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AN EFFECTIVENESS MODEL FOR MULTIPLE ATTACKS AGAINST AN AIRBASE AREA COMPLEX

R. N. Snow

RAND Corporation

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Deputy Chief of Staff, Research and Development (Air Force)

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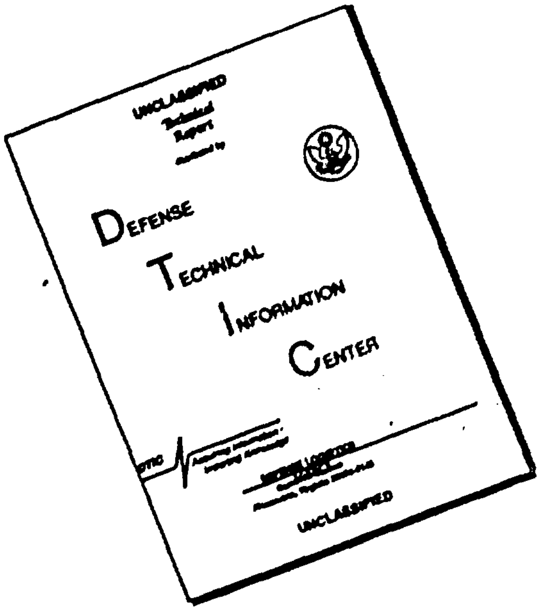

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A Report prepared for

UNITED STATES AIR FORCE PROJECT RAND

Rand
SANTA MONICA, CA. 90406

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An expected value model for computing the effectiveness of multiple attacks against an airbase hangarette complex is obtained and a JOSS program is provided. Effectiveness computations and sensitivity variations are obtained for an aircraft attack and for a remotely piloted vehicle attack on a representative airbase, using typical munitions, aircraft, and delivery conditions. (Author)

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PREFACE

This report presents a model for computing the effectiveness of multiple attacks against an airbase hangarette complex, and gives some effectiveness computations for attacks by aircraft and by remotely piloted vehicles (RPVs). The model was designed for use in Rand studies of nonnuclear attacks on enemy airbases. The computer results in the appendixes were direct inputs to an earlier Rand report, R-671-PR, *Nonnuclear Attack of Enemy Airbases* (U), September 1971, and to a forthcoming report on RPVs for airbase attack.

The effectiveness model was developed as part of Project RAND work on Improved Air-Ground Warfare Analysis Methods; the model should be useful to Air Force analysts interested in extensions to or modifications of the attack conditions on target arrays similar to those considered here. It may be easily modified to apply to more general target arrays, not necess ily confined to an airbase complex.

SUMMARY

An expected value JOSS* model for attacking aircraft in shelters on an airbase is developed in this report for both aircraft and remotely piloted vehicle (RPV) attacks, using a variety of munitions delivered in an area mode (i.e., the munitions are aimed at an area containing several shelters rather than at an individual shelter).

The model was obtained by modification and extension of existing effectiveness models, such as the Target Coverage Model;[1,2] the Quickie Model;[3] and the Hand Calculation Model used for the *Joint Munitions Effectiveness Manual*.[4] The body of the report discusses the basic model for aircraft attacks and modifications required for RPV attacks, and gives an example illustrating its use for a 16-aircraft attack against a representative sheltered airbase. Appendixes A and C present the JOSS program for aircraft attacks and the modifications for RPV attack, instructions for using the model, and some illustrative examples.

Appendix B tabulates effectiveness computations and sensitivity variations for an aircraft attack on a representative airbase, using typical munitions, aircraft, and delivery conditions. Appendix D tabulates similar effectiveness computations and sensitivity variations for an RPV attack on the same airbase and under the same conditions.

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*JOSS is the name of an interactive computer system incorporated in the IBM 370 at Rand and with consoles available at several Air Force installations.

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TABLES

GLOSSARY

A designates properties of the target areas:
- A(-1) = Width to length ratio = A(2)/A(1)
- A(1) = Length of the target area in 10^3 ft
- A(2) = Width of the target area in 10^3 ft
- A(10+ℓ) = Area of target area ℓ in 10^6 sq ft, ℓ = 1,2,...,M

B designates properties of the vulnerability of the hangarettes:
- B(0) = Vulnerability ratio = vulnerable area/ground plane area
- B(1) = Half length of the hangarette vulnerable area, ft
- B(2) = Half width of the hangarette vulnerable area, ft
- B(5) = Intermediate value in effectiveness routine
- B(6) = Intermediate value in effectiveness routine
- B(-1) = Hangarette ground plane area, sq ft

D designates internal variables concerned with weapon spacing:
- D(3) = Maximum distance between weapon CIs in range, ft
- D(4) = Maximum distance between weapon CIs in deflection, ft

E(x,L,s) = Effectiveness function

F(x,y,L,s) = Effectiveness function

G(x) = The cumulative gaussian distribution function

I designates the number of aircraft or RPV types considered

J = An internal variable in the effectiveness subroutine and in a different sense in the trajectory subroutine

K = An internal variable in the effectiveness subroutine and in a different sense in the trajectory subroutine

L designates weapon pattern dimensions, ft:
- L(1) = Dispenser pattern half length
- L(2) = Dispenser pattern half width
- L(3) = Equivalent pattern half length
- L(4) = Equivalent pattern half width
- L(5) = Equivalent half stick length
- L(6) = Equivalent half stick width
- L(7) = Intermediate half length
- L(9) = Intermediate half length
- L(10) = Intermediate half width
- L(11) = Equivalent half stick length for a formation
- L(12) = Equivalent half stick width for a formation

M designates the number of target areas considered; it must be chosen between 1 and 4.

N designates the number of weapons in a dispenser or carried by a delivery vehicle; it also designates the number of aircraft assigned to a target area:

N(-m),
m=1,2, ..,I = Number of weapons carried by an aircraft or RPV of type m
N(1) = Internal variable designating the weapons per vehicle
N(2) = Number of bomblets or submunitions per dispenser
N(3) = Internal variable, the number of release impulses
N(4) = Internal variable, the number of wing stations per vehicle
N(6) = Number of weapons released per impulse (set = 1)
N(7) = Number of waves of aircraft in range against a target
N(8) = Number of aircraft abreast in a wave
N(50) = Internal variable for RPV attack designating the number of attack groups
N(50+ℓ),
ℓ=1,2,...,M = Number of aircraft assigned area ℓ
N(55) = Internal variable used in the assignment of the RPV attack
N(60) = Internal variable used in the RPV attack
N(100+2ℓ-1) = Internal variable used to determine N(7) for aircraft attack
N(100+2ℓ) = Internal variable used to determine N(8) for aircraft attack

P designates probability of damage within a pattern:
P(1) = Internal probability of damage
P(2) = Internal probability of damage

Q designates a probability of survival within a pattern:
Q(1) = Internal probability of survival
Q(2) = Internal probability of survival

S = Slant range, in the trajectory subroutine, used to determine internally the ballistic errors on the ground

T(q) = Internal variable in the optimization routine

V designates speeds for the aircraft, the RPV, or the weapons off the ejection racks:
V(-1) = Speed of the aircraft, kn
V(0) = Speed of the aircraft, ft/sec
V(1) = Rack ejection velocity, ft/sec
V(2) = Intermediate variable in the trajectory subroutine
V(-m-1),
m=1,2,...,I = Speed of aircraft type m, kn

W designates optimal aircraft allocation indices:
W(-m),W(m),
m=1,2,...,I = Optimization indices for an aircraft of type m, used to determine aircraft allocation to target areas

X designates the expected fraction or total of hangarettes damaged, or the expected fractional damage obtained in the effectiveness subroutine:

- X(ℓ), ℓ=1,2,...,M = Expected fraction of hangarettes damaged in area ℓ
- X(5) = Total expected number of hangarettes damaged in all the target areas
- X(14) = Fractional expected damage determined in the effectiveness subroutine if the weapons are dispensers
- X(15) = Fractional expected damage determined in the effectiveness subroutine if the weapons are bombs

Y = Internal variable used in the trajectory subroutine

Z = Internal variable used in the trajectory routine; in the effectiveness routine in a different form; and in the input/output routine with a third meaning

a designates the range locations of weapon CIs:

- a(0) = Range distance on the ground from initial release point to the center of the weapon CI array
- a(i) = Range distance from the CI array center to the CI of weapon "i"

b designates the deflection locations of weapon CIs:

- b(0) = Maximum distance from the CI array center to a weapon CI
- b(i) = Deflection distance from the CI array center to the CI of weapon "i"

d designates spacing variables:

- d(0) = Intervalometer time spacing between weapon releases, sec
- d(3) = Average range weapon CI spacing, ft
- d(4) = Average deflection spacing, ft
- d(7) = Range spacing between aircraft waves
- d(8) = Deflection spacing between aircraft abreast
- d(9) = Internal spacing variable
- d(10) = Internal spacing variable

e = Conversion factor from deg to rad

g(x) = Gaussian density function

i = Dummy variable in the trajectory routine, and with a different meaning in the effectiveness routine

j = Dummy variable in the trajectory routine, and with a different meaning in the effectiveness routine. It is used as a weapon index in the input routine

k = Dummy variable in the input routine, and with a different meaning in the trajectory routine

ℓ = Target area index, ℓ=1,2,...,M, to indicate the different target areas

m = Aircraft type index, m=1,2,...,I

n designates an aiming method index or weapon index:

- n(14) = Weapon index; n(14) is set to 1 if bombs are used
- n(15) = Weapon index; n(15) is set to 1 if dispensers are used
- n(100) = Aiming method index--either single, independent, or random (n(100)=0,1,2)

o designates a correction factor in the effectiveness routine:
- o(1) = Range correction factor for a single attack
- o(3) = Range correction factor for multiple attacks
- o(4) = Deflection correction factor for multiple attacks

p = Weapon reliability factor

q = Dummy variable used in the optimization routine

r designates the ground range traveled by a weapon from release to impact:
- r(i) = Ground range from release to impact of weapon "i"

s designates the ballistic errors of the weapons:
- s(1) = Range ballistic standard deviation on the ground for bombs, ft
- s(2) = Deflection ballistic standard deviation on the ground for bombs, ft
- s(3) = Same as s(1) but for dispensers
- s(4) = Same as s(3) but for dispensers
- s(5),s(6) = Internal variables in the effectiveness routine
- s(7) = Range ballistic standard deviation, mils
- s(8) = Deflection ballistic standard deviation, mils

t designates the aiming accuracy of the delivery vehicles:
- t(0) = Accuracy index used in the input routine; it designates how the aiming accuracy is input, i.e., CEP in mils, CEP on the ground, REP and DEP on the ground, or range and deflection standard deviations on the ground
- t(1) = Range error standard deviation on the ground, ft
- t(2) = Deflection error standard deviation on the ground, ft
- t(7) = Range error standard deviation, mils
- t(8) = Deflection error standard deviation, mils
- t(9),t(10) = Internal variables, the REP and DEP, ft
- t(10+m) = CEP on the ground for aircraft type m, ft
- t(30+m) = CEP for aircraft type m, mils
- t(40+2m-1) = REP on the ground for aircraft type m, ft
- t(40+2m) = DEP on the ground for aircraft type m, ft
- t(50+2m-1) = Range standard deviation on the ground for aircraft type m, ft
- t(50+2m) = Deflection standard deviation on the ground for aircraft type m, ft

u designates aircraft rack offsets:
- u(-m) = Outboard station offset for aircraft type m, ft
- u(1),u(2) = Target offsets (set to zero in program)
- u(4) = Internal variable

v designates angles used in the trajectory routine, including the aircraft dive angle and the weapon rack throw angles:
- v(-m-1) = Dive angle for aircraft type m, deg
- v(-1) = Internal variable, dive angle, deg
- v(0) = Dive angle, rad
- v(1),v(2), v(3),v(4) = Internal angle variables used in the trajectory routine
- v(100) = Internal variable, rack angle, rad

x designates the horizontal travel of the aircraft after the initial weapon release:

- x(0) = Horizontal distance from first release to the release of the center (hypothetical) weapon
- x(i) = Horizontal distance from first release to the release of weapon "i"

z designates the altitude of a weapon:

- z(-m-1) = Altitude of last weapon off for aircraft type m
- z(-1) = Internal variable, altitude of last weapon off
- z(0) = Internal variable, altitude of the center weapon
- z(1) = Internal variable, altitude of first weapon off
- z(j) = Altitude of the j*th* weapon off

I. INTRODUCTION

For recent Rand studies of airbase attacks, it was necessary to develop an airbase attack model and a corresponding computer program to determine the effectiveness of multiple attacks, both by aircraft and by remotely piloted vehicles (RPVs), against an airbase on which aircraft are sheltered in hangarettes. In this report we use the term "hangarette" to mean either the hangarettes themselves or the aircraft sheltered in them; with appropriate selection of hangarette vulnerable areas for an attack, the model presented here can be used for either the hangarettes or the contained aircraft as targets. In the latter case, a "hangarette damaged" means that the aircraft in that hangarette are damaged.

For a single attack on an aircraft hangarette or a single area of hangarettes, the effectiveness of the attack, in terms of either the probability of damage to an individual hangarette or the expected fraction of damage to an area, may be determined by using the Target Coverage Model,[1,2] the Quickie Model,[3] or the Hand Calculated Model used in the Basic JMEM.[4] Each of these models assumes a ripple delivery of either a number of weapons or a number of dispensers which disperse submunitions in a rectangular or elliptical pattern. Each also assumes that the vulnerability of a hangarette to a weapon or submunition may be specified in terms of a rectangular area on the ground, so that the probability of damage to the hangarette is zero for impacts outside this area and constant inside.

For multiple attacks on a complex of several areas of hangarettes, many new factors are introduced. First, although the attacks may be independent, the damage is not necessarily independent of previous or accompanying attacks; the methods used in Refs. 1-4 must be adjusted to take into account the cumulative damage from multiple attacks. Next, there is the question of the optimum choice of aiming points for the several attacks, which is in turn influenced by the choice of intervalometer setting (length of weapon string) for the attacks. For the case of several areas of hangarettes, the problem arises of allocation of attacks to the different areas, particularly when the areas are far enough apart that there is no appreciable interaction (i.e., there is no collateral damage in one area from an attack on another). Finally, it is desirable at times to determine the optimum size of the pattern for dispenser-delivered submunitions, assuming that a dispenser could be designed to produce a desired pattern.

The Airbase Attack Model developed here is based on those in Refs. 1-4. Modifications and simplifying assumptions are made to shorten the computer time for all of the optimizations. For each area of the complex, the measure of effectiveness used in the model is the expected fraction of targets damaged. An equivalent measure for the entire complex, the total expected number of targets damaged, is thus the sum of the products of the number of targets in each area and the fractional expected damage in that area. For the complex, then, the total expected number of targets damaged for the specified multiple attack is taken as the effectiveness measure. The body of this report describes the modifications and simplifications introduced and the resulting model.

Section II considers the basic features of the model that are common to both aircraft and RPV attacks, such as the hangarette complex, the vulnerability features of the targets, the munitions considered, and so forth. Section III discusses the aircraft attack effectiveness model, the pertinent assumptions made, and the range of the parameters considered; some examples are given in Appendix A. Section IV considers the RPV attack model, gives a similar list of assumptions and range of the parameters, and an example is given in Appendix C.

A JOSS* computer program and some example results are given in Appendix A for aircraft attack and in Appendix C for RPV attack. The examples not only illustrate the operation of the model but provide a comparison of results with those obtained from the more time-consuming Quickie Model. Appendixes B and D present results obtained using the JOSS computer program for the airbase studies reported in Refs. 6 and 7 and a number of sensitivity tests for variations of attack and target conditions.

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*JOSS is the name of an interactive computer system incorporated in the IBM 370 at Rand and with consoles available at several Air Force installations. JOSS language is described in Ref. 5.

II. TARGET COMPLEX AND WEAPONS

This section considers some of the model's basic components that are common to both the aircraft and RPV attacks, including the description of the target complex, hypothetical examples of the munitions that can be used, and the manner of specifying the vulnerability of the hangarettes.

A. TARGET COMPLEX

The airbase complex is assumed to consist of a paved runway, an auxiliary sod runway, and several hangarette areas of different sizes, as shown in Fig 1. For our purposes, only the hangarette areas are considered as targets--i.e., aiming points are chosen with only shelters in mind and the collateral damage to other parts of the airbase is not modeled. Up to four separate hangarette areas can be specified in terms of their sizes, their relative locations, and the number of hangarettes in each. For simplicity, each of the hangarette areas is assumed to be a rectangle with a 2-to-1 length-to-width ratio; however, this ratio parameter can easily be changed if desired. For the examples and results presented in the appendixes, three hangarette areas are considered. The smallest area, Area 1, is 10^6 sq ft, and the medium sized one, Area 2, is $2(10)^6$ sq ft; each is assumed to contain 12 hangarettes. The largest, Area 3, is $4(10)^6$ sq ft and contains 16 hangarettes. Within each area, the locations of the hangarettes are assumed to be distributed uniformly randomly--i.e., for any particular hangarette, all locations within the area are equally likely. (For some specific cases reported in Ref. 6, it was assumed that one or more attackers could identify the location of a specific hangarette; for such cases, the remainder of the hangarettes are assumed to be located uniformly randomly throughout the remainder of the area.)

B. HANGARETTE VULNERABILITY

For modeling purposes, the hangarette vulnerability is specified by

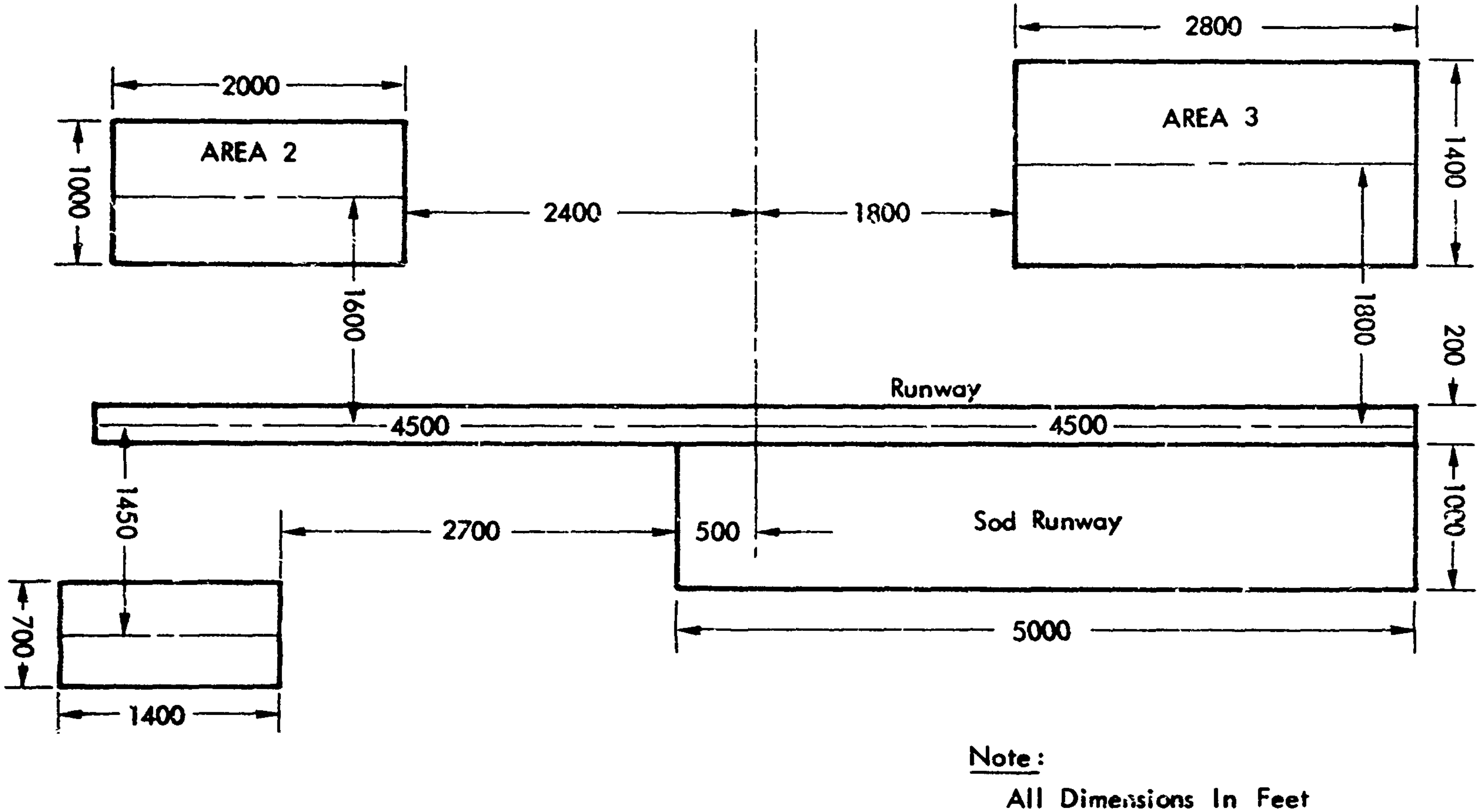

Fig. 1 — Airfield complex schematic

two parameters, the basic floor plan B(-1)* and the vulnerability ratio B(0). For a specific weapon being delivered, the ratio B(0) of the vulnerable area of the hangarette in the ground plane to the basic floor plan area is used as a vulnerability index. Thus, for some weapons, particularly large bombs, the ratio may be greater than one, since near misses with a high-explosive bomb may damage the hangarette. On the other hand, for penetrating weapons the ratio B(0) may be less than one, since some direct hits would not penetrate because of ricochets. For the results in the appendixes, the basic floor plan area B(-1) is taken to be a square of 2450 sq ft.

