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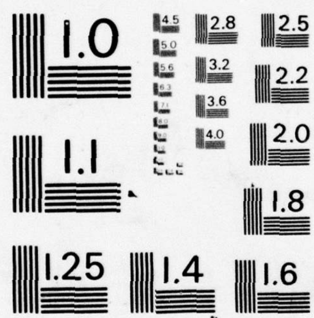

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REPORT NO. R-TR-76-018

AIR DEFENSE ANALYSIS
THE INFLUENCE OF PARAMETRIC VARIATION
ON EFFECTIVENESS OF A SHORT RANGE
AIR DEFENSE SYSTEM
TECHNICAL REPORT

PREPARED BY
CHARLES S. HICKS, P.E.

JANUARY 1976

US ARMY ARMAMENT COMMAND

RESEARCH DIRECTORATE

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

A performance analysis of a generic 30mm air defense gun system was undertaken to determine what factors influence effectiveness of such a system. A computer model that produces contours of constant kill probability vs range was employed.

The significant results and conclusions are as follows:

(1) A new effectiveness measure called Weighted Kill Area (WKA) was developed.

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(2) Curves were produced showing the influence of parameter changes on effectiveness.

(3) High effectiveness can be achieved in two basically different ways.

(4) A trade-off study is needed to determine which is the most cost effective way to get high effectiveness.

(5) Several factors that influence effectiveness could not be covered within the scope of this study. They should be the object of further investigation. Among them are time-of-flight variation, improvements to the computer model, round lethality improvements, and correlations between biases and standard deviations on target position measurement.

TABLE OF CONTENTS

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LIST OF FIGURES

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1.0 INTRODUCTION

This report covers work done under the Automatic Cannon Technology program which is part of an ongoing effort to develop improved firepower to meet future tactical threats to Army field units.

1.1 Objectives

a. Conduct parametric sensitivity analysis of short range air defense system concepts.

b. Develop a data base from these analyses that will aid in formulating advanced air defense system configurations.

c. Develop an effectiveness measure that is related to kill probability, and can be used to rate the effectiveness of competing systems and concepts.

d. Determine the effectiveness of air defense gun systems designs that utilize the concept of high accuracy and low rate of fire.

e. Determine possible parametric relationships that could help the designer and analyst define an effective air defense system.

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2.0 CONCLUSIONS AND RECOMMENDATIONS

2.1 Conclusions

2.1.1 The results of the parametric sensitivity analysis show that equally high effectiveness can be achieved by both very accurate, low-rate-of-fire gun systems and less accurate, high-rate-of-fire gun systems.

2.1.2 It is possible to achieve almost any reasonable value of effectiveness by employing a high enough rate of fire in a system with average biases and standard deviations, or conversely, employing a very low rate of fire in a system with zero biases and very small standard deviations.

2.1.3 Accurate low rate of fire systems tend to have high, narrow effectiveness peaks centered about a precise value of gun barrel dispersion. Increased biases and standard deviations broaden and reduce the peaks making effectiveness lower, but also less sensitive to changes in gun parameters.

2.1.4 The results of the study also indicate that biases and standard deviations on measurement of target position must be approximately equal to each other to achieve peak effectiveness in any given system.

2.1.5 The Weighted Kill Area (WKA) concept, developed as an adjunct to the ISO PK simulation, has proved to be a useful effectiveness measure for rating air defense system performance.

2.1.6 Finally, a data base has been developed and converted into a set of curves which indicate the relationship of the various gun system parameters to performance effectiveness. This will be an aid to the designer in developing advanced air defense system concepts.

2.2 Recommendations

2.2.1 It is recommended that a trade-off study be made to determine which is the most cost-effective approach to producing an effective system; the precision low-rate-of-fire system that is difficult to maintain and calibrate in the field, or the high-firing rate system that is easier to maintain and calibrate, but uses great quantities of ammunition.

2.2.2 Several other factors that influence air defense gun system effectiveness could not be investigated within the scope of this study. Any future air defense gun system effectiveness study should include these items:

a. Develop modifications to ISO PK to improve its sensitivity to certain parameters, incorporate the WKA calculations, and develop a way to compute engagement Probability of Kill (P_K).

b. Determine the influence of improved ammunition effectiveness; specifically the effects of increased round lethality and reduced time of flight.

c. Determine the exact location and shape of the effectiveness peak of the low-rate-of-fire system and the effect on it of gun barrel dispersion and muzzle velocity variation.

d. Investigate in greater detail the effect of gun pointing bias on effectiveness.

e. Investigate in greater detail the influence on effectiveness, of biases and standard deviations on target position measurement.

f. Investigate and try to develop improved methods for modeling advanced fire-control techniques using non-linear prediction against maneuvering targets.

3.0 DISCUSSION

3.1 Method of Approach

The simplest approach seemed to be to exercise one gun system through many variations, and using a proper measure of effectiveness determine what relationships exist. This approach required that a gun system representative of the state-of-the-art, and having reasonable growth potential, be chosen; that a proven and versatile simulation model be available; and that a useful means of measuring effectiveness be available or be developed. How each of these requirements was met is discussed in following sections.

3.1.1 Choice of gun system - The many recent air defense gun studies conducted under the Low Altitude Forward Area Air Defense System (LOFAADS) requirement influenced the choice of gun system used in this study. The choice is a 30mm system using improved GAU-8 ammunition, and having many of the performance characteristics appropriate to the Division Air Defense Study (DIVADS) and the Army Radar Gun Air Defense System (ARGADS) Required Operational Capability (ROC).

3.1.2 Choice of computer model - The choice of the computer simulation suitable for this study was influenced mainly by two requirements:

a. It had to be a general model that could reliably simulate a wide range of gun systems.

b. It had to be thoroughly "debugged" - in other words, a model on which enough experience has been gained that the results can be accepted with a high degree of confidence. Of the models available, ISO PK best fits these requirements. It is described in the following section:

3.1.2.1 Computer model description - ISO PK is a deterministic computer model employing a burst kill algorithm to evaluate the relative effectiveness of high-rate of fire air defense gun systems using burst fire modes. It simulates a one-gun-on-one-target encounter and plots the results of one burst independent of all other bursts at all points within a specified range of the gun. In this study, low-rate-of-fire modes are simulated by reducing the number of rounds in a burst to one, or a few. The burst kill algorithm that is used can be derived from its basic assumptions. Let:

AV be the vulnerable area of the target

BKP(t) be the burst kill probability function

(R_1, R_2) be the burst center coordinate

(X_1, X_2) be the projectile coordinate

n be the number of rounds per burst

where the coordinates are in "azimuth-like" and "elevation-like" coordinates in the plane perpendicular to the line-of-sight of the gun to the target.

Assume the X_1, X_2 are independently distributed where:

$$X_i \sim N\left(R_i, \sigma^2_i\right), \; i = 1, 2$$

Also assume that R_1, R_2 have a bivariate normal distribution with marginal distribution,

$$R_i \sim N\left(\mu_{i+2}, \sigma^2_{i+2}\right), \; i = 1, 2$$

and correlation ρ. The variances σ_1^2, σ_2^2 will result from the dispersion introduced by muzzle velocity variation and gun dynamics. The remaining errors are accounted for in the distribution of (R_1, R_2).

For fixed t we have

$$BKP = E\left\{\frac{nAV}{2\pi\sigma_1\sigma_2} \; e\,x\,p\left(\frac{R_1^{\,2}}{2\sigma_1^2}, \frac{R_2^{\,2}}{2\sigma_2^{\,2}}\right)(R_1, R_2)\right\}$$

The expected value can be solved in and expressed in matrix notation,

Let

$$V = \begin{bmatrix} \sigma_3^2 & \rho\,\sigma_3\,\sigma_4 \\ & \\ \rho\,\sigma_3\,\sigma_4 & \sigma_4^2 \end{bmatrix} \begin{bmatrix} \mu_3 \\ \\ \mu_4 \end{bmatrix}$$

Now, there exists an orthonormal matrix P such that

$$P'VP \begin{bmatrix} \frac{1}{\alpha_1} & 0 \\ 0 & \frac{1}{\alpha_2} \end{bmatrix} = K^2.$$

Set

$$A = K'P' \begin{bmatrix} \frac{1}{\sigma_1^2} & 0 \\ 0 & \frac{1}{\sigma_2^2} \end{bmatrix} PK.$$

Then

$$BKP = \frac{nAV}{2\pi\sigma_1\sigma_2 \left| I+A \right|^{\frac{1}{2}}} \; e\,x\,p \left\{ -\tfrac{1}{2} V'A \left[I-(I+A)^{-1}A \right] V \right\}$$

The output of the model is in the form of a plot of isometric lines of constant kill probability. The inputs to ISO PK consist of:

a. Target and flight path data

b. Target sensor data

c. Gun and ammunition characteristics

d. Output plot dimensions

The target flies straight and level at a constant velocity from right to left across the plot. The target speed and altitude can be specified, and a plot of ISO PK contours in a horizontal plane at that altitude, is produced.

The sensor input data consist of mean measurement errors and standard deviations on six parameters of target position: range, azimuth angle, elevation angle, and their respective rates.

The gun and ammunition input data are: mean muzzle velocity and its standard deviation, range vs. time-of-flight of the projectile, means and standard deviations of gun pointing errors, standard deviation of residual gun barrel dispersion, maximum tracking angle rates, maximum achievable gun barrel elevation angle, and number of rounds fired in the burst.

By varying these inputs it is possible to optimize a system within contraints, such as computer model limitations or practical limitations on parameter values. The problem of determining when a system is "optimized" is a complex one which is discussed in the next section.

3.1.3 Choice of effectiveness measure - The amount of data generated during this study made it necessary to broadly categorize the systems into three groups as an aid to evaluating the results.

These three are defined strictly on the basis of input error budgets to the ISO PK model. In the conventional sense, category 1 systems could be called "super accurate." All system biases are zero, standard deviations on gun pointing are zero, or very small; and standard deviations in measured target position are zero, or very small. A category 1 system could be considered as beyond the present state-of-the-art, at least in some of its characteristics.

Category 2 systems are "accurate;" that is, biases and standard deviations are all quite small, but achievable at the limit of the present state-of-the-art.

Category 3 contains the "field systems." These have biases larger than necessary, indicating that the system requires calibration; large gun pointing sigmas, indicating perhaps the need for servo system maintenance; and large target sensor sigmas, which indicate a need for sensor tuning and maintenance, and so forth.

A criterion for ranking air defense gun systems according to effectiveness is difficult to choose because there are many possible definitions of effectiveness. Some definitions are too complex to be easily understood, and others are simple, but don't give a complete definition. What system analysts and decision makers desire is a measure of effectiveness that can be expressed as one number which describes the gun system's ability to defeat aerial threats - in other words, be related to Probability of Kill, (P_K). This is attractive because P_K best describes a gun's purpose. However, P_K varies with range, and used by itself, raises more questions than it answers. What P_K at what range best describes effectiveness? Is a system that produces high P_K at short range coupled with low P_K at medium and long ranges more effective than a system that has medium P_K at short and medium ranges, with low P_K only at long range?

The answer may depend somewhat on the scenario, but it is difficult to subjectively compare ISO PK plots of several systems and rank them based on the several P_K's and ranges that appear on each plot.

The measure of effectiveness developed during this project is a number related to P_K. It is called Weighted Kill Area and is in units of square kilometers. WKA is computed directly from the output plot of the ISO PK program. Reference to Figure 1 will help clarify the following description of how WKA is computed: The incremental areas contained between successive P_K contours are computed and multiplied by the P_K value of the outer contour in each case. All these areas are then summed and their total becomes the system WKA. A larger WKA value indicates greater effectiveness in killing targets. Each value of WKA applies to a particular gun system against a particular target. It changes appreciably if either gun system characteristics or target scenario (target size, speed, and altitude) are changed. The method appears to be a sensitive indicator of system effectiveness and easily produces relative rankings on groups of systems. The reader can check for himself the difficulty of evaluating gun systems by mentally ranking the four systems whose plots are shown in Figures 2 through 5. The WKA ranking of these systems is given in Appendix A along with the input data for each system.

A computer code (program) has been developed to make the WKA calculation and rank the systems in descending order. It assumes that the P_K contours are ellipses symmetrically disposed about the gun. In certain cases the contours depart from the elliptical shape, and to that extent the results are an approximation. Worthwhile improvements to this method of computing effectiveness could be made by developing a routine to calculate the actual area under the contours by subtracting the small area immediately surrounding the gun where in some cases target angular rates exceed gun slewing rates, and by incorporating the program into ISO PK as a subroutine.

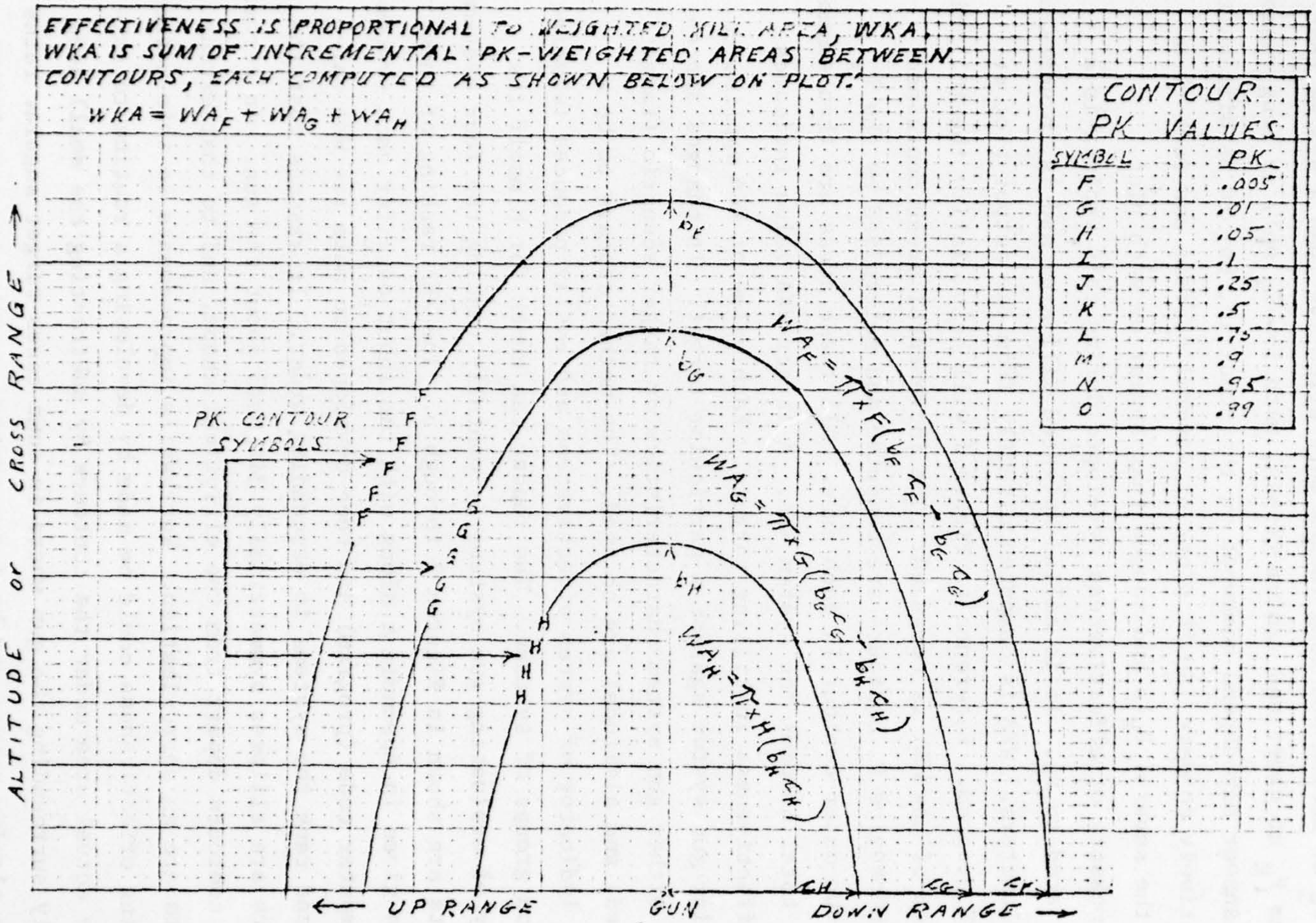

Figure 1 Computation of Effectiveness Measure, WKA

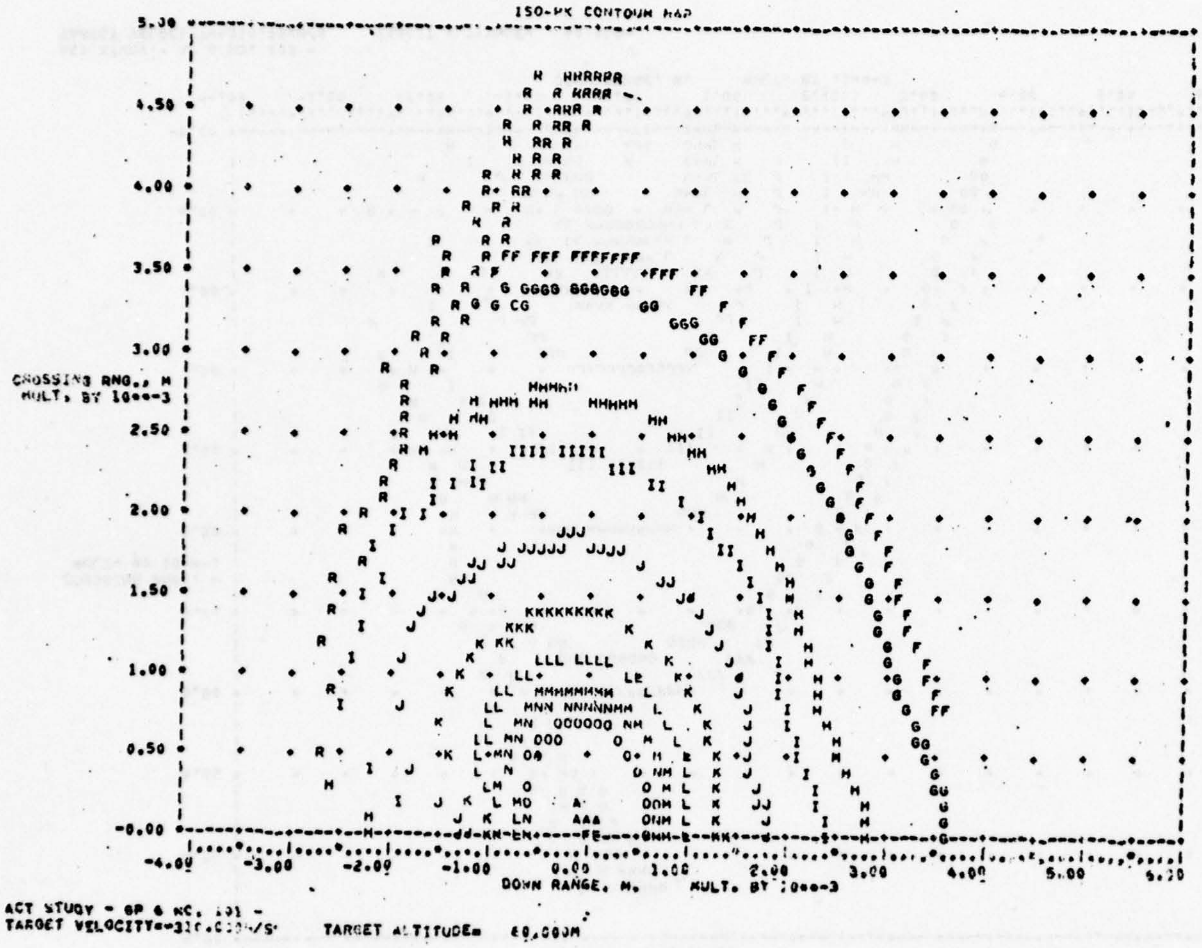

Figure 2 ISO PK Plot, System 101

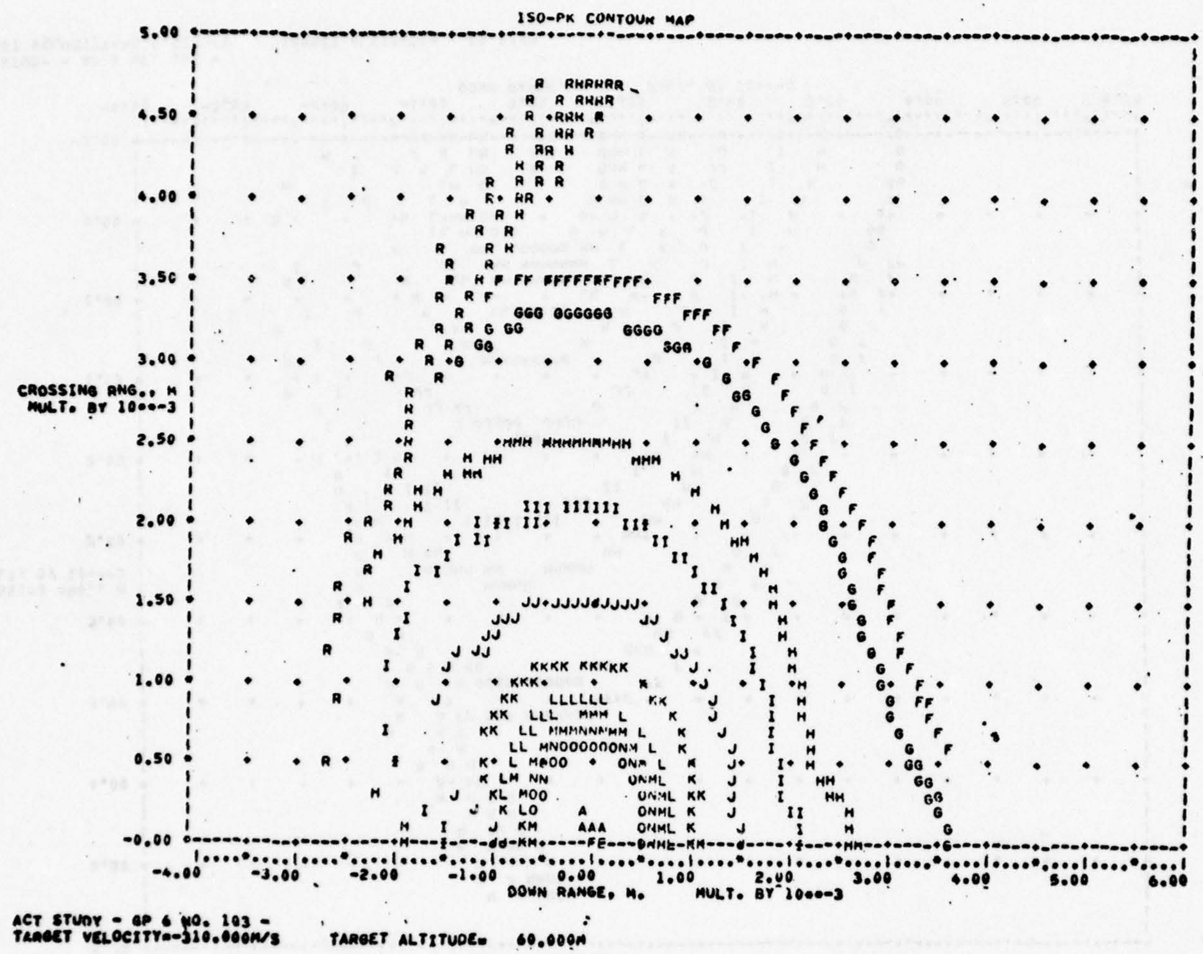

Figure 3 ISO PK Plot, System 103

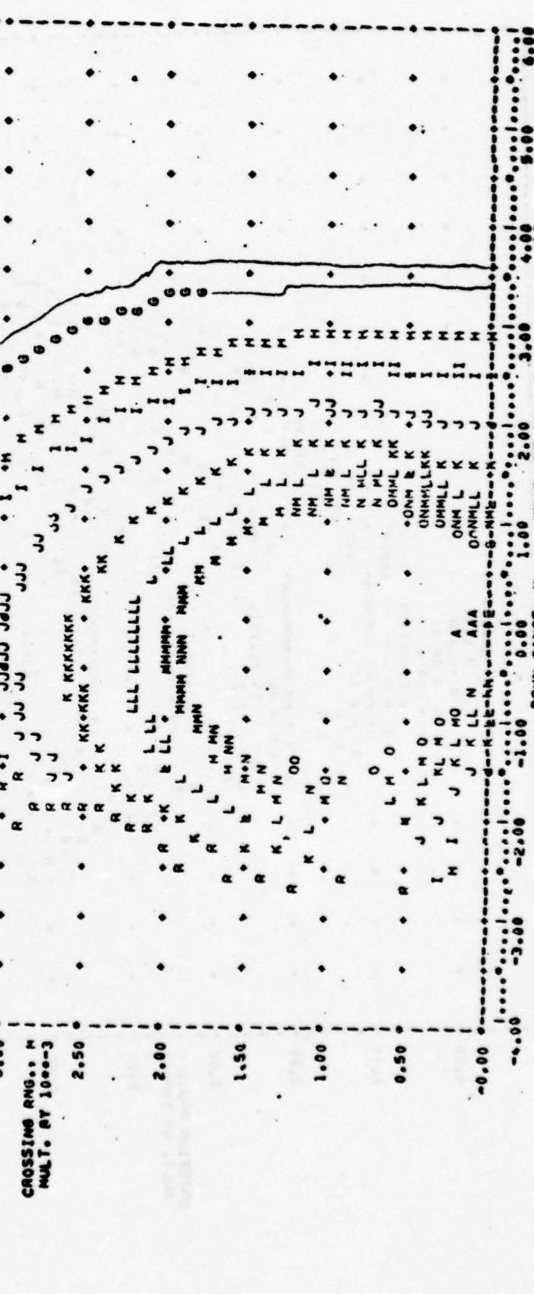

Figure 4 ISO PK Plot, System 358

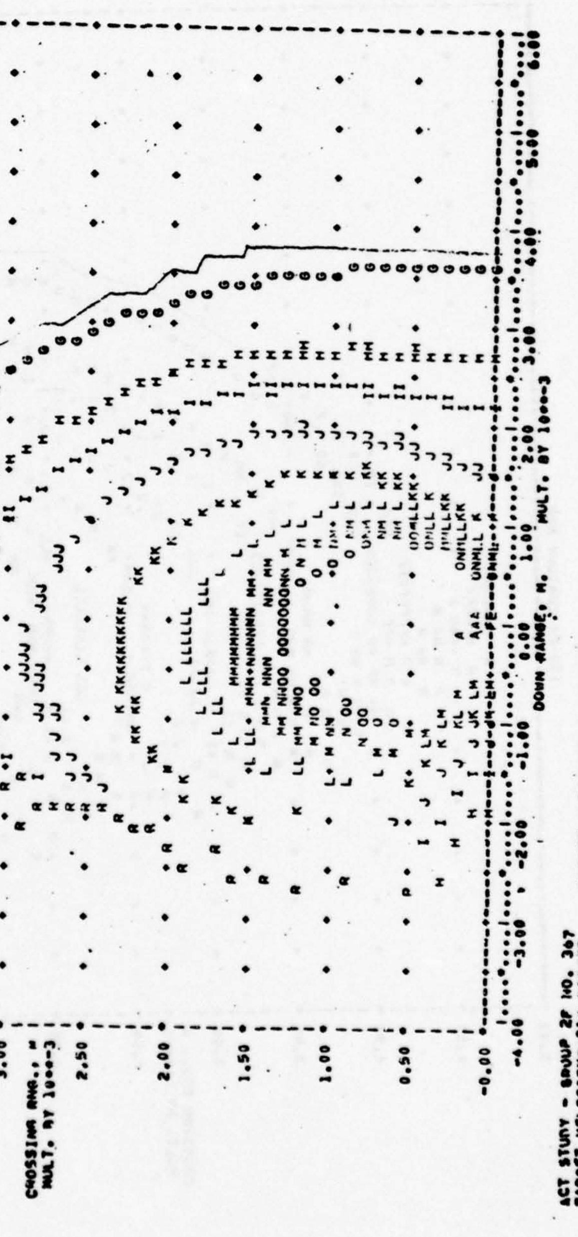

Figure 5 ISO PK Plot, System 367

3.2 Development of the Data Base

Thirty five gun and ammunition parameters, 20 target parameters and 10 to 15 plot parameters can be varied in the ISO PK model. This situation creates an unmanagable number of possible variations, therefore as many variables as possible, were eliminated from consideration. A constant plot size was adhered to throughout the study; the same target aircraft was used; and the same ammunition was used.

