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STATISTICAL PREDICTION OF IMPACT DISPLACEMENT DUE TO THE WIND EFFECT ON AN UNGUIDED ARTILLERY ROCKET DURING POWERED FLIGHT

By

Abel J. Blanco

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March 1972

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UNITED STATES ARMY ELECTRONICS COMMAND - FORT MONMOUTH, NEW JERSEY

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CONTENTS

INTRODUCTION

During the last two years, efforts have been made to reduce the meteorologically induced impact dispersion of tactical unguided projectiles without increasing computational complexity of the manual field prediction techniques. The compensation errors involved in predicting the impact point of a specific trajectory are categorized as follows: hardware, environmental, and aiming errors. The meteorological parameters in the environmental compensation error make a large contribution to the error budget for the M50 unguided rocket; for this reason, individual studies of the meteorological parameters affecting the impact deflection of an unguided projectile have been in progress at Atmospheric Sciences Laboratory (ASL). Extensive statistical studies of the wind effect on the impact of unguided rockets have already been completed. Effects from atmospheric pressure and temperature are presently under investigation.

The current technique used in compensating for the wind effect during powered flight on the impact of an M50 rocket assumes a functional form for the low-level wind in its prediction procedures. Some statistical aspects of this assumed functional form of the wind versus height were studied by Miller, et al[1]. Results indicated that the wind follows a power law form with respect to height, but the power value in the expression varies considerably with time. This raises the possibility that the prediction of the impact deflection due to wind during powered flight could be improved by a least-squares technique applied to impact data. This led to the development of new estimators[2] to reduce the existing dispersion in the predicted impact produced by the current technique.

This study presents computational results of two statistical estimators derived in an earlier study[2] to reduce the impact dispersion of the M50 unguided rocket due to the low-level wind. For completeness, a brief treatment of the ballistic technique currently in use and the two statistical techniques is also presented. To insure valid comparisons between the statistical and ballistic estimators, all computations were performed by the ASL five-degree-of-freedom trajectory simulator.

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[1] Miller, W. B., L. E. Traylor, and A. J. Blanco, 1970, "Some Statistical Aspects of Power Law Profiles," Technical Report ECOM-5303, Atmospheric Sciences Laboratory, U.S. Army Electronics Command, White Sands Missile Range, New Mexico.

[2] Miller, W. B., A. J. Blanco, and L. E. Traylor, 1970, "Impact Deflection Estimators from Single Wind Measurements," Technical Report ECOM-5328, Atmospheric Sciences Laboratory, U. S. Army Electronics Command, White Sands Missile Range, New Mexico.

A total of 1289 wind profiles collected from a relatively flat desert area at White Sands Missile Range (WSMR), New Mexico (1230m MSL) in the spring of 1969 was used to compute the value and to check the stability of the derived statistical estimators. Values for the estimators tested are presented for three quadrant elevation (QE) angles (200, 400, and 800 mils) representative of typical M50 trajectories. Reductions of 56% in the range component and 44% in the cross component of the impact dispersion for a 200 mil trajectory were the highest afforded by the new estimators. One hundred summer and 60 winter wind profiles collected at WSMR in 1967 are used to investigate the behavior of the statistical estimator's stability as compared to the 1969 spring data. Finally, 112 fall of 1967 and 54 summer of 1969 wind profiles collected from foothill terrain at Green River, Utah (1360m MSL and about 800 km to the NW of WSMR), are used to check terrain effects on the value of the new estimators as compared to the WSMR data.

IMPACT DEFLECTION ESTIMATORS

Only the basic development of the cross component for the three estimators tested in this study is presented; for complete details see References 1 and 2. The powered flight wind correction technique as used with the Honest John M50 rocket involves two steps. First, a power law profile for the low-level wind is assumed; from a single wind measurement the current technique then predicts a wind profile from the following expression:

$$U(Z) = U_r \left(\frac{Z}{Z_r}\right)^p$$

where U(Z) is the wind speed at height Z, U_r is the single wind speed measurement at Z_r (the reference height), and p takes on particular values for daytime and nighttime conditions. Secondly, with the wind predicted up to 183 meters by this power law and assumed constant above 183 meters to the motor burnout altitude of the M50, a ballistic weighting technique is utilized to estimate the impact deflection D as

$$D = \delta \int \omega'(Z) U(Z) dZ$$

$$D = \delta \{ \int_{Z_o}^{183} \omega'(Z) \left(\frac{Z}{Z_r}\right)^p dZ + [\omega(Z_b) - \omega(183)] \left(\frac{183}{Z_r}\right)^p \} U_r$$

$$D = A\ U_r$$

where

$$A = \delta\{\int_{Z_o}^{183} \omega'(Z)\left(\frac{Z}{Z_r}\right)^p dZ + [\omega(Z_b) - \omega(183)]\left(\frac{183}{Z_r}\right)^p\},$$

δ is the unit wind effect, $\omega'(Z)$ is the derivative of the cumulative ballistic weighting curve with respect to height, and

$$U_r\left(\frac{Z}{Z_r}\right)^p$$

is the predicted wind profile. The impact displacement due to the low-level wind can now be expressed as the product of the values for the current estimator A and the single wind measurement U_r. A is a function of quadrant elevation, of course. This concept is incorporated into firing tables so that the artilleryman need only measure the wind at Z_r (currently chosen at 15.2 meters) and obtain launcher settings for compensation for the effect of the low-level wind.

The statistical techniques follow the same form as the ballistic technique in predicting the impact point for an unguided projectile, i.e., $D = \alpha U_r$. The artilleryman would go through the same mechanics in acquiring the launcher settings from a firing table containing the computational results of the new technique. These new estimators do not assume either a functional form of the wind with respect to height or any knowledge of a weighting curve. Actual wind profiles are used to calculate simulated impacts; in turn, these impacts, together with a single wind measurement at 15.2 meters from the corresponding profiles, are used to compute an optimal value for the estimator α in the least-squares sense. These new estimators differ from prior ones in that their construction utilizes statistical rather than physical properties, and they possess certain optimal features. The availability of a ballistic simulator permits a purely statistical approach to estimation of impact deflection due solely to wind during powered flight.

