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INVESTIGATIONS OF VERTICAL DISPLAYS OF ALTITUDE INFORMATION

I. COMPARISON OF A MOVING-TAPE AND STANDARD ALTIMETER ON A SIMULATED FLIGHT TASK

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FOREWORD

This report was prepared by the Aviation Psychology Laboratory, University of Illinois, Urbana, Illinois, under Air Force Contract No. AF 33(616)-3000, Task No. 71573, Project 6190 The Air Force Control-Display Integration Program.

Captain Edward L. Brown, Aero-Medical Laboratory was the Task Scientist. Mr. John H. Kearns, Flight Control Laboratory, was the Project Engineer. Research on the contract was under the direction of Dr. Robert C. Houston as principal investigator.

The assistance of the Mssrs. Albert H. Bowman and Rudolf A. Frasca in the construction of the experimental equipment is gratefully acknowledged.

ABSTRACT

This is the first of a planned series of experiments, and was designed to compare performance of experienced pilots on a standard altimeter and a vertical, moving-tape altimeter on a specified series of flight tasks in a Link trainer. Twenty subjects flew the series of maneuvers using each altimeter and deviations from desired altitudes were observed. Analysis of the data resulted in the following conclusions: (1) under the experimental conditions, performance on the standard altimeter was significantly superior to performance on the vertical, moving-tape altimeter, (2) the method of evaluation is sufficiently sensitive to be a useful research tool, and (3) further evaluations of the effects of an expanded scale and additional training should be conducted. The results are discussed relative to the rather small overall difference in performance between the two altimeters.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

for JACK BOLLERUD Lt Col USAF
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Laboratories

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INTRODUCTION

There have been several studies in the past ten years that have been concerned with the problem of developing better methods of displaying altitude information to the pilot. The initial studies were concerned only with presenting altitude information, but more recent studies have considered the problem of presenting command information, integration of altitude information with other parameters, and integration of altitude displays with other displays. These latter considerations have modified the problem and may require compromising the best altitude display in favor of the best integrated display of all parameters.

Grether (2) was the first to investigate experimentally the presentation of altitude information. He compared a variety of altimeter configurations by a paper and pencil technique from which he recorded errors of interpretation as well as interpretation time. The displays included the conventional three-pointer, combinations of a counter and a pointer, a counter alone, and also two configurations of moving-tape, vertical displays. After considering the various uses of altitude information he recommended a counter-pointer display because of the advantages of a moving pointer for check reading purposes. The vertical displays compared quite favorably with the counter-pointer displays under his experimental conditions, and were much superior to the standard altimeter.

Other research on the design of dial shapes, including that by Sleight using tachistoscopic procedures (5), is generally unfavorable toward the use of moving pointer or moving-tape vertical displays. Baker and Grether (1) do not recommend their general use when all factors are taken into consideration.

The special problems associated with the presentation of altitude and command altitude information in aircraft, and its integration with other parameters warrant the continued investigation of methods of vertical display of altitude information, with particular reference to methods of improving such displays. Simon, et al, (3, 4) have investigated various configurations of vertical displays using a moving pointer and fixed scale, but also integrated with the other important parameters of vertical speed and command altitude. Using a paper and pencil evaluation technique, the results of both studies favored the vertical displays over the circular displays in the decision making aspects of vertical flight control.

Additional impetus to the development of vertical reading displays have been provided by Wright in the WADC program for improved flight instrumentation (6). This program proposes a whole panel planning concept, which points up the advantageous use of vertical displays with moving-tapes.

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For various reasons, research in methods of display of altitude information has been limited to static displays presented either tachistoscopically or in booklet form. Little, if any, research has been conducted in which dynamic displays have been used for the control of altitude in an actual or simulated flight task. Because of the increasing interest in vertical displays and their impending operational tryout in aircraft, it would appear that investigation of display characteristics under limited dynamic conditions is required. If such displays appear to be operationally desirable in spite of some presently known disadvantages, then it would be valuable to investigate the methods of improving the displays, or of compensating for the disadvantages. This report is the first of a planned series of studies to investigate, under dynamic display conditions, some of the problems associated with the vertical display of altitude information. Because the problem is complex and there are many possible variables, initial investigations will necessarily involve some simplification of the operational problem.

STATEMENT OF THE PROBLEM

The purpose of this experiment was two-fold. Primarily, it was to compare performance of experienced instrument pilots on a standard altimeter and a vertical, moving-tape display on a specified series of flight tasks in a Link trainer. The experimental design was intentionally kept as simple as possible to yield information with regard to the secondary purpose, that of evaluating the trainer, the task, and the performance criteria as a research tool for investigating altitude displays.

METHOD OF EVALUATION

The experimental design was a simple treatments-by-subjects design in which 20 experienced, instrument rated pilots flew a standard program of maneuvers in a modified C-8 Link type trainer. Each subject flew the same series of maneuvers using each altimeter. Maneuvers were selected to sample flight situations in which altitude control is a primary concern.

EQUIPMENT

Vertical Reading Altimeter

A vertical reading altimeter was constructed in the laboratory workshop. It is a moving-tape, stationary index type and uses 16 mm lead-in (white) movie film with black markings for the tape. Each thousand foot level is numbered as shown in Figure 1, and encompasses a distance of 1.5 inches on the tape. Index marks are placed every 100 feet, as compared to every 20 feet on the standard altimeter. The range covered by the tape was 0-10,000 feet. Characteristics of the display were chosen to approximate a proposed WADC vertical altimeter. An easily removable cover was fitted over the face of the instrument when not in use.

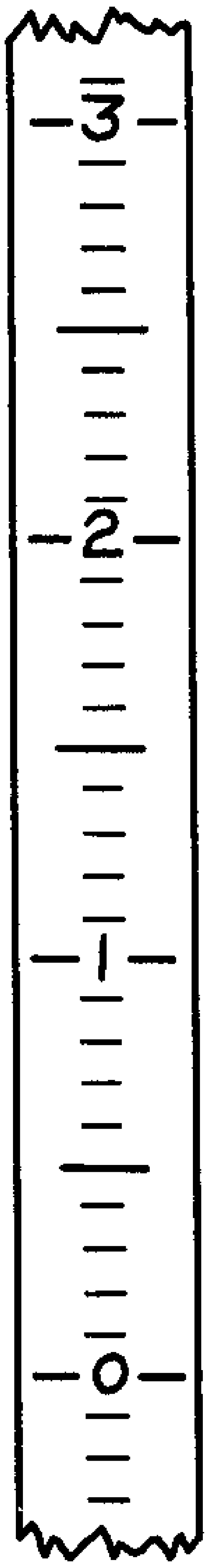

Figure 1. Moving Tape Scale (Actual Size)

Standard Altimeter

The "standard altimeter" used in this experiment is the AN5760 L 4B, a three pointer, circular dial instrument. An easily removable cover was also made for this altimeter.