The parameters that were actually varied include the following:

a. Standard deviation of muzzle velocity.

b. Standard deviation of residual gun barrel dispersion in two axes.

c. Number of rounds fired in a burst.

d. Gun pointing bias in azimuth and elevation.

e. Six biases (mean error) on sensor derived target position, (x, y, z, and their rates).

f. Standard deviations of dynamic gun pointing error in azimuth and elevation at several slewing rates.

g. Standard deviation of sensor derived target position (x, y, z, and their rates).

These parameters were judged to have the most influence on effectiveness. The others generally contribute to system effectiveness in a highly predictable, monotonic fashion, and therefore were fixed at "good design values."

Even with the number of variables reduced to a minimum in this fashion, computer runs were made on some 370 variants of the system. These runs were divided into groups; each group being an investigation of some particular aspect of the parametric correlations being discovered. There are about 30 groups, not all of which produced any useable information. The ones which did are reduced to plots and discussed in the next section. Appendix B contains the input data and output plot of the system ranked No. 1 in each plot group.

3.3 Discussion of Results

Group 1 was a special group of 26 runs designed to check out the ISO PK model limitations. When doing parameter studies, it is possible to cause an "underflow" or "overflow" in the PK algorithm by extreme variation of input values and it is necessary to find these limits. Two limitations were found: Standard deviations of gun barrel dispersion equal to zero, and standard deviations of sensor-derived target position and rate equal to zero. These parameters are limited on the low side therefore, to small finite values. The minimum values of sensor sigmas (σR, σAZ, σEL, $\sigma\dot{R}$, $\sigma\dot{A}Z$, $\sigma\dot{E}L$) were arbitrarily set to the smallest values that would print out (.0001 meter, .0001 radian, etc). The program format could have been changed to print smaller values, but no additional information would be gained.

Some pecularities were noted in the group 1 series about the influence of muzzle velocity variation and gun barrel dispersion on effectiveness, so this was investigated first. The results are given in Figures 6, 7, 8, and 9, in plots of effectiveness versus dispersion.

Figure 6 contains three plots of a category 1, or "super-accurate" system employing three different standard deviations of muzzle velocity. It is a very low rate of fire system, firing only one round per burst. Curves 2A and 2D show that a very high, sharp effectiveness peak can be achieved with a system using ammunition with a small standard deviation of muzzle velocity. However, the dispersion of such a system must be very precise and closely controlled. A small change in either direction drastically reduces effectiveness. The larger standard deviation of muzzle velocity used in curve 2B simply reduces effectiveness of this "super-accurate" system and moves the peak towards zero dispersion. It should be noted that the sigma muzzle velocity of curve 2B is probably a reasonable value for GAU-8 ammunition while the other two may be a little optimistic. Muzzle velocity variation is a factor not entirely under the control of the designer of a gun system. It is affected by such environmental factors as storage conditions, altitude, ambient temperature and so forth. Firing range data on existing ammunition indicates a possibly greater than 3-to-1 variation in sigma muzzle velocity simply due to differences in ambient temperature between a cool autumn day and a hot summer day.

Degradation of effectiveness due to factors not under the control of the designer and user, can be made up to a great extent by an increase

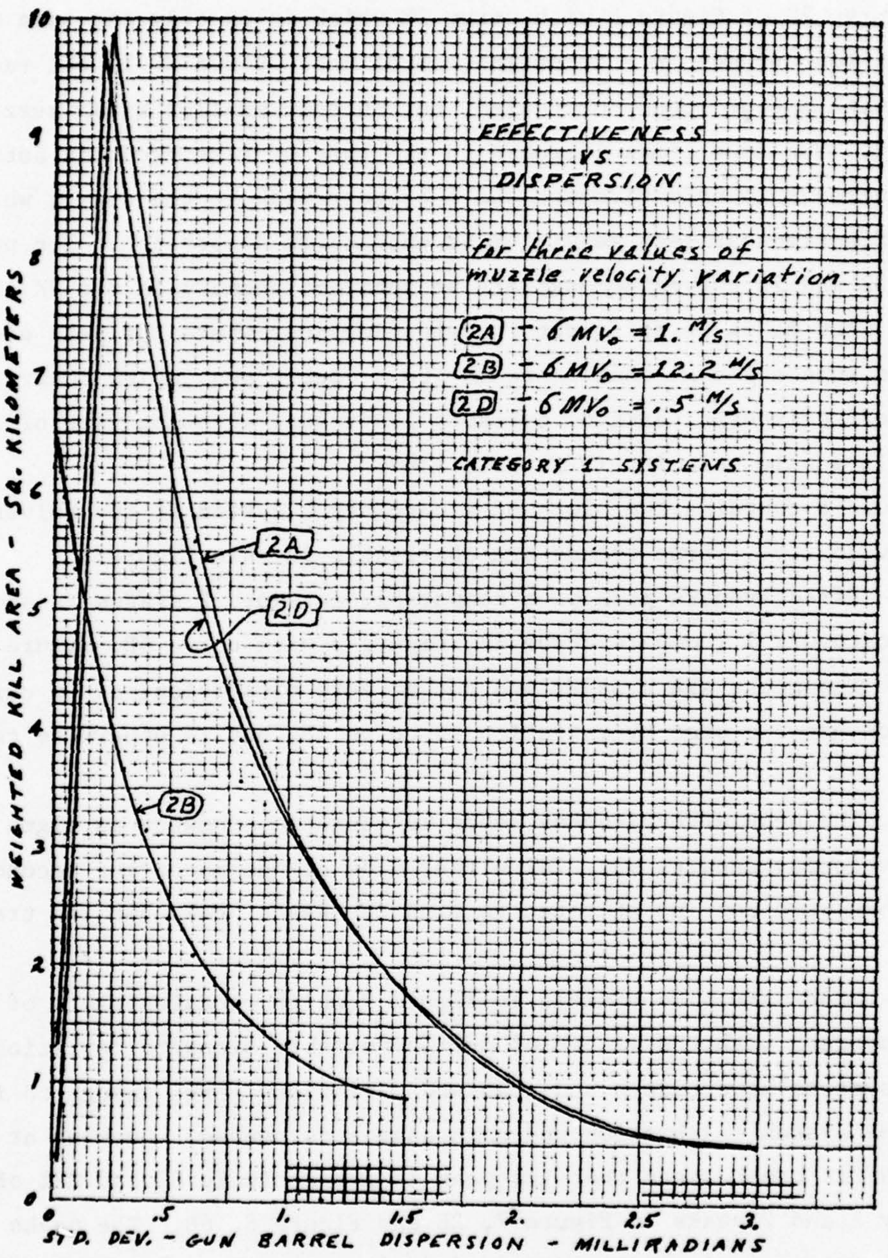

Figure 6 Effectiveness vs Dispersion at 3 values of σMV. Category 1 Systems.

in the rate of fire. Figure 7 (note the change in vertical scale) compares curve 2D of Figure 6 with curve 2E which is exactly the same system, but with four rounds in a burst instead of one. Curve 2F is the same system with a four round burst also, but an even smaller sigma muzzle velocity. The four times increase in the rate of fire produces both a large increase in effectiveness and a broader peak in the curve, which makes effectiveness less sensitive to changes in dispersion. The peak of the 2E and 2F curves demonstrate an apparent anomaly in the PK algorithm that makes it difficult to determine just where the peak occurs. There is some evidence that there may be a double peak which occurs only at the effectiveness peaks of category 1 systems, with low rate of fire and small muzzle velocity (MV) variations.

Figure 8 contains two plots of a category 2 system at two values of muzzle velocity. Three trends are observable in this figure:

(1) Effectiveness peak of a comparable category 2 system is about 27% of category 1 (compare curve 2E, Figure 7 with curve 6B, Figure 8).

(2) The peaks are broader and not at zero dispersion, as in curve 2B, which has the same MV variation as curve 6B, but is otherwise category 1.

(3) The peak effectiveness tends to decrease somewhat as sigma muzzle velocity departs very far either side of one meter per second; variations were not investigated to find the exact peak, but the trend is clear.

The trends are also visible in Figure 9 which contains plots of a category 3 systems with two values of muzzle velocity standard deviation. Category 3 systems have biases and standard deviations large enough to indicate that some system calibration and maintenance is needed. Looking at curve 9, Figure 9, it can be seen that its peak is respectively 6% and 22% of the category 1 and 2 peaks in Figure 7, 2E and Figure 8, 6B. The peaks also occur at successively larger standard deviations of gun barrel dispersion. The peak is at 0.25 milliradian for category 1 (Figure 6), about 0.45 milliradian for category 2 (Figure 8), and about 1.5 milliradians for category 3 (Figure 9). The peaks of the curves also get broader as the systems get less accurate. At the 50% of peak effectiveness level, the category 1

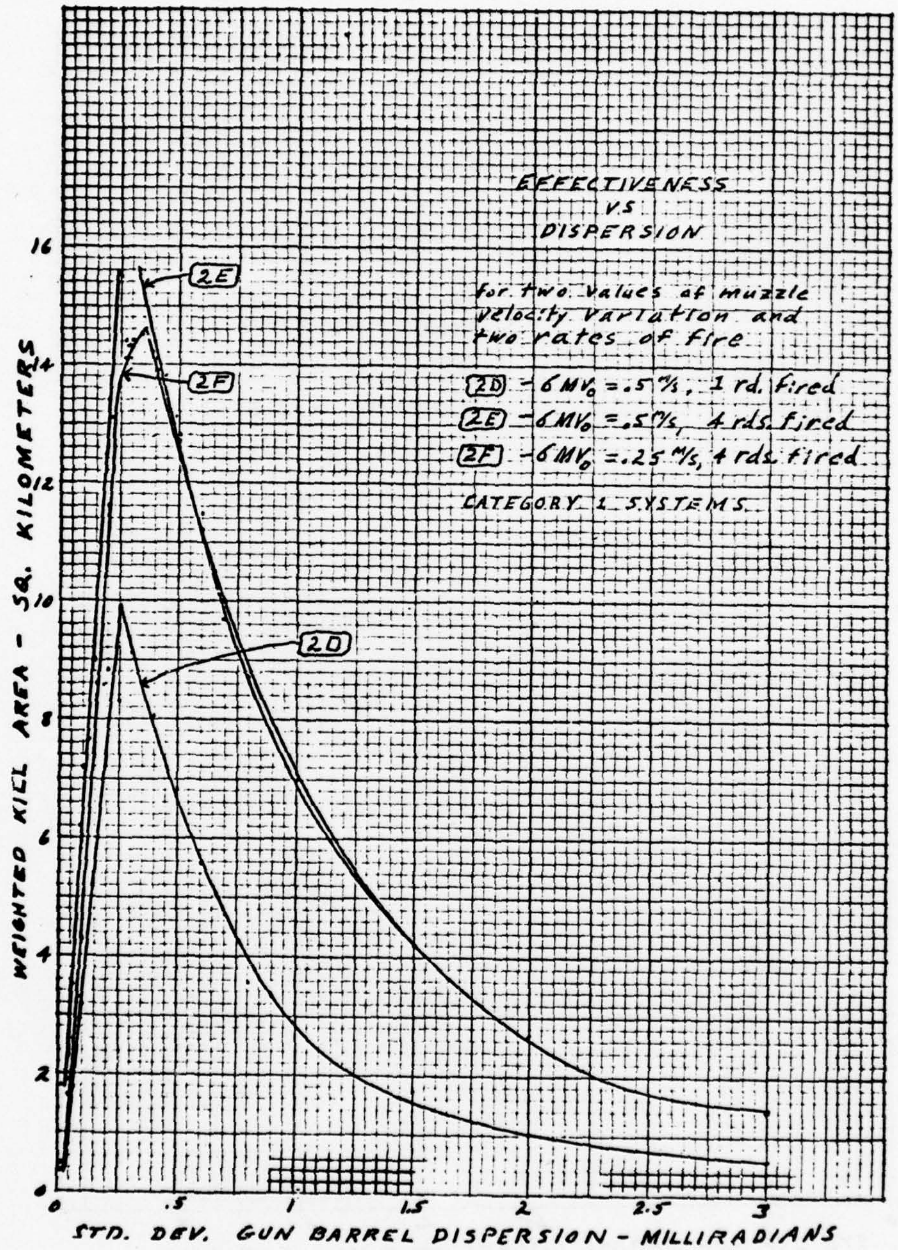

Figure 7 Effectiveness vs Dispersion at 2 rates of fire. Category 1 Systems.

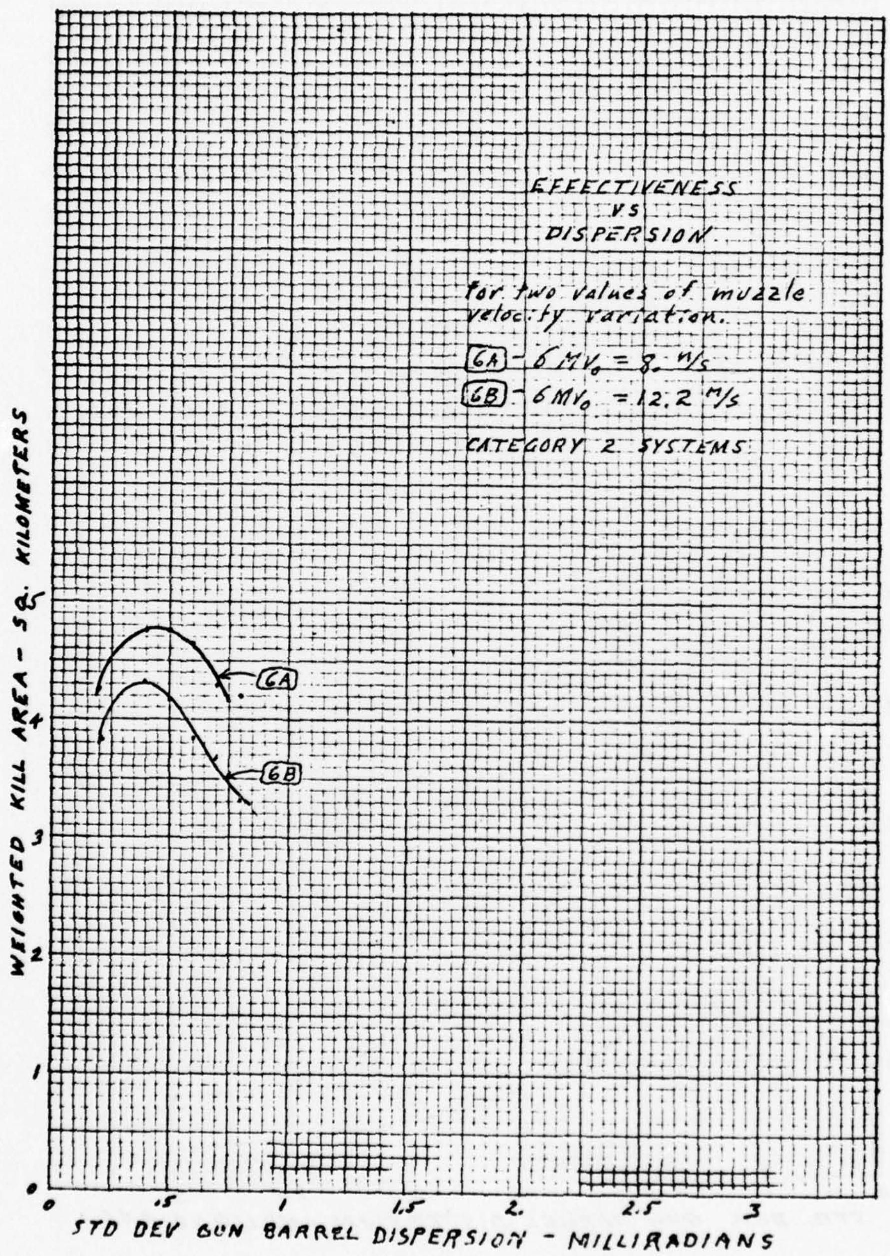

Figure 8 Effectiveness vs Dispersion at 2 values of σMV. Category 2 systems.

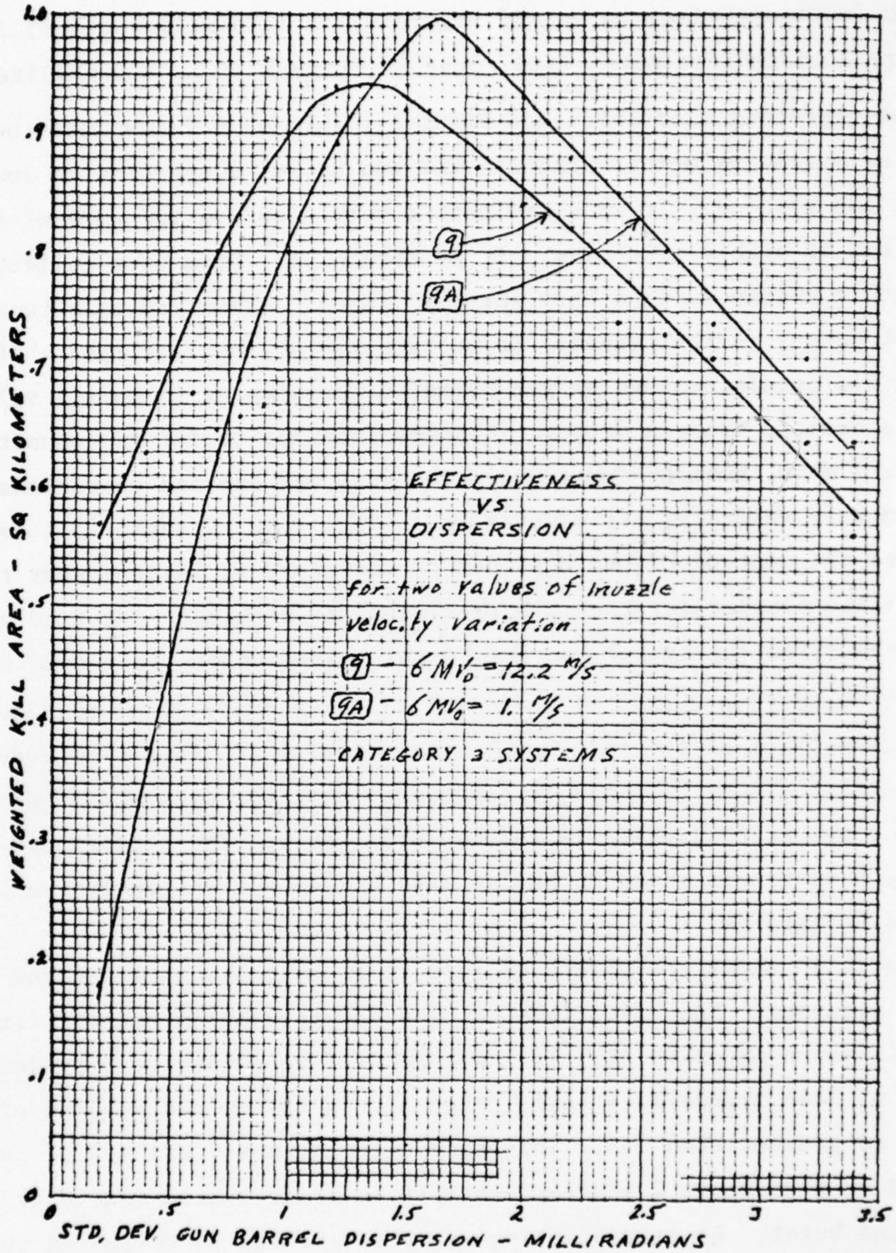

Figure 9 Effectiveness vs Dispersion at 2 values of σMV. Category 3 Systems.

curve is approximatley 0.55 milliradian wide (Figure 6, curve 2D); category 2 width (estimated from curve 6B, Figure 8) is 1.25 milliradians; and category 3 width (estimated from curve 9A, Figure 9) is 3.5 milliradians.

The preceding discussion and Figures 6 through 9 illustrate the effect of muzzle velocity variation and gun barrel dispersion on low rate of fire gun systems. It is clear that a very accurate low-rate-of-fire system can be highly effective. It is also clear, from data collected, that such a system must be very sharply "tuned." When properly tuned, the peak output (effectiveness) is extremely high, but a slight shift in a sensitive parameter such as gun barrel dispersion or in muzzle velocity, causes a drastic drop in output. Changes from lot to lot in ammunition, gun barrel wear, ambient temperature changes, and storage consitions all affect muzzle velocity, and dispersion. Since some of these factors are not under the control of the designer or the user, it is necessary to consider the possibility that the precision and stability required of the low-rate-of-fire gun system can not be maintained under field conditions.

For example, a change of only -0.1 milliradian or +0.45 milliradian in the dispersion of the category 1 system (curve 2A, Figure 6) reduces its effectiveness by 50%, and if any biases develop, or standard deviations increase, the effectiveness is reduced still more. The performance of a category 1 system is based on having zero biases and extremely small standard deviations.

Figure 10 shows the effect of rate of fire as a substitute for extreme accuracy. The effectiveness of a category 1 low rate of fire system is shown in curve 2C. If low rate of fire is arbitrarily defined as four or less rounds in a burst, then such a system can have an effectiveness no greater than 9.5. This same effectiveness (WKA = 9.5) can be achieved by a category 2 state-of-the-art accurate system (curve 6) firing a 19 round burst. By extrapolating curve 5A, it can be estimated that a category 3 field system would need to fire a 160-round burst to have equal effectiveness.