C. WEAPONS

Three general types of weapons are considered for attacking hangarettes; bombs, rockets, and area munitions delivered from clusters or dispensers.** Table 1 includes a listing of hypothetical weapons and the hangarette vulnerable areas assigned to each. The smaller vulnerable areas associated with the high-drag bombs result from the much lower impact velocity for these weapons. Also included in the bomb category are two special type bombs, a high-density penetrator and a FAE bomb, each of which is assumed to be in the 750-lb weight range. In the category of area munitions are several conceptual clusters and dispensers containing a variety of submunitions, including two sizes of Rebit, a kinetic energy penetrator; the REB-LEK, a fragmenting warhead with a rocket motor; two sizes of shaped-charge follow-through munitions; and a proposed FAE submunition. For most of these area munitions, vulnerable area ratios of 0.706 to 1 are considered, corresponding to effective ricochet angles from 45° to 90°.

The dispensers are assumed to follow a free-fall ballistic trajectory, opening at some predetermined altitude or time after release to disperse their submunitions. The resulting submunition impact points on the ground are assumed to be within a rectangular impact pattern,

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*Parameter and variable symbols used in the JOSS program are underlined when they appear in the text. See glossary for a complete listing of program symbols.

**Throughout this report, the word "dispenser" is intended to apply to either dispenser or cluster packaging of submunitions.

the center of the pattern being the (hypothetical) expected impact point of the dispenser. The submunition impact points are assumed to be distributed randomly uniformly throughout the pattern.

Table 1

VULNERABLE AREAS FOR HANGARETTE WEAPONS

Weapon	B(0)	Hangarette Vulnerable Area (sq ft)
Bombs, low-drag		
M-117, 750-lb HE	1.26,[a] 1.80[b]	3087,[a] 4410[b]
MK-81, 250-lb HE	1.1,[a] 1.50[b]	2695,[a] 3675[b]
MK-82, 500-lb HE	1.2,[a] 1.60[b]	2940,[a] 3920[b]
MK-83, 1000-lb HE	1.3	3185
MK-84, 2000-lb HE	1.44	3528
High-density, 750-lb penetrator	1.0	2450
FAE, 750-lb	1.0	2450
Rockets		
5-in. Zuni, 4 per pod	1.0	2450
Clustered 5-in. Zuni, 7 per cluster	0.7, 1.0	1730,2450
Bombs, high-drag		
M-117R, 750-lb HE retarded	0.88	2156
MK-82SE, 500-lb HE Snake Eye	0.77	1887
Area munitions (dispensers)		
Rebit, 115-lb, 7 per dispenser	0.7-1.0	1730-2450
Rebit, 50-lb, 13 per dispenser	0.7-1.0	1730-2450
REB-LEK, 40-lb, 16 per cluster	0.7-1.0	1730-2450
Follow-through shaped-charge, medium, 16 per dispenser	1.0	2450
Follow-through shaped-charge, heavy, 5 per dispenser	1.0	2450
FAE bomblet, 3 per dispenser	1.0	2450

[a]Delivered from dive mode.

[b]Delivered from level flight at 2000 ft altitude.

III. AIRCRAFT ATTACK

Up to four different types of aircraft can be specified in the model in terms of their delivery characteristics. For each type of aircraft, an arbitrary allocation of attackers can be made to each hangarette area. In the computer program, attacks were assumed to be in units of 16 surviving aircraft, allocated among the target areas, but the choice of the unit of 16 was arbitrary and is easily changed. Attrition was not considered in the model. For the special case of repeated attacks, the 16 aircraft attack unit was retained.

We will consider first a simple model based on an attack by an individual aircraft, then treat multiple attacks on a single target area, and finally the more complicated model of the attack of several target areas. Examples illustrating the use of this Airbase Attack Model are given in Appendix A for a single area; the results are then compared with those obtained for the same examples using the Quickie Model of Ref. 3. Appendix B contains results obtained from the Airbase Attack Model for attacks against the complex of three target areas.

A. INDIVIDUAL AIRCRAFT ATTACK

For attacks from aircraft, the weapons are assumed to be carried externally on weapon racks and released sequentially (rippled) with a constant interweapon time determined by an intervalometer; an initial "pickle" by the pilot sets off the entire release sequence. The pertinent delivery conditions are the altitude, speed, and dive angle of the aircraft when weapon release is initiated; intervalometer setting; release sequence for the weapons; and the ejection characteristics of the racks. The aircraft is assumed to hold a constant dive angle during release. In practice, the release altitude pertains to the last weapon off, requiring back-figuring to determine the initial weapon release point. The ballistic trajectories for each weapon, and thus the expected impact conditions, such as impact location (center of impact, CI), impact angle, and impact velocity may be determined from ballistic tables of the weapons involved. The set of expected impact points (CIs) for all the weapons in a single-aircraft delivery will be called the "delivery CI pattern." The center of the delivery CI pattern is defined as the expected impact point (CI) of the (hypothetical) center weapon, which is defined as a weapon delivered from a center-line position with no side throw. The aiming point is the desired location (DPI) of the center of the delivery CI pattern on the ground; if there were no errors, it would be the center of the set of impact points. We thus assume that the pilot attempts to choose a release point such that the expected center of the weapon impact pattern is at the aim point.

Each weapon trajectory is subject to ballistic errors, which are assumed to be gaussian and independent of the other weapons. The ballistic error is usually measured in terms of a standard deviation in mils (1/1000 of a radian) normal to the trajectory. The entire ripple delivery is subject to an aiming error, also assumed gaussian, which results in a displacement of the pattern center and thus the whole delivery CI pattern. The aiming error is often expressed as a CEP (circular error probable) in mils normal to the line of sight from the release point to the aim point.

On any one delivery, the result of the attack is damage to some fraction of the target elements in the target area. We use the expected fraction of the target elements damaged f_d (the average fraction over repeated identical attacks) as the measure of the effectiveness of an attack. We note that f_d is also the probability of damage to a single target element averaged over the entire target area. If the target is a single target element of known location, then the measure of effectiveness becomes the probability of damage p_d.

A.1 Attack Conditions

Attacking aircraft are specified in the model in terms of (a) release conditions, such as speed, altitude, and dive angle of the attacker at initial weapon release, intervalometer setting, and the rack locations, (b) the weapon loadout in terms of placement and number of weapons carried, and (c) the aiming accuracy associated with the aircraft for the particular mode of delivery. The aiming accuracy can be specified as CEP in mils normal to the trajectory, CEP on the ground, REP (range error probable) and DEP (deflection error probable) on the ground, or as range and deflection standard error (sigma) on the ground.

For each aircraft and weapon type, a set of delivery conditions must be specified; for the results in Appendix B, a "standard" set of delivery conditions is assumed and delivery accuracy estimates are made for each weapon-aircraft combination. These standard attack conditions are summarized in Table 2 in Appendix B; for each weapon, the loadout assumed for each attacking aircraft and the corresponding aiming and ballistic errors are listed.

For any single-aircraft attack, the attack conditions (loadout, release conditions, and accuracy assumptions, such as those given in Table 2) are combined with an assumed intervalometer setting in a trajectory program to obtain the expected impact point array on the ground as well as the ballistic and aiming errors in the ground plane. For a simple delivery of weapons, computer trajectory programs are available which use an empirical drag function for each weapon to determine the expected impact points, impact angle, impact velocity, and slant range from the drop point. Here we use the impact angle, impact velocity, and slant range of the hypothetical center weapon as the ripple impact angle, ripple impact velocity, and ripple slant range, respectively, to determine the ballistic errors in the ground plane, assuming that all weapons in the delivery have the same ballistic error. The aiming errors on the ground are assumed to be based on the slant range from the initial weapon release point to the expected location of the center of the delivery CI pattern on the ground. In many cases it is sufficient to determine the "stick length" and "stick width" of the delivery CI pattern instead of the exact location of each CI, where stick length is the maximum distance in range between weapon CIs and stick width is the maximum distance in deflection between weapon CIs.

Curves for such parameters as impact angle, impact velocity, slant range, stick width, and stick length are contained in Ref. 4, the Basic *Joint Munitions Effectiveness Manual*. The model in this report uses a JOSS trajectory program adapted from a computer program in Ref. 8, which was used as the basis for the JMEM curves.

A.2 Effectiveness Model--Individual Attack Against a Single Area Target

The basic model for a single aircraft attack, using a ripple of weapons (either bombs or dispensers) against a single target or an area of target elements, is the Quickie Model of Ref. 3. In Section II.B we specified the vulnerability of the hangarettes by two parameters, the floor plan area B(-1) and the vulnerability ratio B(0), or equivalently the vulnerable area B(-1) × B(0). For simplicity we took this vulnerable area to be a square. Thus, in the terminology of Ref. 3, we have a "geometric" target, i.e., one for which the probability of damage if hit is a constant over a specified geometric area and zero outside. The equivalent length B(3) and width B(4) for our target element is thus

$$B(3) = B(4) = \sqrt{B(-1) \times B(0)} \ . \tag{1}$$

Consider a ripple of N(1) weapons delivered against a rectangular area of length 2A(1) and width 2A(2), with the attack direction along the length of the target area. The area contains one or more identical target elements. The aiming point is assumed to be offset at a point (u,v) from the target area center (0,0), and the aiming error standard deviations in range and deflection on the ground are designated as t(1) and t(2), respectively (trajectory parameters are obtained from the delivery conditions given in Table 2). The fractional expected damage $f_d(u,v)$ to the target area (expected number of elements damaged/total number in area) may be expressed (see Ref. 3) in general form as

$$f_d(u,v) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D_p(x,y)\, h\left(\frac{x-u}{t(1)}, \frac{A(1)}{t(1)}\right) h\left(\frac{y-v}{t(2)}, \frac{A(2)}{t(2)}\right) \frac{dx}{t(1)}\, \frac{dy}{t(2)} \ , \tag{2}$$

where $D_p(x,y)$ is the pattern damage function (to be discussed next) and h(x,A) is the function

$$h(x,A) = \int_{x-A}^{x+A} \frac{g(\varepsilon)d\varepsilon}{2A} = \frac{G(x + A) - G(x - A)}{2A} \ . \tag{3}$$

G(x) is the cumulative gaussian distribution and g(x) is the gaussian density function, i.e.,

$$G(x) = \int_{-\infty}^{\infty} g(\varepsilon)d\varepsilon \tag{4a}$$

$$g(x) = \frac{\exp(-x^2/2)}{\sqrt{2\Pi}} . \tag{4b}$$

Note that if only one target element is contained in the area, then $f_d(u,v)$ is also the probability that this one randomly located target element is damaged.

The pattern damage function $D_p(x,y)$ depends on the target-weapon combination, the delivery methods, the number and type of weapons, and so forth. For the case of an attack against an area of hangarettes by a ripple of bombs, the pattern damage function $D_p(x,y)$ is expressed by formula (3.18) in Ref. 3. The fractional expected damage $f_d(u,v)$ is expressed as X(15) in the FORTRAN version of the Quickie Model in Ref. 3. The pertinent parameters are the number of bombs N(1), the ballistic standard deviations s(1) and s(2) in range and deflection in the ground plane, the range and deflection location of the bomb CIs in the CI pattern [a(i), b(i), i=1,2, ... N(1)], the probability of damage if hit p_{hd}, the bomb reliability p_r, and the length and width dimensions of the target element on the ground B(3) and B(4). The parameters s(1) and s(2) and the a(i), b(i) are determined, as mentioned earlier, as trajectory parameters, and the bomb reliability p_r is obtained from Ref. 4. The target element parameters B(3) and B(4) are given in Eq. (1), and p_{hd} = 1.

For the case of an attack against an area of hangarettes by a ripple of dispensers, the pattern damage function $D_p(x,y)$ is expressed by formula (4.45) in Ref. 3, and the fractional expected damage $f_d(u,v)$ is expressed as X(105) in the FORTRAN version of the Quickie Model in Ref. 3. The pertinent parameters are the number of dispensers N(1), the number of subweapons per dispenser N(2), the ballistic error standard deviations in range and deflection for each dispenser s(3) and s(4), the location of the dispensers' CIs in the dispenser CI pattern a(i) and b(i), the dispenser reliability r, the subweapon reliability p_r, the probability of damage if hit p_{hd}, the equivalent ground dimensions of the target element B(3) and B(4), and the dispenser length and width pattern dimensions 2L(1) and 2L(3). As in the bomb case, the parameters s(3), s(4) and the a(i), b(i) are determined as trajectory parameters. If available, the dispenser and subweapon reliabilities are obtained from Ref. 4. For our purposes, the dispenser pattern dimensions L(1) and L(2) are parameterized. The target element vulnerability inputs B(3) and B(4) are determined, as for bombs, from Eq. (1), and $p_{hd} = 1$.

It should be noted that the FORTRAN version of the Quickie Model does not contain a trajectory subroutine, so that the trajectory parameters must be obtained separately. The JOSS version of the Quickie Model as used in this report has been modified to include the trajectory subroutine discussed in the previous section. Thus, for a single attack on a single area, the JOSS version of the Quickie Model may be used to obtain directly the fractional expected damage from the attack.

A.3 Approximate Effectiveness Equations for Individual Attack

The general formula for the fractional expected damage $f_d(u,v)$ [Eq. (2)] may be greatly simplified if we make some approximations to the pattern damage function $D_p(u,v)$ for each of the cases considered. In general, we will approximate $D_p(u,v)$ by a step function $D_p^*(u,v)$ over a rectangle, i.e.,

$$D_p^*(u,v) = p_{dc} \quad \text{if} \quad \begin{array}{l} -L(9) \le u \le L(9) \quad \text{and} \\ -L(10) \le v \le L(10) \end{array}$$
$$= 0 \quad \text{otherwise}, \tag{5}$$

where L(9), L(10), and p_{dc} are to be determined as discussed below.

We are approximating $D_p(u,v)$ by the damage function $D_p^*(u,v)$, which has a constant damage probability p_{dc} within the rectangle 2L(9), 2L(10), and zero outside. Under this approximation, the expression for $f_d(u,v)$ in Eq. (2) beomes

$$f_d(u,v) = p_{dc}\, F\left(\frac{u}{t(1)}, \frac{L(9)}{t(1)}, \frac{A(1)}{t(1)}\right) F\left(\frac{v}{t(2)}, \frac{L(10)}{t(2)}, \frac{A(2)}{t(2)}\right) , \tag{6}$$

where the function F(u,L,A) is defined as

$$F(u,L,A) = \int_{-L}^{L} h(x - u,A)\, dx , \tag{7}$$

and h(x,A) is given in Eq. (3). The function F(u,L,A) may be expressed as sums of terms in the cumulative gaussian function G(x) and its density function g(x) using Appendix D of Ref. 3. Further, the function

$$F\left(0, \frac{L^*}{REP}(0.3372), \frac{A^*}{REP}(0.3372)\right) = F^*\left(\frac{L^*}{REP}, \frac{A^*}{REP}\right)$$

is presented in Ref. 9 as a set of curves in Fig. C-6, where REP = 0.6744[t(1)] and DEP = 0.6744[t(2)], $A^* = 2A$, and $L^* = 2L$. Note that L(9) and L(10) are the half dimensions of the approximating rectangular pattern damage function, and p_{dc} is the constant damage probability. We will obtain approximating pattern damage functions for both the bomb and the dispenser by choosing appropriate values for the three parameters L(9), L(10), and p_{dc} to fit the respective pattern damage functions $D_p(u,v)$.

In fitting a rectangular damage function $D^*(u,v)$ to a given damage function D(u,v), we will use the following general procedure. First, if possible, we will equate MAEs (mean area of effectiveness), where the MAE of a damage function D(u,v) is defined as

$$MAE = \int_{-\infty}^{\infty} D(u,v)\, du dv . \tag{8}$$

Then we will require that the second moments in the u and v direction be equal, a method similar to fitting an approximating probability distribution function by equating variances in the u and v directions.

Consider first a single bomb. The pattern damage function in this case may be expressed as

$$D_p(u,v) = p_{hd}p_r \frac{B(3)B(4)}{s(1)s(2)} h\left(\frac{u}{s(1)}, \frac{B(3)}{2s(1)}\right) h\left(\frac{v}{s(2)}, \frac{B(4)}{2s(2)}\right) , \qquad (9)$$

where $h(u,B)$ is given in Eq. (3) and $B(3) \times B(4)$ is the effective area of the target element. Let $p' = p_{hd}p_r$. The MAE of the pattern damage function is thus

$$MAE_p = p'B(3)B(4) . \qquad (10)$$

The MAE of the approximating function from Eq. (6) is

$$MAE_p^* = p_{dc}4L(9)L(10) . \qquad (11)$$

Equating MAEs, we obtain

$$p_{dc} = p' \frac{B(3)B(4)}{4L(9)L(10)} . \qquad (12)$$

Thus, the approximating damage function is

$$D_p^*(u,v) = p' \frac{B(3)B(4)}{4L(9)L(10)} , \quad \text{if} \quad \begin{array}{l} -L(9) \le u \le L(9) \\ -L(10) \le v \le L(10) \end{array} \quad \text{and}$$

$$= 0 \text{ otherwise} . \qquad (13)$$

The second moments M(1) and M(2) of the pattern damage function in the u and v directions, using Eq. (9), are

$$M(1) = p'B(3)B(4) \frac{s^2(1) + B^2(3)}{12} ,$$

$$M(2) = p'B(3)B(4) \frac{s^2(2) + B^2(4)}{12} .$$

The second moments $M^*(1)$ and $M^*(2)$ of the approximating damage function, Eq. (13), are

$$M^*(1) = \frac{p'B(3)B(4)L^2(9)}{3} ,$$

$$M^*(2) = \frac{p'B(3)B(4)L^2(10)}{3} .$$

Equating moments, we obtain

$$L(9) = \sqrt{\left(\frac{B(3)}{2}\right)^2 + 3s^2(1)} , \qquad (14a)$$

$$L(10) = \sqrt{\left(\frac{B(4)}{2}\right)^2 + 3s^2(2)} . \qquad (14b)$$

For the case of one weapon, then, the fractional expected damage $f_d(u,v)$ is approximated by Eq. (6), where p_{dc} is given by Eq. (12) and the dimensions L(9) and L(10) of the approximating rectangle [see Eq. (5)] are given in Eqs. (14a) and (14b).