Both instruments were mounted on the panel of a modified C-8 Link type trainer. Because of its "breadboard" construction, the moving-tape display was mounted on the surface of the panel, but the standard altimeter was mounted in the normal manner as shown in Figure 2. Each altimeter was driven by identical teletorques, with a common input from the trainer system. Response of each altimeter in terms of altitude change with control movement was therefore identical.

Link C-8 Type Instrument Trainer

The control characteristics of the C-8 type instrument trainer, Figure 3, were modified to simulate higher performance type aircraft. Normal cruise airspeed was boosted to 400 knots, and climb and dive rates of 4000 fpm were possible. Control wheel sensitivity was increased so that one bar width deviation on the gyro horizon produced a 500 fpm rate of climb or dive. The trainer was further modified so that a 30° bank with no rudder movement set up a standard rate (3° per second) turn.

The only flight instruments visible to the subjects were a gyro horizon, a moving needle compass indicator, and one of the two altimeters. A manifold pressure gauge was present for purposes of establishing a "normal cruise" power setting. The two altimeters were outfitted with removable covers and all remaining instruments had permanent metal covers.

The gyro horizon was modified to enable the subject to set up specified rates of climb or dive without the use of a vertical speed indicator. This was done by placing white reference lines on the face of the instrument and instructing the subject to align the horizon bar with the corresponding line for the desired climbing or descending attitude.

A rough air setting of 25 percent was used during all experimental periods to increase the difficulty of the task.

SUBJECTS

Twenty experienced pilots were selected as subjects for this study, so that the qualifications of the experimental group would closely approximate the qualifications of military pilots. Their qualifications are listed in Table 1. With experienced pilots, the accompanying bias in the experience level favoring the standard altimeter was accepted.

Three pre-experimental subjects were used to provide practice for the experimenter as well as constructive criticism of the flight task and its presentation.

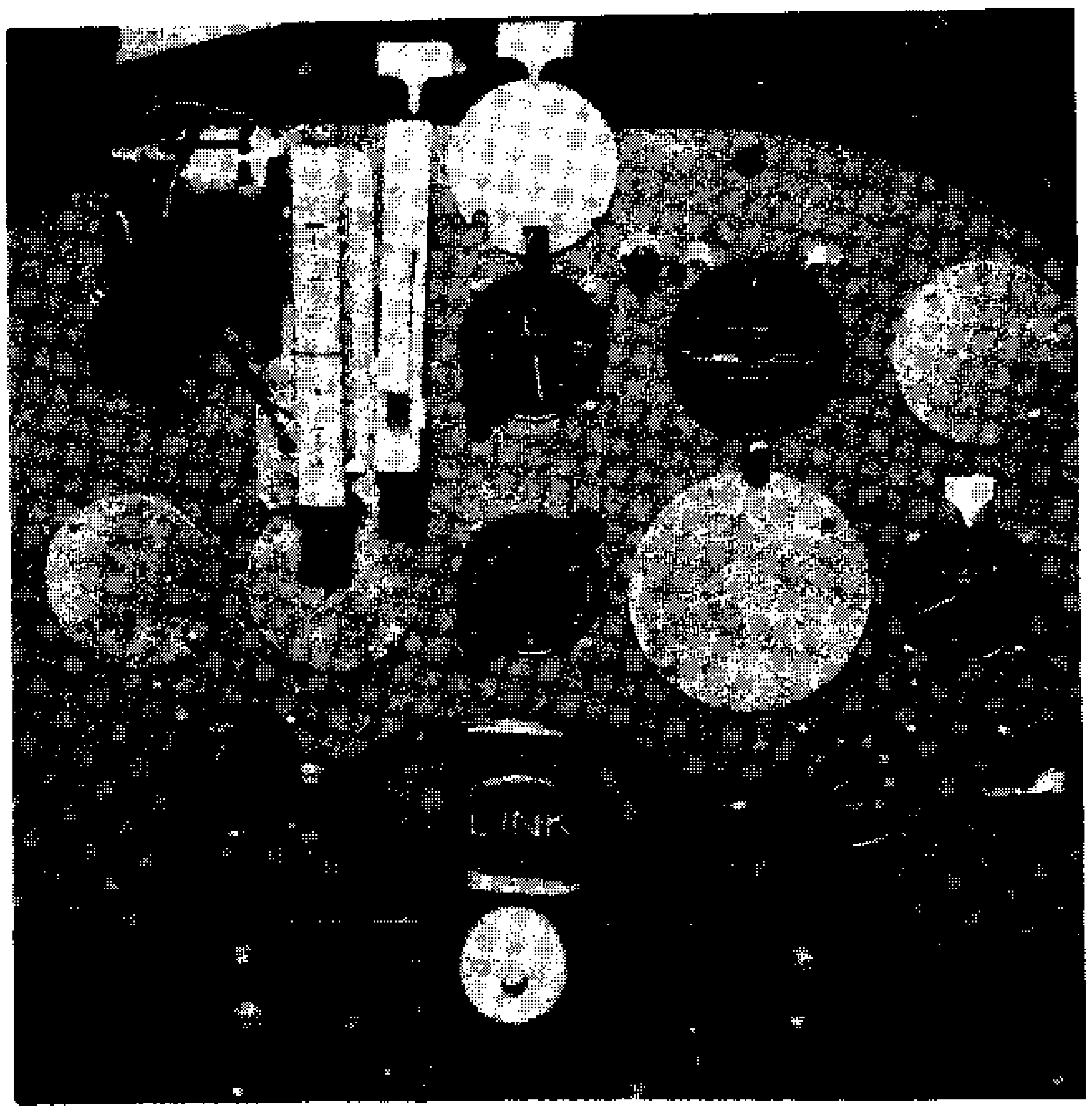

Figure 2. Vertical Display Installation on the Instrument Panel in C-8 Link Trainer.

Figure 3. C-8 Link Type Trainer.