The predicted impacts are represented componentwise by the statistical technique as the sum of the no-wind impact I_o and an impact deflection. The approximation of the actual impact I_a by this sum is then developed by the method of least squares to compute the value of the estimator that will best predict the actual impact for all the profiles in the set of data utilized. For the actual cross impact given by one profile one has

$$I_a \approx I_o + \alpha U_r$$

$$R = I_a - (I_o + \alpha U_r)$$

where R is the residual. The values of the statistical estimators are obtained as follows (treating specifically the cross component):

$$\text{let } D_i = I_{ai} - I_{oi}, \text{ for the ith profile,}$$

$$\text{then } R_i = D_i - \alpha U_{ri}.$$

Requiring that

$$\frac{\partial \Sigma R_i^2}{\partial \alpha} = 0$$

gives

$$\alpha = \frac{\Sigma D_i U_{ri}}{\Sigma U^2_{ri}},$$

and similarly for the range estimator β. Together, α and β comprise statistical estimator #1.

In a similar manner, the second statistical estimator is derived. This time the influence of cross wind on range impact displacement and range wind on cross impact displacement is considered. Let U_r and V_r be the cross and range components of the wind speed at the reference height. The approximation of the actual impact is now represented as

$$I_a \approx I_o + \alpha_1 U_r + \alpha_2 V_r$$

$$R = I_a - (I_o + \alpha_1 U_r + \alpha_2 V_r).$$

The value of the statistical estimator with correlation (statistical estimator #2) is computed by minimizing the sum of the squares of the residuals with respect to both cross and range estimators. The derived optimal estimators for the cross component take the form

$$\frac{\partial}{\partial \alpha_1} [\Sigma(D_i - \alpha_1 U_{ri} - \alpha_2 V_{ri})^2] = 0$$

$$\frac{\partial}{\partial \alpha_2} [\Sigma(D_i - \alpha_1 U_{ri} - \alpha_2 V_{ri})^2] - 0$$

$$\alpha_1 = \frac{\Sigma D_i U_{ri} \Sigma V_{ri}^2 - \Sigma D_i V_{ri} \Sigma V_{ri} U_{ri}}{\Sigma U_{ri}^2 \Sigma V_{ri}^2 - (\Sigma U_{ri} V_{ri})^2}$$

$$\alpha_2 = \frac{\Sigma U_{ri}^2 \Sigma D_i V_{ri} - \Sigma U_{ri} V_{ri} \Sigma D_i U_{ri}}{\Sigma U_{ri}^2 \Sigma V_{ri}^2 - (\Sigma U_{ri} V_{ri})^2} ,$$

and similarly the range component β_1 and β_2 are derived. In summary, the three low-level estimators of impact displacement considered are of the following form:

(1)	(AU_r, BV_r)	Ballistic
(2)	$(\alpha U_r, \beta V_r)$	Statistical #1
(3)	$(\alpha_1 U_r + \alpha_2 V_r, \beta_1 V_r + \beta_2 U_r)$	Statistical #2

EXPERIMENTAL PROCEDURE

Date utilized in this study consisted of met tower data and pilot balloon (pibal) data obtained from T-9 radar tracks. The tower data were taken from the Atmospheric Sciences Laboratory 152.4m meteorological research tower (instrumented at eight levels) located in a relatively flat desert area at White Sands Missile Range, New Mexico, and from a similar met tower located in a foothill area at Green River, Utah. Table I identifies all the reduced tower wind profiles taken from both locations.

At WSMR, wind speed and direction were measured simultaneously at heights of 7.6, 15.2, 38.1, 53.3, 68.6, 91.4 121.9, and 152.4 meters, converted electronically to component form, oriented with respect to true North, and transmitted analog to a NAVCOR A/D converter, where the data flow was sampled at one-second intervals. The data were then passed through the Kineplex data modem and transmitted through range communications to a station where the data were taped and compressed ready for input to a UNIVAC 1108. The data were collected at WSMR over certain two-hour periods: 0930-1130, 1330-1530 local daytime and 0300-0500, 1900-2100 local nighttime during March and early April 1969. These spring data, after being subjected to a visual editing technique, were averaged over 1-, 2-, or 5-minute intervals (each interval being a profile) to conform to the electronic average obtained by the AN/MMQ-1B. The AN/MMQ-1B is the windset used for measuring the wind (in component form U_r, V_r) to supply the single wind measurement for the low-level wind correction of the M50. Tower profiles were also collected during June, July, and December 1967, but this time they were reduced visually from strip charts and averaged over one-minute intervals. The data were collected

TABLE 1

DATES, TIMES AND NUMBER OF TOWER WIND PROFILES FOR WSMR-GREEN RIVER COMPARISON

	WSMR, NEW MEXICO, NUMBER OF PROFILES (901)																			
MONTH	MARCH 69												APR 69		JUN 67		JUL 67	DEC 67	
DATE	10	11	12	14	17	18	19	20	21	24	25	26	1	3	6	7	10	19	20
TIME LST 0300-0500	10		24		12	15	16	15	15		14	9	5	2					30
0930-1130	16	16	28		15	15	15	15	17		14	21	5		20	20	20		
1330-1530	5		27	19	19	16	14	16	16	16	16	22	7		20	20			
1900-3100	7	9	15	8	14	15	15	15	8	14	15	8		3				30	

	GREEN RIVER, UTAH, NUMBER OF PROFILES (166)															
MONTH	AUG 67		SEP 67								OCT 67	JUN 69				
DATE	24	25	7	8	9	10	14	25	28	29	11	5	6	19	23	26
TIME LST 0000-0300		2		8	16					8			11		12	
1900-2400	14		12			3	10	11	21		7	13		6		12

at identical heights except for the second level which was set at 22.9 instead of 15.2 meters.

At Green River, wind tower data were reduced in a similar manner as the Spring 1969 WSMR data; however, these measurements were collected from heights of 12.5, 21.0, 32.9, 46.3, 63.1, 85.9, 112.2, and 139.3 meters on the Green River meteorological tower. All Green River data were collected during nighttime conditions in support of the Athena Project for firings during August, September, and October 1967 and June 1969 and were averaged over one-minute intervals.