Reducing to the lowest possible rate of fire, a one-round burst, the category 1 system represented by curve 2C shows an effectiveness, WKA equal to 4.5. The category 2 system represented by curve 6 requires a

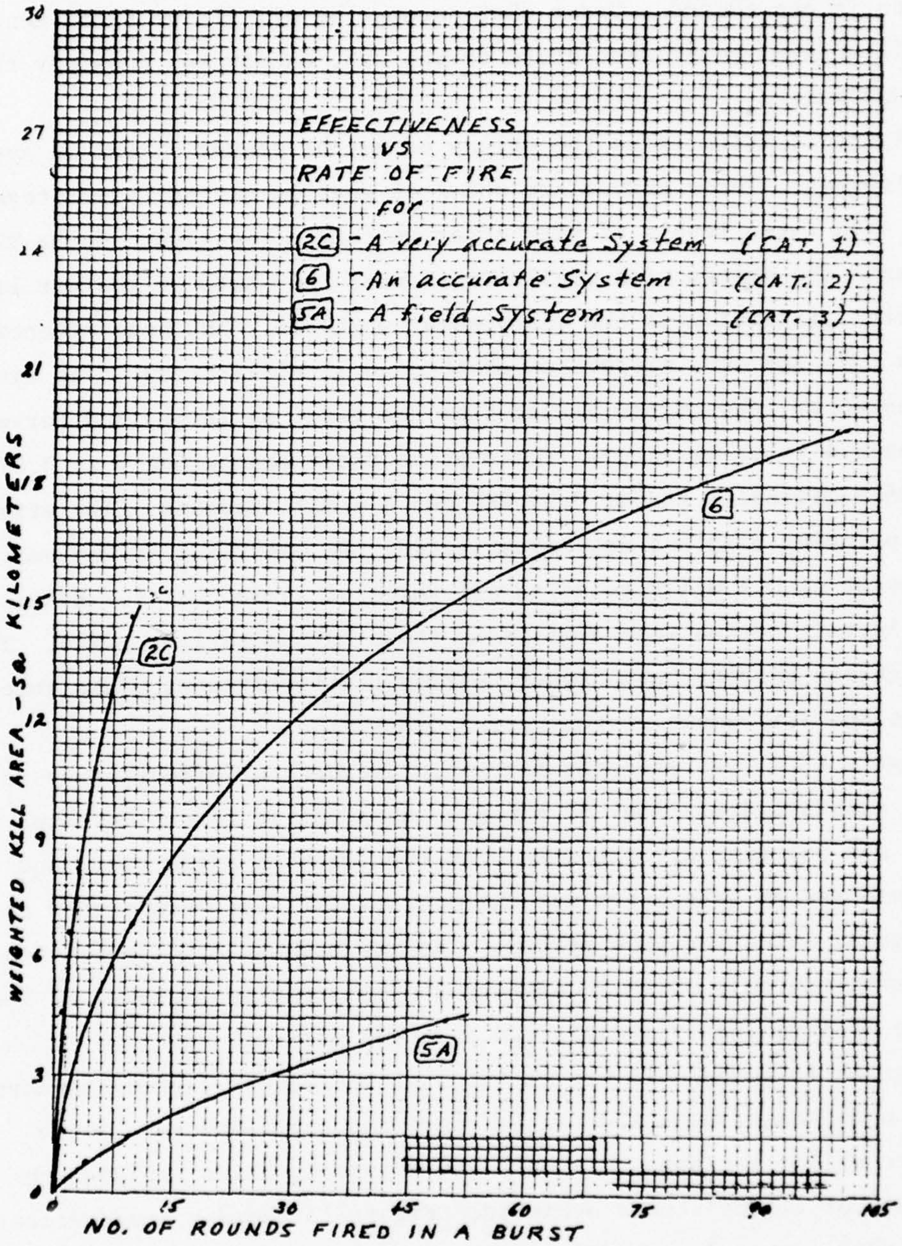

Figure 10 Effectiveness vs Rate of Fire.
Category 1, 2, and 3 Systems.

5 round burst for this effectiveness, and the category 3 (curve 5A) system requires a 50 round burst. A good assumption is that the burst duration is one second. Under that assumption all firing rates mentioned are well within the present state of the art, except for possibly the 160 round burst.

Figure 11 illustrates the strong effect of sensor biases on system effectiveness. Three curves are shown of what is basically a category 3 system with three levels of bias error on target location. Curve 9D represents the system with small biases near the state of the art limit. Gun barrel dispersion is the independent variable. The peak effectiveness is 1.74 WKA at a dispersion of about 0.75 milliradian. The system represented by curve 9 has biases that are twice as large, and curve 9C has biases 4 times as large. These peaks occur respectively at 0.87 WKA and 1.35 milliradian and at 0.25 WKA and 3.4 milliradians. The effect of gun pointing bias was not investigated. It was fixed at the very small value of 0.2 milliradian in all three of these curves. Basically, trends in this series were similar to those in the earlier plots. The more accurate systems have higher, narrower effectiveness peaks which occur at smaller values of gun barrel dispersion.

Figure 12 illustrates the monotonic decrease of effectiveness as the average standard deviations of dynamic gun pointing error increase. Dynamic gun pointing error varies with the tracking angle rate, and the points plotted in this curve are the averages of four such errors at four angular rates for each system. The curve shows a 50% reduction in the effectiveness of this category 2 system for an increase of less than one milliradian in dynamic gun pointing error.

Figures 13 through 17 are plots of effectiveness versus standard deviation of sensor-measured target range and angle errors. These plots are all of variants of a category 3 system, which explains the low values of effectiveness achieved. Figure 13 shows a broad effectiveness peak centered around 4 meters of range error standard deviation. It happens that the sensor range bias error for this series of system variants is also 4 meters, and this may account for the peak. However, further investigation of this aspect was beyond the scope of this study. It would require this series of model runs to be repeated a number of

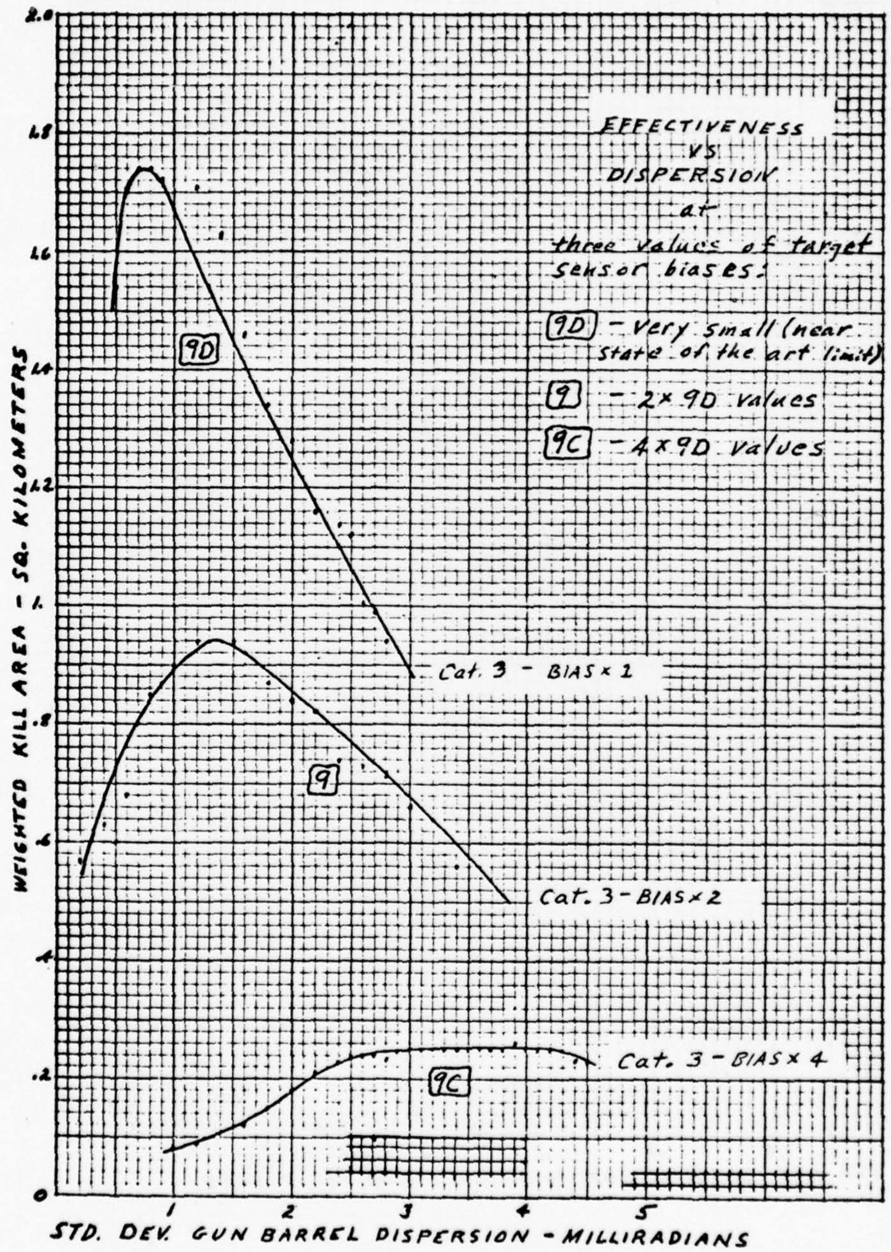

Figure 11 Effectiveness vs Dispersion at 3 values of Sensor Bias. Category 3 Systems.

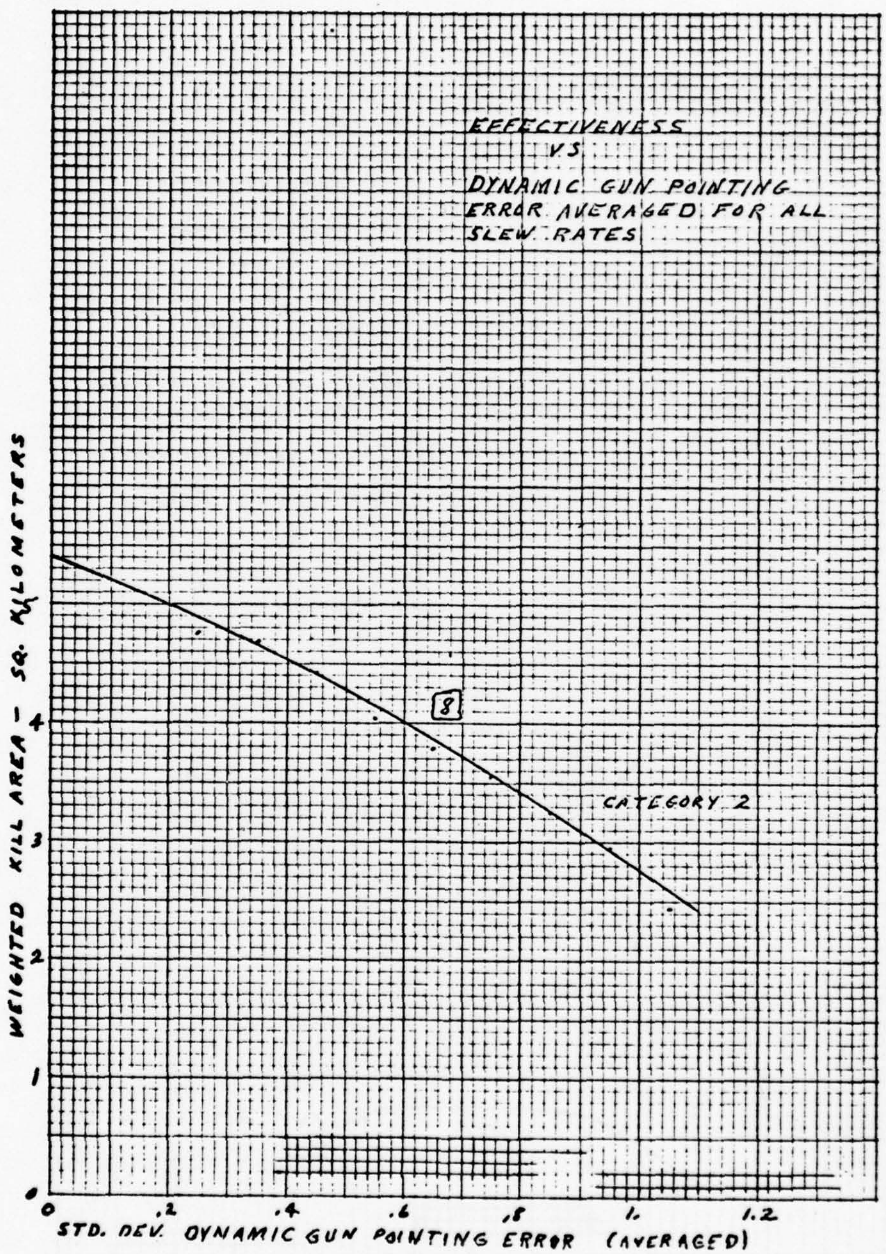

Figure 12 Effectiveness vs Dynamic Gun Pointing Error. Category 2 Systems.

times with different biases to determine the correlation between range bias and range standard deviation.

Figures 14, 15, and 16 which plot standard deviations of target angle, range rate, and angle rate against effectiveness, indicate that system effectiveness is not very sensitive to these parameter changes. Figure 15 indicates that system effectiveness is especially insensitive to standard deviations of range rate. This kind of result is not intuitively obvious, and the possibility that it may be due to a peculiarity in the burst kill algorithm employed to compute burst P_K needs to be investigated further. The method of computing Weighted Kill Area as the effectiveness measure, has been checked and does not seem to be contributing to the problem.

Figure 16 contains two plots of effectiveness against standard deviation of target angle rate, each plot representing a system with a different fixed value of standard deviation of target range rate measurement. Figure 15 showed that variation of $\sigma\dot{R}$ had no appreciable influence on effectiveness. Figure 16 shows the influence of variation of $\sigma\dot{AZ}$ and $\sigma\dot{EL}$ at different values of $\sigma\dot{R}$. The results in Figure 16 show only a 10% change in effectiveness over the range of the plots, and the two plots are coincident until larger values of $\sigma\dot{AZ}$ and $\sigma\dot{EL}$ are reached. The divergence that does occur is small enough to be accounted for by round-off error, therefore it can be concluded that the effect of $\sigma\dot{R}$ variation is negligible and the effect of $\sigma\dot{AZ}$ and $\sigma\dot{EL}$ variation is small over the range plotted, although a definite trend is established.

Figure 17 shows a plot of the square root of the sum of the squares (R.S.S.) of all six standard deviations of measured target range and angle (σR, σAZ, σEL, $\sigma\dot{R}$, $\sigma\dot{AZ}$, $\sigma\dot{EL}$) normalized to 1000 meters range. The normalizing is done at this range because it simplified the calculations and, fortuitously, the projectile flight time to 1000 meters is almost exactly one second. Therefore all normalized values convert to meters of offset at the target. It will be noted that the curve peaks broadly in terms of effectiveness when the R.S.S. total is about 5 meters. Coincidentally the R.S.S. of all of the six sensor <u>biases</u> normalized at this range is 5.1 meters. It is suggested that there is a correlation here,

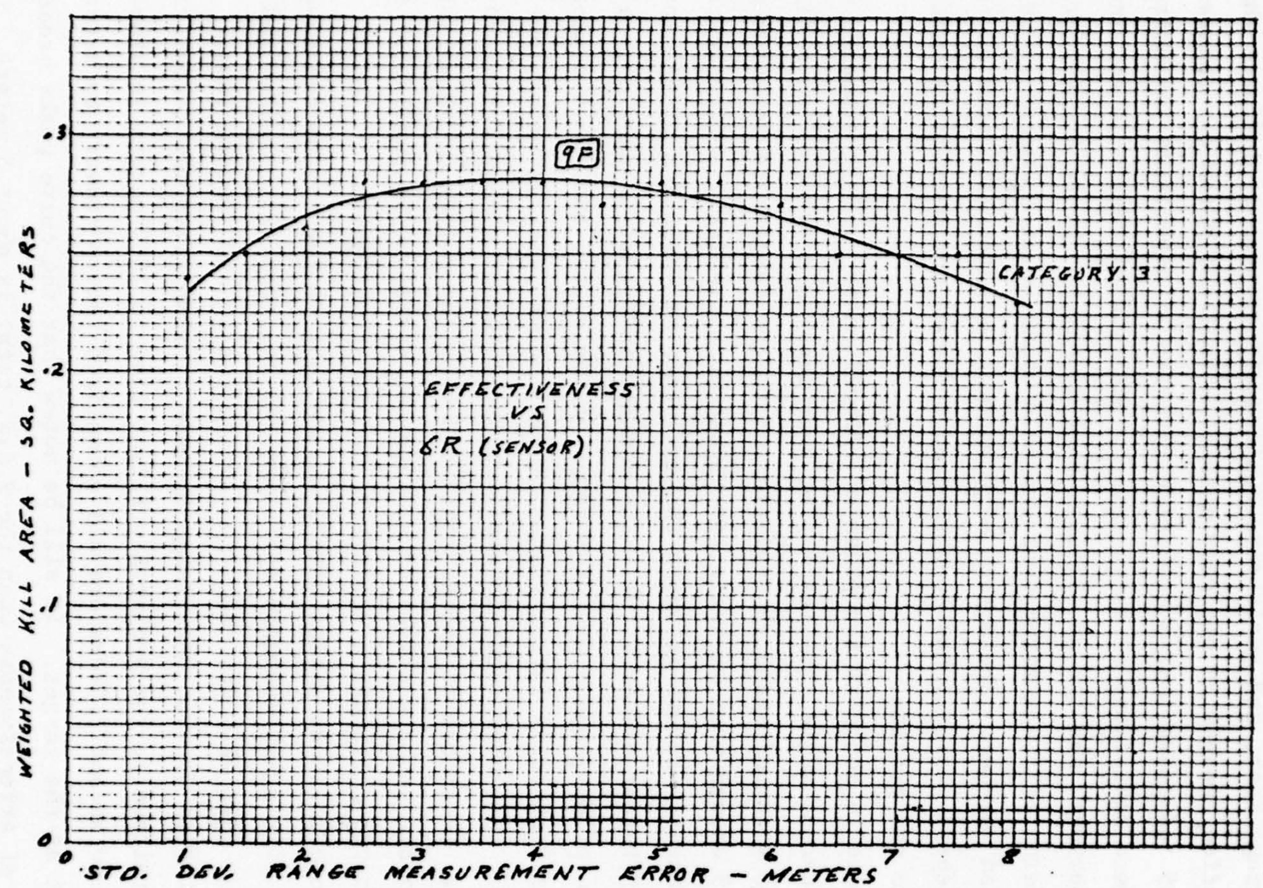

Figure 13 Effectiveness vs Sensor σR. Category 3 Systems.

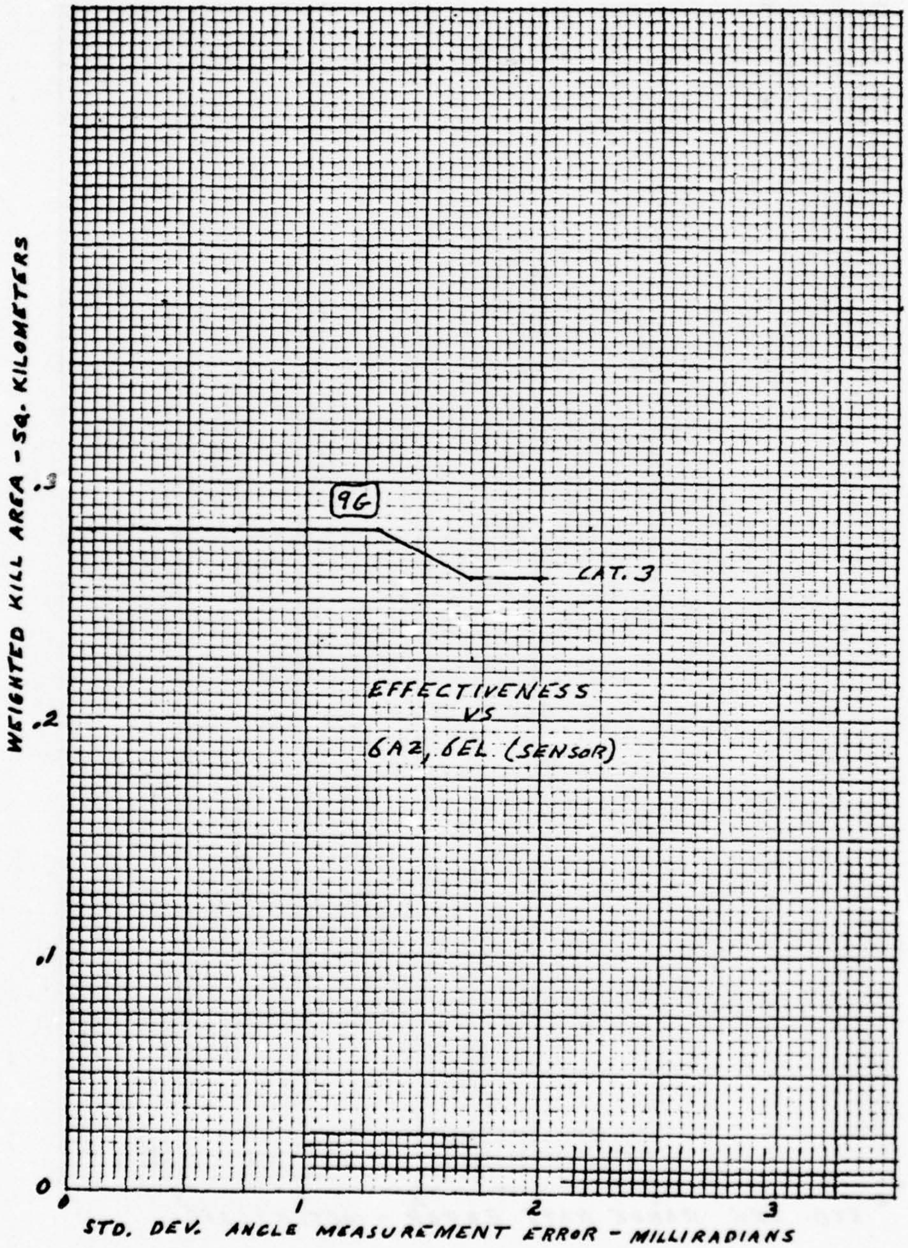

Figure 14 Effectiveness vs Sensor σAZ, σEL.
Category 3 Systems.

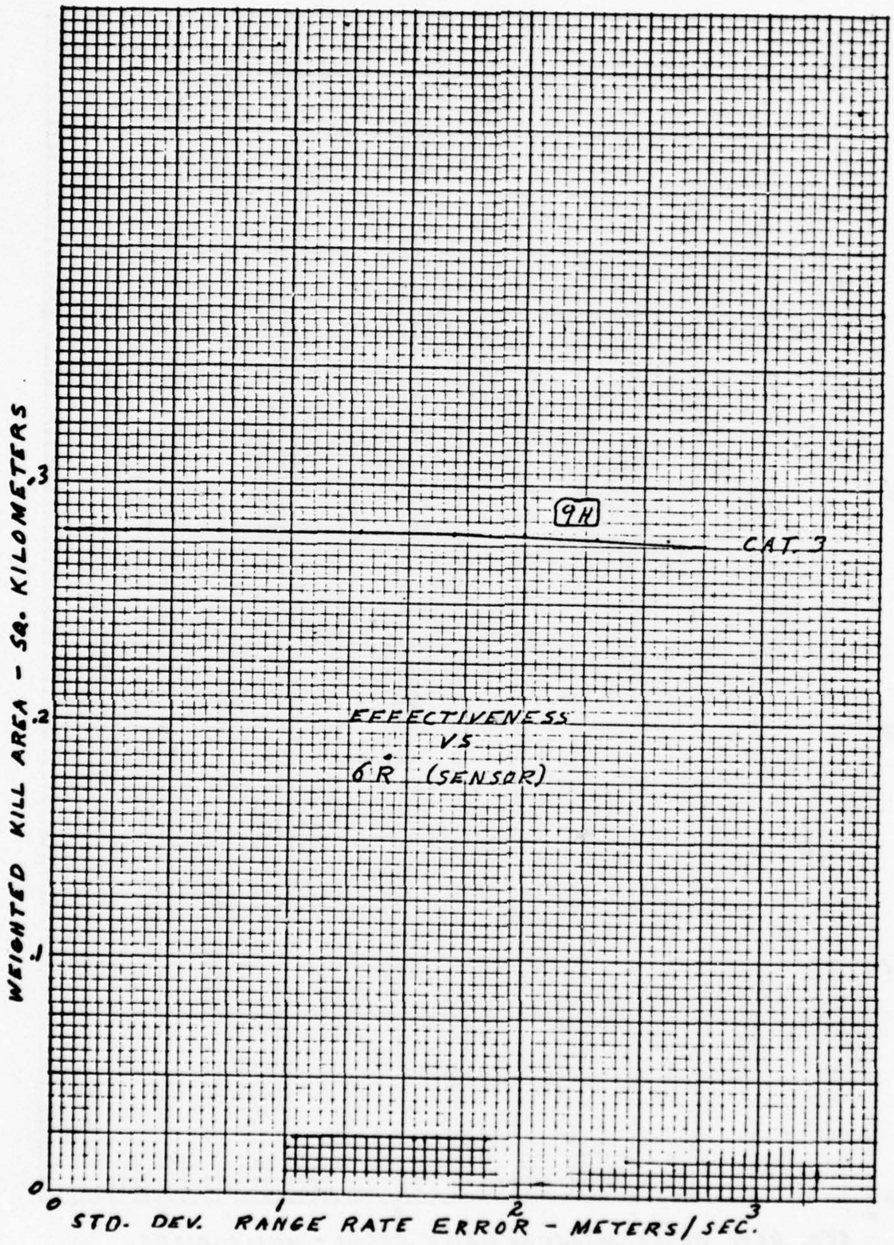

Figure 15 Effectiveness vs Sensor $\sigma\dot{R}$.
Category 3 Systems.

