AFHRL-TR-79-41

LEVEL II

AIR FORCE

HUMAN RESOURCES

ADA097208

INSTRUCTOR/OPERATOR DISPLAY EVALUATION METHODS

By

Charles Elworth
Boeing Aerospace Company
Logistics Support and Services Division
Seattle, Washington 98124

OPERATIONS TRAINING DIVISION
Williams Air Force Base, Arizona 85224

March 1981

Final Report

Approved for public release; distribution unlimited.

LABORATORY

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

NOTICE

This final report was submitted by Boeing Aerospace Company, Logistics Support and Services Division, Seattle, Washington 98124, under Contracts F33615-77-C-0017 and F33615-78-C-0051, Project 6114, with the Operations Training Division, Air Force Human Resources Laboratory (AFSC), Williams Air Force Base, Arizona 85224. Ronald Hughes was the Contract Monitor for the Laboratory.

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

MARTY R. ROCKWAY, Technical Director
Operations Training Division

RONALD W. TERRY, Colonel, USAF
Commander

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFHRL-TR-79-41
2. GOVT ACCESSION NO.: AD-A097 208
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): INSTRUCTOR/OPERATOR DISPLAY EVALUATION METHODS
5. TYPE OF REPORT & PERIOD COVERED: Final
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): Charles Elworth
8. CONTRACT OR GRANT NUMBER(s): F33615-77-C-0017; F33615-78-C-0051
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Boeing Aerospace Company, Logistics Support and Services Division, Seattle, Washington 98124
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62205F; 61142003; 61142309
11. CONTROLLING OFFICE NAME AND ADDRESS: Operations Training Division, Air Force Human Resources Laboratory, Williams Air Force Base, Arizona 85224
12. REPORT DATE: March 1981
13. NUMBER OF PAGES: 192
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited.
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):
CRT displays
display evaluation
flight simulators
instructor/operator station

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this study was to develop an objective, systematic technique for evaluating alternative formats for the displays to be used at the instructor/operator station (IOS) of a flight simulator. A benchmark performance monitoring task was designed which exercises many of the skills used by an instructor at a remote IOS. Measurement techniques were developed for assessing performance of the task. The techniques were demonstrated by using them to compare two popular display formats: digital readouts versus repeater instruments. Three of six variables were monitored with greater accuracy and comprehensiveness using repeater instruments than digital readouts. For the other three variables, there was no difference between display types. Significant effects were caused by both the type of maneuver being flown and the type of question being asked in administering the measurement method. We concluded that the benchmark task approach has considerable merit as a method of evaluating display formats. In-

DD FORM 1473 1 JAN 73

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

410 ...

Item 20 (Continued)

follow-on studi. . additional investigations should be conducted on the specifics of the measurement technique and the possible effects of memory on results.

Accession For	
NTIS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A	

SUMMARY

Objective

In contemporary flight simulators, cathode ray tube (CRT) displays are typically used to display flight information to the instructor/operator. However, no one knows the best formats for displaying this data. Designs are usually based on an engineer's best guess in light of previous experience. As a result, displays are often difficult to use, and too much of the instructor's attention is consumed in merely searching for needed information. The Air Force has initiated a series of studies aimed at systematizing the design of the instructor/operator station (IOS) and improving the utility of associated displays. The purpose of this particular effort was to develop techniques for objectively evaluating alternative formats by assessing their impact on the instructor's performance.

Approach

The approach was to develop a way to measure the instructor's performance on selected tasks. By this means, the effects of alternative display formats could be assessed by having subjects perform instructor tasks using the different displays and comparing the resulting performance measures.

The specific task selected was monitoring the pilot's performance, i.e., observing and assimilating the current flight conditions and progress by watching the display. We developed a benchmark performance monitoring task that we could repeat in an experimental setting. To do this, we used several prerecorded flight segments to drive the display to be evaluated. The subject was required to carefully observe the display. At the conclusion of each segment, we asked specific questions of the subject to test the observations he was capable of making with that display. We reasoned that the success with which a subject is able to make consistently accurate observations is an indication of the display's value in supporting the performance monitoring task.

Specifics

We recorded several flights of each of five basic maneuvers: climb, descent, level turn, climbing turn, and descending turn. For each maneuver, we designed questions to assess the accuracy and comprehensiveness of the subjects' observations during the replay of the segment. These questions concerned maximum and minimum values of key variables and their values at strategic points in the maneuver. The questions were categorized into four types to distinguish whether they pertained to ranges or exact values of variables and whether they concerned observations over a span of time or at one specific time in the maneuver.

Subjects consisted of twenty C-130 and C-141 pilots from McChord AFB, Washington. They were not told what maneuver they were going to observe. Instead, they were advised that they were to watch the display and be prepared to answer questions about their observations regarding the values of major variables during the flight. Using a randomized design, we tested each subject using each of two alternative displays: digital readouts and repeat instruments. Flight segments were randomly selected and replayed on the display being tested. After each segment, the experimenter asked the test questions orally and recorded the responses.

Results of interest concern both the utility of the overall method and the particular comparison of the two displays tested. We concluded that the method is extremely promising for evaluating displays. Our experience suggests some changes need to be made in the particular questions asked and the measurement method used. But the concept of the benchmark task approach has been clearly demonstrated as worthwhile.

Although the intent was to evaluate the methodology rather than achieve a meaningful comparison of displays, it is still of interest to see what the tests revealed. We found that questions regarding pitch, airspeed, and vertical velocity were answered more accurately with the repeater display than with the digital readout display. For questions on roll, heading and altitude, there was no significant difference between the two displays.

For pitch, both the type of maneuver and type of questions produced significant effects. Differences between the two displays occurred only in the climb and climbing turn. Maneuver type also produced a significant effect on airspeed questions. As might be expected, errors were smallest for the level turn. For heading, just the opposite was true, i.e., errors were greater for the level turn than for any other maneuver type.

The type of question produced significant effects for five of the six variables, airspeed being the only exception. On roll, for example, questions on the extremes of roll during the segment had the largest errors, and questions asking for a single value of roll at a specific point had the smallest errors. Other interesting results were found for the remaining variables, but there is no way to rationalize all the findings without additional study.

There was no strong correlation between elapsed time from event to question and the magnitude of errors. However, this is not a conclusive result because the study was not designed to treat elapsed time systematically. This should be studied further before extensive use is made of the method.

In conclusion, the benchmark task approach appears to be an excellent way to evaluate the comparative effectiveness of displays. Additional research needs to be performed on the question set, the particular measures used, and the possible effects of memory on task performance.

PREFACE

This study was conducted under Project 6114, "Simulator Techniques for Aircrew Training," Task 6114-23, "Advanced Simulator Concepts." Ms. Patricia Knoop was Project Scientist and Mr. Patrick Price was Task Scientist. Mr. Joel Schwartz was work unit and contract manager for the Air Force.

The contractor conducted two distinct studies covering this work. The first study is documented in Appendix C, and the second study constitutes the bulk of the main text of the report. The two study reports were reworked slightly by Ms. Knoop and Mr. Schwartz of AFHRL for preparation of this comprehensive report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. Introduction

The Air Force needs an objective technique for evaluating displays to be used at the instructor/operator station (IOS). The customary display mode has been the use of repeater instruments, displays that, for the most part, duplicate those used in the cockpit. Alternative modes of information display may be more effective, but there must be some ways of establishing relative effectiveness before a decision to select one can be made intelligently. Some standard test is required for determining the relative effectiveness of display methods.

The establishment of guidelines for designing and evaluating IOS displays cannot be accomplished by reference to pertinent literature because the relevant data do not exist. This is often the situation when the specifications and recommendations apply to many-faceted complex activities such as the work of the instructor pilot (IP).

The goal of this study is to devise a method for determining IOS display effectiveness and for developing guidelines for display engineering in conformance with human skills and limitations. The approach is to select characteristic monitoring activities of the instructor/operator (IO) located at an IOS remote from the simulator and to develop a benchmark task based on these activities. This task was then performed by subjects using one of the alternative displays to be evaluated. Objective, quantitative performance measures on the task were computed and used to make inferences about the utility of the display in supporting the instructor's monitoring task. The technique was demonstrated by using it to evaluate two display techniques: digital readouts versus repeater instruments.

II. Background

This is the second of two studies supported by AFHRL to develop a technique for the evaluation of displays to be used at an IOS associated with pilot training in simulators. In the first study, the basic methods were developed and exercised in a preliminary demonstration. This first study is documented in Appendix G of this report. The results of the first study showed that the concept of the benchmark task should be of real value in the objective assessment of IOS display effectiveness. The intent of the benchmark task is to provide the basis for a quantitative measurement of display effectiveness, while at the same time permitting the researcher to determine the limits of human abilities regarding perception and retention of visually displayed information. It should be directed most straightforwardly to the activities of the IP. On the other hand, greater generality of the findings from the benchmark task requires that basic human abilities be tapped for a wider application of the results to future IP operational tasks. It is a task whose essential characteristics concern short-term recall abilities, while being constructed in the framework of flight performance monitoring by an IP.

In the first study (see Appendix G), questions were generated to require a single answer, e.g., the maximum or minimum indication for some selected flight parameter or the value shown at some identifiable point during the flight segment. In the second study, the categories of questions were treated systematically, with each of four question types represented once for each maneuver type for each flight parameter (see Figure 1). The inclusion of flight indication ranges throughout the flight segment and over a limited portion of it (question types 1 and 2) was made to represent more realistically the monitoring requirements of the IP.

The first study used a "Multi-Mission Simulator" cockpit analog display with a cathode ray tube digitial display mounted above the instrument panel, where one or the other display was covered during the presentation of a flight segment. For the second study, a remotely piloted vehicle (RPV) control panel simulator was used. The arrangement of instruments and positions of the digital indicators on the CRT were the same in both studies but the RPV simulator was more convenient for the subject and experimenter because of the quality of lighting and wood table surface for writing and leaning on elbows during the segments. The RPV simulator also allowed the experimenter to be located closer to the subject, aiding communication.

The four subjects who served inthe first study were drawn from the Crew Systems organization of Logistics Systems and Support in the Boeing Aerosapce Company and had quite heterogenous flying experiences. Included was a young person with only 40 hours of solo time in a light general aviation aircraft, as well as one subject whose flying time was mostly in helicopters and two other pilots who had flown a wide range of fixed wing aircraft, from early World War II equipment to multi-engine jets.

In the second study, the 20 pilots serving as observers in the study were all currently flying either the C-130 or the C-141 aircraft. They had experience more directly relevant to Air Force interests than did the four subjects in the earlier study.

In the earlier study, each subject made 80 responses, 40 with each of the two displays. In the second study, each subject made 240 responses distributed evenly between the two display types; thus the experimental variables could be treated more systematically. For example, the earlier study was not designed to include questions about all six flight parameters after each flight segment was presented. In the second study, all six were included each time.

The most important area for improvement was in the kinds of data analyses that could be performed on the responses. It was apparent that the analysis of variance (ANOVA) was desirable for what could be shown about interactions among variables, as well as main effects. The larger, more systematic study permitted the demonstration of such interactions. Another benefit from the second study is the ability to do correlational analyses.

		TEMPORAL ASPECT	
		EXTENDED	POINT
NUMERICAL VALUE ASPECT	RANGE	What were the extremes of airspeed in the flight segment? Type 1	What was the change in airspeed in the transition to level-off? Type 2
	SPECIFIC	What was the highest airspeed during the flight segment? Type 3	What was the airspeed just prior to the transition to level-off? Type 4

Figure 1. Sample categories of questions.
(Maneuver: Altitude Change)

Much of the improvement in the second study data analyses was related to the treatment of the data in terms of absolute error instead of error tolerance limits. That is, the difference between the displayed altitude, for example, and the reported altitude (in feet) was the datum to be included in the analysis rather than a dichotomous scoring technique of right vs. wrong based on an arbitrary division point. Other flight parameters were treated similarly.

Another goal in the second study was to develop a single measure of display effectiveness. This was to be based on a transformation of raw error scores into standard scores which assume a normal frequency distribution for each flight parameter. Standard scores are in standard deviation units, i.e., the deviation of the score from the mean value is divided by the standard deviation. Thus, a deviation equalling the standard deviation has a value of 1.0 regardless of the size of the mean or the standard deviation in the original units. The assumption of a normal distribution is accompanied by an assumption of equal importance of all measures to be included in a composite score taken as a figure of merit.

The variable of time interval between the occurrence of a flight indication and the end of the flight segment (when the questions were presented) was not analyzed in the earlier study but it was included in the study reported here.

In summary, a number of changes were made to improve the benchmark task evaluation: the test content, the testing environment, the subject population from which the larger sample of 20 subjects was drawn, the experimental design, the treatment of data as continuous rather than discrete, the use of analysis of variance and correlation techniques, and the collection of more complete data amenable to more sophisticated analyses. Of these, the most important were (a) enlarging the test and improving the questions, (b) gathering more data from a more qualified and homogeneous group, and (c) data analysis.

III. Research Methodology

The results of these studies are to be applied to the evaluation of IOS displays designed for the monitoring of pilot performance when the instructor and the student are not together, as would be the case with a single-place training simulator. Of the many activities a pilot may perform during a mission, e.g., weapon delivery, none is more basic than flight management. For this reason, an important part of the IP's task is to monitor the student pilot's flight performance.

The information chosen for display in this study was that shown in what is sometimes called the "basic T" of flight instruments. The horizontally aligned airspeed indicator, attitude indicator, and altimeter are the crossbar of the "T", while the heading indicator is centered below these three instruments. They are generally positioned in the instrument panel directly in front of the pilot so that they are easy to scan with little or no change in head position from that used for forward extra-cockpit viewing.

The display modes selected for the validation of the benchmark task were repeater instruments and a digital presentation on a CRT. The repeaters are analog displays that require scanning of a type different from that used for the digital readout. A well experienced user of this kind of instrument frequently ignores the numbered dial when reading the pointer indications. An all-digital display cannot be scanned in the same way; it must be read by specifically noting the displayed numbers. These widely disparate modes of display were considered to be good candidates for the validation of the benchmark task.

In the present study of IOS display evaluation methods, the basic "T" configuration mentioned above and an added vertical velocity indicator (VVI) were used. The VVI is an important indicator of altitude change in that it permits the pilot to set the controls so that level flight or ascent/descent at a constant rate is accomplished by reference to a steady state condition rather than a uniform change in altitude indication. Furthermore, the VVI, like the altitude indicator example of the type of analog display in which the orientation of a pointer or a line (relative to a coordinate system based on the instrument panel) is usually of more interest than the actual numerical value of the indication. These flight parameters are displayed to the "experimental IP" (instructor pilot) for assessment of pilot performance as reflected in his recall of specific indications occurring during the flight segment.

The maneuvers represented on the display were of five different types. They encompass the group of maneuvers which comprise the tactics of combat and weapon delivery as well as general aircraft control. The basic maneuvers are climb, descent, level turn, climbing turn, and descending turn.

Flight segments were between 1 and 3 minutes duration. After the flight segment had been presented, the "instructor pilot" was asked to report on such indications as the maxima and minima of flight parameters or on indications occurring at specific places during the maneuver. In the preceding study, the subjects were asked a series of questions which were a random selection of those questions appropriate to the flight segment just presented. The current study included questions from all six flight parameters: airspeed, pitch angle, bank angle, altitude, vertical velocity, and compass heading. Thus all flight parameters were represented in the questions following the presentation of each flight segment to permit a greater amount of comparison between flight segments/ maneuvers. Appendix C contains all of the test questions along with correct responses and question type designators (as shown in Figure 1).

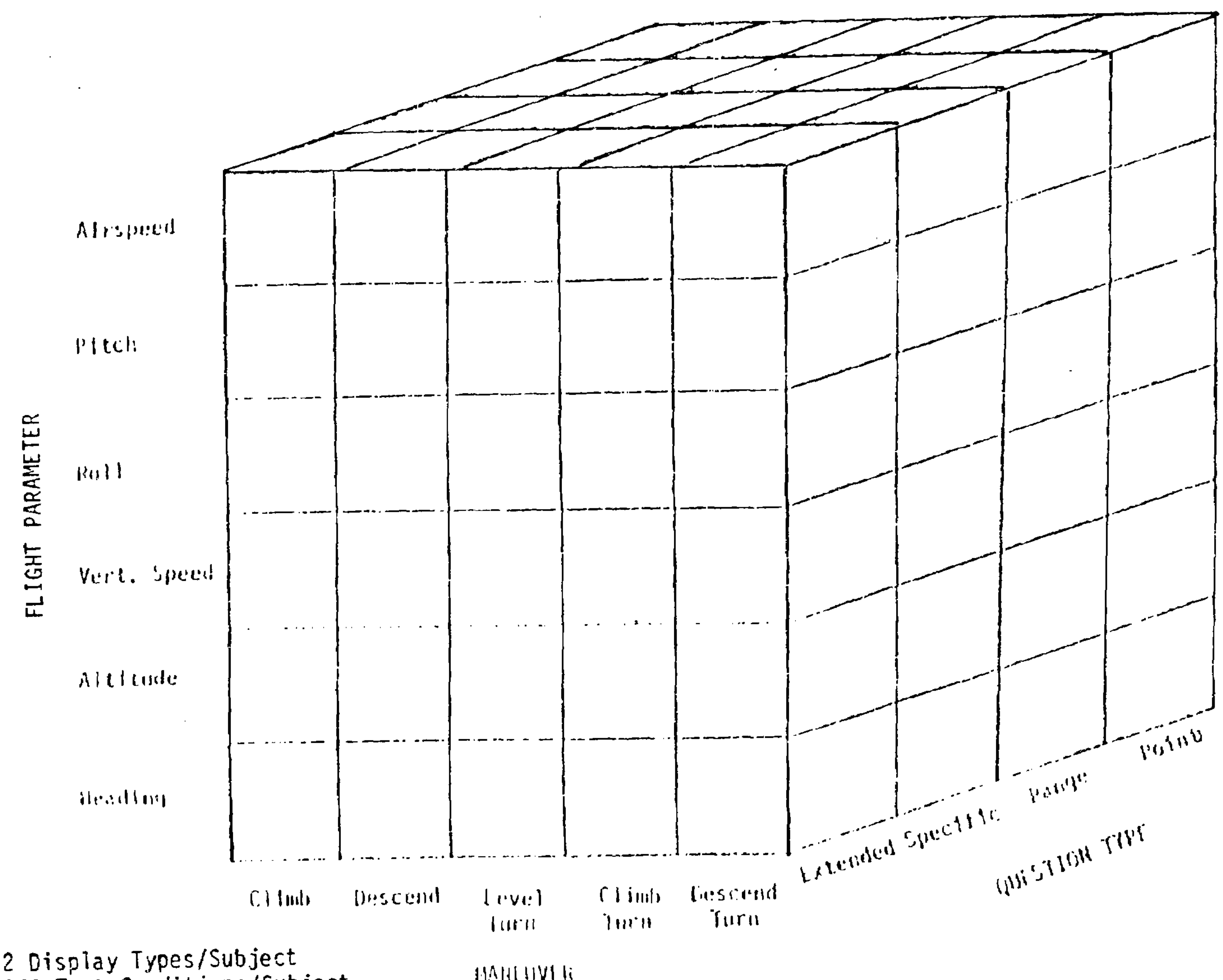
Each experimental subject (pilot) was presented four examples of five maneuvers and asked questions concerning the flight indications at various points and over various spans of time during these maneuvers. The questions required the subjects to remember extreme values of specified flight parameters or to recall a flight indication which occurred at some particular point in the flight segment. The four examples of each maneuver allowed the four types of questions to be presented an equal number of times. Recordings of the maneuvers were made on magnetic tape. Each example of a maneuver was "flown" separately so that the subjects would not be seeing identical flight indications over the four examples of a given flight maneuver. This reduces effects of familiarization with the path flown and the corresponding flight indications. Where such learning effects occur, unwanted variability tends to obscure the experimental effects under study. Learning does occur in any experiment where there are repeated trials. The subject learns something of the approach to measurement used by the individual or group who designed the experiment and of the nature of the task to be performed. In the present study, each flight segment was presented twice to each subject, once with traditional analog instruments (called "round dials" by the pilots) and once on the CRT in digital format. While this repetition of each flight segment may have facilitated recall of the contents of the display, the randomization of flight-segment-by-display-conditions would have minimized any systematic effect of this repetition on recall, i.e., while the variance may have been affected by duplicating a flight segment for the alternate display, this effect would not result in a bias in favor of one or another major variable other than that arising from chance.

The design of any study is generated within the context of limitations of time and other resources. In the present instance, the major concern focused on the feasibility of the approach, namely the development of a benchmark task which could serve as a standard for the evaluation of IOS displays. Maximizing the potential information derivable from such a study means balancing the effects that are to be observed against the potential diminution for the demonstration of the effects of higher priority variables. For example, the subjects were asked to monitor only a few of the types of information that an instructor pilot might have at the IOS. The display modes (analog and digital) and the manner in which the information was presented were somewhat arbitrarily chosen. The analog and digital displays used in this study were not themselves the objects of study; the object of study was the IOS display evaluation technique.

The experimental variables are represented in the accompanying block diagram, Figure 2.

IV. Experimental Design

The design of the present study differs from the previous one primarily in that it utilized a larger number of subjects (20 current Air Force pilots as opposed to four non-military pilots) and yielded three times as much data per subject. The design permits a look at the interactions among the several variables. Of particular interest is the time factor, that is, the time during the flight segment to which the question applies and thus the length of time during which the information must be retained.



2 Display Types/Subject
240 Test Conditions/Subject
20 Subjects

Figure 2. Experimental variables.

The time factor would be expected to interact with display format and type of question. Range-type questions might prove easier to answer. The six questions were generated by reference to strip chart recordings of the six flight parameters displayed for each flight segment. These questions and the correct answers are shown in Appendix D. Question types were counterbalanced to insure their equal representation across maneuver types and flight parameters for each of the two displays. Questions were devised on the basis of subjective decisions regarding the probable clarity with which they would be interpreted by the observer pilots.

In some cases, the questions referred to relatively minor variations of flight indication because of the path flown by the simulator pilot. For example, if the maneuver was a straight climb, successful pilotage would result in a constant heading, though the design of the study would require the generation of a question regarding change of heading.

The time factor was also taken from the strip chart of the various flight parameters. The elapsed time between the occurrence of a requested indication and the end of the flight was noted. Though this datum did not accurately indicate the time between the flight indication and the question pertaining to it (because of sequencing of questions in the post-flight-segment inquiry period), nevertheless it was chosen as the most reasonable approximation, given the alternative of a cumbersome measurement procedure.

The order in which the various flight parameter questions were asked was randomized independently for every flight segment and for each observer pilot. The type of question associated with a given maneuver was counterbalanced across the four examples of that maneuver but remained the same for all observer pilots. The forty flight segments were randomized independently for each observer pilot. Display type and maneuver/replication were thus randomly variable according to a computer-generated random order (2 displays by 5 maneuvers by 4 question types). These are contained in Appendix E.

The primary statistical analysis used for the determination of the adequacy of the IOS display evaluation technique for discriminating between display types was the analysis of variance. This type of analysis was chosen because it permitted the main effects and the interactions among them to be seen. Additional analyses included correlations between display types for each flight parameter and item-test correlations of the mean error for each question with the mean of the total errors for each flight parameter. Error magnitude correlation with time interval was also calculated.

V. Procedure

Those who served as observers in this study were Military Airlift Command pilots from McChord AFB south of Seattle, Washington. Eighteen were C-130 pilots and two were C-141 pilots. All were cooperative and seemed interested in the problem of IOS displays, with the reservation that they tended, in an understandable way, to react to the task within the frame of reference of the MAC pilot rather than as an instructor at an IOS associated with a single seat, high-performance fighter simulator. Because of a belief that the nature of the task required of them would be performed best if they had an opportunity to get away from it periodically, two pilots served alternatively in one-hour sessions. (It soon became evident that this was a prudent step as the pilots wearied at the task after about an hour). Thus, one pilot would observe the displays and answer questions while the other could view nearby simulation facilities, have a cup of coffee in the cafeteria, or read some material of general interest in the laboratory area.

The 40 flight segments comprising the complete session were divided into four sub-sessions of 10 each. These sub-sessions were a little less than an hour's duration and two subjects could be run in a single day, each serving 4 hours at the experimental monitoring task. The McChord AFB pilots were assigned to the 1 day temporary duty to serve in the study on the basis of availability. The average age of the pilots was 29.6 years with a standard deviation (S.D.) of 3.0 years. Total flight hours averaged 2248 (S.D. = 858). Current equipment for 16 pilots was the C-130 in which they averaged 1128 hours (S.D. = 135). All had flown the T-37, ranging from 80 to 1700 hours and all listed time for the T-38. Ten of the 20 pilots also listed civilian light aircraft time.

After arriving pilots had gone through the required check-in procedures, the experimenters led them to the nearby laboratory facility where the display equipment for the test was located (Visual Flight Simulation Laboratory). Each pilot was asked to fill out a brief form (Appendix F) for information about his age, current equipment, and flying time in all types of aircraft. The observer pilot was then given a copy of instructions for performing the task (Appendix A). This briefing material included a general explanation of the goals of the study and a statement to the effect that the pilots were not being evaluated regarding their personal skills but that the display evaluation technique itself was the subject of the investigation.

After reading the instructions, the pilot was asked whether there were any questions about them. The next part of the task familiarization included showing the pilot both of the display types: i.e., analog instruments and digital presentation of the CRT. The pilot was then shown how to cover either of the displays for the viewing of its alternate. It was here explained that the display mode used for any given flight segment was determined by randomization. This was also true for maneuver type, question type, and flight parameter. The presentation orders for each pilot are shown in Appendix E. Flight segment numbers were assigned such that designators 1 through 20 referred to the analog instrument display mode and designators 21 through 40 to the CRT digital display mode. The method of ordering the presentations of the flight segments is called random without replacement, i.e., no flight segment (as designated above) occurred twice for a given observer pilot on the same display.

Prior to the initiation of the first flight segment, the experimenter pointed out the flight instruments to be used and compared them with the same indications as shown on the CRT in the digital display mode. Figure 3 shows both display modes. Figures 4 and 5 show each display separately. The experimenter pointed out the locations of the pitch and bank angle indications on the CRT because the digital attitude display is not integrated as it is in the analog instruments.

The CRT was positioned above the instrument panel with the bottom of the scope at eye level. The pilot's eyes were located about 53 cm from the screen or instruments. Obviously, there were variations in the eye position because of body dimension differences among pilots or different postures.

The tube face was 30 cm wide and 22.5 cm high, while the displayed information was 20 cm wide and 7.5 cm high. Approximate center-to-center distances between adjacent flight indications were between 5 and 6 centimeters. Symbol size was adequate for easy reading.

The analog instruments extended horizontally 38 cm, vertically 22 cm. The ADI was the largest instrument at 10.7 cm width, while the heading indicator just below it was second largest at 9.3 cm width. The other three instruments, i.e., airspeed indicator, vertical velocity indicator, and altimeter, were all 7.3 cm wide. Center-to-center distances from the ADI to the other instruments were 15 cm to the altimeter, and 13 cm to the heading indicator.

A mask for the CRT was made of Fome-Cor and had a hinged door which could swing to one side to expose the face of the CRT. When the CRT was being used, a mask was set in place to occlude the analog instruments. This method permitted the use of simpler equipment design than would have been necessary if one mode had to be disabled while the other was being used.

Before observing the final 10 flight segments, each pilot was asked informally to comment on the conditions of the test. Their comments were recorded on tape (with their awareness) for later study. They were asked to compare the two display modes for each of the six flight parameters and to add anything they might have to say about the quality of the questions they were asked, the reasonableness of the simulation, the quality of the test environment, or the conduct of the test.

Although the subjects were encouraged by the experimenter to keep trying if they expressed doubts about their performance, they were told nothing about the correctness of their answers. If anyone seemed hesitant about answering a question, the experimenter asked that pilot to offer a guess.

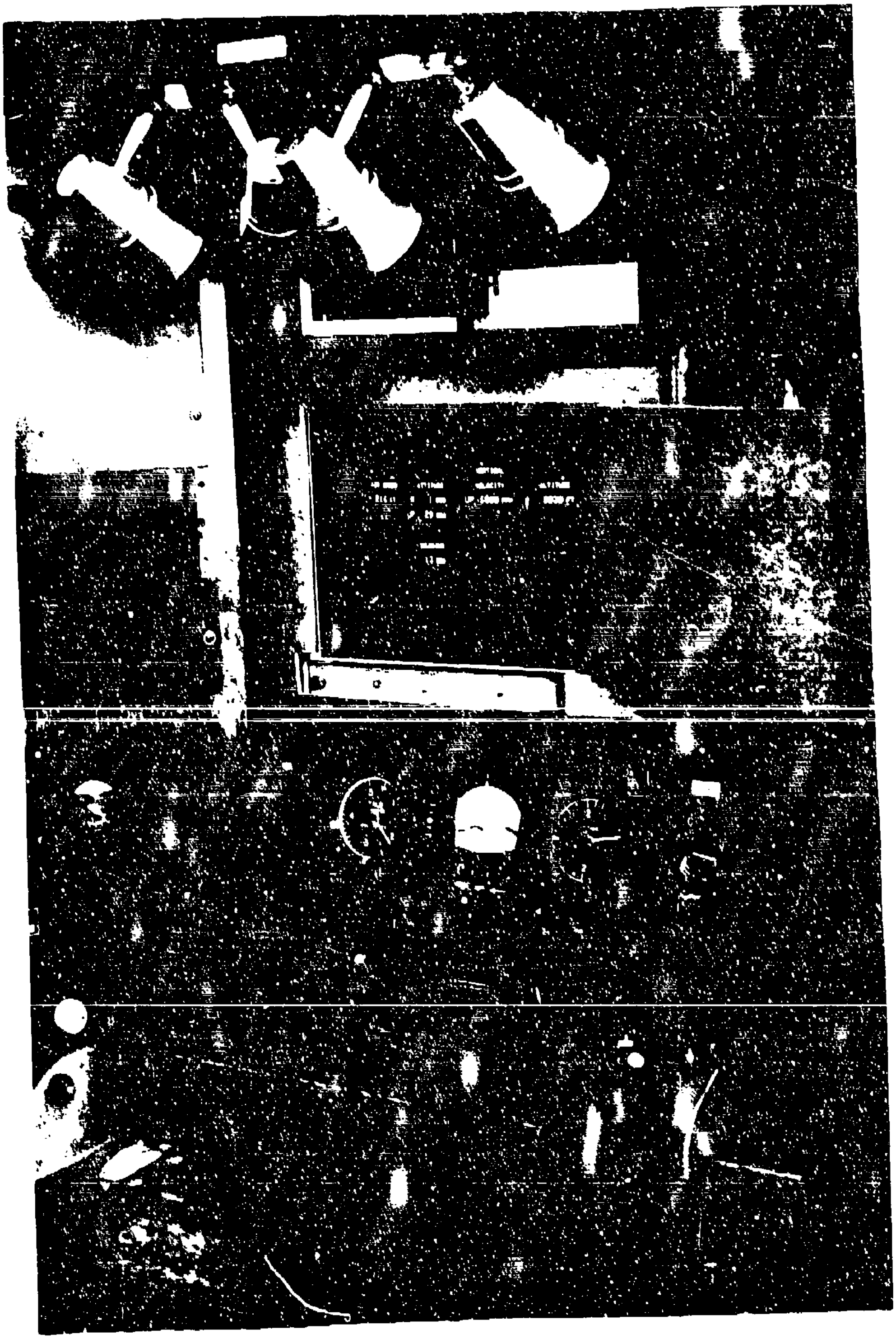
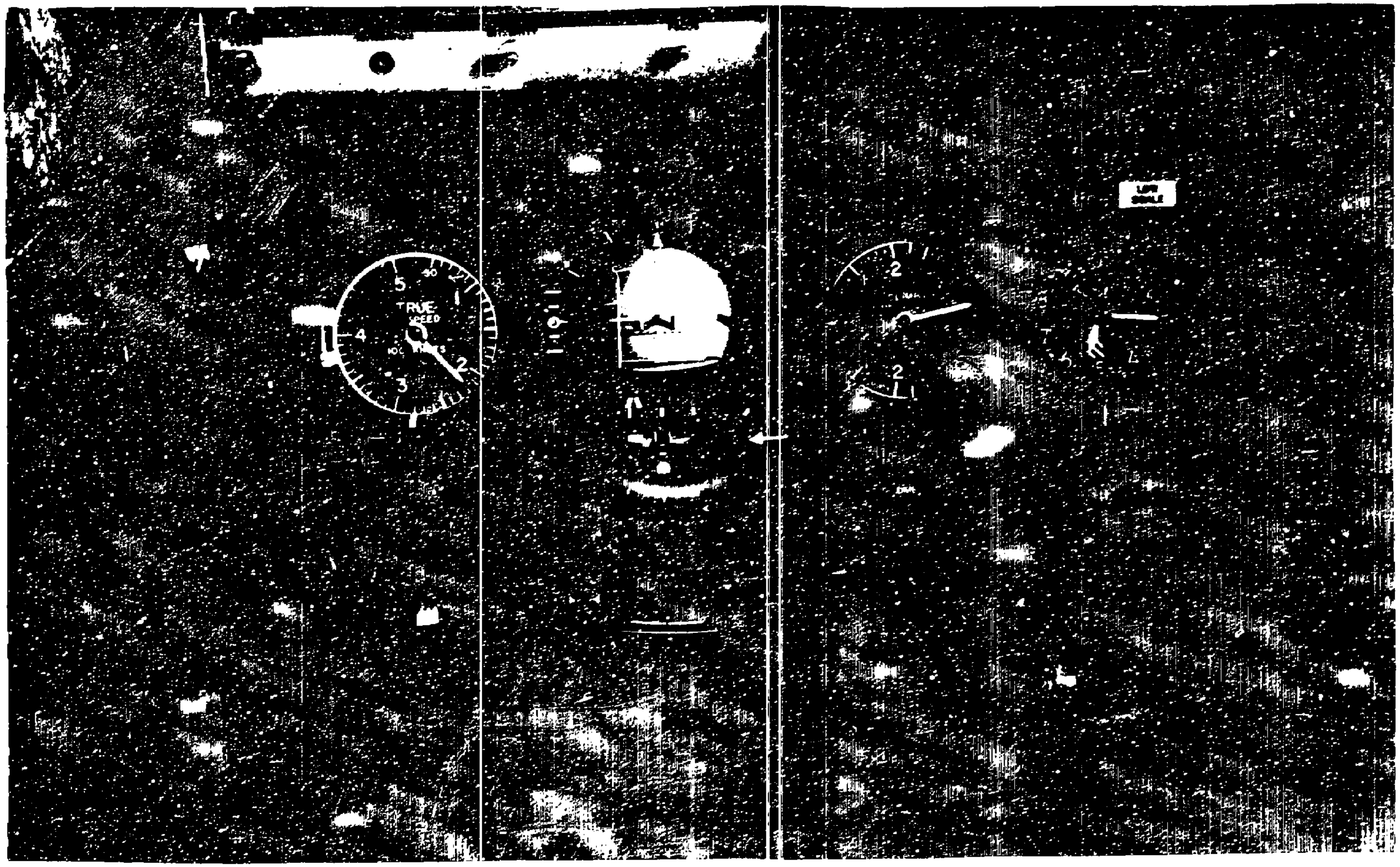


Figure 3. Photograph showing both displays.


TRUE
SPEED

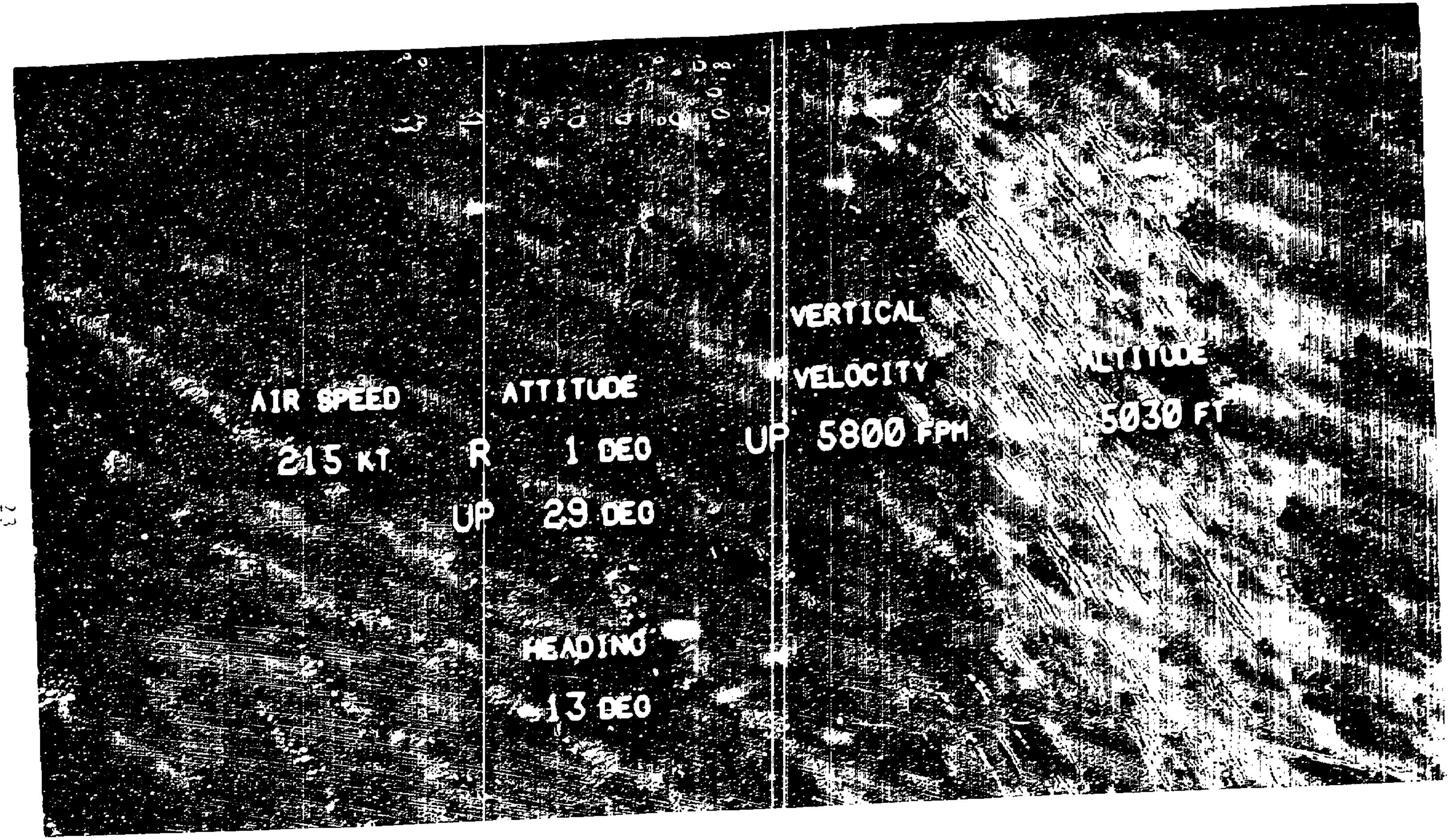


Figure 5. Photograph showing digital display.

VI. Results and Discussion

The independent variable of greatest interest was display mode, analog instruments vs. CRT digital format. To see the effect of this variable on the monitoring task, a separate ANOVA was computed for each of the six flight parameters. The dependent variable in each analysis was the size of the errors in the responses to the questions, the absolute error magnitude. Appendix B contains the raw data, that is, the responses actually given. The score was the absolute difference between the response shown in Appendix B and the correct response for that question shown in Appendix C.

To equate the four question types, the double-answer questions were treated as two separate questions and the sum of the errors for the two were averaged to yield a single score comparable to the single answer questions. These data were used, along with the errors from single-answer questions, in the ANOVA for the six parameters.

The ANOVA and means of pitch angle recall errors is shown in Table 1. Pitch angle responses were given with smaller error when the observer had been viewing the flight segment on the analog instruments compared to his responses after a digital format presentation on the CRT ($p < .05$). While the difference in error is small, 3.04 degrees for analog and 3.64 degrees for digital, the size of the error difference is not as important as the demonstration that a short-term memory task like this one can differentiate between display types.

The type of maneuver is also a significant main effect ($p < .05$). This is expected because of the correlation between maneuver type and variation in flight parameter values. Question type was also significant ($p < .05$) for the pitch angle ANOVA, with the type asking for the extremes of pitch throughout the flight segment (Type 1) yielding smaller error magnitudes than the other three types. The reason for this is not clear, especially in light of the fact that the third type of question asking for just one extreme (half of the Type 1 question) yielded the largest error of the four.

The display type by maneuver interaction is significant ($p < .05$) for the pitch parameter and the means suggest that the difference in favor of the analog display format occurred primarily with the straight climb and, to a lesser degree, with the climbing turn. The superiority of the analog display for pitch information is thus not uniformly evident for all five maneuvers, not appearing in the cases of level turn, descent, and descending turn. Maneuver by question type is also significant ($p < .05$). For example, type 2 questions yielded the worst performance of all 20 combinations (four question types x five maneuvers) with the straight climb maneuver but the best of all with the level turn maneuver.

