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HELICOPTER ARMAMENT PROGRAM

AIR-TO-GROUND RANGE ESTIMATION

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ABERDEEN PROVING GROUND, MARYLAND

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ABSTRACT

This study was conducted to investigate the ability of an observer to estimate slant range from altitudes of 50, 100, and 150 feet, utilizing both "pop-up" and "running" modes of flight over various terrain types.

Twenty percent of the range estimates had overcalls of no greater than 9 percent error and undercalls of no greater than 6 percent error.

The results of the course and altitude variables did not yield a statistically significant difference under either the "running" or "pop-up" mode of flight.

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HELICOPTER ARMAMENT PROGRAM

AIR-TO-GROUND RANGE ESTIMATION

INTRODUCTION

The current concept of immediate armed helicopter engagement with hostile ground forces capitalizes on their speed and maneuverability for the engagement at specific point and area targets as well as targets of opportunity. These features of the helicopter also place a premium on total system response time, as evidenced by probable target detection ranges found in recent studies conducted at Combat Development Experimental Center (1, 2).

Many weapon systems envisioned for such aerial platform use require target range intelligence. This input may need to be extremely accurate, or it may be satisfied by the knowledge that the range exceeds weapon arming distance. An optimum choice of mechanical, electronic, or optical aids over the unaided or more simply aided human observer depends upon the accuracy required, the relative accuracy, and the reliability available. Since it may be a proportionally large part of the over-all system response time, the speed of operation of any range finding aids should also be considered.

Although some work has been done with fixed-wing aircraft, little information is available on slant range estimations made by the unaided eye from low-flying helicopters to ground targets. Preliminary studies conducted at the Human Engineering Laboratories indicate the need for further investigation of an observer's ability to "range in" on a target, while employing both the "pop-up" and "running" flight techniques of a helicopter.

PURPOSE

This study will investigate the ability of an observer to estimate slant range from various altitudes, utilizing both "pop-up" and "running" modes of flight over various terrain types, and the accuracy with which ranges can be estimated and "up-dated" while closing on a target in the "running" technique.

The purpose of the study is to obtain basic data which will aid Ordnance Corps agencies in their efforts to evaluate the practicability of current and potential weapons for Army aerial vehicles. These data will (1) be instrumental in establishing weapon design requirements, (2) provide a more reliable and logical basis for selection and subsequent development of optimally effective armament, and (3) establish baselines to assist in evaluating the degree of, and necessity for, complex fire control equipment.

METHOD

Subjects

The subjects for this study were 18 helicopter pilots, who were on active duty at Fort Ord, California. The subjects had an average age of 31 years ranging from 25 to 45. Each pilot had an average of 1790 hours of flight time, varying from 750 to 5000 hours.

Equipment

Three test courses were established at Hunter-Liggett Military Reservation. Test Course 1 consisted of level and open terrain, having range markers placed at 250, 350, 600, 850, 1250, and 1850 meters (Fig. 1). Test Course 2 had markers located at 150, 250, 400, 650, 1100, and 1750 meters, and consisted of moderately level terrain with mixed vegetation and growth (Fig. 2). Test Course 3 consisted of rolling terrain with extensive vegetation, and had markers located at 200, 300, 500, 750, 1100, and 1800 meters (Fig. 3). These three test courses had several "dummy" markers in addition to the actual test ranges.

A fourth course used for the training of the subjects had markers located at 200, 300, 500, 750, 1000, 1500, 1800, 2000, and 2200 meters (Fig. 4). This course was comprised of mixed vegetation and terrain types.

These four courses were designed so as to be concealed from each other.

Situated at the furthest point on each of the courses was an M-48 tank, located in profile and serving as the target for the experiment. These target M-48's were visible from all markers on each of the four courses.

All of the test flights were flown in H-23 helicopters. Range estimates called in by the subjects were recorded using a Viking Model 95 tape recorder. An Army recording van, housing all of the equipment, was located within the test area. In addition to the tape recording facilities, a radio-equipped jeep manned by a stenographer-recorder was used to insure total coverage. This provided additional coverage in case of tape failure or other possible recording van breakdowns.