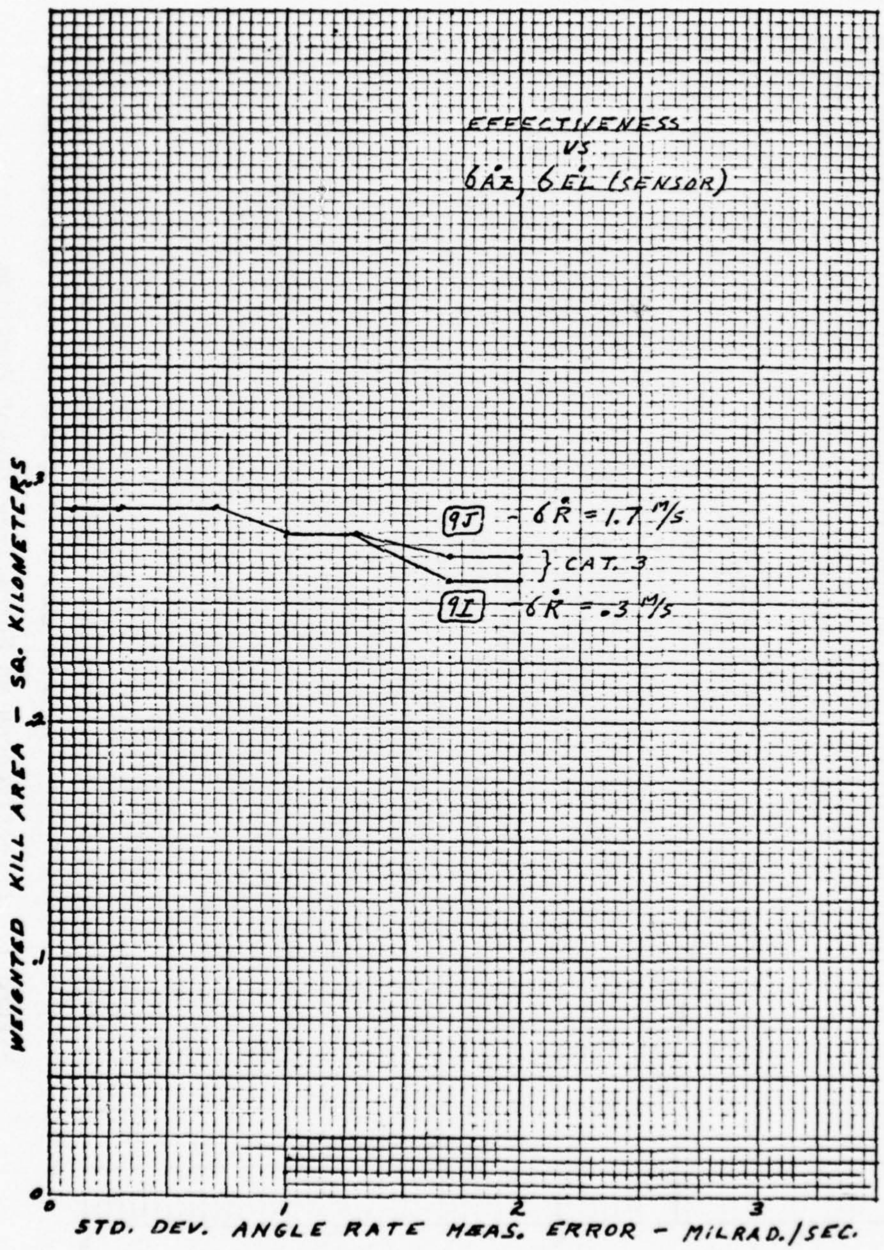

Figure 16 Effectiveness vs Sensor $\sigma\dot{A}Z$, $\sigma\dot{E}L$.
Category 3 Systems.

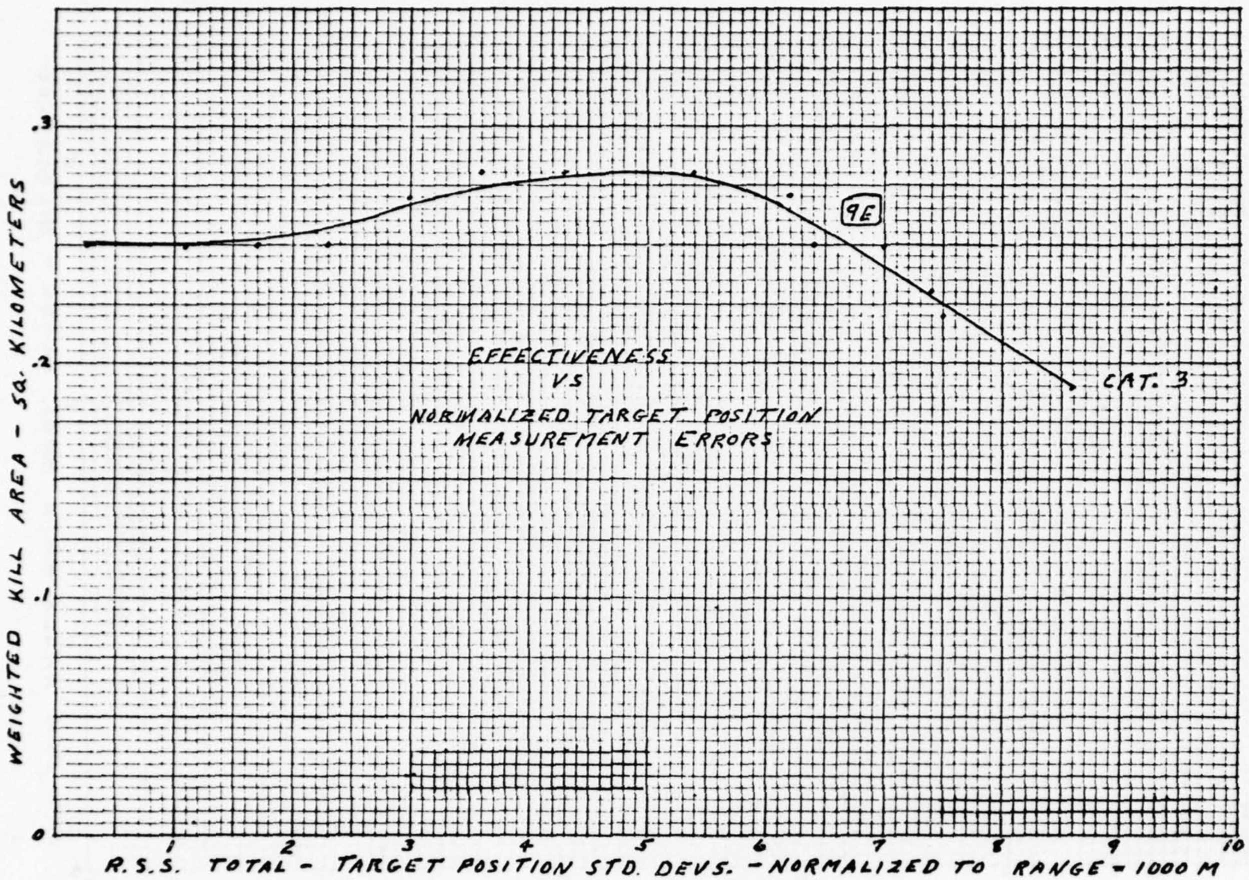

Figure 17 Effectiveness vs Normalized Target Position Measure Errors. Category 3 Systems.

that can be proved or disproved by making another series of computer runs in which controlled variations in bias are also made. The values of biases in this series were:

R = 4 meters, AZ = 2 milliradians, EL = 2 milliradians, $\dot{R}$ = 0.8 meter/sec., $\dot{AZ}$ = 0.8 milliradians/sec., $\dot{EL}$ = 0.8 milliradians/sec.

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A.0 APPENDIX A - WKA RANKING AND SYSTEM DATA FOR FIGURES 2, 3, 4, & 5

The four system illustrated in Figures 2 through 5 have the following WKA ratings in decending order:

Fig. 4, System 358	WKA = 14.505
Fig. 5, System 367	WKA = 11.473
Fig. 2, System 101	WKA = 6.801
Fig. 3, System 103	WKA = 4.880

The input data sheets for these systems are given on the following pages of this section.

GADES ISO-PK CONTOUR PROGRAM --- MARCH 1973

ACT STUDY - GP 6 NO. 101 - C.HICKS 11/18/74

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.000600
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.000600
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	10.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0001
2	0.120	0.0001
3	0.600	0.0001
4	1.200	0.0003

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0001
2	0.120	0.0001
3	0.600	0.0001
4	1.200	0.0003

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

SENSOR ERRORS
MEAN MEASURENT ERRORS XM(I)

RANGE,M	0.50000
AZIMUTH,RAD	0.00010
ELEVATION,RAD	0.00010
RANGE RATE,M/S	0.20000
AZ. RATE,RAD/S	0.00010
EL. RATE,RAD/S	0.00010

MASK	CHARACTER
EL. RATE OR MAX EL	E
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.50	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.200	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001

```
G A D E S   I S O - P K   C O N T O U R   P R O G R A M    ---    M A R C H   1 9 7 3

ACT STUDY - GP 6 NO. 103 -                                              C.HICKS 11/18/74

CALIBER TYPE                                                  2
MUZZLE VELOCITY, M/S                                       1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S                            12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.                  0.000600
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.                  0.000600
MAXIMUM ELEVATION, RAD.                                       1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.                             1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.                               1.20
AVERAGE SYSTEM REACTION TIME, SEC.                            0.0
ROUNDS PER BURST                                              4.
MAXIMUM EFFECTIVE RANGE, METERS                            6000.
RANGE, M. =3500.0000          TIME OF FLIGHT, SECS. =  7.0000          BALLISTIC COEFFICIENT,K-BAR =  0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION       BIAS, RAD.= 0.0
POINT  EL. RATE, R/S        STD DEV OF EL. ERROR, R
  1        0.0                     0.0
  2        0.120                   0.0
  3        0.600                   0.0
  4        1.200                   0.0

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH         BIAS, RAD.= 0.0
POINT  AZ. RATE, R/S        STD DEV OF AZ. ERROR, R
  1        0.0                     0.0
  2        0.120                   0.0
  3        0.600                   0.0
  4        1.200                   0.0
SENSOR ERRORS
MEAN MEASURENT ERRORS XM(I)

    RANGE,M                  0.0
    AZIMUTH,RAD              0.0
    ELEVATION,RAD            0.0
    RANGE RATE,M/S           0.0
    AZ. RATE,RAD/S           0.0
    EL. RATE,RAD/S           0.0
```

CONTOUR	PK	CHARACTER
1	[illegible]	F
2	[illegible]	[illegible]
3	[illegible]	[illegible]
4	[illegible]	[illegible]
5	0.2500	[illegible]
6	0.5000	[illegible]
7	0.7500	[illegible]
8	0.9000	[illegible]
9	0.9500	[illegible]
10	0.9900	0

MASK	CHARACTER
EL. RATE OR MAX EL	F
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.50	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.200	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001

GADES ISO-PK CONTOUR PROGRAM --- MARCH 1973

ACT STUDY - GROUP 2F NO. 358 C.HICKS 04/18/75

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	0.2500
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.000340
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.000340
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	4.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0
2	0.120	0.0
3	0.600	0.0
4	1.200	0.0

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0
2	0.120	0.0
3	0.600	0.0
4	1.200	0.0

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

SENSOR ERRORS
MEAN MEASURENT ERRORS XM(I)

RANGE,M	0.0
AZIMUTH,RAD	0.0
ELEVATION,RAD	0.0
RANGE RATE,M/S	0.0
AZ. RATE,RAD/S	0.0
EL. RATE,RAD/S	0.0

MASK	CHARACTER
EL. RATE OR MAX EL	F
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.00	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001

GADES ISO-PK CONTOUR PROGRAM --- MARCH 1973

ACT STUDY - GROUP 2F NO. 367 C.HICKS 04/18/75

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	0.2500
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.000600
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.000600
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	4.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0
2	0.120	0.0
3	0.600	0.0
4	1.200	0.0

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0
2	0.120	0.0
3	0.600	0.0
4	1.200	0.0

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

SENSOR ERRORS
MEAN MEASUREMENT ERRORS XM(I)

RANGE,M	0.0
AZIMUTH,RAD	0.0
ELEVATION,RAD	0.0
RANGE RATE,M/S	0.0
AZ. RATE,RAD/S	0.0
EL. RATE,RAD/S	0.0

MASK	CHARACTER
EL. RATE OR MAX EL	E
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.00	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001

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B.0 APPENDIX B - CHARACTERISTICS OF THE TOP RANKED SYSTEMS IN EACH DATA BASE GROUP

Following is a list of the No. 1 ranked system for each of the groups plotted in Figures 6 through 17. ISO PK plots and input data for each of these systems are given on the following pages.

	SYSTEM NO.	CATEGORY	WKA VALUE	PAGES
Fig. 6				
GP2A	288	1	9.76	B-3,4
GP2B	286	1	6.17	B-5,6
GP2D	314	1	9.42	B-7,8
Fig. 7				
GP2D	314	1	9.42	B-7,8
GP2E	341	1	15.60	B-9,10
GP2F	359	1	14.57	B-11,12
Fig. 8				
GP6A	87	2	4.77	B-13,14
GP6B	89	2	4.32	B-15,16
Fig. 9				
GP9	146	3	.939	B-17,18
GP9A	186	3	.997	B-19,20
Fig. 10				
GP2C	57	1	14.68	B-21,22
GP5A	83	3	4.43	B-23,24
GP6	102	2	19.38	B-25,26
Fig. 11				
GP9	146	3	.939	B-17,18
GP9C	220	3	.260	B-27,28
GP9D	206	3	1.74	B-29,30
Fig. 12				
GP8	289	2	4.98	B-31,32
Fig. 13				
GP9F	243	3	.285	B-33,34

	SYSTEM NO.	CATEGORY	WKA VALUE	PAGES
Fig. 14				
GP9C	250	3	.285	B-35,36
Fig. 15				
GP9H	252	3	.285	B-37,38
Fig. 16				
GP9I	263	3	.291	B-39,40
GP9J	272	3	.291	B-41,42
Fig. 17				
GP9E	233	3	.280	B-43,44

SADES ISO-PK CONTOUR PROGRAM --- MARCH 1973

ACT STUDY - GROUP 2A NO. 2AA C.HICKS 03/12/75

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	1.0000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.000200
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.000200
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	1.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0
2	0.120	0.0
3	0.600	0.0
4	1.200	0.0

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0
2	0.120	0.0
3	0.600	0.0
4	1.200	0.0

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

SENSOR ERRORS
MEAN MEASUREMENT ERRORS XM(I)

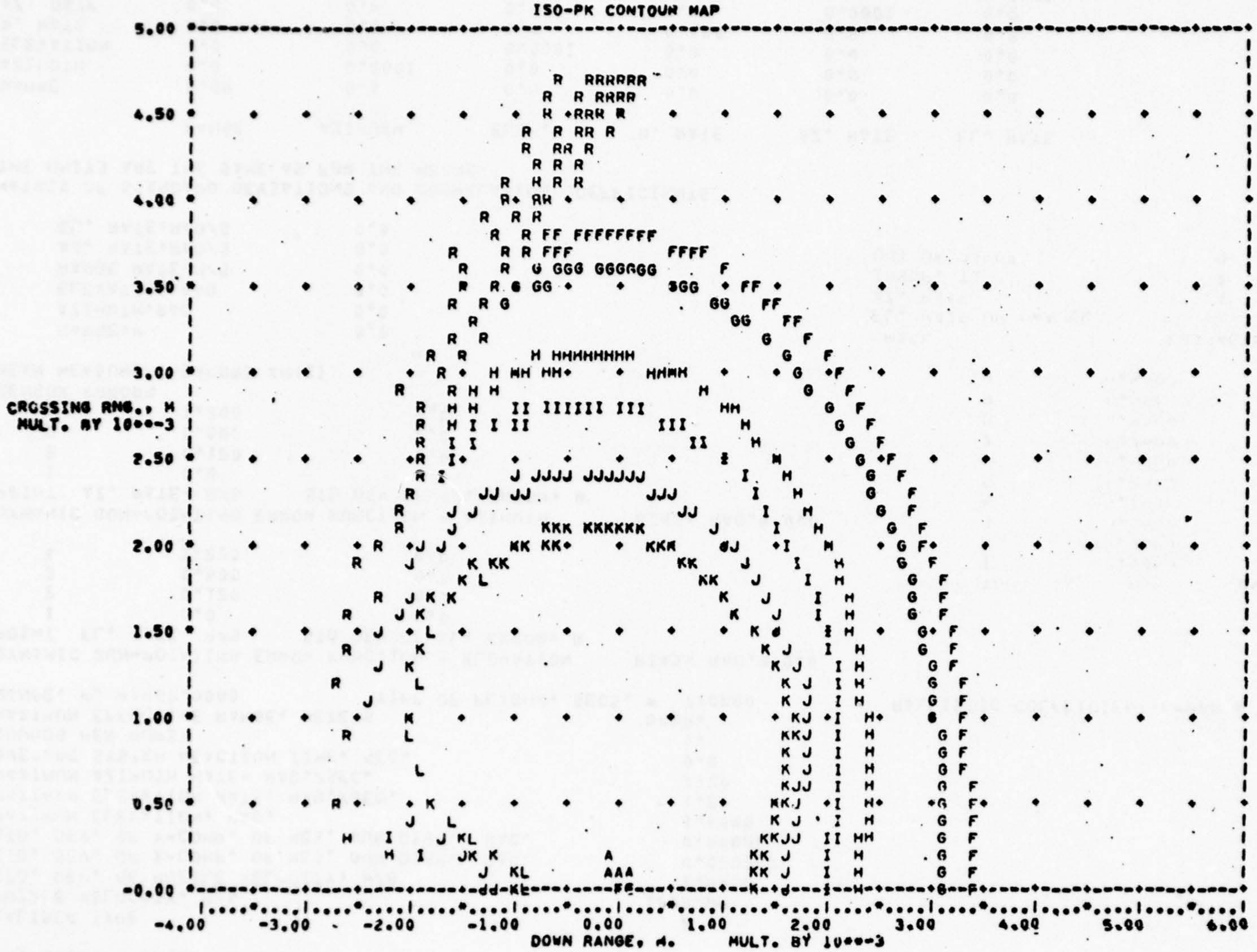
RANGE,M	0.0
AZIMUTH,RAD	0.0
ELEVATION,RAD	0.0
RANGE RATE,M/S	0.0
AZ. RATE,RAD/S	0.0
EL. RATE,RAD/S	0.0

MASK	CHARACTER
EL. RATE OR MAX EL	E
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.00	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001

ISO-PK CONTOUR MAP



ACT STUDY - GROUP 2A NO. 2A8
TARGET VELOCITY=-310.0:0M/S TARGET ALTITUDE= 60.000M

C.HICKS 03/12/75

G A D E S   I S O - P K   C O N T O U R   P R O G R A M   ---   M A R C H   1 9 7 3

ACT STUDY - GROUP 28 NO. 286   C.HICKS 03/11/75

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.000020
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.000020
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	1.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000   TIME OF FLIGHT, SECS. = 7.0000   BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION   BIAS, RAD.= 0.0

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0
2	0.120	0.0
3	0.600	0.0
4	1.200	0.0

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH   BIAS, RAD.= 0.0

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0
2	0.120	0.0
3	0.600	0.0
4	1.200	0.0

SENSOR ERRORS
MEAN MEASUREMENT ERRORS XM(I)

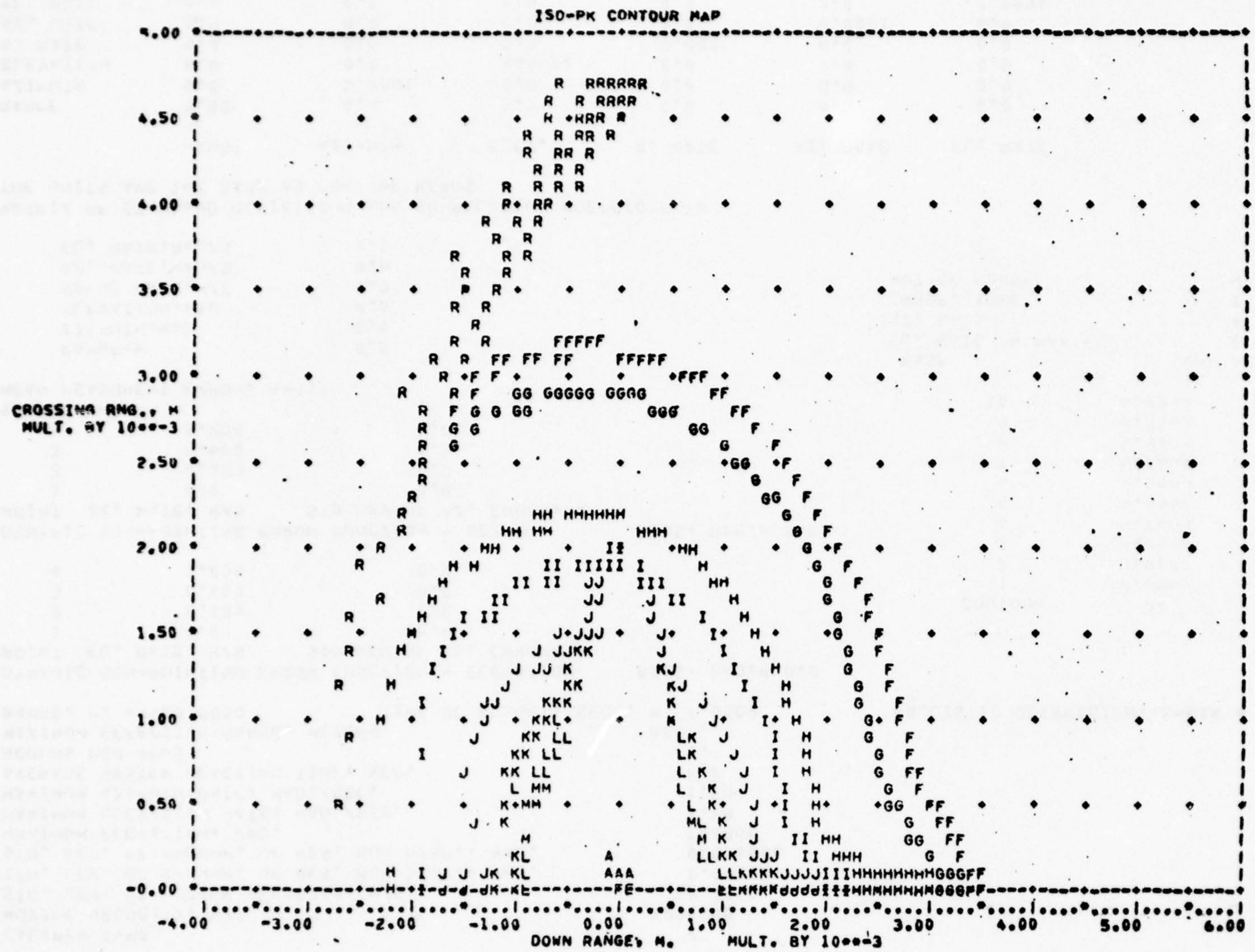
RANGE,M	0.0
AZIMUTH,RAD	0.0
ELEVATION,RAD	0.0
RANGE RATE,M/S	0.0
AZ. RATE,RAD/S	0.0
EL. RATE,RAD/S	0.0

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	[illegible]
3	0.0500	[illegible]
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	[illegible]
9	0.9500	[illegible]
10	0.9900	[illegible]

MASK	CHARACTER
EL. RATE OR MAX EL	E
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.00	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001



ACT STUDY - GROUP 2A NO. 286 C.HICKS 03/11/75

TARGET VELOCITY=-310.000M/S TARGET ALTITUDE= 60.000M

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G A D E S  I S O - P K  C O N T O U R  P R O G R A M   ---   S A F E S  1 9 7 5