Table 1

Flight Qualifications of Subjects

	Ratings					Experience (Hours)		
	Commercial	Instrument	Instructor	Military	Jet	Link	Sim/Actual Instrument	Total Time
1.	x	x	x	x		35	61	1400
2.	x			x		100	300	1700
3.	x*	x	x	x		60	100	4000
4.	x	x	x			40	67	1600
5.	x	x	x	x		35	65	700
6.	x	x	x	x	x	87	142	1000
7.	x	x		x	x	70	110	900
8.	x	x	x	x	x	150	200	4000
9.	x	x	x	x	x	100	950	5300
10.	x	x	x	x	x	220	320	1600
11.	x	x		x	x	80	75	1100
12.	x*	x	x	x		200	135	3800
13.	x	x	x			10	51	750
14.	x	x	x	x		98	129	1900
15.		x		x	x	100	160	1200
16.	x			x	x	75	130	1900
17.	x	x	x			15	30	950
18.	x	x		x	x	150	275	1100
19.	x	x	x	x		65	185	1650
20.	x	x	x	x	x	60	160	1450
Totals	19	18	14	17	10	1750	3645	38000
Average						87.5	182.3	1900

*Air Transport Rating

THE "FLIGHT" TASK

The flight task as shown in Figure 4 was designed to sample basic altitude controlling maneuvers. Level-offs from prolonged climbs and dives, level-offs from short-term climbs and dives, and level turns comprised the task. It was symmetrical in nature and was identical for both altimeters.

Pre-flight briefing was held to a minimum and consisted of a brief explanation of the two altimeters, some flight characteristics of the trainer, and an explanation of how the flight instructions would be given. Although the briefing was not read verbatim, a specific outline was followed and the same information was given to each subject. All flight instructions were given over the trainer's communication system and were read verbatim from typewritten cards. These instructions are reproduced in Appendix A.

Approximately ten minutes were used to obtain information about the subject, explain the scales on the two altimeters, and orient the subject to the trainer. It took approximately forty minutes under the hood to complete the flight task. When this was finished the subject was asked for any comments on the vertical altimeter.

SCORING

The evaluation criterion was selected to be performance in maintaining a designated altitude during and following specified maneuvers. To determine this, deviation from an index of desired performance (IDP) was recorded by the experimenter. This figure was the deviation in feet from a designated altitude and was recorded every five seconds for each of ten maneuvers. The maneuvers and their respective scoring intervals are shown in Table 2. The deviations for each maneuver were summed disregarding signs and averaged to give an "average deviation" for each maneuver. These deviations were then analyzed by the analysis of variance technique. In addition, an overall average deviation per instrument per pilot was computed.

An automatic device was used to signal the experimenter at five-second intervals. He then recorded the deviation from IDP as shown on a standard altimeter at the operator's console. On maneuvers A, D, E, F, G and J, scoring was commenced when the rate of climb instrument on the operator's console indicated a zero or reversed rate of vertical movement. On maneuvers B, C, H and I, scoring was commenced with the start of the maneuver. A scoring sheet was designed to facilitate recording the deviations and is shown in Appendix B.

In addition, initial response of the subject in execution of maneuvers D, E, F and G, was observed to determine if the subject responded in the correct direction. Initial responses in the wrong direction were recorded as reversals.