Finally, the significant ($p < .05$) display by maneuver question type interaction means that the maneuver by question type interaction is different for the two displays, being more marked for the digital than for the analog display.

Table 1

ANOVA and Means of Pitch Angle Recall Errors for Display Type (D), Maneuver Type (M), Question Type (Q), and Interactions

Source	Error Term.	Deg. of Freedom	Sum of Squares	Mean Squares	F Ratio
Subject		19	154.363	8.124	
Display Type	SD	1	73.811	73.811	10.449*
Maneuver	SM	4	962.919	240.730	37.478*
Question Type	SQ	3	236.264	78.755	10.757*
SD		19	134.213	7.064	
SM		76	488.164	6.423	
DM	SDM	4	217.494	54.373	11.541*
SQ		57	417.303	7.321	
DQ	SDQ	3	23.594	7.865	1.246
MQ	SMQ	12	1811.072	150.923	19.484*
SDM		76	358.059	4.711	
SDQ		57	359.863	6.313	
SMQ		228	1766.036	7.746	
DMQ	SDMQ	12	135.224	11.269	2.237*
SDMQ		228	1148.630	5.038	

*$p < .05$

	Climb (1)	Climbing Turn (2)	Level Turn (3)	Descent (4)	Descending Turn (5)
	5.425	3.188	3.144	2.712	2.238
DISPLAY BY MANEUVER					
Analog	4.100	2.938	3.175	2.700	2.275
Digital	6.750	3.438	3.112	2.725	2.200
QUESTION TYPE BY MANEUVER					
(1)	4.825	1.925	1.950	1.750	1.700
(2)	7.825	4.300	1.400	3.175	1.550
(3)	6.725	3.250	1.775	4.175	3.250
(4)	2.325	3.275	7.450	1.750	2.450
DISPLAY BY QUESTION TYPE BY MANEUVER					
Analog-1	3.300	1.800	1.350	1.750	2.150
2	5.200	4.200	1.750	3.050	1.250
3	5.900	3.000	2.000	4.300	3.300
4	2.000	2.750	7.600	1.700	2.400
Digital-1	6.350	2.050	2.550	1.750	1.250
2	10.450	4.400	1.050	3.300	1.850
3	7.550	3.500	1.550	4.050	3.200
4	2.650	3.800	7.300	1.800	2.500

DISPLAY	Analog	Digital
	3.038	3.645

QUESTION TYPE: (1) 2.430, (2) 3.650, (3) 3.835, (4) 3.450

Table 2 shows the ANOVA and means of roll angle recall errors. Roll angle recall performance was not significantly different for the two displays. Maneuver types showed differences since those involving no turns varied little from zero roll. Question type showed significant differences ($p < .05$), with Type 1 (extremes of roll during the flight segment) associated with the largest error and Type 4 (single indication at a specified point in the flight segment) the smallest error. As both maneuver and question type were statistically significant, so also was the interaction between these two factors ($p < .05$); the pattern of this interaction is difficult to interpret, however. One might speculate that in piloting an aircraft with the standard artificial horizon, there is little concern about the specific number of degrees of roll, and that the question asking for this number would tend to place that kind of attitude display at a disadvantage. Nevertheless, there was no significant difference in favor of the digital format.

Table 3 shows the ANOVA and means of heading recall errors. Heading recall was not significantly different for the two display formats. Type of maneuver was a significant factor ($p < .05$) with the level turn resulting in far larger errors than was the case with other maneuvers. It should be pointed out that there was greater opportunity for error in heading recall with this maneuver because the heading change was about 180 degrees, as opposed to the climbing and descending turns which involved heading changes of 90 degrees. Question type significantly affected heading recall performance ($p < .05$), with Type 2 (change in indication during some limited portion of the flight segment) resulting in the largest error. Type 3 questions yielded errors averaging three-fourths the size of Type 2 errors, but the remaining two question types were associated with errors only two-fifths the size of Type 2 errors. There is a significant interaction ($p < .05$) between maneuver type and question type but the range of differences in the 20 combinations of maneuver and question type suggests the possibility of a serious artifact. The largest average error in the matrix was 132.25 for a Type 3 question on a level turn while the same type of question about a straight descent resulted in the smallest average error of 0.125. The heading recall data need closer scrutiny before they can be interpreted unambiguously.

Table 4 shows the ANOVA and means of airspeed recall errors. Airspeed recall performance was significantly better for the analog display format ($p < .05$). Maneuver type was again a significant main effect ($p < .05$) but the reasons for the differences observable in the data are not immediately clear. The average airspeed error for the level turn is about one-half that observed for three of the other four maneuvers and only two thirds of that for the remaining one. Though question type is not significant as a main effect, it does interact significantly with maneuver type ($p < .05$). The basis for this interaction is not apparent.

Table 5 shows the ANOVA and means of altitude recall error. Altitude recall errors were not significantly different for the two display formats. Maneuver type was significant ($p < .05$) with the level turn,

Table 2.

ANOVA and Means of Roll Angle Recall Errors for Display Type (D), Maneuver Type (M), Question Type (Q), and Interactions

Source	Error Term.	Deg. of Freedom	Sum of Square	Mean Squares	F Ratio
Subject		19	1315.544	69.239	
Display Type	SD	1	7.220	7.220	0.094
Maneuver	SM	4	5294.918	1323.729	22.054*
Question Type	SQ	3	746.885	248.962	4.528*
SD		19	1451.626	76.401	
SM		76	4561.660	60.022	
DM	SDM	4	128.523	32.131	0.517
SQ		57	3133.751	54.978	
DQ	SDQ	3	307.470	102.490	1.891
MQ	SMQ	12	2601.275	216.773	4.700*
SDM		76	4725.688	62.180	
SDQ		57	3088.623	54.186	
SMQ		228	10516.60	46.125	
DMQ	SDMQ	12	607.268	50.606	1.103
SDMQ		228	10463.18	45.891	

*$p < .05$

	Climb (1)	Climbing Turn (2)	Level Turn (3)	Descent (4)	Descending Turn (5)
	1.688	5.450	5.700	1.475	8.200

QUESTION TYPE BY MANEUVER

(1)	1.750	8.725	7.350	4.900	5.500
(2)	1.350	5.225	7.750	0.0	8.925
(3)	3.650	3.200	4.350	0.150	12.375
(4)	0.0	4.650	3.350	0.850	6.000

QUESTION TYPE: (1) 5.645, (2) 4.650, (3) 4.745, (4) 2.970

Table 3:

ANOVA and Means of Heading Recall Errors for Display Type (D), Maneuver Type (M), Question Type (Q), and Interactions

Source	Error Term.	Deg. of Freedom	Sum of Squares	Mean Squares	F Ratio
Subject		19	94792.00	4989.051	
Display Type	SD	1	8026.441	8026.441	3.612
Maneuver	SM	4	125262.5	31315.63	8.198*
Question Type	SQ	3	84538.44	28179.48	5.066*
SD		19	42227.18	2222.483	
SM		76	290318.5	3819.980	
DM	SDM	4	7440.688	1860.172	0.541
SQ		57	317027.3	5561.879	
DQ	SDQ	3	2140.688	713.562	0.190
MQ	SMQ	12	536719.8	44726.65	10.178*
SDM		76	261191.4	3436.729	
SDQ		57	214566.9	3764.332	
SMQ		228	1001952.	4394.523	
DMQ	SDMQ	12	26969.56	2247.463	0.804
SDMQ		228	637550.3	2796.273	

*$p \leq .05$

	Climb (1)	Climbing Turn (2)	Level Turn (3)	Descent (4)	Descending Turn (5)
	23.631	28.256	50.875	15.256	19.069

QUESTION TYPE BY MANEUVER

	(1)	(2)	(3)	(4)	(5)
(1)	0.300	52.550	7.675	14.425	14.050
(2)	69.875	53.250	44.275	25.700	19.400
(3)	1.800	2.550	132.250	0.125	19.825
(4)	22.550	4.675	19.300	20.775	23.000

QUESTION TYPE: (1) 17.800, (2) 42.500, (3) 31.310, (4) 18.060

Table 4:

ANOVA and Means of Airspeed Recall Errors for Display Type (D), Maneuver Type (M), Question Type (Q), and Interactions

Source	Error Term.	Deg. of Freedom	Sum of Squares	Mean Squares	F Ratio
Subject		19	7955.516	418.711	
Display Type	SD	1	1180.980	1180.980	4.415*
Maneuver	SM	4	8909.305	2227.326	7.669*
Question Type	SQ	3	1410.525	470.175	2.232
SD		19	5082.129	267.480	
SM		76	22074.07	290.448	
DM	SDM	4	434.387	108.597	0.787
SQ		57	12004.95	210.613	
DQ	SDQ	3	822.610	274.203	2.081
MQ	SMQ	12	7078.277	589.856	2.667*
SDM		76	10489.30	138.017	
SDQ		57	7511.195	131.775	
SMQ		228	50426.39	221.168	
DMQ	SDMQ	12	1205.227	100.436	0.615
SDMQ		228	37208.82	163.197	

*$p < .05$

	Climb (1)	Climbing Turn (2)	Level Turn (3)	Descent (4)	Descending Turn (5)
	14.625	16.881	7.169	11.175	13.962

QUESTION TYPE BY MANEUVER

	(1)	(2)	(3)	(4)	(5)
(1)	9.200	16.600	9.225	9.600	10.825
(2)	13.300	14.425	4.725	15.150	21.825
(3)	16.750	19.750	9.350	12.925	12.375
(4)	19.250	16.750	5.375	7.025	10.825

DISPLAY	Analog	Digital
	11.548	13.978

QUESTION TYPE: (1) 11.090, (2) 13.885, (3) 14.230, (4) 11.845

Table 5:

ANOVA and Means of Altitude Recall Errors for Display Type (D), Maneuver Type (M), Question Type (Q), and Interactions

Source	Error Term	Deg. of Freedom	Sum of Squares	Mean Squares	F Ratio
Subject		19	.45323E 08	2385465	
Display Type	SD	1	.34915E 06	349155	0.100
Maneuver	SM	4	.17753E 08	4438392	2.843*
Question Type	SQ	3	.15627E 08	5209320	3.396*
SD		19	.66584E 08	3504444	
SM		76	.11866E 09	1561343	
DM	SDM	4	.59676E 07	1491920	0.788
SQ		57	.87436E 08	1533975	
DQ	SDQ	3	.16659E 07	555303	0.373
MQ	SMQ	12	.63764E 08	5313693	3.523*
SDM		76	.14380E 09	1892141	
SDQ		57	.84865E 08	1488863	
SMQ		228	.34393E 09	1508472	
DMQ	SDMQ	12	.22421E 08	1868460	1.245
SDMQ		228	.34215E 09	1500682	

*p < .05

Climb (1)	Climbing Turn (2)	Level Turn (3)	Descent (4)	Descending Turn (5)
525.250	597.475	165.319	416.962	358.525

QUESTION TYPE BY MANEUVER

(1)	293.375	216.275	202.625	211.575	369.500
(2)	557.625	1751.625	214.250	472.375	202.800
(3)	692.000	129.375	100.900	430.400	477.550
(4)	558.000	292.625	143.500	553.500	384.250

QUESTION TYPE: (1) 258.670, (2) 639.735, (3) 366.045, (4) 386.375

as expected, associated with the smallest error. Question type was a significant main effect ($p < .05$) with Type 2 questions yielding errors averaging two-thirds larger than the next poorest question, Type 4. Maneuver interacts significantly with question type ($p < .05$) but a look at the matrix suggests cautious interpretation. On several occasions, the pilot not accustomed to reading a three-needle altimeter made errors as large as 10,000 feet.

Table 6 shows the ANOVA and means of vertical velocity recall errors. Vertical velocity indications were recalled significantly more accurately ($p < .05$) with the analog instrument than with the digital presentation on the CRT. The type of maneuver was again significant ($p < .05$) but not in any simple way, since the poorest performance occurred with level turns while the best occurred with straight climbs. Question type is a significant factor with this flight parameter, with the Type 3 question (single extreme value during the entire flight segment) showing two and a half times the error obtained with Type 2 (change during some limited portion of the flight segment). Display format interacts significantly with maneuver ($p < .05$), the largest difference between displays appearing with descending turns where the error with the digital mode was twice that with the analog instruments. Question type also interacts significantly with maneuver ($p < .05$) but not in any clearly systematic way.

The ability to recall information should be related to the elapsed time between the presentation of this information and the recall attempt. Table 7 contains the correlation coefficients for the two displays. In one analysis, error magnitude is compared with the time between the occurrence of the event in question and the end of the flight segment, and in the other analysis, this time period is converted to a percentage of the total flight segment. The coefficients which are significantly different from zero are identified by asterisks ($p < .05$).

Although 36 of the 120 correlations in the table as a whole are statistically significant, the largest is $r = .526$ which corresponds to an index of forecasting efficiency of 15%. % Efficiency = $(1 - \ 1 - r^2)100$. This index shows the percentage reduction in errors in predicting performance from knowledge of the time interval between the event and the end of the flight segment, compared to predicting the mean performance for each time interval. Those correlations around $r = .200$ yield an index of forecasting efficiency of only 2%. It is apparent that there is no strong correlation between time interval and error magnitude.

The analog display mode shows significant correlations in seven cases when time interval is used for the analysis and in eight cases when this time interval is converted to percent of total segment time. Not unexpectedly most of these cases (six out of eight) overlap in the two methods of analysis.

The digital display mode shows significant correlations in 11 cases when the analysis is of time interval and performance and in 10 cases when percent segment time is used, all 10 overlapping with those showing significance in the time interval analysis.

Table 6:

ANOVA and Means of Vertical Velocity Recall Errors for Display Type (D), Maneuver Type (M), Question Type (Q) and Interactions

Source	Error Term.	Deg. of Freedom	Sum of Square	Mean Squares	F Ratio
Subject		19	.4417906E 08	2325213	
Display Type	SD	1	.1709749E 08	17097490	13.066*
Maneuver	SM	4	.2613584E 08	6533960	2.797*
Question Type	SQ	3	.1199948E 09	39998260	19.147*
SD		19	.2486242E 08	1308548	
SM		76	.1775190E 09	2335776	
DM	SDM	4	.1532442E 08	3831104	2.753*
SQ		57	.1190743E 09	2089022	
DQ	SDQ	3	.1354378E 08	4514592	2.415
MQ	SMQ	12	.2548061E 09	21233840	12.287*
SDM		76	.[illegible]57711E 09	1391724	
SDQ		57	.1[illegible]5726E 09	1869694	
SMQ		228	.3940280E 09	1728193	
DMQ	SDMQ	12	.3133226E 08	2611021	1.730
SDMQ		228	.3441272E 09	1509329	

*$p < .05$

	Climb (1)	Climbing Turn (2)	Level Turn (3)	Descent (4)	Descending Turn (5)
	725.844	1119.531	1274.081	1104.806	1077.519
DISPLAY BY MANEUVER					
Analog	767.375	1004.375	1108.712	998.987	691.375
Digital	684.312	1234.688	1439.450	1210.625	1463.662
QUESTION TYPE BY MANEUVER					
(1)	446.375	1165.625	648.875	616.875	963.875
(2)	387.500	1307.500	401.200	482.850	768.700
(3)	1757.000	516.250	3350.000	1658.375	996.250
(4)	312.500	1488.750	696.250	1661.125	1581.250

DISPLAY	Analog	Digital
	914.165	1206.547

QUESTION TYPE: (1) 768.325, (2) 669.550, (3) 1655.575, (4) 1147.975

Table 7:

DISPLAY 1 - (Analog)

Correlations of Error With Segment Time Remaining

Maneuver/	Pitch	Roll	Heading	Airspeed	Altitude	VVI
Climb	.306*	-.526*	-.041	.035	.106	.163
Climbing Turn	.138	-.223*	-.373*	.066	-.032	.131
Level Turn	-.249*	-.082	-.071	-.032	-.116	.153
Descent	-.367*	.176	.114	-.133	-.081	.139
Descending Turn	-.221*	.002	.072	-.365	-.117	-.130

Correlations of Error With Percent Segment Time Remaining

Maneuver/	Pitch	Roll	Heading	Airspeed	Altitude	VVI
Climb	.278*	-.475*	.073	.027	.090	.122
Climbing Turn	.117	-.201*	-.358*	.061	-.043	.133
Level Turn	-.390*	-.010	-.009	-.009	-.126	.212*
Descent	-.252*	.227*	.112	-.129	-.080	.132
Descending Turn	-.104	.017	.061	-.336	-.104	-.088

DISPLAY 2 - (Digital)

Correlations of Error With Segment Time Remaining

Maneuver/	Pitch	Roll	Heading	Airspeed	Altitude	VVI
Climb	.485*	-.238*	-.043	.083	-.066	.006
Climbing Turn	.003	-.188*	-.392*	.234*	.019	-.200*
Level Turn	-.287*	-.172	-.105	.003	-.081	.198*
Descent	-.107	.226*	-.048	-.193*	.006	.169
Descending Turn	-.179	-.155	-.088	-.237*	-.025	.018

Correlations of Error With Percent Segment Time Remaining

Maneuver/	Pitch	Roll	Heading	Airspeed	Altitude	VVI
Climb	.517*	-.174	.044	.081	-.063	.070
Climbing Turn	-.023	-.199*	-.381*	.240*	.002	-.199*
Level Turn	-.268*	-.125	-.040	.027	-.039	.287*
Descent	.174	.284*	-.046	-.186*	.022	.158
Descending Turn	-.168	-.140	-.121	-.240*	-.054	.005

$p < .05$

For the analog display, correlations of error with intervening time were significant in seven instances, only one of which is positive in sign. This instance occurred for the flight parameter of pitch in the climb maneuver. However, each correlation is based on six responses to four questions (see discussion of question types, section) by 20 pilots. While the magnitude of error in a response can vary widely among the 20 pilots, the corresponding time interval is fixed at a single value.

The content of a question was dictated mostly by the availability of an event involving the given flight parameter, that is, an event about which a question could be formed. The starting point for the generation of questions (Appendix C) was the detailed inspection of the strip chart records (Appendix D). The choice of question was further restricted by the question type it had to represent. The point in the time segment where occurred the event corresponding to the desired question left little or no choice for a balanced selection of time intervals.

The digital display yields results similar to the analog display in that the most significant correlations of error performance with time interval are negative (seven out of 11). Since the test is the same as that used with the analog display, the discussion of the results for the analog mode applies here as well.

If the results of the correlational analysis are accepted as meaningful on the basis of statistical probability even though the coefficients are not high, then it is assumed that there is a tendency for the subjects to remember earlier flight indications better than later ones. However the possibility that these results are due to artifacts in the flight segments as flown or in the test questions cannot be excluded.

The study was not designed to treat the elapsed time question in a systematic way. The lack of a strong correlation between error magnitude and elapsed time is therefore not a conclusive finding.

Item-Test Correlations

The item-test correlations are shown in Table 8. The error scores for question types 1 and 2 were the average of the errors in the two answers given. These were added to the error scores from question types 3 and 4 and total errors were summed across the 20 questions (five maneuvers x four question types) for the subject to obtain a single score on that flight parameter. The correlation coefficients range from .810 to .015 in magnitude, and 20 coefficients are negative. The lower the correlation, the less the question contributes to the total score and if the sign is negative, larger errors in responses to that question are associated with smaller total error scores. Such an item lacks homogeneity with the other questions about that flight parameter, and its inclusion in the test tends to weaken or, if negatively correlated with the total, run counter to measurement goals. Therefore removing or improving low and/or negatively correlated items should improve the test.

Table 8:

Item-Test Correlations (Analog Display)

Maneuver	Run	Pitch	Roll	Heading	Airspeed	Altitude	Vertical Velocity
Climb	1	.291	.309	-.343	.579	-.026	.394
	2	.432	.041	.544	.017	.600	-.133
	3	-.102	.207	.486	.155	.261	.174
	4	.194	-	.113	.437	.787	.759
Climbing Turn	1	.356	.025	.200	.439	-.020	.223
	2	.418	.602	.384	.403	.760	.419
	3	-.052	.592	-	.244	-.100	.552
	4	.365	.550	.056	-.070	.269	.277
Level Turn	1	.183	.035	-.206	.065	.180	.229
	2	.528	.201	.405	.196	.086	.492
	3	.355	.516	.316	-.131	-.122	.387
	4	-.176	.215	.035	.581	-.061	.810
Descent	1	.128	.097	.427	.243	.020	.406
	2	.090	-	.359	.344	-.032	.018
	3	.346	.020	.122	.046	-.161	.180
	4	.256	.448	.241	-.066	-.093	-.015
Descending Turn	1	.060	.153	-.352	.187	.848	.144
	2	.049	.547	-.031	.509	.025	-.138
	3	.349	.382	.345	.066	.027	.046
	4	-.109	.166	.040	.127	.851	.361

VII. Conclusions and Recommendations

The objective of this study was to test an STE display evaluation technique, that is, to demonstrate its validity by applying it to two ostensibly different display types and measuring the ability of IP's to recall specific flight indications shown during short flight segments of five different maneuvers, viz., climb, climbing turn, level turn, descent, and descending turn. The flight parameters representing the flight segment included airspeed, pitch angle, roll angle, altitude, vertical velocity, and heading. These six flight parameters were analyzed separately to determine the sensitivity of the evaluation measure to display differences. The goal was to validate the IOS display evaluation technique to determine whether it would be worthwhile for the Air Force to pursue. In light of these results, the IOS display evaluation technique described in this report deserves further attention, given that the goals of the technique in this period of its development appear to have been realized. The deficiencies which are evident are apparently not insuperable, although attention is needed in several aspects of the test.

The most logical approach to the selection of questions for the benchmark task would be to choose flight segments from a larger group of such segments to obtain a greater variety of reportable events and time intervals. Though logical, it may be uneconomical because of the large amount of flight data to be processed. The present results fall short of those ultimately sought but make the effort a worthy one within a realistic framework.

One consideration pertinent to the understanding of the present data relates to the airplane being simulated by the computer program or data base. This simulated airplane is an "educated guess" about the flight characteristics of some future extension of the A-7, referred to informally as the "Super A-7." C-130 or C-141 pilots would be expected to perform much better on a task based on an airplane with more familiar flight characteristics. It may well be necessary to have sets of questions relating to various general aircraft types so that the observers evaluating a display can be matched, in terms of current experience, to the display's intended application. Certainly, the "super performance" of the simulated airplane in this study was confusing to the MAC pilots who served in the present study.

Another aspect of the flight characteristics of the simulated airplane was the interaction of these flight characteristics with the instruments used in the analog display. For example, the strip chart recording of one flight (Climb, Run 2) shows an airspeed of 700 knots though the maximum limit for the airspeed indicator is 500. Another example is the vertical velocity indicator which reads a maximum of 5800 ft/min while vertical speeds frequently exceed this value. (Maximum values for analog instruments were used to set maximum values for the CRT digital display.) These display limitations (or airplane excessive performance) cause the evaluative power of the test to be weakened.

Another weakness in the present study had to do with the current experience of the pilots serving as observers in the study. In several instances an altitude question received a response from a C-141 pilot which was 10,000 ft. in error because he was accustomed to a tape readout rather than dial-and-needle indications.

For some pilots who are accustomed to reading roll angle (bank) indications at the bottom of their ADI, there was a tendency to read right for left and vice versa on the one used in this study which had roll indication at the top. This may account in part for the lack of significant difference between the means for analog vs. digital in the ANOVA, since in the digital mode the left-right designation is alphabetic rather than being a tilt with respect to the artificial horizon. Roll angle interacts with the type of maneuver in some fairly obvious ways; in an attempted straight climb or descent the roll angle will remain close to zero and the size of the average error for these maneuvers will be correspondingly small.

Heading recall errors were difficult to score because the magnitude of the error was not as simply defined as with altitude. For example, should an observer report the heading to be 010 degrees (as presented on the analog instrument) when it was in fact 020 degrees, the error is easily scored as 10. Likewise, a report of 170 degrees instead of the correct heading of 190 degrees is scored as an error of 20. However, if the error is a difference between a heading greater than 270 and less than 090 the magnitude of the error is numerically larger than one of the same angular difference between a heading greater than 090 and less than 270. A solution might be to measure the error as angular difference, but this approach would make no sense applied to the digital display. Since the comparison of the two display types requires comparable measures, it appeared more justifiable to score responses in terms of numerical difference than to treat the digital display responses as though it presented heading information in a way comparable to the analog instrument, i.e., the round dial and pointer.

The vertical velocity, as displayed on the round dial (analog) instrument is another potential source of unwanted variation in the data. If, in a given flight segment, the maximum upward velocity was 5000 (+5000) feet per minute and the maximum downward velocity was 4900 (-4900) feet per minute, a report regarding maximum vertical velocity of -4900 would be scored as an error of 9900 feet per minute. As a deviation from zero feet per minute of vertical velocity the error is only 100 although the algebraic difference is 9900. Of course, the same kind of error may occur with the digital display if the observer recalls a value with a negative sign when it was positive or vice versa. If a value recalled is the largest negative value while the largest value is actually positive, scoring can be based either on the basis of the difference between the absolute values or on the angular difference between reported and correct values (algebraic difference), depending on the conceptual framework used. The choice made for this study was to take the algebraic difference for questions about maximum vertical speed without the direction (up or down) being specified in the question.

Further improvement in the technique for evaluating IOS displays should start with selecting or generating flight segment tapes which have the range and variety of characteristics from which to select items corresponding to the question categories. The events to which the questions refer should be easily distinguishable from other activity in the flight segment. In the present study some events used for the questions were not as distinctly separated from other activity as may be desired.

A longer time should be devoted to making sure that each observer can read the instruments correctly and understand the kinds of questions to be asked. A response system should be developed to permit observers to perform the task without requiring the presence of someone to record data.

The need for quantitative, objective measures of quality for intelligent procurement of advanced displays has received frequent mention, but not much has been done to remedy the problems associated with the more usual haphazard, subjective selection methods. The reason for this state of affairs is probably due to the magnitude of the effort needed to produce an objective evaluation technique.

The concept of the benchmark task applied to this problem is demonstrably worthwhile. Though it may require a number of iterations before it is developed to a satisfactory level, this evaluation technique is a way out of the problems of older methods. The program should receive the continuity of attention required to maintain the momentum necessary to bring it to success.

BIBLIOGRAPHY

Donaldson, T.S. Subjective scaling of student performance. Rand P-4556, March 1971.

Engel, J.D. An approach to standardizing human performance assessment. (AD-717 258). George Washington University, Human Resources Research Organization, October 1970.

*Evaluation of instruction. Chief of Naval Education and Training, CNTECHTRA Instruction 1540.12, 542A as of January 1975.

**Faconti, V., Mortimer, C.P. L., & Simpson, D.W. Automated instruction and performance monitoring in flight simulator training. AFHRL-TR-69-29. AD-704 120. Wright-Patterson AFB, OH: Training Research Division, Air Force Human Resources Laboratory, February 1970.

Faconti, V., & Epps, R. Advanced simulation in Undergraduate Pilot Training: Auto instructional system. AFHRL-TR-75-59(IV). AD-A017-165. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, October 1975.

*Finley, D.L., Robins, J.E., & Ryan, T.G. Training effectiveness evaluation of naval training devices. (AD-908 034). Bunker-Ramo Corporation, Westlake Village Electronic -- Etc., December 1972.

*Fogel, L.J., et. al. Investigation of principles of control/display for RPVs. (AD-767 414). Decision Science, Inc., February 1973.

*Fromer, R., Horowitz, M.W. Flight information display for instructional consoles. Tech. Report 20-DS, -31-1, September 1958.

*Gopher, D., et. al. The measurement of operator capacity by manipulation of dual-task demands. (AD-A006 352). Illinois University Savoy Aviation Research Laboratory.

Hunter, C.C. New dimensions to instruction. USAF Instructors Journal, 1970, 8(2)-11-15

Enhancement of human effectiveness in system design. (AD-A004 149). Training June 1974. Illinois University Savoy Aviation Research Laboratory.

The impact of full mission simulation of the TAC combat crew training system. (AD-B004 457L). Air War College, Maxwell AFB, Alabama, April 1975.

**Kanarick, A.F., et. al. Effects of value on the monitoring of multi-channel displays. Human Factors, 1969, Vol. 11.

*Man - The focus of the training system. (AD-768 756). Proceedings of the Naval -- Etc., Naval Training Equipment Center, Orlando, Florida, November 1973.

McGrath, J., & Harris, D. (Eds.) Adaptive training aviation research monographs. Inst. of Aviation, University of Illinois, August 1971.

*Miller, G.G. Some considerations in the design and utilization of simulators for technical training. AFHRL-TR-74-65, AD-A001-630. Lowry AFB, CO: Technical Training Division, Air Force Human Resources Laboratory, August 1974.

Miller, R.L. Techniques for the initial evaluation of flight simulator effect. (AD-A036 460). Wright-Patterson AFB, OH: Air Force Institute of Technology, December 1976.

*Pearlstein, R.B., Schumacher, S.P., Rifkin, K.E. Information displa guide. Valencia, PA: Applied Sciences Association, Inc., 1974.

Preliminary gound instructor's pilot manual. Naval Air Systems Command, Displays and Debriefing Subsystem (DDS). Air Combat Maneuvering Range, (Second Edition, Johns Hopkins University, Silver Springs, 1975).

**Price, H.E. Human engineering recommendations for the instructor pilot's station of the ASJ-1 weapon system trainer. (AD-678-571 and 370). Report PRA-56-15, September 1956.

*Prophet, W.W., Caro, P.W., Hall, E.R. Some current issues in the design of flight training devices. (AD-743 270). Alexandria, VA: Human Resources Research Organization, 1971.

Rose, H.C. A plan for training evaluation. Training and Development Journal, 1968.

*Ryan, L.E., Puig, J.A., & Micheli, G.S. An evaluation of the training effectiveness of device 2F90. (AD-750 248). Naval Training Equipment Center, Orlando, Florida, August 1972.

Shipley, B.D. Measurement of flight performance in a flight simulator. AD-A004 488. Report No. TR-40830, Arizona State University, Education Department.

Shipley, B.D. An automated measurement technique for evaluating pilot skill. (AD-A033 920). Arizona State University, Tempe College of Education, February 1976.

Smode, A.F. Human factors inputs to the training device design process. NAVTRADEVCEN 69-C-0298-1. NTEC, 1971.

**Smode, A.F. Recent developments in instructor station design/utilization for flight simulators. Human Factors, 1974, Vol. 16.

*Smode, A.F., Lam, K.D. (Eds.) Proceedings of the Conference on Military Instructor Training in Transition. TAEG Report No. 25, May 1975.

Stanley, M.D. A Method for Developing a Criterion for Combat Performance. (AD-765 679). Monterey, CA: Naval Postgraduate School, June 1973.

*Swain, A.D. Guide for the design and evaluation of the instructor's station in training equipment. WADC-TR-54-564, AD-72 105. December 1954.

Synthetic trainer instructor's guide. Fort Rucker, AL: U.S. Army Aviation School, November 1969.

Thomas, R., & Kline, J.M. Pilot performance as a function of three types of altitude displays. (AD-755 729). ASD, WPAFB, August 1972.

**Tyler, D.M., et. al. Monitoring performance across sense modes - an individual difference approach. Human Factors, 1972, Vol. 14.

**Valverde, H.H. A review of flight simulator transfer of training studies. Human Factors, 1973, 15(6).

*Wheaton, G.R., Mirabella, A., & Farina, A.J. Trainee and instructor task qualification: Development of quantitative indices and a predictive methodology. Darin, Dunlap & Association, Inc., January 1971.

Weyer, D.C., & Fuller, J.H. Development of a syllabus and student/instructor guide for use with a full mission simulator. AFHRL-TR-76-90, AD-A035 521. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, December 1976.

Young, F.E. Concept formulation report, synthetic training system. (AD-675 505). Falls Church, VA: Melpar, Inc., April 1966.

**Zipoy, D.R., et. al. Integrated information presentation and control system study. AFFDL-TR-70-79, Vol. I through IV, July 1970 to January 1973.

APPENDIX A: INSTRUCTIONS TO SUBJECTS

You have been asked to take part in a research project aimed at development of evaluation techniques for flight simulator instructor/operator displays. It is to be noted that the displays which you will be viewing are not under evaluation nor do they represent the state of the art in display technology. These displays are merely vehicles for testing the evaluation method under consideration.

A series of short flight segments were flown in a flight simulator and recorded. These recorded data will be played back to you on two different displays - analog flight instruments and digital CRT. After viewing each flight segment you will be asked to respond to a set of questions concerning the displayed data. Basically, we are trying to determine if this method can be used to ascertain the relative efficacy of alternative displays for providing different types of information to the instructor located at a remote station. Keep in mind it is this method for determining the power of the display, to provide certain types of information under certain conditions, which is under evaluation and not your individual powers of observation. It is, in fact, hoped that observers are more alike than different in their powers of observation and that individual differences will prove to be insignificant.

The questions will be of four types categorized on the basis of the kind of memory task implied. For example, the question may relate to the extreme values of a given flight parameter the answer to which requires retention of display contents over the entire flight segment. Such a question may be worded in the following way: "What were the extremes of airspeed during the flight segment?" The question concerns a range of values over an extended period of time.

A second type of question deals also with a range of values but refers to a particular point in the maneuver, e.g., "What was the change in airspeed in the transition to level off:" The answer requires the naming of two values, one displayed just before transition to level-off was started, another after it was completed.

The third and fourth types of question ask for single specific values rather than ranges. Like the first type, the third kind of question applies to the entire flight segment, e.g., "What was the highest airspeed during the flight segment?" (This particular question is implied in the first question about extremes of airspeed.)

The fourth type of question is like the second type in that it asks for display content at some particular point in the flight segment and like the third type in that a single specific value is requested.

The average duration of the flight segments is a little less than 2-1/2 minutes. They will represent five basic flight maneuvers: straight climb, climbing turn, level turn, straight descent, and descending turn.

The flight indications displayed will most probably not be representative of aircraft with which you are familiar since the computer program was designed to simulate a developmental high performance aircraft.

You will be asked questions after each flight segment on each of six fligh parameters: pitch, roll, heading, vertical velocity, altitude, and bearing

APPENDIX B: TEST CONDITIONS AND RAW DATA

INSTRUCTOR/OPERATOR STATION – DISPLAY EVALUATION STUDY – TABULATION OF RESPONSES

FLIGHT PARAMETER = PITCH

		MANEUVER																			
		CLIMB				CLIMBING TURN				LEVEL TURN				DESCENT				DESCENDING TURN			
		QUESTION TYPE																			
PILOT	DISPLAY TYPE	1A	1B	2A	2B	1A	1B	2A	2B	1A	1B	2A	2B	1A	1B	2A	2B	1A	1B	2A	2B
1	1	-4	30	15	0	15	0	1	7	6	2	-2	6	4	-1	-5	5	8	-1	-1	6
1	2	-1	27	21	3	1	9	-9	20	7	2	-3	11	4	-1	4	0	4	-3	-2	6
2	1	0	20	30	5	4	10	-5	10	8	2	-5	5	4	-1	-5	5	4	-2	-5	3
2	2	0	27	30	11	0	8	0	5	6	2	-2	7	0	1	-9	9	0	-5	-4	3
3	1	-1	33	35	7	-2	10	5	13	6	2	-2	5	4	-1	0	10	4	-2	-2	3
3	2	-1	23	0	20	-4	9	-2	4	7	0	-1	7	3	-2	3	7	5	-1	1	4
4	1	0	40	30	5	4	10	-4	10	6	5	-4	9	4	-1	-9	4	4	-2	-2	4
4	2	-2	20	40	5	2	9	-2	10	7	2	2	9	4	-2	4	6	4	-2	-5	1
5	1	3	26	30	15	3	10	3	8	7	3	0	3	4	-1	1	6	-1	4	-1	5
5	2	0	26	30	-10	1	9	-5	12	7	3	-1	8	4	-1	3	9	4	-1	-1	4
6	1	0	30	30	5	5	10	-5	10	6	4	0	10	5	0	5	2	5	0	-2	2
6	2	0	28	5	18	3	9	10	12	6	4	-1	6	5	-1	-8	5	6	-2	-5	2
7	1	0	30	30	4	5	11	-10	5	6	3	0	9	5	0	-2	7	5	0	-5	5
7	2	1	26	30	10	3	8	1	5	8	2	3	6	4	-1	-2	3	4	-2	-4	1
8	1	0	30	25	10	5	10	5	10	7	5	-1	10	5	-2	-10	-3	5	-2	-2	5
8	2	0	17	28	8	-2	9	3	6	0	3	0	9	4	0	4	10	4	0	0	4
9	1	2	30	30	10	0	10	5	10	6	2	-1	6	6	-1	0	6	0	-10	-5	0
9	2	0	17	-5	10	3	9	-8	12	6	0	0	6	4	-5	-1	5	1	-3	-4	4
10	1	0	28	30	5	2	8	-5	5	6	2	0	8	5	-2	0	5	5	-2	-3	5
10	2	-1	13	30	6	-3	6	4	12	5	-5	-3	8	4	-3	0	4	4	-1	-3	1
11	1	0	30	20	8	3	10	-3	8	7	3	0	10	5	-3	3	6	5	-3	-3	4
11	2	0	18	5	22	3	12	0	6	8	-4	3	8	0	-4	5	8	5	-3	-18	0
12	1	0	29	30	12	4	9	14	20	5	3	0	9	4	-1	0	4	4	-1	-2	4
12	2	-2	25	30	12	4	7	3	15	4	5	0	9	4	0	1	4	4	-2	-3	2
13	1	0	29	32	8	2	10	3	12	7	4	1	10	4	0	2	4	4	-1	-4	3
13	2	-1	18	29	15	3	8	4	9	5	2	-2	7	1	-4	-1	2	4	-1	-6	1
14	1	-1	26	30	4	6	12	2	10	6	4	0	8	6	0	0	4	6	-2	2	5
14	2	-2	26	27	6	0	9	-5	6	8	-1	-3	8	4	-1	0	8	6	-3	1	5
15	1	0	28	40	0	5	10	0	5	7	3	2	8	5	-1	4	8	5	0	-2	5
15	2	1	27	15	5	2	10	2	6	6	2	-1	8	4	-2	2	7	5	-5	-10	4
16	1	1	29	30	-2	2	10	-4	5	7	3	0	9	4	-1	0	-1	1	-1	-4	4
16	2	-2	6	17	6	3	7	-3	4	6	3	-2	4	5	-1	-7	3	6	-2	-1	3
17	1	2	29	29	14	5	11	4	9	6	4	1	8	4	0	2	7	4	0	-3	6
17	2	-2	11	26	11	0	8	-5	7	4	6	-3	6	4	-1	-8	5	3	-2	-6	4
18	1	4	30	30	2	3	10	5	20	20	-15	-1	5	4	-1	2	10	5	1	0	4
18	2	4	18	18	4	-3	10	-3	10	35	-15	-1	6	5	-3	2	7	4	-2	-1	4
19	1	-8	20	40	-19	-1	10	0	5	7	0	-3	4	0	-4	0	5	5	0	-4	0
19	2	-2	18	-15	0	0	4	4	13	7	0	-3	4	1	-4	-2	4	2	-5	-2	4
20	1	-10	30	35	20	4	10	-10	20	6	3	-15	10	5	0	0	10	5	0	-5	3
20	2	0	15	17	5	4	10	-5	18	6	1	2	8	4	-1	-6	5	4	-1	-2	2
CORRECT RES		-2	32	40	0	2	31	4	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]							

INSTRUCTOR/OPERATOR STATION - DISPLAY EVALUATION STUDY - TABULATION OF RESPONSES

FLIGHT PARAMETER = PITCH

		MANEUVER									
		CLIMB		CLIMBING TURN		LEVEL TURN		DESCENT		DESCENDING TURN	
		QUESTION TYPE									
PILOT	DISPLAY TYPE	3	4	3	4	3	4	3	4	3	4
1	1	20	3	11	-1	-5	8	-6	2	0	-4
1	2	20	8	17	-1	-1	7	-7	6	-6	-4
2	1	20	7	10	2	5	5	-10	5	-2	-5
2	2	20	11	11	0	-2	6	-6	5	-10	0
3	1	20	3	11	-6	0	9	-10	2	-5	2
3	2	20	3	10	-4	-3	8	-7	4	-3	-6
4	1	20	7	10	-5	1	7	-7	6	-5	-3
4	2	20	4	10	-2	2	7	-3	4	-3	-1
5	1	21	4	12	2	0	9	-5	6	-3	1
5	2	18	4	11	0	0	6	-7	6	-3	1
6	1	20	5	10	-5	4	10	2	5	-5	-3
6	2	20	5	10	0	2	6	-5	4	-5	-2
7	1	20	9	11	-5	1	9	-5	6	-1	-1
7	2	18	8	8	1	1	4	-2	6	-4	-4
8	1	20	5	10	5	-2	7	-5	8	-3	-3
8	2	20	5	10	0	2	10	-4	9	-4	1
9	1	20	2	10	-4	3	7	-5	6	-5	-5
9	2	17	5	10	3	-1	10	-4	6	-4	-5
10	1	18	3	10	-3	-2	6	-7	6	-2	-5
10	2	20	6	9	-4	2	6	-6	6	0	1
11	1	19	6	10	0	-7	8	-2	8	0	-3
11	2	18	0	8	1	0	8	-4	6	-3	2
12	1	21	10	12	-1	0	6	-5	6	-1	1
12	2	19	8	9	-4	0	6	-4	6	-2	-2
13	1	18	4	9	-4	3	8	-7	6	-3	-4
13	2	19	5	10	6	2	8	-5	5	1	-4
14	1	22	5	10	-5	0	8	-5	8	-4	-3
14	2	20	4	12	-5	-2	7	-6	5	-2	-3
15	1	20	4	10	-4	2	8	7	3	-2	-2
15	2	18	3	10	-3	2	8	-10	3	-3	-2
16	1	20	3	7	2	0	7	-8	7	1	1
16	2	18	3	11	-3	1	7	-3	4	-8	1
17	1	22	4	8	-5	0	9	-5	6	-3	1
17	2	11	5	10	11	-1	6	-6	6	-4	-3
18	1	21	6	9	2	0	7	-5	5	-5	-1
18	2	18	7	15	-3	2	7	-3	7	-2	-2
19	1	20	3	12	-7	-2	9	-5	8	-4	-3
19	2	18	-4	3	-3	-3	8	-4	3	-12	-3
20	1	20	5	8	-3	3	5	-5	5	-1	-1
20	2	25	3	8	2	-2	7	-5	7	-3	-1
CORRECT RES		26	3	13	-4	0	0	-9	7	-6	-4

