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SOME HAND-DONE CALCULATIONS ON ATTACKS AGAINST RUNWAYS

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One of the jobs to be done in the recently activated Air Superiority/ Airfield Attack study is that of predicting how successful low-level attacks against enemy runways will or can be. This paper describes some very preliminary work on the subject.

In RM-5054-PR, Jaeger and Green present the results of some machine-runs of attacks on airfields. This study covers several types of attack weapons, various axes of attack, and Monte Carlo's the quite-difficult-to-handle individual bomb or bomblet ballistic dispersion. The current problem being studied involves delivery of retarded weapons on high-speed low-altitude runs. A real difficulty that evolves from these conditions of delivery is the difficulty or impossibility of using the very-short intervalometer settings that are needed. Experience in SEA with the F-111A aircraft indicated that 125 milliseconds (i.e., 8 weapons released per second) was the fastest interval that could be used safely. At the F-111A release speed, this produced an average bomb spacing in a stick of about 100 feet. (For the 12 bombs in the stick, the stick length was 1100 feet.)

The effectiveness criterion in RM-5054 was that no 50-foot width of runway long enough for emergency takeoffs could be left for the enemy's use. The probability of achieving this on a single pass was calculated for 30 feet, 40 feet, and 50 feet bomb spacing. For a cross runway attack, the 50 foot spacing is ideal, since getting the bomb stick across the runway automatically cut all 50-foot slices of the runway. For 40 and 30 feet bomb spacing, the success probabilities drop dramatically, as would be expected.

While no bomb spacings larger than 50 feet were used in RM-5054, it is obvious that, based on the above criterion, the success probability drops off quickly as the interval goes higher above 50 feet. In fact, for the cross attack case with zero ballistic dispersion the single-pass probability of an effective cut is zero for any interval larger than about 60 feet.

We seem to be stuck with the practical 100 foot spacing of retarded weapons; one ploy to regain the optimum spacing would be to attack on an axis 30° from the runway axis. This would put one bomb in each of the 50-foot strips whenever the bomb stick ran completely over the runway.

Both to take a look at this possibility, and to become more familiar with the parameters involved, some hand calculations were done. The principal tools were sheets from Area-Hit-Probability Charts, an unpublished set of charts made up by the author several years ago. Figure 1 shows such a chart, for an elliptical delivery pattern.

In this chart, the area around the target is broken into 100 x 100 foot squares. In each of these squares is shown the percent probability that a single bomb aimed at the center of the chart (the target) will hit in this square.* Figure 1 covers the case for REP = 116', DEP = 58', and CEP = 150'. It should be noted that the numbers given are in percent, the sum of all the numbers in all the squares adding up to 100%.

I will not go into the details here, but the charts can accommodate for the effects of weapon radius, and the effects of using a stick of bombs, rather than just one.

The calculations that were performed involved making an overlay on Figure 1 on which a runway was sketched. Four runway orientations were used: 0^{o}, 30^{o}, 45^{o}, and 90^{o} from the attack axis. A 12-bomb stick of bombs with 100' spacing was used in all calculations. The REP/DEP of 116'/58' in Figure 1 closely enough approximates the 120'/60' values used in RM-5054.

Figure 2 covers the case for an attack perpendicular to the runway. The runway is assumed long enough so that DEP is not pertinent for this particular case. The 116' REP value used is small enough to give 100% probability that the stick always straddles the runway and two hits on the runway will be obtained on every pass made.

Figures 3, 4, and 5 show the results, with the 150' CEP, for attacks 45^{o} off the runway axis, 30^{o} off the axis, and down the runway. Figure 6 is a plot of $P_{ss}(1+)$ and expected fraction of bombs hitting, for the 150' CEP case, versus the attack angle. It will be noted that the attack down the runway is the "gambler's approach" or "go-for-broke approach"; only three quarters of the time will the runway be hit, but it will be hit by all 12 bombs when it is hit. To say it another way,

*The percent value in each circle is the sum of the values in the surrounding four 100 x 100 foot squares.

the single-shot probability of hitting is not as high as desired, but the number of bombs hitting on the average run has the very high value of 9+.

The cross-runway attack is the most conservative approach. The probability of hitting the runway is 100%, but the runway can never be hit with more than two bombs. In-between attack directions are "mid-points" between these two extremes; it will be noted that the 30^{o} attack has an extremely high capability for putting 4 bombs on the runway (94.4%). This would cover very well the requirement in RM-5054 for hitting each 50-foot strip on a single pass.

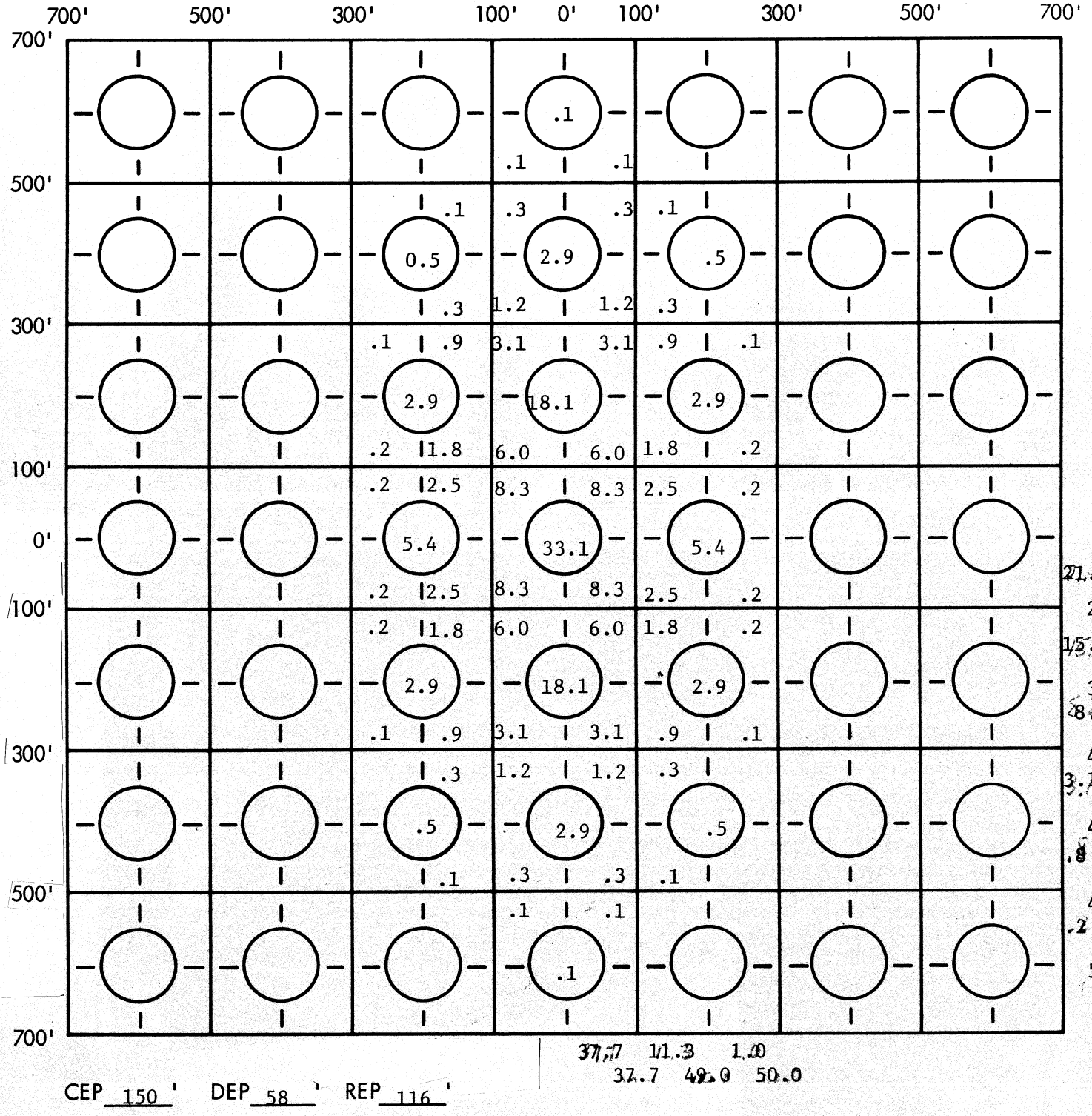
Figure 7 is the Area-Hit-Probability Chart for 300' CEP. Figures 8, 9, 10, and 11 show the results obtained with this 300 foot CEP (REP and DEP values are also doubled). Figures 12 through 16 cover the 600' CEP case.