For testing the new estimators at higher quadrant elevation angles, pilot balloons were released at approximately 10-minute intervals throughout each two-hour period sampled at WSMR during the Spring of 1969. The pibals were tracked by a T-9 radar to obtain a profile from 152.4 meters to burnout altitude of the M50 launched at the higher quadrant elevations. Wind data were sampled at one-second intervals and stored on magnetic tape, transformed to a true-north-oriented cartesian coordinate system identical to that used by the tower data, and averaged over three-second intervals giving approximately 15-meter layers. Table II shows the total number of tower and pibal wind profiles matched to cover the high Q.E. burnout altitudes.

COMPUTATIONAL RESULTS

Comparison of the impact dispersion for the three estimators tested was accomplished by means of the ASL simulator. The ballistic weighting functions together with the value of p used to compute M50 firing table corrections, 0.2 daytime and 0.4 nighttime, were employed to tabulate the estimator (A,B). Measured wind profiles were used as input to the simulator to calculate the actual impacts; these impacts, together with the corresponding wind speed at 15.2 meters, were utilized to compute the value of the statistical estimators (α,β) and $(\alpha_1, \alpha_2; \beta_1, \beta_2)$.

M50 trajectories were computed for 200, 400, and 800 mils quadrant elevations at WSMR, New Mexico (1230.5 meters MSL). All simulated impacts were computed using the MSL elevation from the area of wind profile collection as the launcher MSL position and with firing azimuth due North. The estimator values computed for WSMR are illustrated in Table III. It should be emphasized that these values do not include the low-level wind effect from the surface to 7.6 meters, the height of the first level on the met tower. The 90 five-minute averaged daytime (0930-1130) wind profiles were extrapolated to include the missing 7.6 meters of wind data; the computed values for the three estimators increased as a result of the added wind included in the calculation of the simulated impacts. The values for the 400 mils ballistic (A,B) and statistical (α,β) estimators were as follows:

TABLE II

DATES, TIMES AND NUMBERS OF TOWER + T-9 PIBAL
WIND PROFILES FOR WSMR, NEW MEXICO 1969

		Averaging Interval (minutes)			
		A 5	B	A 2 & 1	B
NO. OF	DAYTIME	90	94	26	45
PROFILES	NIGHTTIME	78	62	26	20

NUMBER OF PROFILES

		5-Minute Average											2-Minute Average			1-Minute Average			
MONTH		MARCH											MARCH	APRIL		MARCH			APRIL
DATE		10	11	12	14	17	18	19	20	21	24	25	26	1	3	10	12	26	1
TIME	0300-0500	2		9		5	8	11	10	9		8	2		2		9	2	5
LST	0930-1130	9	11	12		10	10	9	10	12		7	10	5			11		
	1330-1530			11	12	12	11	9	9	11	11	8	11	7		5	11	11	
	1900-2100		2	11	1	9	12	10	11	1	10	11	8		3	7		8	

A - daytime, 0930-1130; nighttime, 1900-2100.
B - daytime, 1330-1530; nighttime, 0300-0500.

TABLE III

IMPACT DEFLECTION ESTIMATOR VALUES FOR DIFFERENT Q.E. AT WSMR, NEW MEXICO, SPRING (m/MPH)

	DAYTIME (184 PROFILES)				NIGHTTIME (140 PROFILES)		
	BALLISTIC	#1	#2		BALLISTIC	#1	#2
QE(Mils)	A	α	α_1 α_2	CROSS	A	α	α_1 α_2
200	25.15	22.94	22.80 - 0.68		30.22	26.36	26.18 - 0.59
400	62.47	53.63	53.23 - 1.90		82.90	67.80	67.51 - 0.93
800	141.61	119.61	119.06 - 7.91		199.88	149.21	151.43 - 7.18
	B	β	β_2 β_1	RANGE	B	β	β_2 β_1
200	-19.35*	-16.93	0.61-16.78		-22.78*	-17.79	0.83-17.35
400	-33.53*	-28.09	1.00-27.83		-44.43*	-29.62	1.81-28.65
800	-42.14*	-31.94	2.96-31.19		-59.88*	-32.08	3.55-30.19

*Estimators for Head and Tail Averaged.

	(A,B)	(α,β)
from 7.6 meters	(62,-33)	(54,-28)
from surface	(69,-37)	(61,-32)

Since the type of extrapolation applied to the actual wind profiles may also contribute to the increase in estimator value, to avoid data contamination the principal part of this study was performed with the low-level wind effect beginning from the first height on the WSMR tower (7.6m) to burnout altitude.

The standard deviation of impact and mean miss distance given by the new estimators were then compared to those from the ballistic estimators. Table IV presents the reduction in rms miss distance afforded by the new estimators, and the statistical quantities are listed in Table V. As expected, the statistical estimator with correlation (α_1, α_2; β_1, β_2) shows the smallest impact dispersion, but only slightly. Attention will therefore be focused on the less complex linear estimator (α,β). This estimator was checked for stability by dividing the data into sets and computing the estimator value. The results shown in Table VI indicate that the estimator retains its approximate value from data set to data set with only slight dependence on the data. The nighttime conditions illustrate the largest variation in estimator values. For the 200 mils trajectory, comparing the estimator value for the total 240 profiles and the last 50-profile set, there is a variation of 5% in both the cross and range components. For the 800 mils trajectory, a similar comparison between the 140 profiles and the 62 profiles yields a variation of 26% in the cross and 6% in the range component. Even with this maximum spread in estimator value between the different wind profile sets, the new statistical estimator produces a smaller impact dispersion than the ballistic theory - p profile estimator. By reviewing Table III and recalling that the predicted impacts are calculated from the sum of the no-wind impact and the product of the reference wind speed and the estimator value, one can show that if (α,β) are the optimal estimators calculated by the least-squares method, then variation from (α,β) will produce an increase in the rms miss distance, and the ballistic values for nighttime, 800 mils, are considerably different from any of the statistical estimators.