FLIGHT PARAMETER = ROLL

MANEUVER / QUESTION TYPE

PILOT	DISPLAY TYPE	CLIMB 1A	CLIMB 1B	CLIMB 2A	CLIMB 2B	CLIMBING TURN 1A	CLIMBING TURN 1B	CLIMBING TURN 2A	CLIMBING TURN 2B	LEVEL TURN 1A	LEVEL TURN 1B	LEVEL TURN 2A	LEVEL TURN 2B	DESCENT 1A	DESCENT 1B	DESCENT 2A	DESCENT 2B	DESCENDING TURN 1A	DESCENDING TURN 1B	DESCENDING TURN 2A	DESCENDING TURN 2B
1	1	-7	6	0	0	10	-40	0	45	-8	40	0	25	8	-10	0	0	-30	7	0	-30
1	2	-5	7	-2	1	-30	0	26	30	7	0	0	22	12	-7	0	0	-25	9	-25	0
2	1	-8	8	0	0	30	-30	0	30	-27	15	-5	40	8	-8	0	0	-25	11	0	-30
2	2	-4	7	-14	13	0	-40	3	42	-33	15	-27	0	5	-5	0	0	-30	11	0	-24
3	1	-8	8	0	0	0	-45	0	45	-30	15	0	25	8	-5	0	0	-35	15	0	-28
3	2	-7	5	0	7	4	-31	0	31	-29	20	0	10	6	-6	0	0	-26	11	0	-28
4	1	-5	3	0	0	20	-40	0	40	-35	15	0	33	10	-10	0	0	-32	12	0	-30
4	2	-7	9	0	0	10	-40	0	40	-33	7	0	26	11	-9	0	0	-33	3	0	-27
5	1	-5	5	0	0	8	-40	0	40	-34	8	40	0	10	-5	0	0	-35	12	0	-25
5	2	-7	4	0	1	8	-38	0	26	-34	12	0	18	6	-4	0	0	-24	11	0	-30
6	1	-2	2	0	0	20	38	30	45	-30	10	0	32	10	-10	0	0	-32	5	0	-35
6	2	-7	7	0	0	38	-10	0	37	-29	20	0	27	0	-5	0	0	-30	10	0	-38
7	1	-5	5	0	0	40	-10	0	35	-32	12	0	45	2	-2	0	0	-35	5	0	-40
7	2	-6	6	0	2	8	-35	0	28	-32	2	0	28	5	-11	0	0	-20	0	-10	-20
8	1	-3	3	0	0	0	-40	0	40	-30	5	0	35	30	0	0	0	-30	0	-30	-40
8	2	-6	10	0	0	10	-38	0	30	-33	10	0	38	10	-10	0	0	-29	5	0	-25
9	1	-15	10	0	0	30	-35	0	30	-35	20	0	40	7	-8	0	0	-35	10	25	30
9	2	-7	5	-2	2	0	-37	25	40	-27	10	0	23	5	-7	0	0	-27	10	0	-30
10	1	-10	10	0	0	10	-30	0	38	-2	28	25	40	20	-10	0	0	-28	10	0	-28
10	2	0	1	0	2	9	-30	0	32	-30	3	0	28	6	-9	0	0	-10	10	0	-25
11	1	-10	10	0	0	10	-35	0	35	-30	5	0	25	-10	10	0	0	-35	5	-15	-25
11	2	-7	5	-1	1	0	-32	0	37	0	34	0	40	5	-4	0	0	-28	7	0	-24
12	1	-10	10	0	0	35	-30	0	35	-32	15	0	-32	10	-10	0	0	-32	10	0	-35
12	2	-5	5	-2	3	1	-37	0	35	-30	10	0	28	10	-10	0	0	-33	10	0	26
13	1	-6	6	0	0	10	-43	0	35	-16	35	31	25	10	-10	0	0	-2	29	0	-25
13	2	-6	5	0	1	1	-24	0	26	-27	3	0	28	6	-7	0	0	-27	0	0	-31
14	1	-6	6	0	0	10	-35	35	0	-35	16	0	30	10	-10	0	0	-10	32	31	25
14	2	-12	5	0	1	8	-37	0	36	-38	16	0	38	7	-4	0	0	-27	2	0	-30
15	1	-5	5	0	0	7	-35	0	40	-34	6	0	38	5	-5	0	0	-7	30	0	-30
15	2	-8	6	-1	0	8	-28	0	29	-33	13	0	25	-8	7	0	0	-27	8	0	[illegible]
16	1	-2	2	0	0	5	-32	0	45	-45	2	32	20	2	-2	0	0	-32	2	0	-45
16	2	-7	3	-4	4	27	-3	0	29	-28	4	0	24	2	-2	0	0	-17	2	0	-21
17	1	-8	10	0	0	10	-22	0	22	-18	30	0	33	5	-4	0	0	-27	10	-27	-30
17	2	-7	4	0	1	8	-36	0	36	-26	11	0	28	2	-3	0	0	-22	4	-22	-26
18	1	-5	3	0	0	10	-35	0	-40	-15	32	0	0	8	-2	0	0	-25	5	0	40
18	2	-2	2	0	0	5	-33	0	20	-28	0	0	20	5	-5	0	0	-25	5	23	-35
19	1	-3	8	0	3	40	-35	0	30	-30	10	0	35	3	-8	-1	0	-28	8	0	20
19	2	0	5	-2	1	30	-30	0	35	-29	5	0	30	4	-3	0	0	-21	10	0	25
20	1	-5	5	0	0	5	-40	0	45	-30	15	0	40	15	-5	0	0	-30	10	-20	-40
20	2	-6	7	0	5	3	-37	0	42	-30	0	0	37	7	-8	0	0	-29	8	0	-30
CORRECT RES		-7	6	-2	1	9	-38	0	34	-33	15	0	37	12	-9	0	0	-32	11	0	-29

FLIGHT PARAMETER = ROLL

PILOT	DISPLAY TYPE	CLIMB 3	CLIMB 4	CLIMBING TURN 3	CLIMBING TURN 4	LEVEL TURN 3	LEVEL TURN 4	DESCENT 3	DESCENT 4	DESCENDING TURN 3	DESCENDING TURN 4
1	1	-5	0	30	30	35	25	0	1	-20	28
1	2	-5	0	27	-30	31	50	0	1	-10	20
2	1	-2	0	25	27	33	30	0	3	-12	-27
2	2	-2	0	22	40	27	27	0	2	-27	30
3	1	0	0	25	25	30	20	0	4	-60	30
3	2	-5	0	27	24	32	26	0	2	-10	-28
4	1	0	0	30	30	33	30	0	2	-20	25
4	2	-9	0	25	27	33	27	0	2	-25	23
5	1	6	0	30	30	30	25	0	2	-22	25
5	2	-5	0	28	28	31	25	0	1	-20	28
6	1	-3	0	30	30	30	30	0	0	-30	33
6	2	-3	0	25	20	32	27	0	2	-25	29
7	1	-5	0	30	30	30	25	0	2	-20	30
7	2	-3	0	24	24	30	24	0	2	40	24
8	1	0	0	35	30	35	20	0	0	0	25
8	2	-1	0	20	27	29	25	0	1	-5	28
9	1	5	0	30	28	35	28	0	0	-45	26
9	2	-5	0	30	23	35	22	0	3	-40	23
10	1	-3	0	30	28	32	25	0	0	-20	20
10	2	1	0	30	29	2	25	0	1	-35	28
11	1	5	0	30	30	25	28	-2	2	-10	32
11	2	-3	0	26	25	28	23	0	2	-6	23
12	1	-2	0	30	30	5	30	0	1	-20	28
12	2	-5	0	25	27	33	25	0	1	-1	20
13	1	-6	0	30	29	25	25	0	0	-20	33
13	2	-2	0	22	29	26	22	0	2	-5	22
14	1	-5	0	29	30	35	27	0	2	-20	29
14	2	5	0	25	26	33	26	0	1	-15	27
15	1	0	0	30	30	32	25	0	2	-55	25
15	2	-5	0	30	25	30	22	0	1	-10	22
16	1	-1	0	29	20	32	29	0	0	-55	32
16	2	2	0	23	20	31	22	-2	2	-22	27
17	1	-8	0	30	29	32	29	0	1	-15	22
17	2	-4	0	22	27	31	25	0	2	-18	28
18	1	2	0	20	25	5	20	0	3	-30	22
18	2	3	0	15	20	33	20	0	2	-12	25
19	1	0	0	25	30	33	20	-2	0	-5	23
19	2	-9	0	33	35	32	21	0	0	-40	23
20	1	2	0	30	30	30	30	0	1	-20	35
20	2	-3	0	27	27	30	25	0	2	-40	29
CORRECT RES		-5	0	29	30	33	24	0	1	-20	29

MANEUVER / QUESTION TYPE

FLIGHT PARAMETER = HEADING

PILOT	DISPLAY TYPE	CLIMB 1A	CLIMB 1B	CLIMB 2A	CLIMB 2B	CLIMBING TURN 1A	CLIMBING TURN 1B	CLIMBING TURN 2A	CLIMBING TURN 2B	LEVEL TURN 1A	LEVEL TURN 1B	LEVEL TURN 2A	LEVEL TURN 2B	DESCENT 1A	DESCENT 1B	DESCENT 2A	DESCENT 2B	DESCENDING TURN 1A	DESCENDING TURN 1B	DESCENDING TURN 2A	DESCENDING TURN 2B
1	1	96	96	348	350	280	33	98	20	149	269	305	310	275	279	282	284	165	250	160	90
1	2	97	97	350	350	280	37	88	20	130	313	40	359	195	199	265	285	165	253	135	127
2	1	98	98	346	348	280	30	180	90	130	310	200	270	190	205	282	282	220	275	120	120
2	2	97	97	348	348	260	90	88	10	130	250	360	309	184	199	283	283	173	300	120	130
3	1	97	97	350	350	260	38	88	1	135	315	290	310	195	200	283	285	165	360	218	30
3	2	97	97	360	360	280	10	88	300	130	313	10	330	195	198	285	285	165	248	150	120
4	1	97	97	348	348	290	30	90	45	120	310	340	310	195	195	283	283	168	315	115	115
4	2	97	97	348	350	280	37	88	20	130	313	275	309	198	195	283	285	165	249	145	119
5	1	97	97	347	347	260	29	90	20	130	243	306	309	195	199	273	273	210	249	119	119
5	2	97	97	348	348	280	15	88	30	130	313	345	307	195	199	283	283	165	248	122	119
6	1	97	97	1	1	280	38	88	40	135	312	300	310	267	265	285	285	165	265	125	120
6	2	97	97	348	347	280	35	88	40	130	313	350	335	295	296	285	285	165	280	157	117
7	1	97	97	348	348	320	280	88	240	130	330	10	310	193	195	283	285	165	250	151	120
7	2	97	97	1	1	280	10	88	10	130	320	309	351	195	197	283	283	290	348	120	120
8	1	97	97	345	345	260	30	90	350	130	310	310	310	190	190	282	282	165	240	120	120
8	2	97	97	348	350	260	30	88	351	135	313	300	310	195	199	283	283	165	248	120	115
9	1	9.	97	1	1	280	28	89	1	130	313	304	306	264	266	283	283	165	248	120	120
9	2	97	97	8	340	290	28	88	200	130	313	290	309	195	199	283	283	165	249	120	120
10	1	97	97	348	348	280	27	360	45	130	313	300	310	195	199	283	283	155	250	118	116
10	2	97	97	348	348	280	28	30	1	130	310	320	300	195	200	283	283	165	248	117	123
11	1	96	96	340	340	270	28	90	45	130	310	308	314	196	200	283	285	164	350	118	122
11	2	97	97	350	350	260	37	280	10	135	313	360	310	195	199	183	185	165	248	170	219
12	1	97	97	348	346	360	1	90	300	135	312	303	309	195	199	283	283	165	250	120	125
12	2	97	97	348	350	280	27	88	335	140	313	335	340	195	199	283	283	165	330	150	135
13	1	97	97	1	1	280	28	88	360	130	313	1	1	78	78	1	1	165	248	120	120
13	2	97	97	1	1	280	27	89	30	120	313	320	340	95	98	285	285	160	249	[illegible]	1
14	1	97	97	1	1	280	27	88	350	130	315	340	350	194	198	285	285	162	256	120	117
14	2	97	97	350	350	280	27	88	35	130	313	345	300	195	199	1	1	135	230	120	120
15	1	97	97	1	1	280	28	88	350	129	310	305	309	193	199	284	282	165	248	1	1
15	2	97	97	347	350	280	47	28	20	135	310	305	305	195	199	283	283	165	248	127	127
16	1	97	97	346	348	280	30	86	30	130	310	270	310	193	196	285	285	168	248	160	133
16	2	97	97	245	243	260	30	88	360	133	336	340	290	195	198	285	283	165	250	120	111
17	1	93	93	348	350	281	27	88	32	129	313	30	360	193	195	1	1	164	250	120	118
17	2	97	97	348	349	300	27	88	10	130	287	337	347	195	198	284	283	165	248	119	126
18	1	93	93	348	350	360	1	88	10	1	360	265	250	195	200	285	285	160	300	118	122
18	2	97	97	348	348	360	1	88	20	135	315	12	340	197	200	287	283	165	270	180	180
19	1	97	97	348	341	280	1	88	35	133	314	270	240	184	195	268	272	168	245	130	120
19	2	97	97	348	348	270	30	88	43	138	265	330	350	196	198	283	283	170	348	174	148
20	1	96	96	348	349	260	30	88	1	130	315	250	280	195	199	283	283	165	255	125	125
20	2	97	97	348	349	280	19	88	20	130	317	330	350	195	194	283	283	170	250	217	119
CORRECT RES		97	97	350	350	360	1	88	42	130	310	305	310	195	199	285	285	170	250	120	120

FLIGHT PARAMETER = HEADING

PILOT	DISPLAY TYPE	CLIMB 3	CLIMB 4	CLIMBING TURN 3	CLIMBING TURN 4	LEVEL TURN 3	LEVEL TURN 4	DESCENT 3	DESCENT 4	DESCENDING TURN 3	DESCENDING TURN 4
		MANEUVER / QUESTION TYPE									
1	1	14	262	30	14	25	282	12	49	12	250
1	2	14	261	30	16	360	275	12	47	7	265
2	1	13	263	30	15	350	300	12	48	6	270
2	2	14	263	30	10	360	200	12	49	7	250
3	1	13	265	30	15	330	268	12	58	6	270
3	2	13	265	31	16	360	30	12	50	10	260
4	1	13	265	30	16	135	270	13	360	7	270
4	2	13	265	36	16	30	250	12	49	7	260
5	1	12	265	30	16	359	210	12	49	350	40
5	2	13	264	30	16	359	289	12	49	1	251
6	1	13	265	30	15	35	280	12	50	5	255
6	2	13	265	30	16	30	278	12	49	7	240
7	1	13	265	30	16	25	250	12	49	7	250
7	2	13	345	30	100	255	270	12	49	7	260
8	1	15	267	30	15	25	275	10	50	6	260
8	2	13	265	100	20	26	276	12	49	7	250
9	1	13	265	30	16	360	290	12	46	1	250
9	2	16	264	30	16	26	265	12	49	7	250
10	1	13	265	30	16	360	278	12	48	7	260
10	2	14	265	30	16	360	278	12	49	7	255
11	1	14	1	30	16	255	278	11	50	6	250
11	2	13	265	55	16	155	278	12	49	7	250
12	1	16	264	30	18	26	330	12	283	8	256
12	2	14	164	30	16	360	250	12	16	7	253
13	1	12	276	30	16	360	276	12	49	7	250
13	2	13	64	30	16	360	276	12	49	7	250
14	1	13	265	30	17	257	278	13	49	345	245
14	2	14	265	30	18	255	280	12	49	70	252
15	1	13	275	30	30	360	277	12	46	8	256
15	2	13	265	30	16	360	255	12	49	10	270
16	1	12	64	30	16	30	260	12	253	5	163
16	2	16	265	30	16	32	285	12	49	7	26?
17	1	13	264	30	16	360	282	12	49	4	244
17	2	14	264	30	19	360	265	12	49	1	256
18	1	13	265	30	15	360	290	12	52	5	180
18	2	13	263	30	16	360	278	12	49	7	110
19	1	13	264	30	16	255	276	12	50	8	250
19	2	13	265	30	16	100	253	12	49	7	253
20	1	15	265	30	15	310	300	12	49	7	259
20	2	19	264	30	19	19	285	12	49	7	250
CORRECT RES		15	264	30	16	360	280	12	50	7	250

FLIGHT [illegible]METER + AIRSPEED

		MANEUVER																			
		CLIMB				CLIMBING TURN				LEVEL TURN				DESCENT				DESCENDING TURN			
		QUESTION TYPE																			
PILOT	DISPLAY TYPE	1A	1B	2A	2B	1A	1B	2A	2B	1A	1B	2A	2B	1A	1B	2A	2B	1A	1B	2A	2B
1	1	100	500	325	360	225	290	340	320	240	285	290	260	280	330	260	270	240	310	350	290
1	2	100	500	325	360	225	290	340	320	240	265	290	270	283	335	275	295	265	305	355	325
2	1	110	500	340	360	200	270	340	320	240	260	270	270	280	350	240	310	275	300	365	325
2	2	105	500	335	360	240	275	340	325	340	355	265	270	250	325	265	285	290	350	375	275
3	1	110	500	300	330	230	275	340	330	240	260	270	265	280	330	240	280	260	300	360	290
3	2	160	500	345	360	240	270	340	315	230	270	265	265	285	325	270	285	240	310	375	350
4	1	115	500	335	360	220	270	340	320	250	240	270	270	285	330	240	285	260	300	375	320
4	2	110	500	320	360	220	270	320	275	245	255	270	265	280	330	245	290	250	300	360	320
5	1	110	500	335	357	225	275	325	320	240	255	275	270	260	330	250	255	255	290	375	330
5	2	105	500	335	345	215	275	340	320	235	250	265	265	285	330	245	260	285	305	360	260
6	1	130	500	420	360	240	280	320	310	240	260	280	270	260	330	250	250	250	330	370	330
6	2	110	500	330	360	240	260	340	325	240	270	265	270	280	355	280	290	255	305	355	325
7	1	115	500	335	360	220	270	340	325	220	260	275	260	270	340	240	270	250	305	340	330
7	2	110	500	335	355	240	240	335	320	230	255	270	265	265	355	245	270	250	285	375	340
8	1	110	500	340	340	240	260	340	330	280	300	270	270	280	330	240	250	250	302	360	330
8	2	110	500	360	360	225	260	340	320	235	250	265	265	265	310	285	300	250	305	375	350
9	1	110	500	310	340	220	270	325	340	240	265	280	265	285	330	260	285	250	300	375	240
9	2	130	500	330	360	240	240	340	310	240	260	275	265	285	330	265	285	260	310	330	310
10	1	110	500	340	360	240	255	335	325	235	255	260	270	285	330	240	255	250	300	360	330
10	2	110	500	340	360	235	265	335	325	250	255	265	285	260	335	245	265	255	340	365	340
11	1	115	503	330	360	240	280	320	290	240	250	270	290	290	340	240	280	260	310	310	340
11	2	110	500	320	350	240	275	340	318	240	260	265	265	285	310	245	285	290	345	370	265
12	1	112	510	325	350	250	310	232	240	250	310	295	270	298	340	240	270	250	350	370	290
12	2	110	500	330	325	220	260	340	320	225	260	265	270	285	325	270	295	250	300	370	315
13	1	110	500	345	360	240	255	340	350	240	255	270	265	285	330	320	340	250	305	370	20
13	2	110	500	350	360	220	270	335	325	235	255	270	275	275	320	245	255	270	305	375	290
14	1	110	500	330	355	240	300	350	330	230	260	280	270	270	330	240	280	240	310	310	290
14	2	110	500	330	345	230	275	335	325	230	260	275	275	280	330	245	270	250	310	375	330
15	1	110	500	330	340	220	280	330	320	230	260	265	265	280	330	280	300	240	305	360	340
15	2	110	500	335	350	215	260	330	320	250	260	265	265	270	315	245	260	265	300	335	310
16	1	110	500	340	355	225	280	330	320	230	255	270	270	285	330	250	260	255	345	370	320
16	2	110	500	320	360	220	245	340	325	240	255	265	270	260	340	280	325	245	285	355	340
17	1	110	500	320	335	246	285	330	320	237	260	264	270	275	330	240	280	250	305	370	340
17	2	110	500	270	345	245	270	330	325	235	250	260	267	285	330	245	260	255	330	345	290
18	1	110	500	340	355	220	270	340	320	240	265	265	290	230	290	240	260	260	290	360	320
18	2	110	500	345	355	240	270	350	310	240	260	265	270	280	310	250	285	290	310	365	340
19	1	340	500	315	360	240	260	340	310	240	270	260	270	290	320	280	320	260	310	340	290
19	2	340	500	325	340	260	270	340	320	240	255	265	275	285	245	250	295	285	310	375	275
20	1	110	500	360	330	240	280	340	320	240	260	280	270	290	330	280	310	240	310	370	320
20	2	105	500	340	350	225	265	340	325	235	260	270	260	280	330	280	325	255	300	365	365
CORRECT RES		106	500	350	350	214	293	350	330	236	261	270	270	284	338	245	280	249	310	389	340

FLIGHT PARAMETER = AIRSPEED

		MANEUVER									
		CLIMB		CLIMBING TURN		LEVEL TURN		DESCENT		DESCENDING TURN	
		QUESTION TYPE									
PILOT	DISPLAY TYPE	3	4	3	4	3	4	3	4	3	4
1	1	355	215	320	340	290	270	320	310	320	290
1	2	355	215	320	340	290	270	315	310	345	290
2	1	350	220	310	340	260	270	340	310	320	290
2	2	350	250	340	340	265	265	320	310	375	290
3	1	340	220	370	340	280	270	340	310	320	280
3	2	340	215	310	340	270	270	320	305	310	290
4	1	350	220	300	340	280	270	310	310	310	290
4	2	350	240	280	340	280	270	315	310	310	290
5	1	345	270	300	340	280	270	320	292	310	292
5	2	340	215	295	340	285	270	285	300	305	290
6	1	350	240	340	340	285	270	330	310	310	290
6	2	340	215	340	340	280	270	320	310	340	290
7	1	350	220	300	340	285	270	340	310	320	270
7	2	340	215	340	305	280	260	315	305	320	290
8	1	340	220	300	340	290	270	320	300	320	290
8	2	345	250	340	335	285	270	310	310	310	290
9	1	350	220	310	340	290	270	325	320	340	290
9	2	345	315	340	340	290	270	310	310	315	290
10	1	345	220	320	340	270	270	310	310	318	290
10	2	340	225	305	335	275	270	320	305	310	290
11	1	340	220	310	340	290	270	320	310	320	290
11	2	345	215	320	250	275	270	320	310	310	290
12	1	350	270	290	340	290	270	310	310	320	[illegible]
12	2	350	215	330	340	295	270	315	310	310	290
13	1	340	220	320	340	280	270	325	310	318	295
13	2	345	270	285	340	285	275	310	310	315	290
14	1	350	220	300	345	290	270	320	310	315	290
14	2	340	215	330	340	260	270	315	295	310	290
15	1	342	220	310	340	280	270	320	310	310	292
15	2	340	215	315	340	270	270	340	310	320	290
16	1	340	220	320	340	300	270	320	310	315	290
16	2	345	215	360	340	270	275	315	295	340	290
17	1	350	220	320	320	268	270	320	310	314	290
17	2	345	215	340	340	265	270	315	310	330	290
18	1	340	220	320	340	275	270	290	310	324	290
18	2	355	215	320	340	265	270	320	305	310	290
19	1	340	225	320	340	290	260	330	310	315	290
19	2	350	350	340	340	275	270	310	312	310	260
20	1	350	360	300	340	290	270	320	315	310	290
20	2	340	170	320	340	285	270	315	310	305	290
CORRECT RES		362	215	303	353	292	275	329	315	325	300

FLIGHT PARAMETER = ALTITUDE - Note, multiply each number by 10

PILOT	DISPLAY TYPE	CLIMB 1A	CLIMB 1B	CLIMB 2A	CLIMB 2B	CLIMBING TURN 1A	CLIMBING TURN 1B	CLIMBING TURN 2A	CLIMBING TURN 2B	LEVEL TURN 1A	LEVEL TURN 1B	LEVEL TURN 2A	LEVEL TURN 2B	DESCENT 1A	DESCENT 1B	DESCENT 2A	DESCENT 2B	DESCENDING TURN 1A	DESCENDING TURN 1B	DESCENDING TURN 2A	DESCENDING TURN 2B
1	1	490	1950	220	240	1520	2000	1520	1520	1980	2040	2020	2030	2000	1526	2000	2040	1998	1530	2000	2030
1	2	517	2085	220	220	1520	2006	1960	2010	1984	2128	2018	2040	2000	1520	2180	2000	2000	1540	2000	2010
2	1	500	2000	210	230	1550	2010	2000	1500	1980	2040	2000	2100	2000	1500	2030	2020	2000	1520	2000	2000
2	2	480	1970	240	300	1510	2001	2000	1800	1980	2040	2000	2020	2000	1500	1510	1510	2000	1550	2000	2000
3	1	490	1950	235	220	1520	2000	1500	1400	1980	2040	2000	2020	2000	1520	1500	1520	2000	1540	2000	2030
3	2	497	1500	240	350	1552	2000	1300	1300	1984	2020	2003	2030	2000	1522	2000	2030	2000	1540	2000	2040
4	1	500	1950	200	236	2000	1510	1650	1600	1980	2037	2010	2020	2000	1500	2000	2000	1990	1515	2000	2000
4	2	500	1950	240	220	1520	2030	1650	1600	1960	2050	2000	2050	2000	1500	2000	2000	2000	1510	2000	2000
5	1	497	1958	320	320	1517	2006	1640	1520	1980	2042	2008	2035	2003	1528	2002	2022	2000	1550	2005	2005
5	2	496	1970	240	900	1513	2004	1600	1600	1983	2041	2018	2041	2000	1525	2150	2150	2000	1537	2000	2000
6	1	500	1960	240	220	1560	2000	1500	1320	1970	2035	2020	2030	2000	1525	2000	2020	2000	1540	2000	2040
6	2	496	1930	217	248	1554	2004	1740	1540	1941	2041	2020	2040	2000	1546	2000	2020	2000	1530	2000	2030
7	1	500	1940	240	240	1525	1900	1620	1560	1990	2050	2020	2040	2005	1525	2000	2020	2005	1550	2000	2020
7	2	500	1960	240	275	1520	2004	1540	1500	1984	2020	1960	2020	2000	1530	2000	2010	2000	1540	2000	2000
8	1	500	1960	200	250	1520	2000	1640	1540	1960	2030	2000	2040	2000	1600	2000	2030	2000	1550	2000	2050
8	2	500	1960	240	300	1540	2003	1600	1500	1984	2041	2003	2020	2000	1600	2000	2050	2000	1550	2000	2000
9	1	500	1950	240	200	1520	2000	1580	1540	1985	2040	2010	2040	2000	1525	2000	2020	2000	1550	2000	2030
9	2	594	1940	150	360	1520	2012	2020	1520	1984	2020	1940	2000	2000	1520	2000	2018	2000	1600	1600	1600
10	1	500	1970	25	27	1521	2006	640	560	1985	2045	2040	2020	2000	1520	2009	2025	1000	530	2000	2040
10	2	497	1967	215	240	1520	2040	1540	1440	1984	2016	2020	2040	2000	1524	2000	2020	2000	1541	2000	2040
11	1	500	1960	40	40	1520	2005	1540	1500	1985	2040	2010	2050	2000	1500	2000	2020	2000	1500	2010	2040
11	2	497	1965	210	240	1520	2025	1540	1510	1966	2040	2006	2105	2000	1500	2000	2010	2000	1540	2000	2020
12	1	495	1970	225	242	1515	2006	590	390	1904	2025	2020	2050	2000	1525	2000	2020	2000	1450	2000	2010
12	2	497	1965	240	300	1560	2006	1640	1600	1904	2047	1950	2002	2000	1527	2000	2020	2000	1535	2000	2002
13	1	500	1940	220	240	1510	2005	1630	1600	1980	2040	2020	2020	2000	1520	2000	2020	2000	1530	2000	2030
13	2	496	1995	240	215	1520	2004	1670	1630	1984	2040	2020	2020	2000	1520	2000	2020	2000	1540	2000	2020
14	1	500	2000	200	236	1500	2004	1630	1600	1980	2040	2000	2030	2005	1525	2000	2022	2000	1530	2000	2010
14	2	924	1956	230	244	1520	2016	1700	1500	1965	2080	2030	2016	2000	1525	2000	2006	2000	1537	2000	2010
15	1	500	1960	200	350	1520	1990	1630	1500	1980	2040	2000	2040	2000	1520	2000	2010	2006	1506	2000	2030
15	2	439	1990	100	220	1520	2000	1540	1400	1960	2040	1950	2050	2000	1520	2000	2050	2000	1400	2000	2150
16	1	490	1990	225	230	1520	2000	1800	1540	1930	2020	2010	2014	2000	1710	2000	2020	1990	1520	2000	2010
16	2	497	1740	220	215	1520	2010	1940	1600	1960	2130	2010	2030	2000	1560	2000	2015	2000	1538	2000	2020
17	1	500	1950	215	230	1520	2000	1730	1610	1980	2035	2000	2030	2000	1520	1210	2006	2006	1540	1990	2060
17	2	496	1965	650	650	1520	2020	1750	1540	1960	2040	2040	2050	2000	1545	2000	2100	2000	1530	1650	1920
18	1	510	1950	237	240	1520	2000	1700	1500	1950	2070	2020	2040	1995	1520	1995	2000	2030	1300	2020	2025
18	2	497	1990	240	260	1500	2000	530	500	1900	2100	1920	1960	2000	1520	2000	2003	2000	1540	2000	2025
19	1	510	2010	220	260	1540	2020	2000	1560	2000	2060	2130	2160	2020	1550	2000	2020	2015	1530	2000	2017
19	2	497	2000	300	360	1512	2003	2013	1560	1550	2040	2035	2040	2000	1520	2000	2015	2000	1550	2000	2020
20	1	500	2000	240	290	1540	2020	1800	1600	2000	2060	2000	2050	2020	600	2020	2060	2030	1540	2020	2060
20	2	496	2000	230	250	1520	2003	1700	1600	1974	2160	2010	2040	2000	1500	2000	2100	2000	1550	2000	2032
CORRECT RES		495	1952	220	250	1514	2004	1630	1550	1981	2041	2002	2020	2000	1525	2000	2019	2000	1535	2000	2028

FLIGHT PARAMETER = ALTITUDE - Note, multiply each number by 10

		MANEUVER									
		CLIMB		CLIMBING TURN		LEVEL TURN		DESCENT		DESCENDING TURN	
		QUESTION TYPE									
PILOT	DISPLAY TYPE	3	4	3	4	3	4	3	4	3	4
1	1	356	1510	1510	1520	2010	2024	1520	1520	1530	2000
1	2	360	1512	1520	1520	2085	2015	1510	2015	1518	1520
2	1	350	1510	1515	1520	2000	2000	1550	1525	1990	1999
2	2	400	1512	1815	1520	2060	2010	1510	1500	1500	2000
3	1	350	1560	1510	1520	2040	2015	1560	1520	1600	2050
3	2	360	1520	1515	2020	2000	2015	1553	1520	1520	2000
4	1	360	1560	1500	1500	2000	2014	1550	1510	1503	2000
4	2	360	1519	1515	1520	2000	2010	1500	1519	1522	2000
5	1	364	1840	1516	1523	2010	2015	1546	1529	1523	2002
5	2	360	1512	1515	1520	2000	2015	1514	1519	1521	2000
6	1	358	1510	1520	1520	2020	2020	1560	2020	1540	2000
6	2	360	1512	1515	1520	2000	2015	1560	1600	1520	2000
7	1	2060	1520	1520	1525	2010	2015	1520	1540	1550	2000
7	2	350	1512	1515	1520	2040	2015	1640	1518	1630	2000
8	1	360	1510	1520	1520	2020	2020	1600	1550	1523	2000
8	2	360	1512	1520	1520	2000	2012	1500	1519	1520	2000
9	1	356	1529	1517	1520	2000	2020	1560	1520	1520	2000
9	2	360	1512	1515	1520	2000	2015	1500	1519	1520	2000
10	1	358	520	1514	1540	2010	2020	1550	1520	1540	1000
10	2	360	1522	1515	1520	2015	2021	1349	1560	1521	2000
11	1	46	1200	1520	1522	2020	2020	1545	1520	1510	2000
11	2	380	1515	1515	1520	2010	2015	1560	1516	1521	2000
12	1	350	1510	1520	2020	2010	2020	1565	1520	1550	2000
12	2	350	1515	1515	1560	2000	2020	1640	1520	1270	2000
13	1	460	1510	1500	1520	2012	2020	1550	1520	1520	2000
13	2	360	1512	1520	1520	2014	2020	1563	1518	1520	2000
14	1	400	1510	1512	1520	2010	2020	1550	1530	1520	2002
14	2	360	1512	1515	1520	2010	2015	1540	1600	1420	1999
15	1	360	1500	1520	1520	2010	2000	1520	1700	1520	2000
15	2	360	1600	1515	1520	2020	2015	1500	1994	1523	2000
16	1	356	1515	1510	1520	2000	2015	1520	1510	1120	2000
16	2	360	1512	1500	1520	2000	2010	1540	1945	1503	2000
17	1	500	1520	1510	1520	1996	2020	1550	1510	1520	2000
17	2	500	1515	1520	1520	2000	2015	1510	1510	1523	2000
18	1	350	1510	1510	1510	2020	2015	1547	1510	1526	2005
18	2	350	1515	1500	1520	2010	2015	900	1520	1603	2000
19	1	360	1530	1560	1540	2020	2040	1570	1740	1520	2010
19	2	360	1536	1530	1550	2010	2010	1550	1500	1600	2000
20	1	370	1539	1530	1540	2050	2040	1580	1540	1540	2030
20	2	360	1520	1515	1520	2010	2015	1555	1519	1500	2000
CORRECT RES		360	1500	1515	1520	2010	2030	1549	1518	1520	2000

FLIGHT PARAMETER • VERT VEL

		MANEUVER																			
		CLIMB				CLIMBING TURN				LEVEL TURN				DESCENT				DESCENDING TURN			
		QUESTION TYPE																			
PILOT	DISPLAY TYPE	1A	1B	2A	2B	1A	1B	2A	2B	1A	1B	2A	2B	1A	1B	2A	2B	1A	1B	2A	2B
1	1	-50	350	0	580	560	-580	-50	90	-150	200	0	0	150	-580	-340	0	-580	100	0	-360
1	2	-365	50	0	580	580	-200	0	150	-300	250	100	-50	300	-580	-260	0	-560	150	0	-260
2	1	0	580	0	550	560	-580	0	400	-100	100	100	0	200	-200	-350	0	-560	0	0	-400
2	2	0	580	0	580	500	-200	-300	0	-200	200	80	0	120	-350	-350	0	0	560	0	-460
3	1	-100	580	0	580	400	0	-100	0	-180	200	100	0	150	-580	-350	0	-580	100	0	-300
3	2	-30	560	0	580	20	-450	-40	390	-200	390	30	0	150	-480	-360	0	-500	60	0	-270
4	1	0	560	0	580	580	-400	-100	450	-200	200	60	0	100	-580	-350	0	-550	200	0	-350
4	2	-10	580	0	580	580	-580	0	100	-160	220	50	0	100	-580	-350	0	-440	0	10	-350
5	1	0	560	0	560	300	-580	0	20	-150	240	120	0	80	-580	-350	0	-550	20	0	-320
5	2	0	540	0	580	320	-580	0	240	-120	80	60	10	50	-580	-240	0	-460	60	0	-340
6	1	-30	400	0	580	500	-400	-100	400	-150	190	100	0	100	-580	350	0	-580	100	0	-350
6	2	0	580	0	580	560	-580	0	20	-150	100	100	0	50	-580	-360	0	-560	50	0	-355
7	1	0	550	0	560	560	-400	0	350	-150	100	100	0	80	-515	-350	0	-560	110	0	-350
7	2	0	580	0	580	580	-580	0	350	-110	200	50	0	110	-580	-80	0	-580	60	0	-300
8	1	0	560	0	560	560	-580	0	250	-200	200	100	50	100	-580	-350	0	-560	0	0	-350
8	2	0	500	0	580	590	-580	0	450	-150	150	50	0	100	-580	-300	0	-450	0	0	350
9	1	0	580	0	580	580	-400	-100	0	-150	200	50	0	100	-500	-350	10	-500	50	0	-200
9	2	0	360	0	580	580	-300	0	40	-125	200	90	0	90	-580	-345	0	-350	250	0	-370
10	1	0	580	0	550	580	-580	0	200	-180	200	80	0	200	-550	-350	0	-400	200	0	-300
10	2	0	560	0	560	560	-100	-10	0	-200	200	30	5	60	-560	-350	-30	-400	20	0	-350
11	1	0	580	0	580	580	-580	-100	400	200	-200	50	0	200	-580	-350	0	-560	200	0	-350
11	2	0	580	0	560	580	-200	0	250	-180	320	25	5	200	-280	-31	-30	-100	350	50	-320
12	1	0	580	0	580	580	-500	0	50	-160	240	50	0	120	-540	350	0	-580	50	0	-400
12	2	-200	560	0	560	560	-580	0	50	-200	200	50	0	20	-580	-350	0	-480	20	0	-300
13	1	0	560	0	580	580	-550	0	500	-190	260	90	60	90	-560	-350	-40	-560	60	0	-40
13	2	-20	560	0	580	580	-250	-100	340	-80	140	0	0	90	-370	-340	-20	-390	50	0	-300
14	1	0	580	0	200	580	-580	0	250	-150	200	100	0	200	-560	-320	-50	-580	100	-100	-350
14	2	0	560	-20	580	580	-360	0	220	-170	230	120	0	100	-580	-130	0	-450	250	0	-400
15	1	0	580	0	560	580	-590	0	450	200	-200	50	-50	100	-500	-300	0	-500	100	0	-350
15	2	-50	500	0	580	560	-580	0	250	-150	250	50	-50	100	-550	-340	0	-450	100	0	-380
16	1	0	460	0	580	450	-220	0	400	-250	200	0	0	150	-400	-420	0	-560	50	0	-450
16	2	-150	560	0	520	560	-240	0	450	-350	170	220	40	40	-580	-430	0	-420	150	0	-350
17	1	0	400	0	500	560	-580	200	400	-150	200	50	100	40	-500	-31	0	50	-400	-250	-300
17	2	0	580	0	560	580	-565	0	445	-200	80	44	0	60	-580	-350	-30	-460	25	0	-345
18	1	-50	580	0	560	500	-350	0	450	-200	200	-200	0	0	-100	-200	0	-550	200	0	-400
18	2	0	550	0	560	-100	400	0	20	-200	240	80	-80	20	-550	-400	0	-500	30	0	-350
19	1	0	550	0	500	550	-350	0	380	-150	150	100	0	-500	-580	-350	0	-450	50	-200	-350
19	2	-300	400	-580	580	440	-80	0	55	-150	60	-200	-100	200	-550	-340	-80	-300	0	0	-310
20	1	0	560	0	580	580	-580	0	450	-150	200	60	0	0	-580	-350	0	-550	150	0	-350
20	2	0	440	0	560	560	-400	0	320	-170	160	150	0	100	-580	-350	0	-580	30	0	-360
CORRECT RES		-12	560	48	580	580	-580	-60	90	-168	240	120	0	120	-580	-360	0	-560	64	0	-456