Figure 17 shows the single-pass probability of one or more bombs on the runway ($P_s 1+$), and the expected number of hits, for the four CEP values used plotted against the attack axis angle. Again it can be seen that in any such operation against runways, there is inescapably a tactical commander's option that must be decided, i.e., whether the commander wants the largest number of hits on the runway for every ten missions (say), or whether he would prefer to almost guarantee that the runway will be hit on every pass.

It is interesting that the variation with attack axis of the single-shot hit probability (1 or more) and expected number of bombs hitting on an average pass is quite similar to that situation where the attack axis is held constant and the bomb spacing is varied. Figure 18 shows this effect. In an attack directly across the runway, using the 150' CEP numbers used previously, the bomb spacing is here the variable. It can be seen that again that the relative worth or desirability of most bombs on target vs highest probability of some hits is a dominating factor, and this is an operational decision that cannot be decided by analyses such as this one.

CEP 150'
REP 116'
DEP 58'

Area hit probability chart



CEP 150 ' DEP 58 ' REP 116 '

FIGURE 1

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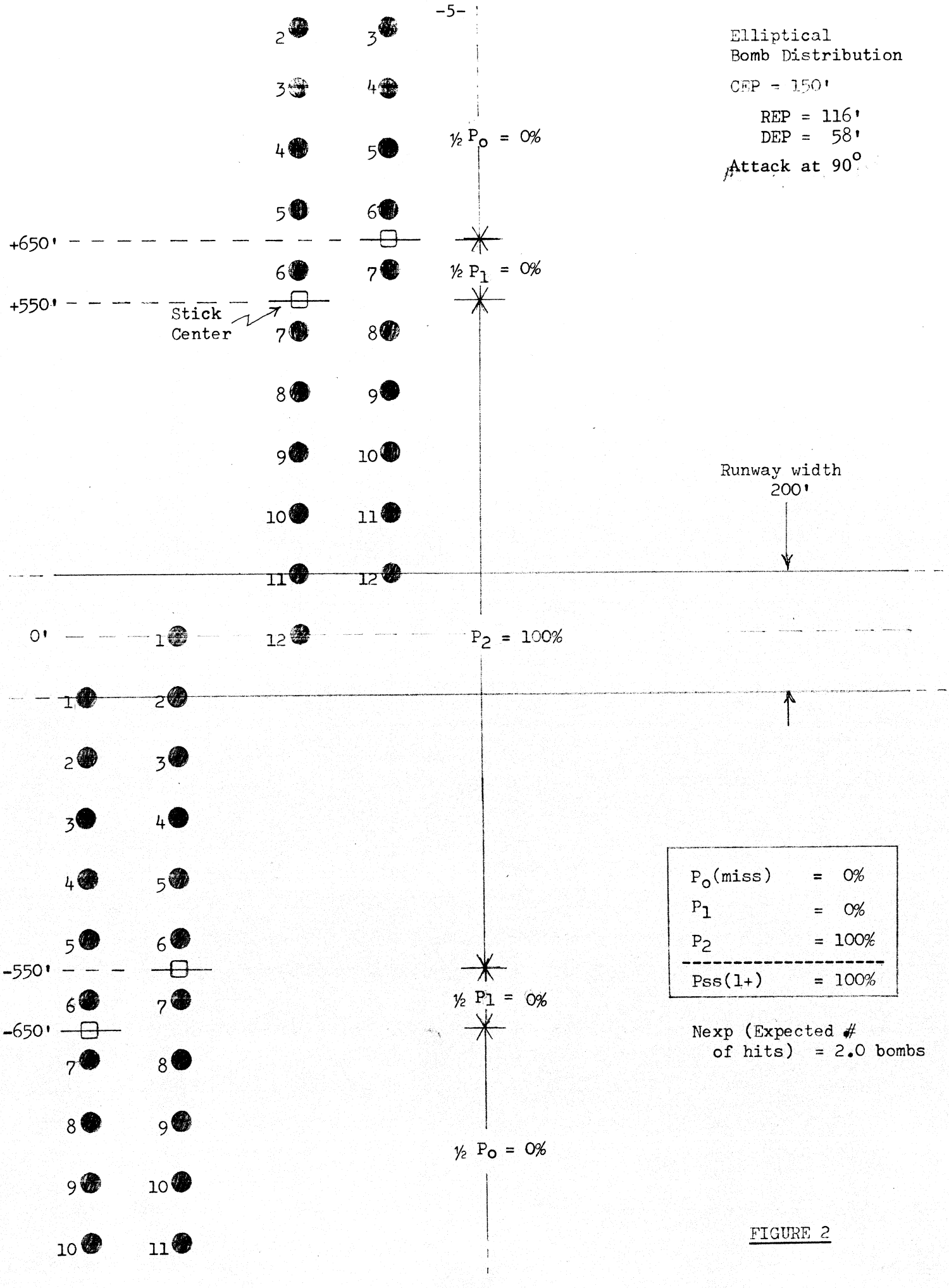
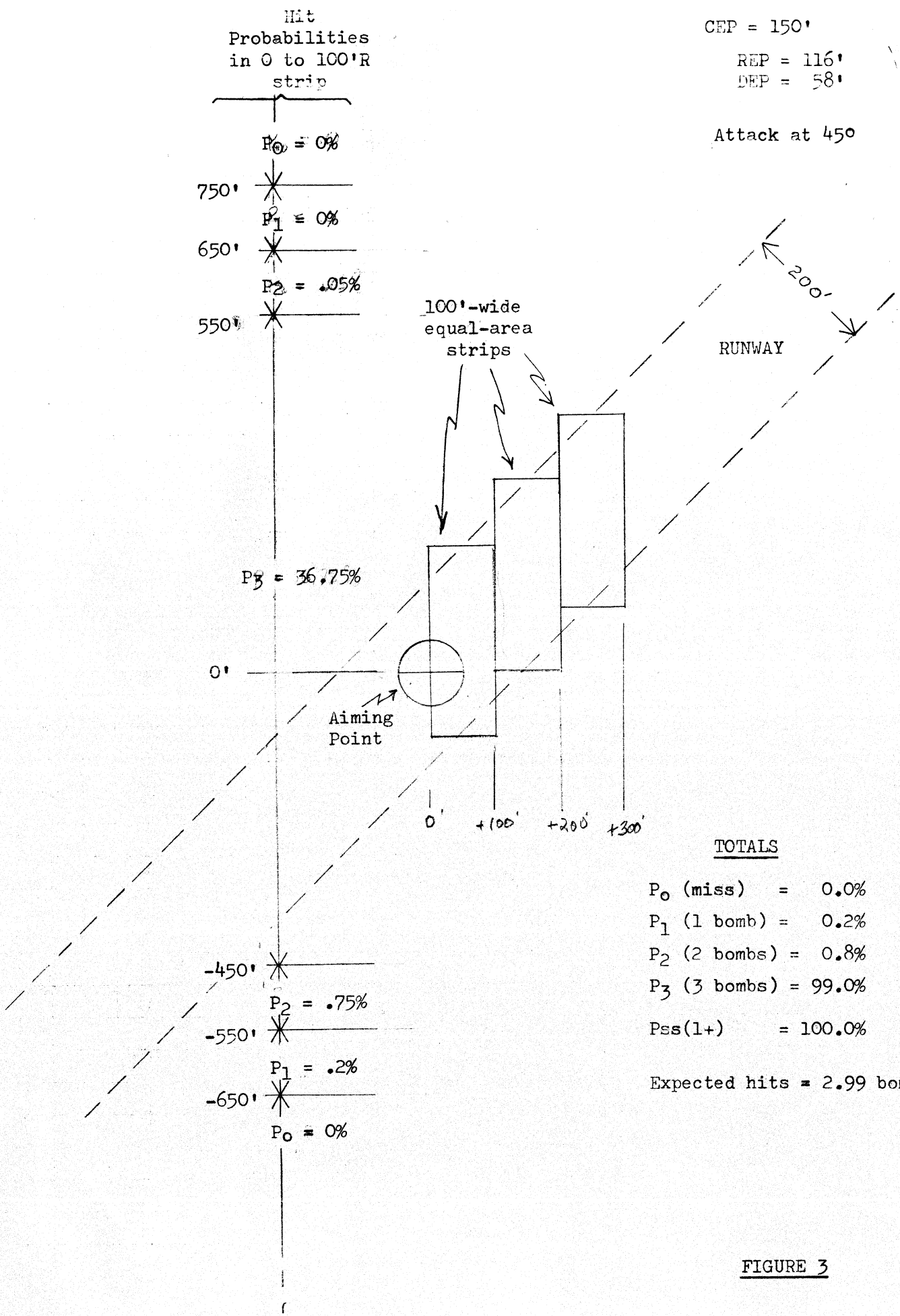