Consider now the case of N(1) bombs where N(1) ≥ 2. The stick length S(1) is defined as the maximum distance in range between bomb CIs, and stick width S(2) as the maximum distance in deflection. We define d(1) and d(2) as the mean spacing between bomb CIs in range and deflection, respectively, so that

$$S(1) = (N(1) - 1)\ d(1) ,$$

$$S(2) = (N(1) - 1)\ d(2) .$$

Assume that the bomb CIs are equally spaced in range and deflection, with spacings d(1) and d(2). Again, equating second moments for the pattern damage function and the approximating rectangle, we obtain L(9) and L(10) as follows:

$$L(9) = \sqrt{\frac{N(1)+1}{N(1)-1}\left(\frac{S(1)}{2}\right)^2 + \left(\frac{B(3)}{2}\right)^2 + 3s^2(1)}\ , \tag{15a}$$

$$L(10) = \sqrt{\frac{N(1)+1}{N(1)-1}\left(\frac{S(2)}{2}\right)^2 + \left(\frac{B(4)}{2}\right)^2 + 3s^2(2)}\ . \tag{15b}$$

If the MAE_p of the pattern damage function is available, then

$$p_{dc} = \frac{MAE_p}{L(9)L(10)}\ .$$

At the moment, pattern MAEs can only be obtained by computations; however, it is possible that certain pattern MAEs obtained in future JMEM computations will be made available in JMEM publications. If the pattern MAE_p is not available, we must approximate p_{dc}. We will use the approximation

$$p_{dc} = 1 - \left(1 - p'\frac{B(1)B(2)n'}{L(9)L(10)}\right)^{N(1)/n'}\ , \tag{16}$$

where $\underline{L(9)}$ and $\underline{L(10)}$ are given by Eqs. (15a) and (15b) and n' is given by

$$n' = \text{Min}\left[N(1),\ \frac{L(9)}{\sqrt{B^2(1) + 3s^2(1)}}\right], \tag{17a}$$

$$B(1) = \frac{B(3)}{2}\ , \tag{17b}$$

$$B(2) = \frac{B(4)}{2}\ . \tag{17c}$$

The factor n' is introduced to account for the fact that the bombs are not actually uniformly distributed over the entire damage pattern but tend to impact near their respective CIs. The restriction that

$n' \leq N(1)$ is needed for the case where the bombs are widely separated and have little if any overlap. The correction factor here is in range only since we are assuming that only one weapon is released per impulse. If more than one weapon were released per impulse, a correction factor in deflection would be included. For the bomb case, the approximation for $f_d(u,v)$ is given by Eq. (6), with p_{dc} given in Eq. (16) and $\underline{L(9)}$, $\underline{L(10)}$ given in Eqs. (15a) and (15b).

Note that we have replaced the actual impact array of the ripple of bombs by a rectangular pattern of dimension $\underline{2L(9)}$, $\underline{2L(10)}$ of impact points with the assumption of a uniformly random distribution of the attack impact points within the pattern. A further refinement is made in Eq. (16) by assuming the uniform distribution to be confined to a portion of the overall rectangular pattern rather than the whole pattern. This same approximation procedure will be used for the case of dispenser attacks, and extended for multiple attacks, both for bombs and dispensers.

For the case of a ripple of dispensers, with pattern dimensions $\underline{2L(1)}$ and $\underline{2L(2)}$, we proceed just as for bombs and obtain the following expressions for the approximating parameters L(9), L(10), and p_{dc}:

$$L(9) = \sqrt{\frac{N(1)+1}{N(1)-1}\left(\frac{S(1)}{2}\right)^2 + L^2(1) + 3s^2(3)}\ , \tag{18a}$$

$$L(10) = \sqrt{\frac{N(1)+1}{N(1)-1}\left(\frac{S(2)}{2}\right)^2 + L^2(2) + 3s^2(4)}\ , \tag{18b}$$

$$p_{dc} = 1 - \left[1 - r\left\{1 - \left(1 - p'\frac{B(1)B(2)}{L(1)L(2)}\right)^{N(2)}\right\}\frac{L(1)L(2)n'}{L(9)L(10)}\right]^{N(1)/n'}\ , \tag{18c}$$

where r is the dispenser reliability and

$$n' = \text{Min}\left[N(1),\ \frac{L(9)}{\sqrt{L^2(1) + 3s^2(3)}}\right]. \tag{19}$$

For the dispenser case, the approximation for $f_d(u,v)$ is given by Eq. (6), with L(9), L(10), and p_{dc} given by Eqs. (18a), (18b), and (18c).

Thus, for an attack by a single aircraft against an area of hangarettes, we may use the Quickie Model and obtain more precise results (Quickie function X(15) for bombs and X(105) for dispensers), or we may use the above approximations developed for the present model, in which we view the attack as the delivery of a single superweapon using an equivalent dispenser containing all the weapons delivered in the attack. These results, for the most part, do not require numerical integration, as does the Quickie Model, but involve merely the use of known functions. Example 2 in Appendix A illustrates the single-attack case of a string of dispensers delivered against a single target area. In this example, as for all that were checked, the approximation was very close to the Quickie value for X(105). Equally close approximations were obtained for the case of bomb delivery; we choose a dispenser example, since in general the dispensers were more effective than strings of bombs.

B. MULTIPLE ATTACKS AGAINST A SINGLE AREA TARGET

For the portion of the Airbase Attack Model that deals with a single target area, we adopted the approximation principles presented in the previous section, but modified the results slightly because of the optimization and allocation problems involved in multiple attacks. The development of the effectiveness portion of the Airbase Attack Model involves a two-step approximation process; a first approximation of a single-aircraft attack by a single equivalent dispenser pattern, as discussed in the previous section, and then a subsequent approximation for the multiple-attack case, using another larger equivalent dispenser pattern.

In the case of a multiple attack on a single area, we consider only attacks by the same type of aircraft, using the same delivery conditions and the same type of weapons. Thus, the attacks on an area are considered to be identical except for the aiming points and aiming errors. We consider only attacks by pairs, i.e., the number of attackers is a multiple of two. It is implicitly assumed that all attacking aircraft arrive essentially simultaneously (i.e., no shoot-look-shoot), and that the number of attackers are those that survived to make the bombing run after incoming attrition. No mixed loads or mixed series of attacks are considered.

Two general methods are considered for positioning the attacks over an area: the "single-aim" attack and the "independent-aim" attack. The first method is essentially a formation type attack, with each member of the attacking force positioning himself relative to the formation leader and all attackers releasing on signal from the leader. In this case, one or more waves of attackers make up the formation, with the attackers assumed to be roughly abreast within waves. The leader of the formation is assumed to use the center of the area as the aim point for the formation--i.e., the expected center of all weapon CIs is placed on the center of the target area. Thus, the total attack on the single target area can be specified by the number of waves, the number of aircraft per wave, the range difference between waves, and the lateral distance between attackers in a wave. Each aircraft is assumed to hold its position within the formation accurately and to release its weapons upon the proper signal, so that there is only one aiming error for the entire formation. For the independent-aim attack case, the same type of attack formation is specified, but each aircraft releases independently using an individual aiming point within the target area; aiming errors are therefore independent. It is assumed that the array of aiming points is preassigned, that each attacker can acquire his individual aiming point, and that he uses it for his weapon release.

B.1 Single Aim

Consider first the single-aim method. As a first approximation, we replace the pattern resulting from the ripple of dispensers or bombs from each attacking aircraft by an equivalent single attack with one pattern containing all the weapons in the ripple, as in subsection A. Viewing each individual aircraft attack as being made by one "superweapon," the multiple-aircraft attack can be viewed as an attack by several superweapons. The common aiming error of the formation can be considered as the aiming error for the total attack. Hence, the spacing of the expected centers of each superweapon is the spacing between attackers in the formation. The "ballistic error" of each superweapon is zero, since we assume the attackers to hold their relative positions (the program could easily be modified to include a spacing error if desired). The superweapon impact pattern size for each aircraft in the total attack is the same as the size of the impact pattern for a single-aircraft attack. We thus may use the function X(106) in the Quickie program (a variation of the function X(105), since there is no additional ballistic dispersion of the pattern) to obtain the fractional damage to the area under attack. Example 4 in Appendix A illustrates this case, using the Quickie Model together with a first superweapon approximation.

The use of the Quickie Model above in conjunction with a first approximation for the effectiveness of an attack ripple still involves a double numerical integration routine and thus considerable time on the computer. We will now make a second approximation, using the same principles as outlined above. Consider a multiple attack on an area that consists of N(7) waves or rows of attackers, each wave consisting of N(8) attackers, with a lateral spacing between attackers in each wave of d(8) and a range spacing between waves of d(7). As above, approximate by considering each attacker delivering a ripple of N(1) weapons as an attacker delivering one superweapon consisting of N(1) weapons within a rectangular pattern of size 2L(9), 2L(10) and an equivalent damage probability p_{dc}. (For bombs, these parameters are given in Eqs. (15a), (15b), and (16) and for dispensers in Eqs. (18a), (18b), and (18c).) Thus we may view the multiple attack as consisting of N(7), N(8) superweapons, with aiming points spaced as above (d(7) and d(8) and with a common aiming error). Following the same procedure, we will approximate this multiple attack by a single attack in which we have replaced the N(7), N(8) rectangular patterns with one "superpattern" with dimensions 2L(11), 2L(12) and a damage probability parameter p^*_{dc}. The stick length S(3) and stick width S(4) are now given by

$$S(3) = (N(7) - 1)\, d(7) \ , \qquad (20a)$$

$$S(4) = (N(8) - 1)\, d(8) \ . \qquad (20b)$$

For this single-aim case, the equivalent ballistic error for the super-pattern is zero. Thus, similar to Eqs. (15), (16), and (18), the approximating parameters L(11), L(12), and p_{dc}^* are given as follows:

$$L(11) = \sqrt{\frac{N(7)+1}{N(7)-1}\left(\frac{S(3)}{2}\right)^2 + L^2(9)} \quad , \qquad (21a)$$

$$L(12) = \sqrt{\frac{N(8)+1}{N(8)-1}\left(\frac{S(4)}{2}\right)^2 + L^2(10)} \quad , \qquad (21b)$$

$$p_{dc}^* = 1 - \left[1 - p_{dc}\,\frac{L(9)L(10)n^*}{L(11)L(12)}\right]^{N(7)N(8)/n^*} \quad , \qquad (21c)$$

where L(9), L(10), and p_{dc} are the appropriate approximating parameters to replace those for bombs in Eqs. (14) and (15) or for dispensers in Eq. (18), the equivalent stick parameters S(3) and S(4) are given in Eq. (20), and n^* is given by

$$n^* = \left\{\text{Min}\left[N(7),\ \frac{L(11)}{L(9)}\right]\right\}\left\{\text{Min}\left[N(8),\ \frac{L(12)}{L(10)}\right]\right\} . \qquad (22)$$

Using Eq. (20), we may rewrite the expressions for L(11) and L(12) as

$$L(11) = \sqrt{\left(\frac{(N^2(7)-1)d(7)}{2}\right)^2 + L^2(9)} \quad , \qquad (23a)$$

$$L(12) = \sqrt{\left(\frac{(N^2(8)-1)d(8)}{2}\right)^2 + L^2(10)} \quad . \qquad (23b)$$

We note that our correction factor n^* is now applicable both in range and deflection. The effectiveness portion of the Airbase Attack Model is based on the above two-step approximation as expressed in Eqs. (21) and (23).

Example 3 in Appendix A, using the same case as in the example computed by the Quickie Model, provides a comparison between the Quickie and the Airbase Models for a single area; although not all check runs produced as close a correspondence (0.501 versus 0.502) in fractional expected damage, for the single-aim case the differences were found generally in the third significant figure, as in this example. Even when there was some difference between the results of the two models for a single area, the relative values of the fractional expected damage for the several different cases remained about the same. The Airbase Attack Model therefore appears adequate for comparisons of different aircraft and munitions. If absolute values are desired, spot checks should be made using the more precise Quickie Model.

B.2 Independent Aim

In the independent-aim method of attack, each attacker independently attacks his own aiming point. We assume that each attacker is able to identify, acquire, and attack his particular assigned aiming point. For this case, the attacks are not necessarily made by flying in formation, but we assume no correlation between attacks nor feedback from one to another. As a first approximation, we again replace each attacker's ripple of dispensers by an equivalent superweapon having a single equivalent expected impact pattern that contains all the weapons of the individual attack. This equivalent superweapon is the same as that used above in the case of single aim. However, in this case, the function X(105) in the Quickie program is applicable, since now the aiming error for each single attack, being independent, can be entered in the Quickie program as ballistic dispersion for the equivalent superweapon, i.e., the ballistic dispersion of the superweapon is used as a proxy for the aiming error of the ripple of munitions. The aiming error for the whole attack is zero, since there are no common aiming errors.

Again, the use of the Quickie Model in conjunction with a first approximation for the effectiveness of an independent ripple attack requires considerable computer time. We therefore make a second approximation, this time of a slightly different nature. Consider as before a multiple attack consisting of N(7) waves or rows of attackers, each wave consisting of $N(8)$ attackers, with a lateral spacing of $d(7)$ and a range spacing of $d(8)$. Unlike the single-aim case, each attacker independently aims at his assigned aiming point (not necessarily at the same time; note that we assume that each attacker can find his assigned aim point, even though there may be some time interval between attacks). Each superweapon is subject to an independent error--the attacker aiming error. Given that the spacing in the aiming point array has been chosen, we first consider each attacker individually and obtain the fractional expected damage to the area target due solely to this attacker aiming at his aim point. Thus, for each attacker, j=1,2, ... N(7), N(8), with the aiming point at (α_j, β_j), and using Eq. (6), the fractional damage f_j is given by

$$f_j = p_{dc}\, F\left(\frac{\alpha_j}{t(1)}, \frac{L(9)}{t(1)}, \frac{A(1)}{t(1)}\right) F\left(\frac{\beta_j}{t(2)}, \frac{L(10)}{t(2)}, \frac{A(2)}{t(2)}\right), \qquad (24)$$

where $L(9)$, $L(10)$, and p_{dc} are the approximating parameters for bombs [Eqs. (15) and (16)] or dispensers [Eq. (18)]. In general, the f_j will be different, since the aiming points are different. If we treat f_j as a probability of damage, then the total probability of damage f_d is given by

$$f_d = 1 - \prod_{j=1}^{N} (1 - f_j) \; . \qquad (25)$$

The exact fractional expected damage to the target area is not given by this expression. However, under the conditions that the aiming points are well scattered over the area, or when the aiming errors are large, f_d is a very good approximation to the fractional damage. In the Airbase Attack Model we make this approximation for the independent-aim case; thus we need only to determine the fractional expected damage for each attacker individually.

C. AIRBASE ATTACK MODEL

The previous section discussed an effectiveness model (an approximation to the Quickie Model) which computes specified input conditions and gives the fractional expected damage to a given target area. For the Airbase Attack Model we consider a complex of several target areas, each containing a specified number of hangarettes; our effectiveness criterion is the expected number of hangarettes (or sheltered aircraft) damaged. Further, we consider different types of aircraft and weapons, different delivery conditions and accuracies, different vulnerabilities for the hangarettes, different aiming modes and spacing of the aircraft attacks, different allocations of aircraft to the target areas, and different sizes of dispenser patterns. In order to consider all these varying conditions, we have designed the Airbase Attack Model in four major subsections or subroutines: (1) the Input/Output Section, (2) the Optimization Section, (3) the Trajectory Section, and (4) the Effectiveness Section. Figure 2 is a flow chart diagram of the Airbase Attack Model. We next discuss each of the four subsections and their functions.

C.1 Effectiveness Section

The Effectiveness Section contains the effectiveness model for both single and independent aiming modes. It is an approximation to the Quickie Model and its precision can be considered to lie between the model used in the Basic JMEM, Ref. 4, and the Quickie Model, Ref. 3. A printout of the Effectiveness Section of the JOSS program appears in Appendix A. The model determines the effectiveness of a specific attack against a given area target in terms of the fractional expected damage, designated function X(15) if the weapon is a bomb type and function X(14) if a dispenser type. These designations correspond to the respective Quickie Model functions X(15) and X(105).

Except for inputs required from the Trajectory Section, such as the average spacing within a ripple of bombs or dispensers, the ballistic errors on the ground, and, when appropriate, the aiming errors on the ground, the inputs for the Effectiveness Section come primarily from the Input/Output Section. The desired aiming mode (single or independent) is determined in the program by an indicator variable set in the Input/Output Section. The output, either X(14) or X(15), is fed back into the Optimization Section until an optimum is determined. This

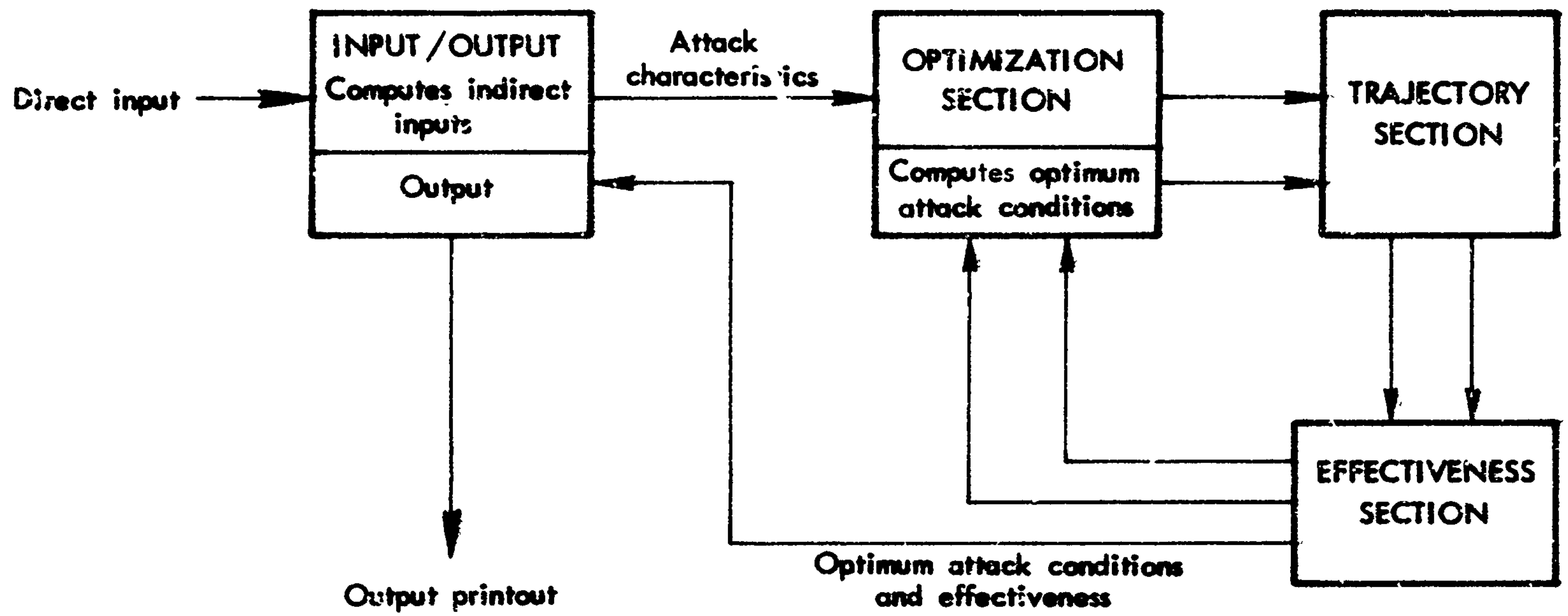

Fig. 2 — Flow diagram of Airbase Attack Model

optimum effectiveness, together with the optimum attack conditions, is then fed into the output part of the Input/Output Section.

C.2 Trajectory Section

The Trajectory Section routine is similar to the JMEM trajectory routine used on the Wang computer and given in Ref. 8. Using delivery condition inputs such as the dive angle, altitude, velocity, and intervalometer setting of the attacker, and the ballistic and aiming errors in mils, it provides as output the expected impact pattern of the ripple of weapons, and the ballistic and aiming errors on the ground. For our approximation in the Effectiveness Section, it provides an average spacing of weapons in the ripple rather than the exact impact point of each one. A printout of the JOSS Trajectory Section is contained in Appendix A.

C.3 Optimization Section

The Optimization Section is designed to obtain the intervalometer setting and spacing of attacking aircraft which, in some sense, maximize the effectiveness of a multiple-aircraft attack against a single target area. The parameters considered are the intervalometer setting d(0), in seconds, the lateral spacing between each attacker within a wave d(8), and the range spacing between waves d(7). A printout of the JOSS Optimization Section is contained in Appendix A.

The optimization model for the single-aim case is somewhat simpler and will be discussed first. In this case the lateral spacing d(8) is optimized first, using fixed values d(0) = 0.1 and d(7) = 600, to find the value of d(8) which maximizes the effectiveness as determined by the effectiveness subroutine. Then using this value of d(8), an optimum value of d(0) is obtained (the value of d(0) was restricted in the program to be between 0.1 and 0.5, representing the practical range of existing intervalometers; the range is easily changed if desired). Finally, using the optimum values of d(8) and d(0), the optimum value of d(7) is determined. The outputs from the Optimization Section are the optimal values d(0), d(7), and d(8) and the corresponding optimum effectiveness (fractional expected damage) X(15) or X(14). The optimum values thus obtained are not actual maximums because at each step only a conditional optimum is obtained for fixed values of the other two parameters. A more precise optimization would result from a second iteration. However, although a second iteration sometimes produced marginally better effectiveness results, there was no appreciable improvement in any of the cases tried. It was therefore felt that one iteration was sufficient for most purposes.