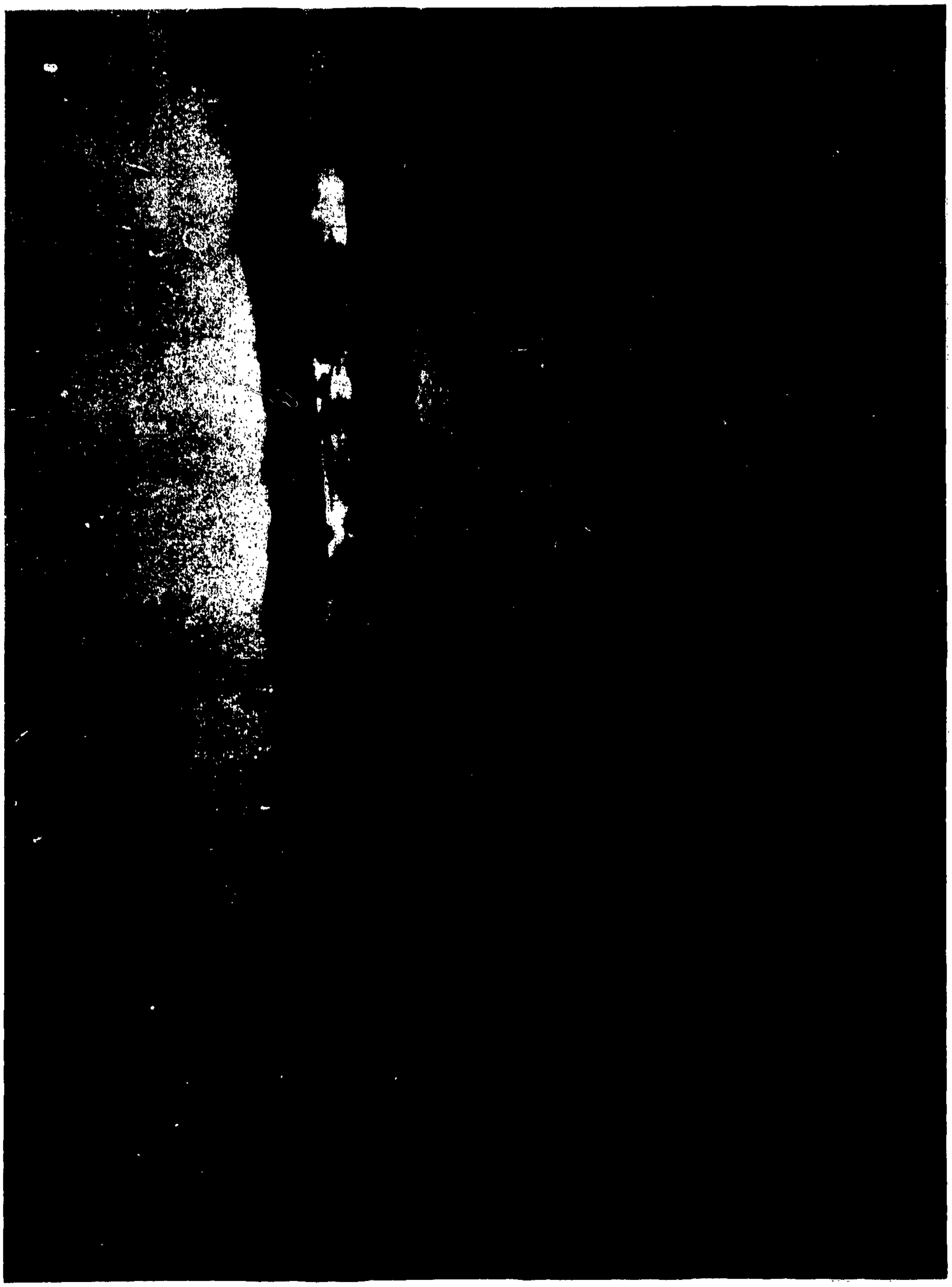

Fig. 1. TEST COURSE 1

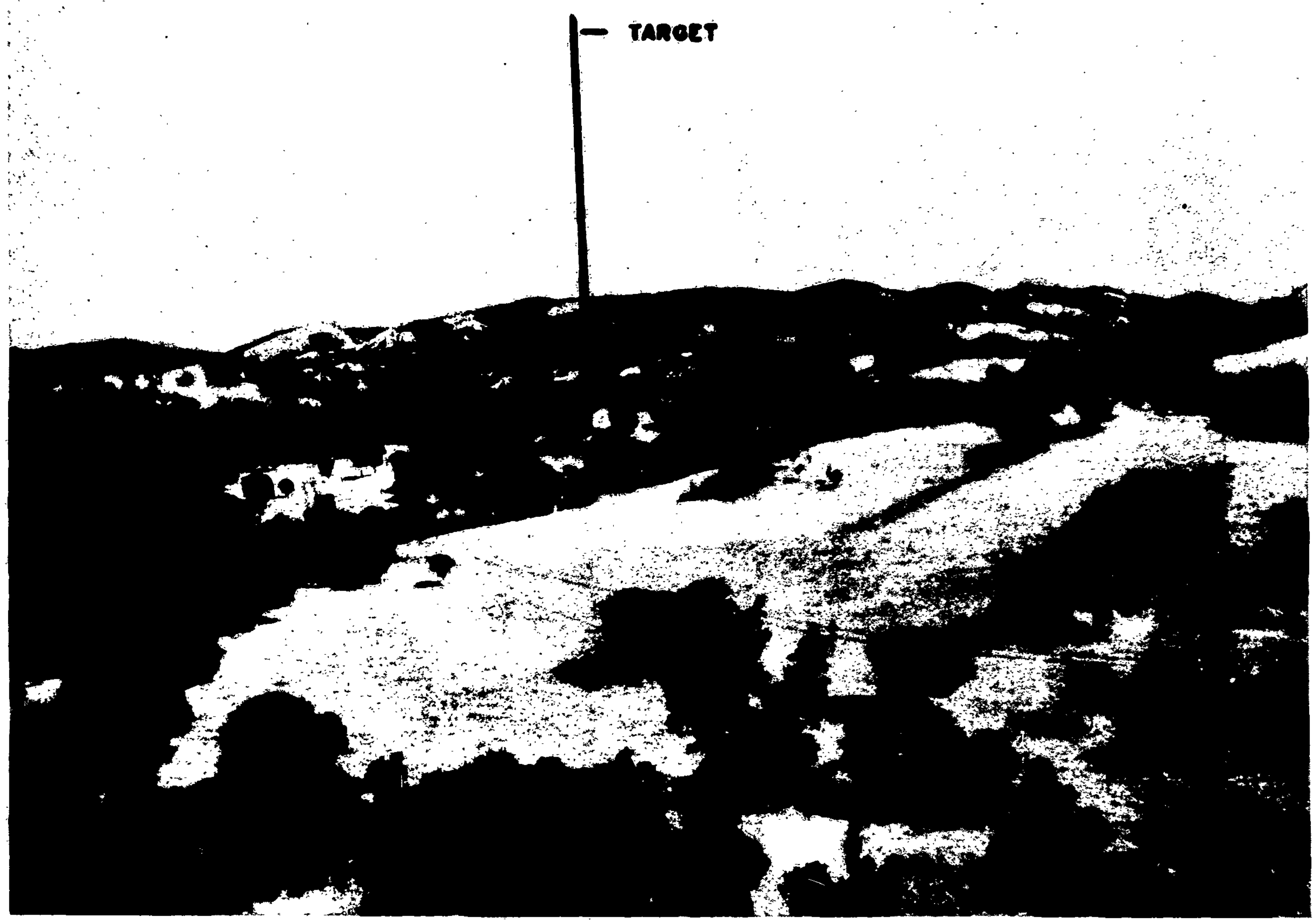

Fig. 2. TEST COURSE 2

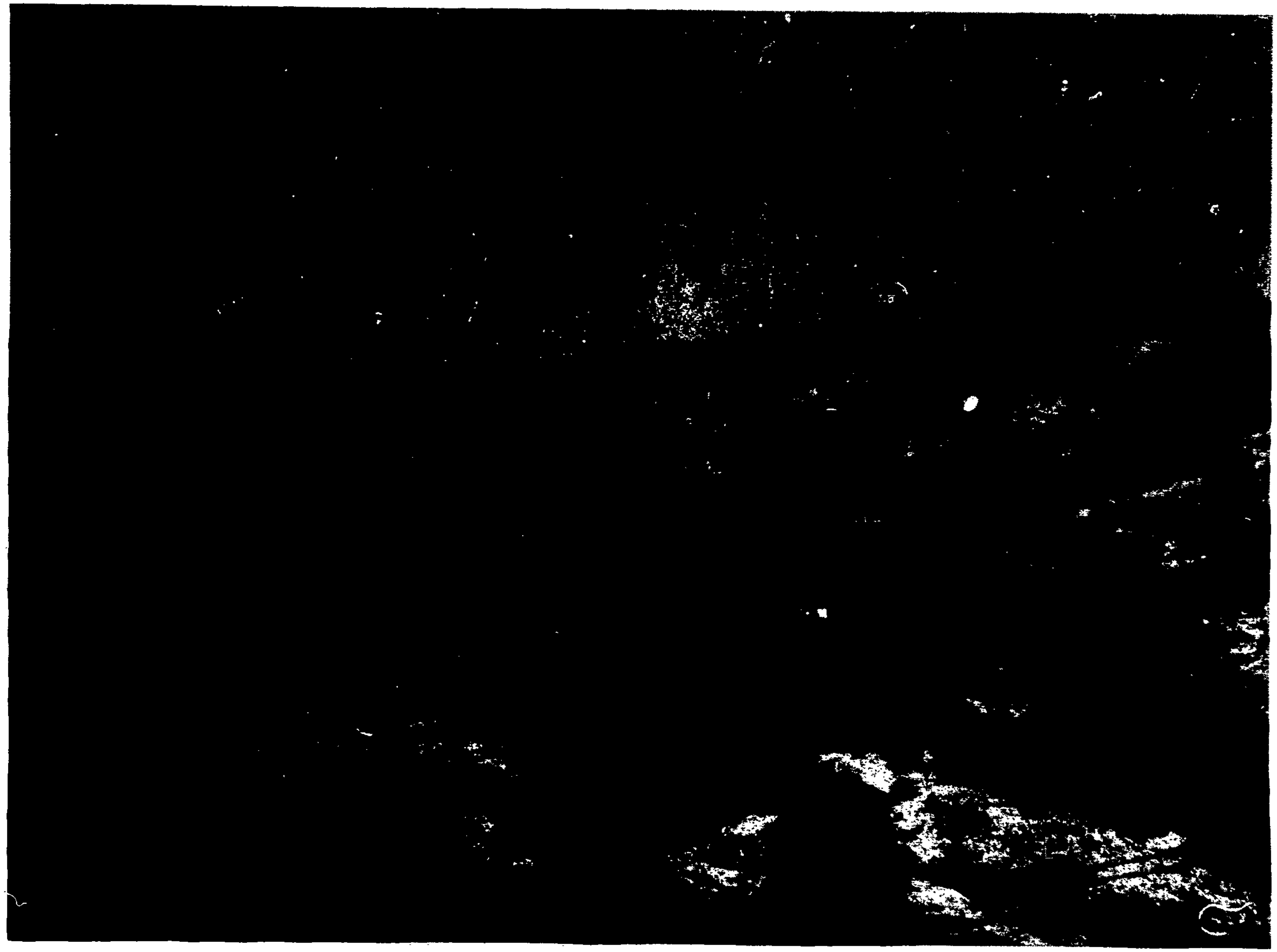

Fig. 3. TEST COURSE 3

Fig. 4. TRAINING COURSE

Experimental Procedure

The four H-23 helicopter pilots who were to fly the actual test runs spent a week in familiarization flights. At the end of this training period, each of the pilots was capable of locating and "popping-up" at any of the given markers on all of the courses. In addition, all of the pilots were able to maintain the test flights at the three pre-chosen altitudes, tree-top or 50 feet, tree-top plus 50 feet, and tree-top plus 100 feet.

This extensive training program for the pilots was to insure replication and standardization of test conditions, in order to afford each of the subjects an equal opportunity to accurately "range in" on the target.

All subjects received an hour of individual pre-test training. This training consisted of a pre-flight program orientation, at which time the objectives of the study and the subjects' individual part in the program were explained. When the subject fully understood what was expected of him, he was flown over the practice course. Here the two modes of flight ("pop-up" and "running") were demonstrated. The H-23 pilot flew the course informing the subject of the actual distances to the M-48 target. He would then make a series of "pop-ups" and inform the subject as to the slant distance to the targets. The subjects were then flown over the practice course and made their own estimates of the ranges, which, when necessary, were corrected by the pilot. These familiarization flights were made to provide each subject with a frame of reference in regard to distance, modes of flight, and target presentation. In addition, transmitting techniques for calling in the ranges were demonstrated and practiced until the subject was familiar with the procedure. The actual test runs were flown the following day.

A typical test run was as follows: The subject received a final review of procedure and was flown to the first test course. The order in which the courses were to be flown had been randomly established. Before entering in upon the test course, the pilot called the recording van giving them the name of the subject, course number, and mode of flight. At this point the helicopter pilot would orient the subject as to the location of the target. While the target was visible to the subject throughout the "straight-in" run, it could not be seen by him during the pre-"pop-up" maneuvers. The target, however, was clearly visible at the apex of the actual "pop-up".

The subject then proceeded to make six "pop-ups" at the different range markers in the course. Two estimates at each of the three different altitudes were made. The order was run according to the pre-determined schedule. The pilot approached the marker, activated his radio and called in the panel by color and letter, for example, White-Victor. This was the cue for the subject to call in the slant range from the helicopter to the target. The color and letter gave his true position from the target. This procedure was repeated until the sequence of "pop-ups" for this course was completed. At this point, the pilot notified the recording van that this portion of the test was completed. The helicopter then proceeded to the next course where the pilot called in the identifying information in regard to course, mode of flight, and subject. The subject was then oriented to the location of the target. The pilot proceeded to make a "running" flight at the target maintaining one of the three altitudes.

The subject called in his range estimate each time the pilot called in a panel marker, for a total of six successive range calls at the completion of the run. The helicopter then proceeded to the third range where the subject would fly the next series of "pop-ups". Upon completion of these, the helicopter returned to the first course flown, where he now would make a "running" attack, where he had previously made the initial series of "pop-ups".

This procedure was followed until all three of the test courses had been flown, utilizing both the "pop-up" and "running" techniques. At the conclusion of a completed series of flights, each subject had made a total of 18 "pop-ups", with six being made at each of the altitudes, and 18 "running" estimates, with six being made at each of the altitudes.

RESULTS

Two independent variables, course and altitude, were investigated under two modes of flight, "running" and "pop-up". The means of the estimated ranges were plotted against the true ranges. The graphs showing the results of each variable are presented in Figs. 5 through 9.