ACT STUDY - GROUP 20 NO. 314                                     C.HICKS 04/10/75

CALIBER TYPE                                                 2
MUZZLE VELOCITY, M/S                                   1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S                        0.5000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.             0.000280
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.             0.000280
MAXIMUM ELEVATION, RAD.                                  1.4900
MAXIMUM ELEVATION RATE, RAD./SEC.                        1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.                          1.20
AVERAGE SYSTEM REACTION TIME, SEC.                       0.0
ROUNDS PER BURST                                         1.
MAXIMUM EFFECTIVE RANGE, METERS                       6000.
RANGE, M. =3500.0000          TIME OF FLIGHT, SECS. =  7.0000        BALLISTIC COEFFICIENT,K-BAR =  0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION      BIAS, RAD.= 0.0
POINT  EL. RATE, R/S      STD DEV OF EL. ERROR, R
    1         0.0                 0.0
    2         0.120               0.0                                CONTOUR        PK         CHARACTER
    3         0.600               0.0                                   1         0.0050          F
    4         1.200               0.0                                   2         0.0100          G
                                                                        3         0.0500          H
DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH        BIAS, RAD.= 0.0    4         0.1000          I
POINT  AZ. RATE, R/S      STD DEV OF AZ. ERROR, R                       5         0.2500          J
    1         0.0                 0.0                                   6         0.5000          K
    2         0.120               0.0                                   7         0.7500          L
    3         0.600               0.0                                   8         0.9000          M
    4         1.200               0.0                                   9         0.9500          N
SENSOR ERRORS                                                          10         0.9900          O
MEAN MEASURENT ERRORS XM(I)
                                                                MASK                       CHARACTER
    RANGE,M                 0.0                                 EL. RATE OR MAX EL              F
    AZIMUTH,RAD             0.0                                 AZ. RATE                        A
    ELEVATION,RAD           0.0                                 INSUF. TIME                     T
    RANGE RATE,M/S          0.0                                 OUT OF RANGE                    R
    AZ. RATE,RAD/S          0.0
    EL. RATE,RAD/S          0.0

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

            RANGE      AZIMUTH      ELEV.       R. RATE      AZ. RATE     EL. RATE

RANGE       0.00       0.0          0.0         0.0          0.0          0.0
AZIMUTH     0.0        0.0001       0.0         0.0          0.0          0.0
ELEVATION   0.0        0.0          0.0001      0.0          0.0          0.0
R. RATE     0.0        0.0          0.0         0.000        0.0          0.0
AZ. RATE    0.0        0.0          0.0         0.0          0.0001       0.0
EL. RATE    0.0        0.0          0.0         0.0          0.0          0.0001
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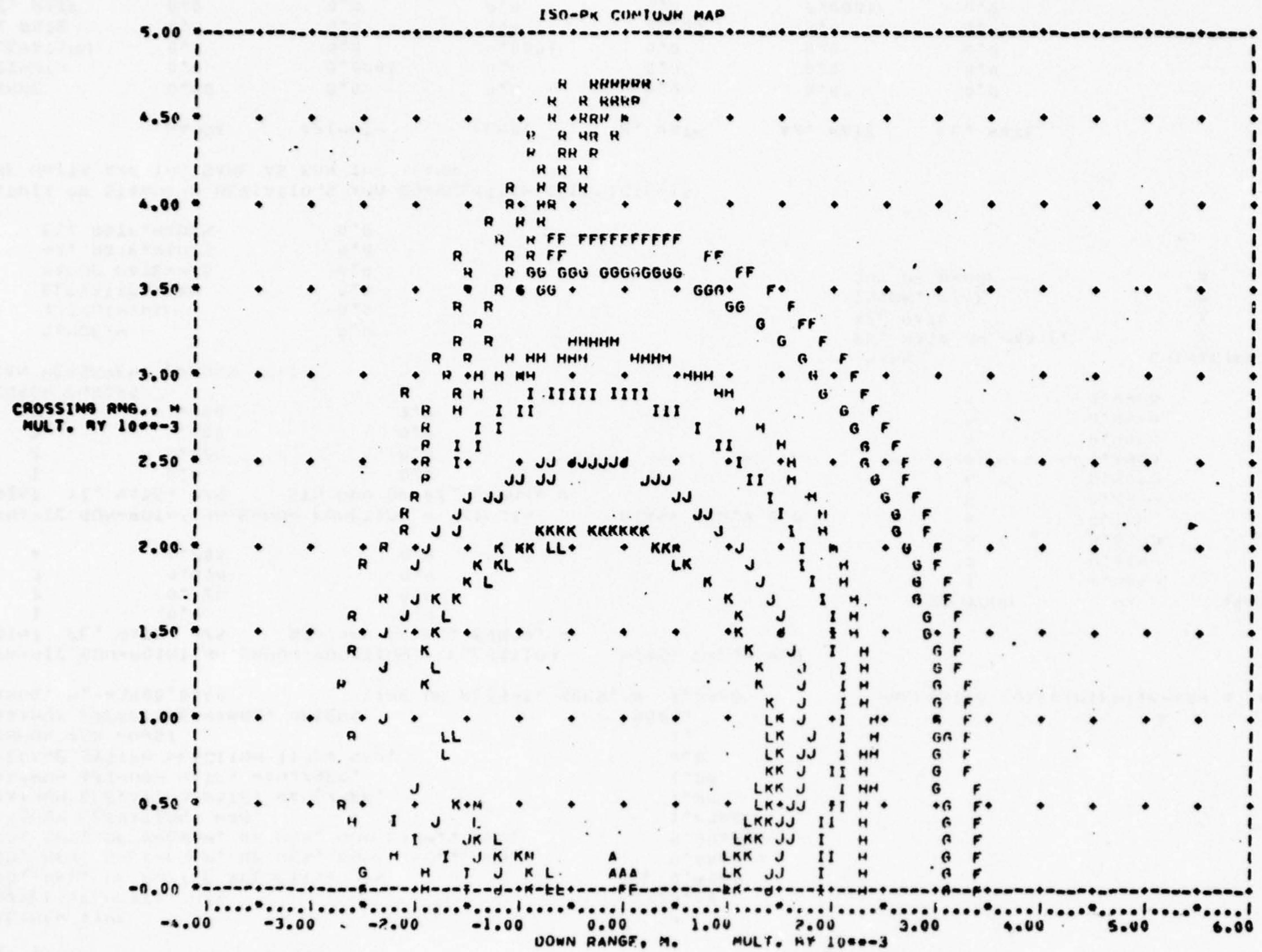


ACT STUDY - GROUP 2D NO. 314 C.HICKS 04/10/75
TARGET VELOCITY=-310.000M/S TARGET ALTITUDE= 60.000M

G A D E S I S O - R A N G E C O N T O U R P R O G R A M --- M A R C H 1 9 7 3

ACT STUDY - GROUP 2E NO. 341 C.HICKS 04/11/75

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	0.5000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.000330
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.000330
MAXIMUM ELEVATION, RAD.	1.4000
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	4.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0
2	0.120	0.0
3	0.600	0.0
4	1.200	0.0

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0
2	0.120	0.0
3	0.600	0.0
4	1.200	0.0

CONTOUR	PK	CHARACTER
1	[illegible]	F
2	[illegible]	[illegible]
3	[illegible]	[illegible]
4	0.1000	I
5	[illegible]	J
6	0.5000	K
7	[illegible]	L
8	0.9000	[illegible]
9	0.9500	[illegible]
10	[illegible]	[illegible]

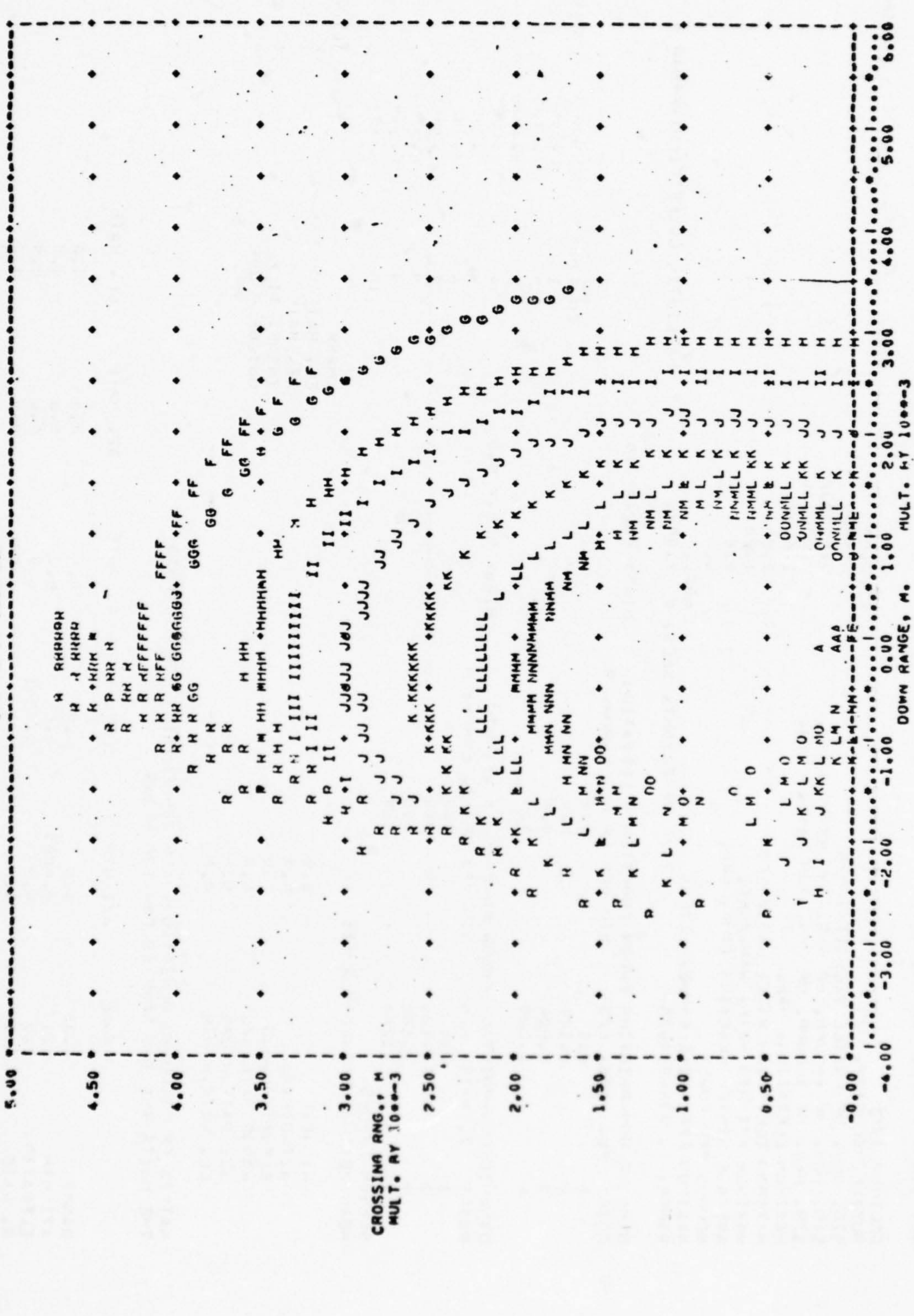
SENSOR ERRORS
MEAN MEASUREMENT ERRORS X(I)

RANGE,M	0.0
AZIMUTH,RAD	0.0
ELEVATION,RAD	0.0
RANGE RATE,M/S	0.0
AZ. RATE,RAD/S	0.0
EL. RATE,RAD/S	0.0

MASK	CHARACTER
EL. RATE OR MAX EL	[illegible]
AZ. RATE	[illegible]
INSUF. TIME	[illegible]
OUT OF RANGE	[illegible]

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS.

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.00	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001


ISO-PK CONTOUR MAP
CROSSING RNG., M
MULT. BY 10**-3
DOWN RANGE, M.
MULT. BY 10**-3
ACT STUDY - GROUP 2E NO. 341
TARGET VELOCITY=-310.000M/S
TARGET ALTITUDE= 60.000M
C.HICKS 04/11/75

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ADES ISO-PK CONTOUR PROGRAM  ---  MARCH 1973
CT STUDY - GROUP 2F NO. 359                         C.HICKS 04/18/75

ALIBER TYPE                                          2
UZZLE VELOCITY, M/S                               1220.00
TD. DEV. OF MUZZLE VELOCITY, M/S                     0.2500
TD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.          0.000360
TD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.          0.000360
AXIMUM ELEVATION, RAD.                               1.4800
AXIMUM ELEVATION RATE, RAD./SEC.                     1.20
AXIMUM AZIMUTH RATE, RAD./SEC.                       1.20
VERAGE SYSTEM REACTION TIME, SEC.                    0.0
OUNDS PER BURST                                      4.
AXIMUM EFFECTIVE RANGE, METERS                    6000.
ANGE, M. =3500.0000        TIME OF FLIGHT, SECS. =   7.0000      BALLISTIC COEFFICIENT,K-BAR =  0.2057

YNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION      BIAS, RAD.= 0.0
OINT  EL. RATE, R/S      STD DEV OF EL. ERROR, R
  1       0.0                 0.0
  2       0.120               0.0
  3       0.600               0.0
  4       1.200               0.0

YNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH        BIAS, RAD.= 0.0
OINT  AZ. RATE, R/S      STD DEV OF AZ. ERROR, R
  1       0.0                 0.0
  2       0.120               0.0
  3       0.600               0.0
  4       1.200               0.0
ENSOR ERRORS
EAN MEASURENT ERRORS XM(I)