The next phase was to investigate seasonal variability of the linear statistical estimator. The statistical estimators computed from the 184 daytime and 140 nighttime profiles collected during the Spring of 1969 at WSMR were compared with estimators computed from 100 daytime Summer of 1967 and 60 nighttime Winter of 1967 profiles collected from the same location. In acquiring the different data it was impossible to obtain data collected at the same heights on the meteorological tower. Since the summer and winter data did not have a wind measurement at 15.2 meters,

TABLE IV

PERCENT REDUCTION OF IMPACT DISPERSION AFFORDED BY THE STATISTICAL CORRECTION TECHNIQUES

BALLISTIC TECHNIQUE TAKEN AS STANDARD

	DAYTIME 184 PROFILES		NIGHTTIME 140 PROFILES	
QE (Mils)	#1	#2	#1	#2
CROSS				
200	40	44	22	22
400	38	40	22	22
800	27	28	24	25
RANGE				
200	51	56	39	41
400	41	43	38	39
800	36	41	39	41

TABLE V

MEAN MISS DISTANCE (m) AND STANDARD DEVIATION(m)

	DAYTIME (184 Profiles)				NIGHTTIME (140 Profiles)			
	CROSS		RANGE		CROSS		RANGE	
	MEAN MISS DISTANCE	STANDARD DEVIATION	MEAN MISS DISTANCE	STANDARD DEVIATION	MEAN MISS DISTANCE	STANDARD DEVIATION	MEAN MISS DISTANCE	STANDARD DEVIATION
200 MILS								
BALLISTIC	4.71	17.92	-11.20	15.54	0.12	45.21	-19.36	32.63
#1	2.79	10.72	- 1.28	9.26	3.87	35.00	- 1.20	23.11
#2	0.40	10.30	- 0.24	8.46	2.18	35.02	- 0.60	22.45
400 MILS								
BALLISTIC	9.83	75.09	-18.41	38.95	-20.56	175.00	-56.94	93.51
#1	2.18	47.04	1.48	25.18	- 5.87	137.96	- 7.11	67.71
#2	-4.49	45.50	3.19	24.16	- 8.55	137.73	- 5.81	66.74
800 MILS								
BALLISTIC	-0.32	215.47	-31.14	70.51	-152.84	547.68	-112.37	154.69
#1	-19.37	155.76	- 0.53	49.34	-103.56	416.86	- 28.19	112.58
#2	-28.49	153.58	4.52	45.17	- 82.97	419.84	- 25.64	110.66

TABLE VI

STATISTICAL IMPACT DEFLECTION ESTIMATOR STABILITY (m/MPH)

DAYTIME # of Profiles	Cross	Range	NIGHTTIME # of Profiles	Cross	Range
200 MILS					
90	23.09	-16.88	78	26.36	-17.58
94	22.86	-17.00	62	26.34	-18.04
90 + 94 = 184	22.94	-16.93	78 + 62 = 140	26.36	-17.79
50	22.99	-16.57	50	26.22	-17.79
50	22.76	-16.61	50	25.00	-18.96
50 + 50 = 100	22.86	-16.59	50 + 50 = 100	26.04	-18.19
184 + 100 = 284	22.91	-16.80	140 + 100 = 240	26.23	-18.02
400 MILS					
90	53.56	-27.85	78	69.22	-28.73
94	53.67	-28.43	62	59.94	-30.73
90 + 94 = 184	53.63	-28.09	78 + 62 = 140	67.80	-29.63
71	53.52	-27.01	46	64.72	-28.33
800 MILS					
90	117.78	-31.07	78	156.22	-30.55
94	120.57	-33.23	62	110.51	-33.99
90 + 94 = 184	119.61	-31.94	78 + 62 = 140	149.21	-32.08

estimator values were computed for the first three levels on the met tower. Figures 1 and 2 present the behavior of ballistic and statistical estimators for the 200 mil trajectory as a function of height in both daytime and nighttime conditions. The reference height becomes an important parameter because in the ballistic technique (if p remains constant) the estimator value becomes a simple power function of the reference height

$$A = \frac{\delta}{Z_r^p} \int \omega'(Z) Z^p dZ.$$

In the statistical technique the estimator value depends on the characteristics of the wind sp[illegible] at the selected reference height

$$\alpha = \frac{\Sigma D_i U_{ri}}{\Sigma U_{ri}^2} .$$

Figure 3 shows the estimator values at 7.6, 15.2, and 38.1 meters for the 184 daytime spring wind profiles versus the values at 7.6, 22.9, and 38.1 meters for the 100 daytime summer wind profiles. For nighttime conditions the estimator values for the 140 spring wind profiles and 60 winter wind profiles are similarly compared. The statistical estimator values for spring and summer were virtually identical in daytime conditions at the relatively flat desert area. For nighttime conditions, the estimator values for spring and winter were somewhat different, which may be due in part to the small sample of winter profiles and the quality of the 60 wind profiles. By comparing Figures 1 and 3, one can see the seasonal variance of the statistical estimator curves versus the constant (with season) ballistic estimator curves. The statistical estimator for the daytime conditions shows merit for it indicates that the ballistic estimator is overestimating in both seasons.

Another investigation concerned the behavior of the statistical estimator with respect to terrain. The flat desert area statistical estimator curves were compared to estimator curves from a rough semi-mountainous terrain at Green River, Utah. All Green River tower wind profiles were collected during nighttime conditions and at different heights than those on the WSMR met tower. The first level on the Green River met tower was set at 12.5 meters above the surface. To compare the estimator curves from the different terrains, 4.9 meters of wind profile were needed for the Green River profiles to include the low-level wind effect from 7.6 meters above the surface to burnout altitude. Linear extrapolation of the Green River wind profiles down to 7.6 meters above the surface was performed. The extra low-level wind effect was then added to the impact calculation from the ASL simulator, and the statistical estimator values for the first three (12.5, 21.0, and 33.9 meters) levels on the Green