"Running" Mode of Flight

Figure 5 shows the results of the course variable in the "running" mode of flight. The means of the subjects' range estimations over the three course types were plotted against the true ranges. From inspection of the graph, the range estimations made on Course 3 deviated more from the true range estimation than the range estimations made on Course 1 or on Course 2. It may also be noted that over all three courses there was less deviation from the true range at the low ranges and at the high ranges on the abscissa, while at the middle ranges on the abscissa there appeared an increase in deviation from the true range.

Figure 6 shows the results of the altitude variable in the "running" mode of flight. The mean range estimations were plotted across all subjects against the true ranges. Again it is to be observed that less deviation from the true range occurred at the low range on the abscissa, while the middle and high range on the abcissa had considerably more deviation with the upper middle ranges having the most extreme deviation from the true range. In comparing the two variables, altitude and course, it may be noted that the subjects' mean range estimations had more deviation on the three different altitudes than on the three course types.

The chi square statistic was computed between the three different courses and the three different altitudes. The statistic was utilized to test the assumption of independence between the three altitudes in relation to the three courses. The chi square obtained was 2.27 with 4 degrees of freedom, which was not significant. Thus, it was concluded that the mean range estimations of the three altitudes in relation to the three mean range estimations of the three courses are independent, and the observed differences in mean range estimations are no greater than chance variation.

"Pop-up" Mode of Flight

The graph in Fig. 7 indicates the results of the course variable in the "pop-up" mode of flight. Again the means of the subjects' range estimations over the three different courses were plotted against the true ranges. This graph indicates that on Course 3 the subjects' mean range estimations have little deviation from the true ranges, while on Course 2 there was more deviation at the low ranges than the high ranges on the abscissa, and on Course 1 there was more deviation at the high ranges than at the low ranges on the abscissa. In comparing the course variable within the two modes of flight, it may be noted that there was more deviation of the mean range estimations to the true ranges on the "pop-up" mode than on the "running" mode of flight.

The graph in Fig. 8 reports the results of the altitude variable in the "pop-up" mode of flight. The mean range estimations were plotted across all subjects for the three altitudes against the true ranges. From inspection of the graph one can observe the extreme deviation of the mean range estimations of all three altitudes. Altitude three (tree-top + 100) appears to have the greatest mean range estimation deviation in respect to the true range. In comparing the altitude variable within the two modes of flight, one can see that the "running" mode of flight has more mean range estimation deviation from the true range in the upper ranges on the abscissa than the "pop-up" mode of flight. The "pop-up" mode of flight appears to have more mean range estimation deviation from the true range in the lower ranges on the abscissa than the "running" mode of flight. Due to the lack of independent observations, it was not possible to compute a meaningful chi square upon the "pop-up" data.

The graph in Fig. 9, however, represents a comparison of the two distributions of the mean range estimations, both the "pop-up" and "running" modes of flight, as a function of the true range, thus combining the variables, course and altitude, within each mode of flight. By inspection of this graph, it would appear that there were only chance variations in the resulting distributions of the mean range estimations plotted against true range between the "running" and "pop-up" modes of flight. Proceeding upon the assumption that these differences were only chance variations, the results of both the "pop-up" and the "running" modes of flight were combined to present an over-all view of the mean range estimations in relation to the true range. Figure 10 shows the mean range estimations over all variables as plotted against the true range, and also the standard deviation around the mean at each range. A further discussion of the justification and assumptions for combining the data and a discussion of the statistics applied to the data is included in the Appendix.