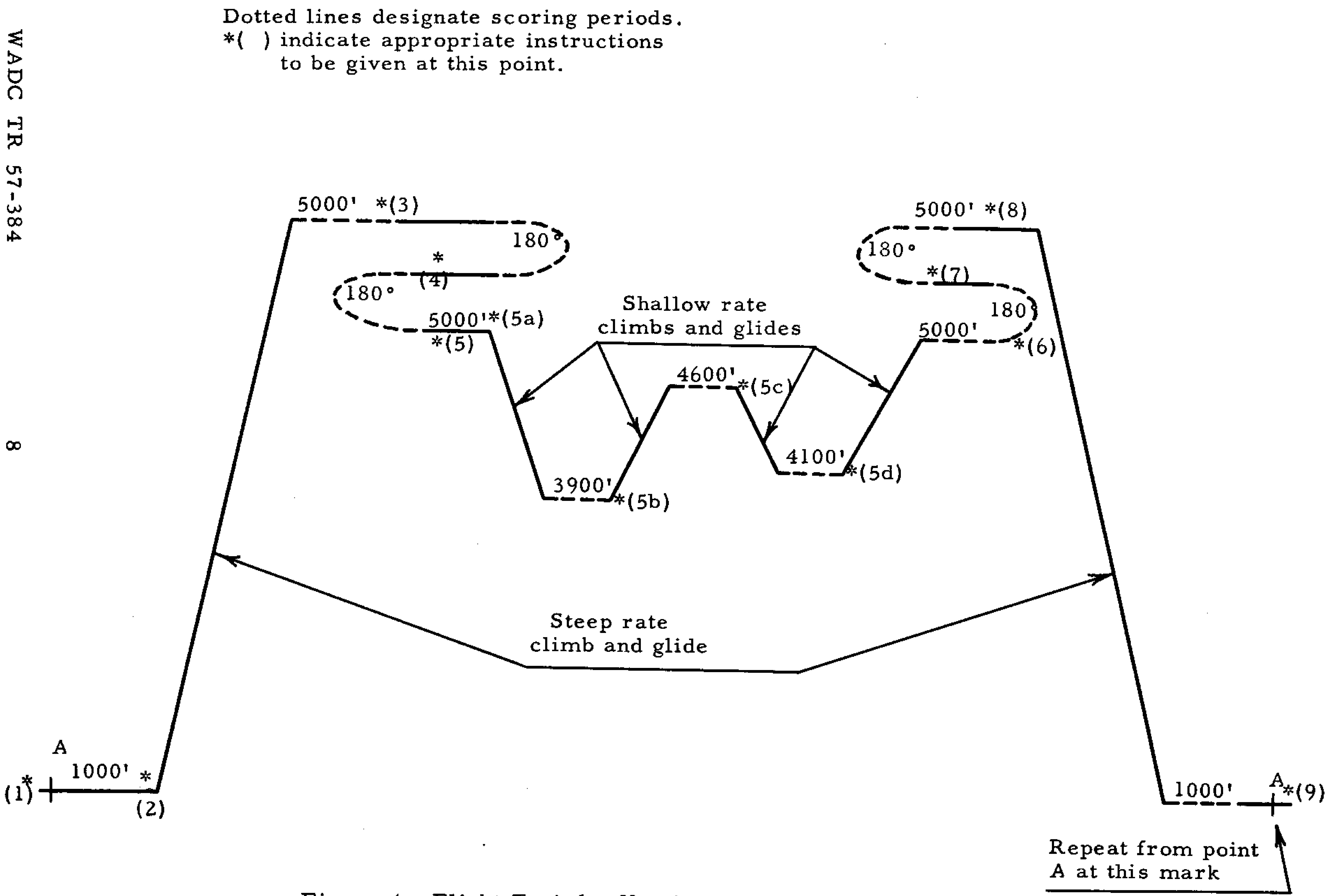

Figure 4. Flight Task for Vertical Altimeter Experiment

Table 2

Scoring Intervals and Observations During the Flight Task Maneuvers

Maneuver	Code	Scoring Interval	Number of Observations
Steep rate climb to 5000' and level off	A	60 Sec.	13
180° level turn to the right	B	60 Sec.	13
180° level turn to the left	C	60 Sec.	13
Shallow rate dive to 3900' and level off	D	30 Sec.	7
Shallow rate climb to 4600' and level off	E	30 Sec.	7
Shallow rate dive to 4100' and level off	F	30 Sec.	7
Shallow rate climb to 5000' and level off	G	30 Sec.	7
180° level turn to the left	H	60 Sec.	13
180° level turn to the right	I	60 Sec.	13
Steep rate dive to 1000' and level off	J	60 Sec.	13

EXPERIMENTAL PROCEDURE

Each subject completed the series of maneuvers once using each altimeter. Order of presentation of the standard and vertical altimeter was counterbalanced to eliminate any bias due to a practice effect. Subjects were given no information on scoring procedures or their level of performance.

RESULTS

The average deviations of five-second observations of altitude for all maneuvers are shown in Table 3 for each subject and each altimeter display. Inspection of this table shows that 17 out of 20 subjects showed less error on the standard altimeter. The mean deviation for the standard altimeter was 18.7 feet, and 24.3 feet for the vertical. Deviations for each maneuver, averaged over all subjects, are presented graphically in Figure 5. Performance on the standard altimeter was superior on all maneuvers with the exception of maneuver D, shallow descent to 3900' and level off. The large differences between altimeters on maneuvers D and G were primarily the result of extensive deviations by one subject. It will be noted that the second set of 180° level turns (maneuvers H and I) showed very small differences between altimeters and lesser deviations from the IDP. Some learning is therefore indicated.

Table 3

Average Deviations in Altitude, All Maneuvers

Subject Number	Standard Altimeter	Vertical Altimeter
1.	37.9	51.8
2.	14.3	23.7
3.	9.9	14.6
4.	32.3	37.5
5.	34.2	31.6 *
6.	14.6	31.8
7.	17.6	16.3 *
8.	11.1	15.9
9.	15.6	19.9
10.	10.7	18.7
11.	12.3	12.5
12.	11.7	28.7
13.	14.8	16.4
14.	16.2	16.7
15.	27.3	15.4 *
16.	14.2	19.2
17.	30.9	44.2
18.	14.2	26.7
19.	18.1	18.7
20.	15.3	24.8
Average	18.7 feet	24.3 feet