Elliptical
Bomb Distribution
CEP = 150'
REP = 116'
DEP = 58'
Attack at 90°
½ P_o = 0%
+650'
½ P_1 = 0%
+550'
Stick
Center
Runway width
200'
0'
P_2 = 100%
-550'
½ P_1 = 0%
-650'
½ P_o = 0%
P_o(miss) = 0%
P_1 = 0%
P_2 = 100%
Pss(1+) = 100%
Nexp (Expected # of hits) = 2.0 bombs

FIGURE 2

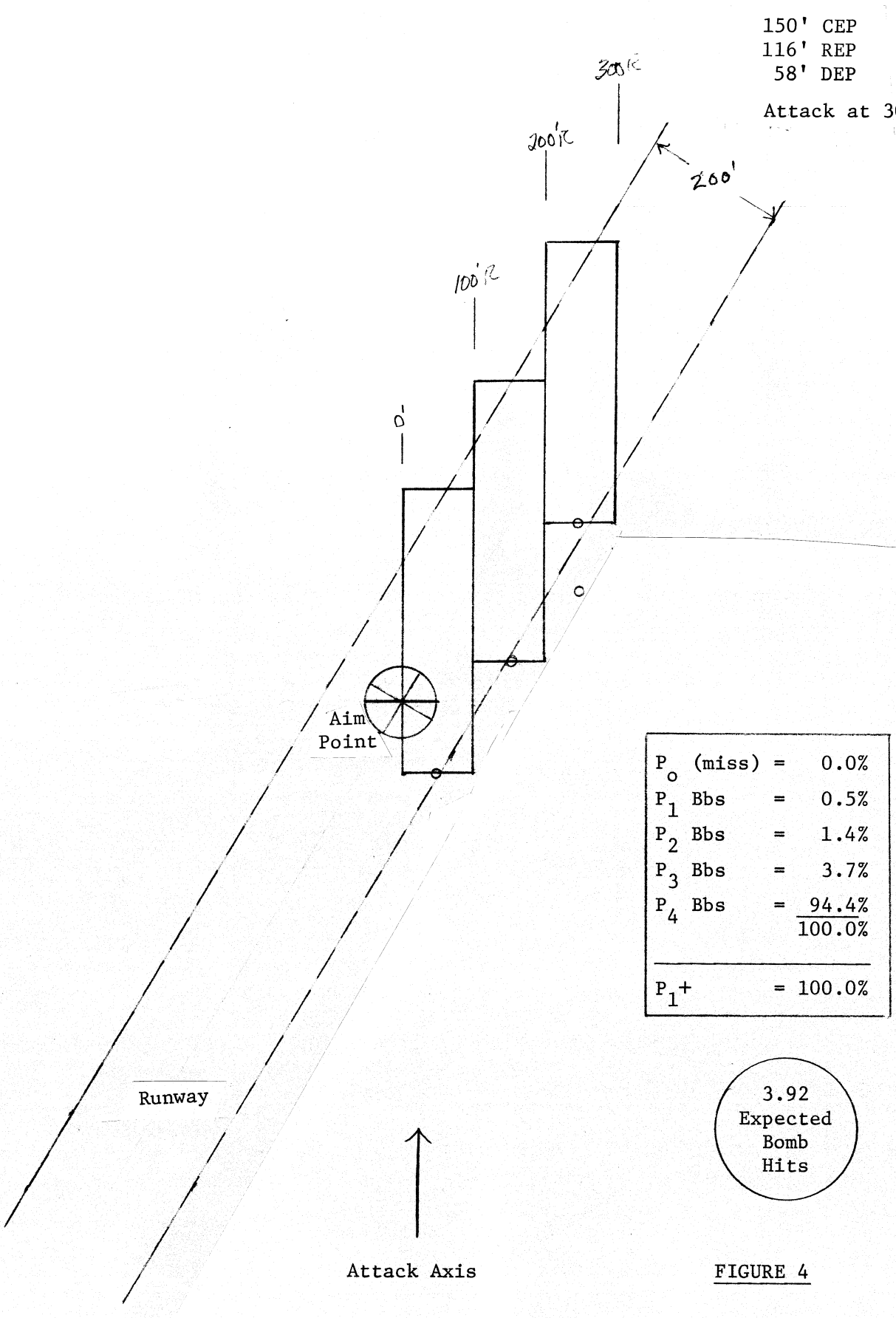


TOTALS

P_o (miss)	= 0.0%
P_1 (1 bomb)	= 0.2%
P_2 (2 bombs)	= 0.8%
P_3 (3 bombs)	= 99.0%
Pss(1+)	= 100.0%

Expected hits = 2.99 bombs

FIGURE 3

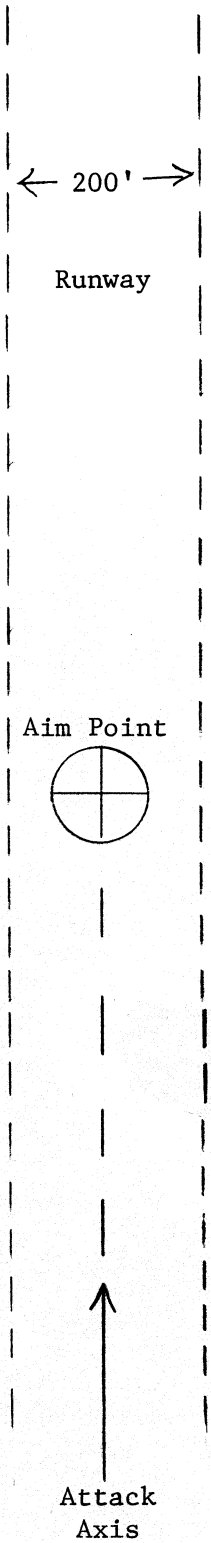


P_o (miss)	=	0.0%
P_1 Bbs	=	0.5%
P_2 Bbs	=	1.4%
P_3 Bbs	=	3.7%
P_4 Bbs	=	94.4%
		100.0%
P_1+	=	100.0%

3.92 Expected Bomb Hits

FIGURE 4

150' CEP
116' REP
58' DEP
Attack at 0°



P_o = 24.6%
P_{12} = 75.4%
P_1+ = 75.4%

9.05
Expected
Bomb
Hits

FIGURE 5

TRAIN-BOMBING AGAINST A 200-FOOT RUNWAY

12-bomb stick
100' spacing
1100' stick length

Accuracy values used

150' CEP; 116' REP; 58' DEP

Attack directions used

0° from runway axis
30° from runway axis
45° from runway axis
90° from runway axis

EXAMPLE

At an attack axis 10° from the runway axis, the probability of one or more hits on the runway is about 92%; 54% of the bombs dropped on the pass (or 6.5 bombs) will hit the runway on an average pass.