FLIGHT PARAMETER = VERT VEL

		MANEUVER									
		CLIMB		CLIMBING TURN		LEVEL TURN		DESCENT		DESCENDING TURN	
		QUESTION TYPE									
PILOT	DISPLAY TYPE	3	4	3	4	3	4	3	4	3	4
1	1	580	580	580	400	-170	150	150	-150	-560	-250
1	2	-580	580	580	350	-350	200	180	-180	-450	-450
2	1	-560	580	580	550	-260	100	100	-580	-560	-500
2	2	0	580	400	580	-200	170	580	-580	-560	-400
3	1	-150	560	580	500	-250	200	300	-250	-500	-400
3	2	-30	560	580	490	280	280	200	-120	-450	-560
4	1	0	560	580	450	-200	200	200	-200	-560	-550
4	2	-100	560	560	440	100	60	100	-500	-540	-550
5	1	-120	560	560	460	150	140	140	-440	-570	-550
5	2	-300	540	580	280	180	120	300	-410	-440	-540
6	1	-100	560	400	500	-300	170	50	-200	-400	-550
6	2	-20	560	350	580	150	230	5	-580	-560	-530
7	1	0	560	580	550	190	120	200	-200	-560	-550
7	2	-30	560	560	320	270	210	5	-345	-500	-290
8	1	-200	560	580	500	350	200	200	-450	-560	-500
8	2	0	580	580	450	60	300	250	-500	-510	-480
9	1	-100	560	580	530	-400	100	300	-400	-460	-560
9	2	-250	560	580	580	-300	145	15	-400	-385	400
10	1	-200	560	580	400	-350	120	200	-200	-550	-550
10	2	-100	560	580	490	-350	400	200	400	-560	415
11	1	-150	560	580	500	400	200	200	-500	-560	-560
11	2	-180	560	580	25	270	180	310	-300	-560	-360
12	1	-100	560	580	400	-400	150	200	-400	-550	-500
12	2	-40	560	560	560	400	270	180	-250	-560	-480
13	1	-80	560	580	450	120	90	150	-350	-560	-500
13	2	-60	560	580	530	60	70	50	-560	-400	-410
14	1	-120	560	580	400	-200	200	200	-500	-560	-560
14	2	-220	560	580	430	450	150	150	-370	-530	-320
15	1	0	560	580	450	200	50	200	-300	-550	-400
15	2	-35	560	580	350	-300	100	50	-520	500	-550
16	1	-50	-560	400	450	300	-350	200	-150	-560	-400
16	2	0	560	445	420	370	220	420	-500	-550	-440
17	1	-60	560	560	400	-220	120	140	-400	-560	-500
17	2	-35	560	580	550	-340	160	31	-30	-540	-320
18	1	-200	560	580	10	-200	20	200	-200	-500	-400
18	2	-10	550	580	150	-200	50	10	-550	-350	-200
19	1	-50	560	300	300	-250	220	250	-400	-350	-500
19	2	-100	580	150	400	400	80	280	-480	-500	-540
20	1	0	560	580	500	-350	150	200	-560	-350	-450
20	2	-30	580	150	560	120	90	150	-580	320	-500
CORRECT RES		-234	560	580	580	-242	150	330	-300	-560	-560

APPENDIX C: TEST QUESTIONS

CLIMB

Flt. 1 and 21 (Case 1, Run 1 - 140 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What were the extremes of pitch angle?	(1)	-2 degrees +32 degrees	120
2.	What was the change in roll angle from the start of the flight segment to the point where the wings were leveled for the rest of the flight?	(2)	-2 degrees +1 degree	19 38
3.	What was the maximum numerical value of heading?	(3)	015 degrees	1
4.	What was the initial airspeed?	(4)	215 knots	1
5.	What were the extremes of altitude in the flight segment?	(1)	4,953 feet 19,523 feet	22 119
6.	What was the vertical speed change at the start of the climb?	(2)	+480 ft/min +5,800 ft/min	20 36

CLIMB
(continued)

Flt. 2 and 22 (Case 1, Run 2 - 140 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What were the highest and lowest pitch angles in the first 30 seconds of the climb?	(2)	+30 degrees 0 degrees	9 23
2.	What was the largest value of roll angle and was it right or left?	(3)	-5 degrees	91
3.	What was the minimum numerical value of heading just before level off?	(4)	264 degrees	115
4.	What were the extremes of airspeed?	(1)	106 knots 500 knots	10 63
5.	What range in altitude fluctuation occurred prior to when a consistent climb was started?	(2)	2,203 feet 2,500 feet	9 22
6.	What was the highest value of vertical descent speed?	(3)	-2,340 ft/min	4

CLIMB
(continued)

Flt. 3 and 23 (Case 1, Run 3 - 180 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What was the highest pitch angle during the segment?	(3)	+26 degrees	51
2.	What was the roll angle in the last part of the climb?	(4)	0 degrees	52
3.	What were the extreme heading values in the segment?	(1)	097 degrees 097 degrees	1 180
4.	What was the change in airspeed in the 20 seconds prior to level-off?	(2)	350 knots 350 knots	115 135
5.	What was the minimum altitude?	(3)	3,600 feet	1
6.	What was the high point in vertical speed reached when the nose was raised in the climb?	(4)	+5,800 ft/min	51

CLIMB
(continued)

Flt. 4 and 24 (Case 1, Run 4 - 110 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What was the lowest pitch angle in the last third of the climb portion of the segment?	(4)	+3 degrees	89
2.	What were the extremes of right and left roll angle in the segment?	(1)	-7 degrees +6 degrees	50 52
3.	What change in heading occurred on the initiation of the climb?	(2)	350 degrees 350 degrees	25 25
4.	What was the highest airspeed?	(3)	362 knots	110
5.	What was the altitude just prior to the marked climb portion of the segment?	(4)	15,000 feet	25
6.	What were the extremes of vertical speed?	(1)	-120 ft/min +5,800 ft/min	1 55

CLIMBING TURN

Flt. 5 and 25 (Case 2, Run 1 - 140 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What were the extremes of pitch angle?	(1)	+2 degrees +11 degrees	17 56
2.	What was the change in roll angle as the turn was initiated?	(2)	0 degrees +34 degrees	24 28
3.	What was the lowest numerical value in heading indications throughout the flight segment?	(3)	030 degrees	25
4.	What was the airspeed after level-off?	(4)	353 knots	115
5.	What were the extreme altitude indications in the flight segment?	(1)	15,143 feet 20,040 feet	20 140
6.	What was the initial change in vertical speed at the beginning of the maneuver?	(2)	-600 ft/min +900 ft/min	15 17

CLIMBING TURN
(continued)

Flt. 6 and 26 (Case 2, Run 2 - 150 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	About half a minute before the end of the segment the pilot lowered the nose and then brought it up again before coming down with it to level-off. How low and how high did the pitch angle go in this portion of the flight segment?	(2)	+4 degrees +8 degrees	30 33
2.	What was the maximum roll angle?	(3)	+29 degrees	27
3.	What was the heading at the beginning of the flight segment?	(4)	016 degrees	25
4.	What were the extremes of airspeed?	(1)	214 knots 283 knots	34 150
5.	What was the altitude change associated with the low pitch angle which occurred in the first half of the flight segment?	(2)	16,300 feet 15,500 feet	45 60
6.	What was the maximum vertical speed?	(3)	+5,800 ft/min	67

CLIMBING TURN
(continued)

Flt. 7 and 27 (Case 2, Run 3 - 150 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What was the highest pitch angle throughout the flight segment?	(3)	+13 degrees	35
2.	What was the maximum roll within the first 10 seconds after initiation of the turn?	(4)	+30 degrees	33
3.	What were the highest and lowest heading indications?	(1)	360 degrees 001 degrees	100
4.	What was the change in airspeed in the transition from climb to level-off?	(2)	350 knots 330 knots	130 140
5.	What was the lowest altitude in the segment?	(3)	15,150 feet	1
6.	What was the high vertical speed at the beginning of the climb?	(4)	+5,800 ft/min	36

CLIMBING TURN
(continued)

Flt. 8 and 28 (Case 2, Run 4 - 140 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What was the low pitch angle just before level off?	(4)	-4 degrees	119
2.	What were the extremes of roll?	(1)	+9 degrees	79
			-33 degrees	84
3.	What was the heading change in the first half of the flight segment?	(2)	088 degrees	11
			042 degrees	70
4.	What was the lowest airspeed in the segment?	(3)	303 knots	37
5.	What was the starting altitude?	(4)	15,200 feet	1
6.	What were the extremes of vertical speed?	(1)	+5,800 ft/min	46
			-5,800 ft/min	119

LEVEL TURN

Flt. 9 and 29 (Case 3, Run 1 - 130 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What were the extremes of pitch angle during the flight segment?	(1)	+7 degrees +3 degrees	47 76
2.	What was the change in roll angle in the first five seconds as the turn was initiated?	(2)	0 degrees +37 degrees	15 18
3.	What was the highest numerical indication of heading in the segment?	(3)	360 degrees	85
4.	What was the airspeed at the end of the flight segment?	(4)	275 knots	130
5.	What were the extremes of altitude?	(1)	19,811 feet 20,410 feet	20 130
6.	What was the change in vertical speed on roll-out?	(2)	+1,200 ft/min 0 ft/min	108 120

LEVEL TURN
(continued)

Flt. 10 and 30 (Case 3, Run 2 - 160 sec.)

Ques. No.		Ques Type	Correct Responses	Time From Start (Seconds)
1.	Shortly before the halfway point the nose comes down to a low point and then pitches up. What were the low and high pitch angles in this portion of the flight segment?	(2)	-1 degree +7 degrees	70 82
2.	What was the maximum roll to the right?	(3)	+33 degrees	67
3.	What was the final heading?	(4)	280 degrees	160
4.	What were the extremes of airspeed in the segment?	(1)	236 knots 261 knots	80 121
5.	There was a low point in altitude about 30 seconds prior to roll out. What change was there between this point and the end?	(2)	20,026 feet 20,200 feet	128 160
6.	What was the greatest vertical speed attained?	(3)	-3,420 ft/min	71

LEVEL TURN
(continued)

Flt. 11 and 31 (Case 3, Run 3 - 200 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What was the lowest pitch angle in the segment?	(3)	0 degrees	131
2.	What was the maximum roll in the first ten seconds after the initiation of the turn?	(4)	+24 degrees	23
3.	What were the highest and lowest heading indications?	(1)	130 degrees 310 degrees	19 178
4.	What was the change in airspeed in transitioning from the bank to wings-level flight?	(2)	270 knots 270 knots	74 85
5.	What was the highest altitude in the flight segment?	(3)	20,104 feet	26
6.	What was the high vertical speed associated with the high pitch angle at the start of the turn?	(4)	+1,500 ft/min	24

LEVEL TURN
(continued)

Flt. 12 and 32 (Case 3, Run 4 - 190 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	About two-thirds the way through the flight segment the airplane pitched up briefly. What was the highest pitch angle in this portion of the flight segment?	(4)	+8 degrees	128
2.	What were the extremes of roll?	(1)	-33 degrees +15 degrees	161 171
3.	What was the heading change in the last 25 seconds of the flight segment?	(2)	305 degrees 310 degrees	165 190
4.	What was the maximum airspeed in the segment?	(3)	292 knots	56
5.	What was the initial altitude?	(4)	20,300 feet	1
6.	What were the extremes of vertical speed?	(1)	-1,680 ft/min +2,400 ft/min	152 128

DESCENT

Flt. 13 and 33 (Case 4, Run 1 - 120 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What were the extremes of pitch angle during the flight segment?	(1)	+5 degrees -4 degrees	22 34
2.	What change in roll occurred in the transition from level flight to descent?	(2)	0 degrees 0 degrees	21 34
3.	What was the lowest numbered heading indication?	(3)	012 degrees	120
4.	What was the airspeed just before the start of level-off?	(4)	315 knots	105
5.	What were the extremes of altitude in the segment?	(1)	20,001 feet 15,253 feet	3 120
6.	What was the change in vertical speed in the transition from descent to level-off?	(2)	-3,600 ft/min 0 ft/min	107 120

DESCENT
(continued)

Flt. 14 and 34 (Case 4, Run 2 - 115 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	Starting from an initial pitch angle in level flight, the nose was brought down, then up, prior to lowering it for the descent. What was this initial pitch change?	(2)	0 degrees +9 degrees	20 24
2.	What was the maximum roll to the left in the descent?	(3)	0 degrees	115
3.	What was the heading just prior to the start of the descent?	(4)	050 degrees	22
4.	What were the extremes of airspeed in the segment?	(1)	284 knots 338 knots	28 63
5.	What was the increase in altitude just prior to the descent?	(2)	20,000 feet 20,190 feet	21 29
6.	What was the highest vertical speed upward?	(3)	+3,300 ft/min	25

DESCENT
(continued)

Flt. 15 and 35 (Case 4, Run 3 - 110 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What was the lowest pitch angle in the flight segment?	(3)	-9 degrees	27
2.	What was the roll angle just before level-off?	(4)	+1 degree	95
3.	What were the highest and lowest heading indications?	(1)	195 degrees 199 degrees	56 110
4.	What was the change in airspeed in the transition to level-off?	(2)	245 knots 280 knots	86 110
5.	What was the minimum altitude?	(3)	15,497 feet	72
6.	What was the greatest downward vertical speed just before level off?	(4)	-3,000 ft/min	97

DESCENT
(continued)

Flt. 16 and 36 (Case 4, Run 4 - 110 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	Upon initiation of the descent the nose is first pitched up. What was the highest pitch angle in this part of the flight segment?	(4)	+7 degrees	17
2.	What were the extremes of roll in the segment?	(1)	+12 degrees -9 degrees	23 47
3.	What heading change occurred in the transition from descent to level-off?	(2)	285 degrees 285 degrees	90 95
4.	What was the highest airspeed in the segment?	(3)	329 knots	77
5.	What was the final altitude?	(4)	15,180 feet	111
6.	What were the extremes of vertical speed?	(1)	+1,200 ft/min -5,800 ft/min	17 85

DESCENDING TURN

Flt. 17 and 37 (Case 5, Run 1 - 132 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What were the extremes of pitch angle in the flight segment?	(1)	+4 degrees -4 degrees	1 36
2.	What was the change in roll within the first ten seconds after the initiation of the turn?	(2)	0 degrees -29 degrees	23 28
3.	What was the heading just prior to the initiation of the descent?	(3)	007 degrees	20
4.	What was the starting airspeed?	(4)	300 knots	1
5.	What were the extremes of altitude?	(1)	20,002 feet 15,353 feet	3 132
6.	What change occurs in vertical speed in the first third of the flight?	(2)	0 ft/min -4,560 ft/min	17 36

DESCENDING TURN
(continued)

Flt. 18 and 38 (Case 5, Run 2 - 170 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What was the change in pitch angle in the transition from descent to level-off?	(2)	-3 degrees +3 degrees	43 65
2.	What was the maximum roll to the left?	(3)	-20 degrees	153
3.	What was the final heading?	(4)	250 degrees	170
4.	What were the extremes of airspeed?	(1)	249 knots 310 knots	50
5.	What increase in altitude occurred before the descent?	(2)	20,000 feet 20,280 feet	12 22
6.	What was the greatest vertical speed in the segment?	(3)	-5,800 ft/min	37

DESCENDING TURN
(continued)

Flt. 19 and 39 (Case 5, Run 3 - 120 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What was the lowest pitch angle in the flight segment?	(3)	-6 degrees	39
2.	What was the maximum roll to the right in the first twenty seconds after initiation of the turn?	(4)	+29 degrees	31
3.	What were the highest and lowest heading indications?	(1)	170 degrees 250 degrees	15 120
4.	What was the change in airspeed from its peak value to its final value?	(2)	389 knots 340 knots	88 120
5.	What was the lowest altitude in the segment?	(3)	15,207 feet	119
6.	What was the greatest vertical speed in the first third of the segment?	(4)	-5,800 ft/min	39

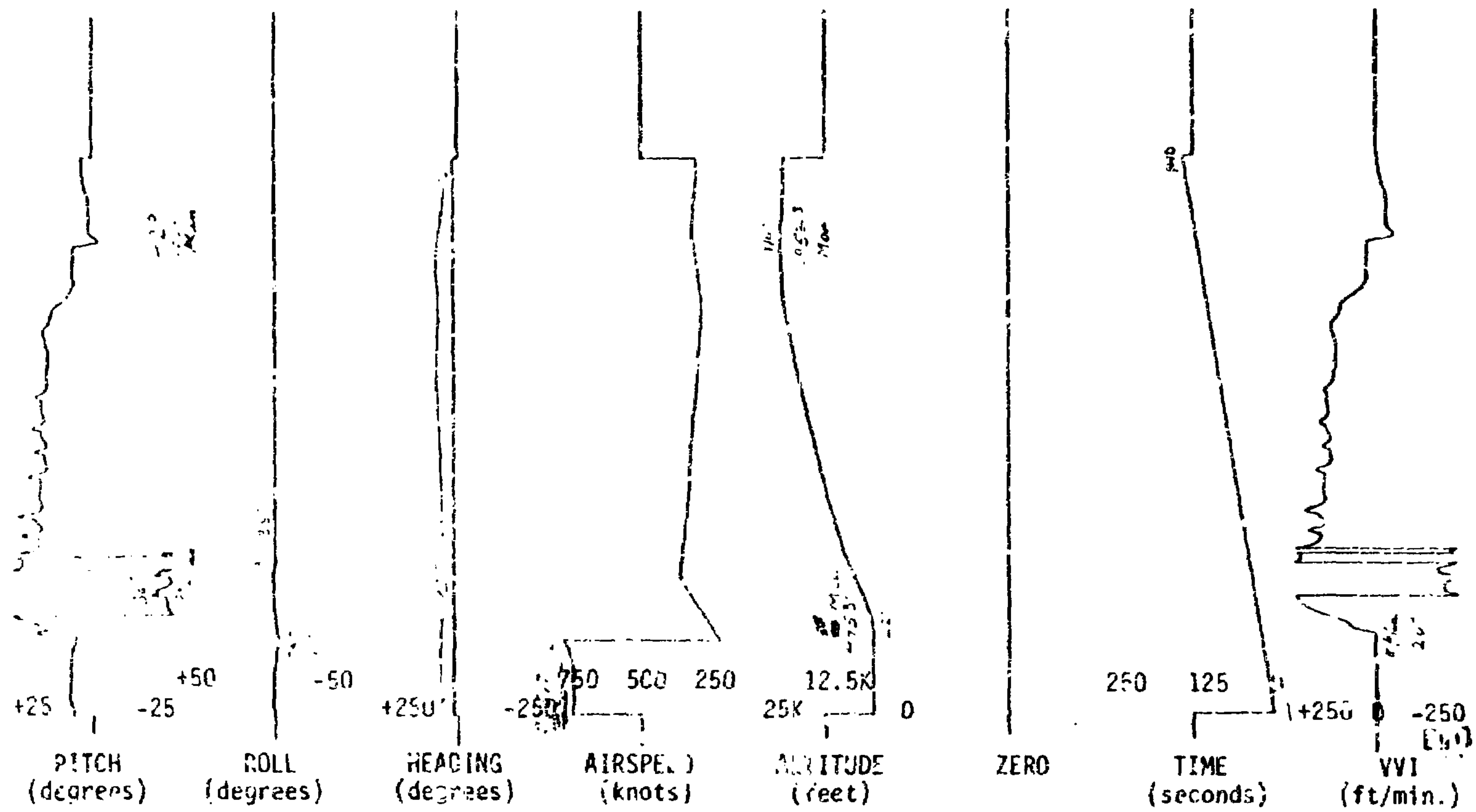
DESCENDING TURN
(continued)

Flt. 20 and 40 (Case 5, Run 4 - 170 sec.)

Ques. No.		Ques. Type	Correct Responses	Time From Start (Seconds)
1.	What was the lowest pitch angle just piror to level off?	(4)	-4 degrees	150
2.	What were the extremes of roll in the segment?	(1)	-32 degrees +11 degrees	66 125
3.	What change in heading occurred during the last 30 seconds of the flight segment?	(2)	120 degrees 120 degrees	140 170
4.	What was the maximum airspeed?	(3)	325 knots	47
5.	What was the starting altitude?	(4)	20,002 feet	3
6.	What were the extremes of vertical speed in the segment?	(1)	-5,800 ft/min +840 ft/min	32 143

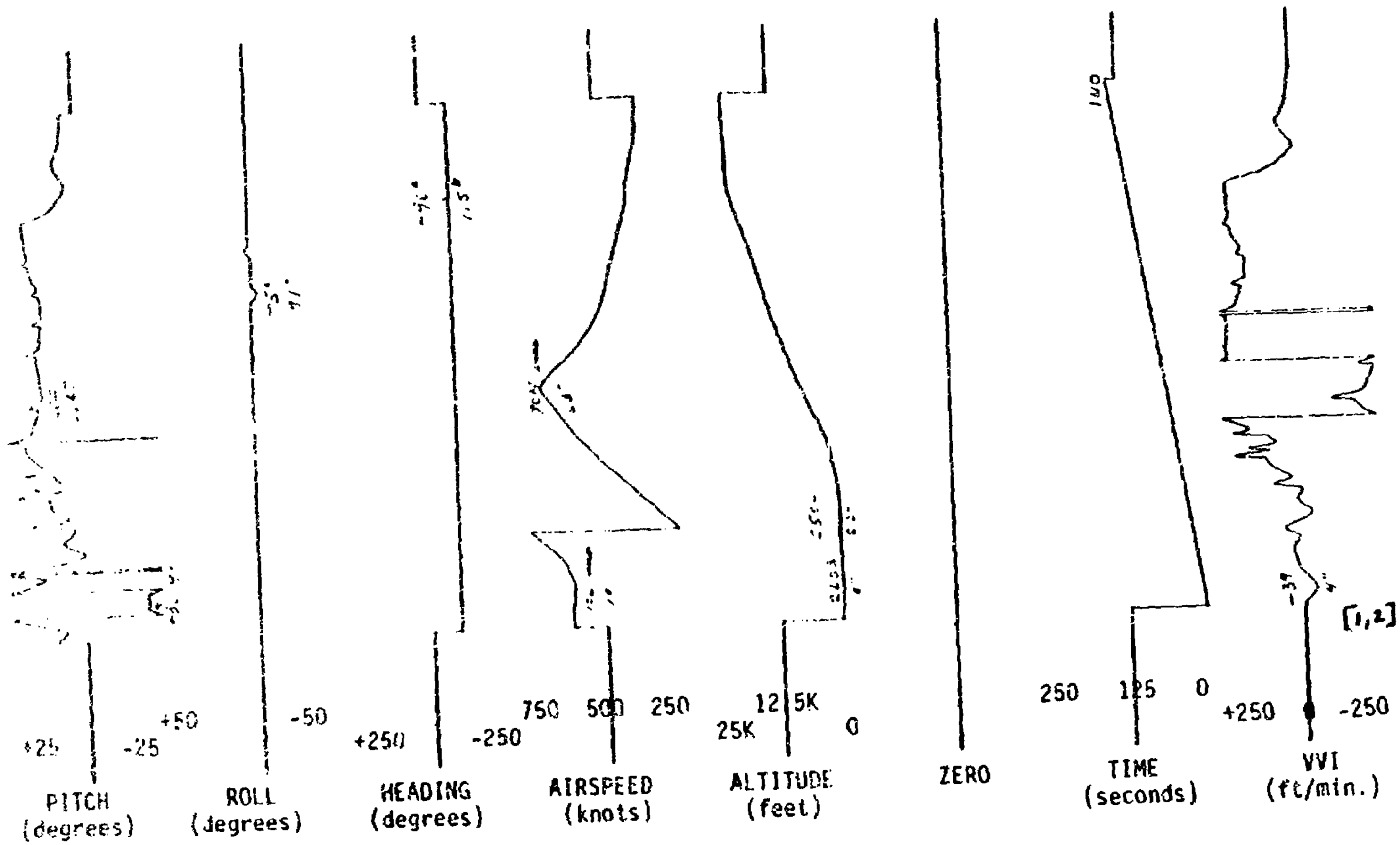
APPENDIX D: STRIP CHART RECORDINGS OF THE SIX FLIGHT PARAMETERS

Climb - Run 1



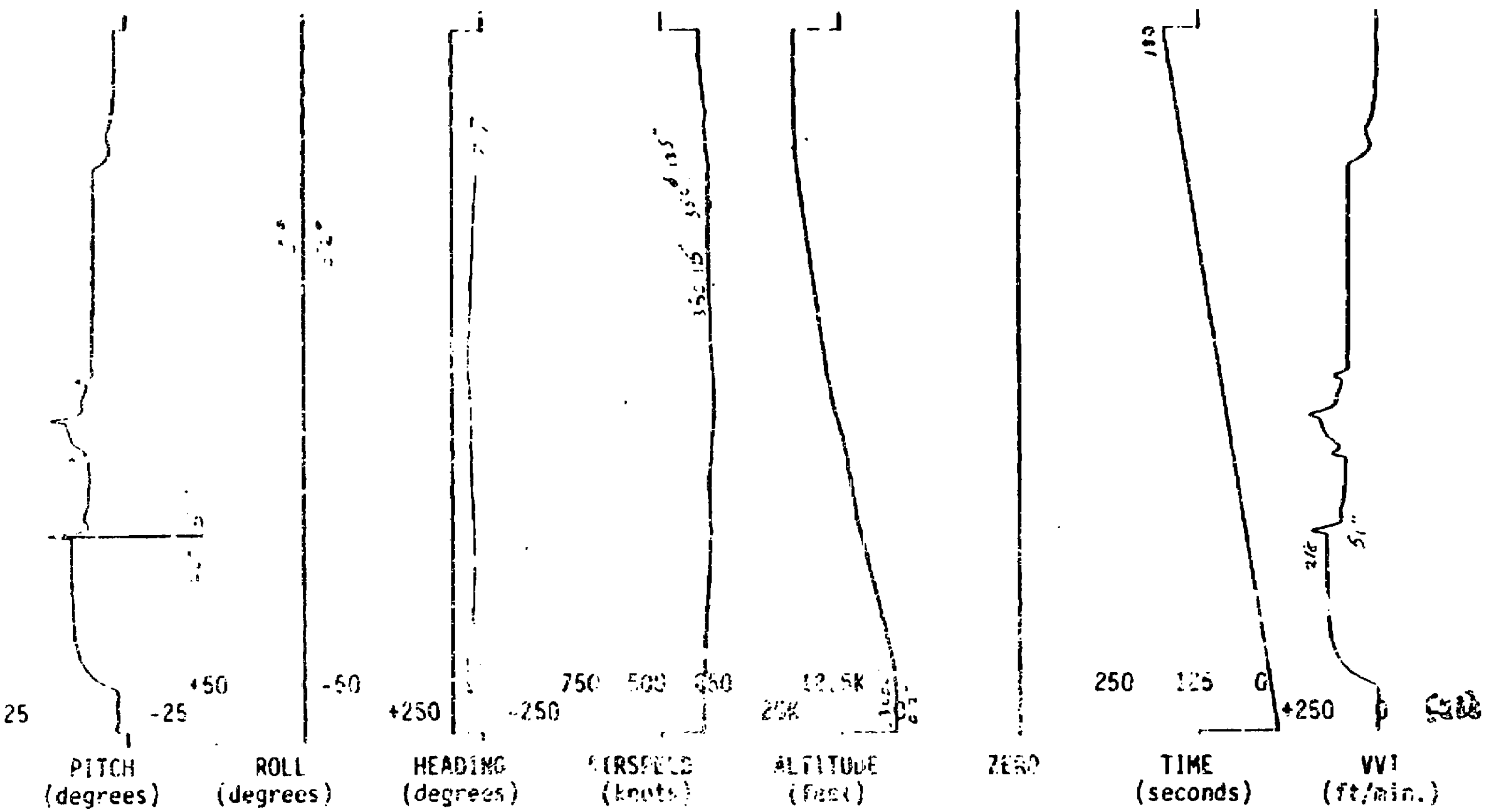
+25
-25
+50
PITCH (degrees)
-50
ROLL (degrees)
+250
-250
HEADING (degrees)
750
500
250
AIRSPEED (knots)
25K
12.5K
0
ALTITUDE (feet)
ZERO
250
125
TIME (seconds)
+250
0
-250
VVI (ft/min.)

Climb - Run 2



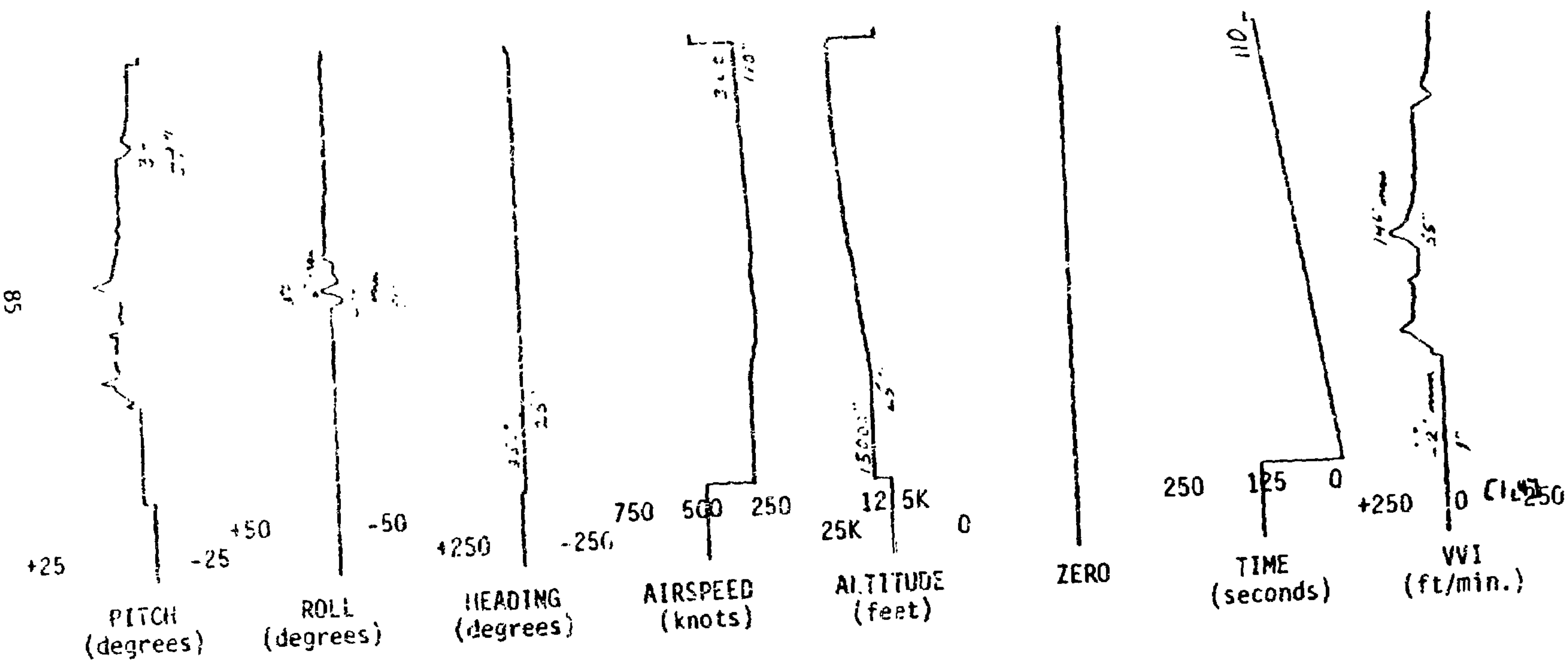
+25
-25
+50
PITCH
(degrees)
-50
ROLL
(degrees)
+250
-250
HEADING
(degrees)
750
500
250
AIRSPEED
(knots)
25K
12.5K
0
ALTITUDE
(feet)
ZERO
250
125
0
TIME
(seconds)
+250
-250
VVI
(ft/min.)
[1,2]

Climb - Run 3



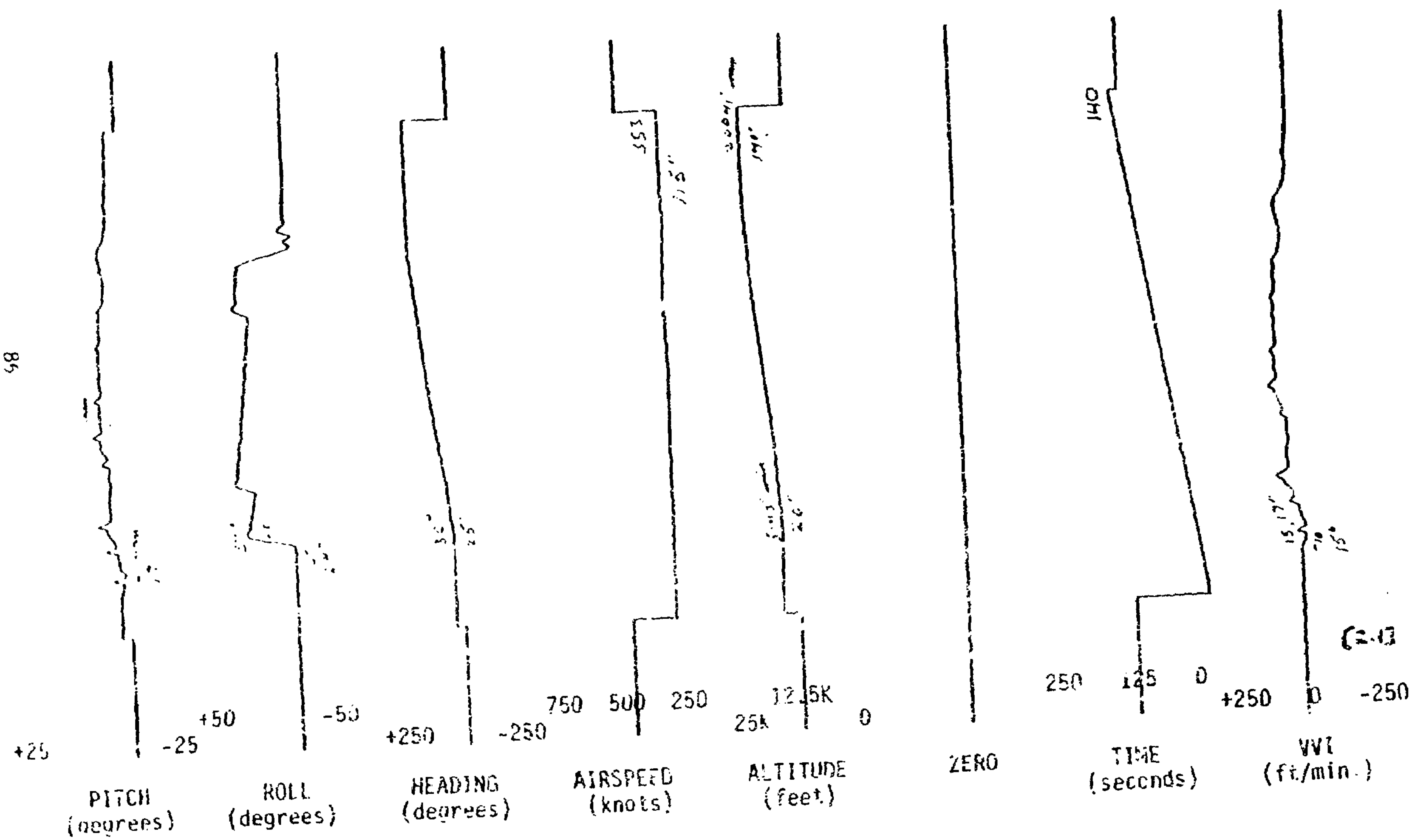
+25
-25
PITCH (degrees)
+50
-50
ROLL (degrees)
+250
-250
HEADING (degrees)
750
500
250
(knots)
25K
12.5K
ALTITUDE
ZERO
250
125
0
TIME (seconds)
+250
0
VVI (ft/min.)

Climb - Run 4

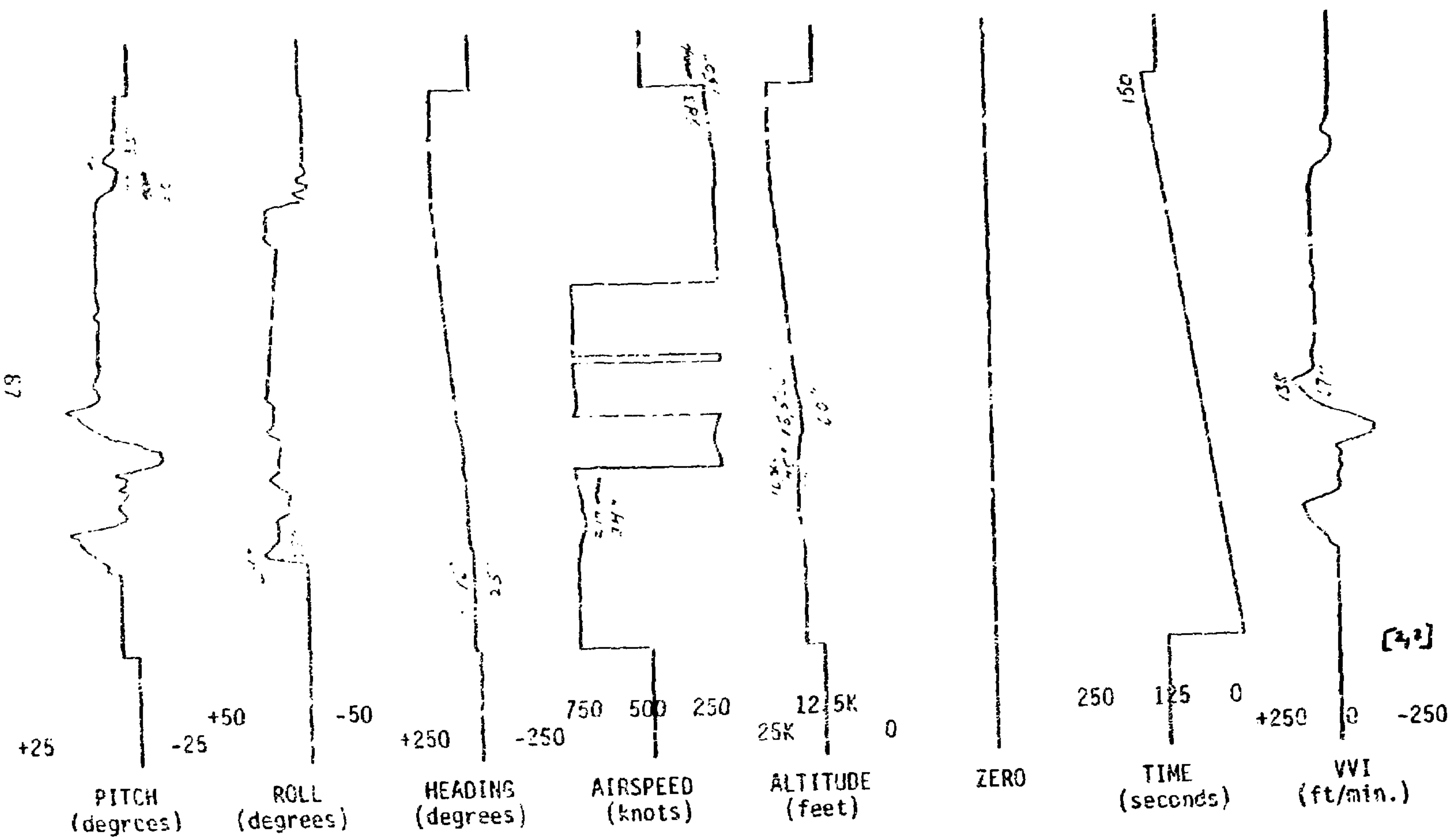


+25
-25
PITCH (degrees)
+50
-50
ROLL (degrees)
+250
-250
HEADING (degrees)
750
500
250
AIRSPEED (knots)
25K
12.5K
0
ALTITUDE (feet)
ZERO
250
125
0
TIME (seconds)
110
+250
0
-250
VVI (ft/min.)