For the case of independent aim, a slightly different optimization model is used. Although the effectiveness model of the previous section gives a very good approximation to the fractional expected damage for any reasonable specified aiming point array, it cannot be used to determine the optimal spacing of attacks because it indicates that maximum effectiveness is achieved when all deliveries are aimed at the center of the target area. The reason for this anomaly is that the approximation used in determining the effectiveness is good only when the aiming points are fairly well uniformly scattered over the target area. For the case of all deliveries aimed at the center, the approximation is no longer valid. We therefore need to determine an "optimal" set of delivery conditions ($\underline{d(0)}$, $\underline{d(7)}$, and $\underline{d(8)}$) by some other means. For this we determine a "good" set of conditions by making the same second approximation for the independent case as for the single-aim case in subsection B.1 above.

First, as before, we approximate each attacker delivering $\underline{N(1)}$ weapons by a delivery of one superweapon with parameters $\underline{L(9)}$, $\underline{L(10)}$, and p_{dc}. As before, we view the multiple attack as consisting of $\underline{N(7)} \times \underline{N(8)}$ superweapons, with an aiming point array having a lateral spacing of $\underline{d(8)}$ and a range spacing of $\underline{d(7)}$. Following the same procedure as used before, we approximate this multiple attack by a single attack in which we have replaced the $\underline{N(7)} \times \underline{N(8)}$ rectangular patterns with one superpattern with parameters $\underline{2L(11)}$, $\underline{2L(12)}$, and $\underline{p^*_{dc}}$. The stick length $\underline{S(3)}$ and stick width $\underline{S(4)}$ are as given in Eq. (20). For the independent-aim case, however, the equivalent ballistic error for this superpattern is not zero but rather the aiming error for each individual attack, i.e., $\underline{t(1)}$ and $\underline{t(2)}$. Further, for this case the aiming error for the superattack is zero. The approximating parameters $\underline{L(11)}$, $\underline{L(12)}$, and $\underline{p^*_{dc}}$ are similar to Eq. (21) and are given by

$$L(11) = \sqrt{\frac{N(7)+1}{N(7)-1}\left(\frac{S(3)}{2}\right)^2 + L^2(9) + 3t^2(1)}\ , \qquad (26a)$$

$$L(12) = \sqrt{N(8)+1 \left(S(4)\right)^2 + \cdot^2(10) + 3t^2(2)}\ , \qquad (26b)$$

$$p^*_{dc} = 1 - \left(1 - p_{dc}\frac{L(9)L(10)n^*}{L(11)L(12)}\right)^{N(7)N(8)/n^*}\ , \qquad (26c)$$

where L(9), L(10), and p^*_{dc} are the appropriate approximating parameters for bombs or dispensers, and n^* is given by Eq. (22). The expression for effectiveness in this case is obtained from Eq. (6), using L(11) and L(12) instead of L(9) and L(10) and setting t(1) and t(2) equal to zero. From expressions contained in Ref. 3, it can be shown that the following limit holds:

$$\lim_{t\to\infty} F\left(\frac{u}{t}, \frac{L}{t}, \frac{A}{t}\right) = F^*(u,L,A) = \gamma(U + L,A) - \gamma(U - L,A) \qquad (27)$$

where

$$\left.\begin{array}{lll} \gamma(u,A) = 0 & \text{if} & u < -A \\ \gamma(u,A) = \frac{u+A}{2A} & \text{if} & -A \le u \le A \\ \gamma(u,A) = 1 & \text{if} & u > A \end{array}\right\} \qquad (28)$$

Thus, from Eq. (6), we obtain for this case

$$f_d(u,v) = p^*_{dc}\, F^*\left(u,L(11), A(1)\right) F^*\left(v,L(12), A(2)\right)\ , \qquad (29)$$

where F^* is defined in Eq. (27) and the parameters L(11), L(12), and p^*_{dc} in Eq. (26).

For the independent-aim case, then, we obtain our "good" delivery conditions d(0), d(7), and d(8) based on the effectiveness given in

Eq. (29). Through experience we found that delivery conditions d(0), d(7), and d(8) thus obtained were indeed close to optimum when used in the model for independent aim in subsection B.2. Thus the optimization routine uses the effectiveness as given in Eq. (29) to determine our choice of d(0), d(7), and d(8). We computed the final effectiveness, however, by entering these inputs into the model as given by Eqs. (24) and (25). The effectiveness answer obtained using Eq. (29) was not greatly in error, but we found that Eqs. (24) and (25) gave more precise results, where the standard of precision is the result given by the most complex model available. The "optimum" effectiveness, with respect to the delivery conditions, has a broad maximum, so that the "quasi-optimum" conditions obtained are sufficiently close for our purpose and probably are on the conservative side.

C.4 Input/Output Section

The Input/Output Section is the control section for the Airbase Attack Model. It requests needed inputs, computes others internally as needed, requests the attack allocation, directs the computations over the range of aircraft and over the areas of the target complex, assembles the outputs from the optimization section, and provides an output printout of the results of the attack, including the effectiveness in terms of the fractional damage to each area and the total expected number of hangarettes damaged.

A printout of the JOSS Input/Output Section (parts* 59 through 65) is contained in Appendix A. Part 59 is a direct input subroutine that requests the various general inputs required, such as the aiming mode, target vulnerability parameters, type of weapon, number, size, and contents of the target areas, dispenser parameters (where appropriate), and types of aircraft considered, including their delivery conditions, loadouts, and accuracies. Part 61 sets forth the characteristics of each aircraft type and directs the program over the different types

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*In a JOSS routine, all statements are numbered; a part N (an integer) consists of all statements (usually related) numbered between N and N+1. Thus part 59, for instance, consists of all statements numbered greater or equal to 59 and less than 60.

desired. Part 62 requests the allocation of attack aircraft to target areas and assigns the attack plan in terms of the number of waves and the number of aircraft per wave. The number of waves and the number of aircraft per wave for each target area are determined within the subroutine according to the number of aircraft allocated to the target area. Part 63 sets the hangarette vulnerable area. Part 64 directs the program computation over the various target areas, collects the fractional expected damage to each area, computes the total expected number of hangarettes damaged and prints these as the final results.

Part 65 directs, for each target area, the computation of the optimum effectiveness by the Optimization Section. For each area j, of which there may be up to four, it assigns the respective optimum fractional damage values. Further, it computes two sets of allocation indicators, W(j) and W(-j), which serve as a guide to determine the optimum allocation of attackers to areas. W(j) is an approximation to the increase in effectiveness for the respective target areas if two more attackers are added to the allocation against that area. W(-j) is an approximation to the decrease in effectiveness if two fewer attackers are allocated against that area. Thus, the optimum allocation of attackers is not built into the program but is accomplished by trial and error. An original guess is made for the initial allocation; a better allocation is then obtained from the allocation indicators. In general, the indicators provided a good criterion of optimum allocation. At times, when the indicators are close, the actual optimum might be slightly different, but the difference in effectiveness would be very slight. For each target area considered, a printout gives the optimum effectiveness X(j), the optimum conditions d(0), d(7), and d(8), and the values of the pair of allocation indicators W(j) and W(-j).

D. COMPUTATION RESULTS

The JOSS Airbase Attack Model was used to obtain attack effectiveness for the "standard" attack conditions given in Table 2 of Appendix B against the target complex discussed in general in Section II.A and specified in Appendix B. The basic results are in Appendix B, using "standard" parameter values and assumptions for the model. Also in

Appendix B, several variations in assumptions and parameters are given, varying one factor at a time to obtain some measure of the sensitivity of the results; the case of night or all-weather attacks is considered, for which the model is slightly different. The effect of variations in the delivery accuracy is discussed. All of these results are obtained either by direct use of the JOSS Airbase Attack Model or by very simple modifications in the model.

IV. RPV ATTACK

The remotely piloted vehicle (RPV) attack is patterned after the aircraft attack, so that direct comparisons can easily be made between the two types of attack. The Airbase Attack Model for aircraft attack is easily modified for the RPV case. The same basic target configuration is used; the hangarette areas, the type of hangarettes, and the types of weapons are the same. In general, the basic model for the RPV attack is based on independent attacks of either 4 or 16 RPVs against a particular hangarette area. Multiple attacks are considered in turn against each of the target areas. The final allocation of attacks between areas and the total expected damage from the whole attack are obtained by hand from the single-area attack results.

A. ATTACK CONDITIONS

Three basic attacking RPVs were modeled, the RMS II, RMS III, and RMS IV (see Ref. 7). For present purposes, the major differences are defined in terms of their respective loadout capabilities, i.e., weapons per RPV. For each of the three types of weapons considered (MK-82 bombs, REB-LEKs, and clustered Zuni rockets),* the same standard delivery conditions were assumed as for a comparable aircraft attack using the same weapon. If more than one weapon is carried per RPV, it was assumed that the weapons could be released at intervals, as for the aircraft attack. It was assumed that each RPV is independently aimed and that it is possible to choose an array of optimum aiming points for the whole attack. Table 19 in Appendix D gives a summary of the RPV weapon attack conditions considered "standard" for the RPV attack computations.

B. MULTIPLE ATTACK--SINGLE TARGET AREA

Multiple RPV attacks on a single area are treated similarly to aircraft attacks--we consider only attacks by the same type of RPVs using the same delivery conditions and type of weapons. Thus the attacks are considered identical except for the aiming points and aiming errors. Attacks are assigned to an area in terms of multiples of a

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*See Table 1 for descriptions.

unit number of weapons per attack, which differs slightly depending on the number N(1) and type of weapons carried per RPV. (The unit number must be divisible by N(1).) For instance, for N(1) = 4 dispensers, the attack unit number was 32 weapons (8 vehicles) and attacks were considered for 32, 64, 96, 128, and 164 weapons. For the results in Appendix D, the value for N(1) was 2, 6, or 8 for bombs, and 1, 4, and 5 for dispensers. However, the model allows a choice of N(1) from 1 to 20, except for the prime numbers 11, 13, 17, and 19. In all cases, an independent aim was assumed. Further, for any specific case, as for aircraft, the total array of aiming points was chosen to maximize the expected damage. However, the aiming point array was limited to not more than five aiming points on any lateral line of points of the array. No restriction was placed on the spacing of the array in range. The same optimization program used by the aircraft attack model was used, i.e., we optimized the effectiveness with respect to the interval between weapons, the range spacing, and the lateral spacing of the aim points.

It was found more expedient for the RPV attacks to consider each area separately, rather than obtain directly an optimum allocation between the different h arette target areas. Thus, the Airbase Attack Model is modified to consider a range of attacks for each area and the resulting expected damage, each based on its particular optimization. This modification results, for any case considered, in a table of results for each of the target areas, and these tables may then be used to obtain by hand an optimum allocation table and the corresponding values for the expected damage. There are thus two sets of tables for any particular case, the direct model output in terms of individual target area damage and a consolidated total damage table based on an optimum allocation between areas. Examples are shown in Tables 20 and 23 in Appendix D for an MK-82 RPV attack.

C. AIRBASE RPV ATTACK MODEL

The RPV Airbase Attack Model contains the same general subsections as the basic Airbase Attack Model described in Section III.C, and the flow diagram in Fig. 2 holds. The Input/Output Section has been somewhat changed because a different type of output is desired. In the JOSS computer model, only this subroutine has been significantly changed. The description of the Effectiveness and Trajectory Sections in Section III remain valid for the RPV model and use the JOSS subroutines in Appendix A. The Optimization Section is slightly changed and the JOSS subroutine is in Appendix C.

The Input/Output Section is similar to that in the aircraft attack model; it is the control section for the RPV attack model, requesting needed inputs, computing others internally where needed, directing the computations over the range of attack size, the different target areas, and the different types of RPVs. The output printout, in this case, is a table of the number of RPVs used, the number of weapons carried, the fractional expected damage, the expected number of hangarettes damaged, and the damage difference, according to target area and type of RPV. The damage difference column, used when determining the optimum allocation, gives the incremental expected damage for additional attacks on the particular area. A listing of the JOSS Input/Output Section is in Appendix C. Part 59, the direct input subroutine, is the same as for the aircraft case and is contained in Appendix A. Part 61 sets the characteristics of each RPV type and directs the program over the different types desired. Part 62 sets the unit number of attacking weapons, while part 63 sets the hangarette vulnerable area. Part 64 directs the computation over the various target areas, and for each area directs the attack over the multiples of the unit attacks. Part 65, for each area and each attack assignment, sets the attack plans in terms of the number of waves of RPVs and the number per wave, directs the computation of the optimum effectiveness by the Optimization Section, and prints out a table of results in terms of the expected fractional damage and the expected number of hangarettes damaged, area by area, as a function of the number of RPVs and weapons assigned. Note that for the RPV case, the area allocation indicators have been omitted, since the tables will be used to allocate between areas.

D. EFFECTIVENESS RESULTS FOR RPV ATTACKS

The JOSS RPV Airbase Attack Model was used to compute the attack effectiveness results for the conditions given in Table 19, Appendix D.

The basic results are in Appendix D, using "standard" parameter values and assumptions for the RPV model. Two variations explore the sensitivity of the results as one varies the vulnerability of the hangarettes and the hangarette density in the target areas.

Appendix A

AIRBASE ATTACK MODEL--AIRCRAFT ATTACK

This appendix contains the basic Airbase Attack JOSS program used for the aircraft attack computations. There is a complete listing of the basic program and a complete computer run for an attack on the hangarette complex with dispensers carrying REB-LEK weapons (see Table 8 in Appendix B). Examples of the model operation include both single-aim and independent-aim variations with the other parameters held constant. To compare the Airbase Attack Model and the Quickie Model, examples are shown that use the REB-LEK weapon, one type of aircraft only, and assume attack against only one area.

JOSS PROGRAM FOR AIRBASE ATTACK BY AIRCRAFT

As discussed in Section III, the Airbase Attack Model is divided into four main sections: (1) Input/Output, (2) Optimization, (3) Trajectory, and (4) Effectiveness; see Fig. 2 for a schematic flow diagram. To run the sensitivity variations in Appendix B, minor modifications were made as necessary to the basic computer model to vary the desired parameters. In most cases, these modifications are self-explanatory. For the case of random independent aiming points in variation (b), the index n(100) is set equal to 2; for the standard conditions, n(100) = 0 calls for the case of single aim, while n(100) = 1 calls for the independent-aim case. The use of the program is illustrated by the example on p. 49ff.

The JOSS Airbase Attack program is contained in special library JOSS file J0010.A1682. The subroutines comprising the aircraft-attack version are filed under two item names:

ABACinpt
ABACprog

The input section of the input/output subroutine is contained in ABACinpt, and the remaining subroutines are in ABACprog.

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Input/Output Routine

The direct input part of the input/output routine is filed as item ABACinpt. To obtain access to this subroutine, command "Recall ABACinpt from file J0010.A1682." It is activated by the command "Do part 59." The necessary direct inputs will be requested, part 59 will be deleted, and the remainder of the aircraft attack program will be recalled. The remainder of the input/output routine is contained in file item ABACprog in file J0010.A1682 and is composed of parts 60 through 65; these parts are the major portion of this subroutine and may be used over and over. To activate this portion, i.e., to make another computation without using the direct input part, change whichever inputs are desired and command "Do part 60." A listing of the input/output routine printout is presented on p. 40.

Optimization Routine

The optimization routine is organized in three parts, 96, 97, and 99. Part 96 optimizes the lateral spacing d(8). The intervalometer setting is set to d(0) = 0.1 and the range spacing d(7) = 600. The minimum spacing allowable for d(8) is 50 ft. Part 97 optimizes the intervalometer setting d(0), using the same value of d(7) = 600, but the optimum value of d(8). The value of d(0) is constrained to the interval 0.1 to 0.5 sec and is determined to the nearest tenth of a second. Part 99 optimizes the range spacing d(7). The minimum spacing for d(7) is 400 ft and the optimum spacing is determined to the nearest 100 ft. This subroutine is usually not used by itself; however, if it is desired to use it, the activation command is "Do part 96." A listing of this routine is given on p. 44.

Trajectory Routine

The trajectory routine is composed of parts 90, 91, and 92. Using delivery condition inputs such as dive angle, altitude, velocity, and intervalometer setting of the attacker, it computes expected impact points, impact angles, and slant ranges: it converts the slant ranges and the ballistic and aiming errors (in mils) to ballistic and aiming errors on the ground. The command to activate this subroutine is "Do part 90." A listing of the subroutine is given on p. 45.

Effectiveness Routine

The effectiveness routine is composed of parts 15, 16, 17, 18, and 19. It has been set up to compute the effectiveness of either dispensers (X(14)) or bombs (X(15)). Two primary aiming modes are available, depending on the value of the index n(100). Part 15 computes the effectiveness of either bombs or dispensers for a single-aim mode, as given in Section III.B. It is also used in the independent-aim mode (n(100) = 1) to determine the optimum spacing and intervalometer setting, as given in Section III.C. The final effectiveness computations for the independent-aim mode is then made using parts 16, 17, and 19, based on the results of Section III.B. As a special case, there is available a third aiming mode, random aim, which is computed if n(100) = 2. The command to activate this subroutine is "Do part 15." A listing of the effectiveness routine is given on p. 47.

Input/Output Routine

File Item ABACINPT, File J0010.A16822

```
59 **Inputs.
59.1 Set n=0.
59.11 Type "For independent aim, set aim index to 1;single aim, 0".
59.12 Demand  n(100) as "Aiming Method Index".
59.13 Line.
59.15 Type "If dispensers are used, set weapon index to 1; if bombs, 0".
59.16 Demand j as "Weapon Index".
59.17 Set k=[j=1:14;15].
59.175 Line.
59.18 Set n(k)=1.
59.19 Let n be sparse.
59.2 ***Target Inputs.
59.21 Type "One to four separate target areas may be used.".
59.215 Line.
59.22 Demand M as "Number of Target areas".
59.23 Set l=1.
59.235 Line.
59.24 Type l in form 90.
59.25 Demand A(10+l) as "Target Area in 10**6 sq ft".
59.26 Demand w(l) as "No of Shelters in Target Area".
59.265 Line.
59.27 To step 59.3 if l=M.
59.28 Set l=l+1.
59.29 To step 59.24.
59.3 Demand B(-1) as "Shelter Ground Plane Area".
59.31 Demand B(0) as "Vulnerability Ratio".
59.32 Demand p as "Weapon reliability".
59.33 To step 59.4 if n(15)=1.
59.34 Demand L(1) as "Dispenser Pattern Half Length, feet".
59.35 Demand L(2) as "Dispenser Pattern Half Width, feet".
59.36 Demand N(2) as "Number of Bomblets in Dispenser".
59.39 Line.
59.4 ***Aircraft Inputs.
59.41 Type "One to four aircraft types may be used.".
59.42 Demand I as "Number of aircraft types".
59.425 Line.
59.43 Set m=1.
59.44 Type m in form 91.
59.45 Demand N(-m) as "Number of Weapons".
59.46 Demand V(-m-1) as "Aircraft Speed, knots".
59.47 Demand y(-m-1) as "Aircraft Dive Angle, degrees".
59.48 Demand z(-m-1) as "Altitude of last weapon off, ft".
59.482 Demand u(-m) as "Outboard Station Offset, ft".
59.484 Demand v(100+m) as "Outboard Rack Throw Angle, degrees".
59.485 To step  59.5 if m>1.
59.49 Line.
59.491 Type "If aiming accuracy is specified as CEP in mils, set".
59.492 Type "accuracy index to 0; if CEP on ground,to 1; if REP".
59.493 Type "and DEP on ground to 2; if range and deflection ".
59.494 Type "standard deviation on the ground, to 3".
59.495 Demand t(0) as "Accuracy Index".
```

```
59.496 Line.
59.5 To step 59.55 if t(0)>0.
59.51 Demand t(10+m) as "CEP, mils".
59.52 To step 59.7.
59.55 To step 59.6 if t(0)>1.
59.56 Demand t(30+m) as "CEP, ground, feet".
59.57 To step 59.7.
59.6 To step 59.65 if t(0)=3.
59.61 Demand t(40+2*m-1) as "REP, feet".
59.62 Demand t(40+2*m) as "DEP, feet".
59.63 To step 59.7.
59.65 Demand t(50+2*m-1) as "Range St Dev, feet".
59.66 Demand t(50+2*m) as "Deflection St Dev, feet".
59.7 To step 59.8 if m=I.
59.71 Line.
59.75 Set m=m+1.
59.76 To step 59.44.
59.8 To part 60.

60.1 Delete part 59.
60.11 Recall ABACprog from file J0010.A1682.
```