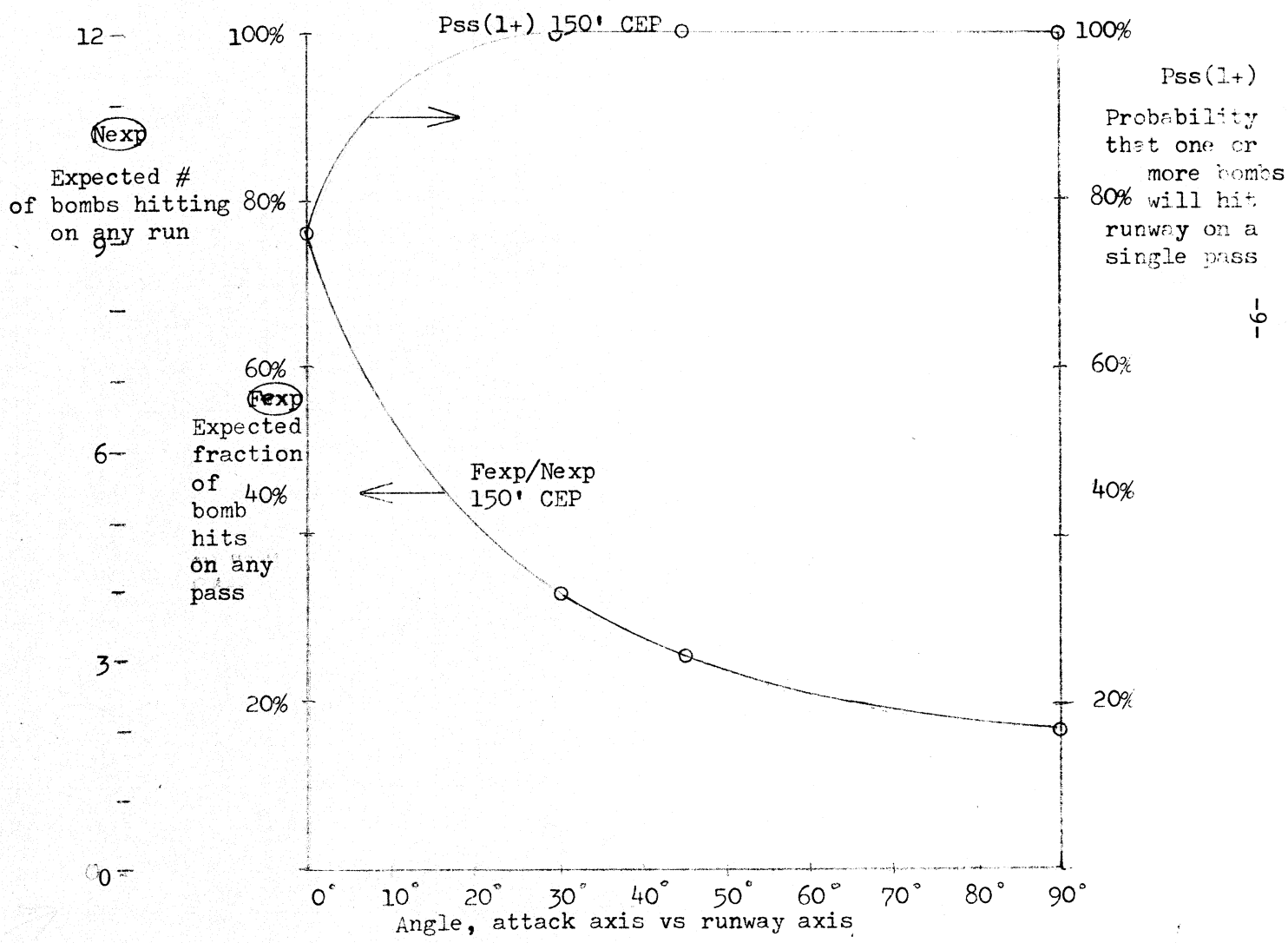
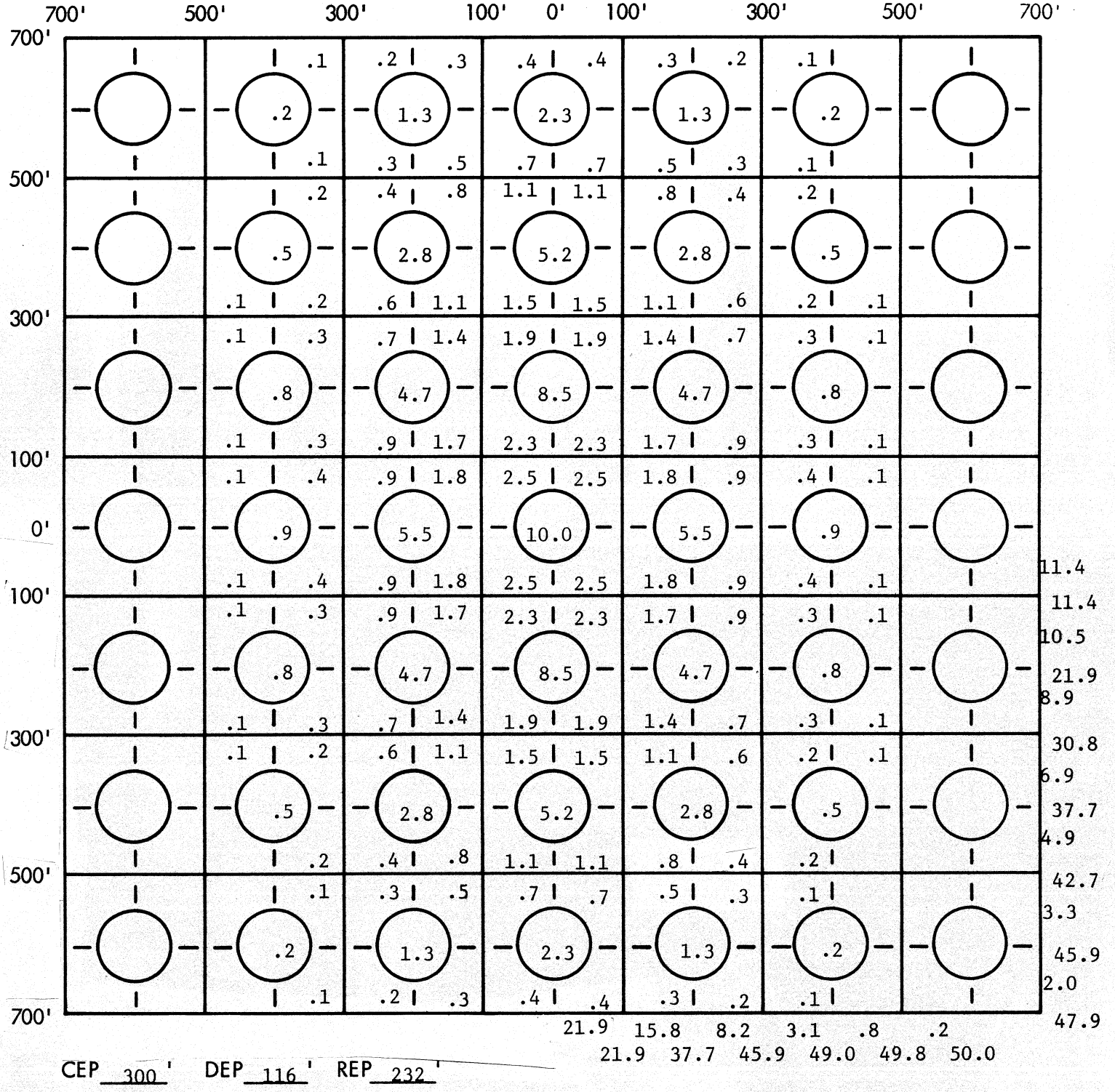


FIGURE 6

CEP 300'
REP 232'
DEP 116'

Area hit probability chart



CEP 300' DEP 116' REP 232'

FIGURE 7

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300' CEP
232' REP
116' DEP
Attack at 90°