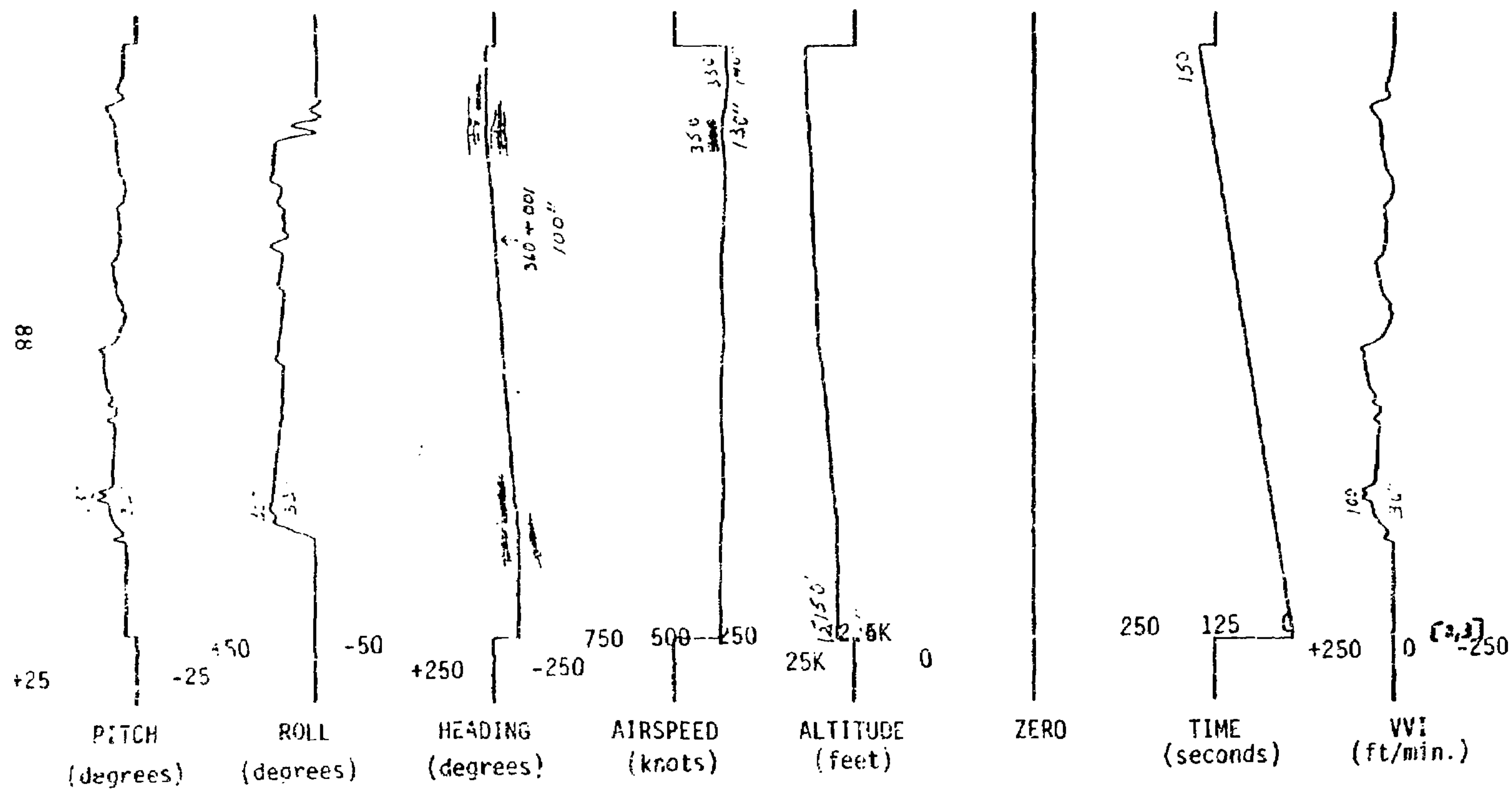
Climbing Turn - Run 1



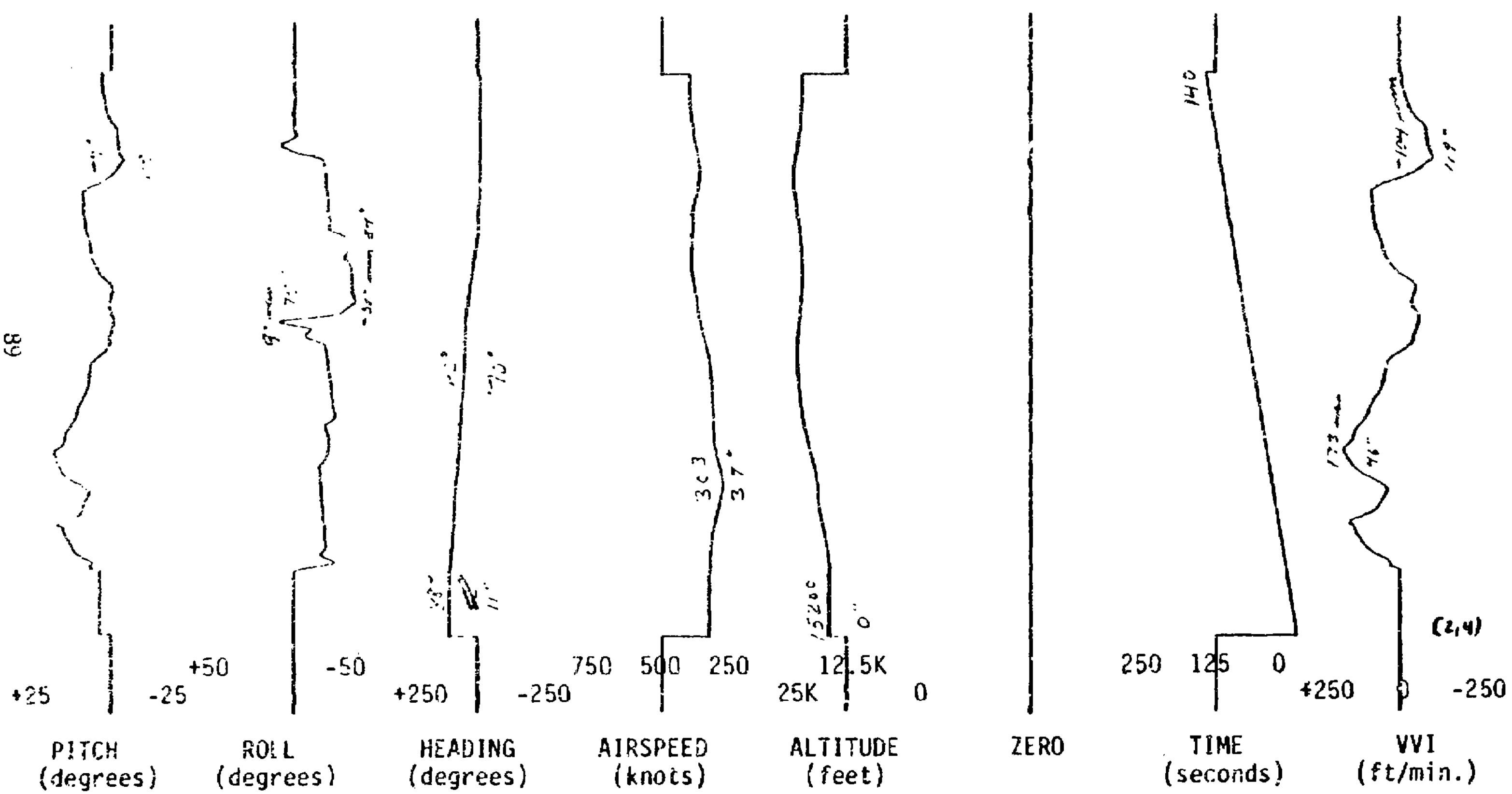
Climbing Turn - Run 2



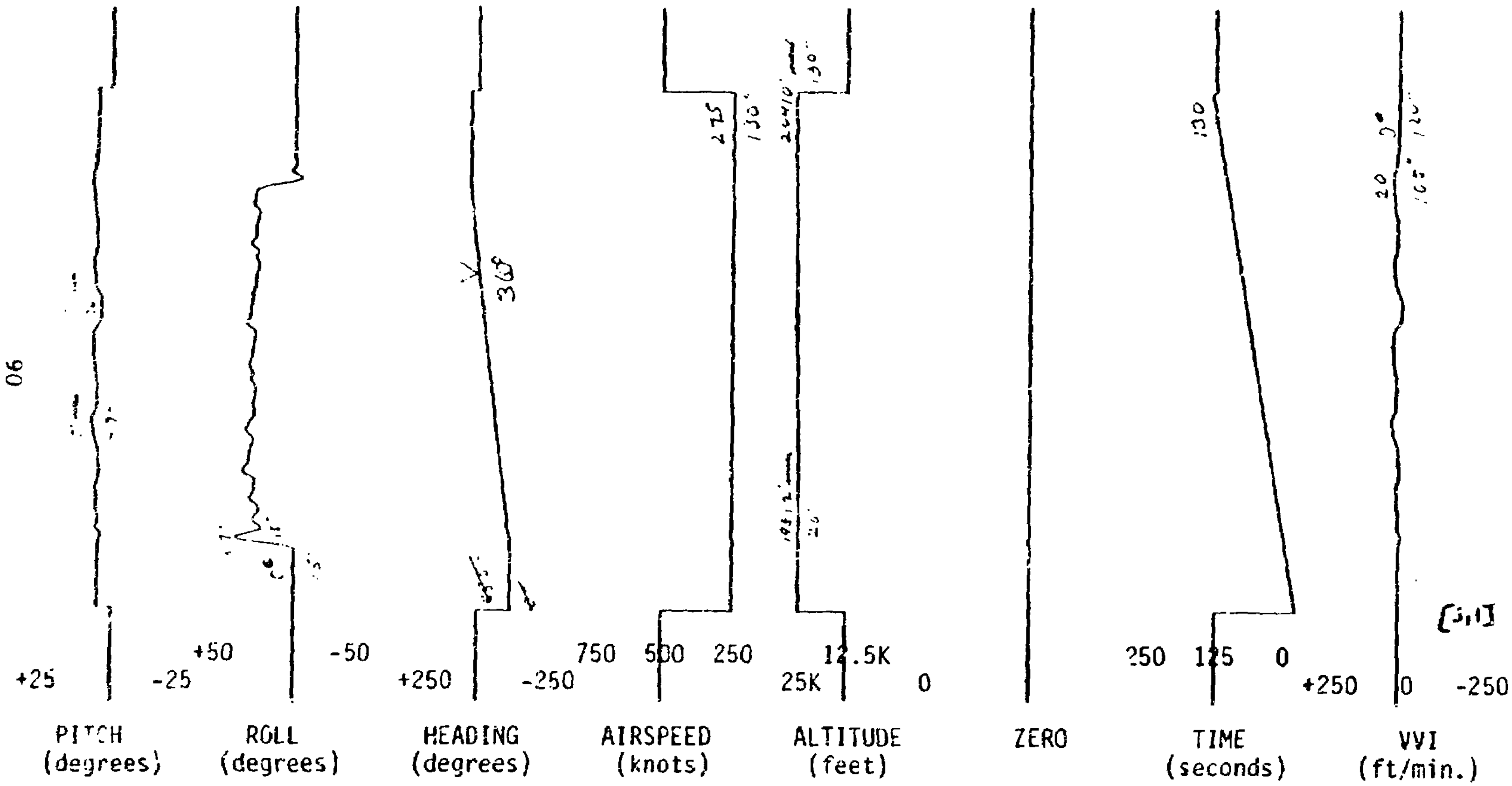
Climbing Turn - Run 3



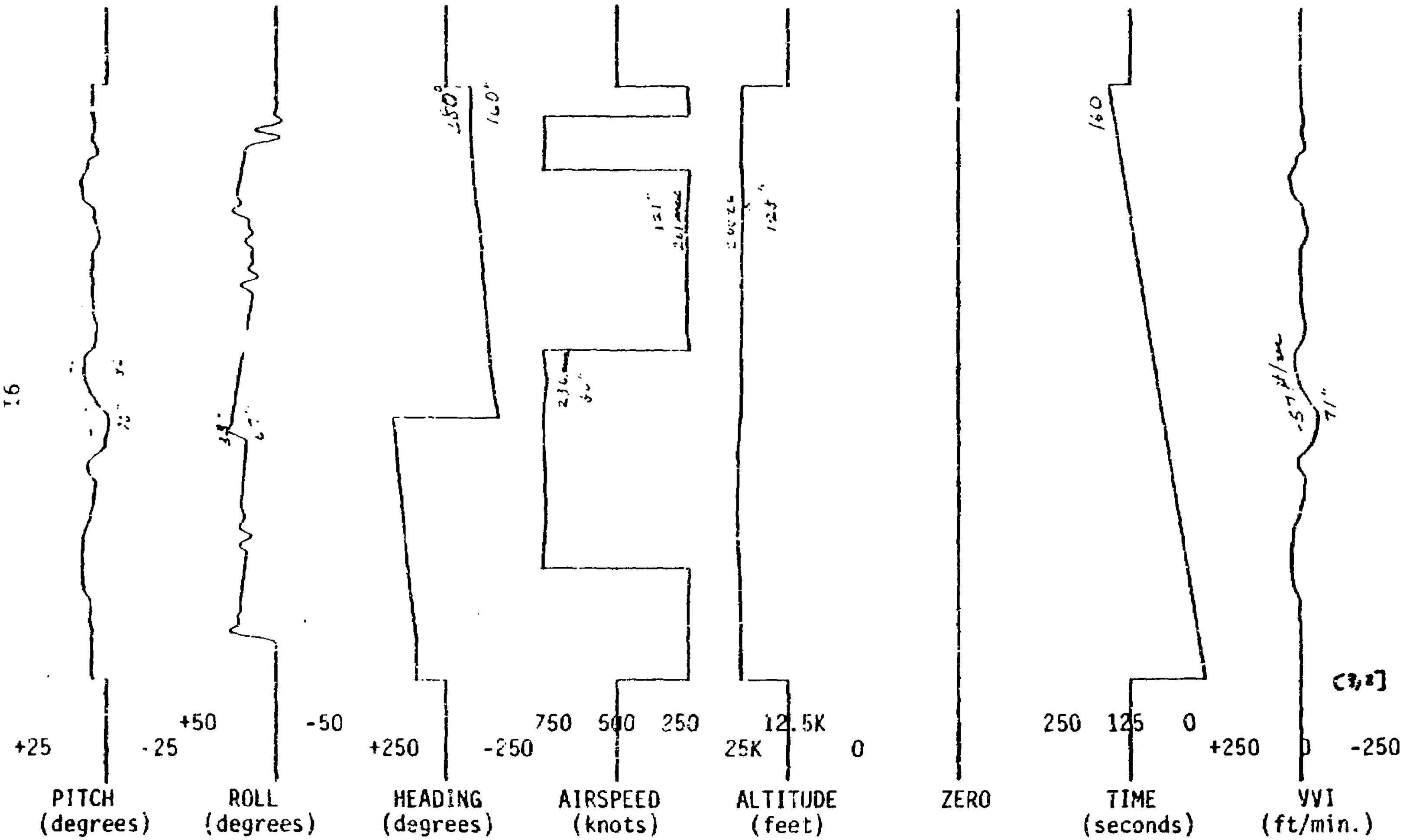
Climbing Turn - Run 4



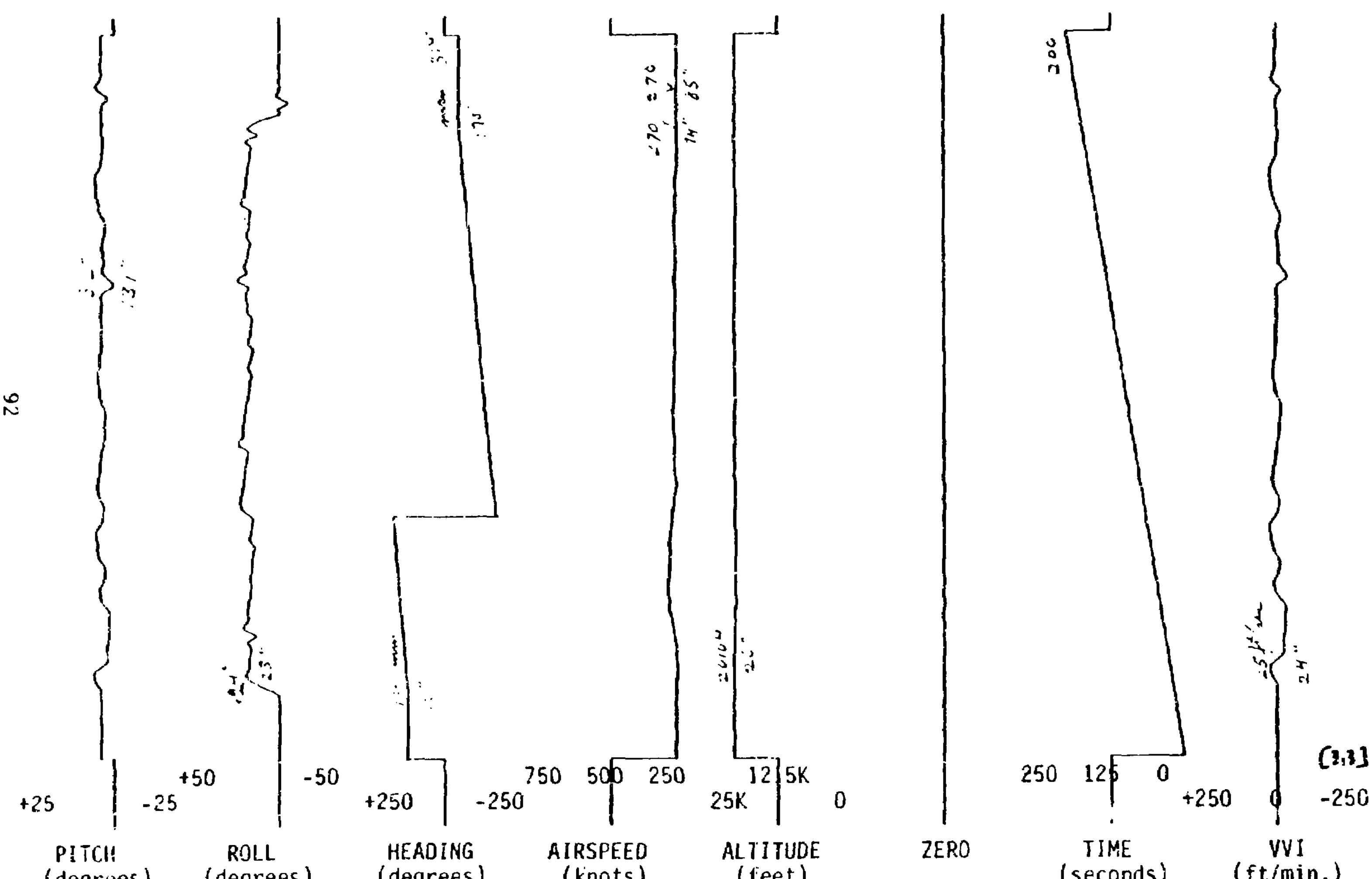
Level Turn - Run 1



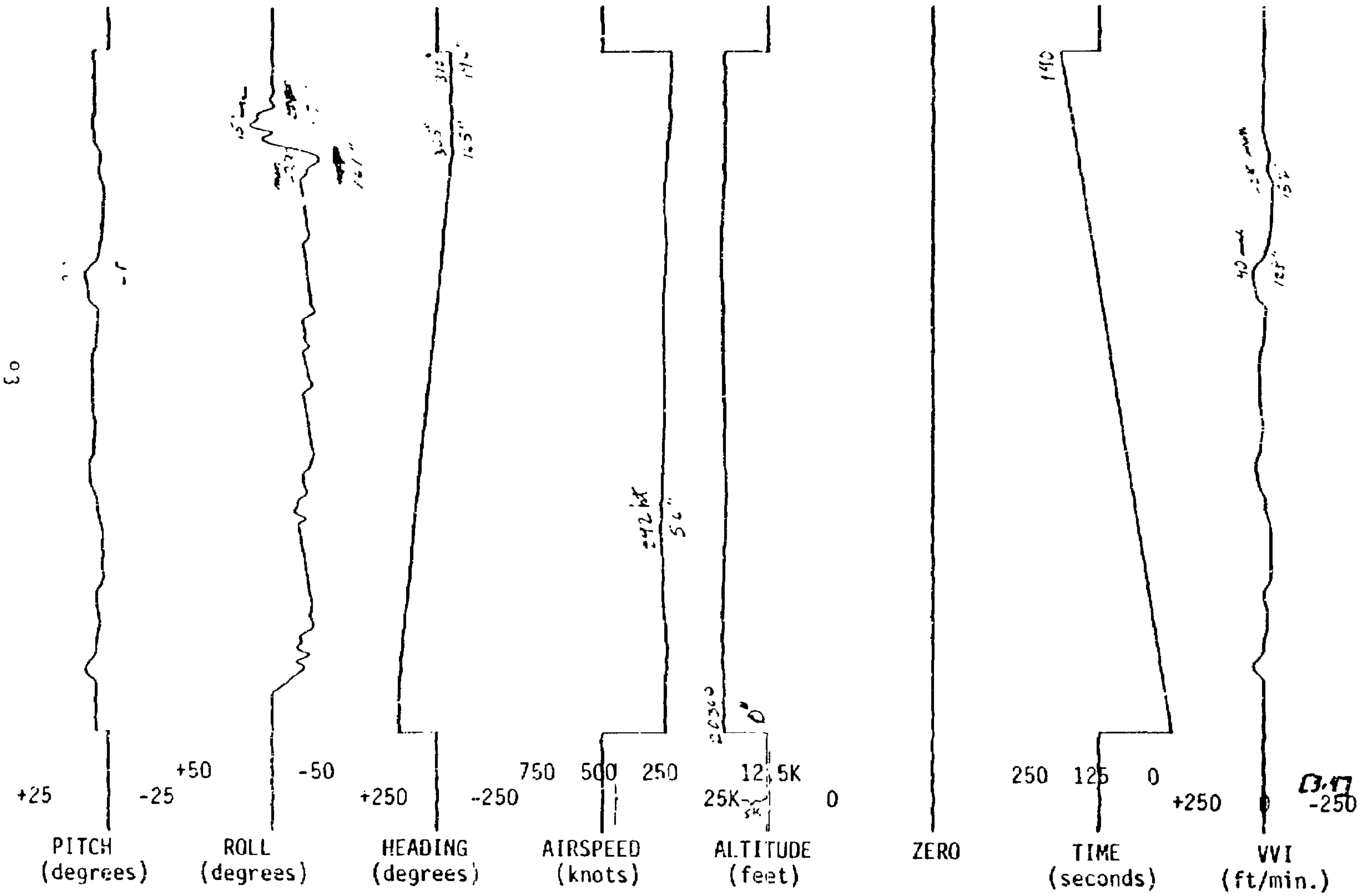
Level Turn - Run 2



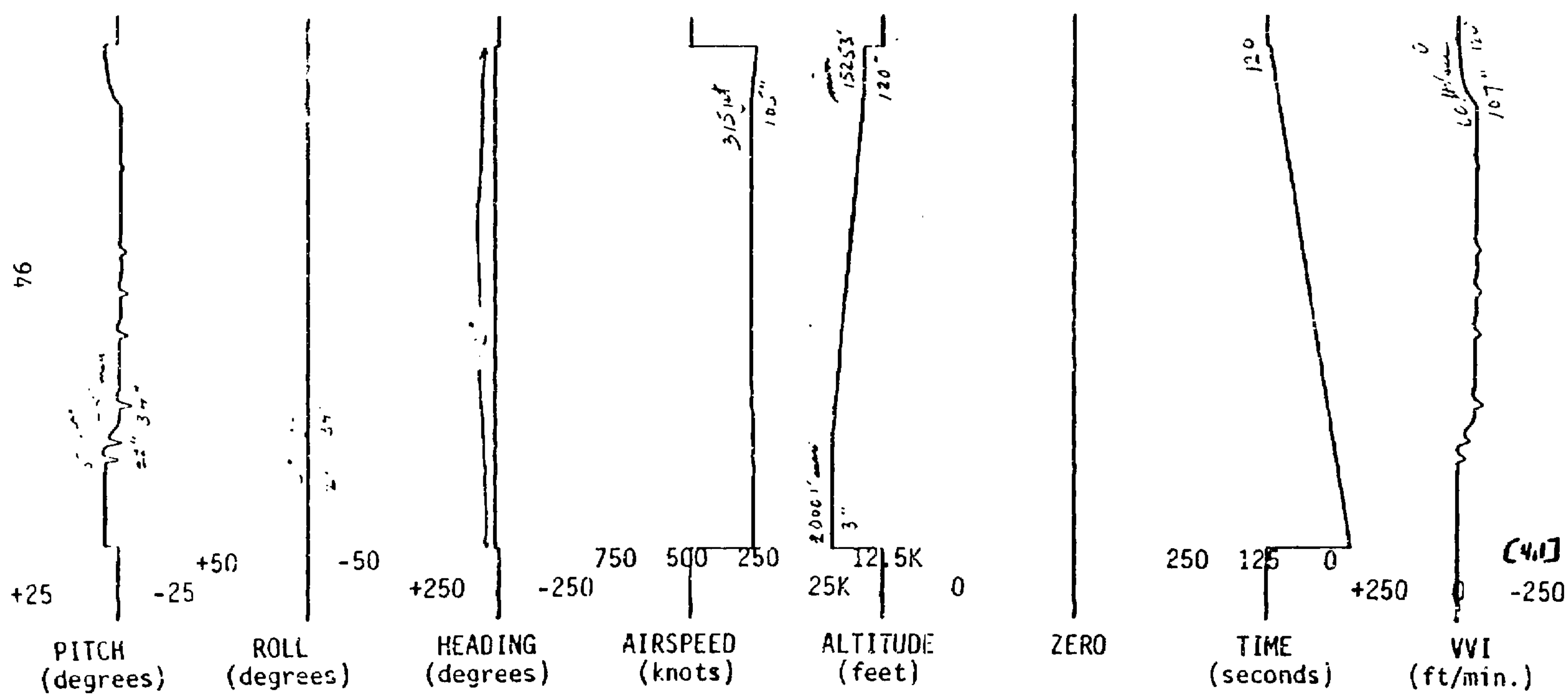
Level Turn - Run 3



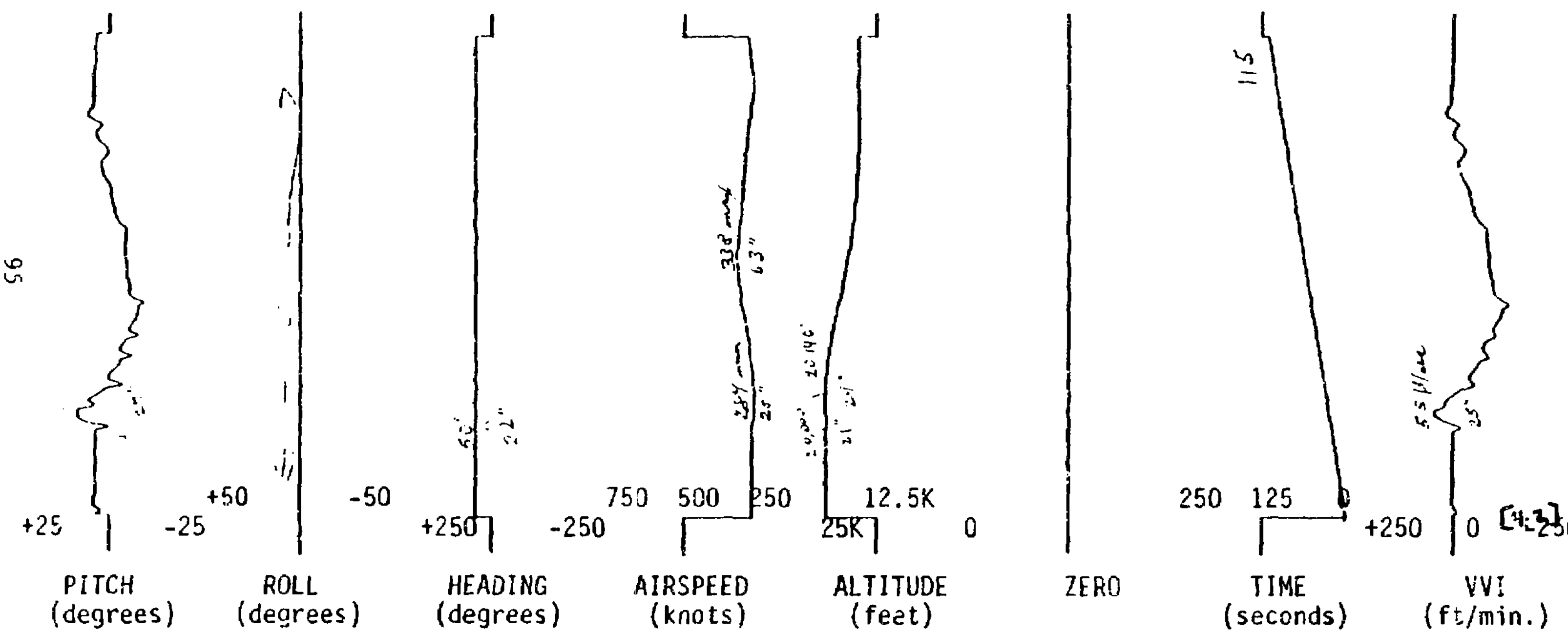
Level Turn - Run 4



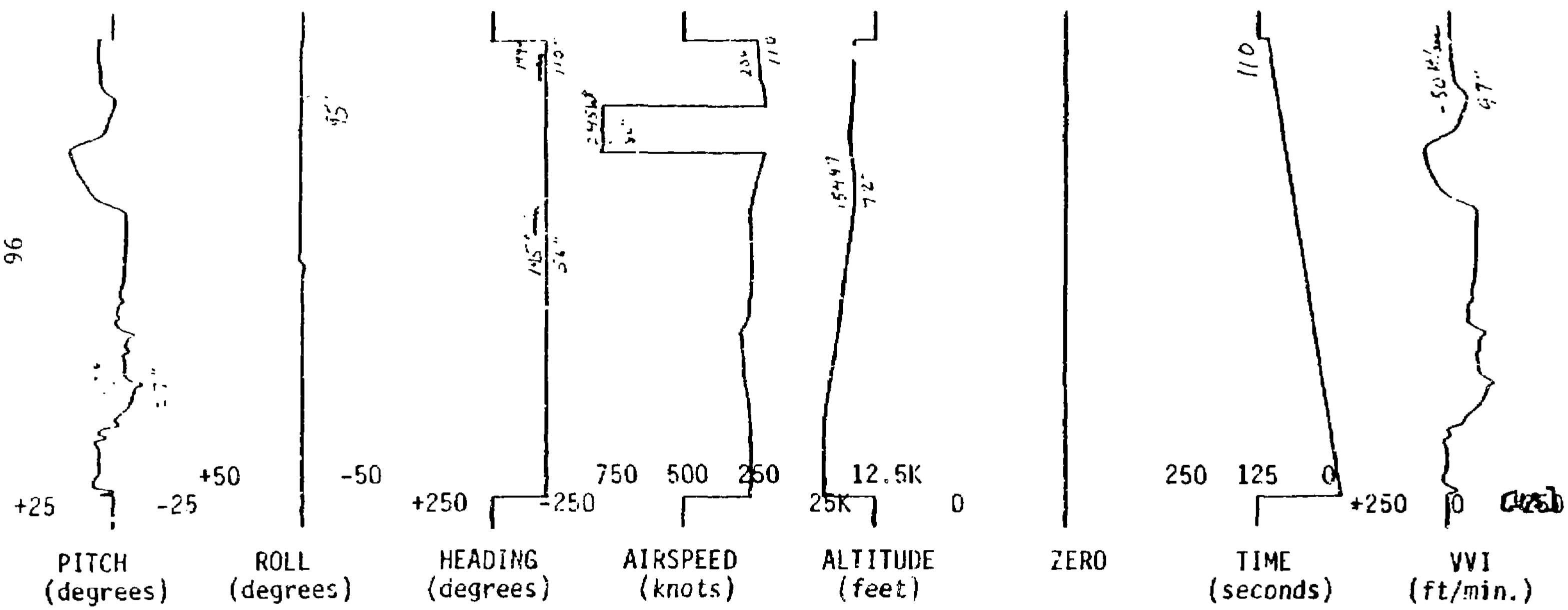
Descent - Run 1



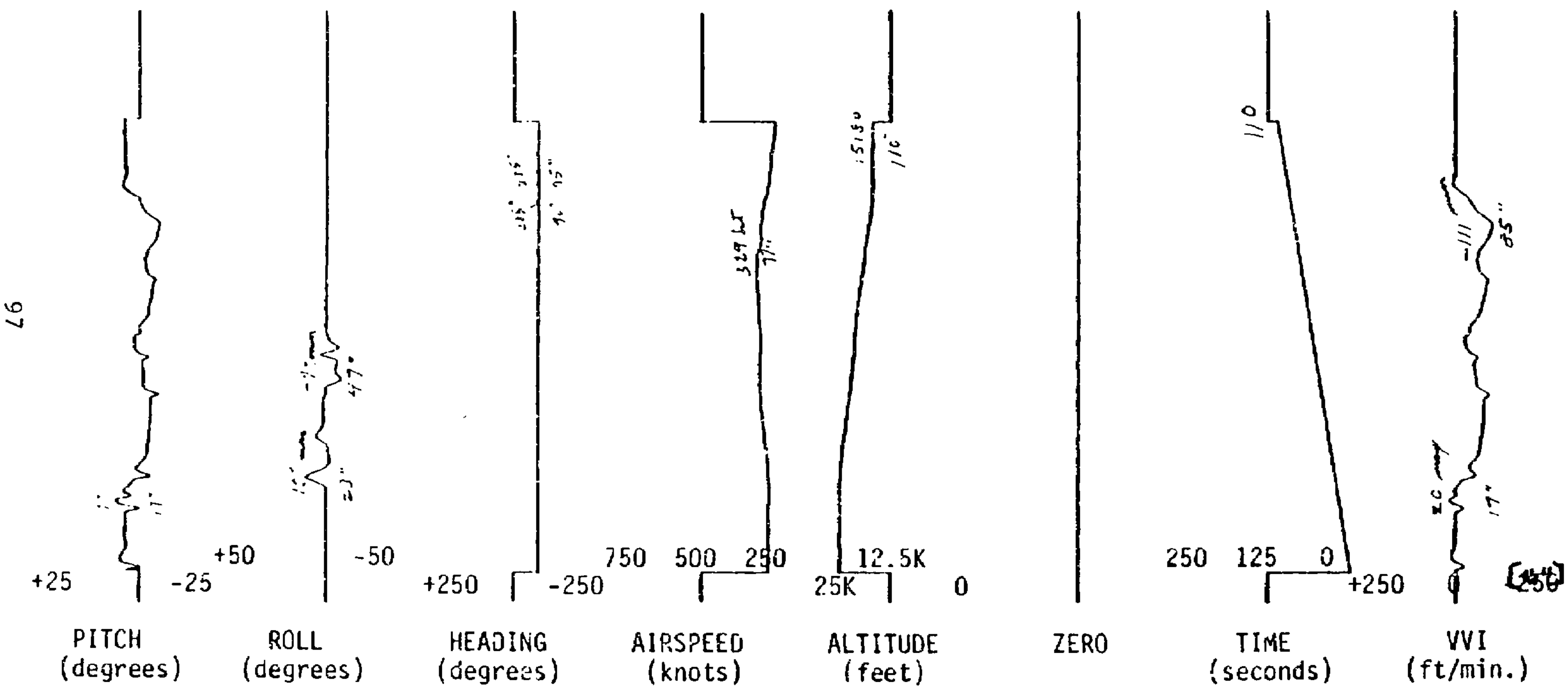
Descent - Run 2



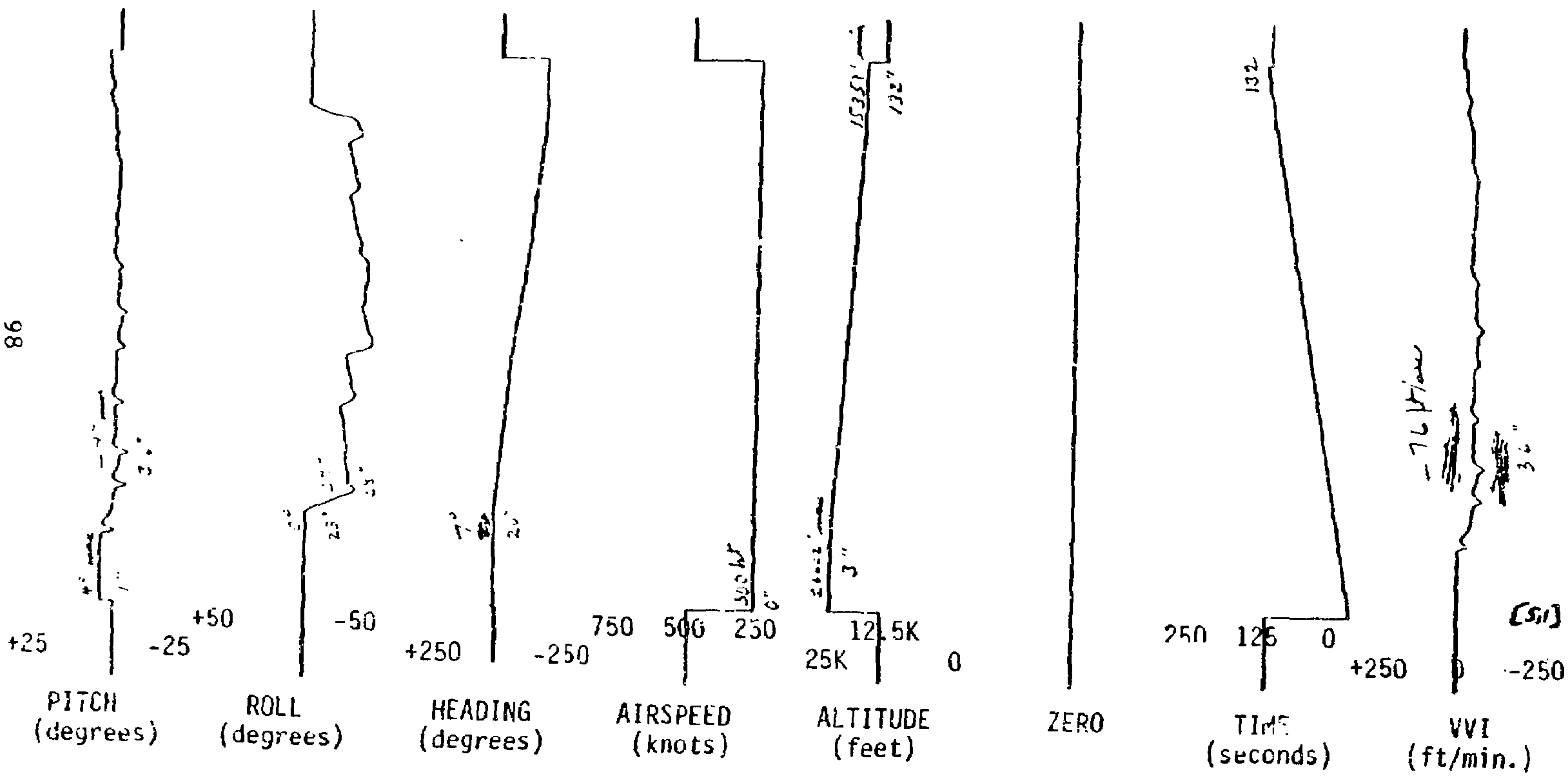
Descent - Run 3



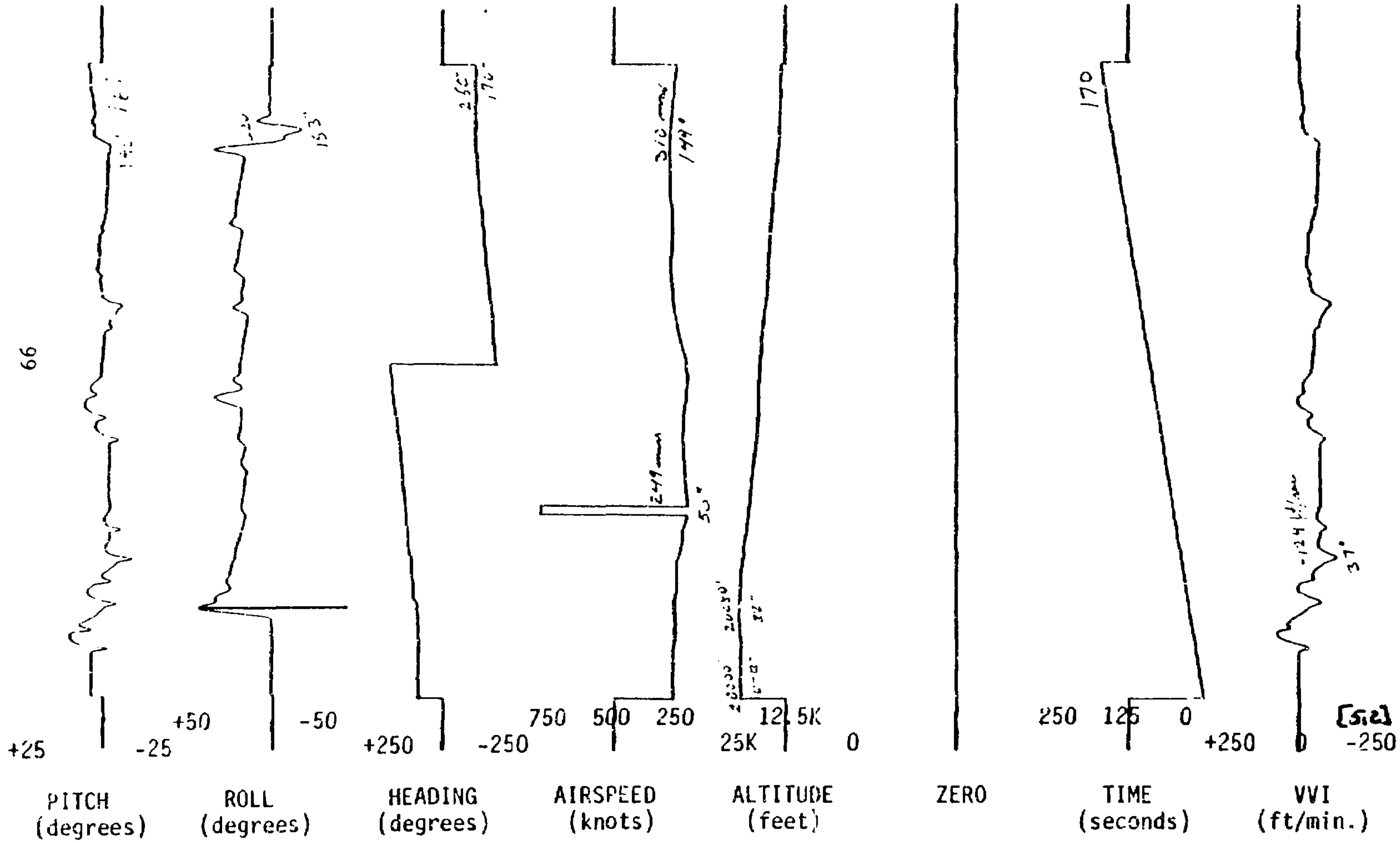
Descent - Run 4



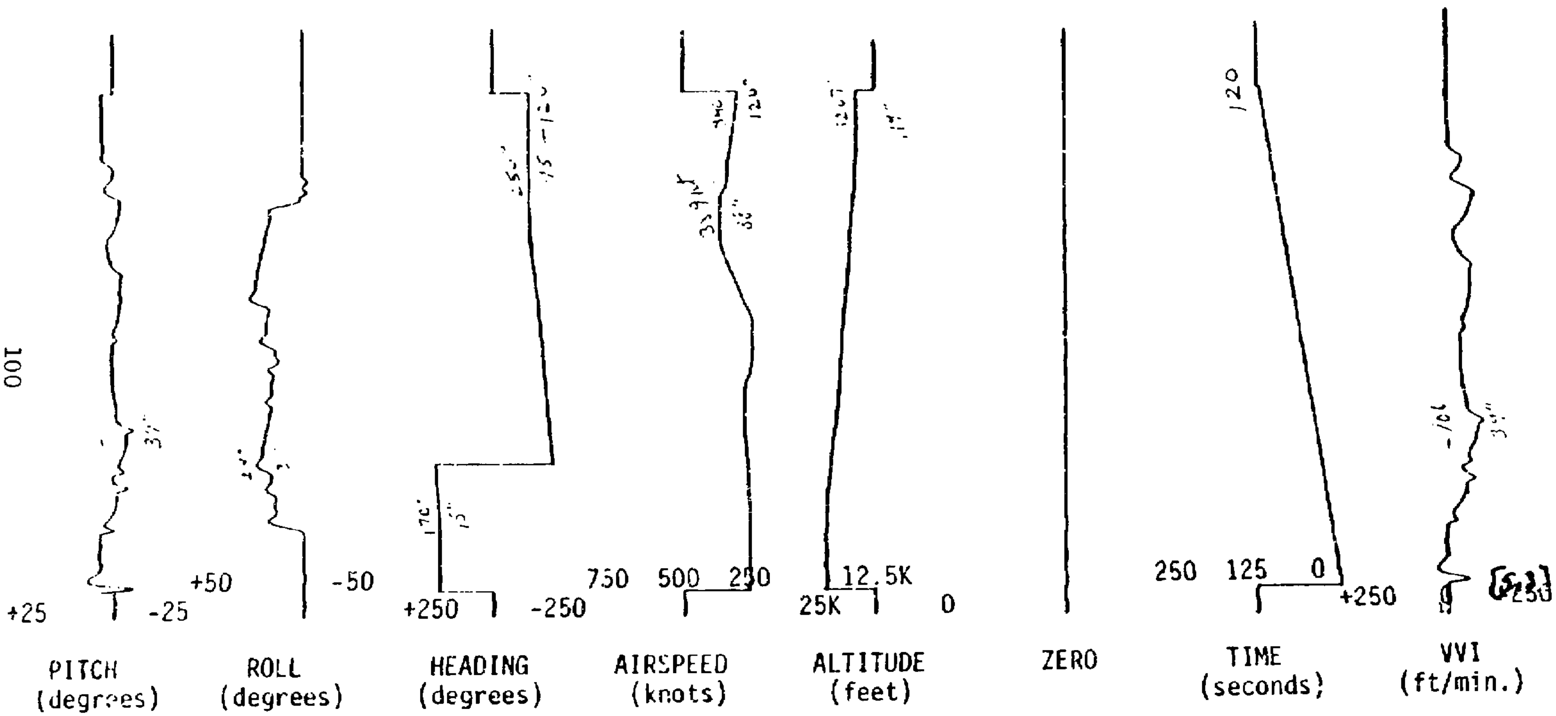
Descending Turn - Run 1



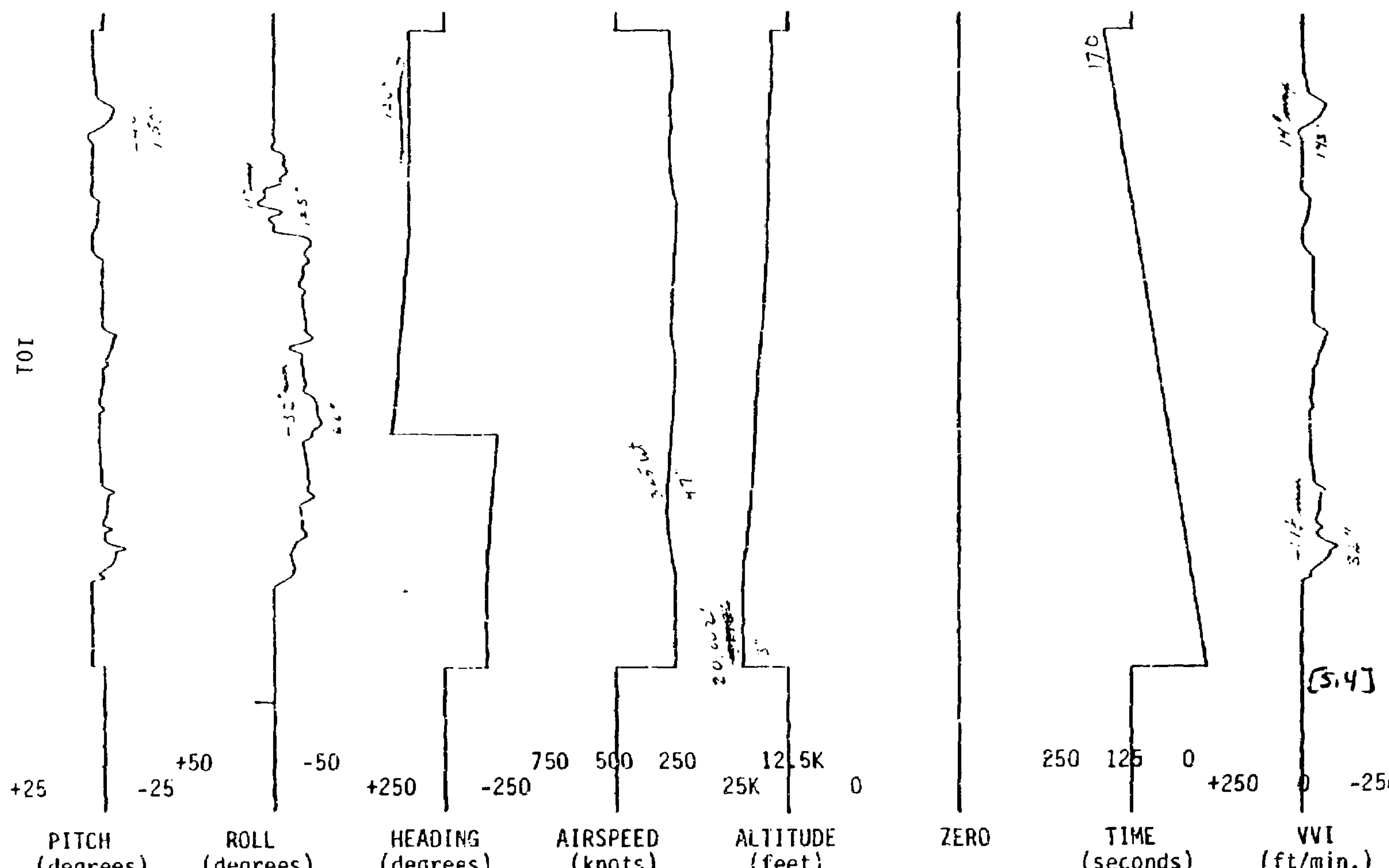
Descending Turn - Run 2



Descending Turn - Run 3



Descending Turn - Run 4



APPENDIX E: PRESENTATION ORDER FOR FLIGHT SEGMENTS AND QUESTIONS

PILOT NO. 1

SUB-SESSION 1

Flight Parameters

Flt. Seg.						
24	3	1	4	2	6	5
5	1	2	5	6	4	3
6	6	5	2	1	3	4
7	2	3	5	6	4	1
22	5	3	1	6	4	2
28	2	3	4	5	6	1
3	1	6	5	4	2	3
1	4	1	2	3	5	6
13	4	6	3	5	1	2
5	3	1	2	6	5	4

2

Flt. Seg.						
9	6	1	5	4	2	3
39	3	4	5	2	1	6
37	4	2	5	6	3	1
33	5	3	4	6	1	2
10	2	1	6	5	3	4
31	6	2	3	5	4	1
2	6	1	2	5	4	3
16	6	2	5	1	4	3
40	4	5	1	3	6	2
12	2	1	4	3	6	5

3

Flt. Seg.						
8	5	3	1	6	2	4
14	2	6	4	5	3	1
27	1	3	4	2	6	5
23	5	3	4	1	2	6
35	1	5	6	3	4	2
19	3	1	6	2	5	4
25	3	1	4	2	6	5
30	5	6	3	4	1	2
29	6	4	2	3	1	5
26	1	3	2	6	5	4

4

Flt. Seg.						
20	2	6	3	5	1	4
11	1	5	6	2	4	3
4	5	6	3	2	4	1
17	4	5	1	6	2	3
32	5	2	3	1	4	6
34	2	3	4	5	6	1
36	3	1	4	5	2	6
38	2	4	3	6	1	5
10	1	2	3	4	6	5
21	2	4	1	3	5	

PILOT NO. 2

SUB-SESSION 1

Flt. Seg.	Flight Parameters					
10	1	4	3	6	2	5
1	3	6	5	2	4	1
21	5	2	6	3	4	1
13	4	5	3	1	6	2
33	2	3	[illegible]	6	5	1
39	3	5	6	2	1	4
12	2	5	4	1	6	3
20	6	5	1	4	2	3
35	2	1	6	3	5	4
6	3	5	4	1	6	2

2

34	3	1	5	6	2	4
15	5	6	2	4	3	1
24	1	4	3	6	5	2
26	5	2	3	6	4	1
5	1	3	4	5	6	2
18	4	1	2	5	3	6
6	1	5	6	4	2	3
23	5	1	2	4	6	3
29	4	2	5	1	6	3
17	1	6	2	5	3	4

3

3	2	5	6	3	4	1
2	2	3	1	5	4	6
14	4	1	2	6	3	5
37	3	4	5	2	6	1
22	5	4	2	1	3	6
27	5	2	1	3	6	4
25	3	1	5	2	4	6
11	3	6	4	5	2	1
40	1	3	5	4	2	6
[illegible]	6	2	1	3	4	5

4

16	5	2	3	6	1	4
36	3	6	5	1	2	4
31	1	4	3	6	2	5
30	4	3	6	2	1	5
9	4	2	1	6	3	5
7	3	5	4	1	6	2
32	2	4	6	1	5	3
28	6	3	1	5	2	4
19	6	4	3	1	2	5
38	6	2	1	4	5	3

PILOT NO. 3

SUB-SESSION 1

Flt. Seg.	Flight Parameters					
4	3	5	2	1	6	4
11	6	5	1	2	4	3
22	5	6	1	2	4	3
2	5	4	2	6	1	3
16	4	3	5	1	6	2
30	6	4	5	1	2	3
38	3	1	6	2	5	4
14	6	4	5	1	2	3
19	6	3	2	4	5	1
39	2	1	6	5	3	4

2

13	4	5	6	1	3	2
24	3	5	2	4	1	6
25	6	1	2	4	5	3
6	1	5	4	2	3	6
23	3	6	4	1	2	5
10	1	3	6	5	2	4
8	2	5	4	3	1	6
5	1	6	2	5	4	3
40	5	1	6	4	2	3
27	4	6	5	1	2	3

3

34	5	4	6	3	1	2
37	4	6	5	3	2	1
29	6	1	3	5	4	2
12	5	6	4	3	2	1
35	1	3	6	2	4	5
9	6	3	5	1	4	2
15	6	2	5	3	1	4
26	5	1	6	2	3	4
3	3	1	4	6	2	5
1	5	3	2	6	1	4

4

36	1	4	2	6	5	3
20	5	2	1	4	3	6
32	3	6	2	1	5	4
7	6	4	3	2	1	5
33	4	1	6	2	3	5
21	6	2	4	3	5	1
28	5	3	2	1	4	6
17	2	4	3	5	6	1
18	4	3	5	6	1	2
31	5	3	4	6	2	1

PILOT NO. 4

SUB-SESSION

1

Flt. Seg.	Flight Parameters					
11	1	2	3	4	5	6
30	3	6	2	1	5	4
39	6	4	3	2	5	1
10	4	6	1	2	3	5
15	6	2	5	3	4	1
23	4	6	3	1	5	2
7	2	5	3	6	4	1
40	3	1	5	2	6	4
37	2	4	6	1	5	3
33	1	2	6	5	4	3

2

13	6	4	5	3	1	2
6	4	2	3	1	5	6
26	2	3	1	6	5	4
5	3	1	2	6	4	5
8	1	3	4	2	5	6
31	4	3	6	1	2	5
17	3	5	1	2	6	4
27	4	1	6	3	5	2
4	6	3	2	5	4	1
24	2	6	3	5	4	1
34						

3

	4	3	5	6	2	1
26	6	2	5	3	1	4
30	2	5	4	6	1	3
32	3	1	6	5	4	2
19	4	1	6	3	2	5
29	6	3	4	2	5	1
18	5	6	3	1	2	4
14	6	2	1	3	5	4
12	4	1	5	2	3	6
38	5	6	4	2	3	1

4

16	1	3	2	5	6	4
9	5	2	1	6	4	[illegible]
7	1	5	2	6	3	4
22	6	4	5	1	3	[illegible]
21	1	6	4	5	2	[illegible]
35	4	3	6	2	1	[illegible]
3	4	2	5	3	6	1
20	3	6	4	5	1	[illegible]
25	5	4	6	1	2	[illegible]
2	5	1	4	6	3	[illegible]

PILOT NO. 5

SUB-SESSION 1

Flight Parameters

Flt. Seq.						
25	1	2	6	3	4	5
19	5	2	1	4	3	6
16	3	5	2	1	[illegible]	4
28	1	3	4	2	6	5
12	4	6	1	5	2	3
27	4	6	1	3	2	5
32	3	2	4	5	1	6
40	2	3	6	1	4	5
22	4	3	1	2	5	6
26	2	3	5	1	4	5

2

Flt. Seq.						
15	1	2	5	4	6	3
37	6	1	4	3	5	2
9	4	5	2	1	3	6
24	5	3	1	4	2	6
7	5	1	6	4	2	3
1	1	4	5	6	3	2
11	4	6	2	5	1	3
33	5	3	6	2	1	4
36	4	1	2	5	3	6
8	1	3	2	4	6	5

3

Flt. Seq.						
14	3	1	2	4	6	5
4	5	2	6	1	4	3
34	1	6	2	5	3	4
2	2	5	1	6	4	3
38	2	3	5	6	1	4
10	5	6	2	3	4	1
31	6	4	3	2	1	5
6	2	5	4	1	3	6
35	5	2	4	3	1	6
3	3	1	4	5	6	2

4

Flt. Seq.						
18	4	1	3	6	2	5
30	5	3	6	4	1	2
5	5	4	2	6	1	3
39	3	6	1	5	4	2
13	5	4	3	1	6	2
21	1	4	3	6	2	5
20	4	5	6	2	1	3
29	6	2	4	3	5	1
17	4	5	3	1	6	2
23	6	3	4	1	2	5

SUB-SESSION

PILOT NO. 6

1

Flt. Seg.	Flight Parameters					
38	5	3	6	4	1	2
3	6	5	2	3	4	1
1	1	3	2	5	4	6
8	5	3	4	1	6	2
14	1	6	3	2	4	5
2	6	1	3	2	4	5
11	6	4	5	3	2	1
5	3	5	4	1	6	2
13	5	3	4	6	2	1
18	4	3	1	2	5	6

2

6	2	5	4	6	3	1
26	6	5	2	4	3	[illegible]
21	6	1	5	3	4	[illegible]
7	3	2	5	1	6	[illegible]
12	2	1	3	4	5	[illegible]
25	2	1	3	6	4	[illegible]
29	1	5	4	2	3	[illegible]
15	4	6	5	1	2	
23	5	4	1	6	3	
30	4	5	2	3	1	

3

4	6	2	5	4	3	1
16	5	1	6	4	2	3
34	4	2	3	5	6	1
20	1	4	6	5	3	2
31	4	5	2	3	6	1
36	2	3	1	5	6	4
37	2	4	6	3	1	5
19	1	6	4	2	3	5
39	2	4	3	1	5	6
24	1	4	2	5	3	6

4

35	5	3	1	2	6
22	4	5	6	2	1
10	1	3	6	5	4
32	6	4	2	3	5
27	3	6	1	4	5
33	5	6	3	1	2
9	1	5	4	6	2
40	4	1	6	5	2
28	6	4	5	3	2
17	6	2	3	1	5

PILOT NO. 7

SUB-SESSION 1

Flt. Seg.	Flight Parameters					
19	5	6	1	2	4	3
17	1	2	3	5	4	6
23	1	6	2	3	4	5
12	1	5	3	4	2	6
10	5	3	4	1	6	2
3	5	4	1	2	6	3
18	4	5	3	2	6	1
5	6	2	5	3	4	1
8	4	3	5	1	2	6
24	6	4	5	1	2	3

2

34	6	1	3	2	5	4
21	2	4	6	1	3	5
27	6	5	2	4	3	1
36	6	5	1	3	4	2
25	4	2	3	1	5	6
6	3	5	6	4	1	2
13	3	6	2	5	4	1
38	1	5	6	2	3	4
35	3	2	4	6	1	5
33	1	4	5	2	3	6

3

37	6	5	2	3	1	4
1	5	2	6	4	3	1
32	5	6	2	4	3	1
30	4	3	2	5	6	1
2	6	2	1	5	3	4
7	4	6	5	3	2	1
4	6	1	3	5	4	2
31	2	4	5	6	1	3
29	6	5	4	2	3	1
40	3	5	2	1	6	4

4

15	1	4	2	3	5	6
16	5	1	4	2	3	6
28	3	6	4	2	1	5
39	1	3	2	5	4	6
11	6	2	5	3	4	1
22	1	2	3	5	6	4
9	3	5	2	1	4	6
20	3	4	5	2	6	1
14	3	6	5	2	4	1
26	4	2	1	5	6	3

PILOT NO. 8

SUB-SESSION

1

Flt. Seg.	Flight Parameters					
20	6	1	3	2	5	4
36	5	6	1	2	4	3
39	1	2	3	5	6	4
5	5	4	2	3	6	1
11	1	2	3	4	5	6
38	6	3	5	1	4	2
34	3	6	1	2	4	5
22	4	3	6	2	1	5
27	6	2	1	3	4	5
12	6	3	5	1	2	4

2

32	3	4	6	1	2	5
14	3	1	6	2	5	4
2	2	4	3	6	1	5
15	5	6	2	4	1	3
9	5	1	4	3	6	2
30	3	5	6	1	2	4
28	5	1	3	4	2	6
16	2	6	1	4	5	3
18	1	3	4	6	5	2
6	3	2	4	6	5	1

3

17	5	4	1	6	3	2
19	5	4	1	3	2	6
23	1	3	6	4	2	5
10	3	1	2	4	6	5
26	5	2	6	1	4	3
21	1	6	2	5	3	4
37	5	6	4	3	2	1
25	3	1	2	4	5	6
31	2	4	6	5	3	1
33	1	4	3	2	6	5

4

29	2	4	3	5	1	6
4	1	2	4	3	5	6
8	5	1	3	2	4	6
13	5	3	6	2	4	1
7	5	2	3	4	1	6
3	4	2	5	6	1	3
40	1	6	5	4	3	2
24	5	6	2	1	3	4
35	3	4	5	2	6	1
1	3	6	4	2	1	5

PILOT NO. 9

SUB-SESSION 1

Flt. Seg.	Flight Parameters					
11	1	2	6	5	3	4
5	3	1	5	2	6	4
23	4	1	6	5	2	3
34	5	2	3	4	1	6
13	5	4	2	6	1	3
17	1	3	2	5	4	6
18	6	3	4	5	1	2
22	1	6	4	2	3	5
24	6	1	4	5	2	3
39	4	2	6	3	5	1

2

8	4	2	5	1	3	6
6	2	3	4	5	6	1
37	4	3	1	6	5	2
10	6	4	2	1	3	5
35	3	2	6	5	4	1
32	2	1	5	3	4	6
21	4	5	3	1	6	2
31	5	3	1	4	6	2
26	5	1	6	4	2	3
16	1	4	3	2	5	6

3

19	4	2	5	1	6	3
7	5	3	4	2	1	6
28	2	5	6	3	1	4
27	5	6	2	4	1	3
2	2	1	3	4	6	5
9	4	3	5	6	2	1
30	1	6	4	3	5	2
3	6	4	1	3	2	5
4	5	3	1	4	6	2
29	2	4	5	3	6	1

4

20	3	6	1	2	4	5
15	2	5	4	1	3	6
33	1	2	5	3	4	6
12	4	1	5	2	3	6
1	4	6	3	5	2	1
14	3	5	1	4	6	2
40	1	6	4	3	2	5
25	1	3	6	4	5	2
38	5	4	3	1	6	2
36	3	4	1	6	2	5

SUB-SESSION I

PILOT NO. 10

Flight Parameters

Flt. Seg.						
35	5	4	6	1	3	2
1	6	2	5	3	1	4
30	5	3	1	6	4	2
25	4	6	1	5	2	3
18	1	3	2	5	4	6
17	1	4	2	6	5	3
7	3	2	5	4	1	6
16	3	6	2	5	1	4
2	1	4	6	2	3	5
27	3	6	4	2	5	1

2

21	6	2	1	3	4	5
39	4	3	2	5	1	6
38	6	4	2	1	3	5
31	3	1	5	2	4	6
14	2	4	5	6	3	1
3	5	6	2	4	1	3
40	5	6	1	3	2	4
8	4	2	5	1	3	6
36	2	3	1	6	5	4
19	2	6	3	4	1	5

3

23	1	4	3	6	5	2
26	4	3	5	6	2	1
11	5	3	4	6	1	2
9	6	1	4	3	5	2
33	3	5	6	4	2	1
37	5	1	6	4	2	3
24	4	3	6	1	2	5
29	1	6	4	5	3	2
22	5	6	2	3	4	1
5	3	5	2	4	1	6

4

6	6	1	2	3	4	5
32	6	4	1	2	3	5
34	5	3	6	1	2	4
28	6	2	1	3	5	4
20	4	1	3	2	5	6
4	4	6	3	2	1	5
10	1	5	3	4	2	6
12	4	2	6	3	1	5
13	1	5	3	6	2	
15	2	5	3	1	6	

PILOT NO. 11

SUB-SESSION 1

Flt. Seg.	Flight Parameters					
17	6	3	5	2	4	1
18	2	5	3	1	6	4
40	5	6	2	3	1	4
37	4	5	3	2	1	6
23	4	3	6	5	2	1
5	1	3	6	5	4	2
7	6	4	2	5	3	1
22	1	6	3	4	5	2
33	2	4	3	1	5	6
38	1	6	4	2	3	5

2

2	4	1	3	6	2	5
24	6	2	4	3	1	5
20	4	3	2	5	1	6
19	3	6	2	1	4	5
28	4	3	1	2	5	6
32	5	4	2	1	6	3
11	5	3	2	4	6	1
15	4	5	6	3	1	2
31	6	3	5	1	2	4
3	2	1	3	6	5	4

3

25	2	6	3	4	1	5
4	1	4	3	5	2	6
35	4	3	2	1	6	5
27	1	5	3	2	4	6
16	2	6	1	3	5	4
36	[illegible]	2	5	4	3	1
26	6	1	2	4	5	3
12	4	3	2	6	5	1
10	6	2	1	3	5	4
34	2	6	[illegible]	3	5	1

4

6	5	1	3	6	2	4
1	2	4	1	3	6	5
39	3	4	5	2	6	1
30	2	4	3	5	1	6
8	1	2	4	5	3	6
9	3	1	6	5	2	4
21	3	6	5	2	4	1
14	3	2	1	5	4	6
13	4	2	6	3	5	1
29	5	3	6	4	1	2

PILOT NO. 12

SUB-SESSION 1

Flt. Seg.	Flight Parameters					
4	4	1	2	6	3	5
29	1	4	6	5	2	3
25	6	4	3	1	5	2
6	4	2	5	3	1	6
20	4	1	3	6	5	2
40	4	6	5	2	3	1
36	1	3	5	4	2	6
17	6	5	2	3	4	1
19	3	2	5	4	1	6
11	2	3	4	5	1	6

2

Flt. Seg.	Flight Parameters					
12	3	4	5	2	6	1
28	6	1	4	2	3	5
15	6	2	1	3	4	5
9	6	3	5	1	2	4
38	5	4	2	6	3	1
33	4	3	5	2	1	6
2	6	5	2	1	4	3
30	3	2	6	5	4	1
26	2	1	5	3	4	6
10	5	3	2	1	4	6

3

Flt. Seg.	Flight Parameters					
21	5	3	1	6	2	4
23	2	3	5	4	6	1
16	3	6	1	2	5	4
14	3	2	4	6	5	1
1	1	3	6	5	2	4
37	2	5	6	3	1	4
32	1	2	6	5	4	3
18	3	1	2	6	4	5
13	4	2	6	1	5	3
24	1	6	4	3	5	2

4

Flt. Seg.	Flight Parameters					
22	2	1	4	6	3	5
8	6	1	3	5	4	2
27	6	4	1	3	2	5
5	1	6	3	2	4	5
3	2	4	5	1	3	6
39	6	2	1	3	5	4
35	4	5	1	6	3	2
34	4	3	6	2	5	1
31	1	3	2	4	5	6
7	4	2	6	5	3	1

PILOT NO. 13

SUB-SESSION 1

Flt. Seg.	Flight Parameters					
4	3	1	5	4	6	2