File Item ABACPROG, file J0010.A1682

```
60.1 **Go.
60.11 **Go.
60.13 Type form 55 if n(100)=1.
60.14 Type form 56 if n(100)=0.
60.15 Line.
60.16 Set c=arg(-1,0)
60.2 To part 61.

61.05 **Aircraft Values.
61.1 Set m=1.
61.2 Set N(1)=N(-m).
61.21 Set V(-1)=V(-m-1).
61.22 Set v(-1)=v(-m-1).
61.23 Set z(-1)=z(-m-1).
61.24 Set u(4)=u(-m).
61.25 Set v(100)=v(100+m)*arg(-1,0)/180.
61.3 To step 61.4 if t(0)>0.
61.31 Set t(7) = t(10+m)/1.1774.
61.32 Set t(8)=t(7).
61.33 To step 61.7.
61.4 To step 61.5 if t(0)>1.
61.41 Set t(1)=t(30+m)/1.1774.
61.42 Set t(2)=t(1).
61.43 To step 61.7.
61.5 To step  61.6 if t(0)=3.
61.52 Set t(1)=t(40+2*m-1)/.6744.
61.53 Set t(2)=t(40+2*m)/.6744.
61.54 To step 61.7.
61.6 Set t(1)=t(50+2*m-1).
61.61 Set t(2)=t(50+2*m).
```

```
61.7 **Other Values.
61.9 Set N(3)=N(1).
61.91 Set N(6)=1.
61.915 Set N(4)=[u(4)=0:1;2].
61.92 Set N(10)=N(6)/N(4).
61.925 Set d(10)=u(4).
61.93 Set V(1)=6.
61.94 Set s(7)=5.
61.945 Set s(8)=5.
61.95 Set u(1)=0.
61.955 Set u(2)=0.
61.965 Set d(5)=2.
61.97 Do part 62.
61.98 Done if m=I.
61.985 Set m=m+1.
61.99 To step 61.2.

62.02 Line.
62.03 Type m in form 231.
62.05 Set l=1.
62.1 Type l in form 230.
62.11 Demand N(50+l) as "Planes Assigned".
62.12 Set N(7)=N(50+l).
62.13 Set N(100+2*l-1)=[N(7)=0:0;N(7)<=4:1;N(7)<=10:2;N(7)=12:3;N(7)>=16:4].
62.14 Set N(100+2*l)=[N(7)=0:0;N(7)/N(100+2*l-1)].
62.2 To step 62.4 if l=M.
62.25 Set l=l+1.
62.3 To step 62.1.
62.4 Line.
62.45 To part 63.

63.1 Set B(1)=sqrt(B(0)*B(-1))/2.
63.11 Set B(2)=B(1).
63.3 Do part 64.

64.1 Set d(7)=600.
64.11 Set X=0.
64.12 Let X be sparse.
64.13 Set W=0.
64.15 Set A(-1)=2.
64.2 Do part 65 for l=1(1)M.
64.205 Line.
64.21 Set X(5)=sum[l=1(1)M:w(l)*X(l)].
64.22 Type form 52.
64.23 Type form 53.
64.7 Type B(0),X(1),X(2),X(3),X(4),X(5) in form 51.
64.8 Line.

65.04 Type form 49 if l =1.
65.11 Type l in form 80.
65.14 Set A(2)=10**3*sqrt(A(10+l)/A(-1))/2.
65.15 Set A(1)=A(2)*A(-1).
65.2 Set N(7)=N(100+2*l-1).
65.21 Set N(8)=N(100+2*l).
65.22 To step 65.9 if N(7)*N(8)=0.
```

```
65.4 Do part 96.
65.41 Set X(1)=[n(15)=1:X(15);X(14)].
65.43 Set Z=(1-X(1))**(2/N(7)/N(8)).
65.44 Set W(1)=w(1)*(1-X(1))*(1-Z).
65.45 Set W(-1)=[Z=0:0;W(1)/Z].
65.456 To step 65.5 if N(7)*N(8)=1.
65.46 Type d(7),d(8),d(0),X(1),W(1),W(-1) in form 50.
65.47 Done.
65.5  Type _,_,d(0),X(1),W(1),W(-1) in form 50.
65.51 Done.
65.9 Set X(1)=0.
```

Optimization Routine

File Item ABACPROG, File J0010.A1682

```
96.06 To part 97 if n(100)=2.
96.1 Set d(0)=.1.
96.2 Set q=1.
96.21 Do part 90.
96.22 Set d(8)=q*50.
96.25 Do part 15.
96.26 Set T(q)=[n(15)=1:X(15);X(14)].
96.28 To step 96.4 if q=1.
96.3 To step 96.8 if T(q)<=T(q-1).
96.4 Set q=q+1.
96.41 To step 96.22.
96.8 Set d(8)=(q-1)*50.
96.801 To part 97.

97.11 Set q=1.
97.2 Set d(0)=q*.1.
97.3 Do part 90.
97.31 Do part 15.
97.4 Set T(q)=[n(15)=1:X(15);X(14)].
97.415 To step 97.5 if q=1.
97.42 To step 97.81 if T(q)<=T(q-1).
97.421 To step 97.9 if q=5.
97.5 Set q=q+1.
97.6 To step 97.2.
97.81 Set d(0)=(q-1)*.1.
97.82 To part 99.
97.9 Set d(0)=q*.1.
97.95 To part 99.

99.05 To step 99.96 if n(100)=2.
99.1 Set q=4.
99.12 Do part 90.
99.2 Set d(7)=q*100.
99.25 Do part 15.
99.26 Set T(q)=[n(15)=1:X(15);X(14)].
99.28 To step 99.4 if q=4.
99.3 To step 99.8 if T(q)<=T(q-1).
99.4 Set q=q+1.
99.41 To step 99.2.
99.8 Set d(7)=(q-1)*100.
99.96 Do part 90.
99.961 Do part 15.
99.97 Done if n(100)\=1.
99.98 Do part 16 if n(100)=1.
```

Trajectory Routine

File Item ABACPROG, file J0010.A1682

```
90.04 Set V(0)=V(-1)*1.689.
90.05 Set a=0.
90.055 Set b 0.
90.06 Set e=arg(-1,0)/180.
90.065 Set v(0)=v(-1)*e.
90.07 Set z(1)=z(-1)+(N(3)-1)*V(0)*d(0)*sin(v(0)).
90.09 Let v be sparse.
90.091 Let a be sparse.
90.092 Let b be sparse.
90.1 Set V(2)=sqrt[V(0)**2+V(1)**2].
90.25 Do part 91 for j=0.
90.26 Done if d(5)\=2.
90.3 Do part 91 for j=1,N(3).
90.31 Set t(9)=t(1)*.6744.
90.32 Set t(10)=t(2)*.6744.
90.34 Set D(3)=[max(j=1(1)N(1):a(j))-min(j=1(1)N(1):a(j))].
90.341 Set d(3)=[N(3)=1:0;D(3)/(N(3)-1)].
90.355 To step 90.365.
90.36 Set D(4)=[max(j=1(1)N(1):b(j))-min(j=1(1)N(1):b(j))].
90.365  Set D(4)=2*b(0).
90.366 Set d(4)=[N(4)=1:0;D(4)/(N(4)-1)].
90.371 Set d(9)=(d(4)-d(10))*(N(4)-1)/2.

91.05 To step 91.5 if j=0.
91.1 Set Z=(j-1)*V(0)*d(0).
91.11 Set z(j)=z(1)-Z*sin(v(0)).
91.12 Set x(j)=Z*cos(v(0)).
91.2 Do part 92 for k=1(1)N(6).
91.3 Done if j\=1.
91.35 Done if t(0)>0.
91.4 Set S=10**(-3)*sqrt[z(1)**2+a(0)**2].
91.41 Set t(2)=t(8)*S.
91.42 Set t(1)=t(7)*S/sin(v(1)).
91.45 Done.
91.5 Set Z=(N(3)-1)/2*V(0)*d(0).
91.51 Set x(0)=Z*cos(v(0)].
91.52 Set z(0)=z(1)-Z*sin(v(0)).
91.525 To step 91.55 if d(5)\=2.
91.53 Set v(4)=v(100).
91.54 Do part 92 for k=1.
91.55 Set v(4)=0.
91.56 Do part 92 for k=0.

92.2 Set i=[j=0:0;(j-1)*N(6)+k].
92.25 Set J=V(0)*sin(v(0))+V(1)*cos(v(0))*cos(v(i+4)).
92.26 Set v(3)=arg[sqrt(V(2)**2-J**2),J].
92.3 Set K=V(0)*cos(v(0))-V(1)*sin(v(0))*cos(v(i+4)).
92.31 Set v(2)=arg[K,V(1)*sin(v(i+4))].
92.32 Set Z=sqrt[V(2)**2*sin(v(3))**2+2*32.2*z(j)]-V(2)*sin(v(3)).
92.33 Set r(i)=V(2)*cos(v(3))*Z/32.2.
```

```
92.335 To step 92.4 if i=0.
92.35 Set a(i)=x(j)+r(i)*cos(v(2))-a(0).
92.355 Done.
92.36 Set b(i)=r(i)*sin(v(2))+u(i+4).
92.37 Done.
92.4 To step 92.6 if k=1.
92.41 Set a(0)=x(0)+r(0).
92.47 Set Y=Z/V(2)/cos(v(3))+sin(v(3))/cos(v(3)).
92.48 Set v(1)=arg[1,Y].
92.5 Set S=10**(-3)*sqrt[z(0)**2+r(0)**2].
92.51 Set s(1)=s(7)*S/sin(v(1)).
92.52 Set s(2)=s(8)*S.
92.53 Set s(3)=s(1).
92.54 Set s(4)=s(2).
92.55 Done.
92.6 Set b(0)=r(0)*sin(v(2))+u(4).
```

Effectiveness Routine

File Item ABACPROG, file J0010.A1682

```
15.16 Set L(5)=sqrt(N(3)**2-1)*d(3)/2.
15.17 Set L(6) =sqrt[N(4)**2-1]*d(4)/2.
15.18 Set L(11)=sqrt(N(7)**2-1)*d(7)/2.
15.19 Set L(12)=sqrt(N(8)**2-1)*d(8)/2.
15.20 Set B(5)=[n(15)=1:B(1);L(1)].
15.21 Set B(6)=[n(15)=1:B(2);L(2)].
15.22 Set s(5)=[n(15)=1:s(1);s(3)].
15.23 Set s(6)=[n(15)=1:s(2);s(4)].
15.24 Set L(7)=sqrt[3*s(5)**2+B(5)**2].
15.26 Set L(9)=sqrt[L(7)**2+L(5)**2].
15.27 Set L(10)=sqrt[L(6)**2+B(6)**2+3*s(6)**2+2*d(9)**2].
15.271 To step 15.28 if n(100)=0.
15.272 Set L(3)=sqrt[L(9)**2+L(11)**2+3*t(1)**2].
15.273 Set L(4)=sqrt[L(10)**2+L(12)**2+3*t(2)**2].
15.274 Set K=F(u(1),L(3),A(1),0)*F(u(2),L(4),A(2),0).
15.275 To step 15.31.
15.28 Set L(3)=sqrt[L(9)**2+L(11)**2].
15.29 Set L(4)=sqrt[L(10)**2+L(12)**2].
15.30 Set K=F(u(1),L(3),A(1),t(1))*F(u(2),L(4),A(2),t(2)).
15.31 Set o(1)=min[L(9)/L(7),N(3)].
15.33 Set o(3)=min[L(3)/L(9),N(7)].
15.34 Set o(4)=min[L(4)/L(10),N(8)].
15.35  Set P(1)=[n(15)=1:p;1-(1-p*B(1)*B(2)/L(1)/L(2))**N(2)].
15.36 Set Q(1) =1-P(1)*B(5)*B(6)/L(9)/L(10)*o(1).
15.37 Set P(2)=1-Q(1)**(N(3)/o(1)).
15.371 To part 18 if n(100)=2.
15.38 Set Q(2)=1-P(2)*L(9)*L(10)/L(3)/L(4)*o(3)*o(4).
15.385 Set Q(2)=[Q(2)<0:0;Q(2)>1:1;Q(2)].
15.39 Set Z=K*[1-Q(2)**(N(7)*N(8)/o(3)/o(4))].
15.40 Set X(15)=Z if n(15)=1.
15.41 Set X(14)=Z if n(14)=1.

16.05 Let K(i,j)=F(a(i),L(9),A(1),t(1))*F(b(j),L(10),A(2),t(2)).
16.06 Do part 17 for i=1(1)N(8).
16.07 Do part 19 for j=1(1)N(7).
16.1 Set Z=prod[i=1(1)N(7):prod[j=1(1)N(8):1-P(2)*K(i,j)]].
16.2 Set X(15)=1-Z if n(15)=1.
16.3 Set X(14)=1-Z if n(14)=1.

17.2 Set b(i)=[2*(i-1)+1-N(8)]*d(8)/2.

18.2 Set K=F(0,A(1),A(1),t(1))*F(0,A(2),A(2),t(2)).
18.25 Set J=F(0,L(9),A(1),0)*F(0,L(10),A(2),0).
18.3 Set X(15)=1-exp(-N(7)*N(8)*P(2)*J*K).
18.4 Set X(14)=X(15) if n(14)=1.

19.1 Set a(j)=[2*(j-1)+1-N(7)]*d(7)/2.
```

Formulas

```
Let E(x,L,s)=[s\=0:H(x/s,L/s);x<-L:0;x>L:1;(x+L)/2/L].
Let F(x,y,L,s)=E(x+y,L,s)-E(x-y,L,s).
Let G(x)=.5+.5*sgn(x)*[1-exp(-2*[x-x**3/(140+1.8*x**2+.6*x**4)]**2/c)]**.5.
Let H(x,L)=[L=0:G(x);[(x+L)*G(x+L)-(x-L)*G(x-L)+g(x+L)-g(x-L)]/2/L].
Let f(x,y,s)=[s\=0:G((x+y)/s)-G((x-y)/s);|x|<=y:1;0].
Let g(x)=exp(-x*x/2)/sqrt(2*3.14159).
Let h(x,L)=[L=0:g(x);f(x,L,1)/2/L].
```

EXAMPLE OF USE OF AIRBASE ATTACK PROGRAM

To give an example of the operation of the Airbase Attack Model, the following pages give the complete set of commands, input data, and output printout for the case of an attack of 16 aircraft carrying dispensers containing 16 REB-LEKs. Input data are as indicated in Tables 1 and 2, and output data are as shown in Table 8, Appendix B. The computations are for single aim in Example 1a and for independent aim in Example 1b.

***Example 1a: REB-LEK Attack, Single Aim**

```
Recall ABACINPT from file J0010 A1662

Done.

Do part 59

For independent aim, set aim index to 1;single aim, 0
Aiming Method Index = 0

If dispensers are used, set weapon index to 1; if bombs, 0
Weapon Index = 1

One to four separate target areas may be used.

Number of Target areas = 3

      Area 1
Target Area in 10**6 sq ft = 1
No of Shelters in Target Area = 12

      Area 2
Target Area in 10**6 sq ft = 2
No of Shelters in Target Area = 12

      Area 3
Target Area in 10**6 sq ft = 4
No of Shelters in Target Area = 16

Shelter Ground Plane Area = 2450
Vulnerability Ratio = .706
Weapon reliability = .95
Dispenser Pattern Half Length, feet = 200
Dispenser Pattern Half Width, feet = 200
Number of Bomblets in Dispenser = 16
One to four aircraft types may be used.
Number of aircraft types = 4

      Aircraft Type 1
Number of Weapons = 8
Aircraft Speed, knots = 450
Aircraft Dive Angle, degrees = 0
Altitude of last weapon off, ft = 500
Outboard Station Offset, ft = 11
Outboard Back Throw Angle, degrees = 58.5

If aiming accuracy is specified as CEP in mils, set
accuracy index to 0; if CEP on ground,to 1; if REP
and DEP on ground to 2; if range and deflection
standard deviation on the ground, to 3
Accuracy Index = 2

REP, feet = 300
DEP, feet = 40

      Aircraft Type 2
```

Number of Weapons = 12
Aircraft Speed, knots = 450
Aircraft Dive Angle, degrees = 0
Altitude of last weapon off, ft = 500
Outboard Station Offset, ft = 11
Outboard Rack Throw Angle, degrees = 45
REP, feet = 300
DEP, feet = 40

Aircraft Type 3
Number of Weapons = 17
Aircraft Speed, knots = 450
Aircraft Dive Angle, degrees = 0
Altitude of last weapon off, ft = 500
Outboard Station Offset, ft = 15
Outboard Rack Throw Angle, degrees = 45
REP, feet = 300
DEP, feet = 40

Aircraft Type 4
Number of Weapons = 11
Aircraft Speed, knots = 450
Aircraft Dive Angle, degrees = 0
Altitude of last weapon off, ft = 500
Outboard Station Offset, ft = 45
Outboard Rack Throw Angle, degrees = 45
REP, feet = 300
DEP, feet = 40

Single Aim

Aircraft Type 1

AREA 1
Planes Assigned = 6
AREA 2
Planes Assigned = 6
AREA 3
Planes Assigned = 4

	Range	Width	Interv	Fraction	Indicators	
Area 1	600	200	.20	.502	1.24	1.56
Area 2	700	300	.20	.365	1.07	1.25
Area 3	400	350	.30	.165	1.15	1.26

	Vulner Ratio	Fract Area 1	Fract Area 2	Fract Area 3	Fract Area 4	Expected No Damaged	
******	.706	.502	.365	.165	.000	13.06	******

Aircraft Type 2

AREA 1
Planes Assigned = 6
AREA 2
Planes Assigned = 6
AREA 3
Planes Assigned = 4

	Range	Width	Interv	Fraction	Indicators	
Area 1	400	200	.20	.617	1.26	1.73
Area 2	400	350	.20	.466	1.21	1.49
Area 3	400	350	.20	.231	1.51	1.73

	Vulner Ratio	Fract Area 1	Fract Area 2	Fract Area 3	Fract Area 4	Expected No Damaged	
******	.706	.617	.466	.231	.000	16.69	******

Aircraft Type 3

AREA 1
Planes Assigned = 6
AREA 2
Planes Assigned = 4
AREA 3
Planes Assigned = 6

	Range	Width	Interv	Fraction	Indicators	
Area 1	800	250	.10	.709	1.18	1.78
Area 2	400	250	.10	.428	1.67	2.21
Area 3	400	450	.20	.409	1.52	1.81

	Vulner Ratio	Fract Area 1	Fract Area 2	Fract Area 3	Fract Area 4	Expected No Damaged	
******	.706	.709	.428	.409	.000	20.18	******

Aircraft Type 4

AREA 1
Planes Assigned = 6
AREA 2
Planes Assigned = 6
AREA 3
Planes Assigned = 4

	Range	Width	Interv	Fraction	Indicators	
Area 1	400	200	.20	.593	1.26	1.71
Area 2	500	350	.20	.441	1.18	1.43
Area 3	400	350	.30	.213	1.42	1.60

	Vulner Ratio	Fract Area 1	Fract Area 2	Fract Area 3	Fract Area 4	Expected No Damaged	
******	.706	.593	.441	.213	.000	15.83	******

***Example 1b: REB-LEK Attack, Independent Aim**

n(100)=1

Do part 60
Independent Aim

Aircraft Type 1

AREA 1
Planes Assigned = 6
AREA 2
Planes Assigned = 6
AREA 3
Planes Assigned = 4

	Range	Width	Interv	Fraction	Indicators	
Area 1	400	150	.10	.534	1.26	1.62
Area 2	400	300	.20	.367	1.07	1.25
Area 3	400	350	.40	.154	1.08	1.18

	Vulner Ratio	Fract Area 1	Fract Area 2	Fract Area 3	Fract Area 4	Expected No Damaged	
******	.706	.534	.367	.154	.000	13.28	******

Aircraft Type 2

AREA 1
Planes Assigned = 6
AREA 2
Planes Assigned = 6
AREA 3
Planes Assigned = 4

	Range	Width	Interv	Fraction	Indicators	
Area 1	400	200	.10	.640	1.25	1.75
Area 2	400	300	.10	.461	1.20	1.48
Area 3	400	350	.20	.216	1.44	1.62

	Vulner Ratio	Fract Area 1	Fract Area 2	Fract Area 3	Fract Area 4	Expected No Damaged	
******	.706	640	.461	.216	.000	16.66	******

Aircraft Type 3

AREA 1
Planes Assigned = 6
AREA 2
Planes Assigned = 4
AREA 3
Planes Assigned = 6

	Range	Width	Interv	Fraction	Indicators	
Area 1	400	200	.10	.745	1.12	1.77
Area 2	400	200	.10	.443	1.70	2.27
Area 3	400	450	.20	.392	1.49	1.76

	Vulner Ratio	Fract Area 1	Fract Area 2	Fract Area 3	Fract Area 4	Expected No Damaged	
******	.706	.745	.443	.392	.000	20.53	******

Aircraft Type 4

AREA 1
Planes Assigned = 6
AREA 2
Planes Assigned = 6
AREA 3
Planes Assigned = 4

	Range	Width	Interv	Fraction	Indicators	
Area 1	400	200	.10	.612	1.26	1.73
Area 2	400	300	.10	.435	1.18	1.42
Area 3	400	350	.30	.199	1.35	1.50

	Vulner Ratio	Fract Area 1	Fract Area 2	Fract Area 3	Fract Area 4	Expected No Damaged	
******	.706	.612	.435	.199	.000	15.75	******

EXAMPLES COMPARING THE AIRBASE AND QUICKIE MODELS

For this comparison, we will use the same case as above, but will consider only the F-4 aircraft attacking Area 1. The attacks are by one F-4 and by six F-4s against Area 1, both in the single-aim mode. We will use the intervalometer setting of 0.2 obtained in the appropriate part of Example 1a and the optimum spacing obtained there for the attack of six aircraft.