In order to present the results of this study in terms of the probable error (3) of a single range estimation, the experimenter felt that the presentation of the mean range estimation and the standard deviation around each mean would lead to erroneous conclusions in terms of percent of error. The possibility of erroneous interpretations of the results would occur due to the fact that the mean is greatly influenced by extreme scores. Examination of the raw data shows that most of the range estimations clustered around the true range. However, a few isolated estimations deviated a great deal from the true range, thus yielding a mean range estimation which was not representative of the majority of the range estimations.

Using the combined data, the range estimates around each true range were ranked from the highest range estimate to the lowest range estimate. Then the best 10 percent of the range estimates around the true range, the best 20 percent of the range estimates around the true range, the best 30 percent, etc., were determined on each true range. A theoretical curve for each percent level of cases around the true range was determined by averaging the values at each level across all ranges. Figure 11 compares the derived theoretical curve of the sample distribution based on the percent of cases around the true range with the theoretical percent of error curves, both above and below the true range. In plotting the theoretical curves based upon the sample percentage of cases around the true range, it was assumed that all subjects would estimate the range at the target as zero range when the true range in fact was zero range. Figure 11 shows that 90 percent of the range estimates in estimating range between 0 and 1850 meters lie between plus 55 percent error and minus 42 percent error. Approximately 50 percent of the range estimates lie between a plus 29 percent error and a minus 22 percent error, etc. Table 1 is a summary of the results based upon the curves in Fig. 11. In Table 1, the percentage of cases around the true range were tabled from 0 percent to 100 percent in equal intervals. The values corresponding to the percent of range estimates are the percentages of error in range estimation for both the range estimates above the true response line (0 error) and below the true response line (0 error).

TABLE 1

Summary of the Percent of Range Estimates

With the Percent of Error Above and Below the True Response Line (0 error)

Percent of Range Estimates	Error No Greater Than (Percent)	
	Above	Below
100	65	48
90	55	42
80	49	39
70	44	32
60	34	28
50	29	22
40	22	15
30	18	10
20	9	6
10	2	3
0	--	--

SUMMARY AND CONCLUSIONS

The purpose of this study was to investigate the ability of a trained observer to make slant range estimates from a moving helicopter. Two independent variables, course and altitude, were investigated under two modes of flight, "running" and "pop-up".

The results and conclusions of the investigation are:

a. Twenty percent of the range estimates had overcalls of no greater than 9 percent error and undercalls of no greater than 6 percent error. A more complete reporting of the distribution can be found in Table 1.

b. The results of the course variable did not yield statistically significant differences under either the "running" or the "pop-up" mode of flight.

c. The results of the altitude variable did not yield a statistically significant difference under either the "running" or the "pop-up" mode of flight.

It should be noted that, while both course type and altitude in this study did not yield significant differences, it is not possible to make a broad generalization eliminating the effects of these variables upon slant range estimates. It can only be concluded that the range estimates were not significantly affected by the three altitudes (50, 100, and 150 feet) investigated in this study.

It must be also noted that, while the course types employed in this study did not affect the range estimates, it is probable that a wider divergence of the terrain and vegetation type would have a significant effect upon the accuracy of the range estimates.

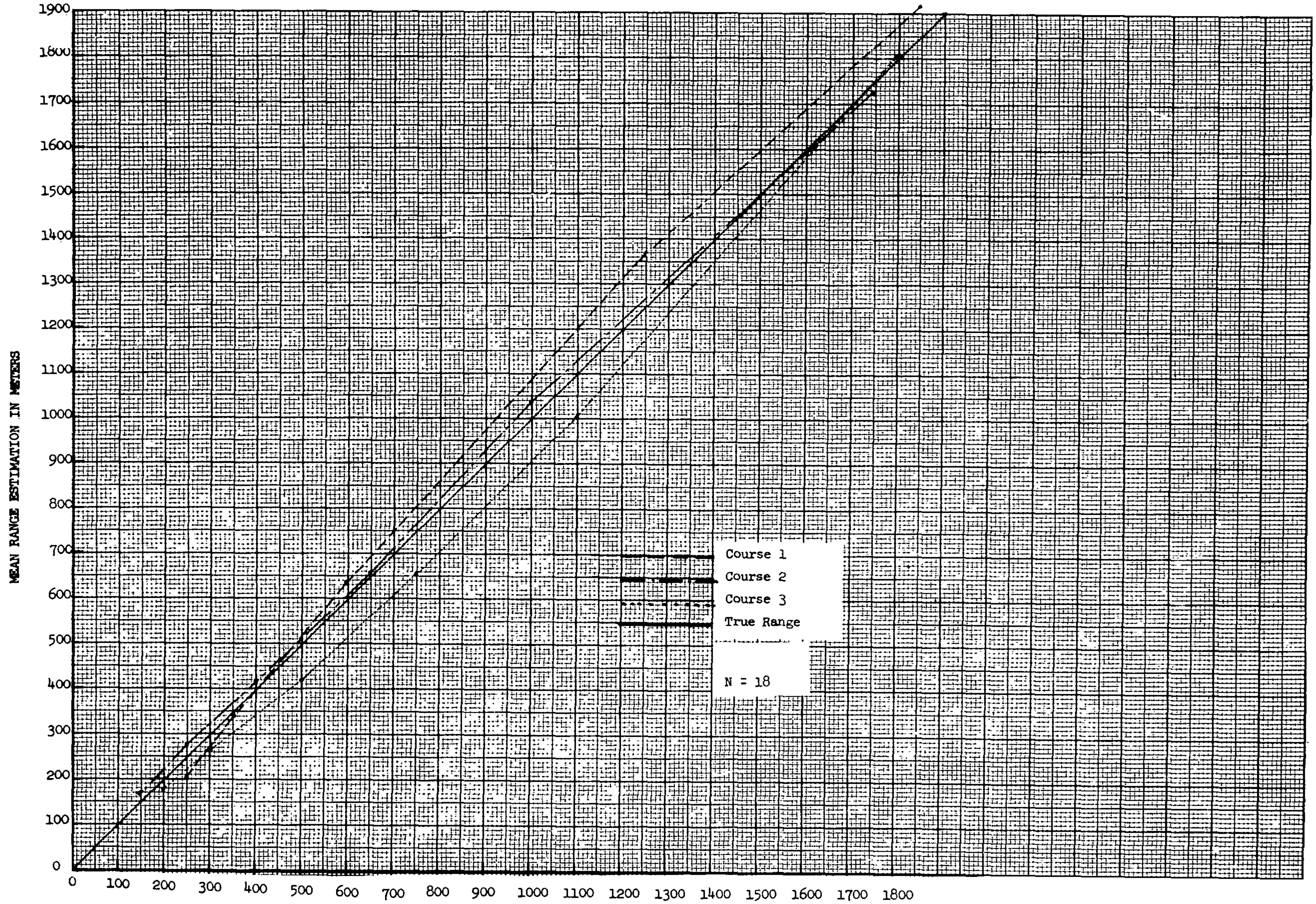

Fig. 5. MEAN RANGE ESTIMATION AS A FUNCTION OF TRUE RANGE IN REFERENCE TO COURSE TYPE ("RUNNING" MODE OF FLIGHT)