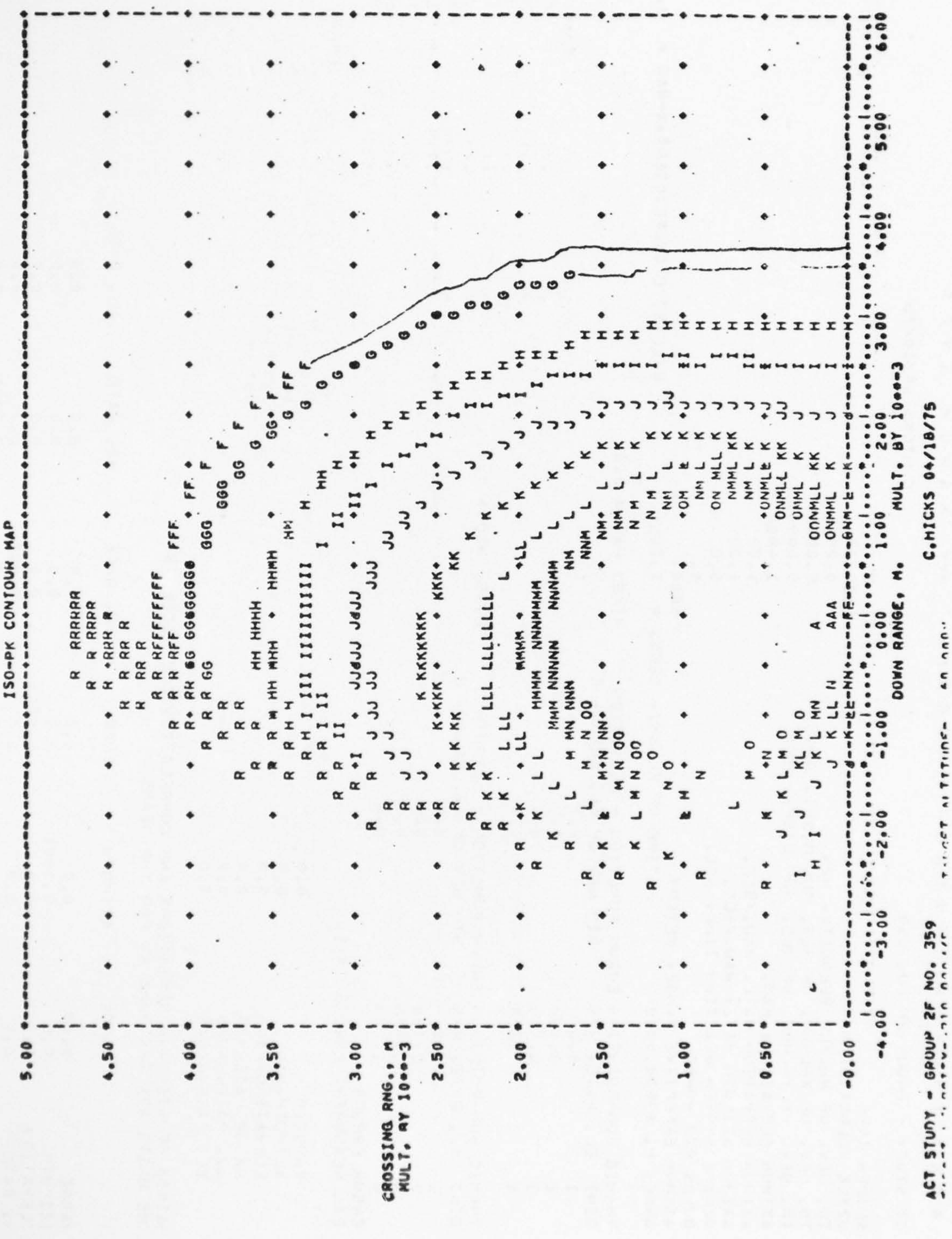
    RANGE,M                  0.0
    AZIMUTH,RAD              0.0
    ELEVATION,RAD            0.0
    RANGE RATE,M/S           0.0
    AZ. RATE,RAD/S           0.0
    EL. RATE,RAD/S           0.0
```

CONTOUR	PK	CHARACTER
1	[illegible]	F
2	[illegible]	[illegible]
3	[illegible]	[illegible]
4	[illegible]	I
5	[illegible]	J
6	[illegible]	K
7	[illegible]	L
8	[illegible]	[illegible]
9	[illegible]	[illegible]
10	[illegible]	[illegible]

MASK	CHARACTER
EL. RATE OR MAX EL. [illegible]	[illegible]
AZ. RATE	[illegible]
INSUF. TIME	I
OUT OF RANGE	[illegible]

IATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
'HE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.00	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001


ISO-PK CONTOUR MAP
CROSSING RNG., M
MULT. BY 10**-3
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
-0.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
DOWN RANGE, M.
MULT. BY 10**-3
C.HICKS 04/18/75
ACT STUDY - GROUP 2F NO. 359

G&DES ISO-PK CONTOUR PROGRAM --- MARCH 1973

ACT STUDY - GP 6 NO. 87 - C.HICKS 11/14/74

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	8.0000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.000500
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.000500
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	4.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000   TIME OF FLIGHT, SECS. = 7.0000   BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION   BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0002
2	0.120	0.0002
3	0.600	0.0002
4	1.200	0.0005

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH   BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0002
2	0.120	0.0002
3	0.600	0.0002
4	1.200	0.0005

SENSOR ERRORS
MEAN MEASURENT ERRORS XM(I)

RANGE,M	0.50000
AZIMUTH,RAD	0.00010
ELEVATION,RAD	0.00010
RANGE RATE,M/S	0.20000
AZ. RATE,RAD/S	0.00010
EL. RATE,RAD/S	0.00010

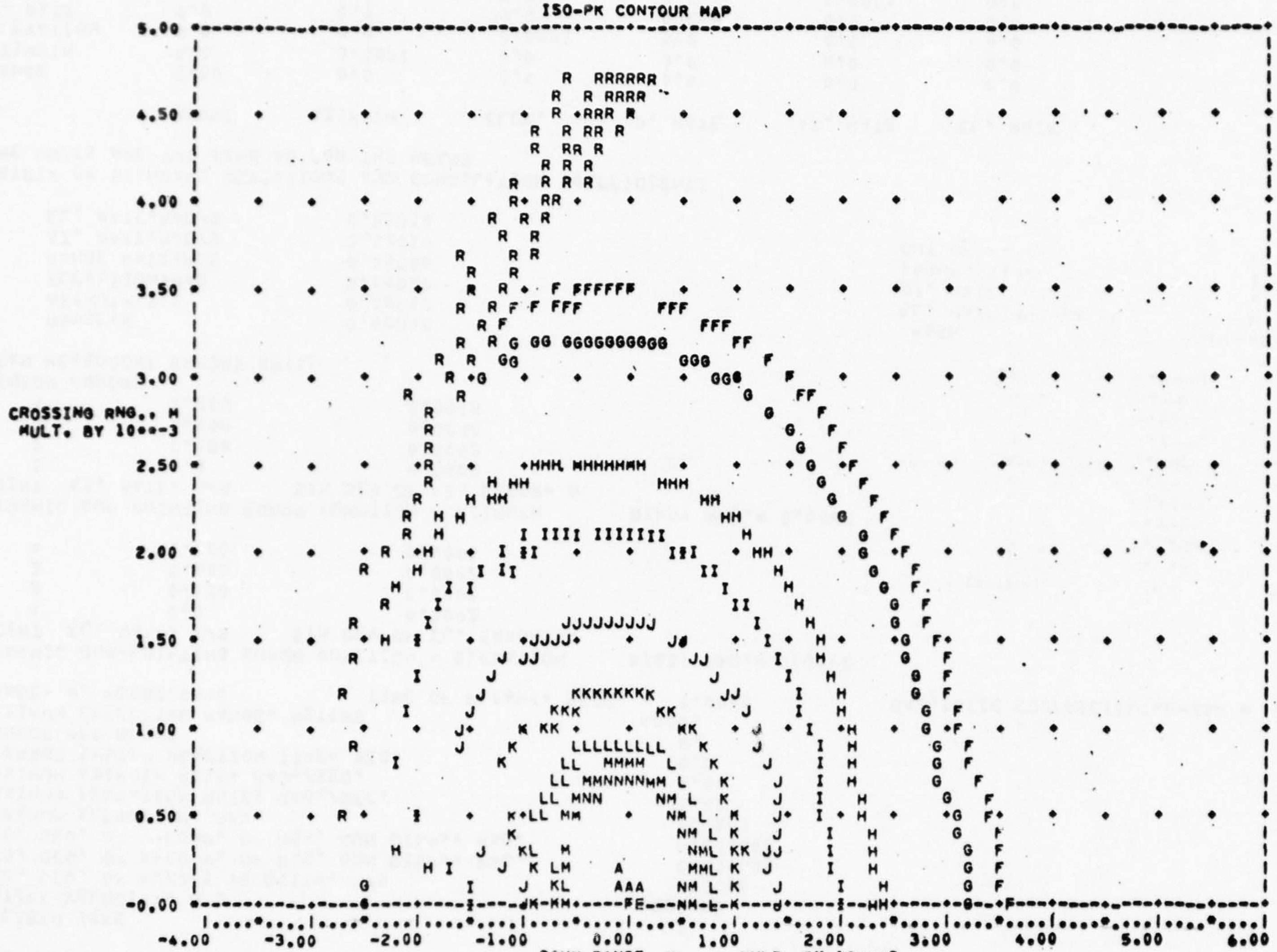
CONTOUR	PK	CHARACTER
1	[illegible]	[illegible]
2	[illegible]	[illegible]
3	[illegible]	[illegible]
4	[illegible]	I
5	[illegible]	[illegible]
6	[illegible]	[illegible]
7	[illegible]	L
8	[illegible]	[illegible]
9	[illegible]	[illegible]
10	[illegible]	[illegible]

MASK	CHARACTER
EL. RATE [illegible]	[illegible]
AZ. RATE	[illegible]
INSUF. [illegible]	T
OUT OF [illegible]	[illegible]

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.50	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.200	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001

ISO-PK CONTOUR MAP



ACT STUDY - GP 6 NO. 87 -
TARGET VELOCITY=-310.000M/S TARGET ALTITUDE= 60.000M

C.HICKS 11/14/74

BADES ISO-PK CONTOUR PROGRAM --- MARCH 1973

ACT STUDY - GP 6 NO. 89 - C.HICKS 11/14/74

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.000400
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.000400
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	4.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0002
2	0.120	0.0002
3	0.600	0.0002
4	1.200	0.0005

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0002
2	0.120	0.0002
3	0.600	0.0002
4	1.200	0.0005

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

SENSOR ERRORS

MEAN MEASURENT ERRORS XM(I)

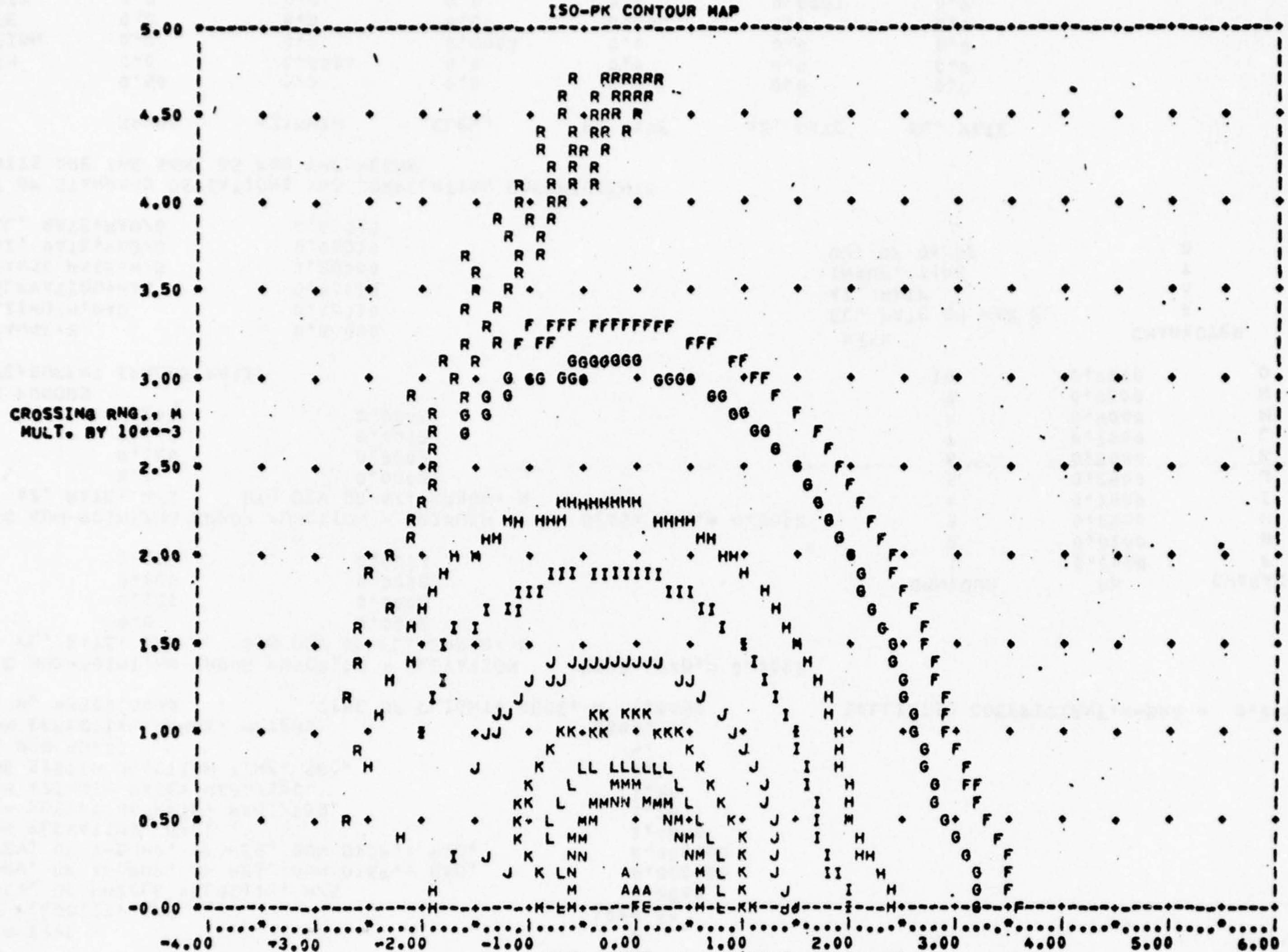
RANGE,M	0.50000
AZIMUTH,RAD	0.00010
ELEVATION,RAD	0.00010
RANGE RATE,M/S	0.20000
AZ. RATE,RAD/S	0.00010
EL. RATE,RAD/S	0.00010

MASK	CHARACTER
EL. RATE OR MAX EL	E
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.50	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.200	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001

ISO-PK CONTOUR MAP



ACT STUDY - GP 6 NO. 89 -
TARGET VELOCITY=-310.000M/S TARGET ALTITUDE= 60.000M

C.HICKS 11/14/74

G A D E S I S O - P K C O N T O U R P R O G R A M --- M A R C H 1 9 7 3

ACT STUDY - GROUP 9 NO. 146 C.HICKS 01/10/75

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CALIBER TYPE                                          2
MUZZLE VELOCITY, M/S                               1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S                    12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.          0.001400
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.          0.001400
MAXIMUM ELEVATION, RAD.                               1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.                     1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.                       1.20
AVERAGE SYSTEM REACTION TIME, SEC.                    0.0
ROUNDS PER BURST                                      4.
MAXIMUM EFFECTIVE RANGE, METERS                    6000.
RANGE, M. =3500.0000        TIME OF FLIGHT, SECS. =   7.0000      BALLISTIC COEFFICIENT,K-BAR =  0.2057
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DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

SENSOR ERRORS

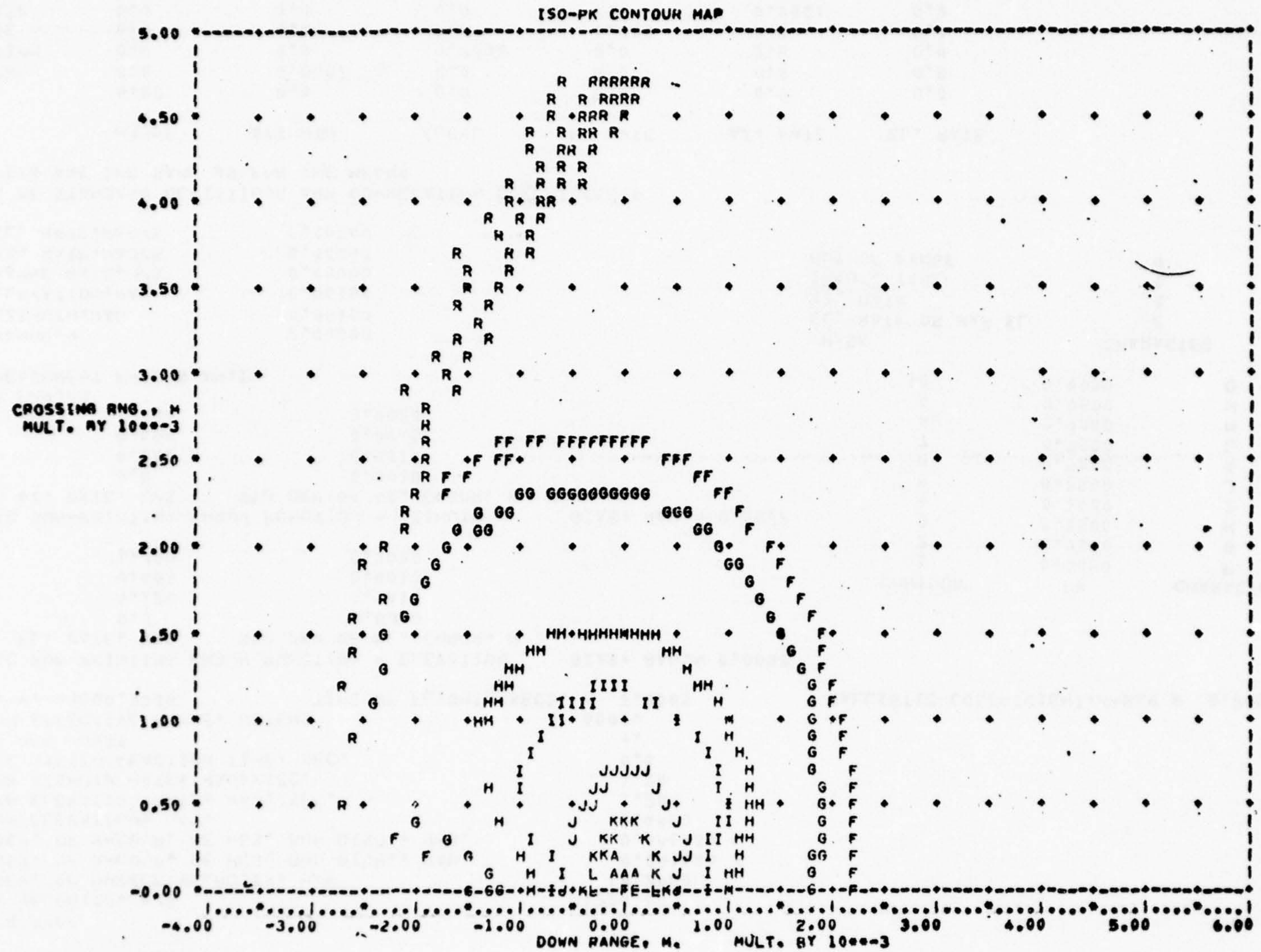
MEAN MEASUREMENT ERRORS XM(I)

RANGE,M	2.00000
AZIMUTH,RAD	0.00100
ELEVATION,RAD	0.00100
RANGE RATE,M/S	0.40000
AZ. RATE,RAD/S	0.00040
EL. RATE,RAD/S	0.00040

MASK	CHARACTER
EL. RATE OR MAX EL	E
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.00	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001



ACT STUDY - GROUP 9 NO. 146 C.HICKS 01/10/75
TARGET VELOCITY=-310.000M/S TARGET ALTITUDE= 60.000M

G A D E S I S O - P K C O N T O U R P R O G R A M --- M A R C H 1 9 7 3

ACT STUDY - GROUP 9A NO. 186 C.HICKS 01/15/75

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	1.0000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.001700
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.001700
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	4.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

SENSOR ERRORS
MEAN MEASURENT ERRORS XM(I)

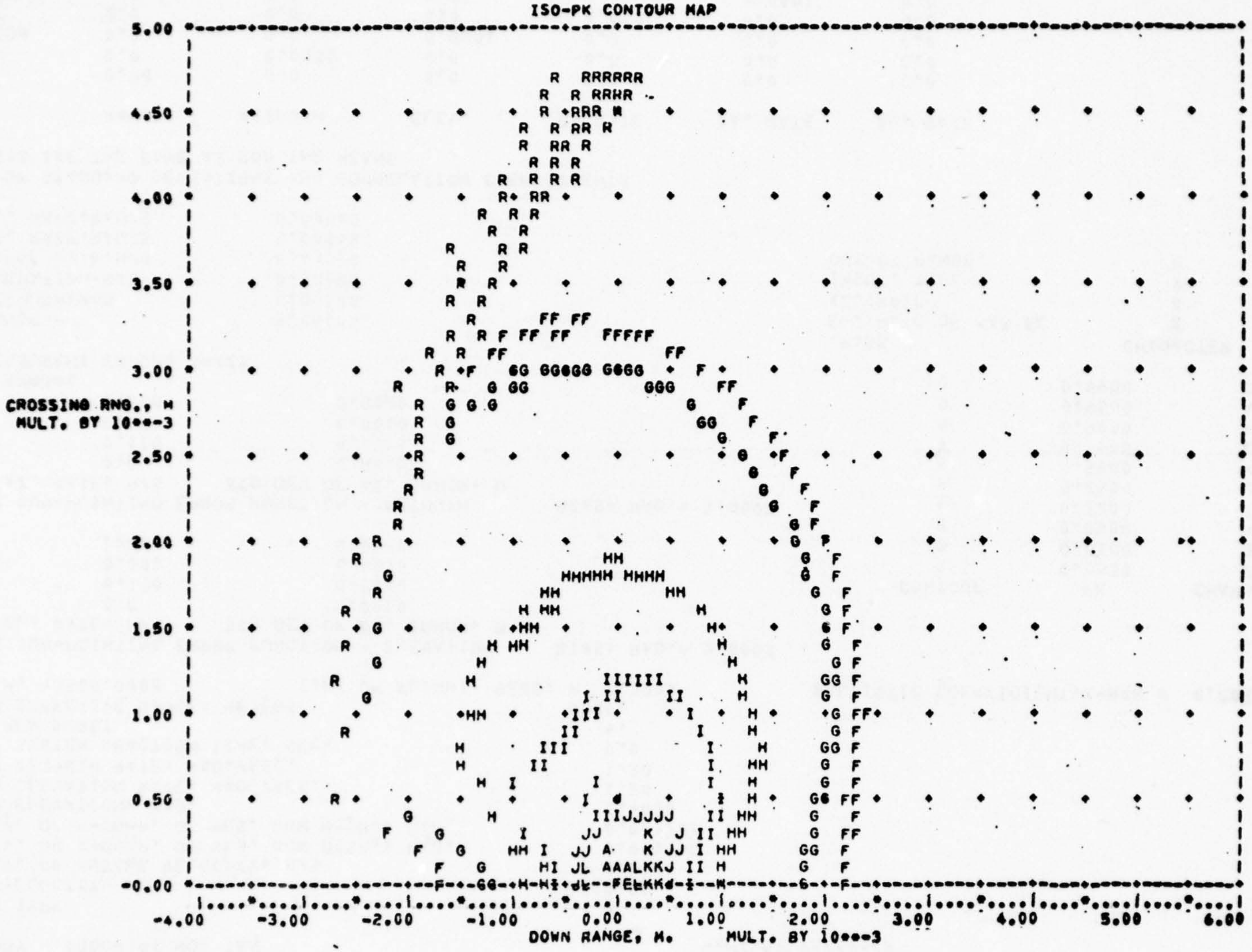
RANGE,M	2.00000
AZIMUTH,RAD	0.00100
ELEVATION,RAD	0.00100
RANGE RATE,M/S	0.40000
AZ. RATE,RAD/S	0.00040
EL. RATE,RAD/S	0.00040

MASK	CHARACTER
EL. RATE OR MAX EL	E
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.00	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001

ISO-PK CONTOUR MAP



ACT STUDY - GROUP 9A NO. 186 C.HICKS 01/15/75
TARGET VELOCITY=-310.000M/S TARGET ALTITUDE= 60.000M

G A D E S I S O - P K C O N T O U R P R O G R A M --- M A R C H 1 9 7 3

ACT STUDY - NO. 57 - A & LR GP2 - SIGMV VS SIG X,Y - C.HICKS 11/04/74

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	1.0000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.000700
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.000700
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	10.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0
2	0.120	0.0
3	0.600	0.0
4	1.200	0.0

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0
2	0.120	0.0
3	0.600	0.0
4	1.200 1	0.0

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

SENSOR ERRORS
MEAN MEASUREMENT ERRORS XM(I)

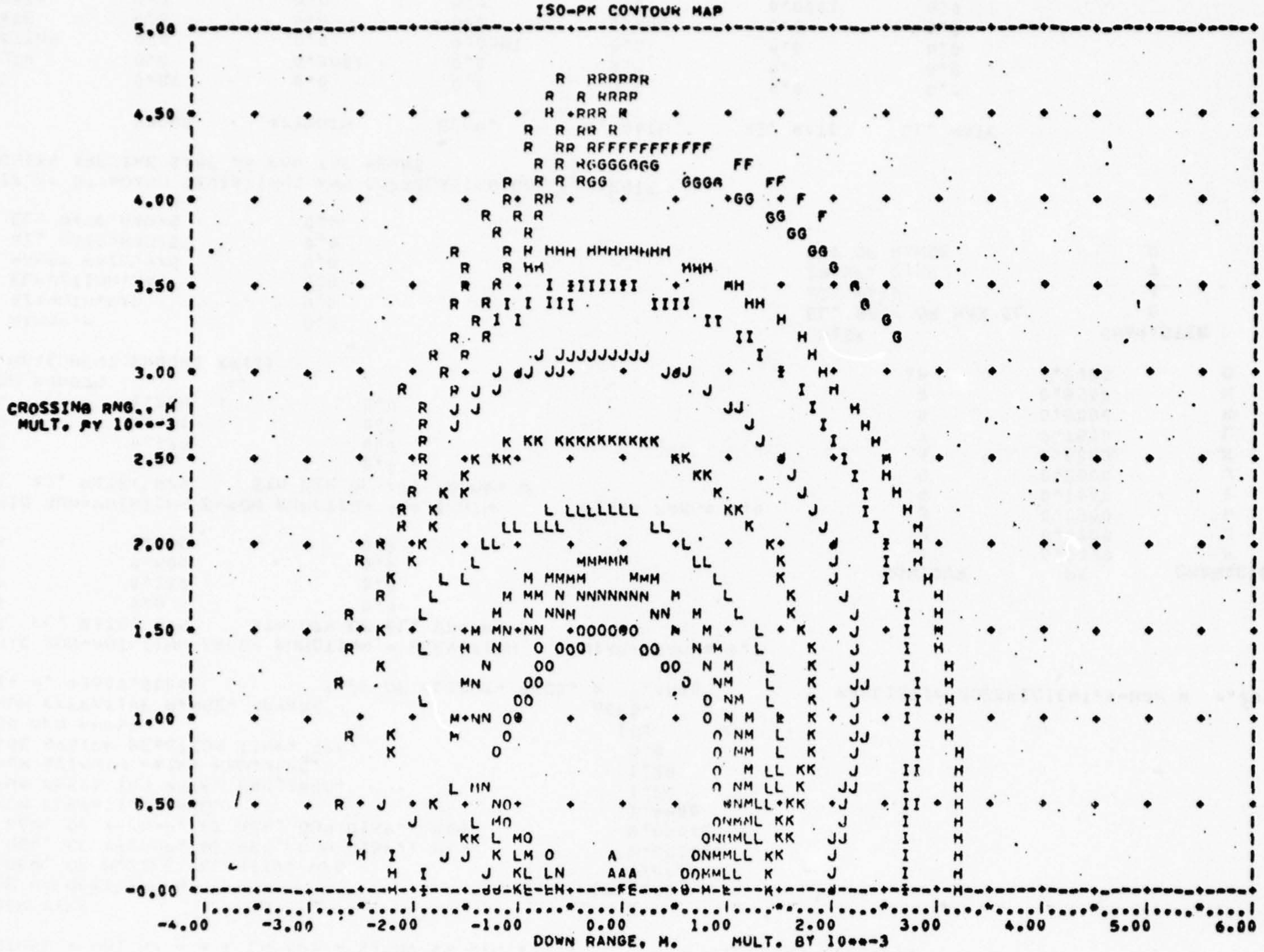
RANGE,M	0.0
AZIMUTH,RAD	0.0
ELEVATION,RAD	0.0
RANGE RATE,M/S	0.0
AZ. RATE,RAD/S	0.0
EL. RATE,RAD/S	0.0

MASK	CHARACTER
EL. RATE OR MAX EL	E
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.00	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001

ISO-PK CONTOUR MAP



ACT STUDY - NO. 57 - A & LR GP2 - SIGMV VS SIG X,Y - C.HICKS 11/04/74
TARGET VELOCITY=-310.000M/S TARGET ALTITUDE= 60.000M

G A D E S I S O - P K C O N T O U R P R O G R A M --- M A R C H 1 9 7 3

ACT STUDY - GP 5 NO. 83 - STD DEV. C.HICKS 11/08/74

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.002000
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.002000
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	50.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0015
2	0.120	0.0015
3	0.600	0.0020
4	1.200	0.0030

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0015
2	0.120	0.0015
3	0.600	0.0020
4	1.200	0.0030

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	[illegible]
9	0.9500	[illegible]
10	0.9900	O