Single Attack by an F-4 Against Area 1

We consider a single delivery of eight REB-LEK dispensers, each containing 16 REB-LEKs, by an F-4 flying straight and level at 500 ft altitude, speed of 450 kn, with an intervalometer setting of 0.2 sec. In Example 2a, we show the complete JOSS Quickie run for this case; note that here we are determining the exact expected impact point for each dispenser. The fractional damage obtained against Area 1, given by X(105) in Example 3, is X(105) = 0.132. In Example 2b, we use the Airbase Attack Model for this same case, obtaining the expected fractional damage F(1) to Area 1 as F(1) = 0.133. Not all cases examined were this close, but in general the Quickie and Airbase Attack answers differed only in the third decimal. It was felt that the approximations used in the Airbase Model were accurate enough for our purposes.

***Example 2a: Single F-4 REB-LEK Attack Against Area 1, Quickie Model**

```
Recall QKinput from file J0010.A1662

Done.

Do part 2

INPUT INSTRUCTIONS
If no input instructions are desired, set K=1; otherwise
set K=0
           K = 1

Problem Desired = 105


Area Length, Range, CAP-A(3) = 1000*sqrt(2)
Area Width, Defl., CAP-A(4) = 500*sqrt(2)
Target Element Index, CAP-E(-1) = 2
Dispenser Rect Pattern Half Length, CAP-L(3) = 200
Dispenser Rect Pattern Half Width, CAP-L(4) = 200
Total Number of Weapons, CAP-N(1) = 8
Number of Bomblets per Dispenser, CAP-N(2) = 16
Number of Impulses, CAP-N(3) = 8
Number of Wing Stations, CAP-N(4) = 2
Number of Weapons/Station/Impulse, CAP-N(5) = 1
DPI Coordinate flag d(5) = 2
Initial Velocity, knots, CAP-V(-1) = 450
Dive Angle, degrees, v(-1) = 0
Pullout Altitude, feet, z(-1) = 500
Intervalometer setting, seconds, d(20) = .2
Range Ballistic Sd Dev, mils, s(7) = 5
Defl Ballistic Sd Dev, mils, s(8) = 5
Range Aiming Sd Dev, mils, t(7) = 20
Defl Aiming Sd Dev, mils, t(8) = 20
Rack Ejection Velocity, feet/sec,CAP-V(1) = 6
Wing Station  1
Station offset, feet, w(j) = 11
Wing Station  2
Station offset, feet, w(j) = -11
Drag Index, Cap-V(10) = 0
        a(1) =     -532.035
        a(2) =     -380.025
        a(3) =     -228.015
        a(4) =      -76.005
        a(5) =      116.30241
        a(6) =      268.31241
        a(7) =      420.32241
        a(8) =      572.33241
a is sparse
        b(1) =       11
        b(2) =      -11
        b(3) =       11
        b(4) =      -11
        b(5) =      -16.0909133
        b(6) =      -38.0909133
        b(7) =      -16.0909133
        b(8) =      -38.0909133
```

```
b is sparse
        s(3) =       89.7511316
        s(4) =       20.6336907
        t(1) =      404.98662
        t(2) =       93.1059974
Impact Angle  13.3 degrees
Vulnerable Area, Ground Plane, CAP-b(0) = _706*2450
Number of Integration Steps, Range,CAP-U(1) = 8
Number of Integration Steps, Defl, CAP-U(2) = 8
Target Offset, Range u(1) = 0
Target Offset, Defl  u(2) = 0
Weapon Reliability = .95
Dispenser Reliability = 1


        t(1) = 300/ 6744
        t(2) = 40/ 6744


The S(j)s are the partial integration sums in the y direction

      j         S(j)
      1       .00000960
      2       .00160353
      3       .02738769
      4       .09430901
      5       .15944994
      6       .19344207
      7       .19269397
      8       .18280318
      9       .18183028
     10       .18928706
     11       .19549726
     12       .17343646
     13       .11417762
     14       .04403740
     15       .00440701
     16       .00065463
      X(105) =          .132415969
```

***Example 2b: Single F-4 REB-LEK Attack Against Area 1, Airbase Model**

The general inputs are the same as in Example 1a, except that we use only one aircraft--an F-4--and attack only Area 1.

```
I=1

Do part 61

                        Aircraft Type 1
         AREA 1
Planes Assigned = 1
         AREA 2
Planes Assigned = 0
         AREA 3
Planes Assigned = 0

         Range Width Interv   Fraction        Indicators
Area 1
                       20        .133        2.58     3.43
Area 2
Area 3

         Vulner      Fract  Fract    Fract  Fract     Expected
         Ratio       Area 1 Area 2   Area 3 Area 4    No Damaged
******   .706        .133   .000     .000   .000         1.59   ******
```

Attack of Six F-4s Against Area 1

We next took the optimum attack conditions obtained in Example 1 for the case of an F-4 attack using REB-LEKs, and compared the results of the Airbase Attack Model with those of the Quickie Model. The fractional damage against Area 1 using the Airbase Attack Model is contained in the results of Example 1a. For convenience we have rerun this case to consider only aircraft assigned to Area 1, as shown in Example 3b. From the Airbase run for a single attack, we find the pattern dimensions to be L(3) = 654, L(4) = 214. From Example 1a, the optimum conditions were an intervalometer setting of 0.2 sec, a lateral spacing of 200 ft, and a range spacing of 600 ft, with two waves of three attackers abreast. Example 3a gives the JOSS Quickie run for this case; the inputs shown are the changes from the ones used in Example 1a. The Airbase Attack Model gave a fractional damage F(1) = 0.502, and the Quickie run gave an answer of X(106) = 0.501. Again, not all cases gave this good an approximation, but, as for the single-attack case, it was felt that the approximations used in the Airbase Attack Model were sufficiently accurate for our purposes. We have presented these examples only to indicate the type of checking which was done. If one wished to consider a change in parameters, further runs on JOSS would be easy to accomplish.

***Example 3a: 6 F-4s with REB-LEKs Against Area 1, Quickie Model**

(Changes in inputs from Example 2a)

```
n(105)=0
n(106)=1

L(3)=654
L(4)=214
N(1)=6
N(2)=128
N(3)=6

Delete a,b

a(1)=300
a(2)=300
a(3)=300
a(4)=-300
a(5)=-300
a(6)=-300

b(1)=200
b(2)=0
b(3)=-200
b(4)=200
b(5)=0
b(6)=-200

Do part 3

The S(j)s are the partial integration sums in the y direction

     j        S(j)
     1      .44577334
     2      .44577334
     3      .44577334
     4      .44577334
     5      .44577334
     6      .67870879
     7      .67870879
     8      .67870879
     9      .67870879
    10      .67870879
    11      .67870885
    12      .44577334
    13      .44577334
    14      .44577334
    15      .44577334
    16      .44577334
     X(106) =          .500776306
```

***Example 3b: 6 F-4s with REB-LEKs Against Area 1, Single Aim, Airbase Model**

I=1

*only one type of aircraft considered

*6 F-4s, single aim same inputs otherwise as Example 1a

Do part 61

Aircraft Type 1

AREA 1
Planes Assigned = 6
AREA 2
Planes Assigned = 0
AREA 3
Planes Assigned = 0

	Range	Width	Interv	Fraction	Indicators	
Area 1	600	200	.20	.502	1.24	1.56
Area 2						
Area 3						

	Vulner Ratio	Fract Area 1	Fract Area 2	Fract Area 3	Fract Area 4	Expected No Damaged	
******	.706	.502	.000	.000	.000	6.03	******

Appendix B

AIRCRAFT ATTACK COMPUTATION RESULTS

The JOSS Airbase Attack Model was used to obtain attack effectiveness for the "standard" attack conditions given in Table 2 against a target complex consisting of three areas of hangarettes, as discussed in Section II.A; the computation results are reported in this appendix. Figure 1 shows the airfield complex schematic used for the computations. We first give the basic results using standard parameter values and assumptions for the model. Then several variations in assumptions and parameter values are considered, varying one factor at a time to obtain some measure of the sensitivity of the results. Finally, the case is analyzed of night or all-weather attacks, for which the model is slightly different. In this appendix we also consider the effect of variation in the assumption of the delivery accuracy. All of these results are obtained either by direct use of the JOSS Airbase Attack Model or by very simple modifications in the model.

Three basic attacking aircraft were modeled: the F-4, A-7, and F-111. Two combat radii were considered for the F-111: 300 n mi and 500 n mi. The long-distance F-111 carried a smaller load due to the requirement for extra external fuel tanks. The major difference between the three aircraft was defined in terms of their loadout capability, although differences in aiming accuracy were also introduced. For each weapon type, a standard set of delivery conditions was assumed. Delivery accuracy estimates were made for each weapon-aircraft combination. In general, low-drag bombs were delivered in a dive mode at relatively high altitude, high-drag bombs and rockets were delivered at low altitude, and the area weapons in either a high dive mode or at low level depending on the type of subweapon. For the high-altitude delivery, the accuracy was assumed to be given in mils normal to the trajectory, i.e., a 20-mil CEP for the F-4 and a 15-mil CEP for both the A-7 and F-111. In all cases a gaussian error was assumed. For each bomb or dispenser the ballistic error standard deviation was assumed to be 5 mils, also with a gaussian distribution. For the low-level attacks,

Table 2

INDIVIDUAL AIRCRAFT-WEAPON LOADOUT AND DELIVERY[a]

Weapon	B(0)[b]	No. Dispensers	Loadout (No. Weapons or Dispensers)				Delivery			Accuracy[c]
			F-4	A-7	F-111 (300 n mi radius)	F-111 (500 n mi radius)	Angle (deg)	Velocity (ft/sec)	Altitude (ft)	F-4/F-7, F-111
Bombs, low-drag										
M-117HE	1.26		10	12	18	12	45	450	6500	20/15 mils
MK-81HE	1.10		17	35	47	33	45	450	6500	20/15 mils
MK-82HE	1.20		11	20	30	20	45	450	6500	20/15 mils
MK-83HE	1.30		3	5	7	5	45	450	6500	20/15 mils
MK-84HE	1.44		3	4	7	5	45	450	6500	20/15 mils
High-density	1.0		11	20	28	19	45	450	6500	20/15 mils
FAE bomb	1.0		2	4	6	5	45	450	6800	20/15 mils
Bombs, high-drag										
M-117R	0.88		8	11	15	10	0	450	500	300 ft REP, 40 ft DEP
MK-82SE	0.77		11	17	26	17	0	450	500	300 ft REP, 40 ft DEP
Rockets										
Zuni	1.0	4	8	17	23	16	0	450	500	140 ft REP, 35 ft DEP
Clustered Zuni	1.0	7	8	12	19	12		450	500	300 ft REP, 40 ft DEP
Area munitions										
Rebit, 115-lb	0.7	6	8	11	16	11	45	450	6500	20/15 mils
Rebit, 50-lb	0.7	13	10	12	18	12	45	450	6500	20/15 mils
REB-LEK, 40-lb	0.7	16	8	12	17	11	0	450	500	300 ft REP, 40 ft DEP
Follow-through shaped-charge, medium	1.0	16	8	12	17	11	0	450	300	270 ft REP, 70 ft DEP
Follow-through shaped-charge, heavy	1.0	5	8	13	19	12	0	450	300	270 ft REP, 70 ft DEP
FAE bomblet	1.0	3	11	20	30	20	0	450	300	270 ft REP, 70 ft DEP

[a] One ECM pod is included on each mission.

[b] Ratio of the vulnerable area of the hangarette to the basic floor plan area.

[c] For all bombs and dispensers, a gaussian ballistic error of 5 mils was used.

the ballistic errors were as above, but the aiming errors were specified for each weapon in terms of the REP and DEP on the ground, assuming a bivariate gaussian distribution. Table 2 summarizes, for each weapon, the loadout assumed for each attacking aircraft and the corresponding aiming and ballistic errors. These conditions will be referred to as standard attack conditions.

BASIC RESULTS

Tables 3 through 9 give the JOSS computer results for the basic aircraft-weapon attack conditions of Table 2 as obtained from the Airbase Attack Model.. For each weapon and attack condition, we show the results for three aircraft--the F-4, A-7, and F-111--with two loadout conditions for the F-111, depending on the number of external fuel tanks carried. In general, two attack aiming modes are considered: the single-aim or aim-on-leader case and the independent-aim case. For each aiming mode, the optimum allocation of aircraft for an attack force of 16 aircraft and the optimum intervalometer setting and aircraft spacing for each area attacked of the total target complex are given. The expected fractional damage is given for each area and the expected number of hangarettes damaged is given for the total complex. The results of high-level day attacks with bombs and similar weapons are presented in Tables 3, 4, and 5. Table 6 shows the effectiveness results for high-level attacks by dispensers containing Rebits, which are high-density penetrators. A standard pattern area of 400 by 400 ft was used for dispensers since this pattern size was usually close to optimum and it was felt that design of such a pattern was achievable. The effectiveness of low-level high-drag bombs is given in Table 7. Table 8 contains results of low-level dispenser attacks using REB-LEKs, shaped-charge bomblets (follow-through munitions), and an FAE bomblet. For the medium-sized shaped-charge bomblet, there was considerable doubt because of the standoff problem as to its effectiveness in penetrating the layer of dirt or sand assumed to cover the hangarette. Thus separate computations for the dispenser containing 16 of these subweapons were not presented, since they would be about as effective as the REB-LEK if the munition functioned properly. Finally, the results for rocket attacks are given in Table 9, both for a pod of four Zunis and for a

Table 3

HIGH-ALTITUDE DAY ATTACKS: M-117 AND MK-81 BOMBS

(Release altitude 6500 ft, dive angle 45 deg)

Weapon	A/C	Aim Mode	N(1) No. A/C	Allocation	Area 1			Area 2			Total X(4)
					Intv[a]	Spacing[b]	X(1)	Intv	Spacing	X(2)	
M-117	F-4	Single	10	10/6/0	0.2	100/600	0.197	0.3	200/700	0.077	3.30
B(0) = 1.26	A-7	Single	12	10/6/0	0.2	100/600	0.248	0.3	250/800	0.095	4.11
	F-111	Single	18	10/6/0	0.2	100/600	0.329	0.3	250/600	0.134	5.55
	F-111	Single	12	10/6/0	0.2	100/600	0.248	0.3	250/800	0.095	4.11
	F-4	Indep.	10	10/6/0	0.3	50/600	0.214	0.4	250/800	0.074	3.45
	A-7	Indep.	12	10/6/0	0.3	100/600	0.248	0.5	250/700	0.089	4.05
	F-111	Indep.	18	10/6/0	0.2	100/600	0.339	0.2	300/800	0.126	5.59
	F-111	Indep.	12	10/6/0	0.3	100/600	0.248	0.5	250/700	0.089	4.05
MK-81	F-4	Single	17	10/6/0	0.2	100/600	0.261	0.2	250/700	0.109	4.43
B(0) = 1.1	A-7	Single	35	10/6/0	0.1	150/600	0.459	0.2	250/400	0.204	7.96
	F-111	Single	47	10/6/0	0.1	150/600	0.535	0.1	300/800	0.263	9.58
	F-111	Single	33	10/6/0	0.1	150/600	0.443	0.2	250/500	0.196	7.66
	F-4	Indep.	17	10/6/0	0.2	50/500	0.295	0.2	250/700	0.106	4.82
	A-7	Indep.	35	10/6/0	0.1	100/600	0.481	0.2	250/600	0.197	8.14
	F-111	Indep.	47	10/6/0	0.1	50/400	0.610	0.1	250/900	0.247	10.28
	F-111	Indep.	33	10/6/0	0.1	100/600	0.466	0.2	250/600	0.190	7.88

[a]Intervalometer setting, sec.

[b]The first value is the lateral spacing between aircraft; the second value is the range spacing between waves of attacking aircraft.

Table 4

HIGH-ALTITUDE DAY ATTACKS: MK-82 AND MK-83 BOMBS

(Release altitude 6500 ft, dive angle 45 deg)

Weapon	A/C	Aim Mode	N(1) No. A/C	Allocation	Area 1			Area 2			Total X(4)
					Intv[a]	Spacing[b]	X(1)	Intv	Spacing	X(2)	
MK-82 B(0) = 1.2	F-4	Single	11	10/6/0	0.2	100/500	0.205	0.4	200/600	0.080	3.41
	A-7	Single	20	10/6/0	0.2	100/600	0.338	0.2	250/800	0.142	5.97
	F-111	Single	30	10/6/0	0.1	150/600	0.442	0.2	250/700	0.189	7.83
	F-111	Single	20	10/6/0	0.2	100/600	0.338	0.2	250/800	0.134	5.90
	F-4	Indep.	11	10/6/0	0.2	50/600	0.225	0.3	250/600	0.079	3.64
	A-7	Indep.	20	10/6/0	0.2	100/500	0.358	0.3	250/700	0.134	5.90
	F-111	Indep.	30	10/6/0	0.1	100/600	0.464	0.2	250/700	0.189	7.83
	F-111	Indep.	20	10/6/0	0.2	100/500	0.358	0.3	250/700	0.134	5.90
MK-83 B(0) = 1.3	F-4	Single	3	10/6/0	0.5	50/500	0.075	0.5	150/700	0.026	1.22
	A-7	Single	5	10/6/0	0.5	100/500	0.125	0.5	250/700	0.043	2.01
	F-111	Single	7	10/6/0	0.4	100/600	0.165	0.4	250/700	0.059	2.69
	F-111	Single	5	10/6/0	0.5	100/500	0.125	0.5	250/700	0.043	2.01
	F-4	Indep.	3	10/6/0	0.5	50/700	0.078	0.5	250/400	0.025	1.23
	A-7	Indep.	5	10/6/0	0.5	100/700	0.123	0.5	250/500	0.042	1.98
	F-111	Indep.	7	10/6/0	0.4	100/600	0.167	0.4	300/600	0.056	2.68
	F-111	Indep.	5	10/6/0	0.5	100/700	0.123	0.5	250/500	0.042	1.98

[a] Intervalometer setting, sec.

[b] The first value is the lateral spacing between aircraft; the second value is the range spacing between waves of attacking aircraft.

Table 5

HIGH-ALTITUDE DAY ATTACKS: MK-84 AND HIGH-DENSITY PENETRATOR BOMBS

(Release altitude 6500 ft, dive angle 45 deg)

Weapon	A/C	Aim Mode	N(1) No. A/C	Allocation	Area 1			Area 2			Total X(4)
					Intv[a]	Spacing[b]	X(1)	Intv	Spacing	X(2)	
MK-84 B(0) = 1.44	F-4	Single	3	10/6/0	0.5	50/500	0.083	0.5	200/700	0.028	1.33
	A-7	Single	4	10/6/0	0.5	100/500	0.113	0.5	200/800	0.038	1.81
	F-111	Single	7	10/6/0	0.4	100/600	0.181	0.4	250/700	0.065	2.95
	F-111	Single	5	10/6/0	0.5	100/500	0.136	0.5	250/700	0.047	2.21
	F-4	Indep.	3	10/6/0	0.5	50/700	0.086	0.5	250/600	0.028	1.36
	A-7	Indep.	4	10/6/0	0.5	100/700	0.112	0.5	250/400	0.038	1.79
	F-111	Indep.	7	10/6/0	0.4	100/600	0.183	0.5	300/800	0.062	2.93
	F-111	Indep.	5	10/6/0	0.5	100/700	0.135	0.5	250/1000	0.046	2.17
High-density B(0) = 1.0	F-4	Single	11	10/6/0	0.2	100/500	0.177	0.3	200/700	0.068	2.95
	A-7	Single	20	10/6/0	0.2	100/500	0.297	0.3	250/500	0.118	4.99
	F-111	Single	28	10/6/0	0.1	100/600	0.377	0.2	250/600	0.154	6.43
	F-111	Single	19	10/6/0	0.2	100/500	0.287	0.3	250/600	0.113	4.81
	F-4	Indep.	11	10/6/0	0.2	50/600	0.193	0.3	250/600	0.066	3.12
	A-7	Indep.	20	10/6/0	0.2	100/500	0.311	0.3	250/700	0.114	5.10
	F-111	Indep.	28	10/6/0	0.1	100/600	0.394	0.2	250/800	0.151	6.55
	F-111	Indep.	19	10/6/0	0.2	100/600	0.294	0.2	300/800	0.108	4.82

[a]Intervalometer setting, sec.