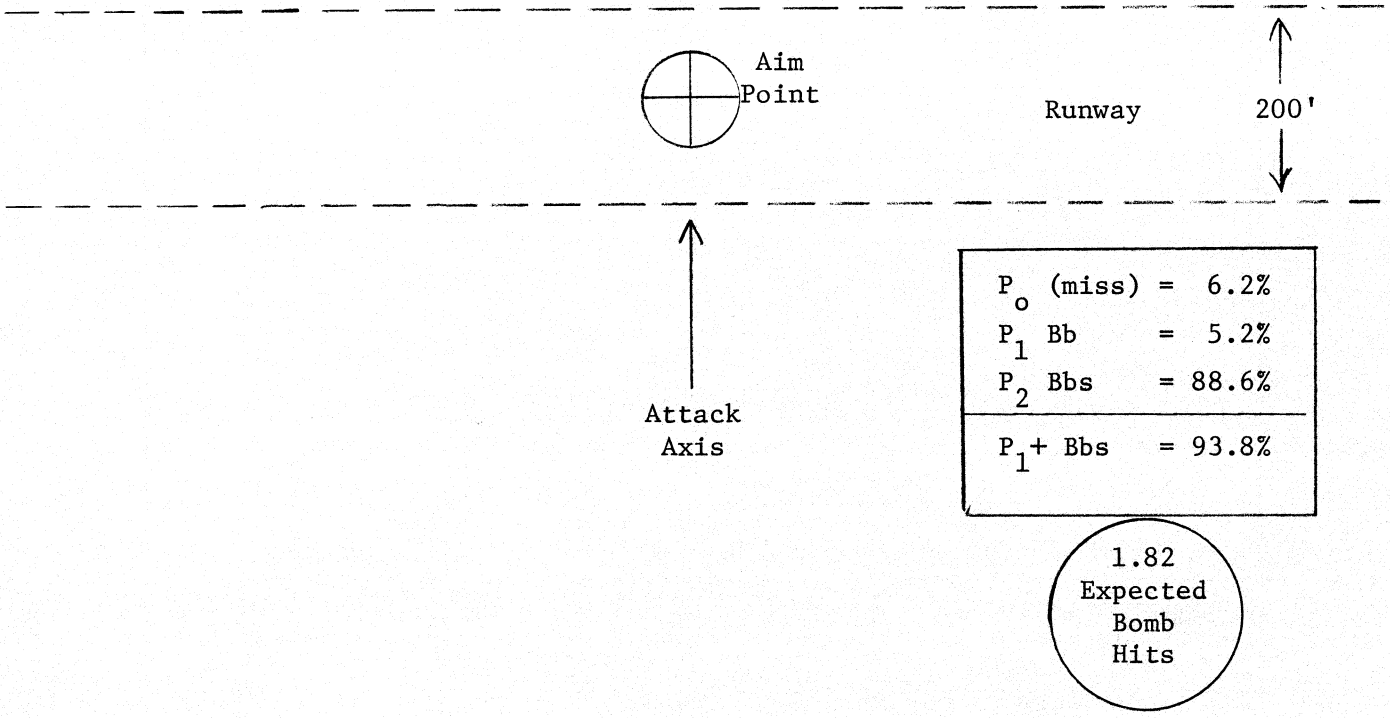


FIGURE 8

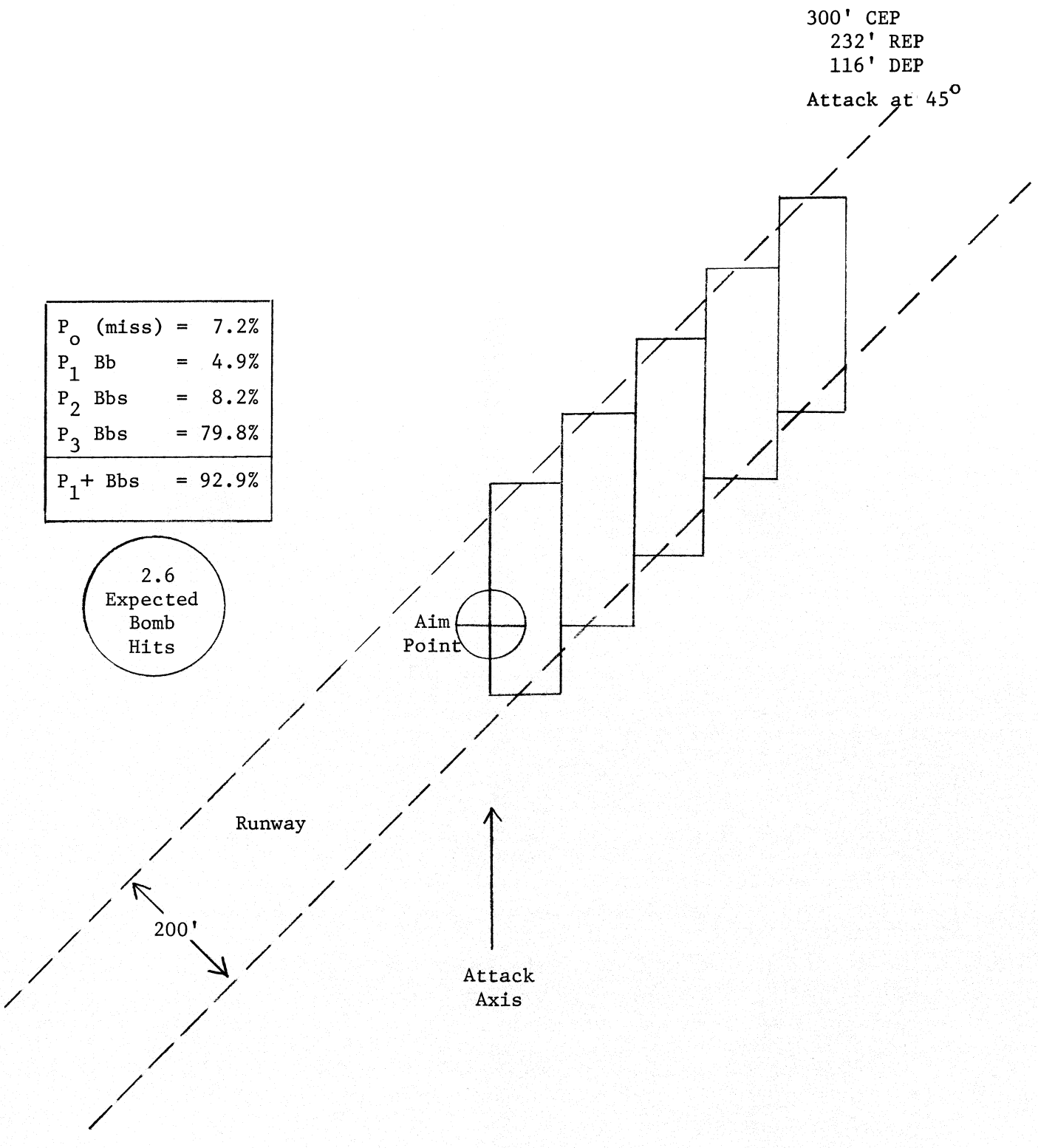

300' CEP
232' REP
116' DEP
Attack at 45°
P_o (miss) = 7.2%
P_1 Bb = 4.9%
P_2 Bbs = 8.2%
P_3 Bbs = 79.8%
P_1+ Bbs = 92.9%
2.6 Expected Bomb Hits
Aim Point
Runway
200'
Attack Axis

FIGURE 9

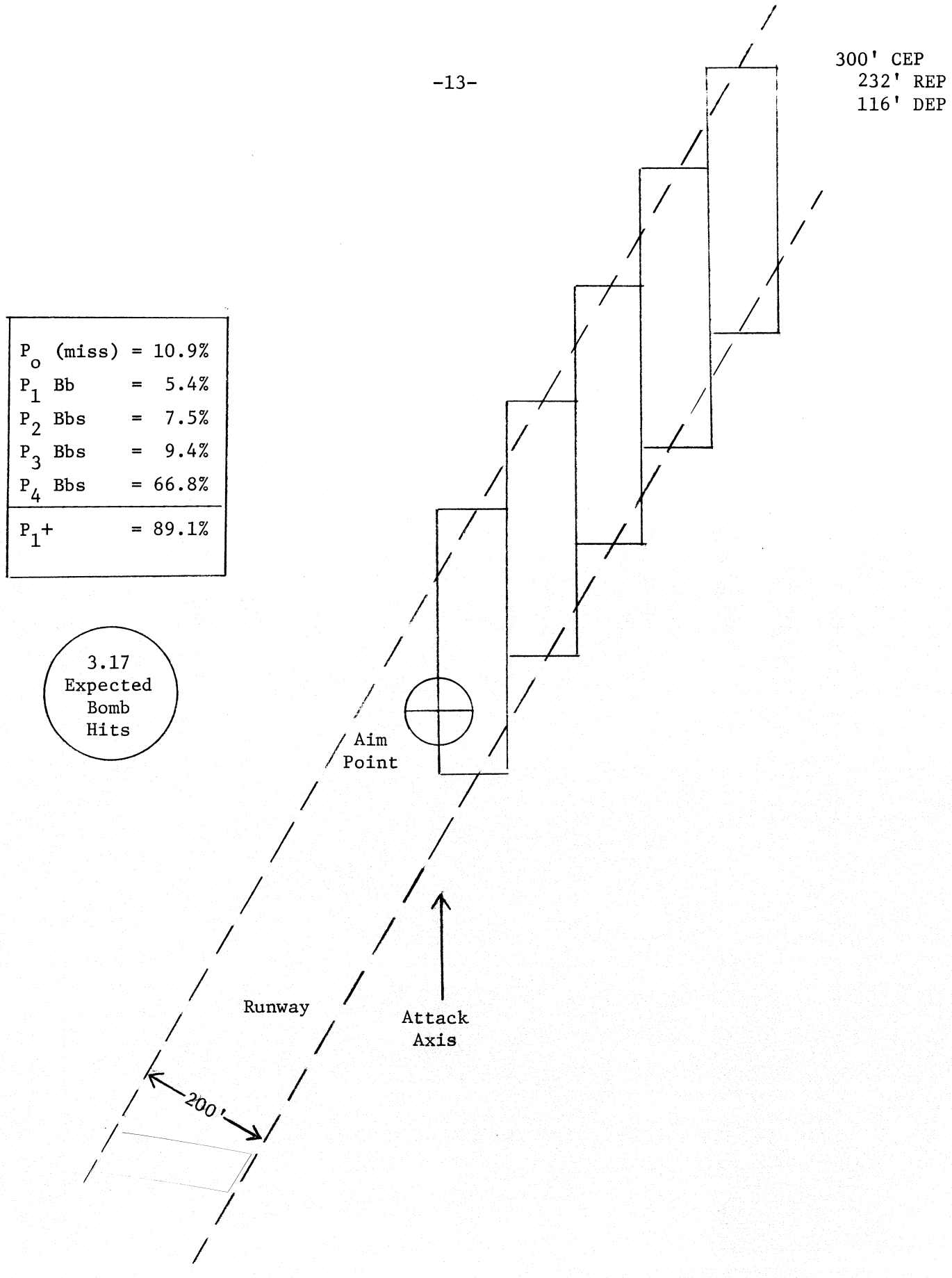
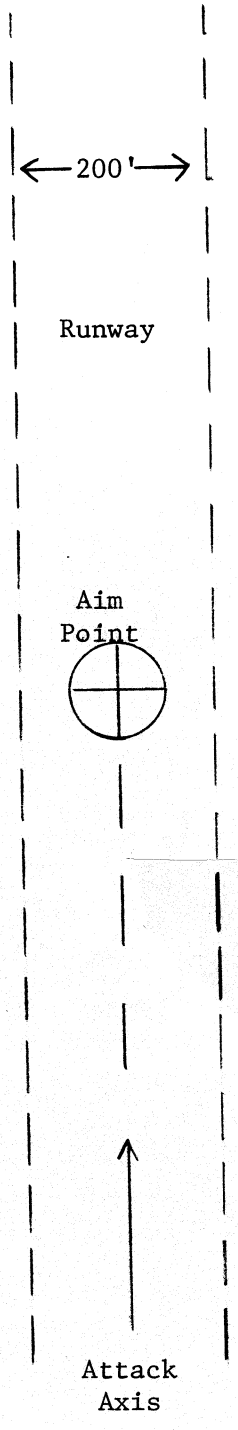