14	5	1	4	6	2	3
11	6	4	1	2	3	5
23	3	6	2	1	5	4
38	1	5	6	3	2	4
13	4	5	1	2	3	6
3	4	5	1	2	6	3
17	3	2	1	5	4	6
33	1	2	5	6	4	3
21	3	o	1	5	4	2

SUB-SESSION 2

2	o	5	4	1	3	2
20	1	6	4	2	3	5
12	4	6	1	2	3	5
36	1	4	2	6	3	5
29	4	2	5	1	3	o
6	2	4	3	6	5	1
25	3	1	5	2	6	4
27	2	6	5	1	4	3
1	6	2	5	4	1	3
19	6	4	1	3	5	2

SUB-SESSION 3

32	3	5	4	1	6	2
15	6	1	5	4	3	2
31	2	5	6	4	3	1
16	5	6	3	2	1	4
37	4	3	2	5	6	1
7	1	5	6	2	3	4
8	2	1	4	5	3	6
26	1	6	2	5	4	3
24	6	1	3	4	2	5
9	6	2	4	5	1	3

SUB-SESSION 4

28	5	4	2	3	1	6
22	5	1	4	6	2	3
39	2	5	3	6	1	4
40	4	1	2	3	o	5
5	5	3	4	2	6	1
10	2	4	5	1	3	6
34	1	o	2	5	3	4
35	5	1	3	2	6	4
18	3	1	6	2	4	5
30	3	2	1	6	5	4

PILOT NO. 14

SUB-SESSION 1

Flt. Seg.	Flight Parameters					
7	2	6	1	3	4	5
2	2	1	3	5	4	6
14	2	4	1	6	5	3
29	1	3	6	2	4	5
23	2	3	4	1	5	6
28	6	2	1	3	5	4
38	6	1	3	2	5	4
5	3	1	4	6	2	5
30	1	5	3	4	2	6
11	6	2	4	5	3	1

2

Flt. Seg.						
1	5	2	1	6	3	4
31	3	5	6	1	4	2
34	1	6	4	2	3	5
40	4	6	3	5	2	1
3	4	2	6	5	3	1
6	3	5	6	1	2	4
21	5	4	6	1	2	3
39	3	1	4	5	6	2
10	6	5	2	1	4	3
37	6	3	2	4	5	1

3

Flt. Seg.						
13	4	1	6	3	5	2
9	3	6	5	1	4	2
36	6	1	5	4	3	2
32	6	3	1	4	2	5
12	3	4	5	6	1	2
24	6	2	4	1	5	3
33	1	5	6	2	3	4
16	5	1	6	3	2	4
4	1	6	3	4	2	5
20	2	3	1	4	6	5

4

Flt. Seg.						
35	6	2	5	1	4	3
15	1	2	4	3	5	6
26	2	5	4	6	1	3
25	3	1	5	4	2	6
18	2	6	5	3	4	1
17	6	4	1	5	2	3
8	3	6	2	1	5	4
27	1	5	2	3	4	6
19	5	3	1	2	4	6
22	4	6	1	2	5	3

PILOT NO. 15

SUB-SESSION 1

Flt. Seg.	Flight Parameters					
6	5	6	1	3	4	2
9	2	4	5	6	1	3
32	2	1	5	6	3	4
34	4	1	2	6	5	3
21	3	4	1	6	2	5
38	3	4	6	5	1	2
33	6	2	5	3	1	4
14	3	5	4	2	1	6
27	3	6	4	5	2	1
5	3	2	1	5	6	4

2

39	1	4	6	3	2	5
20	3	2	1	5	6	4
22	3	4	2	1	5	6
12	1	4	6	2	3	5
24	4	3	6	5	2	1
18	1	4	2	3	6	5
26	4	3	6	5	1	2
7	5	4	6	1	2	3
40	5	1	3	2	6	4
10	2	6	3	1	4	5

3

23	5	2	1	4	6	3
13	6	1	2	5	3	4
1	3	2	4	5	1	6
36	6	1	3	4	5	2
31	2	5	6	4	3	1
28	1	5	3	2	4	6
11	4	2	5	6	3	1
17	1	3	5	6	4	2
35	2	5	1	3	4	6
29	6	3	2	5	4	1

4

8	6	5	2	4	1	3
10	5	2	6	1	4	3
2	1	5	2	3	6	4
30	2	1	6	3	4	5
4	5	3	1	4	6	2
25	4	1	2	5	6	3
19	1	6	3	2	4	5
15	2	3	5	1	4	6
3	1	2	6	3	5	4
37	6	1	5	2	3	4

PILOT NO. 17

SUB-SESSION 1

Flt. Seg.	Flight Parameters					
5	4	2	5	1	6	3
15	1	4	2	5	3	6
21	4	1	2	3	6	5
39	6	1	3	4	5	2
36	2	1	4	6	3	5
20	6	4	1	2	5	3
3	2	3	5	1	4	6
13	5	6	1	3	4	2
35	3	5	6	2	1	4
18	4	3	6	5	2	1

SUB-SESSION 2

Flt. Seg.	Flight Parameters					
4	1	6	5	4	3	2
26	5	2	4	6	1	3
11	3	6	1	4	5	2
33	5	4	6	1	3	2
22	5	4	1	2	6	3
10	5	6	4	2	3	1
28	4	2	5	3	6	1
30	4	5	3	1	6	2
17	2	4	5	6	3	1
2	6	3	5	2	1	4

SUB-SESSION 3

Flt. Seg.	Flight Parameters					
36	3	4	6	1	2	5
7	3	2	1	4	6	5
29	4	1	5	3	2	6
19	6	3	2	5	1	4
32	3	5	2	4	1	6
1	2	1	3	6	4	5
6	1	6	3	5	2	4
31	4	6	2	1	3	5
40	3	6	1	5	2	4
24	2	1	5	3	6	4

SUB-SESSION 4

Flt. Seg.	Flight Parameters					
16	1	3	2	4	6	5
34	2	6	1	4	3	5
37	5	2	4	6	3	1
14	4	5	1	3	2	6
6	2	4	6	5	3	1
23	2	5	3	6	1	4
12	2	5	4	3	6	1
27	3	4	6	2	5	1
9	5	3	4	1	2	6
25	1	5	2	3	4	6

PILOT NO. 18

SUB-SESSION 1

Flt. Seg.	Flight Parameters					
6	6	1	5	4	2	3
16	4	5	2	6	3	1
24	1	5	6	3	2	4
38	5	6	2	3	4	1
20	6	5	3	4	1	2
2	2	4	1	6	3	5
15	6	5	3	2	4	1
12	2	4	3	5	1	6
3	1	2	5	3	4	6
35	4	5	3	2	1	6

2

25	3	1	4	2	6	5
22	1	3	6	4	5	2
17	1	4	5	6	2	3
21	3	2	1	5	6	4
37	3	5	2	1	6	4
26	5	4	3	2	6	1
30	4	3	1	2	6	5
34	4	2	6	5	3	1
4	4	5	6	1	3	2
27	2	5	6	1	4	3

3

10	4	1	5	2	3	6
9	6	5	2	1	4	3
28	1	3	6	4	2	5
18	2	6	1	5	3	4
13	4	6	5	1	3	2
23	2	3	1	4	5	6
11	2	6	3	5	4	1
5	1	3	5	6	4	2
14	6	2	4	1	3	5
7	3	5	1	6	4	2

4

31	6	1	4	5	3	2
19	3	2	6	5	4	1
36	6	3	1	4	2	5
39	4	3	2	6	1	5
40	1	5	4	3	6	2
8	4	6	2	5	3	1
29	5	3	1	4	6	2
33	6	4	1	3	2	5
1	5	3	4	2	6	1
32	3	4	6	1	5	2

PILOT NO. 18

SUB-SESSION 1

Flt. Seg.	Flight Prameters					
36	1	3	2	6	4	5
14	6	1	2	5	4	3
35	4	3	2	1	6	5
24	5	2	6	3	1	4
23	2	1	4	6	3	5
3	3	1	6	4	5	2
2	2	1	4	3	6	5
18	1	4	6	2	3	5
38	2	3	6	5	1	4
27	5	2	1	3	4	6

2

Flt. Seg.						
26	4	1	5	2	3	6
39	4	3	6	2	1	5
30	1	5	3	4	2	6
6	4	2	1	3	6	5
21	3	2	5	6	1	4
16	5	3	4	1	2	6
33	1	5	6	2	4	3
29	5	6	4	2	3	1
13	1	6	2	3	4	5
8	4	6	3	5	1	2

3

Flt. Seg.						
5	6	4	2	1	5	3
7	3	1	5	2	4	6
10	2	6	4	1	3	5
37	6	2	1	5	4	3
1	5	1	2	3	4	6
32	4	5	6	1	3	2
31	6	1	3	4	5	2
20	6	1	2	5	4	3
4	1	4	3	6	5	2
25	4	2	6	1	5	3

4

Flt. Seg.						
19	1	3	5	2	6	4
11	2	1	5	3	4	6
28	1	5	6	4	2	3
22	2	1	6	4	3	5
9	5	2	4	1	6	3
17	1	4	5	3	6	2
15	2	6	4	3	1	5
34	3	1	6	5	4	2
12	4	6	2	3	1	5
40	6	5	1	2	4	3

PILOT NO. 19

SUB-SESSION 1

Flt. Seg.	Flight Parameters					
12	6	1	2	3	5	4
22	1	5	6	4	2	3
34	5	6	2	4	3	1
38	3	2	4	6	1	5
6	1	4	5	3	6	2
11	5	1	4	6	2	3
30	6	1	5	4	3	2
40	4	6	2	3	1	5
25	1	4	6	2	5	3
35	3	4	5	1	6	2

2

13	1	5	6	3	2	4
26	4	1	3	2	5	6
7	4	5	6	2	3	1
14	3	2	5	6	1	4
37	5	4	2	6	1	3
32	5	3	2	6	1	4
39	3	5	2	1	6	4
27	3	4	5	2	6	1
16	4	6	3	2	5	1
1	1	2	4	6	3	5

3

20	3	6	5	1	4	2
17	2	5	3	6	4	1
10	6	3	5	2	1	4
24	6	4	3	1	2	5
3	6	2	3	5	4	1
15	5	1	2	3	4	6
9	3	2	5	1	6	4
33	3	1	5	6	2	4
21	2	1	5	4	6	3
28	1	5	3	2	4	6

4

5	4	6	3	1	2	5
18	3	4	5	2	1	6
8	2	4	5	3	1	6
4	6	5	2	4	3	1
31	5	6	2	4	3	1
29	4	2	6	1	5	3
2	4	2	5	3	1	6
36	5	6	2	3	[illegible]	1
19	2	1	3	5	[illegible]	4
23	2	4	1	5	6	3

SUB-SESSION

PILOT NO. 20

1

Flt. Seg.	Flight Parameters					
29	1	5	3	2	6	4
11	2	6	5	3	1	4
6	1	3	2	4	6	5
27	6	1	2	4	5	3
25	4	5	3	6	2	1
19	1	5	6	3	4	2
33	4	6	2	5	3	1
10	5	3	1	4	6	2
28	4	1	5	6	2	3
39	1	4	3	6	2	5

2

36	5	4	2	1	3	6
32	1	6	4	3	5	2
12	3	1	5	2	4	6
7	4	1	6	2	3	5
20	5	2	1	6	3	4
30	1	2	6	3	4	5
3	1	6	3	5	4	2
23	2	3	4	5	1	6
40	3	4	6	5	2	1
22	5	6	3	2	4	1

3

24	6	5	4	3	2	1
21	6	2	3	1	5	4
26	2	3	4	6	1	5
17	4	1	3	6	5	2
34	2	4	3	6	1	5
35	1	6	5	4	2	3
5	6	1	4	3	5	2
1	6	3	5	1	2	4
16	6	1	3	4	5	2
31	2	3	5	4	6	1

4

15	3	4	1	5	2	[illegible]
14	5	2	4	1	6	[illegible]
13	5	4	3	6	1	[illegible]
4	2	1	6	5	3	[illegible]
37	1	6	2	5	4	[illegible]
2	2	3	1	4	6	[illegible]
8	4	6	2	1	3	[illegible]
38	1	2	4	5	3	[illegible]
18	2	4	5	6	1	[illegible]
9	2	3	1	5	4	[illegible]

APPENDIX F: OBSERVER PILOT INFORMATION FORM

Pilot # ______________

Date ________________________

Name ______________________ Rank __________________ Age _____________

Total Flight Hours _____________

Present Equipment ______________________ Flt.Hrs. ____________________

Hours
In Other Equipment __________________ Type ______________________________

__________________ Type ______________________________

__________________ Type ______________________________

__________________ Type ______________________________

__________________ Type ______________________________

__________________ Type ______________________________

Comments: ____

____

____

____

____

____

____

____

Experimenter __________________________

APPENDIX G: INITIAL EXPLORATORY STUDY

By

Charles Elworth

Winifred Lee

Boeing Aerospace Company

Logistics Support and Services Division

Seattle, Washington 98124

I. INTRODUCTION

The purpose of this initial study was to develop and implement a recommended method of evaluating alternative display formats for use in the instructor/operator station of a flight simulator. The work included conducting a brief literature survey, analyzing the instructor's job, and developing a good approach to display evaluation. Our approach centered around developing a benchmark task that exercises many of the skills used by an instructor; developing ways to measure a subject's performance of that task; and using the derived measurement method experimentally to infer the effectiveness of a given display format.

The following sections document this work and present conclusions and recommendations. Important refinements of the method were then performed, and a more comprehensive test and demonstration of the method was conducted as a second study and is documented in the main body of the report.

II. LITERATURE SEARCH

We began with a literature survey to determine the current capabilities and knowledge regarding man-machine system performance in training systems. In particular, we selected and reviewed 50 documents pertaining to human-monitoring behavior, performance measurement/evaluation techniques, CRT display systems and human factors technology. These are listed in Appendix H. This first review was primarily focused on the abstracts and, where appropriate, summaries. In general, most reports reviewed dealt with analysis, evaluation, design, and development of flight simulator systems and subsystems. Typically, emphasis focused on wide angle visual systems, complex motion platforms, sophisticated CRT cockpit displays and crew interfaces. Research relative to the functions and interfaces for the instructor was virtually nonexistent. (It would appear that the design of the instructor consoles has been dictated by simulator design rather than by instructor functions and information requirements.)

Of the 50 abstracts reviewed, 26 appeared to contain information applicable to this research. We ordered complete documentation for these works and reviewed them in more detail. These 26 reports are indicated by asterisks in Appendix H.

The second level of examination focused on identification of those documents with specific application to this program. Through this examination, we identified 17 documents (indicated by double asterisks in Appendix H) that were useful to the program and analyzed them in greater detail. This analysis identified the technology category of applicability (man/machine systems, task/workload, display systems, performance measurement, and performance evaluation), produced abstracts of study scope, and summarized primary study techniques used, salient input/output parameters, special capabilities and limitations and areas of program applicability. The results of this review are summarized in Appendix I.