[b]The first value is the lateral spacing between aircraft; the second value is the range spacing between waves of attacking aircraft.

Table 6

HIGH-ALTITUDE DISPENSER ATTACK: REBIT

(Release altitude 6500 ft, dive angle 45 deg)

Weapon	A/C	Aim Mode	N(1) No. A/C	Allocation	Pattern Dim.	Area 1			Area 2			Area 3			Total X(4)
						Intv[a]	Spacing[b]	X(1)	Intv	Spacing	X(2)	Intv	Spacing	X(3)	
115-lb Rebit, 6 per dispenser B(0) = 0.706	F-4	Single	8	10/6/0	400×400	0.2	100/700	0.396	0.4	200/800	0.179				6.90
	A-7	Single	11	10/6/0	400×400	0.3	100/700	0.513	0.4	250/800	0.241				9.05
	F-111	Single	16	8/6/2	400×400	0.2	150/700	0.558	0.3	250/800	0.319	0.5	500/400	0.071	11.66
	F-111	Single	11	10/6/0	400×400	0.3	100/700	0.513	0.4	250/810	0.241				9.05
	F-4	Indep.	8	10/6/0	400×400	0.3	50/600	0.444	0.4	250/900	0.172				7.40
	A-7	Indep.	11	10/6/0	400×400	0.3	50/600	0.567	0.5	250/800	0.229				9.56
	F-111	Indep.	16	8/6/2	400×400	0.2	100/600	0.594	0.4	250/700	0.306	0.5	500/400	0.070	11.91
	F-111	Indep.	11	10/6/0	400×400	0.3	50/600	0.567	0.5	250/800	0.229				9.56
Rebit, 13 per dispenser B(0) = 0.706	F-4	Single	10	6/6/4	400×400	0.2	200/700	0.513	0.5	300/800	0.364	0.5	350/400	0.146	12.85
	A-7	Single	12	6/6/4	400×400	0.3	200/700	0.610	0.5	300/800	0.435	0.5	350/400	0.179	15.41
	F-111	Single	18	6/6/4	400×400	0.2	250/700	0.725	0.3	350/900	0.553	0.5	350/400	0.264	19.55
	F-111	Single	12	6/6/4	400×400	0.3	200/700	0.610	0.5	300/800	0.435	0.5	350/400	0.179	15.41
	F-4	Indep.	10	6/6/4	400×400	0.3	50/600	0.566	0.5	250/800	0.365	0.5	300/400	0.154	13.63
	A-7	Indep.	12	6/6/4	400×400	0.3	100/600	0.643	0.5	250/700	0.433	0.5	300/400	0.185	15.87
	F-111	Indep.	18	6/6/4	400×400	0.2	100/600	0.754	0.4	300/500	0.544	0.5	300/400	0.264	19.80
	F-111	Indep.	12	6/6/4	400×400	0.3	100/600	0.643	0.5	250/700	0.433	0.5	300/400	0.185	15.87

[a] Intervalometer setting, sec.

[b] The first value is the lateral spacing between aircraft; the second value is the range spacing between waves of attacking aircraft.

Table 7

LOW-LEVEL DAY ATTACKS: M-117R AND MK-82SE HIGH-DRAG BOMBS

(Release altitude 500 ft)

Weapon	A/C	Aim Mode	N(1) No. A/C	Allocation	Area 1			Area 2			Total X(4)
					Intv[a]	Spacing[b]	X(1)	Intv	Spacing	X(2)	
M-117R B(0) = 0.88	F-4	Single	8	12/4/0	0.1	50/400	0.135	0.1	150/400	0.030	1.97
	A-7	Single	11	12/4/0	0.1	50/400	0.172	0.1	200/400	0.040	2.55
	F-111	Single	15	12/4/0	0.1	50/400	0.219	0.1	200/400	0.053	3.26
	F-111	Single	10	12/4/0	0.1	50/400	0.160	0.1	200/400	0.037	2.37
	F-4	Indep.	8	12/4/0	0.1	50/400	0.143	0.2	200/400	0.028	2.25
	A-7	Indep.	11	12/4/0	0.1	50/400	0.189	0.1	200/400	0.040	2.74
	F-111	Indep.	15	12/4/0	0.1	50/400	0.238	0.1	200/400	0.052	3.49
	F-111	Indep.	10	12/4/0	0.1	50/400	0.175	0.1	200/400	0.036	2.53
MK-82SE B(0) = 0.77	F-4	Single	11	12/4/0	0.1	50/400	0.157	0.1	150/400	0.035	2.30
	A-7	Single	17	12/4/0	0.1	50/400	0.214	0.1	200/400	0.053	3.20
	F-111	Single	26	12/4/0	0.1	50/400	0.271	0.1	150/400	0.072	4.12
	F-111	Single	17	12/4/0	0.1	50/400	0.214	0.1	200/400	0.053	3.20
	F-4	Indep.	11	12/4/0	0.1	50/400	0.165	0.1	200/400	0.034	2.40
	A-7	Indep.	17	12/4/0	0.1	50/400	0.231	0.1	200/400	0.052	3.39
	F-111	Indep.	26	12/4/0	0.1	50/400	0.289	0.1	200/400	0.070	4.31
	F-111	Indep.	17	12/4/0	0.1	50/400	0.231	0.1	200/400	0.052	3.39

[a] Intervalometer setting, sec.

[b] The first value is the lateral spacing between aircraft; the second value is the range spacing between waves of attacking aircraft.

Table 8

LOW-LEVEL DISPENSER ATTACK: REB-LEK, FOLLOW-THROUGH SHAPED-CHARGE, FAE BOMBLET

(Release altitude 300 to 500 ft)

Weapon	A/C	Aim Mode	N(1) No. A/C	Allocation	Pattern Dim.	Area 1 Intv[a]	Area 1 Spacing[b]	Area 1 X(1)	Area 2 Intv	Area 2 Spacing	Area 2 X(2)	Area 3 Intv	Area 3 Spacing	Area 3 X(3)	Total X(4)
REB-LEK, 16 per dispenser, B(0) = 0.706	F-4	Single	8	6/6/4	400×400	0.2	200/600	0.502	0.2	300/700	0.365	0.3	350/400	0.165	13.06
	A-7	Single	12	6/6/4	400×400	0.2	200/400	0.617	0.2	350/400	0.466	0.2	350/400	0.231	16.69
	F-111	Single	17	6/4/6	400×400	0.1	250/800	0.709	0.1	250/400	0.428	0.2	450/400	0.409	20.18
	F-111	Single	11	6/6/4	400×400	0.2	200/400	0.593	0.2	350/500	0.441	0.3	350/400	0.213	15.83
	F-4	Indep.	8	6/6/4	400×400	0.1	150/400	0.734	0.2	300/400	0.367	0.4	350/400	0.154	13.28
	A-7	Indep.	12	6/6/4	400×400	0.1	200/400	0.640	0.1	300/400	0.461	0.2	350/400	0.216	16.66
	F-111	Indep.	17	6/4/6	400×400	0.1	200/400	0.745	0.1	200/400	0.443	0.2	450/400	0.392	20.53
	F-111	Indep.	11	6/6/4	400×400	0.1	200/400	0.612	0.1	300/400	0.435	0.3	350/400	0.199	15.75
Follow-through shaped-charge, heavy, 5 per dispenser, B(0) = 1	F-4	Indep.	8	8/6/2	400×400	0.1	50/400	0.408	0.2	200/400	0.205	0.4	650/400	0.040	8.01
	A-7	Indep.	13	8/6/2	400×400	0.1	50/400	0.564	0.1	250/500	0.297	0.2	600/400	0.066	11.38
	F-111	Indep.	19	6/6/4	400×400	0.1	50/400	0.570	0.1	250/400	0.393	0.1	300/400	0.170	14.26
	F-111	Indep.	12	8/6/2	400×400	0.1	50/400	0.538	0.1	250/600	0.275	0.2	600/400	0.062	10.74
FAE bomblet, 3 per dispenser, B(0) = 1	F-4	Indep.	11		400×400	0.1	50/400	0.415	0.1	200/600	0.174				7.07
	A-7	Indep.	20		400×400	0.1	50/400	0.510	0.1	250/400	0.277	0.1	600/400	0.062	10.44
	F-111	Indep.	30		400×400	0.1	50/400	0.481	0.1	250/400	0.346	0.1	300/400	0.162	12.58
	F-111	Indep.			400×400	0.1	50/400	0.510	0.1	250/400	0.277	0.1	600/400	0.062	10.44

NOTE: If the medium follow-through shaped-charge (16 per dispenser) works as its adherents claim, its attributes will be similar to those of REB-LEK.

[a]Intervalometer setting, sec.

[b]The first value is the lateral spacing between aircraft; the second value is the range spacing between waves of attacking aircraft.

Table 9

ROCKET ATTACKS: ZUNI AND CLUSTERED ZUNI

Weapon	A/C	Aim Mode	N(1) No. A/C	Allocation	Pattern Dim.	Area 1 Intv[a]	Area 1 Spacing[b]	Area 1 X(1)	Area 2 Intv	Area 2 Spacing	Area 2 X(2)	Area 3 Intv	Area 3 Spacing	Area 3 X(3)	Total X(4)
Clustered Zuni,	F-4	Single	8	8/6/2	400×400	0.1	150/500	0.451	0.2	300/500	0.260	0.3	450/400	0.058	9.46
[illegible] cluster	A-7	Single	12	8/6/2	400×400	0.1	150/800	0.567	0.1	300/800	0.350	0.2	450/400	0.083	12.43
β(0) = 1	F-111	Single	19	8/6/2	400×400	0.1	150/800	0.697	0.1	300/800	0.472	0.1	450/400	0.121	15.96
	F-111	Single	12	8/6/2	400×400	0.1	150/800	0.567	0.1	300/800	0.350	0.2	450/400	0.083	12.43
	F-4	Indep.	8	8/6/2	400×400	0.1	100/400	0.504	0.1	300/500	0.253	0.3	450/400	0.057	9.99
	A-7	Indep.	12	8/6/2	400×400	0.1	150/400	0.605	0.1	300/400	0.348	0.2	600/400	0.082	12.75
	F-111	Indep.	19	8/6/2	400×400	0.1	150/400	0.740	0.1	300/400	0.474	0.1	450/400	0.117	16.44
	F-111	Indep.	12	8/6/2	400×400	0.1	150/400	0.605	0.1	300/400	0.348	0.2	600/400	0.082	12.75
β(0) = 0.706	F-4	Indep.	8	8/6/2	400×400	0.1	100/400	0.403	0.1	300/500	0.194	0.3	450/400	0.041	7.83
	A-7	Indep.	12	8/6/2	400×400	0.1	150/400	0.497	0.1	300/400	0.273	0.2	500/400	0.060	10.20
	F-111	Indep.	19	8/6/2	400×400	0.1	150/400	0.629	0.1	300/400	0.380	0.1	500/400	0.089	13.53
	F-111	Indep.	12	8/6/2	400×400	0.1	150/400	0.497	0.1	300/400	0.273	0.2	500/400	0.060	10.20
Zuni, 4 per pod,	F-4	Indep.	8	10/6/0		0.4	50/600	0.426	0.5	250/800	0.166				7.12
dive mode	A-7	Indep.	17	10/6/0		0.2	100/600	0.638	0.4	250/600	0.309				11.36
β(0) = 1.0	F-111	Indep.	23	10/6/0		0.2	100/500	0.743	0.3	300/600	0.368				13.34
	F-111	Indep.	16	10/6/0		0.2	100/600	0.623	0.4	300/700	0.284				10.88
β(0) = 0.706	F-4	Indep.	8	10/6/0		0.4	50/600	0.334	0.5	750/900	0.122				5.47
	A-7	Indep.	17	10/6/0		0.2	100/600	0.542	0.4	250/600	0.237				9.34
	F-111	Indep.	23	10/6/0		0.2	100/500	0.644	0.3	300/600	0.288				11.18
	F-111	Indep.	16	10/6/0		0.2	100/600	0.526	0.4	300/700	0.217				8.91

[a] Intervalometer setting, sec.

[b] The first value is the lateral spacing between aircraft; the second value is the range spacing between waves of attacking aircraft.

clustered Zuni containing seven rockets. Note that we have included two levels of vulnerability for rockets.

A complete example is given showing the entire JOSS computation run for the REB-LEK results shown in Table 8, both for single aim and independent aim. The single-aim example may be found in Example 1a of Appendix A and the independent-aim case in Example 1b. We note that parts of these examples are used to give further examples of the effectiveness part of the Airbase Attack Model. Any of the results given in Tables 3 through 9 may be obtained using the same general approach as that shown in the two examples.

SENSITIVITY VARIATIONS

The effectiveness results given in Tables 3 through 9 were, in general, based on the assumption of a specific method of operation or specified values for the pertinent parameters. We investigate here, for the F-4 aircraft and in some instances the long-distance F-111, the relative effects of variations in several of these aspects of the problem. The weapons will be restricted to the MK-82 as representative of a bomb-type weapon and the REB-LEK as representative of an area-type dispenser weapon. The conditions used in the basic cases will be considered standard and held constant while the particular parameter or operating mode being investigated is varied. The seven sensitivity variations are: (a) allocation of attacks to target areas, (b) aiming modes, (c) vulnerable area as a parameter, (d) effect of reliability coefficient, (e) size of target complex as a parameter, (f) dispenser pattern size as a parameter, and (g) effect of attack size.

Allocation of Attacks to Target Areas

An optimum allocation of the 16 attackers to the three target areas was obtained in the basic results. In this variation, we present effectiveness results for allocations other than optimum. We limited consideration to the F-4 aircraft and to attacks with the MK-82 bomb and the dispenser-delivered REB-LEK, delivered in the independent-aiming mode. For the MK-82, the vulnerable area ratio B(0) is 1.2, and the aiming accuracy is 20 mils. For the REB-LEK, the vulnerable area ratio

B(0) is 0.706, the dispenser pattern size is 400 by 400 ft, and the aiming accuracy is 300 ft REP, 40 ft DEP. The size of the attacking group is 16 aircraft, the reliability index is 0.95 and the sizes of the target areas are 10^6, $2(10)^6$, and $4(10)^6$ sq ft for Area 1, Area 2, and Area 3, respectively. Table 10 gives the results for various allocations. Note that for the optimum conditions, the allocations and results are the same as in the basic results in Tables 4 and 8.

Table 10

SENSITIVITY OF EFFECT OF AIRCRAFT ALLOCATION

I. Attack by 16 F-4 aircraft carrying 8 dispensers, with 16 REB-LEKs per dispenser, B(0) = 0.706, pattern 400×400 ft

Allocation To			Fractional Damage			Total Damage
Area 1	Area 2	Area 3	X(1)	X(2)	X(3)	X(4)
14	2	0	0.791	0.150		11.30
12	4	0	0.758	0.272		12.35
10	6	0	0.710	0.367		12.94
8	6	2	0.613	0.367	0.084	13.12
6	6	4	0.534	0.367	0.154	13.28
6	4	6	0.534	0.272	0.224	13.26
4	6	6	0.416	0.367	0.224	12.99
4	8	4	0.416	0.462	0.154	12.99
4	4	8	0.416	0.272	0.278	12.69

II. Attack by 16 F-4 aircraft carrying 11 MK-82 bombs, B(0) = 1.2

Allocation To			Fractional Damage			Total Damage
Area 1	Area 2	Area 3	X(1)	X(2)	X(3)	X(4)
16	0	0	0.298			3.58
10	6	0	0.225	0.079		3.64
8	8	0	0.185	0.099		3.41
4	4	8	0.102	0.052	0.054	2.72

Aiming Modes

To recapitulate, two aiming modes are considered in the basic results: a single-aim or formation-type delivery and independent aim by each attacker on specified aiming points. For the independent-aim case, it is assumed that a more or less optimum spacing of aiming points was chosen and that the attackers would be able to use these best aim points. Here we consider two less optimistic assumptions about the aiming points available for independent attack. The case of random independent-aim points assumes that each attacker chooses an aim point uniformly at random within the target area, with no correlation between attackers. The second assumption is that each attacker is assigned an optimum aim point, but that he actually aims at a point offset from his assigned point. The amount of the offset is assumed to be a random variable with a gaussian distribution; the standard deviations are assumed to be functions of the target area size, with values as follows: Area 1, $\sigma(1) = 96$ ft; Area 2, $\sigma(2) = 163$ ft; Area 3, $\sigma(3) = 210$ ft. Table 11 gives the results for these four cases of different aiming modes; it is seen that the effectiveness does not vary greatly with the choice of aiming mode. The standard condition of independent aim is only marginally better than the other conditions.

Vulnerable Area as a Parameter

As mentioned previously, the vulnerable area parameter used in the Airbase Attack Model is the vulnerable area ratio B(0), which is multiplied by the hangarette plan area of 2450 sq ft to obtain the vulnerable area used. Variations in B(0) for specific weapons are based on weapon-target interactions such as ricochet angle and blast effect. In this sensitivity variation, we investigate the effect of a different hangarette plan area. With areas of 1000, 4000, and 6500 sq ft, we use values of B(0) of 0.408, 1.633, and 2.654, the ratios between the assumed area and the standard area of 2450 sq ft. We consider an attack by F-4s and F-111s, using MK-82s, REB-LEKs, or clustered Zuni rockets; aside from B(0), standard values are used for the computations. For comparison, the case of a standard value of B(0) is given for each combination, from

Table 11

SENSITIVITY OF EFFECT OF AIMING MODE

(F-4 attack with MK-82 or REB-LEKs)

I. Attack by 16 F-4 aircraft carrying 8 dispensers, with 16 REB-LEKs per dispenser, B(0) = 0.706, pattern 400×400 ft, allocation 6/6/4

Aiming Policy	Fractional Damage X(1)	Fractional Damage X(2)	Fractional Damage X(3)	Total Damage X(4)
Single aim (formation)	0.502	0.365	0.165	13.06
Independent	0.534	0.367	0.154	13.28
Independent--offset	0.514	0.342	0.155	12.39
Independent--random	0.472	0.362	0.149	12.39

II. Attack by 16 F-4 aircraft carrying 11 MK-82 bombs, B(0) = 1.2, allocation 10/6/0

Aiming Policy	Fractional Damage X(1)	Fractional Damage X(2)	Fractional Damage X(3)	Total Damage X(4)
Single	0.205	0.080		3.41
Independent	0.225	0.079		3.64
Independent--offset	0.215	0.073		3.46
Independent--random	0.188	0.067		3.07

the appropriate tables for the basic cases. Table 12 presents the results of these variations in vulnerable area through the parameter B(0). Note that the optimum allocation has been determined for each case.

Effect of the Reliability Coefficient p

The standard value for the subweapon reliability coefficient in the basic computations was p = 0.95. Table 13 shows the results of varying p between 0.9 and 1, for aircraft carrying either MK-82 bombs or dispensers with REB-LEK submunitions and standard conditions other than p.