300' CEP
232' REP
116' DEP
P_o (miss) = 10.9%
P_1 Bb = 5.4%
P_2 Bbs = 7.5%
P_3 Bbs = 9.4%
P_4 Bbs = 66.8%
P_1+ = 89.1%
3.17 Expected Bomb Hits
Aim Point
Runway
Attack Axis
200'

FIGURE 10

300' CEP
232' REP
116' DEP
Attack at 0^{o}



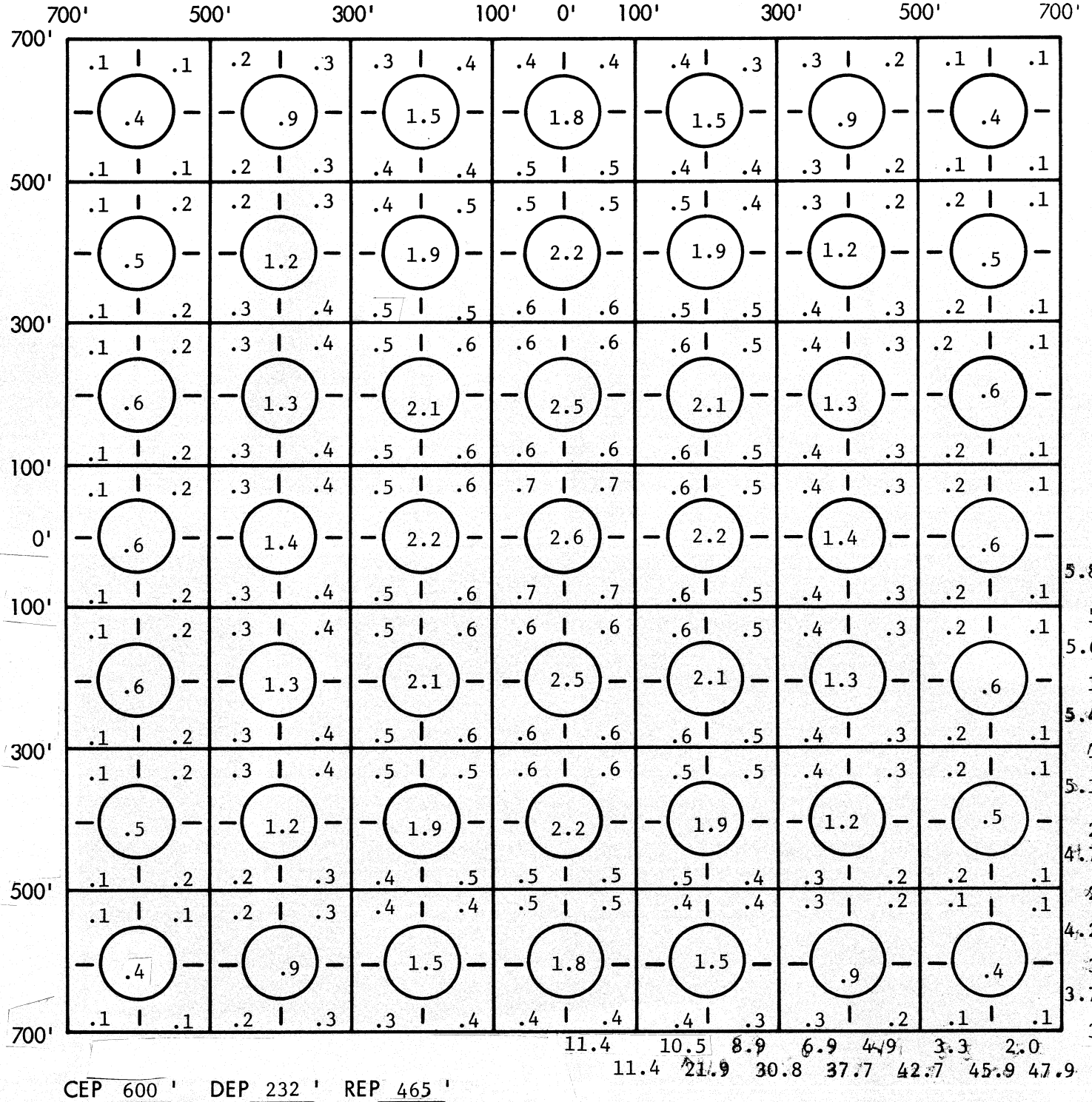
P_o (miss)	= 56.2%
P_{12} Bbs	= 43.8%
P_1+ Bbs	= 43.8%

5.3
Expected
Bomb
Hits

FIGURE 11

CEP 600'
REP 465'
DEP 232'

Area hit probability chart



CEP 600 ' DEP 232 ' REP 465 '

FIGURE 12

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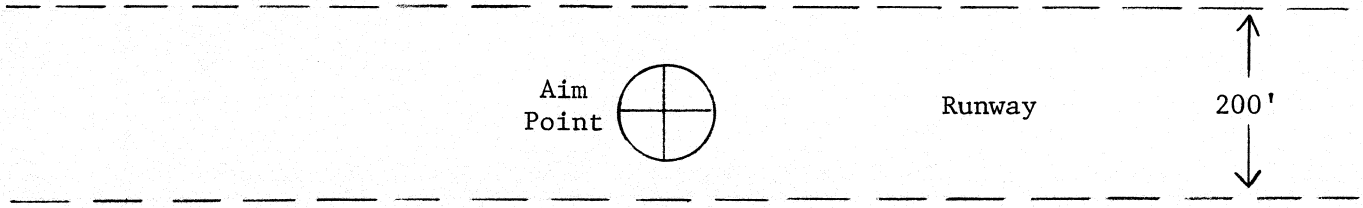
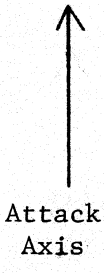
600' CEP
465' REP
232' DEP
Attack at 90°