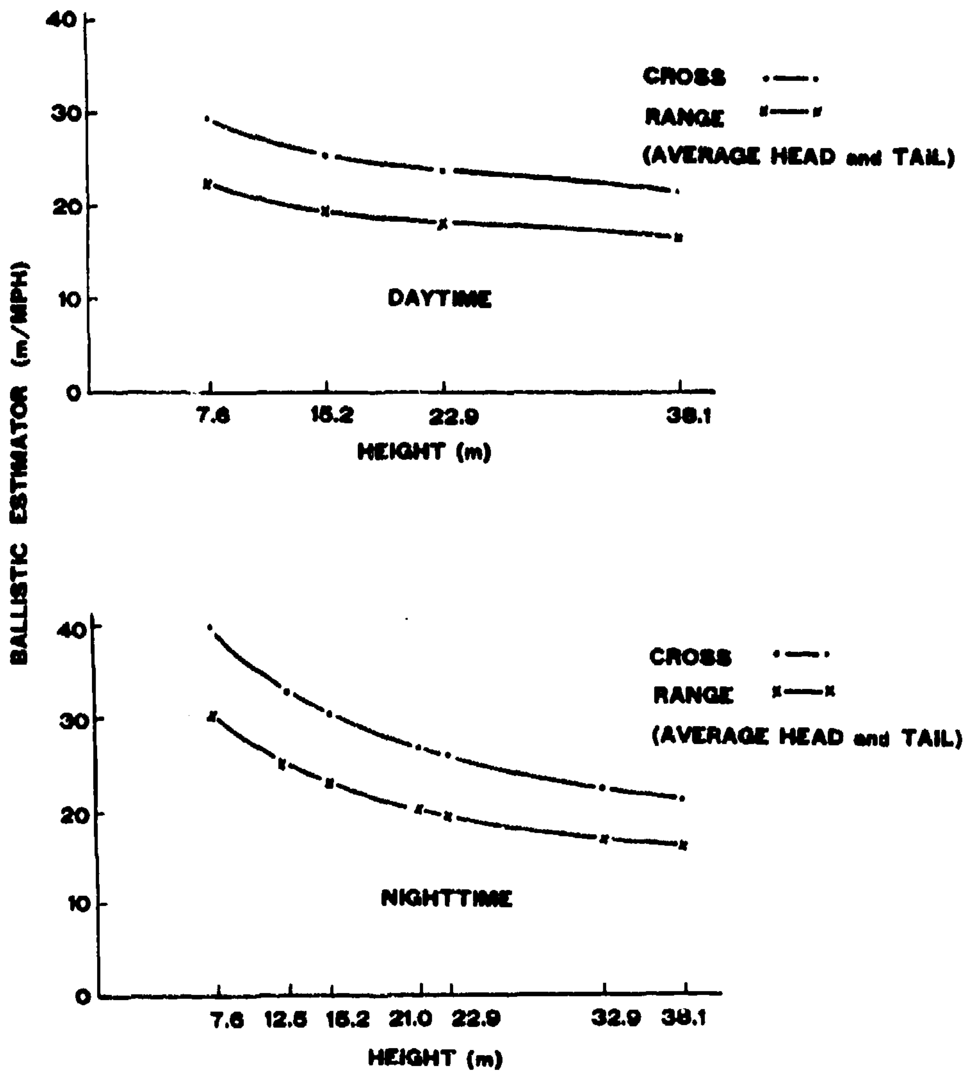

FIGURE 1. WSMR 200 MILS Q.E., BALLISTIC ESTIMATOR VERSUS HEIGHT.

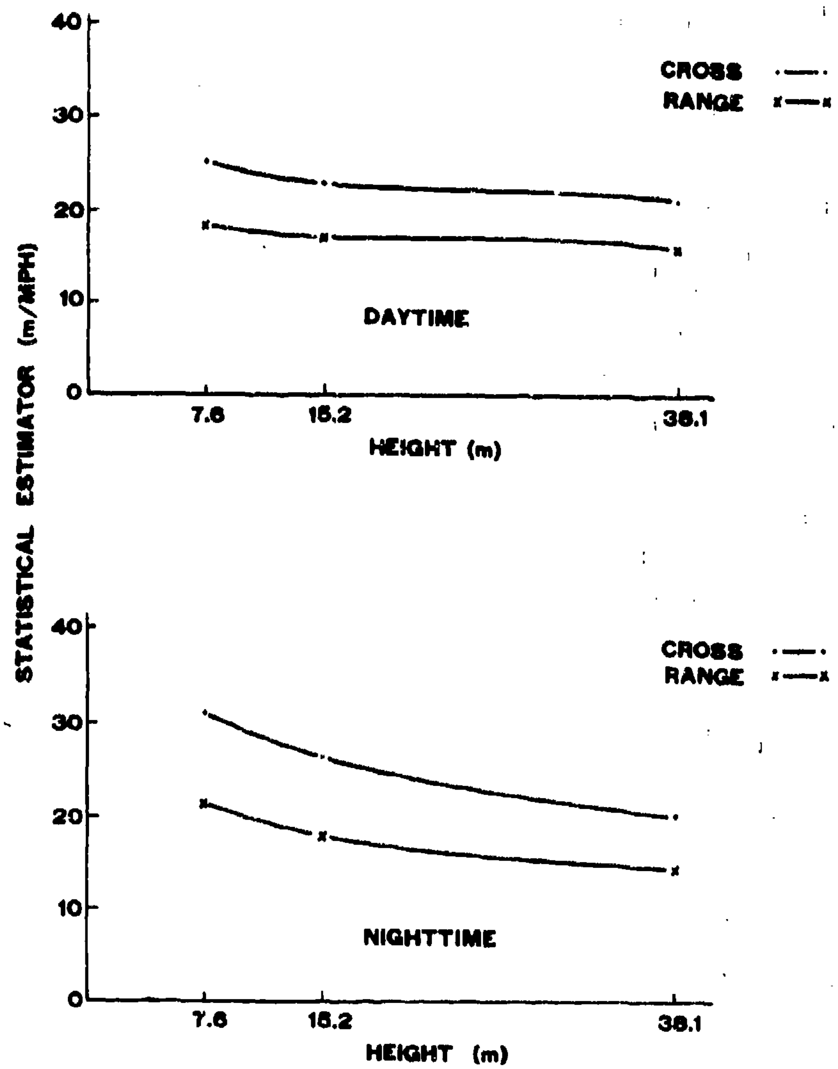

FIGURE 2. WSMR 200 MILS Q.E., STATISTICAL ESTIMATOR VERSUS HEIGHT; VALID FOR SPRING 1969 DATA— 184 DAYTIME AND 140 NIGHTTIME WIND PROFILES.