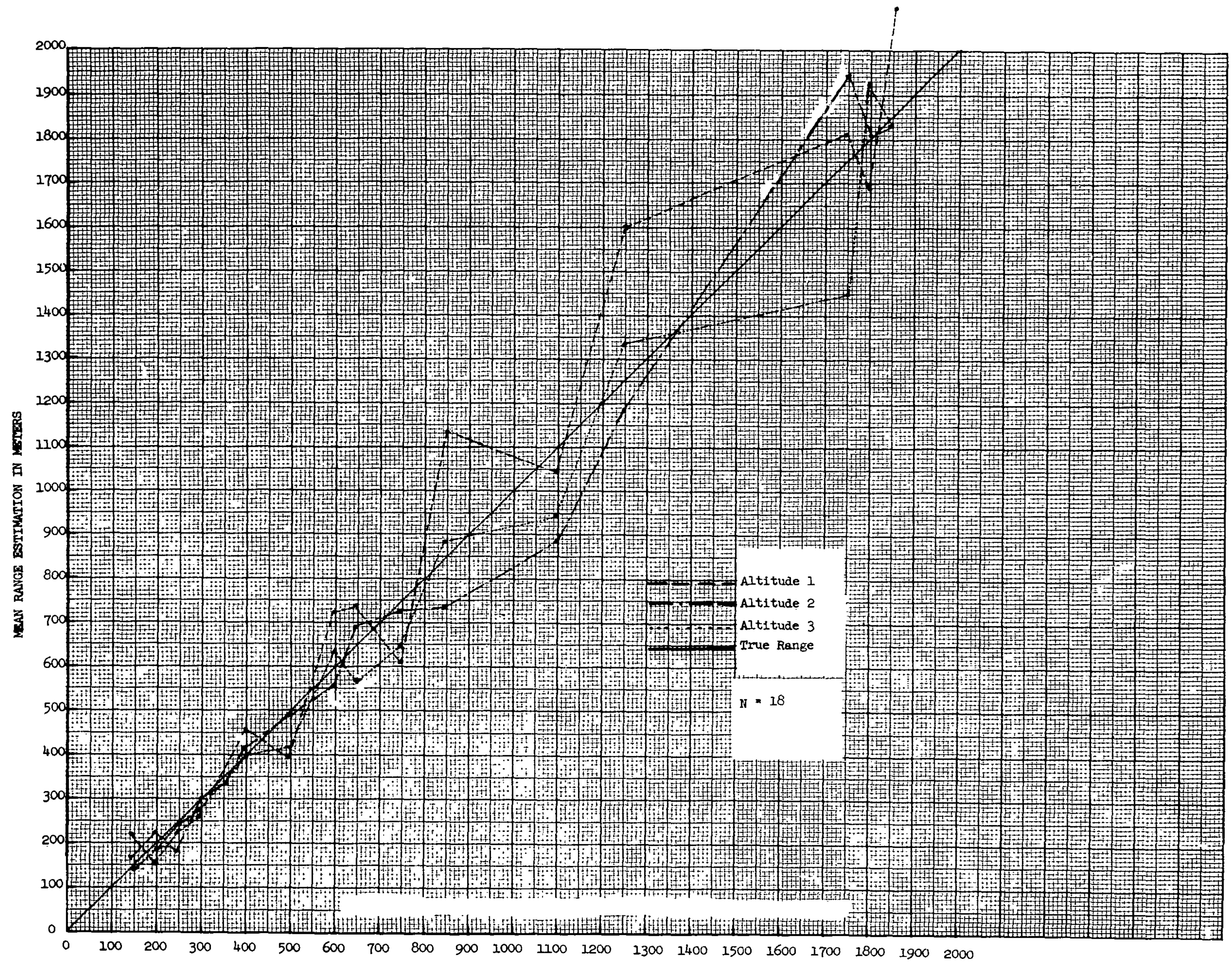

Fig. 6. MEAN RANGE ESTIMATION AS A FUNCTION OF TRUE RANGE IN REFERENCE TO ALTITUDE ("RUNNING" MODE OF FLIGHT)

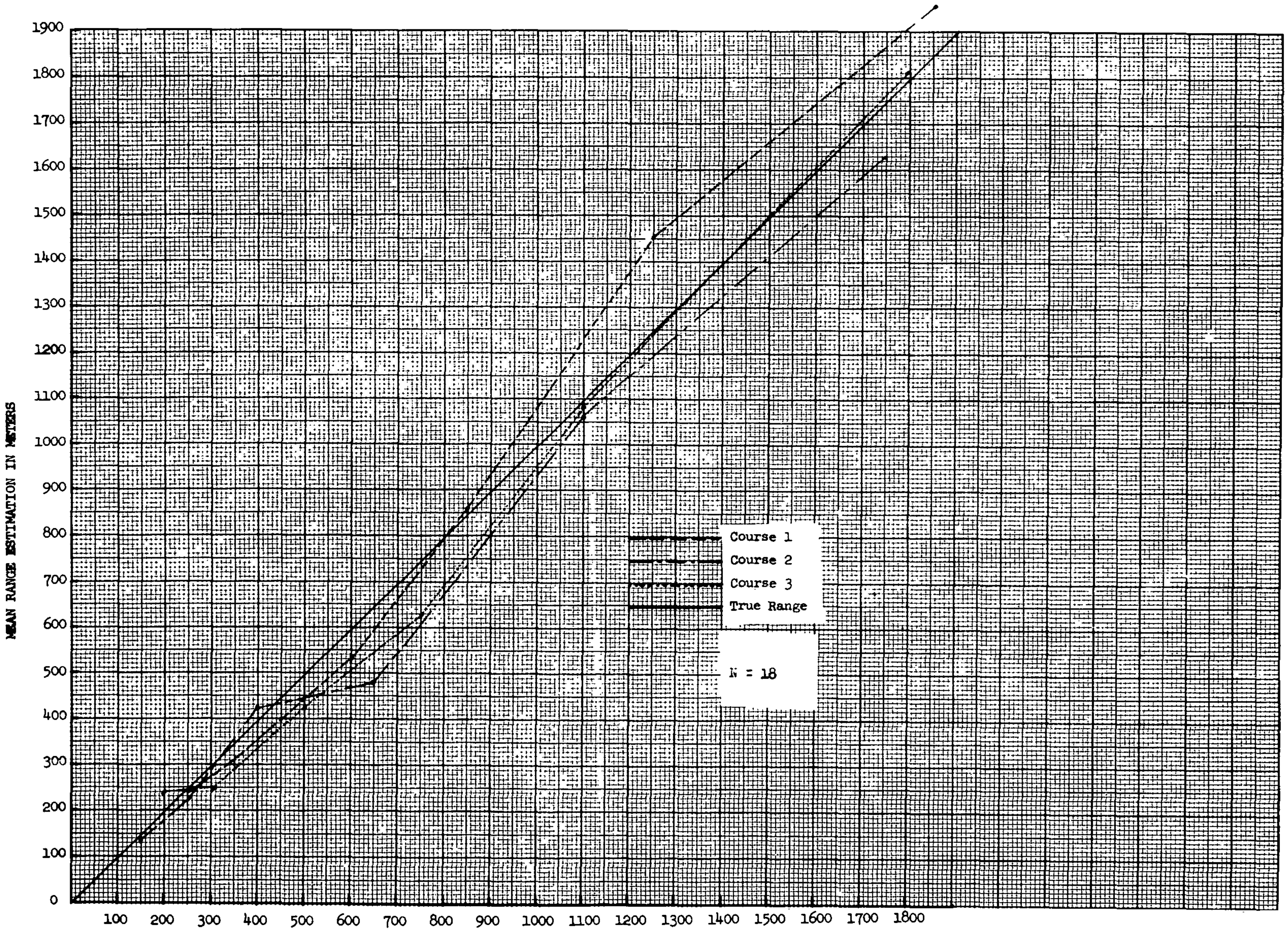

Fig. 7. MEAN RANGE ESTIMATION AS A FUNCTION OF TRUE RANGE IN REFERENCE TO COURSE TYPE ("POP-UP" MODE OF FLIGHT)