P_o (miss)	= 34.7%
P_1 Bb	= 7.9%
P_2 Bbs	= 57.4%
P_1+	= 65.3%

1.13
Expected
Bomb
Hits

FIGURE 13

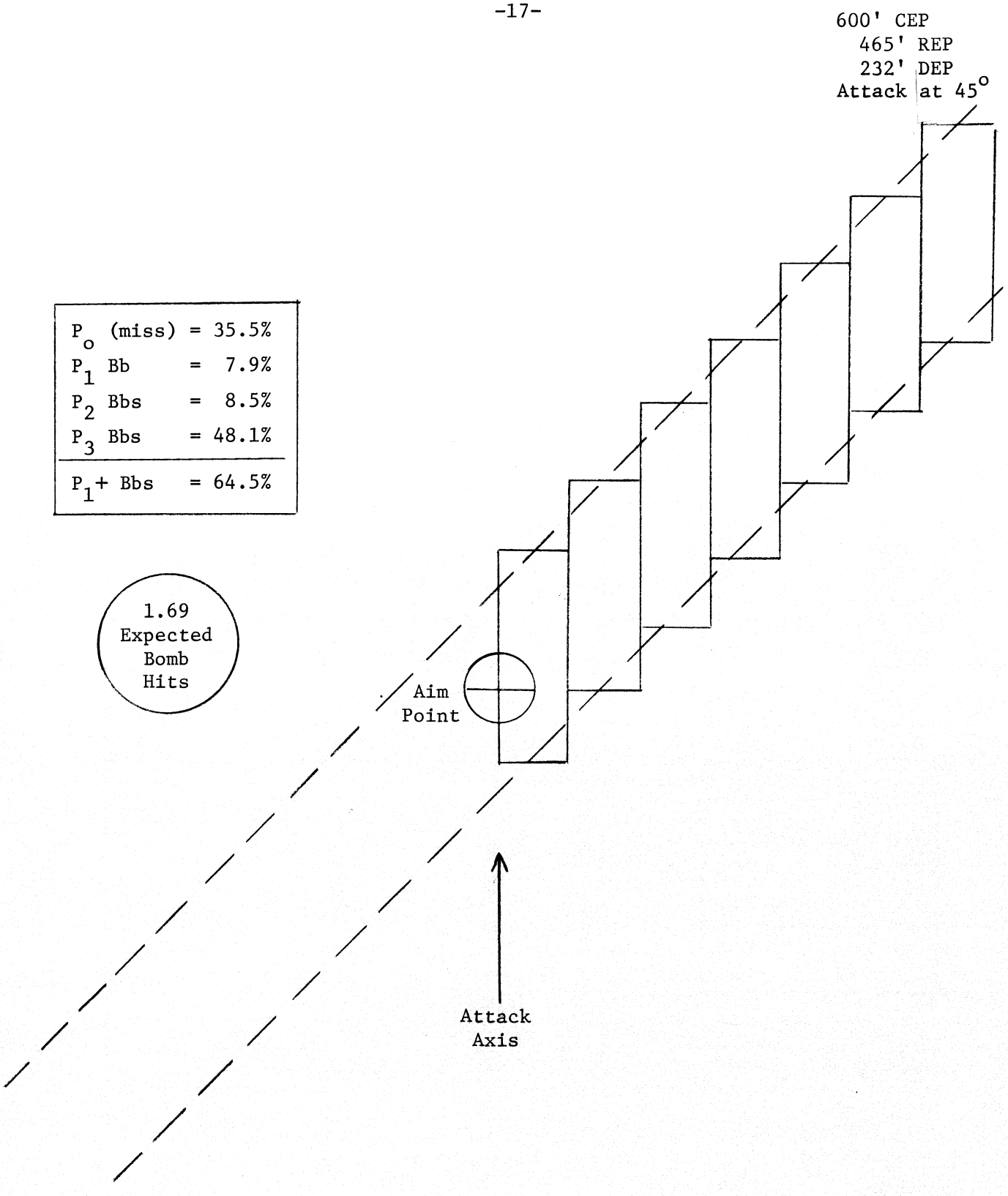

600' CEP
465' REP
232' DEP
Attack at 45°
P_o (miss) = 35.5%
P_1 Bb = 7.9%
P_2 Bbs = 8.5%
P_3 Bbs = 48.1%
P_1+ Bbs = 64.5%
1.69
Expected
Bomb
Hits
Aim
Point
Attack
Axis

FIGURE 14

600' CEP
465' REP
232' DEP

Attack at 30°

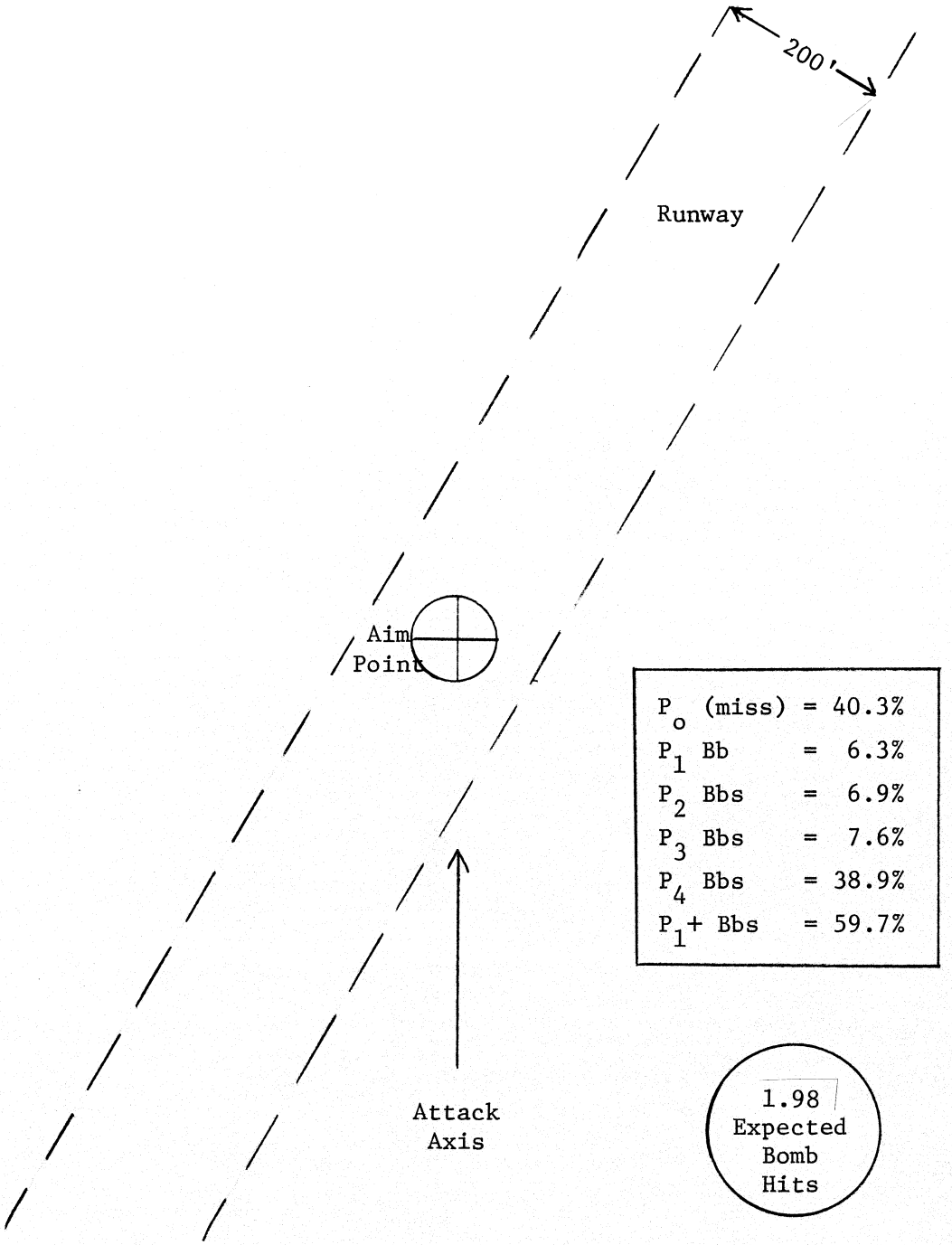
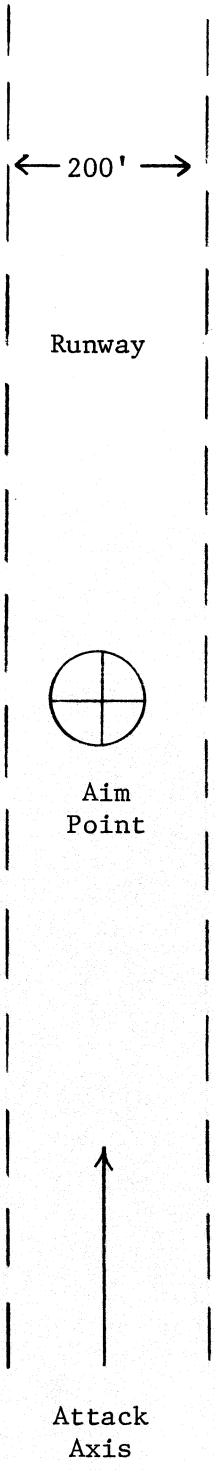