In general, although data were available which applied to many issues requiring consideration in the conduct of this study (such as task analysis, man/machine task allocation, advanced display technology, and operator performance evaluation), no data were available relative to the development of methodologies that could be used to quantitatively compare the relative merits or deficiencies of one display system with another. However, the literature review did prove useful in establishing an understanding of the potential technical problems and in reinforcing our knowledge that this effort would be exploratory in nature.

III. INSTRUCTOR PILOT JOB ANALYSIS

To determine candidate maneuvers that could be used in benchmark task approach to the evaluation of IOS displays, we conducted a brief analysis of the role and duties of the simulator IP. This analysis addressed (1) IP duties, (2) IP tasks and skills, and (3) IP information requirements. Analysis methodology as well as results are discussed in the following paragraphs.

IP Duty Analysis

We identified the overall duties of a typical remotely located IP, monitoring and controlling student performance in a simulator, and categorized them as follows: simulator set-up, problem set-up, system/student performance monitoring and assessment, communicate/monitor programs, on-line/off-line debriefing, and altering or adapting the training problem depending on the student pilot's performance. The relationship of the aforementioned IP duties are illustrated in Figure G-1.

As the operator of the simulator (set up simulator), the IP is expected to check the system to insure that it is ready for the training session to be undertaken at that time. This may involve the removal of some conditions left over from a previous flight, coordinating with the software control operator, as well as testing and validating operability of the systems and its components.

In setting up the problem the IP must prepare inputs required to properly initiate the system as well as convey to the trainee what is expected of him. The amount of interaction between the IP and trainee(s) depends on the qualification and experience of the trainee and the level of difficulty of the task to be trained. Thus, even though the overall duty of the IP remains the same, the amount of time and the level of detail of interaction can vary significantly.

Monitoring of simulator functioning should be performed by the system

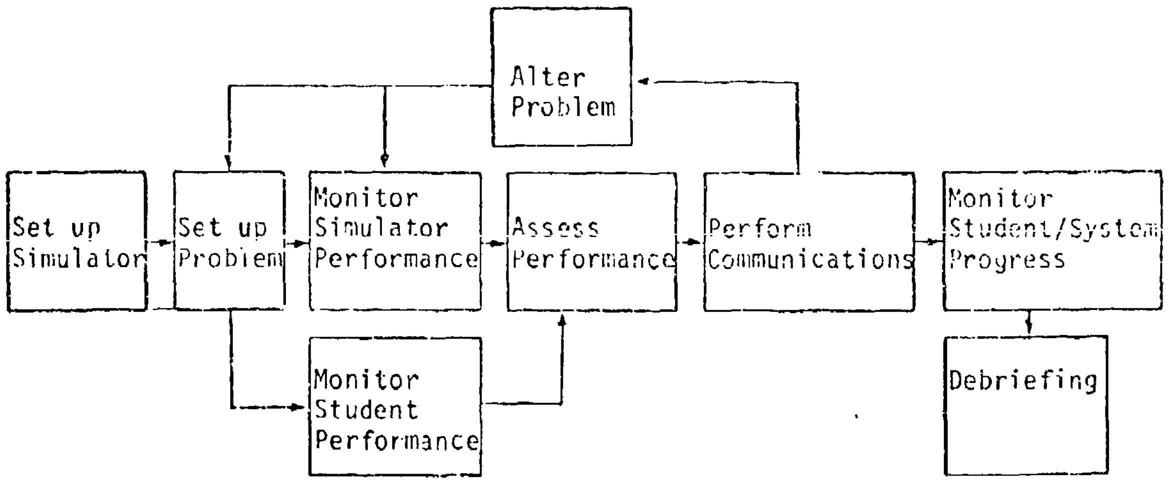


Figure G-1. Typical Instructor Duties

operator; however, the IP is quite often required to perform this function merely because his activity overlaps with that of the operator. Also, for reasons of continuity or to minimize delay, the IP will in many instances, automatically monitor the system functions even though he is not required to do so. Though this activity does not usually require excessive IP time or attention, it could be a significant consideration during heavy task loading and multi-cockpit monitoring situations.

The task of monitoring student or trainee performance demands the primary attention of the IP. He is both the certifier and diagnostician. Instructor efficiency depends on the capability to detect indications of student performance. Such indications are the logical basis for his assessment of student performance of the trainee, and the IP's duty will vary. In retraining, the instructor will be required to alter the problem, communicate with the trainee and/or support personnel and determine the effectiveness of the remedial measures taken. If the trainee's performance is satisfactory, then the task of the IP is greatly simplified; he merely monitors the student's performance to verify that it continues to be satisfactory and prescribes new material or higher levels of difficulty.

IP Tasks and Skills

For the purposes of this study, we developed an operational scenario upon which the IP's task and skill analysis was performed. The operational mission selected represented a typical air-to-ground mission emphasizing the terminal penetration and attack phase. We selected this phase since it involved a variety of activities (in the context of monitoring student/system performance) that require the IP to utilize various processes, skills, and content of information presented.

The functions of the terminal navigation and attack phase include (a) monitor simulator performance, (b) navigate, (c) search for and acquire target, (d) prepare for attack, and (e) deliver weapon. Within each function, we identified tasks that needed to be performed by the student pilot. We then examined each of the pilot's tasks from the viewpoint of the IP as a monitor and evaluator of the student pilot's performance of that task. With the exception of monitoring the simulator function, the tasks for the student were found to be quite different from those of the IP in that the former primarily involve physical actions such as activate, insert, etc., and the latter primarily involve mental actions such as observe, decide, verify, etc. We used the identified IP tasks as the basis upon which to generate specific information required as well as display options that are currently available. Results of that analysis are shown in Table G-1.

Specific skills the instructor must have to carry out these tasks are varied. The type of tasks performed by the IP and their relationship to the process used and the typical behavior or skill required are depicted

Table G-1. Task Analysis Summary

FUNCTION	PILOT TASKS	INSTRUCTOR TASKS	INFORMATION REQUIRED	DISPLAY OPTIONS
A/C PERFORMANCE	MONITOR & CONTROL PITCH & ROLL	MONITOR, ASSESS & RECORD	ANGLE AND RATE	ADI, EADI, HDG IND.
	MONITOR & CONTROL YAW	MONITOR, ASSESS & RECORD	ANGLE AND RATE	T/SI, VSD
	MONITOR & CONTROL ALTITUDE	MONITOR, ASSESS & RECORD	TERRAIN CLEARANCE AND PRES. ALT.	ALTIMETER, VERT BAR, S OF GREY
	MONITOR & CONTROL ALTITUDE RATE	MONITOR, ASSESS & RECORD	ANGLE AND RATE	VVI, VSD, VERTICAL BAR
	MONITOR & CONTROL HEADING	MONITOR, ASSESS & RECORD	ANGLE AND RATE	HDG, IND., HSD, A/N CHAR. T/SI
	MONITOR & CONTROL SPEED	MONITOR, ASSESS & RECORD	RATE-TAS, MACH	ASI; VERTICAL BAR, A/N CHAR
	MONITOR & CONTROL ANGLE OF ATTACK	MONITOR, ASSESS & RECORD	ANGLE	DIGITAL (A/N), MOVING MAP
	MONITOR AND CONTROL MODE OF ATTACK	MONITOR, ASSESS & RECORD	MODE SELECTED	(DISCRETE)' SYMBOL, A/N CHAR
	MONITOR & CONTROL A/C STATUS (FUEL, ENERGY MGMT, ENGINES, ETC.)	MONITOR, ASSESS & RECORD	PROPULSION PARAMETERS FUEL FLOW, ENGINE CONTROL	BAR GRAPH
NAVIGATION 1 NAVAIDS	SELECT NAV. AID EQUIPMENT (E.G., TACAN)	OBSERVE SELECTION/PERFORMANCE	EQUIP. SELECTED	ILLUM IND., A TONE IND., A/N C
	SELECT OPER. MODE & FREQUENCY	OBSERVE SELECTION/PERFORMANCE	M/F SELECTED	ILLUM IND., A TONE IND., A/N C
	SELECT OTHER EQUIP. USING DISTANCE/ BEARING INFO.	OBSERVE SELECTION/PERFORMANCE	EQUIP. SELECTED	ILLUM IND., A TONE IND., A/N C
2 TERMINAL NAV.	INSERT IP COORDINATES (SELECT & ENTER)	MONITOR INSERTION PROCESSES	LAT/LONG	A/N CHAR
	INSERT PROFILE	MONITOR INSERTION PROCESSES		A/N CHAR
	INSERT RP COORDINATES	MONITOR INSERTION PROCESSES	LAT/LONG	A/N CHAR
	INSERT BALLISTIC WIND	MONITOR INSERTION PROCESSES	RATE & DIRECTION	A/N CHAR
	MONITOR, CONTROL & TRACK DELIVERY PROF	MONITOR STATUS	PROFILE PARAMETERS (TIME ETC)	GRAPHIC PROF, BASIC FLT INSTR
	MONITOR, CONTROL & TRACK ESCAPE WPNS PROF	MONITOR STATUS	PROFILE PARAMETERS	GRAPHIC PROF, BASIC FLT INSTR
	MONITOR, CONTROL & TRACK EVADE DEFENSES PROFILE	MONITOR STATUS	PROFILE PARAMETERS	GRAPHIC PROF, BASIC FLT INSTR
	MONITOR COMPUTED TIME INTERVALS	MONITOR STATUS	PROFILE PARAMETERS	A/N CHAR
SEARCH & ACQUIRE	SELECT & ACTIVATE SENSOR	OBSERVE SELECTION/APPROPRIATENESS	SENSOR SELECTED & ACTIVATED	ILLUM IND., A TONE IND., A/N
	INITIATE SEARCH (SELECT MODE /RANGE)	MONITOR	RANGE SELECTED	ILLUM IND., A TONE IND., A/N
	ACQUIRE TARGET	MONITOR ACQUISITION	LOCATION (VISUAL)	ILLUM IND., A TONE IND., A/N
	SELECT VISUAL AID	MONITOR	AID SELECTED	ILLUM IND., A TONE IND., A/N
	SELECT VIEWING ANGLE	MONITOR	ANGLE	A/N CHAR
	VIEW AREA FOR DESCRIBED CUES	MONITOR APPRO. VIEWING AREA	SPECIFIC CUES	MOVING MAP

Table G-1 (Continued)

FUNCTION	PILOT TASKS	INSTRUCTOR TASKS	INFORMATION REQUIRED	DISPLAY OPTIONS
COMBAT PREPARATION	SELECT WEAPON	MONITOR	WEAPON SELECTED	A/N CHAR.; ILLUMINATED IND
	SELECT DELIVERY MODE	MONITOR	MODE SELECTED	A/N CHAR.; ILLUMINATED IND
	SELECT DELIVERY RATE	MONITOR	RATE SELECTED	A/N CHAR.; ILLUMINATED IND
	ARM WEAPON	MONITOR TIME & PROCEDURE	WEAPON ARMED	A/N CHAR.; ILLUMINATED IND
	SELECT/VERIFY SENSOR	MONITOR	SENSOR SELECTED	A/N CHAR.; ILLUMINATED IND
	ALIGN COURSE WITH PREDICATED TARGET	MONITOR FLIGHT COURSE PROGRESS	LOCATION, FLIGHT PARAMETERS	MOVING MAP
	MONITOR A/C MANEUVER LIMITS & EQUATIONS FROM NAV. COMP.	MONITOR	FLIGHT PARAMETERS, A/N CHAR.	GRAPHIC
	MONITOR A/C PERFORMANCE RE COMMAND	MONITOR	COMMAND & ACTUAL PARAMETERS	[illegible], A/N CHAR.
	EVALUATE SENSOR INFORMATION	MONITOR AND EVALUATION	INFORMATION EVALUATED	A/N CHAR.
	VERIFY TARGET LOCATION RE KNOWN CHAR	MONITOR	LAT/LONG	A/N CHAR.
	DESIGNATE TARGET	MONITOR TIME & PROCEDURES	LOCATION (VISUAL) OR , TIME	GRAPHIC W/CURSOR
	SELECT LOCK ON TO TARGET	MONITOR	MODE SELECTED	A/N CHAR., ILLUMINATED BUTTON
	IDENTIFY TARGET VISUALLY	MONITOR & VERIFY IDENTIFICATION	LOCATION (VISUAL)	MOVING MAP
	PROVIDE TARGET LOCATION TO OTHER SYS	MONITOR	SYSTEMS INFORMED	A/N CHAR., ILLUMINATED BUTTON
	NAVIGATE TO SPECIFIC COORDINATES	MONITOR	FLIGHT PARAMETERS	MOVING MAP, GRAPHIC PROFILE, BASIC INSTR.
WEAPON DELIVERY	CHECK WEAPON AVAILABILITY	MONITOR	AVAILABILITY CHECKED	AUDIO INDICATOR
	NAVIGATE TO RP	MONITOR PROFILE	FLIGHT PROFILE PARAMETERS	MOVING MAP; GRAPHIC
	RELEASE WEAPON	MONITOR TIME	TIMING	A/N CHAR.
	MONITOR WEAPONS EFFECTS	MONITOR	EFFECTIVENESS MET	AUDIO INDICATOR
	FLY ESCAPE MANEUVERS	MONITOR PROFILE	FLIGHT PROFILE PARAMETERS	MOVING MAPS, GRAPHIC
	FLY EVASIVE MANEUVERS	MONITOR	FLIGHT PROFILE PARAMETERS	MOVING MAP, GRAPHIC

in Table G-2.

For the IP to perform his duties efficiently he must possess a variety of inherent knowledges in addition to the specific skills. The IP must know how the simulator reacts to control inputs and what its limitations are. He must also know the operational role of the simulated system, its missions and intended use. Knowledge of simulator operation is obviously required. The training philosophy underlying the content and order of items in the training syllabus as well as the manner in which it must be followed should also be known and understood by the instructor pilot. The monitoring of student performance at the instructor's console for the purpose of evaluation requires considerations based on this philosophy.

Knowledge of the student pilot's relevant background of experience is also required as it may impinge on the approach to be used in training. To train a pilot to fly a jet-powered airplane when his prior experience was limited to propeller-driven machines would involve a considerably different process than training someone whose flying experience included an airplane which was closely similar to the one he is learning to fly.

The job knowledge required of the IP, as well as specific activities involved, depends on the mission and operational characteristics. IP job knowledge required to perform flight simulation training duty is shown in Table G-3.

Table G-2. Instructor Pilot Tasks, Processes, and Skills

Task	Process	Skill
Search for & receiving information	Perceptual	Detect, inspect, observe and scan
Identify objects or events		Discriminate, identify, locate
Process information	Mediational	Categorize, calculate, code, compute
Problem solving/decision making		Analyze, choose
Communicating	Vocal	Advise, answer, direct, inform
Simple/discrete	Motor	Activate, connect, join, set
Complex/continuous		Adjust, align, regulate, synchronize

Table G-3. IP Knowledge Requirements

IP FUNCTION / REQUIRED KNOWLEDGE	A/C CAPABILITY AND OPERATIONAL ROLE	SIMULATOR OPERATIONS	TRAINING TECHNIQUES	PSYCHOLOGICAL JUDGMENT	TACTICS FAMILIARITY	MAN/MACHINE INTERFACE	STUDENT'S BACKGROUND
MONITOR SYSTEM STATUS		X					
MONITOR OPERATIONAL SEQUENCING	X	X			X		
MONITOR STUDENT PERFORMANCE	X		X	X	X		
MONITOR SIMULATOR OPERATION		X					
EVALUATE STUDENT PERFORMANCE	X	X	X	X	X	X	X
EVALUATE SYSTEM PERFORMANCE	X	X					
EVALUATE MAN-MACHINE INTERFACES	X	X			X	X	X

Information Requirements

During the analysis of the IP's role and duties, we concluded that his job in simulator training can be generally categorized into five major functions: (1) simulator set-up, (2) problem set-up, (3) simulator/student performance monitoring and assessment, (4) communications, and (5) on-line/off-line debriefing.

Although IOS displays could be used in the performance of all of these functions, the third function, monitoring and assessment of performance, appeared to be the appropriate focus for this study. In reviewing the IP's monitoring duties, four general categories were identified: (1) monitor only (results in no specific action), (2) monitor-record (results in IP recording information), (3) monitor-decide-act (results in a decision which forces some kind of action) and (4) monitor-analyze (results in on-line assessment of system/student performance.

Information type and manner of display required by an IP depends on the operational situation. The relationship between the aforementioned categories of monitoring duty and mission segments selected is shown in Table G-4. Display information required by the IP was derived based on detailed task analysis of both the student and the IP, the results of which were presented earlier in Table G-1.

Table G-4. Function/Task Allocation

INSTRUCTOR TASKS / STUDENT FUNCTION CATEGORIES	MONITOR ONLY	MONITOR AND RECORD	MONITOR AND DECIDE	MONITOR AND ANALYZE	MONITOR ONLY: INSTRUMENT STATUS	MONITOR ONLY: OPERATIONAL PROCEDURES	MONITOR ONLY: STUDENT PERFORMANCE	MONITOR ONLY: SIMULATOR OPERATIONS	MONITOR & RECORD: SYSTEM STATUS	MONITOR & RECORD: OP. SEQUENCE DEVIATION	MONITOR & RECORD: STUDENT PERFORMANCE	MONITOR & RECORD: SIMULATOR OP. INADEQUACIES	MONITOR & DECIDE: DISPLAY DISCRETE OR CONTINUOUS	MONITOR & DECIDE: MALFUNCTION ISOLATION	MONITOR & DECIDE: MISSION ABORT OR CONTINUOUS	MONITOR & ANALYZE: QUALITY OF SYST PERFORMANCE	MONITOR & ANALYZE: QUALITY OF STUDENT PERFORM	MONITOR & ANALYZE: DISPLAYED INFORMATION ADEQUACY
A/C PERFORMANCE																		
FLIGHT PROFILE	X	X	X		X		X	X	X	X	X	X	X			X	X	X
A/C STATUS	X	X	X	X	X			X	X				X	X	X	X		X
NAVIGATION																		
NAV. AID SELECTION	X	X				X	X	X		X	X	X	X				X	X
TERMINAL NAV.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SEARCH & ACQUIRE																		
TGT. AREA LOCAL.	X		X	X		X	X	X	X	X	X	X	X		X	X	X	X
VISUAL IDENT.	X	X	X				X	X			X	X	X		X		X	X
COMBAT PREPARATION																		
TGT/WEAPON MATCH	X	X	X				X				X				X		X	X
TGT/AC ALIGNMENT	X	X	X		X		X	X	X		X	X	X	X	X	X	X	X
TGT LOCK-ON	X	X	X		X		X	X	X		X	X	X		X	X	X	X
WEAPON DELIVERY																		
RP NAVIGATION	X	X	X		X		X	X	X		X	X	X	X		X	X	X
WEAPON RELEASE	X	X			X		X		X		X					X	X	
ESCAPE NAVIGATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X

IV. BENCHMARK TASK

Benchmark Task Criteria

To be a suitable benchmark task, the task must be one which can be used to evaluate the effectiveness of different displays in meeting a wide variety of IP information requirements. Accordingly, criteria for the development of the benchmark task must include: (1) criticality, (2) frequency, (3) complexity, (4) measurability, (5) implementability to multi-cockpit monitoring. These criteria are explained in the following discussion.

Criticality. The task developed must be one which includes information that is basic to the success of the IP performing his function. Since much of this information will vary from maneuver to maneuver, the benchmark task should contain information elements that are both critical and common across a large number of maneuvers. For example, the requirement for airspeed information is critical to many maneuvers and is controlled solely by actions of the student. On the other hand, while fuel pressure information would be critical to the student in the event of a fuel pump failure, this failure would have been instigated by the instructor, and therefore, the information would not be critical to the instructor.

Frequency. The benchmark task should contain subtasks which are frequently performed by the IP. As used here, frequency includes both the amount of time spent performing a function and the number of times the function is performed. As with the criterion of criticality, for a function to satisfy the criterion of frequency, it should be considered frequent across a significant number of flight maneuvers. For example, the turn and bank indicator is monitored with high frequency during particular maneuvers but is seldom monitored at other times. Monitoring of altitude, however, is virtually continuous during all phases of flight and would unquestionably meet the frequency criterion.

Complexity. The IP job is complex. He must observe and integrate data to determine if the aircraft is at the desired point in space, at the desired speed or aceleration, and whether or not the aircraft is properly configured (power, trim, etc.) to produce the desired performance. For the benchmark task to be valid, it must require the IP to perform such complex functions.

Measurability. For the benchmark task to meet the criterion of measurability, it must lend itself to the taking of quantitative measures. This will help ensure that the display evaluation is objective rather than subjective. That is, the derived figure of merit for a given display must be based on how effectively or efficiently the information required by the IP has been displayed as opposed to how well the IP liked the display.

Implementability. As used herein, the criterion of implementability refers to the ease with which the benchmark task can be used in a laboratory setting for the evaluation of alternative displays. This requires that the source data for the generation of information to be displayed be in a format which, if not common to, is at least easily adaptable to present and anticipated display hardware.

Multi-Cockpit Monitoring. The establishment of a benchmark task suitable for use in the evaluation of displays to be used for multi-cockpit monitoring requires that the information presented be taken from maneuvers considered reasonable candidates for multi-cockpit instruction.

Benchmark Task Development

A review of the IP Job Analysis reported in Section III of this appendix reveals that the IP's prime function is to monitor. Furthermore, information relative to basic aircraft flight parameters is required during all phases of flight regardless of the procedure or maneuver being flown. While a wide variety of maneuvers of varying length and complexity could be used to generate the information which would satisfy the benchmark task criteria, five basic flight maneuvers, climb and level-off, descent and level-off, level turn, climbing turn, and descending turn were selected on the basis of their comprehensiveness, representativeness, and simplicity. Analysis of these maneuvers reveals that the transition and steady-state conditions could be strung together in a manner which would describe almost any flight maneuver. While this concept may have certain limits, the maneuvers selected are considered to generate the majority of IP information requirements relative to the monitoring of aircraft control performance. The IP information requirements generated by these maneuvers are representative of those found in most flight training situations and satisfy the criticality, frequency, and complexity criteria. The parameters used to define these maneuvers lend themselves to the collection of quantitative data as required by the measurability criterion. In view of the fact that the maneuvers are not very complex and can be adequately displayed through indications of five flight parameters, i.e., airspeed, attitude, altitude, vertical velocity, and heading, there should be very little problem developing source data to implement the benchmark task on a wide variety of displays. Furthermore, the maneuvers and the task of monitoring flight instruments are typical of what is expected to be encountered in a multicockpit monitoring situation.

In summary, the benchmark task developed for this effort consists of monitoring five flight parameters (airspeed, attitude, altitude, vertical velocity, and heading) during ten flight segments consisting of two repetitions of five basic flight maneuvers (climb and level-off, descent and level-off, level turn, climbing turn and descending turn). The manner in which the flight segments were developed and presented and the manner in which the benchmark task was performed and tested are covered in detail in Section VI of this Appendix.

V. PERFORMANCE MEASURES

The objective of this phase of the effort was to develop performance measures which would discriminate the relative effectiveness of alternative display formats and configurations. Display effectiveness is best defined as the ability of a display to impart desired information to an observer. In that there are no means to directly measure this ability, it was necessary to devise some means of determining how much displayed data had in fact been perceived by the observer. Since the IP cannot respond to something he has failed to notice, the most straightforward way to measure display effectiveness is to determine whether the information on the display was noted by the IP and, if so, how much of it was retained. Accordingly, the procedure developed to do this required subjects to observe displayed flight information generated by a series of short simulated flight segments and to respond to questions concerning the values of certain of the displayed flight parameters at specific points during the segment. This approach is desirable in that a response may be obtained regardless of the quality of flight or the observer's knowledge of such things as correct procedures or aircraft performance characteristics. The observer is not required to judge the goodness of what he has observed but merely to report that which has been observed.

On the basis of the IP information requirements determined during the IP task analysis (see Table G-2), we developed eight questions for each of the five basic maneuvers. The manner in which these questions were employed to collect data is discussed in detail in Section VI.

There was no clear way of establishing what limits should be set for scoring a response as "correct"; therefore, we examined the collected data and selected limits which would provide maximum sensitivity to the effects of various conditions. Since this was not an evaluation of displays but rather a search for a feasible means to evaluate such displays, this was considered to be both a proper and necessary manner in which to proceed.

In scoring responses to the questions on altitude or vertical velocity, a response in error greater than 500 feet was considered incorrect and scored zero, an error of less than 500 feet was considered correct and scored one. The choice of 500 feet as a cut off point was based on a first cut analysis of the raw data which indicated that 500 foot cut off point would provide a measure with good sensitivity to variability of performance. Similar rationale led to establish a five degree error limit for heading, roll, and pitch and a corresponding ten knot allowable margin for airspeed.

In the absence of sufficient data to establish statistically reliable response distributions, no attempt was made to give differential credit for more accurate responses.

In summary, the metric of display effectiveness used was an indirect measure based on the percentage of correct observer responses made to questions about displayed flight information, where the criteria for "correctness" were estimated by the investigators.

VI. DEMONSTRATION AND TEST PROCEDURE

Approach

As stated previously, the objective of this research was to develop a means of evaluating the relative effectiveness of candidate flight simulator instructor/operator station displays. The approach taken was to develop a benchmark task and performance measure such that when the benchmark task was performed using alternative displays and the performance measures applied, relative effectiveness of the displays could be determined. Toward this end, the benchmark task established was one which required an observer to view prerecorded flight information on a candidate display and to respond to questions about the displayed information.

General Discussion. To demonstrate the above approach and to test its feasibility, four test observers performed the benchmark task using both an analog flight instrument display and a CRT digital display. The test conducted was a first look at the feasibility of the benchmark task approach and as such did not produce sufficient data for rigorous statistical analysis. However, it was considered to be a reasonable compromise between a vigorously quantitative test and a purely subjective one.

Test Subjects. Four test subjects were used for this test. Three of the subjects were well qualified pilots with prior military flying, over 3,000 pilot hours, and experience as instructor pilots. Qualification of the fourth subject was limited to flying experience of about 40 hours of piloting a light plane under visual flight rules (VFR) conditions only. The rationale for including a subject with minimum experience was to gain some initial data on whether or not extensive prior experience using a standard instrument display might inhibit the experienced pilot's ability to work with a non-standard display format, viz., the CRT digital display, or otherwise bias the data in favor of the standard display. Presumably, the highly experienced pilot would have a relatively greater difficulty with the strange format than someone who was not overpracticed with the standard instrument display. The preliminary test thus represented a broad range of experience, and individual differences in ability on the task were accentuated by this selection.

Test Material. The displays representing the five maneuvers previously discussed constituted the test materials of the benchmark task. The two types of displays used were standard flight instruments and digital presentations on the CRT. The instrument panel had the airspeed indicator, the attitude indicator (artificial horizon), the vertical velocity indicator, heading indicator, and the altimeter. The arrangement of flight indications on the CRT was identical to the instrument panel. No other instruments in the instrument panel were activated. On the CRT, all of the indications were presented in digital form, white on black background. For pitch and roll information, the symbols "UP," "DN," "L," and "R" appeared to the left of the digits as appropriate.

The CRT was located just above the instrument panel at the same viewing distance as the analog instruments. The information was displayed simultaneously on the instruments and CRT. The CRT unit had a cover which could be positioned over the tube face when the information was to be viewed on the instruments. Instruments were likewise covered when the CRT was exposed.

Test Facility. The experiment utilized a general purpose simulation facility, multi-mission simulator (MMS) developed for conducting research requiring man-in-the-loop simulation.

Figure 6-2 is a block diagram showing the major elements of the

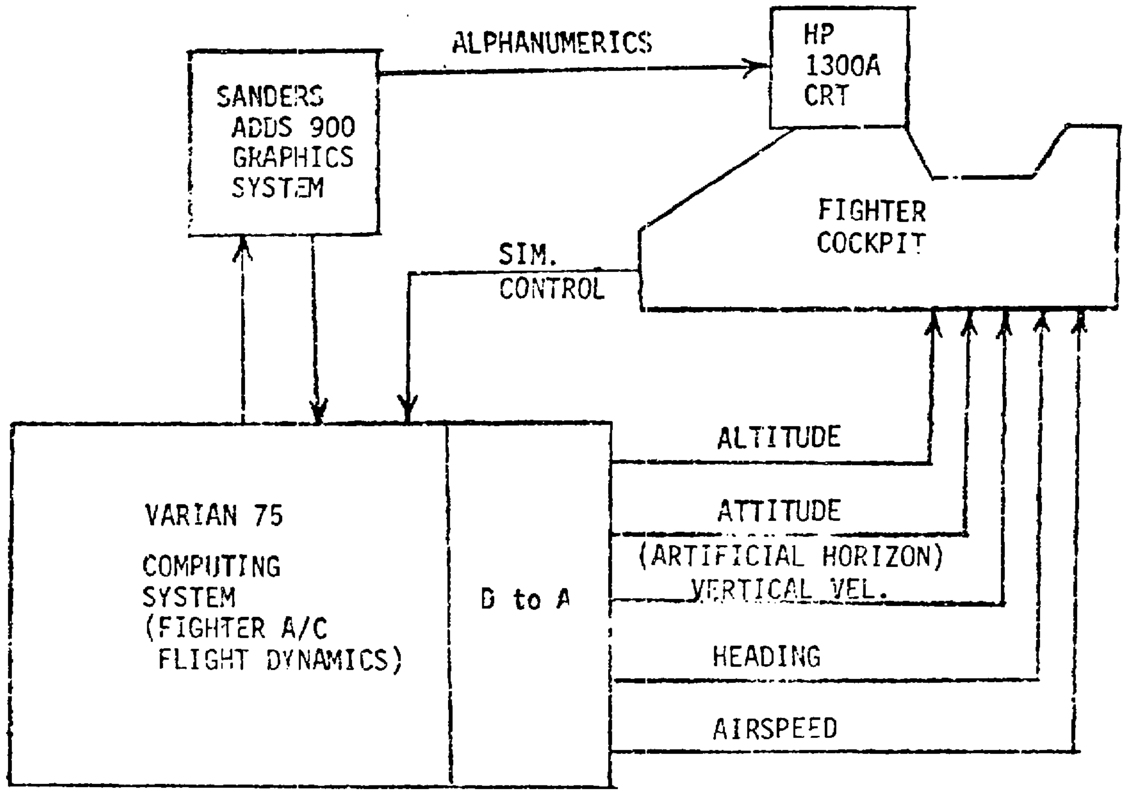


Figure G-2. Major Elements of Flight Simulator flight simulator utilized. "CANNED" missions were provided by flying closed-loop man-in-the-loop mission segments and recording the pilot input commands to the digital computer.

The Varian 73 computing system solves the equations of motion of a representative fighter aircraft and provides simultaneous display inputs to a Sanders Adds 900 graphics system and to the flight instruments in the simulated fighter cab.

The Sanders graphics system provides digital information for display on a 10-inch Hewlett-Packard 1300A CRT. The digital information displayed on the CRT represents the same type of information provided to the analog flight instruments (altitude, attitude, and heading). Simultaneous information was provided to both the CRT and the flight instruments. Special masks were used over the displays which allowed the test subject to view either the analog flight instruments or the digital display on the CRT.

Only the rear station of a two station cockpit was utilized, and the Hewlett-Packard CRT was mounted directly above the rear station flight instrument panel. The arrangement of the analog flight instruments was as shown in Figure G-3.

Existing software was used which had been developed for an Advanced Tactical Fighter Simulation. This program was made up of standard modules and aircraft-unique modules. There were six standard modules

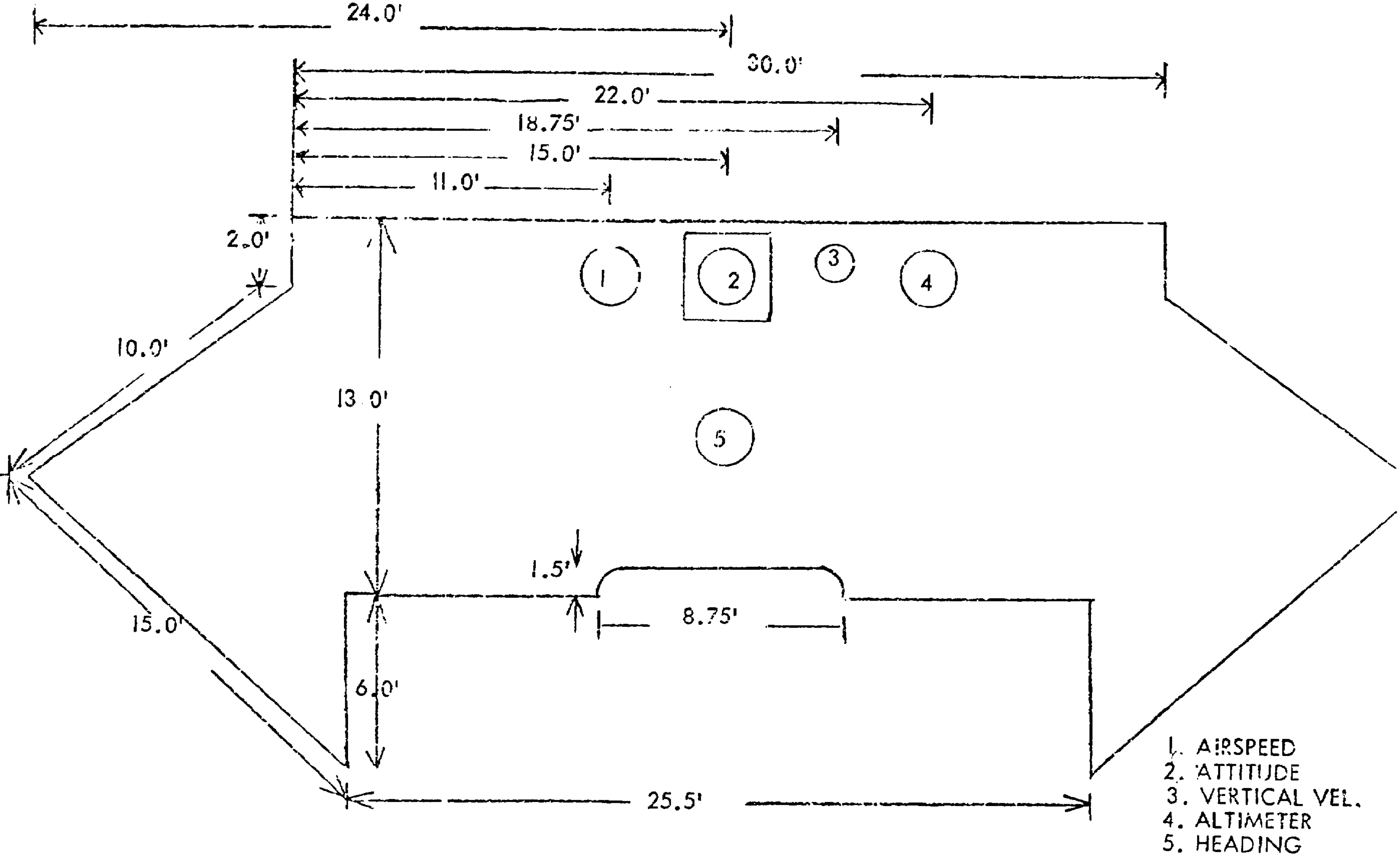


Figure G-3. Arrangement of Analog Instruments in Crew Station used in this simulation. Four of those (transformation matrix, equations of motion, integration, and aircraft related quantities) provided the capability to determine the aircraft trajectory, orientation, and dynamic response. The remaining two standard modules (atmosphere and winds) provided the natural environment surrounding the aircraft. The equipment used included two Varian 75 minicomputers with 48K 16-bit words of memory each. One computer was used to drive the graphics, and the second was used to simulate the fighter.

Test Procedure. The five maneuvers were flown four times each two duplicates of each maneuver on each of the two display formats, for a total of twenty flight segments. Prior to presenting these to the test subjects, the flight segments were randomized. Eight questions were generated (Appendix I) for each of the five maneuvers and these were also randomized. The randomized displays, questions, and flight segments are shown in Appendix J. A randomized set of four questions was given after the first replication of a given maneuver shown on a display, and the remaining four were given after the second replication of the same maneuver shown on the same display. Specific test procedures for each of the subjects were as follows:

The subject was seated in the cockpit of the MMS with the experimenter sitting beside him outside the cockpit. He was given written briefing material to read consisting of general instructions to the effect that all the participant was required to do was to observe indications as directed on either the analog instruments or on the CRT.

After the subject finished reading the briefing instructions, he was shown how to position a special mask to occlude the indications on the display which he was not to use, and how to expose those he was to use. (During the test, the experimenter ensured that the proper display was indeed occluded.) The observer was then given a typed set of instructions regarding his task (Appendix D). These were intended to prepare him for the kinds of questions he would be asked. The subject was then presented with a randomized flight segment on one of the two displays for a duration of 1-3 minutes (depending on the particular flight segment). At the conclusion of the presentation, he was asked four pre-randomized questions by the experimenter. This procedure was repeated for each of the 20 flight segments, with a five-minute break after 10 flight segments. The session for each subject was completed in approximately one and a half hours including the break. The subjects had no practice on either of the test displays prior to the actual testing.

After all four subjects had completed the experiment, they were debriefed in an informal, unstructured manner. The results of this debriefing are treated in Section VII. (Results and Discussions).

VII. RESULTS AND DISCUSSION

The test conducted was concerned primarily with demonstrating the feasibility of the benchmark task approach for the evaluation of displays to be used at a remote IUS. Since insufficient data were taken to perform statistical tests of differences, the only "analysis" performed on the data was the summing of correct responses across the several factors.

Overall performance (all subjects and all flight segments) was derived by summing all the correct responses by four subjects to the questions about the twenty flight segments viewed on two displays, and dividing that sum by the total number of questions asked. The resultant outcome of this calculation of 66% was a fortunate one in that it is in a range which allows for variability in both directions. Obviously, a mean percentage of control responses close to zero or one hundred would have forced the distribution to be skewed and would have indicated that the questions were either too difficult or too easy.

The major factor in the test was display type. We expected that the standard instruments would prove more efficient for use by those already familiar with this type of display than the all-digital display on the CRT. The results support this expectation in direction but not in magnitude of the difference, 68% correct for instruments and 64% for CRT. This small difference would not likely be statistically significant, considering the relatively large variability due to other factors. It should be noted, however, that had the method of scoring been more sensitive, e.g., differential rather than binary, the magnitude of the difference might be more substantial.

As shown in Table G-5, the range in scores (80% to 55%) due to pilct

Table G-5. Data Summary by Display, Maneuver, and Pilot

	No. of Correct Responses											
	Instrument						CRT					
Pilots	A	B	C	D	Σ	%	A	B	C	D	Σ	%
<u>Maneuver</u>												
Climb	8	4	7	8	26	81	6	5	6	7	24	75
Level Turn	7	3	6	4	20	62	5	4	7	7	23	72
Descent	5	5	7	6	23	72	7	4	6	7	24	75
Climbing Turn	3	4	6	3	16	50	4	3	4	3	14	44
Descending Turn	6	6	6	5	23	72	6	2	4	6	18	56
Σ	29	22	32	26	108		28	18	27	30	103	
%	72	55	80	65	68		70	45	68	75	64	

differences with instruments is 25 percentage points, while with the CRT, it is 30 percentage points 75% and 45%). This is six to seven times the range in scores due to display differences 68% and 64%. If we compare correct responses for individual subjects, we see that Pilot A distributed his correct responses nearly evenly between the two displays, Pilots B and C gave 55% and 54% of their correct responses, respectively, to instruments, and Pilot D gave only 46% of his correct responses to instruments. Pilots A, B, and D have many hours of experience looking at instruments while Pilot C has only a few and all of Pilot C's flying has been VFR. Thus, the experience factor does not seem to account for the differences among pilots in this study.

We might note further that less experienced Pilot C not only was the top performer with instruments but also showed the largest difference in favor of instruments. One might have thought this pilot would have performed relatively better with the CRT display than would the pilots with long experience using instruments. Pilot C also had the best performance overall, which also was a finding not predicted. Although looking for "reasons" behind the observed differences among subjects is merely speculative, one is tempted to suggest that the superior performance of Pilot C may be due to youth more than anything else. Profering an alternate potential explanation, it might be suggested that a lot of experience leads pilots to be more selective in their monitoring of flight indications.

Comparing display formats at the level of the individual maneuvers, we observe differences of an inconsistent nature. In two of the five maneuvers, the total percent correct responses over all subjects is numerically higher for the CRT display. No inferences are drawn with regard to the confidence to be placed in such an observation (as with other observations in this discussion) but, on the other hand, it would weaken any tendency to take seriously the overall performance difference in favor of instruments.

As to the differences in correct responses for the various maneuvers, the data sorted in this way are very hard to interpret. The eight questions for each maneuver were not generated with a requirement that they be of equal difficulty among maneuvers. Not even the simplicity of the maneuver is reflected in any consistent way in the responses. Why should a climbing turn be more difficult to monitor than a descending turn? But then, we have no reason to assume equivalence in the conditions present in the test.