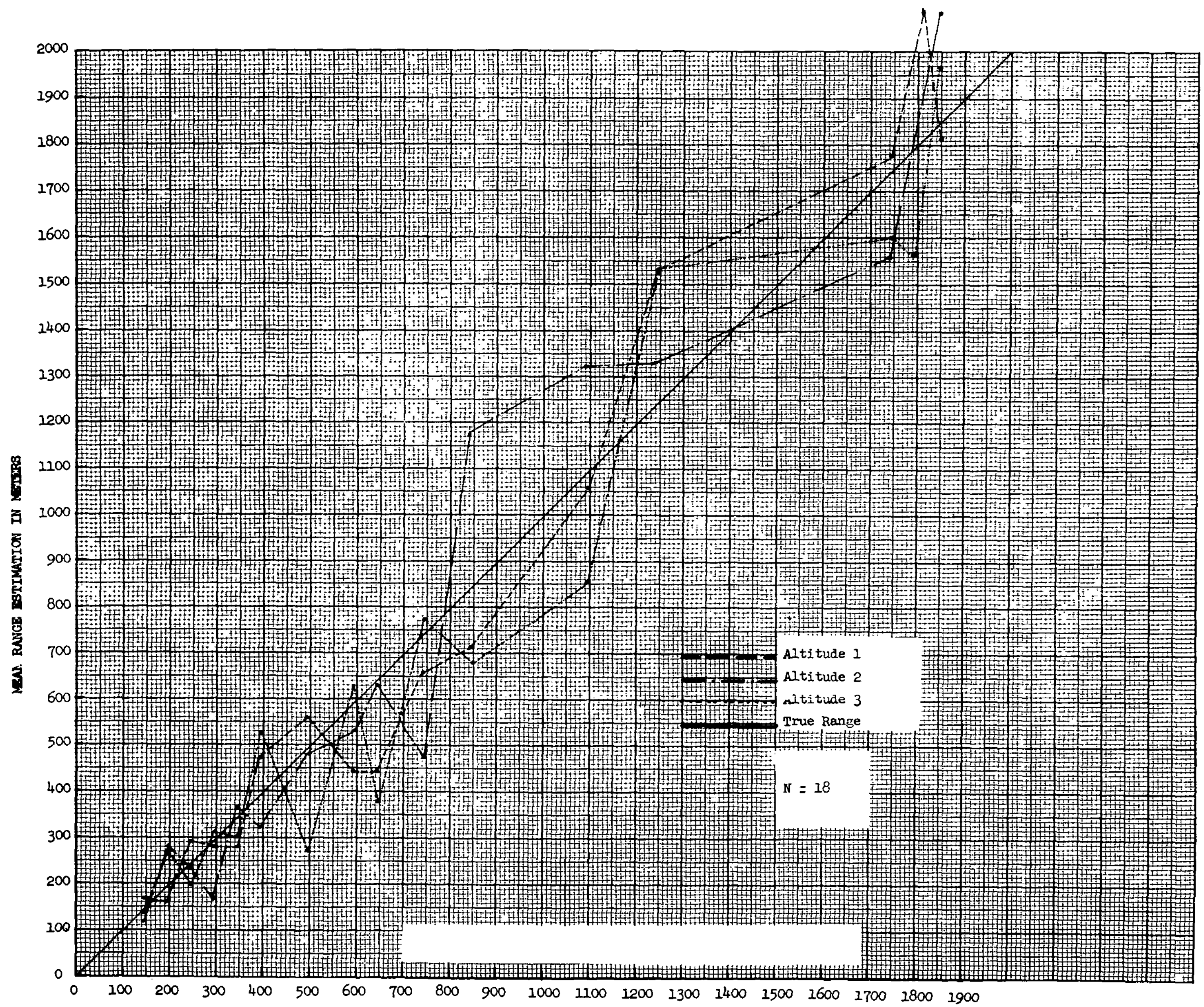

Fig. 8. **MEAN RANGE ESTIMATION AS A FUNCTION OF TRUE RANGE IN REFERENCE TO ALTITUDE ("POP-UP" MODE OF FLIGHT)**

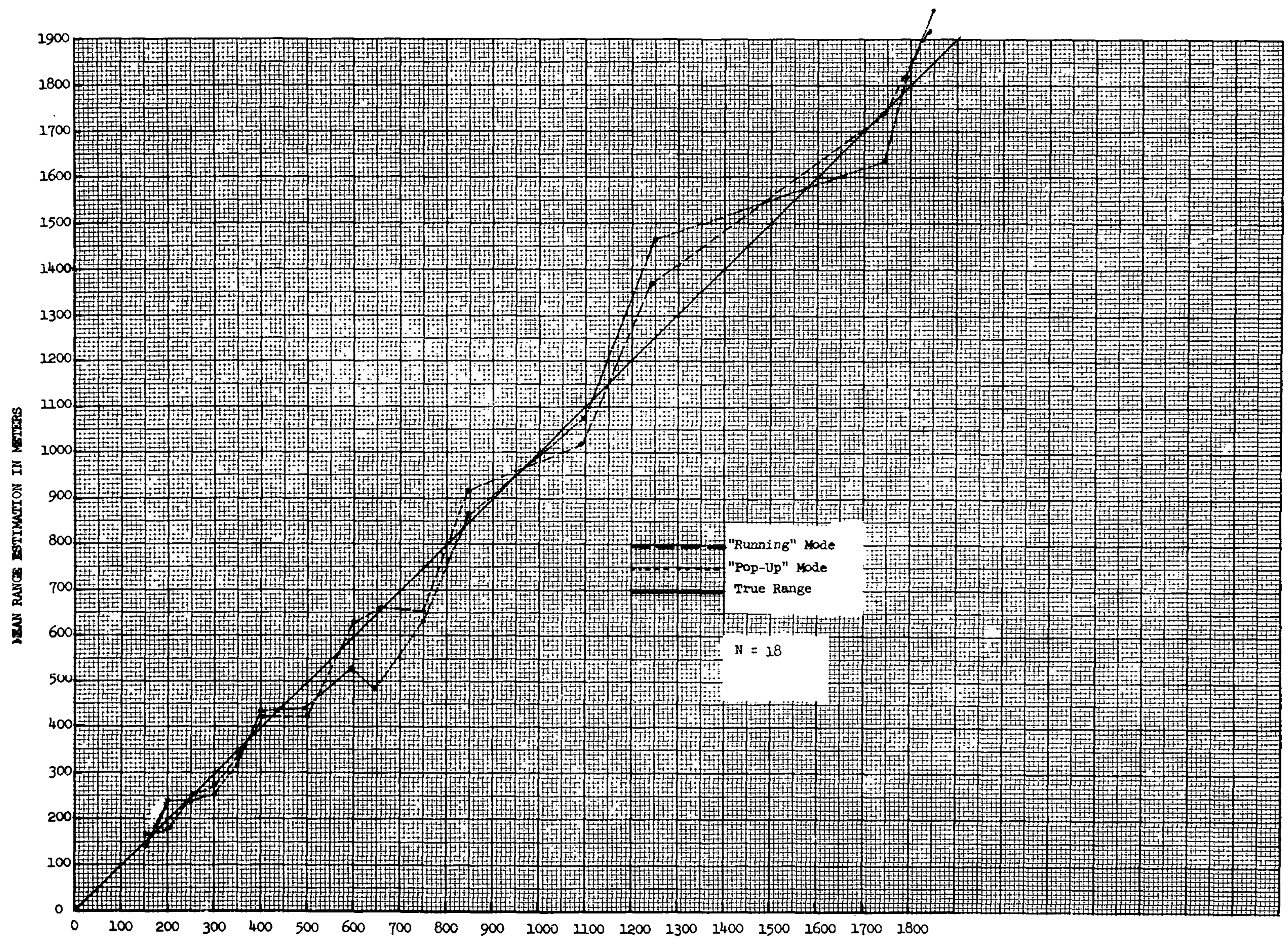

Fig. 9. MEAN RANGE ESTIMATION AS A FUNCTION OF TRUE RANGE COMBINING COURSE AND ALTITUDE

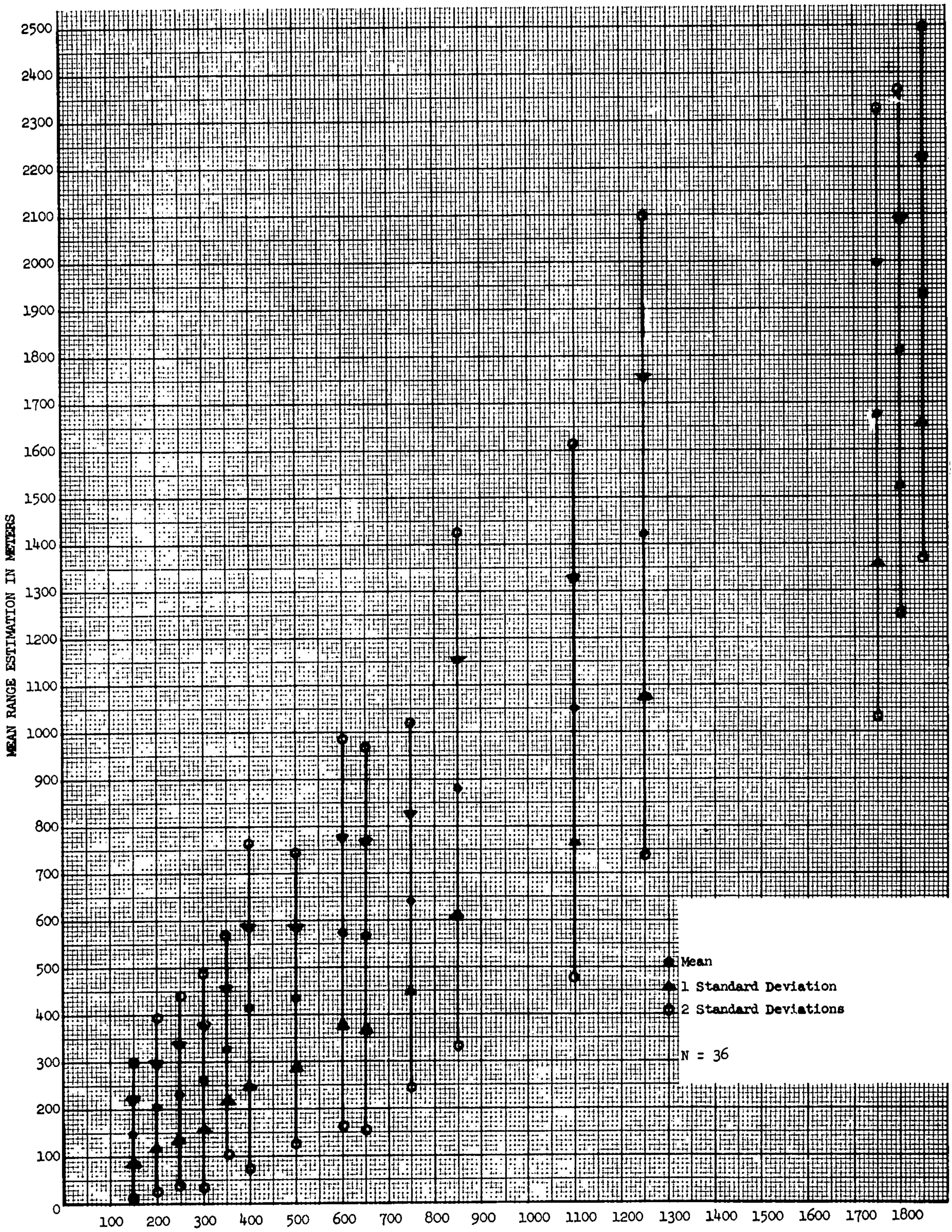

Fig. 10. MEAN RANGE ESTIMATION AS A FUNCTION OF TRUE RANGE COMBINING TOTAL DATA

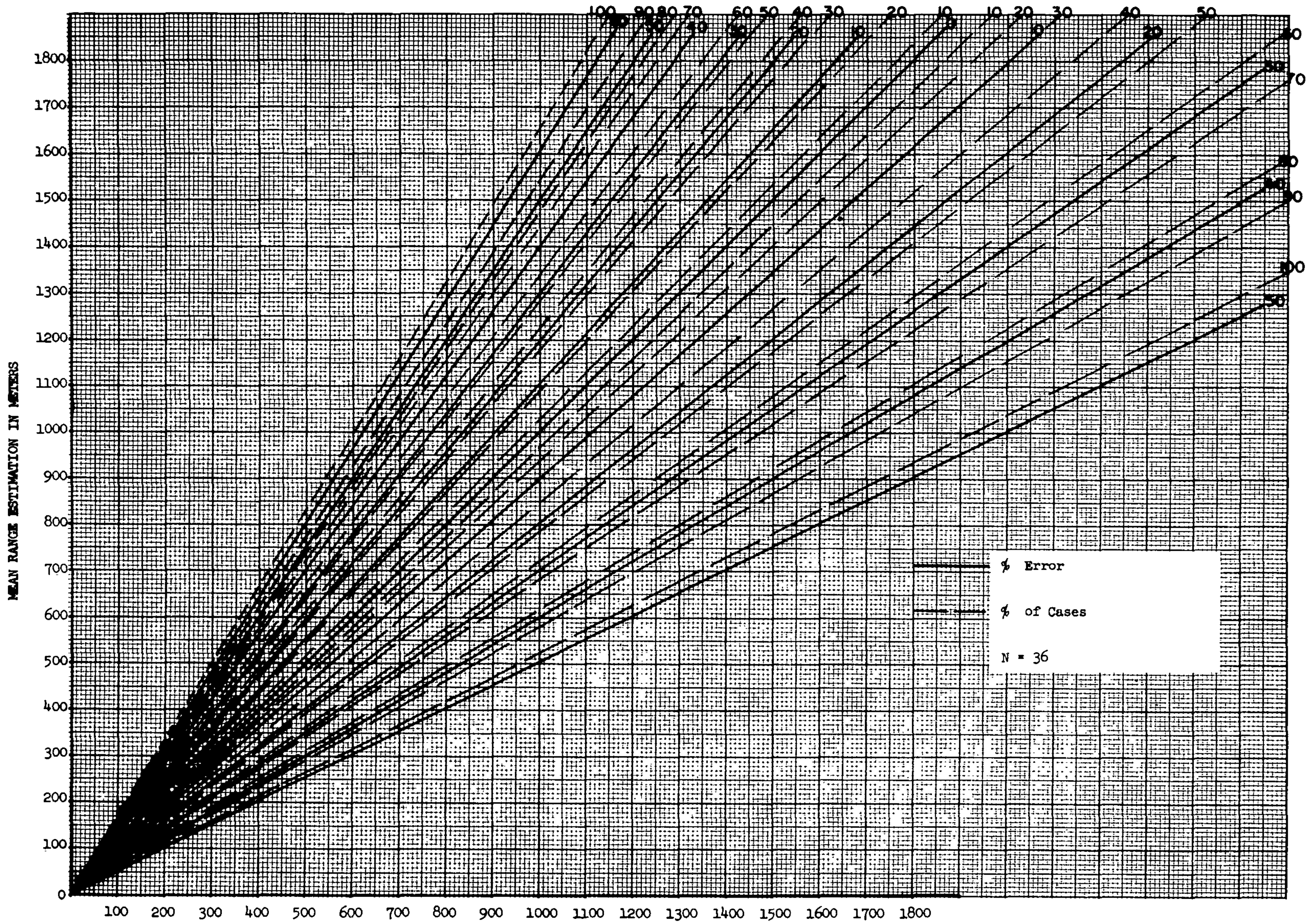

Fig. 11. MEAN RANGE ESTIMATION AS A FUNCTION OF TRUE RANGE IN REFERENCE TO THE PERCENT OF CASES OF THE SAMPLE COMPARED WITH THE TRUE ERROR

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APPENDIX

APPENDIX

DISCUSSION OF STATISTICAL ANALYSES

An F test was used to determine if there were any significant differences between the three altitudes on each course for the "running" mode of flight. The summary tables for each analysis of variance are presented in Tables 1 through 3. The F tests show that there were no significant differences between the three altitudes on the three courses. On the basis of the F tests, the data of the three altitudes over the three courses were combined in the "running" mode of flight.

Tables 4 through 6 show the summary tables for each analysis of variance between the three altitudes for each different course on the "pop-up" mode of flight. Again the F tests show that there were no significant differences between the three altitudes on the three courses. Thus, on the basis of the F tests, the data of the three altitudes over the three courses was combined in the "pop-up" mode of flight.

In general, the various error terms of the analysis of variance were very large. The extreme variance that any one range contributed was not totally unexpected. However, due to the large differences in variance at each range, Bartlett's test of homogeneity of variance was computed. In all cases the Bartlett tests were highly significant (Table 7), indicating that homogeneity of variance was not present. However, Box (4) has shown that Bartlett's test is as sensitive to non-normality as to differences in