SENSOR ERRORS
MEAN MEASUREMENT ERRORS XM(I)

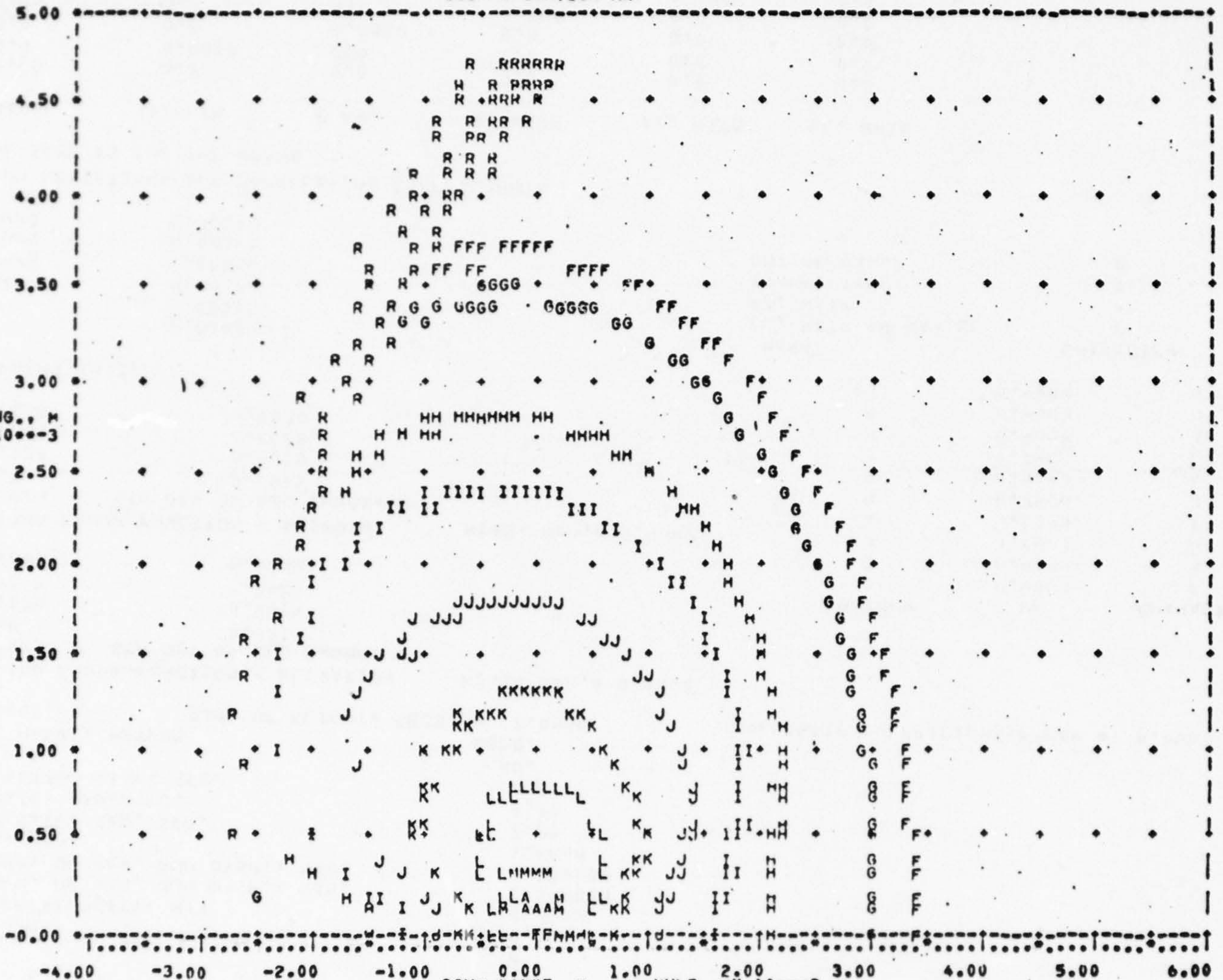
RANGE,M	2.00000
AZIMUTH,RAD	0.00100
ELEVATION,RAD	0.00100
RANGE RATE,M/S	0.40000
AZ. RATE,RAD/S	0.00040
EL. RATE,RAD/S	0.00040

MASK	CHARACTER
EL. RATE OR MAA EL	F
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.50	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0010	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0010	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.200	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0005	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0005

ISO-PK CONTOUR MAP



ACT STUDY - GP 5 NO. 83 - STD DEV.
TARGET VELOCITY=-310.000M/S   TARGET ALTITUDE= 60.000M

C.HICKS 11/08/74

G A D E S I S O - P K C O N T O U R P R O G R A M --- M A R C H 1 9 7 3

ACT STUDY - GP 6 NO. 102 - C.HICKS 11/19/74

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.000600
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.000600
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	100.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0001
2	0.120	0.0001
3	0.600	0.0001
4	1.200	0.0003

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0001
2	0.120	0.0001
3	0.600	0.0001
4	1.200	0.0003

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

SENSOR ERRORS
MEAN MEASURENT ERRORS XM(I)

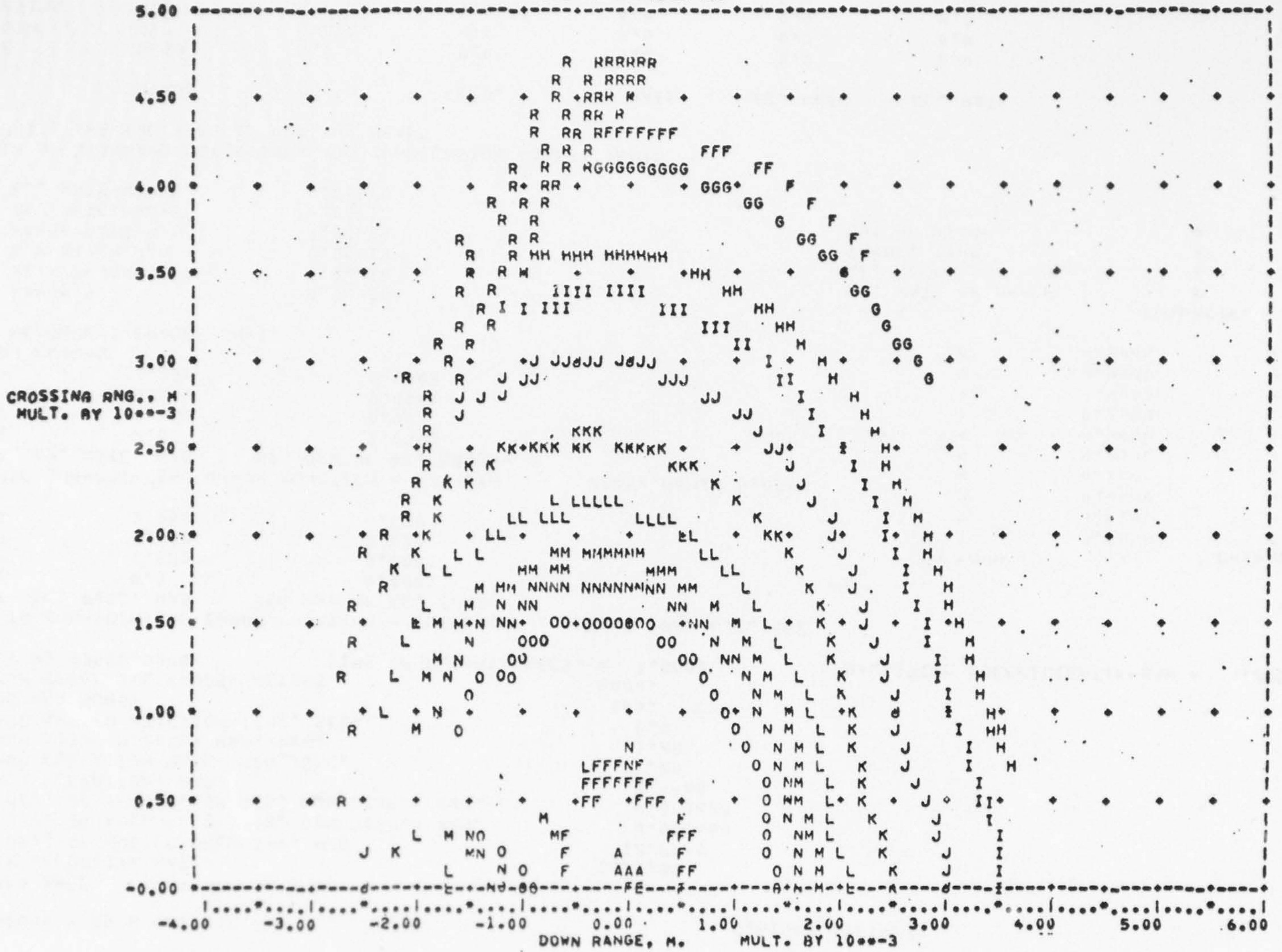
RANGE,M	0.50000
AZIMUTH,RAD	0.00010
ELEVATION,RAD	0.00010
RANGE RATE,M/S	0.20000
AZ. RATE,RAD/S	0.00010
EL. RATE,RAD/S	0.00010

MASK	CHARACTER
EL. RATE OR MAX EL	E
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.50	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.200	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001

ISO-PK CONTOUR MAP



ACT STUDY - GP 6 NO. 102 -
TARGET VELOCITY=-310.000M/S TARGET ALTITUDE= 60.000M

C.HICKS 11/19/74

G A D E S I S O - P K C O N T O U R P R O G R A M --- M A R C H 1 9 7 3

ACT STUDY - GROUP 9C NO. 220 C.HICKS 01/29/75

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.003900
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.003900
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	4.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

SENSOR ERRORS
MEAN MEASURENT ERRORS XM(I)

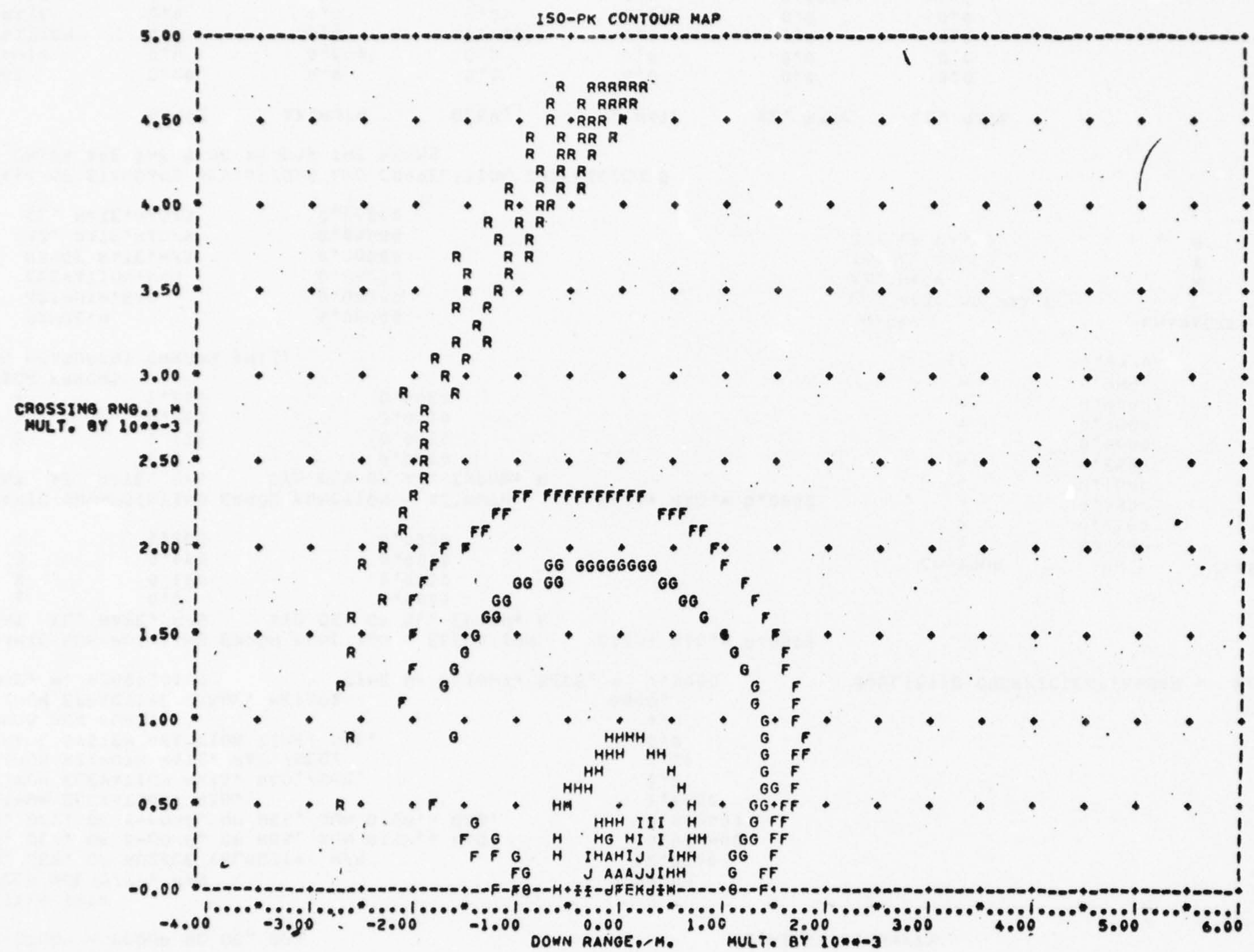
RANGE,M	4.00000
AZIMUTH,RAD	0.00200
ELEVATION,RAD	0.00200
RANGE RATE,M/S	0.80000
AZ. RATE,RAD/S	0.00080
EL. RATE,RAD/S	0.00080

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

MASK	CHARACTER
EL. RATE OR MAX EL	E
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.00	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001



ACT STUDY - GROUP 9C NO. 220
TARGET VELOCITY=-310.000M/S TARGET ALTITUDE= 60.000M
C.HICKS 01/29/75

GADES ISO-PK CONTOUR PROGRAM --- MARCH 1973

ACT STUDY - GROUP 9D NO. 206 C.HICKS 01/15/75

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.000800
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.000800
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	4.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

SENSOR ERRORS
MEAN MEASURENT ERRORS XM(I)

RANGE,M	1.00000
AZIMUTH,RAD	0.00050
ELEVATION,RAD	0.00050
RANGE RATE,M/S	0.20000
AZ. RATE,RAD/S	0.00020
EL. RATE,RAD/S	0.00020

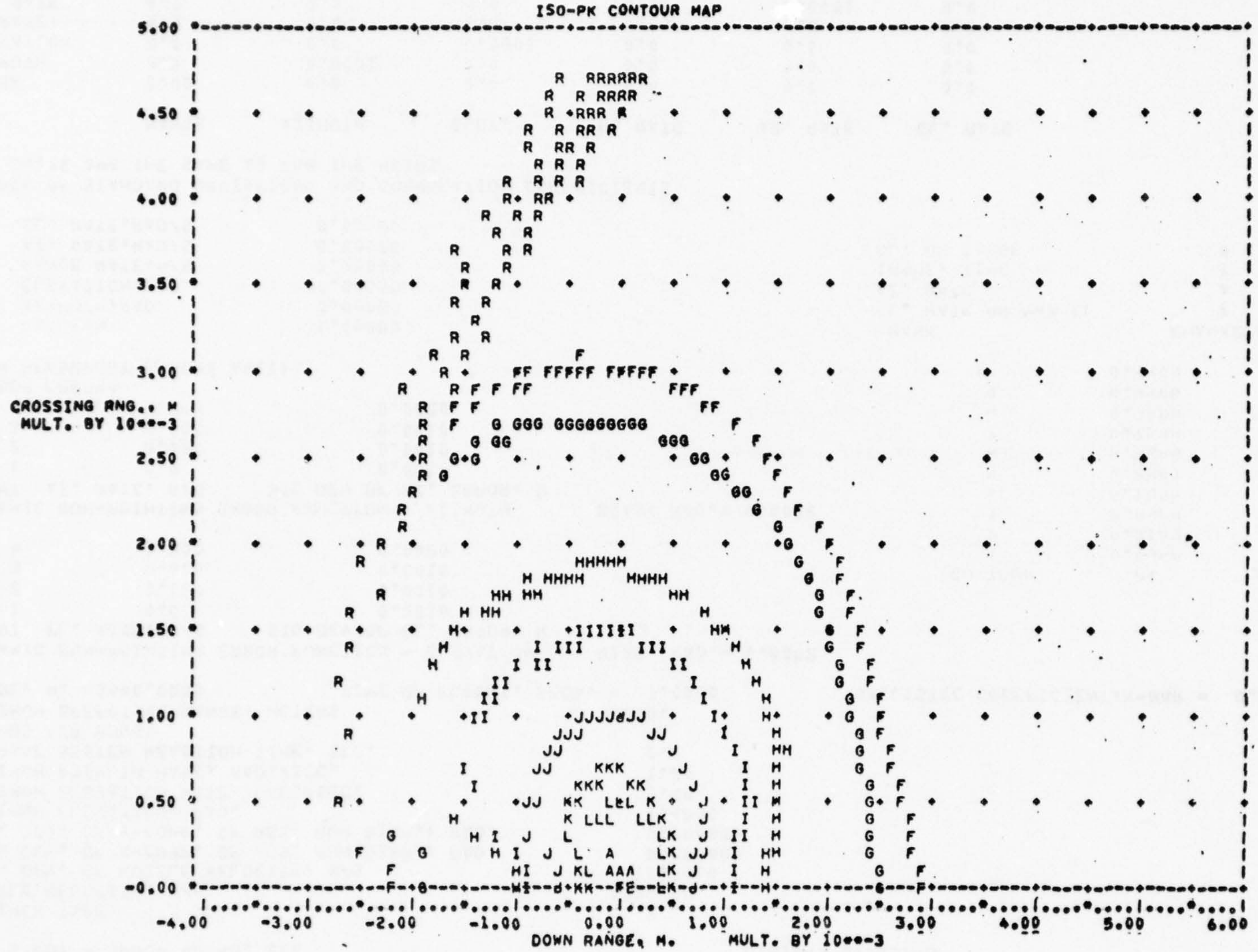
CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

MASK	CHARACTER
EL. RATE OR MAX EL	E
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.00	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001

ISO-PK CONTOUR MAP



ACT STUDY - GROUP 9D NO. 206
TARGET VELOCITY=-310.000M/S TARGET ALTITUDE= 60.000M

C.HICKS 01/15/75

G A D E S I S O - P K C O N T O U R P R O G R A M --- M A R C H 1 9 7 3

ACT STUDY - GP 8 NO. 2?9 C.HICKS 04/ U 75

CALIPER TYPE	2		
MUZZLE VELOCITY, M/S	1220.00		
STD. DEV. OF MUZZLE VELOCITY, M/S	8.0000		
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.000400		
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.000400		
MAXIMUM ELEVATION, RAD.	1.4800		
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20		
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20		
AVERAGE SYSTEM REACTION TIME, SEC.	0.0		
ROUNDS PER BURST	4.		
MAXIMUM EFFECTIVE RANGE, METERS	6000.		
RANGE, 4. =3500.0000	TIME OF FLIGHT, SECS. = 7.0000		BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0001
2	0.120	0.0001
3	0.600	0.0001
4	1.200	0.0003

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0001
2	0.120	0.0001
3	0.600	0.0001
4	1.200	0.0003

[illegible]	[illegible]	CHARACTER
1	[illegible]	[illegible]
[illegible]	[illegible]	G
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	I
[illegible]	[illegible]	J
[illegible]	[illegible]	K
7	[illegible]	L
[illegible]	[illegible]	M
[illegible]	[illegible]	N
10	[illegible]	O

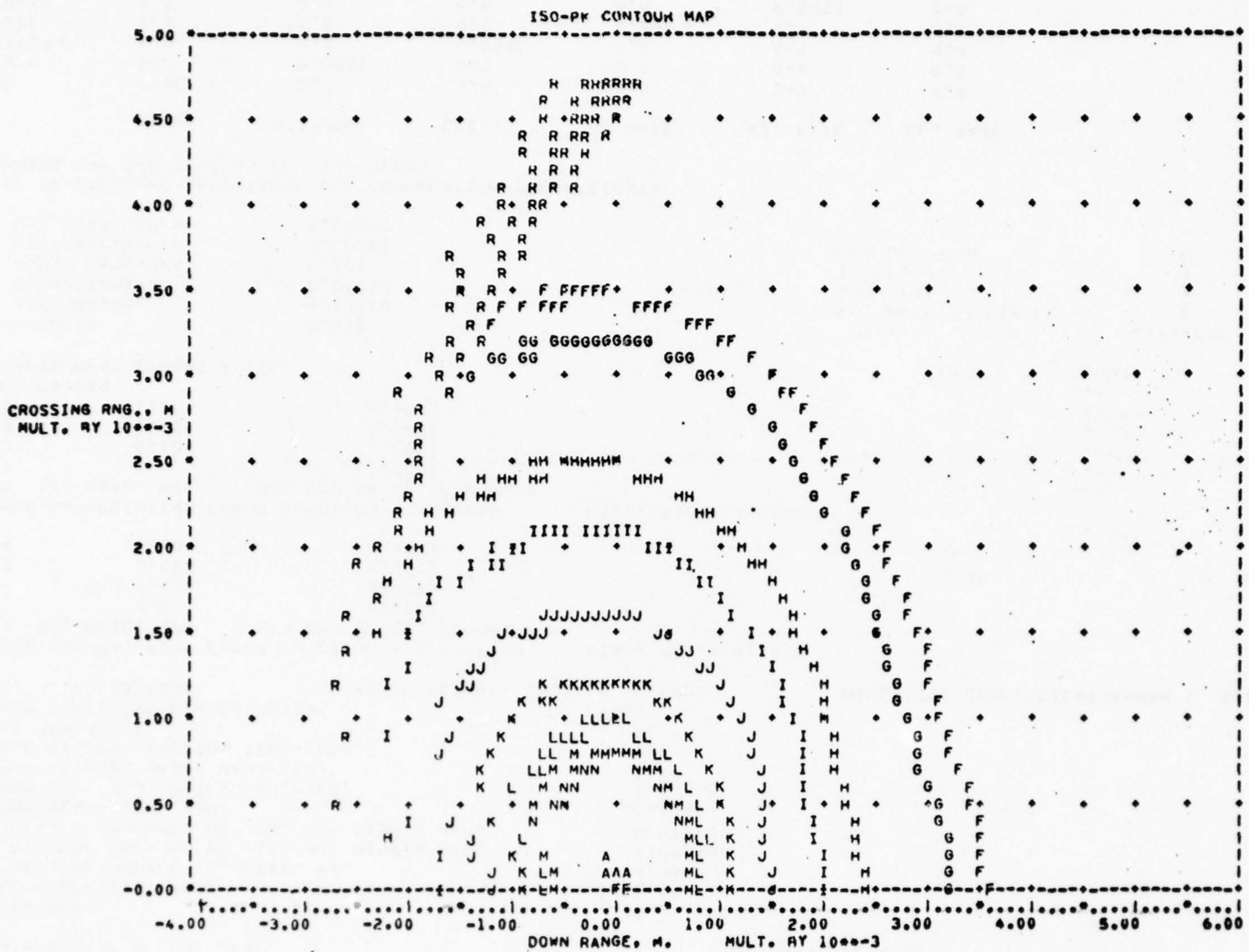
SENSOR ERRORS
MEAN MEASUREMENT ERRORS XM(I)

RANGE,M	0.500
AZIMUTH,RAD	0.00010
ELEVATION,RAD	0.00010
RANGE RATE,M/S	0.200
AZ. RATE,RAD/S	0.00010
EL. RATE,RAD/S	0.00010

[illegible]	CHARACTER
EL. RATE [illegible]	E
AZ. RATE	A
I[illegible]E. TIME	T
OUT OF RANGE	D

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	0.50	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0001	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0001	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.200	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001



ACT STUDY - GP B NO. 289
TARGET VELOCITY=-310.000M/S TARGET ALTITUDE= 60.000M
C.HICKS 04/ U 75

GADES ISO-PK CONTOUR PROGRAM --- MARCH 1973

ACT STUDY - GROUP 9E NO. 243 C.HICKS 02/07/75

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.003400
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.003400
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	4.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

SENSOR ERRORS
MEAN MEASUREMENT ERRORS XM(I)

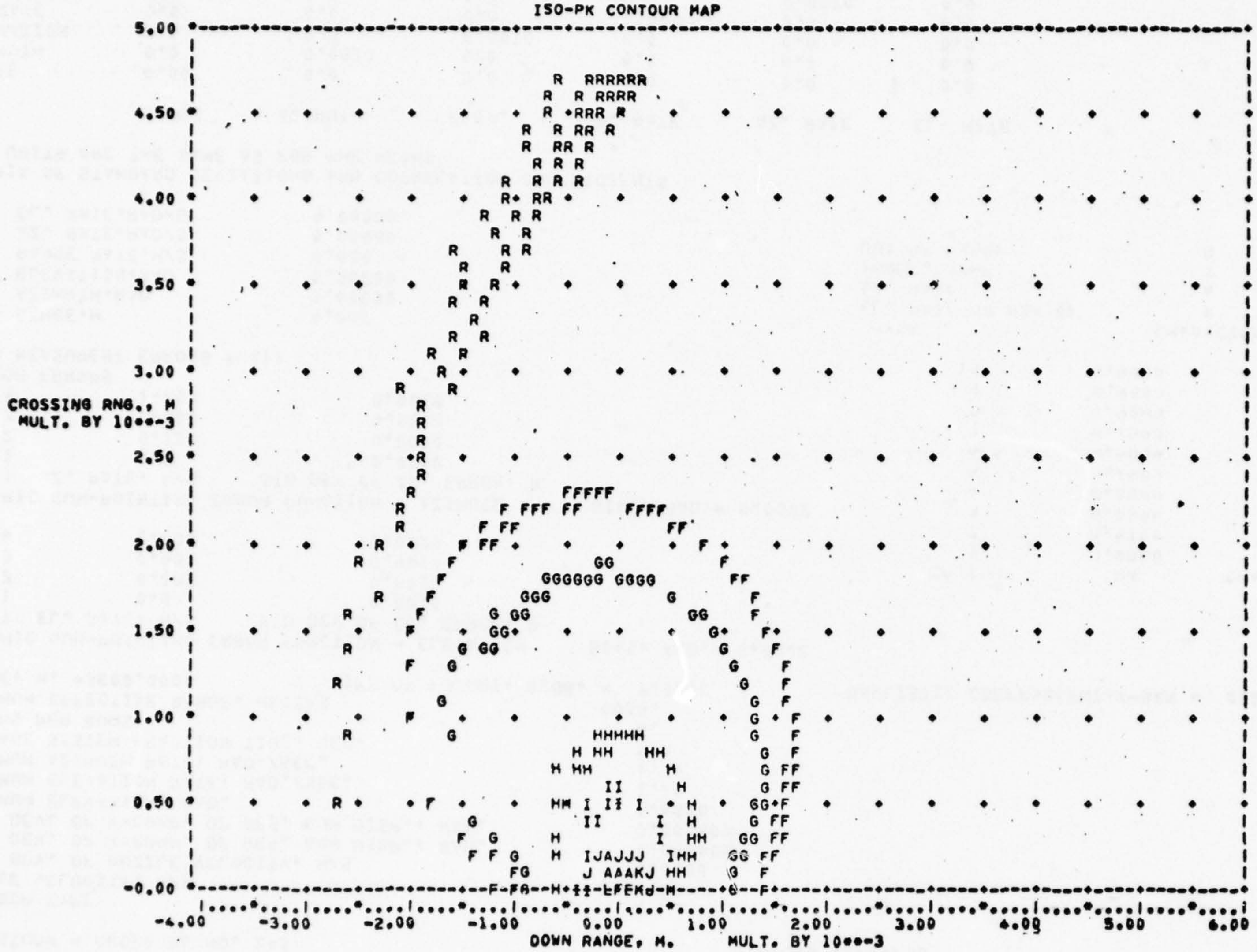
RANGE,M	4.000
AZIMUTH,RAD	0.00200
ELEVATION,RAD	0.00200
RANGE RATE,M/S	0.800
AZ. RATE,RAD/S	0.00080
EL. RATE,RAD/S	0.00080

MASK	CHARACTER
EL. RATE OR MAX EL	F
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	4.00	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0010	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0010	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	1.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0010	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0010

ISO-PK CONTOUR MAP



ACT STUDY - GROUP 9E NO. 243

C.HICKS 02/07/75

GADES ISO-PK CONTOUR PROGRAM --- MARCH 1973

ACT STUDY - GROUP 96 NO. 250 C.HICKS 02/19/75

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.003400
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.003400
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	4.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M, =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

SENSOR ERRORS

MEAN MEASURENT ERRORS XM(I)

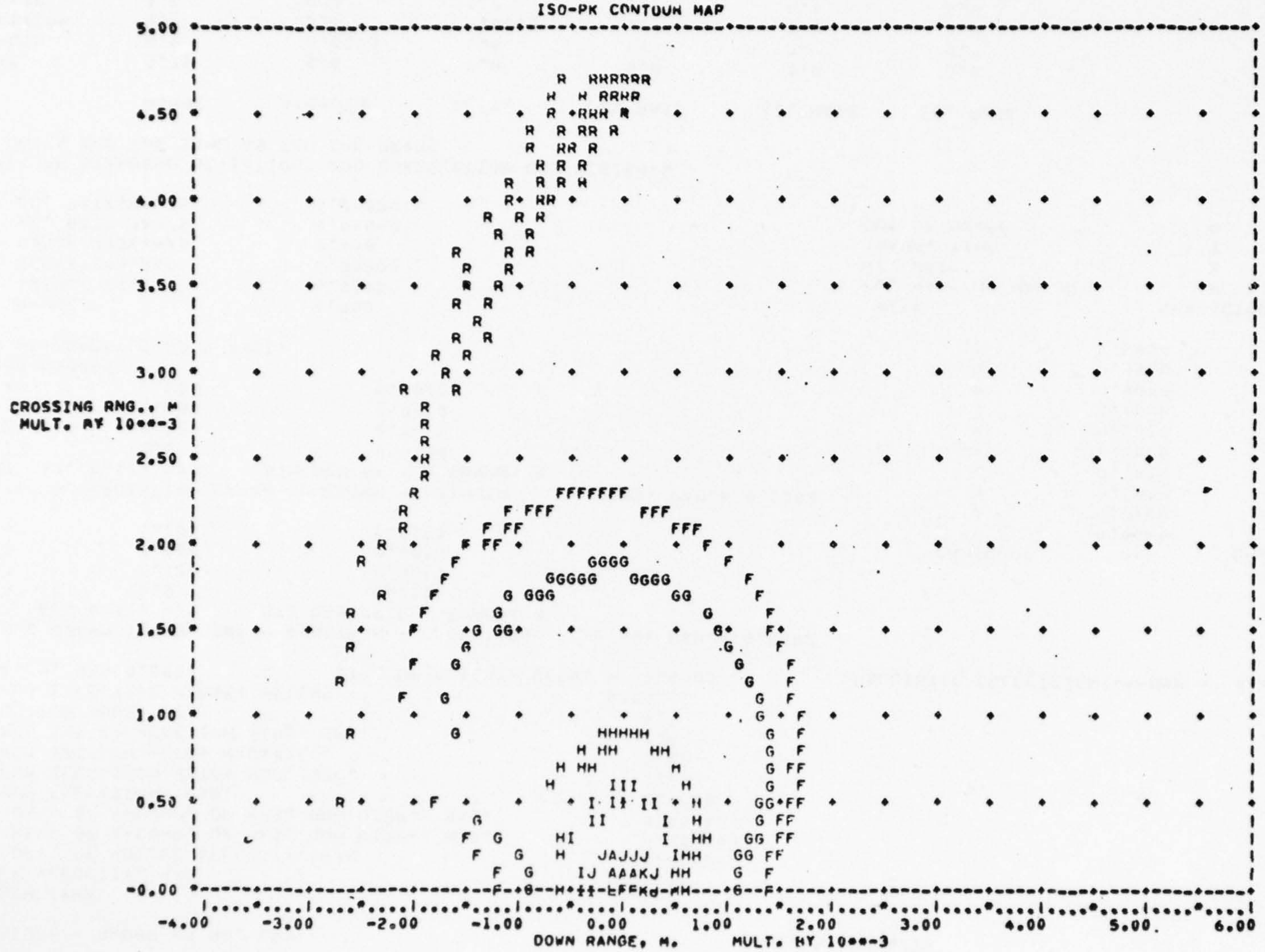
RANGE,M	4.000
AZIMUTH,RAD	0.00200
ELEVATION,RAD	0.00200
RANGE RATE,M/S	0.800
AZ. RATE,RAD/S	0.00080
EL. RATE,RAD/S	0.00080

MASK	CHARACTER
EL. RATE OR MAX EL	E
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	3.75	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0003	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0003	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	1.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0010	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0010

ISO-PK CONTOUR MAP



ACT STUDY - GROUP 9G NO. 250 C.HICKS 02/19/7

GADES ISO-PK CONTOUR PROGRAM --- MARCH 1973

ACT STUDY - GROUP 96 NO. 252 C.HICKS 02/19/75

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.003400
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.003400
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	4.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

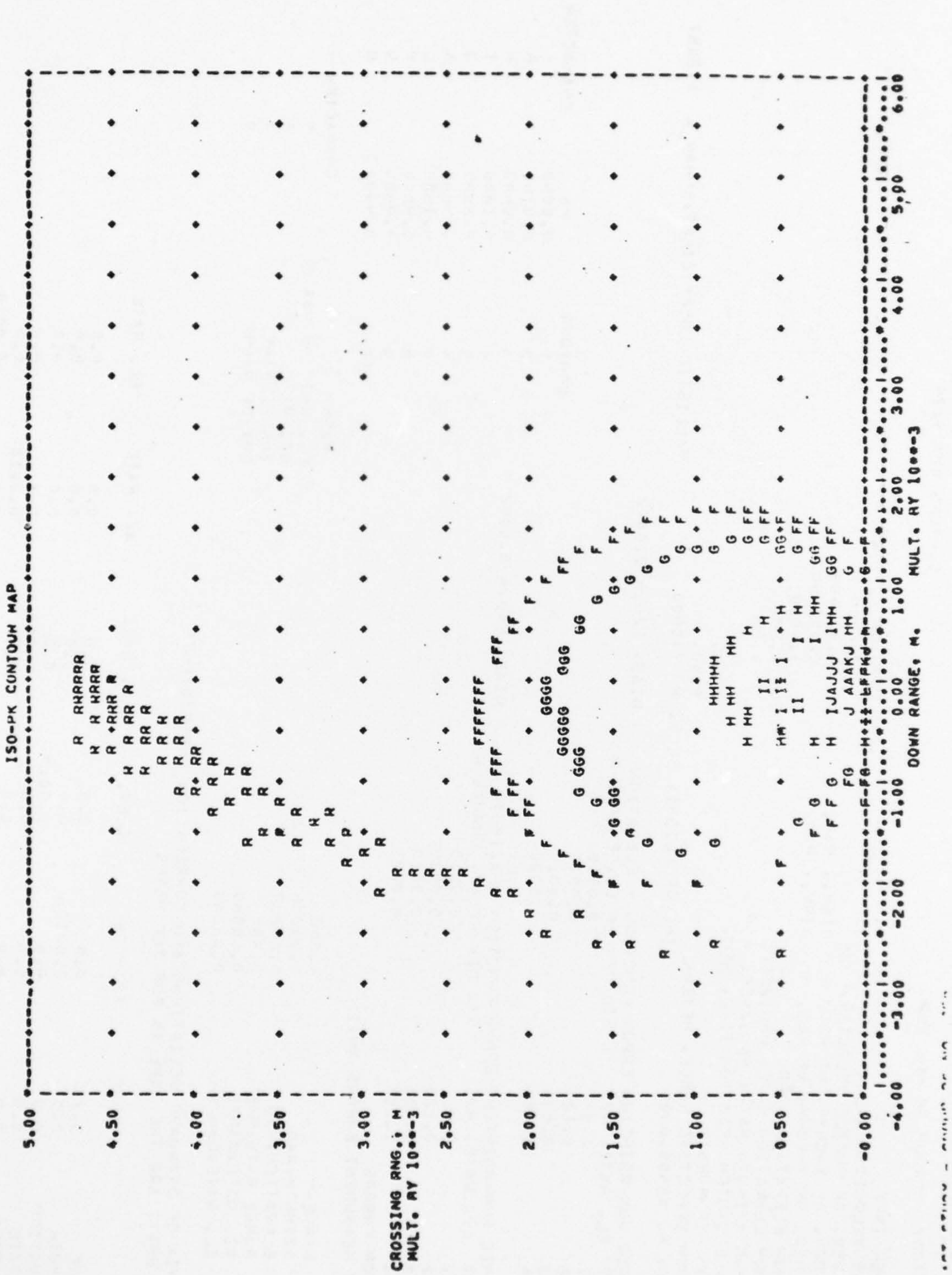
SENSOR ERRORS
MEAN MEASURENT ERRORS XM(I)

RANGE,M	4.000
AZIMUTH,RAD	0.00200
ELEVATION,RAD	0.00200
RANGE RATE,M/S	0.800