When the data are summarized by maneuver and flight indication (Appendix L), the numbers in individual cells are too small to discuss, but in a larger study, one may be able to place flight indications in order of importance and monitoring difficulty. Since the same flights were seen where instruments were monitored as when the indications were presented on the CRT, and, similarly, the same questions were asked, we may assume that where differences between the two displays are large, there is a strong suggestion that the observed difference would hold up in a larger study. For example, questions about altitude were answered correctly 78% of the time when the information was read from the instruments out only 50% of the time from the CRT. Roll also was read more often correctly (and remembered) with the instruments, 90% as opposed to 60% of the CRT. On the other hand, pitch questions were scored correct only 56% of the time with instruments, but 81% with the CRT. The other three flight indications show much smaller differences between displays.

One would expect to see learning over the course of the twenty flight segments because of the unusual character of the task. As shown in Appendix M, two of the pilots (B and C) show some evidence of learning based on the number of correct responses in each quarter of the questions. However, pilots A and D shown no learning trends.

After all pilot observers had completed their participation in the test, they were given an opportunity to express their opinion about the techniques used. They indicated that the task was a difficult one, primarily because they did not know what the maneuver was to be or what questions they would be asked. They pointed out that in flying to an artificial horizon they are less interested in the specific values if the airplane is in the attitude they intend it to be in, whereas the CRT display required them to read the digital presentation. The least experienced pilot missed the "seat of the pants" feedback experienced in a light airplane.

When asked about the task of an instructor pilot as represented in the development of better displays for an IOS, they pointed out the individualistic approach to the use of instrument indications, suggesting that one arrangement might not best suit all IPs. They also felt that the interaction between IP and student must be tailored to the situation and the personalities of both. Should the IP be simply a checker of student activity? Should he adopt a tutorial attitude? Should he behave like a martinet? Should he concentrate on building the student's confidence? No single answer can be given.

VIII. CONCLUSIONS AND RECOMMENDATIONS

While the scope of this program did not permit quantitative scaling of responses, it did allow for quantitative comparison among displays. Although the evidence is not unequivocal, the test conducted demonstrated that the approach used is feasible for the evaluation of displays and could prove useful in the development of design specifications for displays to be used at a remote IOS.

If more data could be collected and the questions and responses refined, the development of an "instructor pilot standard observer" representing average monitoring abilities and tendencies would be possible. With the collection of sufficient data, standardized scores could be computed which would permit future evaluations to be made against a scale having the necessary statistical properties.

A problem associated with the approach used is that the IP quite often looks at the flight indications as a group rather than a set of individual indications. That is, if the combination of indications in a given instance is correct, the IP may not take particular note of each specific value, but merely satisfy himself that indications are correct in aggregate. Should this occur, although the display performed its function of providing the information, the observer may not be able to respond to a question relative to its value at that point in the maneuver. However, careful analysis, to ensure that the questions asked pertain to information considered important at a certain point in the maneuver, should minimize this problem.

While every effort was made to develop a benchmark task applicable to the broadest possible range of IP monitoring functions, the scope of this effort did not permit development of maneuver segments which would generate all of the IP information requirements. Additional work is required to determine what all of the IP information requirements are.

The present study has shown that one should expect a wide variation in the ability to monitor instruments, or other displays, even for highly experienced pilots. This may mean that IPs, if more carefully selected and/or trained, could show greater efficiency in their monitoring performance.

The benchmark task approach quite obviously should undergo considerable refinement before its utility can be validated. Extension of the present effort should include thorough study of the training situations of interest. Perhaps more important, future studies need to explore the use of more sensitive measures of performance on the benchmark task. Instructor tasks and the information needed to perform them should be researched more thoroughly. Meaningful alternative approaches to display techniques could then be compared for effectiveness and cost.

While this effort was directed towards developing a means of evaluating rather than of designing displays, the work evoked considerable thought and discussion relative to design. This information is summarized in the following paragraphs.

An effort should be conducted relative to optimizing the display format according to the type of information. Pointers and dials may remain best for certain indications but most likely not for all the indications they are used for the typical cockpit. Good inspection of trends, for example would certainly be easier with a display that showed more than the present status, e.g., a simple graph of flight status vs. time.

The type and format of information presentation is a significant factor. For example, an altitude profile displayed on a CRT may permit an IP to keep track of a student with less effort. On the other hand, a single digital indication may be sufficient for the recording of extreme values for something like maximum G force or exhaust gas temperature.

Another way to enhance the capacity of a display and the speed of response or retention of details by the IP is the use of a color CRT. Color may be used to separate types of indications more clearly or it may be used to show the severity of a condition, e.g., red for low fuel reserves or angles of attack close to stall conditions.

The constraints of the cockpit environment should not be retained for the IOS if some other display technique will permit the IP to perform his task more easily. If the IP does not have to monitor all instruments, he shouldn't have them cluttering up the IOS display area. Furthermore, if the display format enhances those indications requiring his attention, the IP may be able to monitor several students at the same time.

A program of research in IOS displays from the standpoint of human resources should include a strong emphasis in visual perceptual abilities. Differential sensitivity associated with retinal location are particularly important in a monitoring task since the relatively low acuity in the periphery means that some way is needed to bring the observer to fixate the indication of importance with central high acuity vision. (A flashing light has been successfully used for this.)

In summary, the benchmark task approach to IOS display evaluation is considered feasible and further refinement and investigation is recommended.

BIBLIOGRAPHY FOR APPENDIX G

Alba, E. A time-based methodology for assessment of individualized performance. Washington, D.C.: U.S. HEW, April 1972.

**Arntz, N.J. Methodology for the definition of a space vehicle display system. Technical Paper Published in the Society for Information Display, 1971.

Benenati, A.T., Hull, R., Korbow, N., & Nieradtowski, W. Development of an automatic monitoring system for flight simulators. AMRL-TDR-62-47, AD-283 008. Wright-Patterson AFB, OH: May 1962.

**Blaiwes, A.S., et. al. Transfer of training and measurement of training effectiveness. Human Factors, 1973, 15(6).

Bradley, A. Experimental design for quantitative measurement and evaluation of pilot performance on cockpit displays. NADC, (AD-833-432L) June 1961.

*Brecke, F., & Reiser, R. Critical components of flight instruction as perceived by instr -- Etc. (AD-758-227). Arizona State University Tempe Instructional Resources Laboratory, November 1972.

*Brooker, S.L. Instructor console instrument simulation. (AD-731-759). HTEC, September 1971.

Caro, P.W. Aircraft simulators and pilot training. (AD-A002-614). Alexandria, VA: Human Resources Research Organization, 1973.

Cogan, E.A., & Lyons, J.D. Frameworks for measurement and quality control. Hum RRO Professional Paper 11-12, July 1972.

**Connelly, E.M., Bourne, F.J., Loental, D.G., & Knoop, P.A. Computer-aided techniques for providing operator performance measures. AFHRL-TR-74-87. AD-A014 330. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, December 1974.

**Connelly, E.M., Schuler, A.P., & Knoop, P.A. Study of adaptive mathematical models for deriving automated pilot performance measurement techniques: Model development. AFHRL-TR-69-7(I). AD-704 597. Wright-Patterson AFB, OH: Training Research Division, Air Force Human Resources Laboratory, October 1969.

Cyrus, M.L., & Woodruff, R.R. Grading system for T-4G simulator students in UPT studies. AFHRL-TR-74-91. AD-A004 605. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, November 1974.

* and ** Reports identified as most applicable and reviewed in detail.
** Reports reviewed in greatest detail.

APPENDIX H: LITERATURE SURVEY ABSTRACTS

AUTHOR TITLE AND NUMBER	TECHNOLOGY CATEGORY: MAN SYSTEMS	[illegible]	DISPLAY SYSTEMS	[illegible]	PERFORMANCE [illegible]	ABSTRACT	PRIMARY TECHNIQUES USED: ANALYSIS	COMPUTER [illegible]	LABORATORY TESTS	SIMULATOR TESTS	FIELD TESTS	SALIENT PARAMETERS: INPUTS	OUTPUTS	SPECIAL CAPABILITIES	LIMITATIONS	[illegible]
[illegible] ET AL [illegible] FEB. [illegible]	X	X	X	X		OBJECTIVE OF THE STUDY IS TO DEVELOP MODULAR APPROACHES TO IMPLEMENTING AUTOMATED INSTRUCTION AND PERFORMANCE MONITORING TRAINING CAPABILITIES. [illegible] INDIVIDUAL TRAINING CAPABILITIES ARE CONSIDERED. TWO INTEGRATED SYSTEMS THAT INCLUDE [illegible] 8 AREAS REPRESENTING THE SIMPLEST TO HIGHLY COMPLEX COMPONENTS ARE DESIGNED.	X	X				GENERAL	GENERAL	FLEXIBILITY OF APPROACHES WITH VARYING DEGREES OF [illegible] PLEXITY AND COSTS [illegible]	THE SYSTEM IS [illegible]	[illegible]
[illegible] ET AL [illegible] VOL. 14 NO. 6	X		X	X		A LABORATORY EXPERIMENT ATTEMPTING TO EQUATE TASK DIFFICULTY ACROSS SENSE MODES ON AN INDIVIDUAL BASIS. SENSE MODES USED ARE AN AUDITORY TONE AND A RED LIGHT. RESULTS INDICATE A COMMON "VIGILANCE FACTOR"	X		X			SENSE MODE	DECTION TIME		DISPLAYS USED ARE NOT OPT.	[illegible]
[illegible], A. F. ET AL EFFECTS OF VALUE [illegible] MULTI-CHANNEL DISPLAYS [illegible] VOL. 11, NO. 4	X		X	X	X	TO DETERMINE THE EFFECT OF DIFFERENTIAL PAYOFF VALUES ON OPERATOR PERFORMANCE IN MONITORING MULTI-CHANNEL DISPLAYED INFORMATION. TWO DISPLAY FORMATS-CONCENTRATED AND DIFFUSED ARE USED. INFORMATION EXPOSURE TIME WAS CONTROLLED. RESULTS INDICATE THAT SUBJECTS PAID MORE ATTENTION TO HIGH VALUE DISPLAYS. SELECTIVITY WAS ALSO PROPORTIONAL TO OPERATOR LOAD. ALSO REHEARSED TIME INCREASES MONITORING ABILITY. CONCENTRATED FORMAT [illegible] EFFECT.	X		X			NO. OF CHANNELS EXPOSE TIME DISPLAY FORMAT	1)NO. OF CORRECT RESPONSES 2)NO. OF ERRORS		1)GROUP OF SUBJECTS WERE COMPETING FOR CASH [illegible] 2)INCORRECT RESPONSES WERE NOT [illegible] 3)SPEED OF RESPONSES NOT COUNTED	APPLICABLE TO MULTI[illegible] MONITORING

AUTHOR TITLE I.D NUMBER	TECHNOLOGY CATEGORY: M/M SYSTEMS	[illegible] LOAD	[illegible] SYSTEMS	[illegible]	[illegible]	ABSTRACT	PRIMARY TECHNIQUES USED: ANALYSIS	COMPUTER [illegible]	LABORATORY TESTS	SIMULATOR TESTS	FIELD TESTS	SALIENT PARAMETERS: INPUTS	OUTPUTS	SPECIAL CAPABILITIES	LIMITATIONS	APPLICATIONS
CONNELLY, E. M., ET AL [illegible]	X			X	X	DEVELOPMENT OF AN AUTOMATED PERFORMANCE MEASUREMENT PROCESSOR THAT ACCEPTS DEMONSTRATION DATA REPRESENTING VARIOUS LEVELS OF PERFORMANCE, UNDER USER CONTROL, TO PROVIDE CANDIDATE PERFORMANCE MEASURES. IT ALSO CONDUCTS VALIDATION TESTS AND ORDERS CANDIDATE MEASURES ACCORDING TO [illegible] MEASUREMENT VALUE	X	X				• DEMO DATA • SPECIFIC INSTRUCTIONS	• PERF. CRITERIA • DEVIATIONS FROM CRITERIA • SUMMARY DATA	STANDARDIZE COMPUTER ROUTINES FOR PROCESSING DEMO DATA	PERFORMANCE MEASURES OBTAINED ARE CRITICAL SENSITIVE TO DEMO. DATA	SOME PERFORMANCE MEASURES [illegible]
[illegible]	X	X	X			A METHODOLOGY DESIGNED FOR A SYSTEMS APPROACH TO THE DEFINITION OF A DISPLAY SYSTEM FOR SPACE VEHICLES. THREE FUNCTIONAL ALTERNATES OF INDIVIDUAL, TIME-SHARED AND INTEGRATED [illegible] DISPLAYS [illegible] ARE IDENTIFIED. THE [illegible] CONSISTS OF 4 STEPS: REQUIREMENT DEFINITION, SCREENING, FUNCTION-ALTERNATE TRADES AND DESIGN-APPROACH TRADE.	X					N/A	N/A	AN INTEGRATED METHODOLOGY INCORPORATING ALL BASIC ASPECTS OF MISSION-DISPLAY-OPERATOR M/M RELATIONSHIP	NOT SUFFICIENT IN DETAIL [illegible] METRIC ANALYSIS	[illegible]
[illegible]	X	X	X		X	RECOMMENDATIONS FOR THE DESIGN CONTENT AND ARRANGEMENT OF THE A3J-1 INSTRUCTOR'S CONSOLE BASED IN TASK AND BEHAVIORAL REQUIREMENTS OF THE TRAINEES IN PERFORMING A BOMBING MISSION.	X					NONE	NONE			
[illegible]	X	X	X	X	X	A CHRONOLOGICAL PROGRESS REVIEW OF THE PAST 3 DECADES IN INSTRUCTOR-STATION DESIGN IS PRESENTED. RECENT DEVELOPMENTS IN INSTRUCTIONAL CAPABILITIES IN THE AREA COMPUTER IMPACT, ADAPTIVE SIMULATION, PERFORMANCE INVENTORY AND IP STATION DESIGN CONFIGURATIONS ARE DISCUSSED AND REFERENCED PROGRAMS IDENTIFIED.	X					—	—	PROVIDES A GOOD REVIEW OF THE SOA TECHNOLOGY AVAILABILITY IN IP STATION D DESIGN/DEVELOPMENT	NO EMPIRICAL TEST DATA ARE PRESENTED.	[illegible]

TITLE AND NUMBER	TECHNOLOGY CATEGORY: M/M SYSTEMS	[illegible]	DISPLAY SYSTEMS	PERF. MEASUREMENT	[illegible]	ABSTRACT	PRIMARY TECHNIQUES USED: ANALYSIS	COMPUTER PROGRAMS	LABORATORY TESTS	SIMULATOR TESTS	FIELD TESTS	SALIENT PARAMETERS: INPUTS	OUTPUTS	SPECIAL CAPABILITIES	LIMITATIONS	APPLICATIONS
[illegible], E. M. ET AL. [illegible]					X	A SET OF COMPUTER MODELS DEVELOPED TO EXAMINE PERFORMANCE DATA CORRESPONDING TO KNOWN SKILL LEVELS. A METHOD IS ALSO DEVELOPED FOR [illegible] EVALUATION. 3 TYPES OF MODELS TO DERIVE: 1) STATE-TRANSFER MEASURES, 2) ABSOLUTE MEASURES, AND 3) RELATIVE MEASURES	X	X				BASELINE STATE/PERFORMANCE DATA	PROCESSED DATA CORRESPONDING TO BASELINE INPUTS	1) DISCRETE [illegible] MODELING-DO NOT REQUIRE EXCESSIVE CORE STORAGE 2) ON LINE REGRESSION ANALYSIS	1) NO ACTUAL FLIGHT PERFORMANCE DATA WAS USED 2) NO SPECIFIC [illegible] ARE [illegible]	[illegible]
[illegible], H. H. [illegible] VOL. 15, #6	X	X			X	A GROSS SURVEY OF TRANSFER OF TRAINING STUDIES FOR THE PERIOD FROM 1950-72. 3 MAJOR CATEGORIES WERE CONSIDERED: FIXED WING, ROTARY WING SYSTEMS AND MOTION SYSTEMS. CURSORY BUT [illegible] DESCRIPTIONS WERE GIVEN TO EXPERIMENTAL CONDITIONS, DESIGN AND ASSOCIATED PROBLEM AREAS.	X					—	—	1) GOOD DESCRIPTION OF A VARIETY OF PROBLEM AREAS DERIVED AS A RESULT OF OPERATIONAL CONSTRAINTS, M/M INTERFACES AND TECHNOLOGY INADEQUACIES	NO QUANTIFIABLE RESULTING DATA WERE PRESENTED.	[illegible]
[illegible], A. S. ET AL. [illegible] TRAINING EFFECT. [illegible] VOL. 15, [illegible]	X			X	X	EXPERIMENTAL AND DESCRIPTIVE MODELS, APPLICABLE TO CONDUCT RESEARCH TO DEFINE SIMULATOR TRAINING ARE DISCUSSED. DESIRABLE FEATURES FOR AN APPLIED RESEARCH PROGRAM APPLYING THE TRANSFER OF TRAINING METHOD ARE IDENTIFIED TOGETHER WITH ASSOCIATED PROBLEMS AND CANDIDATE SOLUTIONS.	X					GENERALIZED CATEGORIES OF INDEPENDENT VARIABLES	TRAINING TIME	1) GOOD OVERVIEW OF PROBLEMS ASSOCIATED WITH EXPERIMENTAL DESIGNS THAT CONTRIBUTE TO DIFFERENCES OF RESULTS OBTAINED FROM OPERATIONAL SETTINGS	NO DETAIL APPROACH IS DEFINED.	[illegible] OF THE [illegible] EVALUATION

ABSTRACTS OF RELEVANT LITERATURE, Sheet 4 of 4

AUTHOR TITLE AND NUMBER	TECHNOLOGY CATEGORY					ABSTRACT	PRIMARY TECHNIQUES USED					SALIENT PARAMETERS		SPECIAL CAPABILITIES	LIMITATIONS	APPLICATIONS
	M/M SYSTEMS	TASK/WORKLOAD	CONTROL SYSTEMS	[illegible]	PERFORMANCE EVALUATION		ANALYSIS	COMPUTER PROGRAMS	LABORATORY TESTS	SIMULATOR TESTS	FIELD TESTS	INPUTS	OUTPUTS			
ZIFCY, D. R. ET AL [illegible] AFFDL-TR-70-79 VOL. I, II, III & IV [illegible] 1973)	X	X	X	X	X	DEVELOPMENT OF A TACTICAL FIGHTER COCKPIT CONCEPT FOR USE IN THE 1975-80 TIME PERIOD. PRIMARY EMPHASIS WAS GIVEN TO ALLOW THE PILOT TO HAVE MAXIMUM FREEDOM FOR ON-LINE WEAPON SYSTEM MANAGEMENT. VOL I IS AS DEDICATED TO THE [illegible] OF SYSTEM CONCEPTS WHEREBY THE [illegible] OF THE TYPES OF CONTROLS AND DISPLAYS WAS EXTENSIVELY [illegible]. VOL. II WAS TO [illegible] SYSTEMS ANALYSIS [illegible] A SYSTEMS APPROACH WAS [illegible] TO THE DEVELOPMENT OF AN ADVANCED COCKPIT THAT SIGNIFICANTLY [illegible] THE PILOT WORKLOAD AND [illegible] EFFECTIVENESS. VOL. III WAS THE DEGRADE MODE [illegible] TO [illegible] THE CAPABILITY TO SAFELY [illegible] AFTER SUSTAINING [illegible] TO AN [illegible] LEVEL. VOL. IV WAS THE [illegible] PROGRAM [illegible] PILOT ACCEPTABILITY OF THE ENERGY MANAGEMENT AND DISPLAY CONCEPTS.	X			X		—	—	COMPUTERIZED PROGRAM TO ASSESS THE PILOT WORKLOAD AS A FUNCTIONAL OF MISSION/OPER. CHARACTERISTICS	—	SOME ELECTRONIC DISPLAY [illegible] ARE [illegible] TO INSTRUCTOR STATION DISPLAYS

APPENDIX I: TEST QUESTIONS

CLIMB AND LEVEL OFF

C1 At what altitude did the aircraft start to nose over to level flight?

C-2 What was the highest altitude reached?

C-3 At level off, what was the heading?

C-4 What was the vertical velocity just before the start of level off?

C-5 What was the highest airspeed in the climb?

C-6 What was the roll angle in the transition from climb to level flight?

C-7 What was the maximum pitch up angle?

C-8 What heading changes were there, if any?

Correct Answers

Question	Flight Segment Number 1	2	3	4	Unit
C-1	19670	19880	19500	19700	ft.
C-2	19830	20010	19940	19920	ft.
C-3	0	0	0	1	degrees
C-4	5600	5800	5800	3100	ft/min.
C-5	360	680	365	350	knots
C-6	0	0	0	1	degrees
C-7	23	29	15	12	degrees
C-8	0	0	0	0	degrees

LEVEL TURN

LT-9 What was the maximum roll angle?

LT-10 What was the minimum altitude during the turn?

LT-11 What was the maximum altitude during the turn?

LT-12 At what heading did the roll out begin?

LT-13 What was the airspeed just before roll-in?

LT-14 What was the airspeed just after roll out?

LT-15 What was the maximum airspeed in the turn?

LT-16 What was the minimum airspeed in the turn?

Correct Answers

	Flight Segment Number				
Question	5	6	7	8	Unit
LT-9	34	32	28	33	degrees
LT-10	19810	20030	19710	19690	ft.
LT-11	20400	20950	20100	20580	ft.
LT-12	131	176	92	263	degrees
LT-13	280	255	270	275	knots
LT-14	275	245	270	265	knots
LT-15	280	260	295	290	knots
LT-16	275	235	265	270	knots

DESCENT

D-17	What was the pitch angle when the nose was lowest?
D-18	What was the airspeed just before the aircraft nosed over for the descent?
D-19	What was the airspeed just after level-off?
D-20	What was the altitude prior to the descent?
D-21	What was the altitude after the descent?
D-22	What was the initial heading?
D-23	What was the heading after level off?
D-24	What was the maximum roll angle (left or right)?

Correct Answers

Question	Flight Segment Number 9	10	11	12	Unit
D-17	-1	-7	-[illegible]	-6	degrees
D-18	310	285	295	290	knots
D-19	315	300	285	295	knots
D-20	20000	20220	20130	20240	ft.
D-21	15370	15100	15490	15170	ft.
D-22	0	0	0	0	degrees
D-23	0	0	2	0	degrees
D-24	0	0	2R	11R	degrees

CLIMBING TURN

CT-25	What was the airspeed just after roll out?
CT-26	At what heading did the roll out begin?
CT-27	At what heading did the roll out begin?
CT-28	What was the maximum pitch-up angle?
CT-29	What was the highest airspeed in the climb?
CT-30	What was the vertical velocity just before start of level off?
CT-31	At level off, what was the heading?
CT-32	At what altitude did the aircraft start to nose over to level flight?

Correct Answers

Question	Flight Segment Number 13	14	15	16	Unit
CT-25	345	255	335	400	knots
CT-26	126	122	107	260	degrees
CT-27	40	27	29	38	degrees
CT-28	9	19	11	16	degrees
CT-29	350	270	345	390	knots
CT-30	3050	4000	4300	4950	ft/min.
CT-31	127	122	107	262	degrees
CT-32	19750	19800	20140	20140	ft.

DESCENDING TURN

DT-33 At what heading did the roll out begin?

DT-34 What was the pitch angle when the nose was lowest?

DT-35 What was the airspeed just before the aircraft nosed over for the descent?

DT-36 What was the airspeed just after level-off?

DT-37 What was the altitude prior to the descent?

DT-38 What was the altitude after the descent and level-off?

DT-39 What was the initial heading?

DT-40 What was the maximum roll angle (left or right)?

Correct Answers

	Flight Segment Number				
Question	17	18	19	20	Unit
DT-33	216	167	84	262	degrees
DT-34	-1	-5	-4	-5	degrees
DT-35	300	295	300	300	knots
DT-36	295	300	350	315	knots
DT-37	20000	20320	19890	20000	ft.
DT-38	15520	13360	15230	15610	ft.
DT-39	0	0	0	0	degrees
DT-40	39L	47R	32R	32L	degrees

Pilot A

	Maneuver	Flight Segment	Display	Question	Reported	Indicated
1)	LT	8	CRT	10	?*	19,690 ft
				16	245	270 kt
				11	20,000	20,580 ft
				15	285	290 kt
				Correct = 1		
2)	CT	14	CRT	29	225	270 kt
				28	14	19°
				30	4,000	4,000 ft/min
				25	225	255 kt
				Correct = 2		
3)	DT	18	CRT	37	20,000	20,320 ft
				36	300	300 kt
				38	15,000	13,360 ft
				33	165	167°
				Correct = 3		
4)	CT	13	inst.	30	4,000	3,050 ft/min
				28	?*	9°
				26	115	126°
				31	125	127°
				Correct = 1		
5)	LT	5	inst.	14	280	275 kt
				12	?*	131°
				10	19,900	19,810 ft
				15	280	280 kt
				Correct = 3		
6)	D	9	inst.	22	0	0°
				20	?*	20,000 ft
				18	310	310 kt
				23	0	0°
				Correct = 3		
7)	C	1	inst.	6	0	0°
				4	5,000	5,000 ft/min
				2	19,900	19,830 ft
				7	20	23°
				Correct = 3		
8)	C	4	CRT	2	19,900	19,920 ft
				8	none	none
				3	0	1°
				7	10	12°
				Correct = 4		

* Indicates the response "I don't know."

	Maneuver	Flight Segment	Display	Question	Reported	Indicated
9)	D	12	CRT	18	300	290 kt
				24	6	11°R
				19	325	295 kt
				23	0	0°
				Correct = 3		
10)	D	10	CRT	21	15,000	15,100 ft
				20	20,000	20,220 ft
				22	0	0°
				17	-7	-7°
				Correct = 4		
11)	D	11	inst.	24	3	2°
				19	300	285 kt
				21	15,500	15,490 ft
				17	?*	-7°
				Correct = 2		
12)	DT	20	CRT	34	-2	-5°
				40	25	32°
				35	300	300 kt
				39	0	0°
				Correct = 3		
13)	DT	19	inst.	40	29	32°
				35	300	300 kt
				37	20,000	19,890 ft
				33	?*	84°
				Correct = 3		
14)	CT	15	inst.	32	19,500	20,140 ft
				27	25	29°
				29	360	345 kt
				25	340	335 kt
				Correct = 2		
15)	LT	7	inst.	16	270	265 kt
				11	20,250	20,100 ft
				13	280	270 kt
				9	28-30	28°
				Correct = 4		
16)	C	2	CRT	5	615	680 kt
				4	5,800	5,800 ft/min
				6	0	0°
				1	?*	19,880 ft
				Correct = 2		

* Indicates the response "I don't know."

	Maneuver	Flight Segment	Display	Question	Reported	Indicated
17)	CT	16	CRT	26	?*	260°
				32	19,800	20,740 ft
				27	33	38°
				31	260	262°
				Correct = 2		
18)	DT	17	inst.	38	15,500	15,520 ft
				36	300	295 kt
				34	?*	-1°
				39	0	0°
				Correct = 3		
19)	C	3	inst.	8	+4	none
				3	4	0°
				1	19,500	19,600 ft
				5	370	365 kt
				Correct = 4		
20)	LT	6	CRT	13	245	255 kt
				12	176	176°
				14	250	245 kt
				9	29	32°
				Correct = 4		

Pilot B

	Maneuver	Flight Segment	Display	Question	Reported	Indicated
1)	D	11	CRT	22	0	0°
				23	4	2°
				18	390	295 kt
				24	4	2°
				Correct = 3		
2)	LT	6	inst.	13	280	255 kt
				14	280	245 kt
				15	280	260 kt
				10	20,300	20,030 ft
				Correct = 1		
3)	LT	7	CRT	14	270	270 kt
				15	295	295 kt
				10	19,500	19,710 ft
				16	270	265 kt
				Correct = 4		
4)	DT	19	CRT	38	19,300	15,230 ft
				39	?*	0°
				34	-15	-4°
				40	25	32°
				Correct = 0		
5)	D	9	CRT	19	340	315 kt
				21	19,300	15,370 ft
				17	-1	-1°
				20	24,000	20,000 ft
				Correct = 1		
6)	DT	17	CRT	35	290	300 kt
				37	21,000	20,000 ft
				33	340	216°
				36	295	295 kt
				Correct = 2		
7)	C	2	inst.	5	700	680 kt
				6	0	0°
				7	10	29°
				2	19,300	20,010 ft
				Correct = 1		
8)	CT	15	CRT	30	?*	4,300 ft/min
				31	100	107°
				26	80	107°
				32	18,000	20,140 ft
				Correct = 0		

* Indicates the response "Idon't know."

	Maneuver	Flight Segment	Display	Question	Reported	Indicated
9)	D	10	inst.	21	13,300	15,100 ft
				22	0	0°
				23	0	0°
				18	380	285 kts
				Correct = 2		
10)	DT	18	inst.	37	20,000	20,320 ft
				38	13,000	13,360 ft
				39	0	0°
				34	-5	-5°
				Correct = 4		
11)	LT	8	inst.	16	300	270 kt
				11	20,300	20,580 ft
				12	300	263°
				9	31	33°
				Correct = 2		
12)	LT	5	CRT	11	24,000	20,400 ft
				13	295	280 kt
				9	15	34°
				12	024	131°
				Correct = 0		
13)	D	12	inst.	24	10	11° R
				19	320	295 kt
				20	20,400	20,240 ft
				17	-10	-6°
				Correct = 3		
14)	C	4	inst.	8	none	none
				3	0	1°
				4	4,000+	3,100 ft/min
				1	19,300	19,700 ft
				Correct = 3		
15)	CT	13	CRT	27	44	40°
				29	345	350 kt
				25	330	345 kt
				28	10	9°
				Correct = 3		
16)	C	1	CRT	3	0	0°
				5	345	360 kt
				1	13,000	19,670 ft
				4	200	5,800 ft/min
				Correct = 1		

	Maneuver	Flight Segment	Display	Question	Reported	Indicated
17)	CT	14	inst.	29	280	270 kt
				30	4,000 +	4,000 ft/min
				31	120	122°
				26	090	122°
				Correct = 3		
18)	DT	20	inst.	40	30	32° L
				35	280	300 kt
				36	300	315 kt
				[illegible]	260	262°
				Correct = 2		
19)	C	3	CRT	6	0	0°
				7	14	15°
				2	19,700	19,940 ft
				8	none	none
				Correct = 4		
20)	CT	16	inst.	32	20,600	20,740 ft
				27	32	38°
				28	10	16°
				25	320	400 kt
				Correct = 1		

Pilot C

	Maneuver	Flight Segment	Display	Question	Reported	Indicated
1)	LT	6	CRT	14	240	245 kt
				15	260	260 kt
				16	240	235 kt
				10	20,000	20,030 ft
				Correct = 4		
2)	C	3	inst.	6	0	0°
				3	0	0°
				1	20,000	19,600 ft
				2	20,000	19,940 ft
				Correct = 4		
3)	DT	17	inst.	36	300	295 ft
				40	35	39°
				39	0	0°
				37	20,000	20,000 ft
				Correct = 4		
4)	CT	16	CRT	28	16	16°
				27	26	38°
				25	390	400 [illegible]
				29	330	390 kt
				Correct = 2		
5)	C	2	CRT	6	0	0°
				7	15	29°
				8	1	none
				2	19,990	20,010 ft
				Correct = 3		
6)	LT	7	inst.	14	300	270 kt
				11	20,000	20,100 ft
				9	25	28°
				10	19,600	19,710 ft
				Correct = 3		
7)	CT	15	inst.	30	2,000	4,300 ft/min
				27	30	29°
				25	340	335 kt
				26	80	107°
				Correct = 2		
8)	DT	19	inst.	38	16,000	15,230 ft
				35	300	300 kt
				33	80	84°
				34	[illegible]	-4°
				Correct = 2		

* Indicates the response "I don't know."

	Maneuver	Flight Segment	Display	Question	Reported	Indicated
9)	DT	20	CRT	36	300	315 kt
				35	300	300 kt
				33	250	262°
				37	20,000	20,000 ft
				Correct = 2		
10)	D	11	inst.	22	0	0°
				19	250	285 kt
				17	-10	-7°
				18	300	295 kt
				Correct = 3		
11)	D	10	CRT	22	0	0°
				23	0	0°
				18	295	285 kt
				24	7	0°
				Correct = 3		
12)	D	12	CRT	19	350	295 kt
				20	20,000	20,240 ft
				17	-9	-6°
				21	15,000	15,170 ft
				Correct = 3		
13)	C	4	CRT	4	2,000	3,100 ft/min
				3	1	1°
				1	20,000	19,700 ft
				5	350	350 kt
				Correct = 3		
14)	C	1	inst.	4	5,000	5,800 ft/min
				8	none	none
				7	20	23°
				5	350	360 kt
				Correct = 3		
15)	D	9	inst.	20	20,000	20,000 ft
				24	0	0°
				23	0	0°
				21	15,500	15,370 ft
				Correct = 4		
16)	LT	5	inst.	12	120	131°
				16	280	275 kt
				15	280	280 kt
				13	280	280 kt
				Correct = 3		

	Maneuver	Flight Segment	Display	Question	Reported	Indicated
17)	CT	13	inst.	28	8	9°
				32	19,700	19,750 ft
				31	130	127°
				29	350	350 kt
				Correct = 4		
18)	DT	18	CRT	38	15,500	13,360 ft
				39	0	0°
				40	26	47° R
				34	-4	-5°
				Correct = 2		
19)	CT	14	CRT	30	2,500	4,000 ft/min
				31	122	122°
				32	?*	19,800 ft
				26	120	122°
				Correct = 2		
20)	LT	8	CRT	12	260	263°
				11	20,500	20,580 ft
				9	25	33°
				13	280	275 kt
				Correct = 3		

* Indicates the response "I don't know."

Pilot D

	Maneuver	Flight Segment	Display	Question	Reported	Indicated
1)	CT	16	inst.	31	?*	262°
				26	?*	260°
				29	300	390 kt
				28	10	16°
				Correct = 0		
2)	C	3	CRT	5	355	365 kt
				8	none	none
				4	5,800	5,800 ft/min
				6	0	0°
				Correct = 4		
3)	DT	20	inst.	39	3	0°
				34	-6	-5°
				37	19,000	20,000 ft
				36	300	315 kt
				Correct = 2		
4)	CT	14	inst.	32	19,000	19,800 ft
				25	260	255 kt
				27	25	27°
				30	4,000	4,000 ft/min
				Correct = 3		
5)	C	1	CRT	3	0	0°
				1	19,800	19,670 ft
				2	20,000	19,830 ft
				7	16	23°
				Correct = 3		
6)	CT	13	CRT	27	40	40°
				25	300	345 kt
				26	90	126°
				31	90	127°
				Correct = 1		
7)	C	4	inst.	7	12	12°
				2	20,000	19,920 ft
				5	360	350 kt
				4	3,000	3,100 ft/min
				Correct = 4		
8)	D	12	inst.	23	0	0°
				18	360	290 kt
				21	15,000	15,170 ft
				20	19,000	20,240 ft
				Correct = 2		

* Indicates the response "I don't know."

	Maneuver	Flight Segment	Display	Question	Reported	Indicated
9)	LT	5	CRT	11	20,300	20,400 ft
				9	30	34°
				10	19,000	19,810 ft
				15	275	275 kt
				Correct = 3		
10)	LT	8	inst.	15	280	290 kt
				10	20,000	19,690 ft
				13	280	275 kt
				12	270	263°
				Correct = 3		
11)	DT	18	inst.	40	45	47°
				33	140	167°
				35	300	295 kt
				38	13,000	13,360 ft
				Correct = 3		
12)	D	10	inst.	24	0	0°
				17	-12	-7°
				19	310	300 kt
				22	0	0°
				Correct = 4		
13)	CT	15	CRT	29	350	345 kt
				32	15,000	20,140 ft
				28	8	11°
				30	1,000	4,300 ft/min
				Correct = 2		
14)	C	2	inst.	8	none	none
				1	19,500	19,880 ft
				3	0	0°
				6	0	0°
				Correct = 4		
15)	DT	17	CRT	35	300	300 kt
				33	190	216°
				34	-2	-1°
				39	0	0°
				Correct 3		
16)	D	9	CRT	19	310	315 kt
				17	-2	-1°
				18	300	310 kt
				23	0	0°
				Correct = 4		

	Maneuver	Flight Segment	Display	Question	Reported	Indicated
17)	DT	19	CRT	37	19,900	19,890 ft
				40	26	32°
				36	360	350 kt
				38	15,000	15,230 ft
				Correct = 3		
18)	LT	7	CRT	13	275	270 kt
				16	270	265 kt
				12	90	92°
				14	275	270 kt
				Correct = 4		
19)	LT	6	inst.	16	260	235 kt
				9	25	32°
				11	20,500	20,950 ft
				14	260	245 kt
				Correct = 1		
20)	D	11	CRT	21	17,000	15,490 ft
				24	2	2°
				20	20,100	20,130 ft
				22	0	0°
				Correct = 3		

APPENDIX K: TEST IP BRIEFING

You are being asked to participate in a test which is being developed for future evaluation of cockpit displays. In the present instance, we are limiting the display to the flight performance indications, specifically a) airspeed, b) airplane pitch and bank attitude, c) altitude, d) vertical velocity, and e) heading.

You will see two types of displays, standard instruments and digital presentation on a cathode ray tube. These have not been chosen because of a question about their relative effectiveness but because of their dissimilarity. It's rather like the difference between a traditional watch with dial and hands and the new digital watches; one format may be good in one situation while the other may best suit another.

It is important that you know that, although we ask you to work sincerely at the task, we are not testing your ability but rather the efficiency of our approach to the evaluation of displays. Since you will see both types of displays, we can compare your performance with one type against your performance with the other type. Thus we are not concerned with comparisons between your performance and someone else's, only with how effective is our approach to display evaluation.

In this, the initial stage of research in this area - information displays at an instructor/operator station in conjunction with flight simulator training - some artificialities are required. For example, we will ask you to view a series of short one or two minute flight segments without describing the maneuver before its presentation. The information presented to you will be limited to that mentioned earlier; airspeed, attitude, altitude, vertical velocity, and heading. This will be shown either in digital form on a cathode ray tube or on standard instruments, circular dial with pointer except for the attitude indicator. The arrangement will be standard with the airspeed on the left, attitude indicator in the middle above the heading indicator, and altitude on the right next to the VVI. The digital format on the cathode ray tube (located above the standard instruments, which will be covered during the cathode ray tube presentations) will be arranged in the same manner as the standard instruments.

After each flight segment presentation, you will be asked questions about the information shown in the display. These questions will be concerned with the values displayed at various points in the maneuver such as maximum and minimum altitude, attitude, airspeed, vertical velocity, or heading at various points in the maneuver. You are being asked to remain alert to all of the five instrument indications throughout the short flight segment, this being the reason for your not being told about the maneuver beforehand.

The questions have been selected to represent typical student errors in flying in a simulator and will therefore be relevant to the maneuver presented. However, since you will not be told about the maneuver prior to the presentation, the questions will be related to identifiable portions of it such as beginning airspeed in a turn or altitude at level-off in a climb.

This research is being conducted as part of an Air Force contract with the Boeing Company. As a research and development effort conducted under contract, the Air Force is, of course, not responsible for the specifics of this test. However, the Company has obvious interest in its success. We, therefore, ask you to do your best in the task in which you are participating, and we welcome any suggestions you may have for improving the quality of this evaluation technique.

APPENDIX L: DATA SUMMARY BY MANEUVER AND INDICATION

		INSTRUMENTS						CRT					
		A	H	VV	AS	R	P	A	H	VV	AS	R	P
C	POSS.	8	8	4	4	4	4	8	8	4	4	4	4
	CORRECT	7	8	2	3	4	3	6	8	2	2	4	2
LT	POSS.	8	4	-	16	4	-	8	4	-	16	4	-
	CORRECT	8	0	-	9	3	-	4	3	-	14	2	-
D	POSS.	8	8	-	8	4	4	8	8	-	8	4	4
	CORRECT	5	8	-	3	4	3	4	8	-	4	3	4
CT	POSS.	4	8	4	8	4	4	4	8	4	8	4	4
	CORRECT	2	3	2	5	3	1	0	3	1	3	3	4
DT	POSS.	8	8	-	8	4	4	8	8	-	8	4	4
	CORRECT	6	6	-	5	4	2	4	4	-	7	0	3
TOTAL	POSS.	36	36	8	44	20	16	36	36	8	44	20	16
	CORRECT	28	25	4	25	18	9	18	26	3	30	12	13
	% CORRECT	78	69	50	57	90	56	50	72	38	68	60	81

68% OVERALL

64% OVERALL

A - ALTITUDE
H - HEADING
VV - VERTICAL VELOCITY

AS - AIR SPEED
R - ROLL
P - PITCH

APPENDIX M: LEARNING EFFECTS

Flight Segment Order	Number of Correct Answers — Pilot A	B	C	D
1	1	3	4	0
2	2	1	4	4
3	3	4	4	2
4	1	0	2	3
5	3	1	3	3
	10	9	17	12
6	3	2	3	1
7	4	1	2	4
8	4	0	2	2
9	3	2	2	3
10	4	4	3	3
	18	9	12	13
11	2	2	3	3
12	3	0	3	4
13	3	3	3	2
14	2	3	3	4
15	4	3	4	3
	14	11	16	16
16	2	1	3	4
17	2	3	4	3
18	3	[illegible]	2	4
19	[illegible]	[illegible]	2	1
20	4	1	3	3
	15	11	14	15