224

AFHRL/TSZ 38
Brooks AFB, TX 78235

Dr. Genevieve Haddad 1
AFOSR/NL
Bolling AFB
Washington, D.C. 20332

Lt. Col. Jefferson Koonce 1
USAFA/DFBL
USAF Academy, CO 80840

CDR Joseph Funaro 1
Code 602
Human Factors Engineering
Division
Naval Air Development Center
Warminster, PA 18974

Lt. Col. David L. Hosley 1
OASD/MRA&L, Room 2D261
Pentagon
Washington, D.C. 20330

15 AF/DOTP 1
March AFB, CA 92518

93 BMW/DO5 1
Castle AFB, CA 95342

USAFTAWC/TN 1
Eglin AFB, FL 32542

U.S. Army Research Institute 2
Field Unit
Attn: Mr. C.A. Gainer
P. O. Box 476
Fort Rucker, AL 36362

Study Center 1
National Maritime Research Center
Kings Point, NY 11024

Officer Commanding 1
RAF School of Education
RAF Newton
Nottingham NG13 8HL
ENGLAND

AD/HF(A) 1
Ministry of Defense
Main Building
Whitehall, London SW1A 2HB
ENGLAND

Dr. William E. Collins 1
FAA, CAMI (AAC 118)
P. O. Box 25082
Oklahoma City, OK 73125

ASD/YW-AZS (Capt. L. D. Puckett) 1
Wright-Patterson AFB, OH 45433

HQ USAFA/RRE 1
USAF Academy, CO 80840

Chief of Naval Education and 2
Training
TDT&E Branch
Pensacola, FL 32508

Army Training Support Center 1
ATIC-SMD
Attn: James S. Herndon
Fort Eustis, VA 23604

3400 TCHTW/TTS (Lt. Eckert) 2
Lowry AFB, CO 80230

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