* Reversal

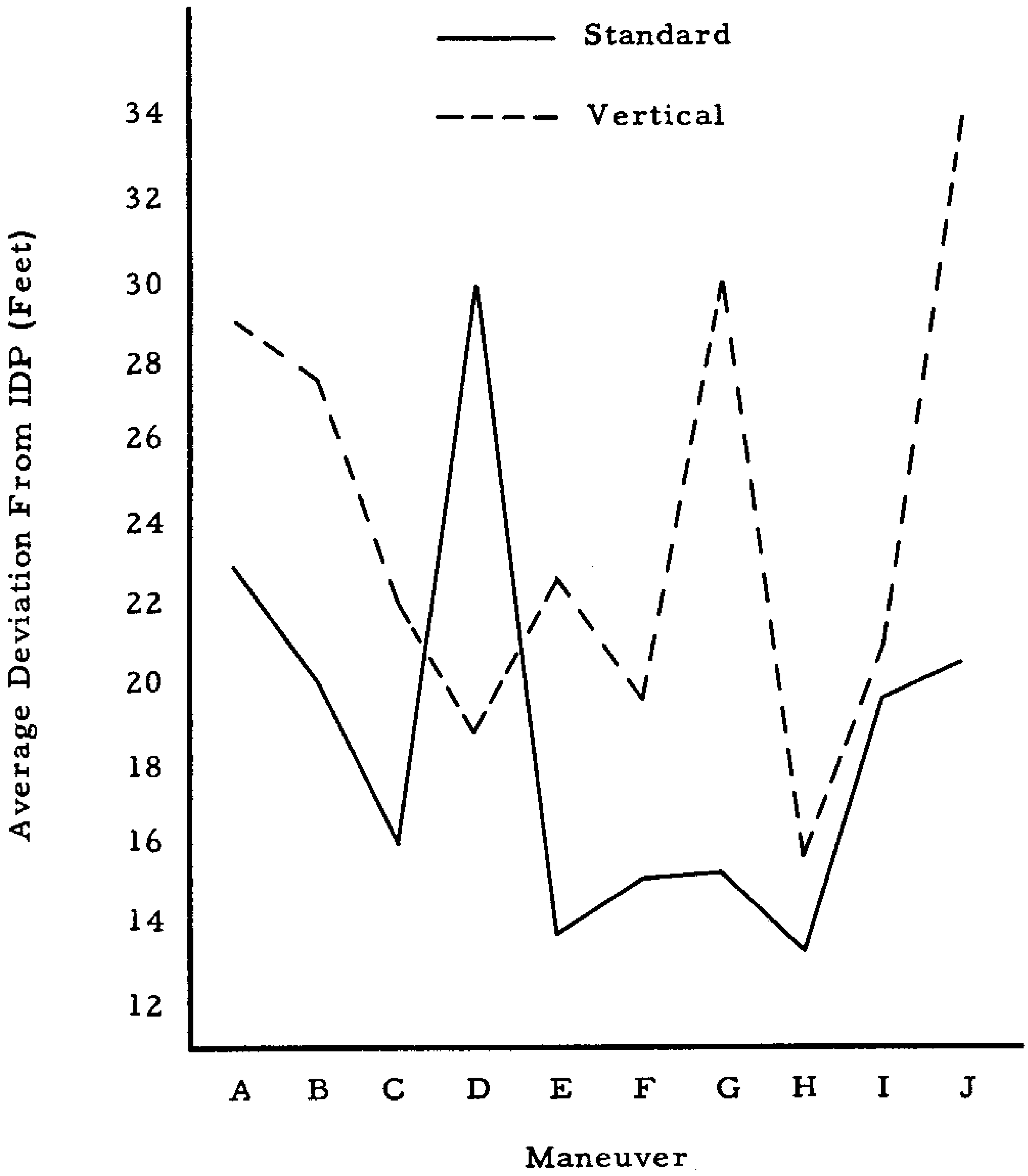

Figure 5. Average Deviations in Altitude for All Subjects by Maneuver

Significance of differences was tested by the analysis of variance technique. The analysis is summarized in Table 4. Inspection of the table shows that the differences between instruments are highly significant statistically. These differences favor the standard altimeter as indicated by Table 3. Differences between maneuvers are also significant, but such differences would be expected as there was no effort made to equate the difficulty of maneuvers. Significant differences between subjects would also be expected. The possible significance of the instruments by maneuvers interaction indicates that the standard display is not significantly superior in all maneuvers; graphic results discussed above bear this out. Other effects are not significant.

Observations for correct direction of initial movement yielded three errors, or reversals, out of a possible total of 160. All reversals recorded occurred when the vertical altimeter was being used. It is possible that unobserved reversals occurred, but if so, there was no apparent confusion in using the new display for the very first time.

Table 4

Analysis of Variance of Average Deviations in Altitude for Each Maneuver

Source of Variation	Sum of Squares	df	Mean Square	F
Between Instruments	2855.4	1	2855.4	12.82**
Between Maneuvers	6007.4	9	667.5	3.00**
Between Subjects	30900.3	19	1626.3	7.30**
Interaction: I x M	4645.4	9	516.2	2.32*
Interaction: I x S	5133.3	19	270.2	
Interaction: M x S	41823.9	171	244.6	
Interaction: I x M x S	38093.8	171	222.8	
	129459.5	399		

** 1%

* 5%

The verbal comments on the vertical altimeter are given in Appendix C. Some tendencies to reverse were noted, but many of the subjects stated that they could more quickly determine their altitude when using the vertical altimeter. The most prevalent negative comment expressed the need for a more expanded or precise scale. With the consideration that these pilots had no previous experience with a vertical altimeter, these comments appear to be generally favorable towards this display.

Figures 6, 7, and 8 compare performance on the standard and vertical altimeters for all subjects by showing the mean deviation for each of the five-second scoring intervals for maneuvers A, E and B. Although the patterns are different for each maneuver, the similarity of the curves for the two altimeters is readily apparent, indicating that the responses of this group of subjects were essentially the same on both altimeters.

Figure 6 shows that in a level-off from a prolonged climb, subjects tended to overshoot the desired altitude, with the average error almost identical for both types of altimeters. Because of the much slower rate of movement of the moving-tape as compared to the movement of the pointer, it had been anticipated that there might be more of a tendency to overshoot the desired altitude using the moving-tape display. This did not occur on the prolonged climb, and on a short climb subjects flying the moving-tape display tended to undershoot slightly. The type of errors was essentially the same on both altimeters and only the magnitude of error differed.

The pattern of pilot responses in level-off is an interesting one. As shown in Figure 6, pilots tended to overshoot the desired altitude. Return to the desired altitude, in the case of the standard altimeter, was with considerable precision. On the short term climb, Figure 7, the pilots overcontrolled in stopping the rate of climb and as a result initially leveled off too low. In Figure 8, a level turn, the subjects again overcontrolled in applying back stick pressure and, on the average, gained altitude in the first half of the turn. Some of these errors could, of course, be attributed to lack of familiarity with the particular Link trainer used in the experiment.

The average errors shown in the above graphs differ from the average deviations used in the analysis of the data. In the graphs the direction of the deviation is considered, and positive and negative errors balance out unless there is a definite constant error. Differences between the instruments might also appear to be less, for means are shown rather than measures of variability.