variance. Also, "the F test for means is, like the t-test, remarkably insensitive to non-normality of the population distribution, provided the departures from normality are of the same kind for the various populations sampled. Thus, for example, if the population of observations represented by one treatment is skewed and if the populations for the various other treatments are skewed in the same direction, the F test will be primarily sensitive to differences in means and not to the skewness" (5). The data in this study was skewed in a positive direction at each range, thus the tests of homogeneity probably were indicating non-normality rather than differences in variance. However, Edwards (5) points out that "where the number of observations is the same for the various treatments, the F test for the means in the analysis of variance is little influenced by heterogeneity of variance".

Thus, in this study the F tests are interpreted as testing the differences between the means and not skewness, and the Bartlett test was sensitive mostly to the skewness rather than differences in variance.

TABLE 1

ANALYSIS OF VARIANCE OF ERROR SCORES

FOR THE "RUNNING" MODE OF FLIGHT ON COURSE ONE

SOURCE	SS	df	MS	F
Altitude	89,491	2	44,745	--
Between Ss within groups	733,889	15	48,925	
Total between Ss	823,380	17		
Range	569,074	5	113,814	8.728**
Range x Altitude	263,565	10	26,356	2.02*
Pooled Ss x Range	977,986	75	13,039	
Total within Ss	1,810,625	90		
TOTAL	2,634,005	107		

* .05 level of significance
** .01 level of significance

TABLE 2

ANALYSIS OF VARIANCE OF ERROR SCORES

FOR THE "RUNNING" MODE OF FLIGHT ON COURSE TWO

SOURCE	SS	df	MS	F
Altitude	80,775	2	40,386	1.3309
Between Ss within Groups	455,157	15	30,344	
Total Between Ss	535,932	17		
Range	338,154	5	67,631	35.5952**
Range x Altitude	745,306	10	74,531	39.2268**
Pooled Ss x Range	142,477	75	1,900	
Total within Ss	1,225,937	90		
TOTAL	1,761,869	107		

** .01 Level of significance

TABLE 3

ANALYSIS OF VARIANCE OF ERROR SCORES

FOR THE "RUNNING" MODE OF FLIGHT ON COURSE THREE

SOURCE	SS	df	MS	F
Altitude	6,435	2	3,217	--