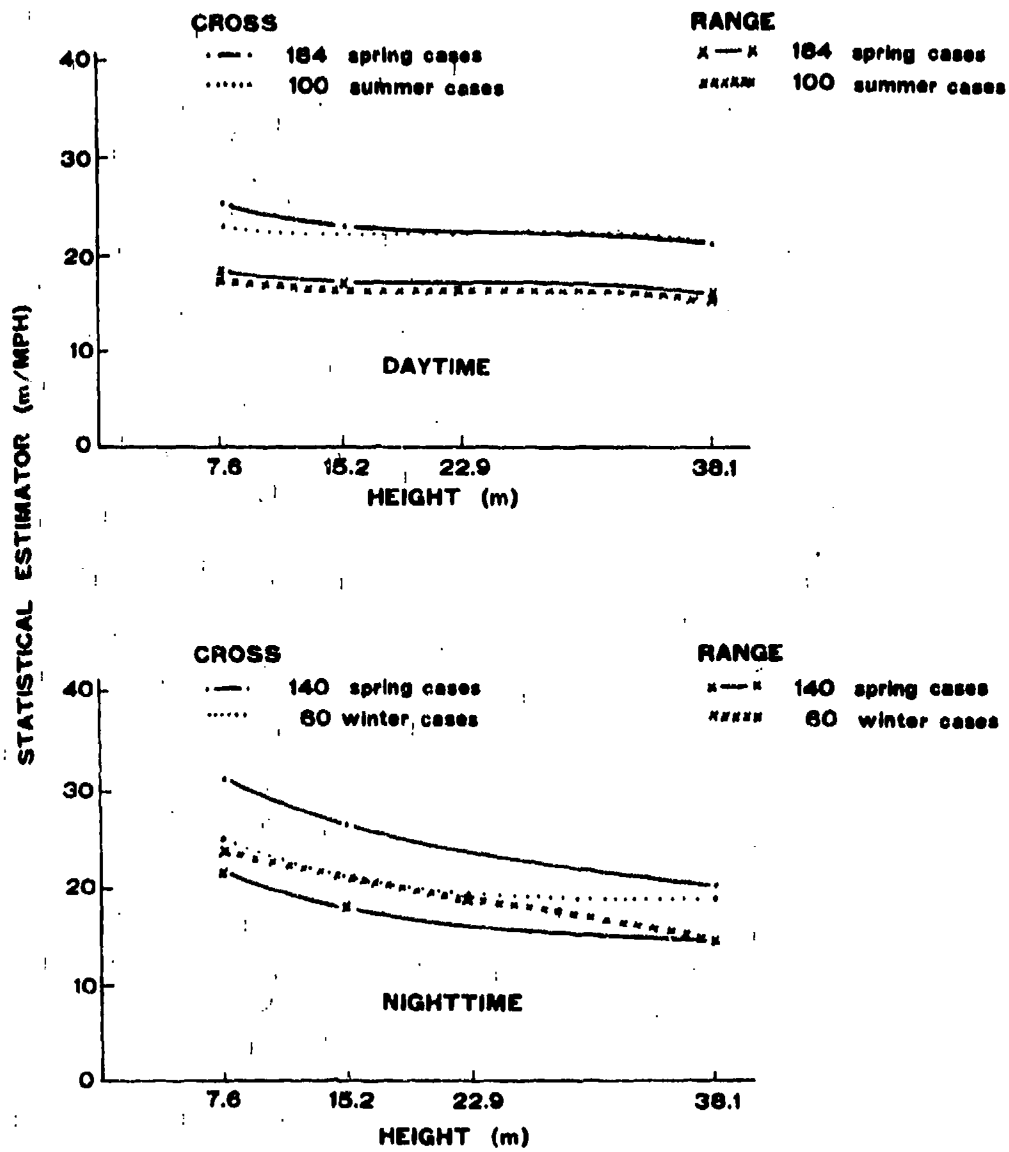

FIGURE 3. WSMR 200 MILS Q.E., STATISTICAL ESTIMATOR COMPARED SEASONALLY; 184 AND 140 MARCH 1969 WIND PROFILES AGAINST 100 JUNE–JULY 1967 AND 60 DECEMBER 1967 WIND PROFILES.

River tower were computed. Figure 4 illustrates the statistical estimator curves for a flat desert area and a semi-mountainous terrain at different seasons. The change in MSL elevation between the two sites has little effect in changing estimator values because the unit wind effects for the two sites are virtually identical. The variance in estimator curves may be due to difference in terrain, small number of wind profiles from Green River, and the different seasons in which the profiles are collected. The range estimator curves in Figure 4 indicate a strong possibility that there may not be an estimator difference from terrain effects. By comparing the fall and summer estimator curves for the semi-mountainous terrain, one can see seasonal variance of the estimator values similar to spring and winter estimator curves for the flat desert area.

SUMMARY AND CONCLUSIONS

Reductions in impact dispersion (rms miss distance) due to wind during powered flight ranging from 22 to 56% were afforded by the new statistical estimators developed for the 200, 400, and 800 mils M50 trajectories. The maximum percentage reduction occurred in the 200 mil short range trajectory. Figures 5 through 7 summarize the improvement presented by the statistical estimator in the reduction of both the mean miss distance and impact standard deviation. The new estimator derived from measured low-level wind profiles appears to be stable between different independent sets of profiles in the same season for the same terrain. The pilot study in seasonal stability indicated that spring and summer estimators may be identical, while spring and winter estimators may differ. The results from investigating the terrain effects on the estimator revealed some variation but also indicated a possibility that the estimators may be stable between the relatively flat desert and foothills terrain by the close agreement between the range estimator statistical curve from the 54 summer Green River wind profiles and the analogous curve from the 140 spring WSMR wind profiles. Overall, the statistical estimator curves were always below the ballistic estimator curve, indicating the presence of a bias.