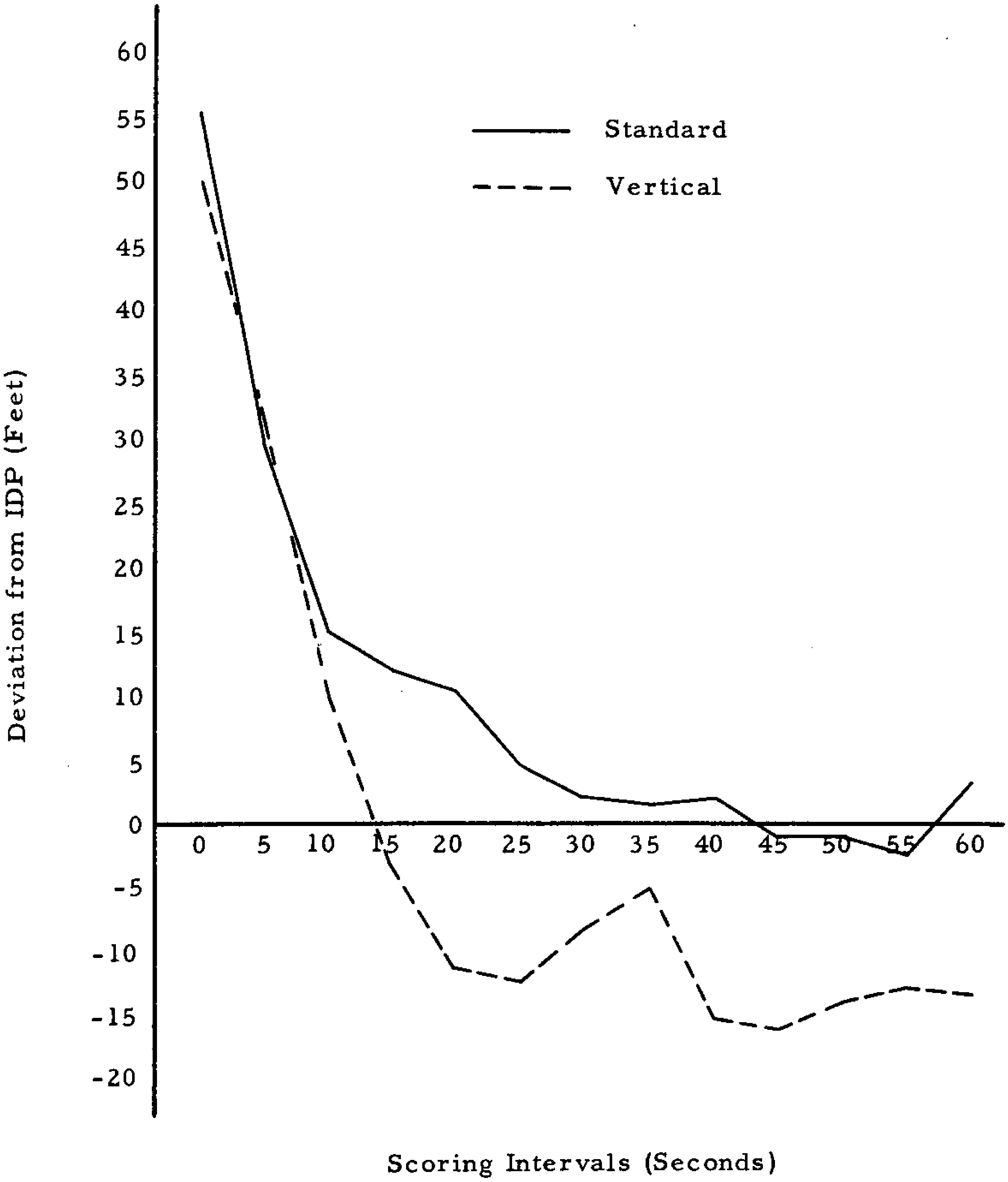

Figure 6. Mean Deviation for 20 Subjects for Maneuver A (Level-off at 5000' From Long Climb)

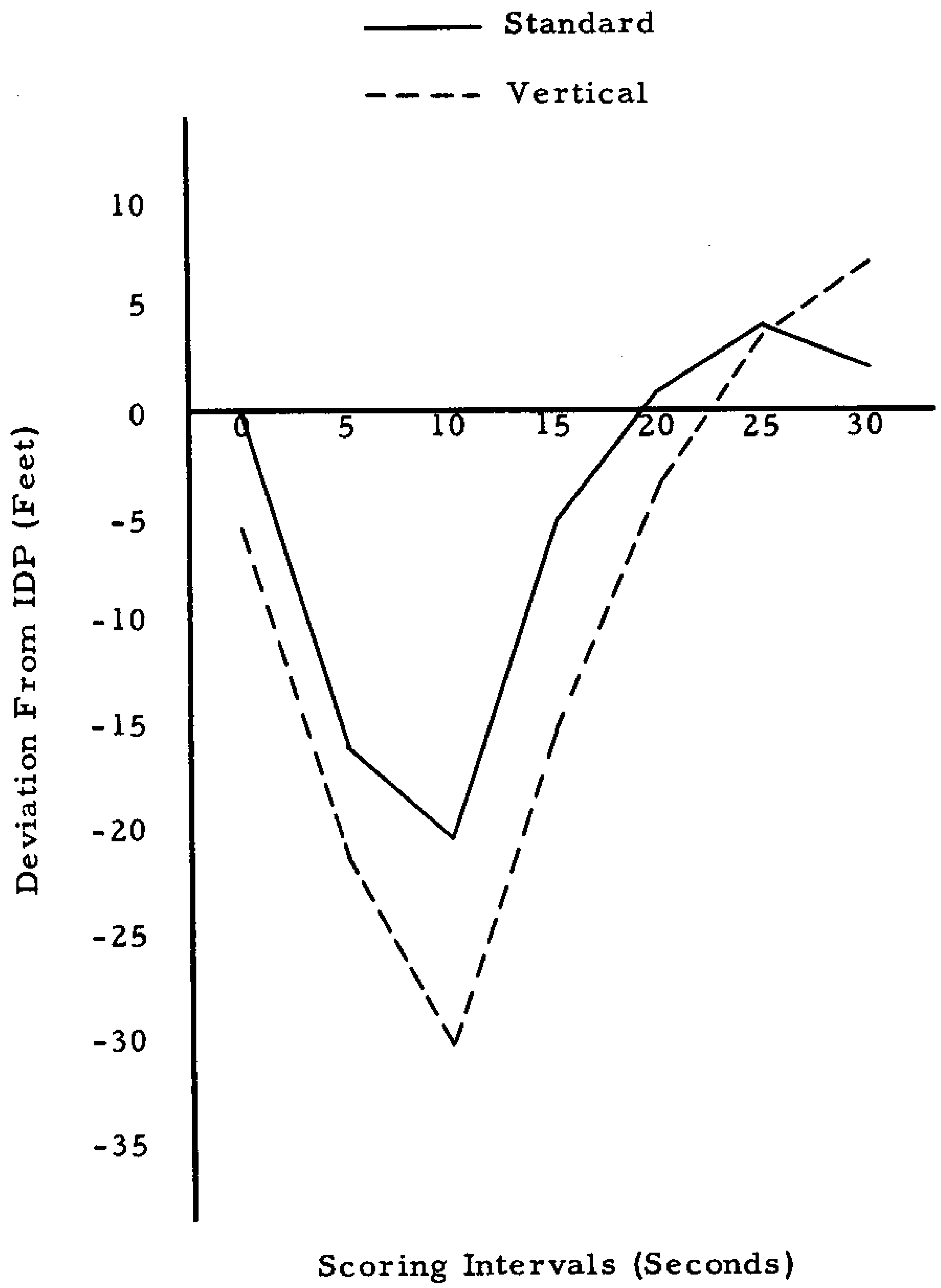

Figure 7. Mean Deviation for 20 Subjects for Maneuver E (Level-off at 4600' From Short Climb)