AZ. RATE,RAD/S	0.00080
EL. RATE,RAD/S	0.00080

MASK	CHARACTER
EL. RATE OR MAX EL	E
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	3.75	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0010	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0010	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	1.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0010	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0010


ISO-PK CONTOUR MAP
CROSSING RNG., M
MULT. BY 10**-3
DOWN RANGE, M.
MULT. BY 10**-3
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
-0.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00

GADES ISO-PK CONTOUR PROGRAM --- MARCH 1973

ACT STUDY - GROUP 91 NO. 263 C.HICKS 02/24/75

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.003400
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.003400
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	4.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

SENSOR ERRORS
MEAN MEASURENT ERRORS XM(I)

RANGE,M	4.00000
AZIMUTH,RAD	0.00200
ELEVATION,RAD	0.00200
RANGE RATE,M/S	0.80000
AZ. RATE,RAD/S	0.00080
EL. RATE,RAD/S	0.00080

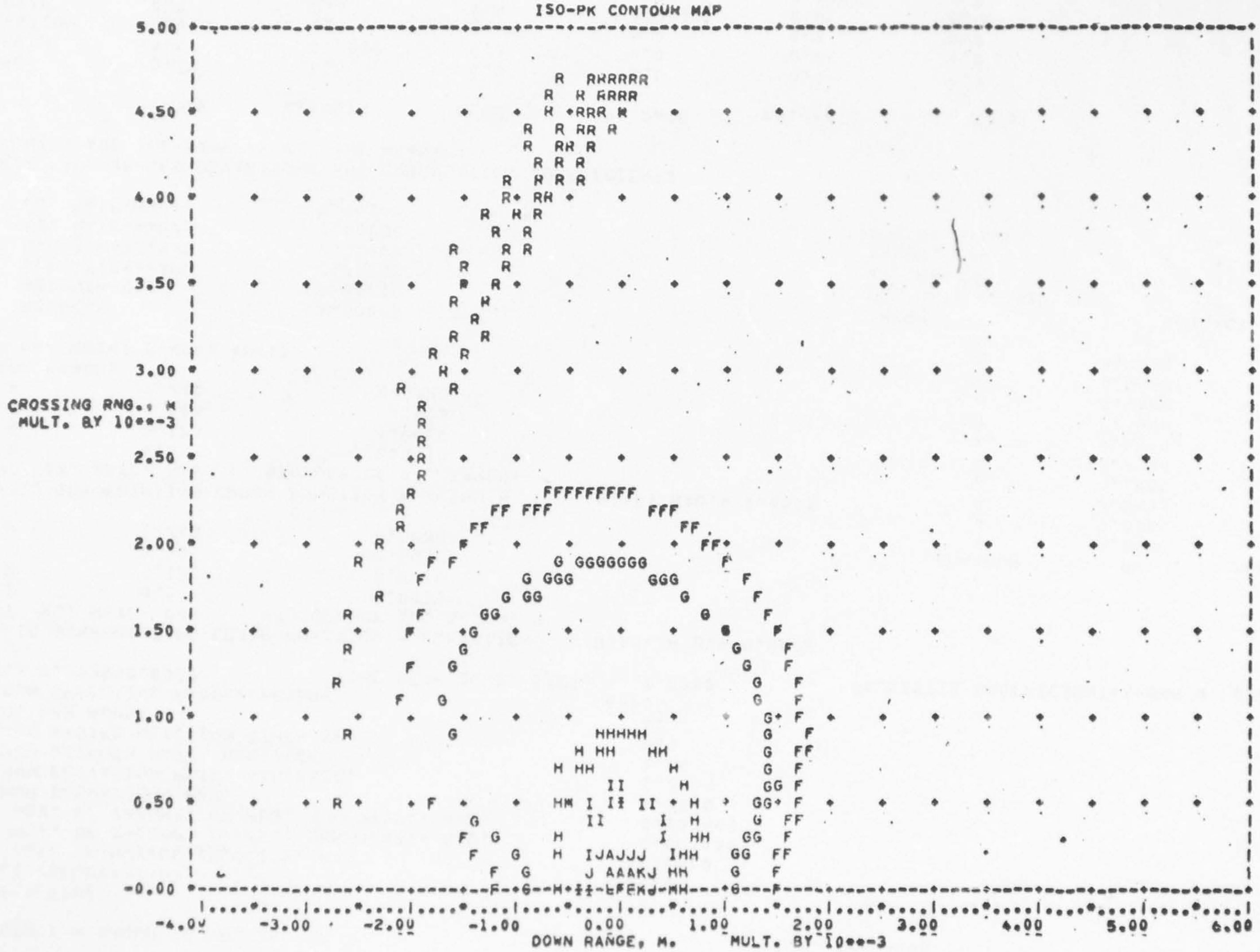
CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

MASK	CHARACTER
EL. RATE OR MAX EL	E
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	3.75	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0010	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0010	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	0.300	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0001	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0001

ISO-PK CONTOUR MAP



ACT STUDY - GROUP 9I NO. 263
TARGET VELOCITY=-310.000M/S TARGET ALTITUDE= 60.000M

C.HICKS 02/24/7[illegible]

G A D E S   I S U - P K   C O N T O U R   P R O G R A M   ---   M A R C H   1 9 7 3

ACT STUDY - GROUP 9.1 NO. 272   C.HICKS 02/21/75

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.003400
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.003400
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	4.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M. =3500.0000   TIME OF FLIGHT, SECS. = 7.0000   BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION   BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH   BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

SENSOR ERRORS
MEAN MEASUREMENT ERRORS XM(I)

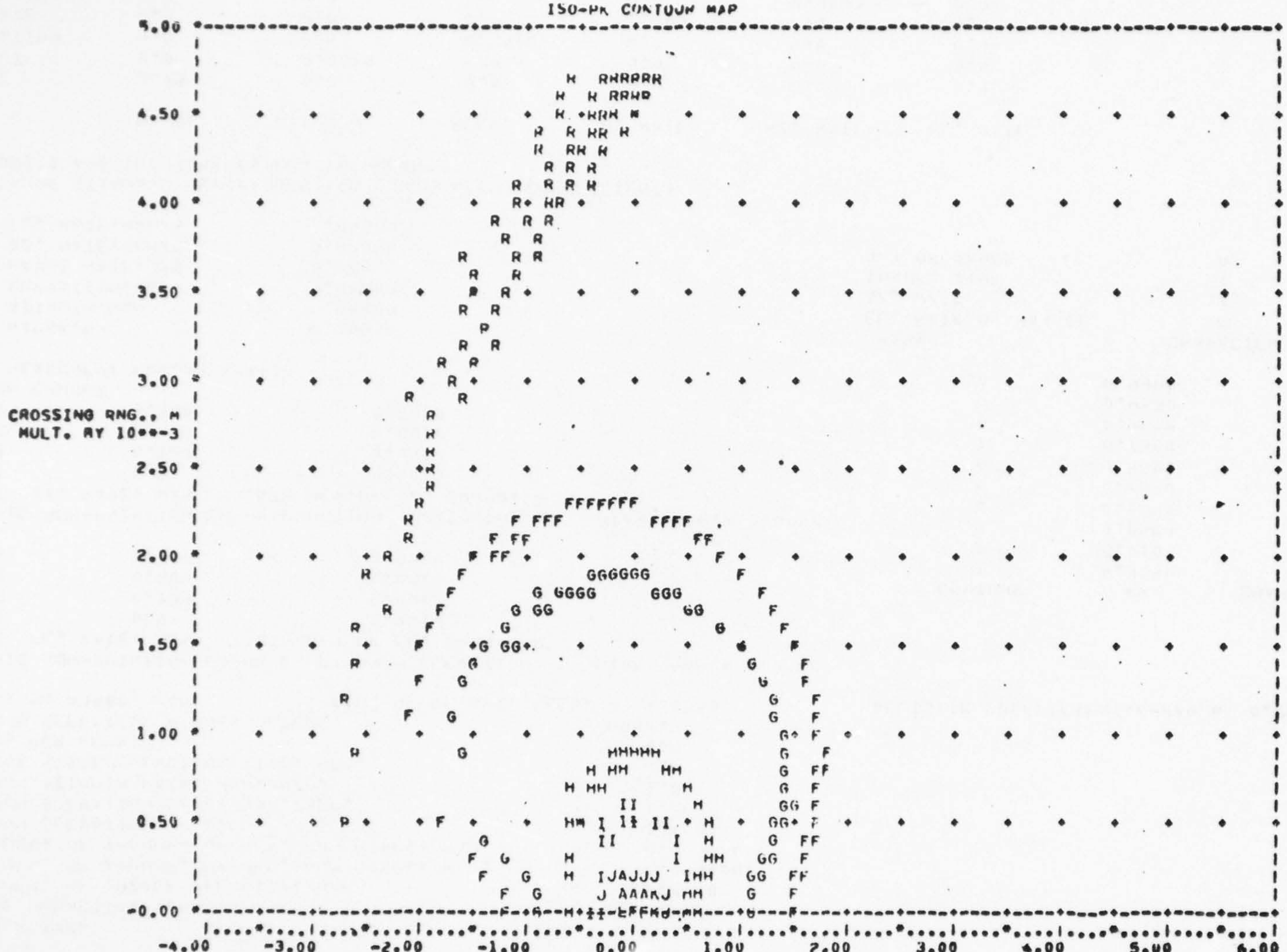
RANGE,M	4.000
AZIMUTH,RAD	0.00200
ELEVATION,RAD	0.00200
RANGE RATE,M/S	0.800
AZ. RATE,RAD/S	0.00080
EL. RATE,RAD/S	0.00080

MASK	CHARACTER
EL. RATE OR MAX EL	F
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	3.75	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0010	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0010	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	1.700	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0003	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0003

ISO-PK CONTOUR MAP



ACT STUDY - GROUP 9J NO. 272

C.HICKS 02/27/75

GADES ISO-PK CONTOUR PROGRAM --- MARCH 1973

ACT STUDY - GROUP 9E NO. 233 C.HICKS 01/31/75

CALIBER TYPE	2
MUZZLE VELOCITY, M/S	1220.00
STD. DEV. OF MUZZLE VELOCITY, M/S	12.2000
STD. DEV. OF X-COMP. OF RES. GUN DISP., RAD.	0.003400
STD. DEV. OF Y-COMP. OF RES. GUN DISP., RAD.	0.003400
MAXIMUM ELEVATION, RAD.	1.4800
MAXIMUM ELEVATION RATE, RAD./SEC.	1.20
MAXIMUM AZIMUTH RATE, RAD./SEC.	1.20
AVERAGE SYSTEM REACTION TIME, SEC.	0.0
ROUNDS PER BURST	4.
MAXIMUM EFFECTIVE RANGE, METERS	6000.

RANGE, M, =3500.0000 TIME OF FLIGHT, SECS. = 7.0000 BALLISTIC COEFFICIENT,K-BAR = 0.2057

DYNAMIC GUN-POINTING ERROR FUNCTION - ELEVATION BIAS, RAD.= 0.0002

POINT	EL. RATE, R/S	STD DEV OF EL. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

DYNAMIC GUN-POINTING ERROR FUNCTION - AZIMUTH BIAS, RAD.= 0.0002

POINT	AZ. RATE, R/S	STD DEV OF AZ. ERROR, R
1	0.0	0.0010
2	0.120	0.0010
3	0.600	0.0010
4	1.200	0.0020

SENSOR ERRORS
MEAN MEASUREMENT ERRORS XM(I)

RANGE,M	4.00000
AZIMUTH,RAD	0.00200
ELEVATION,RAD	0.00200
RANGE RATE,M/S	0.80000
AZ. RATE,RAD/S	0.00080
EL. RATE,RAD/S	0.00080

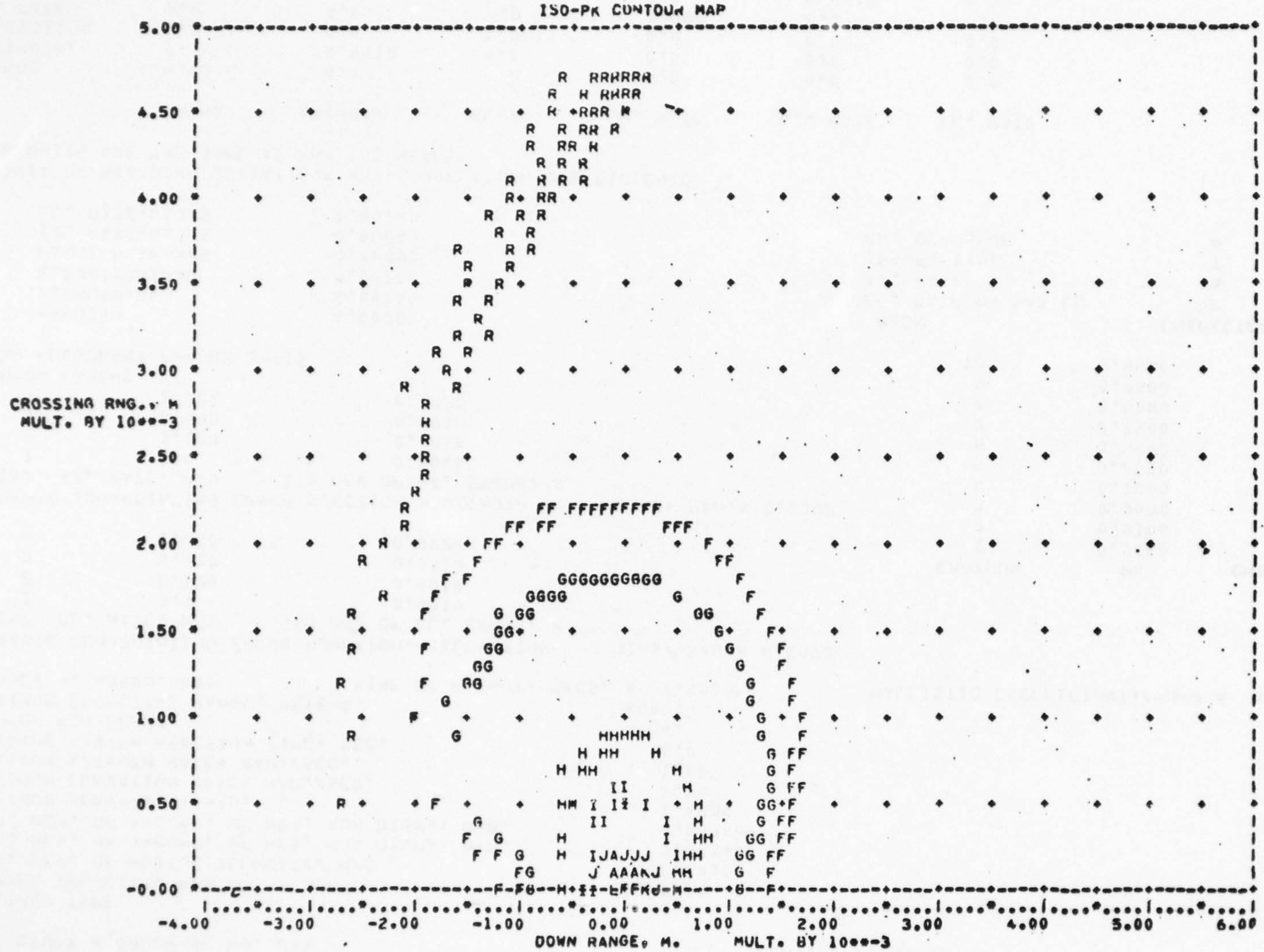
CONTOUR	PK	CHARACTER
1	0.0050	F
2	0.0100	G
3	0.0500	H
4	0.1000	I
5	0.2500	J
6	0.5000	K
7	0.7500	L
8	0.9000	M
9	0.9500	N
10	0.9900	O

MASK	CHARACTER
EL. RATE OR MAX EL	F
AZ. RATE	A
INSUF. TIME	T
OUT OF RANGE	R

MATRIX OF STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS
THE UNITS ARE THE SAME AS FOR THE MEANS

	RANGE	AZIMUTH	ELEV.	R. RATE	AZ. RATE	EL. RATE
RANGE	4.00	0.0	0.0	0.0	0.0	0.0
AZIMUTH	0.0	0.0010	0.0	0.0	0.0	0.0
ELEVATION	0.0	0.0	0.0010	0.0	0.0	0.0
R. RATE	0.0	0.0	0.0	3.000	0.0	0.0
AZ. RATE	0.0	0.0	0.0	0.0	0.0010	0.0
EL. RATE	0.0	0.0	0.0	0.0	0.0	0.0010

ISO-PK CONTOUR MAP



ACT STUDY - GROUP 9E NO. 233 C.HICKS 01/31/75
TARGET VELOCITY=-310.000M/S TARGET ALTITUDE= 60.000M

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General Thomas J. Rodman Laboratory
Rock Island Arsenal, Rock Island, Illinois 61201

Air Defense Analysis
The Influence of Parametric Variation on
Effectiveness of a Short Range Air Defense System

Prepared by: Charles S. Hicks, P.E.

Technical Report

93 Pages, Incl Figures

A performance analysis of a genertic 30mm air defense gun system was undertaken to determine what factors influence effectiveness of such a system. A computer model that produces contours of constant kill probability vs range was employed.

The significant results and conclusions are as follows:

(1) A new effectiveness measure call Weighted Kill Area (WKA) was developed.

(2) Curves were produced showing the influence of parameter changes on effectiveness.

(3) High effectiveness can be achieved in two basically different ways.

(4) A trade-off study is needed to determine which is the most cost effective way to get high effectiveness.

1. SHORAD System
2. Air Defense Analysis
3. Definition of Effectiveness
4. Kill Probability Calculation
5. Burst Kill Algorithm
6. Gun System Modeling
7. Target Vulnerability Modeling
8. Parameter Variation
9. Effectiveness Calculation

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General Thomas J. Rodman Laboratory
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Rock Island Arsenal, Rock Island, Illinois 61201

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(2) Curves were produced showing the influence of parameter changes on effectiveness.

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1. SHORAD System
2. Air Defense Analysis
3. Definition of Effectiveness
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5. Burst Kill Algorithm
6. Gun System Modeling
7. Target Vulnerability Modeling
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A performance analysis of a genertic 30mm air defense gun system was undertaken to determine what factors influence effectiveness of such a system. A computer model that produces contours of constant kill probability vs range was employed.

The significant results and conclusions are as follows:

(1) A new effectiveness measure call Weighted Kill Area (WKA) was developed.

(2) Curves were produced showing the influence of parameter changes on effectiveness.

(3) High effectiveness can be achieved in two basically different ways.

(4) A trade-off study is needed to determine which is the most cost effective way to get high effectiveness.

1. SHORAD System
2. Air Defense Analysis
3. Definition of Effectiveness
4. Kill Probability Calculation
5. Burst Kill Algorithm
6. Gun System Modeling
7. Target Vulnerability Modeling
8. Parameter Variation
9. Effectiveness Calculation

I. Charles S. Hicks, P.E.
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Rock Island Arsenal

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Air Defense Analysis
The Influence of Parametric Variation on
Effectiveness of a Short Range Air Defense System

Prepared by: Charles S. Hicks, P.E.

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