The percent reduction in rms miss distance due to low-level winds is significant. For the range impact deflection, the low-level wind has a minor effect as compared to the other atmospheric parameters. In the intermediate range (400 mils) and daytime cases, about 11% of the total range probable error is due to the low-level wind. Results from this study indicate a reduction of 7% in the total probable error. For the cross impact deflection, however, the low-level wind has a major effect, contributing 56% of the total probable error. The statistical technique has afforded a 29% reduction in the total cross probable error. With this in mind, a more complete study of terrain and season estimator variation is needed to ascertain more accurately the degree of stability exhibited

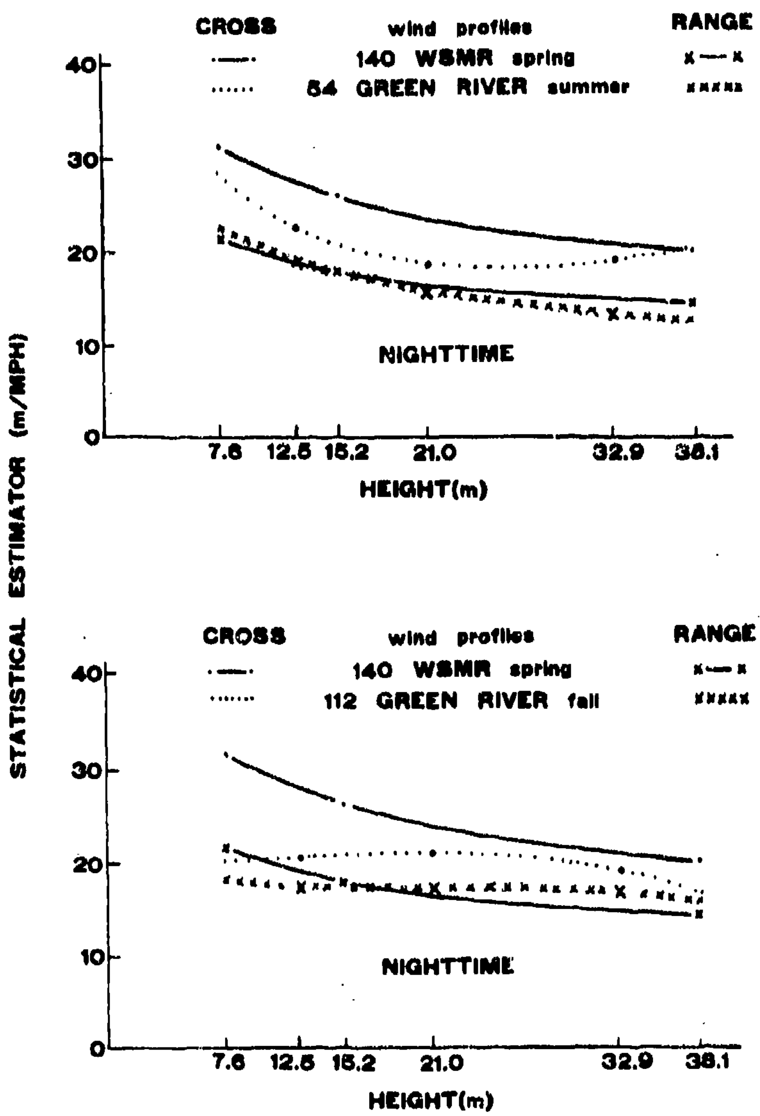

FIGURE 4. WSMR AND GREEN RIVER 200 MILS Q.E., STATISTICAL ESTIMATOR COMPARISON; WSMR 140 MARCH 1969 WIND PROFILES AND GREEN RIVER 54 JUNE 1969 AND 112 AUGUST, SEPTEMBER, AND OCTOBER 1967 WIND PROFILES.

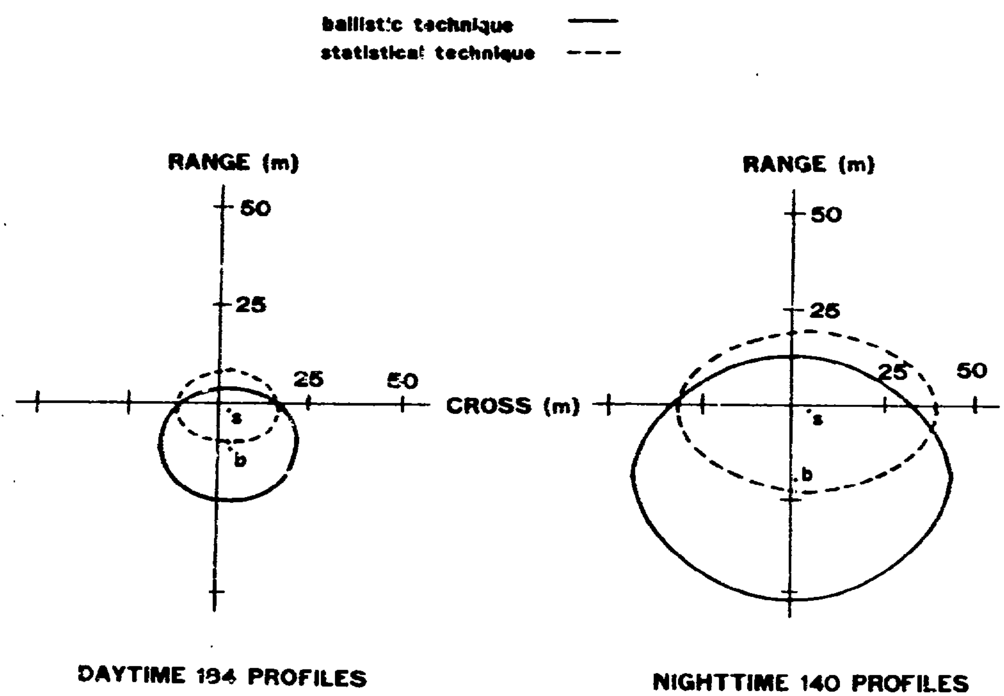

FIGURE 5. MEAN MISS DISTANCE AND STANDARD DEVIATION OF IMPACTS COMPUTED BY THE BALLISTIC AND STATISTICAL LOW-LEVEL WIND CORRECTION TECHNIQUES FOR THE HONEST JOHN ROCKET AT 200 MILS Q.E.