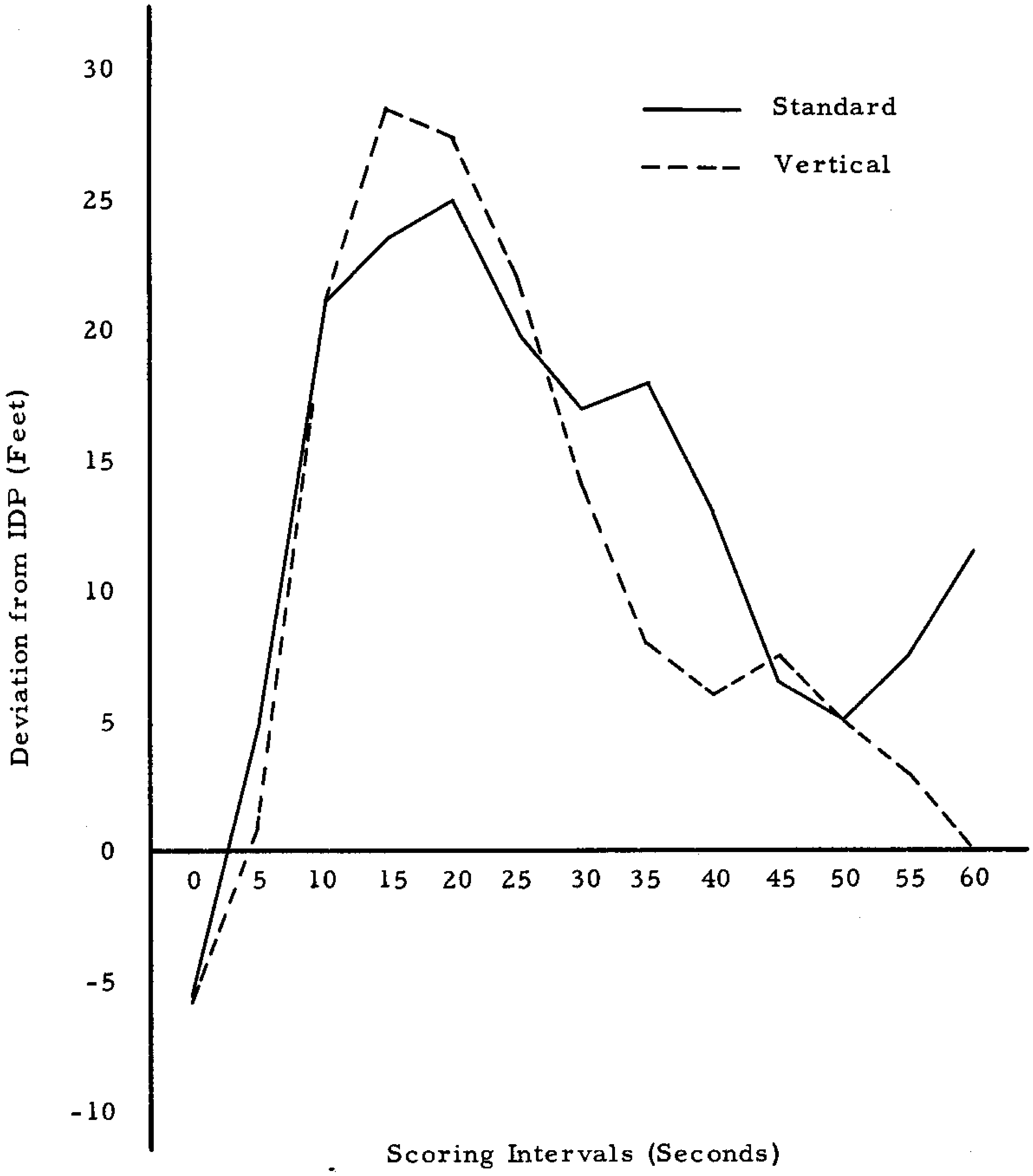

Figure 8. Mean Deviation for 20 Subjects for Maneuver B (180° Level Right Turn).

DISCUSSION OF RESULTS

The results of this initial comparison leave little room for doubt that reference to the standard altimeter makes greater precision of control possible than reference to the moving-tape display used in this study. In addition, the results indicate that the technique of evaluation is sufficiently sensitive to make it a useful research tool.

The magnitude of the difference between altimeters, taken over all maneuvers, is quite small. Table 3 shows that the difference between the mean deviations for all subjects and all maneuvers is only 5.6 feet. When the difference between the scales of the altimeters is considered, it is surprising that subjects were able to control altitude as precisely as they did using the vertical display. Since the magnitude of the difference is small, three questions might be asked:

1. Is this difference of operational significance?
2. Could this difference be overcome by practice on the vertical display?
3. Could this difference be overcome by a scale change of the vertical display?

One of the principle considerations in selecting the scale for the moving-tape altimeter was that altitude control to less than fifty feet is normally not expected in jet aircraft. In a high performance jet, precise altitude control is quite difficult, and at high altitudes altimeter error is often as high as one to two thousand feet. Precise altitude control is required during the final approach and touchdown of a landing, but this is not done with reference to the altimeter. Interpolation to fifty feet may therefore be adequate provided change in altitude is sufficiently apparent to permit adequate control. The overall difference between the two altimeters, then, cannot be considered of operational significance, but the fact remains that it was possible for the subjects to control altitude more precisely using the standard altimeter with control sensitivities that approach jet sensitivities. It would be undesirable to completely dismiss the differences but rather to test the altimeters under conditions that more closely approximate high performance jet control sensitivities. It would also be desirable to investigate methods of improving the vertical display.

It is possible that the difference between altimeters could be eliminated or reduced by practice on the new display. Inspection of Figure 5 shows less difference between altimeters on the second pair of 180° turns, maneuvers H and I, than on the first pair, maneuvers B and C. The subjects in this experiment had no practice on the new display, therefore, some improvement with practice would be expected.

There is no doubt that a change in the scale factor of the moving-tape display would improve the precision with which altitude could be controlled. The magnitude of the difference obtained in this experiment indicates that a scale factor equivalent to that of the standard altimeter (approximately 10" per thousand feet) would not be necessary, but that some factor considerably less would suffice. The specific scale factor will have to be determined experimentally under appropriate conditions of control sensitivity. It is also possible that the proper integration of other parameters, such as vertical speed, would make it feasible to use a very coarse altitude scale with sufficient precision.

One of the disadvantages of a moving-tape display is the ambiguity inherent in its direction of movement. If the tape is labeled to show increasing altitudes at the top, as would seem to be logical, then the tape will have to move down as altitude increases. The movement ambiguity could be solved by labeling the tape in reverse and showing increasing altitudes at the bottom of the display, but this would present a rather confusing static display. Small altitude changes were included in the flight task primarily to increase the opportunity for reversals, but very few were recorded. Within the limits of this study, then, the direction of movement of the tape caused little or no confusion.

Because of the large difference in scale factor, the rate of movement of the tape and the altimeter pointer differed considerably. Maneuvers requiring level-off from a relatively high rate of climb and descent were introduced to test the subjects' ability to anticipate altitudes on each altimeter. Analysis of maneuvers A and E by five-second intervals as shown in Figures 6 and 7 fails to reveal any difference in pilot technique on the two altimeters.