FIGURE 15

600' CEP
465' REP
232' DEP
Attack at 0°



P_o (miss)	= 77.2%
P_{12} Bbs	= 22.8%
P_1+ Bbs	= 22.8%

2.74 Expected Bomb Hits

FIGURE 16

TRAIN-BOMBING AGAINST A 200-FOOT RUNWAY

12-Bomb Stick
100' spacing
1100' stick length

Accuracy values used

600' CEP; 464'REP; 232'DEP
300' CEP; 232'REP; 116'DEP
150' CEP; 116'REP; 58'DEP

Attack directions used

0° from runway axis
30° " " "
60° " " "
90° " " "

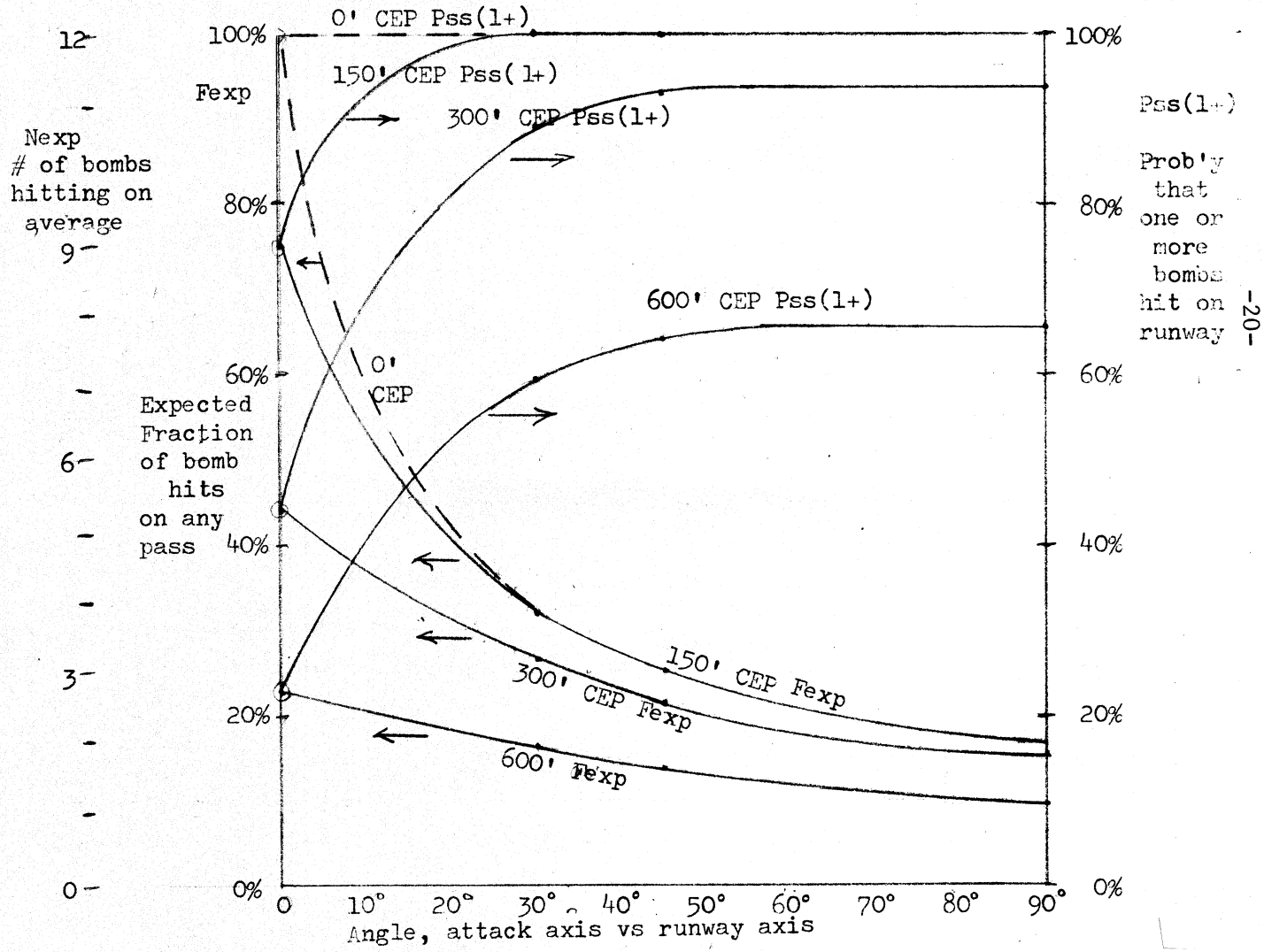
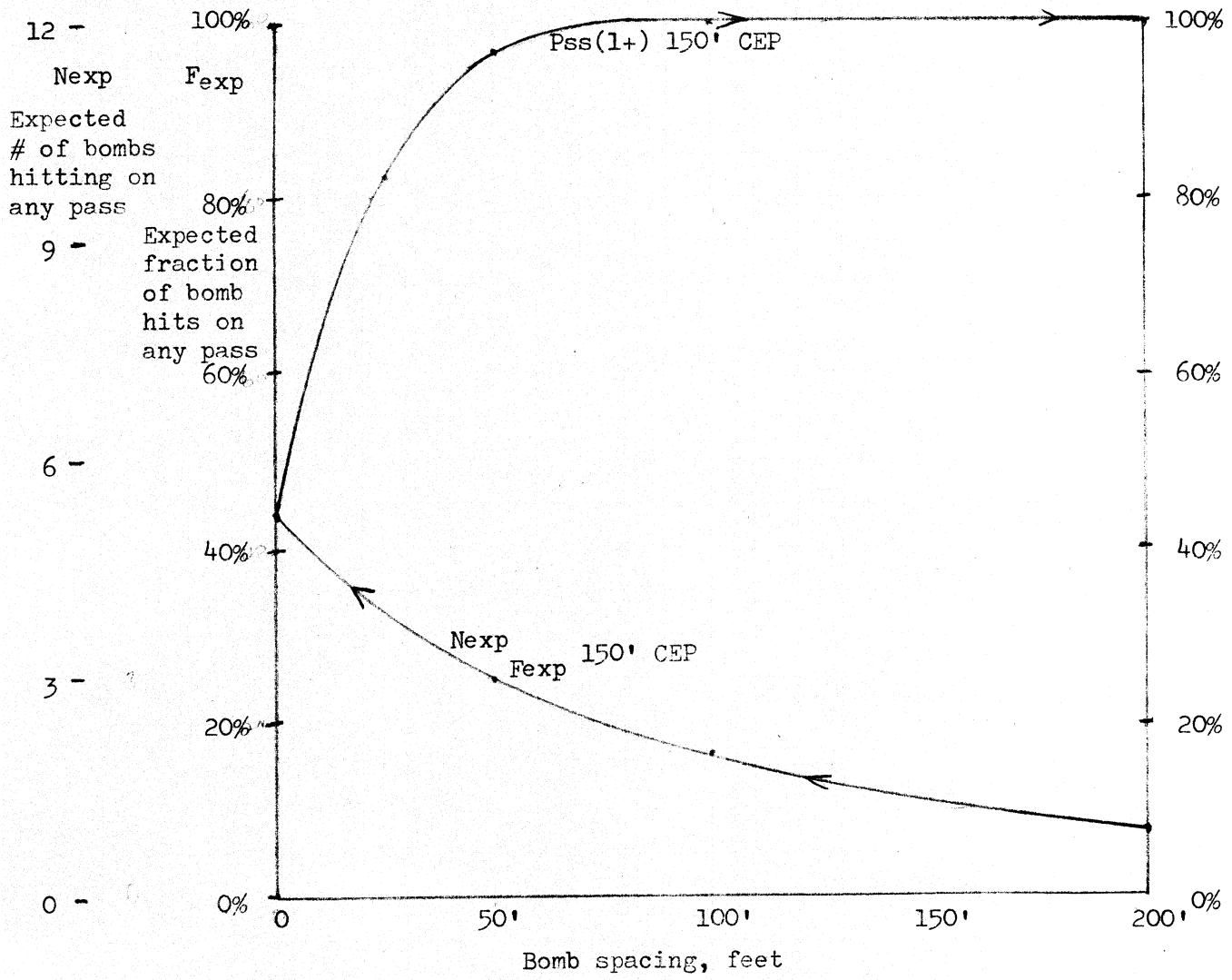


FIGURE 17

TRAIN-BOMBING AGAINST A 200-FOOT RUNWAY

12-bomb stick
Variable spacing
Attack axis perpendicular to runway
CEP 150' REP 116'; DEP 58'



Pss(1+)

Probability that one or more bombs will hit runway on a single pass

FIGURE 18