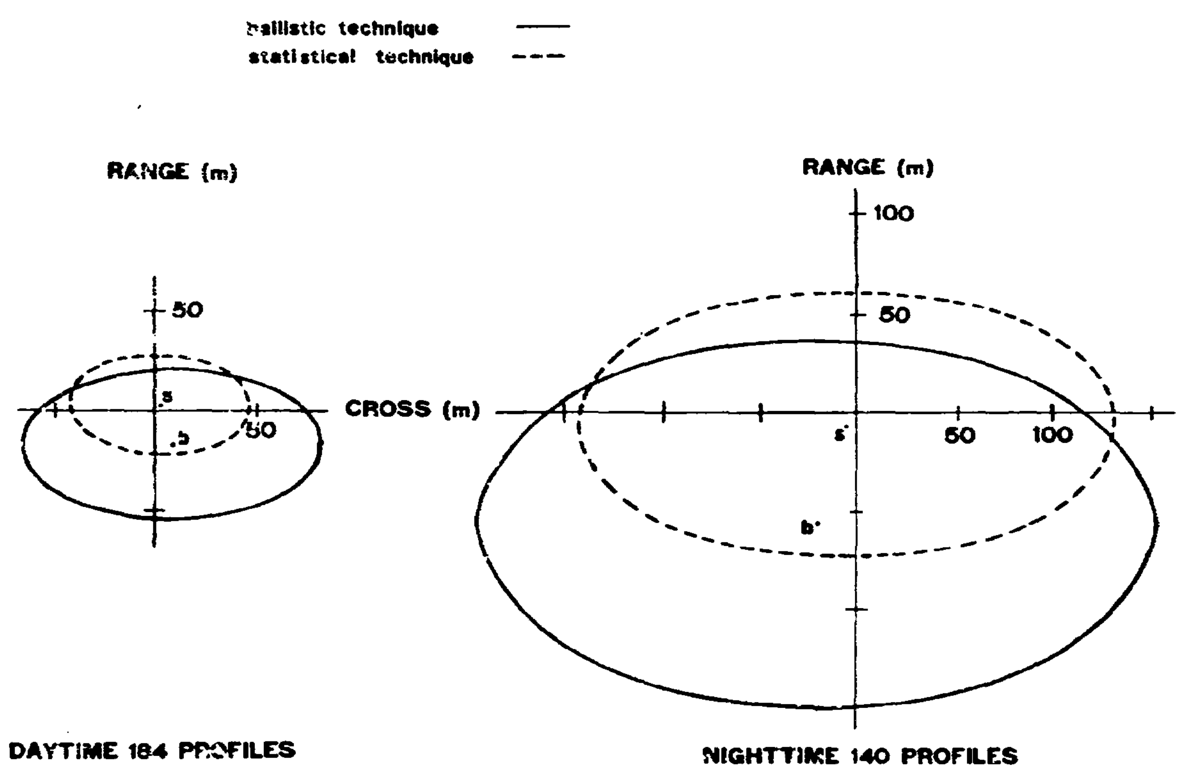

FIGURE 6. MEAN MISS DISTANCE AND STANDARD DEVIATION OF IMPACTS COMPUTED BY THE BALLISTIC AND STATISTICAL LOW-LEVEL WIND CORRECTION TECHNIQUES FOR THE HONEST JOHN ROCKET AT 400 MILS Q.E.

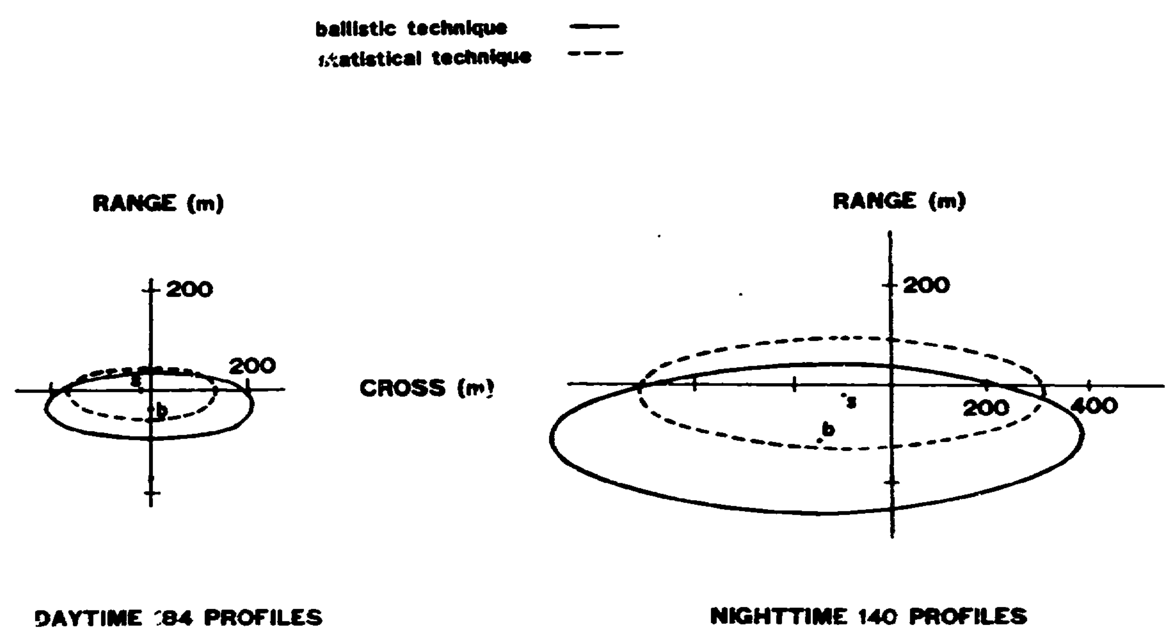

FIGURE 7. MEAN MISS DISTANCE AND STANDARD DEVIATION OF IMPACTS COMPUTED BY THE BALLISTIC AND STATISTICAL LOW-LEVEL WIND CORRECTION TECHNIQUES FOR THE HONEST JOHN ROCKET AT 800 MILS Q.E.

by the statistical estimators. If the estimators are not stable, they could be classified as to general terrain and season. On the other hand, if they are proven to be nearly constant, no changes in field operational methods are necessary to acquire the significant reduction in impact dispersion.

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