SUMMARY AND CONCLUSIONS

As the first of a planned series of studies, a standard altimeter and a moving-tape vertical altimeter were experimentally compared on a simulated flight task. Experienced pilots flew each display through a series of maneuvers designed to sample altitude control situations, and deviations from desired altitudes were observed. Performance of pilots was compared in terms of these deviations.

The conclusions may be stated as follows:

1. Under the experimental conditions, performance on the standard altimeter was significantly superior to performance on the vertical, moving-tape altimeter.

2. The method of evaluation is sufficiently sensitive to be a useful research tool for experimental determinations of altimeter display characteristics.

3. Further evaluations of vertical altimeters should be conducted to investigate the effects of an expanded scale and the effects of additional training on performance of simulated flight tasks.

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APPENDIX A

Flight Instructions

(1) How do you read me?
All right - you may now remove the cover from the altimeter. You will note that you are at an altitude of 1000 feet. Maintain this altitude and your heading of zero degrees. You need not acknowledge any further instructions.

(2) At the signal, go to 5000 feet.
Use full power and the steep rate position on the gyro horizon. Maintain your heading of zero degrees. Upon reaching 5000 feet, level off using the normal cruise power setting and maintain straight and level flight.
Begin NOW.

(3) Make any necessary corrections to maintain 5000 feet and a heading of zero degrees.
At the signal, you are to make a 180° level turn to the right. Use a 30° bank and maintain 5000 feet. Your new heading will be 180°.
Begin your turn NOW.

(4) Make any necessary corrections to maintain 5000 feet and a heading of 180°.
At the signal, you are to make a 180° level turn to the left. Use a 30° bank and maintain 5000 feet. Your new heading will be zero degrees.
Begin your turn NOW.

(5) Make any necessary corrections to maintain 5000 feet and a heading of zero degrees.
You will now make a series of climbs and glides. These are to be done with the normal cruise power setting and using the respective indicated shallow climb and glide marks on the gyro horizon. Hold your heading of zero degrees throughout this series. Upon reaching an assigned altitude, level off and maintain this altitude until a new assignment is given.

(5a) Maintain a heading of zero degrees. Use shallow rate. Go to 3900 feet NOW.

(5b) Maintain a heading of zero degrees. Use shallow rate. Go to 4600 feet NOW.

(5c) Maintain a heading of zero degrees. Use shallow rate. Go to 4100 feet NOW.

(5d) Maintain a heading of zero degrees. Use shallow rate. Go to 5000 feet NOW.

(6) Make any necessary corrections to maintain 5000 feet and a heading of zero degrees.
At the signal, you are to make a 180° level turn to the left. Use a 30° bank and maintain 5000 feet. Your new heading will be 180°.
Begin your turn NOW.

(7) Make any necessary corrections to maintain 5000 feet and a heading of 180°.
At the signal, you are to make a 180° level turn to the right. Use a 30° bank and maintain 5000 feet. Your new heading will be zero degrees.
Begin your turn NOW.

(8) At the signal, go to 1000 feet.
Use power OFF and the steep rate position on the gyro horizon.
Hold your heading of zero degrees. Upon reaching 1000 feet, level off using the normal cruise power setting and maintain straight and level flight.
Do not allow the trainer to rest on the full nose down stop.
Begin NOW.

(9) You may now remove the cover from the ______________ altimeter, and replace the cover on the altimeter that you have been using.
Maintain 1000 feet and a heading of zero degrees.
You should now be able to see only one altimeter, the ___________ one.

Repeat instructions 2 through 8.

(10) All right - you may slide back the hood now, the experiment is finished.

Scoring Sheet for Vertical Altimeter Experiment

Level Off 5000'

Start	
5	
10	
15	
20	
25	
30	
35	
40	
45	
50	
55	
60	

180° Turn Right

Start	
5	
10	
15	
20	
25	
30	
35	
40	
45	
50	
55	
60	

180° Turn Left

Start	
5	
10	
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35	
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50	
55	
60	

180° Turn Left

Start	
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180° Turn Right

Start	
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50	
55	
60	

Level Off 1000'

Start	
5	
10	
15	
20	
25	
30	
35	
40	
45	
50	
55	
60	

Level Off 3900'

Y N

Start	
5	
10	
15	
20	
25	
30	

Level Off 4600'

Y N

Start	
5	
10	
15	
20	
25	
30	

Level Off 4100'

Y N

Start	
5	
10	
15	
20	
25	
30	

Level Off 5000'

Y N

Start	
5	
10	
15	
20	
25	
30	

Date ____________ Time ______

Name ______________________

Address ______________________

Telephone ____________

Total Flight Time ____________

Instrument Time [A] ______ [S] ______

Total Link Time ________

Flight Ratings:

_____P P Instructor _____

_____C P Instrument _____

_____Military Jet _____

APPENDIX C

Voluntary Comments on the Vertical Altimeter

Positive comments:

1. No reversals (7 subjects).
2. No reversal, but had to think about it once.
3. No reversals, but was in doubt as to direction three times.
4. Had initial reversal when he first looked at it, but none after.
5. No trouble in interpreting it.
6. Sees no chance for confusion on multiples of 10,000 feet.
7. Less chance for error.
8. Felt it was easier.
9. Easier to do as far as retaining altitude.
10. Easier to maintain precision - not as much fluctuation.
11. Easier to find odd level-off altitudes - less computation in mind.
12. Can see where you are at a glance.
13. Likes being able to look at one point in order to get reading.
14. Direction of movement is consistent at all times.
15. No confusion as to which way was up - although one subject had indecisions at first on movement.
16. Doesn't see how there would be any problem in learning to use it.
17. Much less distracting.
18. Had feeling he wasn't doing as well at first - but later felt much better about it.
19. Very nice.
20. Liked it (5 subjects).
21. One subject wasn't sure if he liked it or not.

Negative comments:

1. Not fine or precise enough (5 subjects).
2. Could be more sensitive.
3. Difficult to make fine discriminations.
4. Calibrations too gross to make early corrections.
5. Takes too long to fixate on.
6. Easy enough to read, but felt he had to look at it more.
7. Unable to use peripheral vision for guarding.
8. Doesn't catch your eye as easy as sensitive altimeter in rapid scan.
9. For flying basic instruments, vertical altimeter would have to tell him more than it does.
10. Feels it looks like an artificial horizon for going up and down.
11. Prefer that it be placed close to gyro horizon.