Between Ss within Groups	553,872	15	36,924	
Total Between Ss	560,307	17		
Range	346,904	5	69,381	9.896**
Range x Altitude	466,765	10	46,677	6.657**
Pooled Ss x Range	525,810	75	7,011	
Total within Ss	1,339,479	90		
Total	1,761,869	107		

** .01 Level of Significance

TABLE 4

ANALYSIS OF VARIANCE OF ERROR SCORES

FOR THE "POP-UP" MODE OF FLIGHT ON COURSE ONE

SOURCE	SS	df	MS	F
Between Range	920,186	5	184,037	6.9374**
Between Altitude	8,831	2	4,415	--
Altitude x Range	230,575	10	23,057	--
Within Groups	2,387,608	90	26,520	
TOTAL	3,547,200	107		

** .01 Level of Significance

TABLE 5

ANALYSIS OF VARIANCE OF ERROR SCORES

FOR THE "POP-UP" MODE OF FLIGHT ON COURSE TWO

SOURCE	SS	df	MS	F
Between Range	871,163	5	174,233	6.344**
Between Altitude	13,229	2	6,615	--
Altitude x Range	101,750	10	10,175	--
Within Groups	2,471,931	90	27,466	
TOTAL	3,458,073	107		

** .01 Level of Significance

TABLE 6

ANALYSIS OF VARIANCE OF ERROR SCORES

FOR THE "POP-UP" MODE OF FLIGHT ON COURSE THREE

SOURCE	SS	df	MS	F
Between Range	594,630	5	118,926	5.149**
Between Altitude	28,553	2	14,276	--
Altitude x Range	212,605	10	21,260	--
Within Groups	2,078,495	90	23,094	
TOTAL	2,914,283	107		

** .01 Level of Significance

TABLE 7

TESTS OF HOMOGENEITY

Course	Df	X^2
	"Pop-up" Mode of Flight	
1	5	35.8953**
2	5	75.4183**
3	5	34.0586**
	"Running" Mode of Flight	
Course	Df	X^2
1	5	48.3460**
2	5	30.1665**
3	5	36.9345**

** .01 Level of Significance

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Professional Assistance of Calvin G. Moler

Tech Memo 2-62 Unclassified

This study was conducted to investigate the ability of an observer to estimate slant range from altitudes of 50, 100, and 150 feet, utilizing both "pop-up" and "running" modes of flight over various terrain types.

Twenty percent of the range estimates had overcalls of no greater than 9 percent error and undercalls of no greater than 6 percent error.

The results of the course and altitude variables did not yield a statistically significant difference under either the "running" or "pop-up" mode of flight.

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