Table 12

SENSITIVITY OF EFFECT OF VULNERABLE AREA OF HANGARETTES

I. Attack by 16 aircraft carrying 16 REB-LEKs per dispenser, pattern 400×400 ft, independent aim mode

Aircraft	B(0)	VA[a]	Dispensers per Aircraft	Allocation	Fractional Damage X(1)	Fractional Damage X(2)	Fractional Damage X(3)	Total Damage X(4)
F-4	0.408	1000	8	8/6/2	0.482	0.240	0.053	9.51
	0.706[b]	1730	8	6/6/4	0.534	0.367	0.154	13.28
	1.633	4000	8	6/6/4	0.759	0.581	0.290	20.72
	2.654	6500	8	4/6/6	0.735	0.685	0.530	25.52
F-111	0.408	1000	17	6/6/4	0.584	0.423	0.182	14.99
	0.706[b]	1730	17	6/6/4	0.745	0.443	0.392	20.53
	1.633	4000	17	4/6/6	0.794	0.720	0.607	27.89
	2.654	6500	17	4/6/6	0.868	0.773	0.707	31.01

II. Attack by 16 aircraft carrying MK-82 bombs, independent aim

Aircraft	B(0)	VA[a]	Dispensers per Aircraft	Allocation	X(1)	X(2)	X(3)	X(4)
F-4	0.408	1000	11	10/6/0	0.087	0.028		1.38
	1.2[b]	2940	11	10/6/0	0.225	0.079		3.64
	1.633	4000	11	10/6/0	0.290	0.103		4.71
	2.654	6500	11	10/6/0	0.408	0.154		6.75
F-111	0.408	1000	30	10/6/0	0.209	0.072		3.37
	1.2[b]	2940	30	10/6/0	0.464	0.189		7.83
	1.633	4000	30	10/6/0	0.551	0.238		9.48
	2.654	6500	30	8/6/2	0.612	0.332	0.081	12.65

III. Attack by 16 aircraft carrying 7 clustered Zunis per dispenser, pattern 400×400 ft, independent aim

Aircraft	B(0)	VA[a]	Dispensers per Aircraft	Allocation	X(1)	X(2)	X(3)	X(4)
F-4	0.408	1000	8	10/6/0	0.313	0.123		5.23
	1.00[b]	2450	8	8/6/2	0.504	0.253	0.057	9.99
	1.633	4000	8	8/6/2	0.618	0.372	0.086	13.26
	2.654	6500	8	6/6/4	0.672	0.498	0.236	17.71

[a] Vulnerable area.

[b] Standard conditions as in Table 2.

Table 13

SENSITIVITY OF EFFECT OF THE RELIABILITY COEFFICIENT p

I. Attack by 16 aircraft carrying 16 REB-LEKs per dispenser, pattern 400×400 ft, independent aim, B(0) = 0.706

Aircraft	Dispensers per Aircraft	Reliability p	Allocation	Fractional Damage			Total Damage
				X(1)	X(2)	X(3)	X(4)
F-4	8	1	6/6/4	0.548	0.380	0.160	13.70
		0.95[a]	6/6/4	0.534	0.367	0.154	13.28
		0.9	6/6/4	0.519	0.354	0.147	12.83
A-7	11	1	6/6/4	0.654	0.473	0.224	17.10
		0.95[a]	6/6/4	0.640	0.461	0.216	16.66
		0.9	6/6/4	0.625	0.448	0.207	16.19
F-111	16	1	6/4/6	0.758	0.455	0.405	21.04
		0.95[a]	6/4/6	0.745	0.443	0.392	20.53
		0.9	6/4/6	0.731	0.430	0.379	19.99

II. Attack by 16 aircraft carrying MK-82 bombs, independent aim, B(0) = 1.2

Aircraft	Dispensers per Aircraft	Reliability p	Allocation	X(1)	X(2)	X(3)	X(4)
F-4	11	1		0.235	0.082		3.80
		0.95[a]		0.225	0.079		3.64
		0.9		0.215	0.074		3.48
A-7	20	1		0.372	0.140		6.14
		0.95[a]		0.358	0.134		5.90
		0.9		0.344	0.128		5.65
F-111	30	1		0.478	0.198		8.11
		0.95[a]		0.464	0.189		7.83
		0.9		0.448	0.181		7.35

[a]Standard condition.

Size of Target Complex as a Parameter

Table 14 shows the effects of variations in the total area of the target complex. The standard target area complex is three rectangles of areas 10^6, $2(10)^6$, and $4(10)^6$. For each area, the length is twice the width and the total area is $7(10)^6$. Our two variations assume the total area is 1.5 and 2 times greater, i.e., $10.5(10)^6$ and $14(10)^6$ sq ft. The relative target sizes and shapes of the rectangles remain constant. Again, we consider F-4 and F-111 aircraft with REB-LEKs and MK-82 bombs.

Table 14

SENSITIVITY OF EFFECT OF TARGET COMPLEX SIZE

I. Attack by 16 aircraft carrying 16 REB-LEKs per dispenser, pattern 400×400 ft, independent aim, B(0) = 0.706, p = 0.95

Aircraft	Dispensers per Aircraft	Total Target Area	Allocation	Fractional Damage X(1)	Fractional Damage X(2)	Fractional Damage X(3)	Total Damage X(4)
F-4	8	$7(10)^{6}$ [a]	6/6/4	0.534	0.367	0.154	13.28
		$10.5(10)^{6}$	8/6/2	0.500	0.259	0.059	10.30
		$14(10)^{6}$	10/6/0	0.510	0.224		8.81
F-111	17	$7(10)^{6}$ [a]	6/4/6	0.745	0.443	0.392	20.53
		$10.5(10)^{6}$	6/6/4	0.649	0.440	0.214	16.49
		$14(10)^{6}$	6/6/4	0.570	0.392		14.21

II. Attack by 16 aircraft carrying MK-82 bombs, independent aim, B(0) = 1.2, p = 0.95

Aircraft	Dispensers per Aircraft	Total Target Area	Allocation	Fractional Damage X(1)	Fractional Damage X(2)	Fractional Damage X(3)	Total Damage X(4)
F-4	11	$7(10)^{6}$ [a]	10/6/0	0.225	0.079		3.64
		$10.5(10)^{6}$	10/6/0	0.157	0.054		2.53
		$14(10)^{6}$	10/6/0	0.092	0.032		1.49
F-111	30	$7(10)^{6}$ [a]	10/6/0	0.464	0.189		7.83
		$10.5(10)^{6}$	10/6/0	0.342	0.135		5.73
		$14(10)^{6}$	10/6/0	0.287	0.105		4.70

[a] Standard conditions.

Dispenser Pattern Size as a Parameter

In the basic results, we used a standard value of the dispenser pattern of 400 by 400 ft. Here we vary the assumed dispenser pattern size for a REB-LEK attack, using both F-4 and F-111 aircraft. We have kept the pattern square but have varied the area. The results are given in Table 15. We note that for the cases shown, the optimum value of the pattern size lies somewhere between the standard 400×400 and the larger pattern 800×800; however, the difference in effectiveness is not appreciable. For some other cases considered, the 400×400 pattern size was slightly better. We chose the smaller value as standard, since there was only a marginal increase in effectiveness in any case for the

Table 15

SENSITIVITY OF EFFECT OF DISPENSER PATTERN SIZE

Attack by 16 aircraft carrying 16 REB-LEKs per dispenser, independent aim, B(0) = 0.706, p = 0.95

Aircraft	Dispensers per Aircraft	Pattern Size	Allocation	Fractional Damage			Total Damage
				X(1)	X(2)	X(3)	X(4)
F-4	8	200×200	8/6/2	0.557	0.313	0.069	11.55
		400×400[a]	6/6/4	0.534	0.367	0.154	13.28
		800×800	6/6/4	0.542	0.385	0.161	13.69
F-111	17	200×200	6/6/4	0.657	0.474	0.235	17.32
		400×400[a]	6/4/6	0.745	0.443	0.392	20.53
		800×800	6/4/6	0.779	0.482	0.393	21.42

[a]Standard conditions.

larger pattern. For smaller areas, it is likely that the smaller pattern would be superior. Further, the achievement of the smaller pattern by the proper design of the dispenser would probably be easier.

Effect of Attack Size

In this variation we consider the effect of the total attack size on an airbase. The attacks occur in groups of 16 aircraft, allocated to the three target areas. REB-LEKs and MK-82 bombs are delivered by F-4s and F-111s. The results in terms of the total expected number of hangarettes damaged and the fraction of the 40 total hangarettes destroyed are given in Table 16. Note that for the REB-LEK attack, a value of B(0) of 0.866 rather than the standard value of 0.706 was used. The computations were continued until 90 percent total damage was obtained. The model used does not include any bomb damage assessment or possible repair.

NIGHT AND ALL-WEATHER ATTACKS

For night and all-weather attacks, the attack conditions were somewhat different from the basic cases, as were the corresponding vulnerability ratios. Two types of night attacks were considered, a level

Table 16

SENSITIVITY OF EFFECT OF NUMBER OF AIRCRAFT IN ATTACK

I. Dispenser attack, 16 REB-LEKs per dispenser, independent aim, pattern 400×400 ft, B(0) = 0.866, p = 0.95

Aircraft	Dispensers per Aircraft	No. of Aircraft	Allocation	Expected No. Hangarettes Damaged	Fraction of Hangarettes Damaged
F-4	8	16	6/4/6	14.98	0.375
		32	10/10/12	23.52	0.588
		48	12/16/20	28.68	0.717
		64	16/20/28	32.62	0.816
		80	16/24/40	35.00	0.875
		96	20/28/48	36.08	0.902
F-111	17	16	6/4/6	22.77	0.569
		32	8/12/12	31.69	0.792
		48	12/16/20	35.92	0.898

II. MK-82 attack, independent aim, B(0) = 1.2, p = 0.95

F-4	11	16		3.64	0.091
		32		6.76	0.169
		64		10.96	0.274
		128		17.28	0.432
		256		26.16	0.654
		384		31.56	0.789
		512		34.80	0.870
F-111	30	16		7.84	0.196
		32		12.84	0.321
		64		20.20	0.505
		128		29.48	0.737
		192		34.44	0.861
		224		35.92	0.898

attack at 2000 ft altitude with a CEP of 400 ft (corresponding to use of the LORAN radar technique) and, for the F-111, a level attack at 500 ft altitude with a CEP of 320 ft. The major change in the model was the introduction of CEP instead of REP and DEP. For the LORAN-type attack, all aircraft types were considered, with two types of dispensers and four types of bombs. For the F-111 attack, only the two dispenser munitions, REB-LEK and Rebit, were included with the retarded MK-82.

Table 17 presents these results, showing for each case the value of the vulnerability ratio B(0) used. Since the delivery accuracy for night attacks was expressed as a single parameter, CEP, they were used to investigate the effect of delivery accuracy on attack damage. For both F-4s and F-111s, attacking in groups of 16, we considered a variation in CEP for both REB-LEK dispensers and MK-82 bombs. The effect of CEP on hangarette damage is shown in the results displayed in Table 18.

Table 17

NIGHT AND ALL-WEATHER ATTACKS

I. Night attack, 16 aircraft, 2000 ft altitude, CEP = 400 ft (LORAN), independent aim, pattern 400×400 ft

Weapon	B(0)	Aircraft	Weapons per Aircraft	Allocation	Fractional Damage X(1)	Fractional Damage X(2)	Fractional Damage X(3)	Total Damage X(4)
REB-LEK (16)	0.707	F-4	8	6/6/4	0.458	0.340	0.154	12.04
		A-7	12	6/6/4	0.580	0.452	0.217	15.85
		F-111	17	6/4/6	0.681	0.418	0.390	19.44
		F-111	11	6/6/4	0.554	0.431	0.201	15.03
Rebit (13)	0.605	F-4	10	6/6/4	0.426	0.315	0.139	11.12
		A-7	12	6/6/4	0.477	0.340	0.163	12.42
		F-111	18	6/6/4	0.588	0.465	0.220	16.16
		F-111	12	6/6/4	0.477	0.340	0.163	12.42
MK-81	1.5	F-4	11	10/6/0	0.204	0.085		3.46
		A-7	35	10/6/0	0.345	0.194		6.47
		F-111	47	10/6/0	0.348	0.200		6.57
		F-111	33	10/6/0	0.345	0.194		6.45
MK-82	1.6	F-4	11	10/6/0	0.215	0.088		3.64
		A-7	20	10/6/0	0.316	0.154		5.64
		F-111	30	10/6/0	0.348	0.200		6.64
		F-111	20	10/6/0	0.316	0.154		5.64
M-117	1.8	F-4	10	10/6/0	0.221	0.097		3.75
		A-7	12	10/6/0	0.253	0.106		4.31
		F-111	18	10/6/0	0.329	0.154		5.80
		F-111	12	10/6/0	0.253	0.106		4.31
MK-82SE	0.77	F-4	11	10/6/0	0.112	0.045		1.89
		A-7	17	10/6/0	0.156	0.067		2.67

II. Night attack, 16 F-111s, 500 ft altitude, CEP = 320 ft, independent aim, pattern 400×400 ft

Weapon	B(0)	Aircraft	Weapons per Aircraft	Allocation	Fractional Damage X(1)	Fractional Damage X(2)	Fractional Damage X(3)	Total Damage X(4)
REB-LEK (16)	0.707		11	6/6/4	0.611	0.469	0.203	16.2
			17	6/4/6	0.743	0.447	0.389	20.5
Rebit (13)	0.68		12	6/6/4	0.572	0.421	0.176	14.73
			18	6/4/6	0.689	0.405	0.347	18.69
MK-82SE	0.77		17	10/6/0	0.184	0.072		3.07
			26	10/6/0	0.219	0.104		3.87

Table 18

EFFECT OF CEP ON HANGARETTE DAMAGE

(2000 ft altitude level delivery)

I. Attack by 16 aircraft carrying 16 REB-LEKs per dispenser, pattern size 400×400 ft, B(0) = 0.706, independent aim

Aircraft	Weapons per Aircraft	CEP	Allocation	Fractional Damage X(1)	Fractional Damage X(2)	Fractional Damage X(3)	Total Damage X(4)
F-4	8	200	6/6/4	0.568	0.376	0.163	13.95
		300	6/6/4	0.517	0.369	0.158	13.16
		400	6/6/4	0.458	0.340	0.154	12.04
		700	6/6/4	0.275	0.225	0.122	7.95
F-111	17	200	6/4/6	0.837	0.477	0.400	22.17
		300	6/4/6	0.765	0.464	0.394	21.06
		400	6/4/6	0.681	0.418	0.390	19.44
		700	6/4/6	0.449	0.281	0.293	13.45

II. Attack by 16 aircraft carrying MK-82 bombs, B(0) = 1.2, independent aim

Aircraft	Weapons per Aircraft	CEP	Allocation	X(1)	X(2)	X(3)	X(4)
F-4	11	100	10/6/0	0.231	0.079		3.72
		200	10/6/0	0.228	0.075		3.64
		400	10/6/0	0.168	0.068		2.83
		700	10/6/0	0.091	0.045		1.63
		1000	10/6/0	0.053	0.029		0.98
F-111		100	10/6/0	0.379	0.185		6.77
		200	10/6/0	0.368	0.171		6.47
		400	10/6/0	0.285	0.152		5.24
		700	10/6/0	0.178	0.099		3.32
		1000	10/6/0	0.116	0.066		2.18

Appendix C

MODIFIED AIRBASE ATTACK MODEL FOR RPV ATTACK

This appendix contains the modified Airbase Attack Model JOSS program used for the RPV attack computations. After a short discussion of the modifications and a listing of the modified parts of the basic program, an example of a complete JOSS run is given for the case of an RPV attack using RMS II missiles carrying REB-LEK dispensers.

MODIFIED AIRBASE ATTACK MODEL--RPV ATTACK

The modified Airbase Attack Model is set up like the basic Airbase Attack Model in four main sections: (1) Input/Output, (2) Optimization, (3) Trajectory, and (4) Effectiveness. Sections 3 and 4 are exactly the same as in the basic model; printouts are contained in Appendix A. The input/output routine is also divided for the RPV program; the direct input part is contained in file item ABRVinpt and is almost identical with the aircraft-attack direct input part. The major portion of the RPV input/output subroutine is contained in file item ABRVprog and contains most of the modifications necessary to adapt the model for RPV attacks. It is activated by the command "Do part 60" and consists of modified parts 60 through 65. In addition, there were slight modifications made to the optimization routine in parts 95 and 99. Printouts of the modified input/output routine are given on p. 85 and of the optimization routine on p. 89.

EXAMPLE OF THE USE OF THE RPV AIRBASE ATTACK PROGRAM

Example 4 gives a complete set of commands, input data, and output printout for the case of an RMS II attack carrying REB-LEK dispensers. The input data are as contained in Table 8 of Appendix A and the output data obtained are included in Table 21.

RPV INPUT/OUTPUT ROUTINE

FILE ITEM ABRVINPT, FILE J0010.A1662

```
59 **Inputs.
59.1 Set n=0.
59.11 Type "For independent aim, set aim index to 1;single aim, 0".
59.12 Demand  n(100) as "Aiming Method Index".
59.13 Line.
59.15 Type "If dispensers are used, set weapon index to 1; if bombs, 0".
59.16 Demand j as "Weapon Index".
59.17 Set k=[j=1:14;15].
59.175 Line.
59.18 Set n(k)=1.
59.19 Let n be sparse.
59.2 ***Target Inputs.
59.21 Type "One to four separate target areas may be used.".
59.215 Line.
59.22 Demand M as "Number of Target areas".
59.23 Set l=1.
59.235 Line.
59.24 Type l in form 90.
59.25 Demand A(10+l) as "Target Area in 10**6 sq ft".
59.26 Demand w(l) as "No of Shelters in Target Area".
59.265 Line.
59.27 To step 59.3 if l=M.
59.28 Set l=l+1.
59.29 To step 59.24.
59.3 Demand B(-1) as "Shelter Ground Plane Area".
59.31 Demand B(0) as "Vulnerability Ratio".
59.32 Demand p as "Weapon reliability".
59.33 To step 59.4 if n(15)=1.
59.34 Demand L(1) as "Dispenser Pattern Half Length, feet".
59.35 Demand L(2) as "Dispenser Pattern Half Width, feet".
59.36 Demand N(2) as "Number of Bomblets in Dispenser".
59.39 Line.
59.4 ***Aircraft Inputs.
59.41 Type "One to four aircraft types may be used.".
59.42 Demand I as "Number of aircraft types".
59.425 Line.
59.43 Set m=1.
59.44 Type m in form 91.
59.45 Demand N(-m) as "Number of Weapons".
59.46 Demand V(-m-1) as "Aircraft Speed, knots".
59.47 Demand v(-m-1) as "Aircraft Dive Angle, degrees".
59.48 Demand z(-m-1) as "Altitude of last weapon off, ft".
59.482 Demand u(-m) as "Outboard Station Offset, ft".
59.484 Demand v(100+m) as "Outboard Rack Throw Angle, degrees".
59.485 To step  59.5 if m>1.
59.49 Line.
59.491 Type "If aiming accuracy is specified as CEP in mils, set".
59.492 Type "accuracy index to 0; if CEP on ground,to 1; if REP".
59.493 Type "and DEP on ground to 2; if range and deflection ".
```

```
59.494 Type "standard deviation on the ground, to 3".
59.495 Demand t(0) as "Accuracy Index".
59.496 Line.
59.5 To step 59.55 if t(0)>0.
59.51 Demand t(10+m) as "CEP, mils".
59.52 To step 59.7.
59.55 To step 59.6 if t(0)>1.
59.56 Demand t(30+m) as "CEP, ground, feet".
59.57 To step 59.7.
59.6 To step 59.65 if t(0)=3.
59.61 Demand t(40+2*m-1) as "REP, feet".
59.62 Demand t(40+2*m) as "DEP, feet".
59.63 To step 59.7.
59.65 Demand t(50+2*m-1) as "Range St Dev, feet".
59.66 Demand t(50+2*m) as "Deflection St Dev, feet".
59.7 To step 59.8 if m=I.
59.71 Line.
59.75 Set m=m+1.
59.76 To step 59.44.
59.8 To part 60.

60.1 Delete part 59.
60.11 Recall ABACprog from file J0010.A1682.


FILE ITEM ABRVPROG, FILE J0010.A1682

60.1 ***Go.
60.11 ***Go.
60.12 Page.
60.15 Line.
60.2 To part 61.

61.05 ***Delivery Vehicle Values.
61.1 Set m=1.
61.15 Set c=arg(-1,0).
61.2 Set N(1)=N(-m).
61.21 Set V(-1)=V(-m-1).
61.22 Set v(-1)=v(-m-1).
61.23 Set z(-1)=z(-m-1).
61.24 Set u(4)=u(-m).
61.25 Set v(100)=v(100+m)*c/180.
61.3 To step 61.4 if t(0)>0.
61.31 Set t(7)=t(10+m)/1.1774.
61.32 Set t(8)=t(7).
61.33 To step 61.7.
61.4 To step 61.5 if t(0)>1.
61.41 Set t(1)=t(30+m)/1.1774.
61.42 Set t(2)=t(1).
61.43 To step 61.7.
61.5 To step 61.6 if t(0)=3.
61.51 Set t(1)=t(40+2*m-1)/.6744.
61.52 Set t(2)=t(40+2*m)/.6744.
61.53 To step 61.7.
```

```
61.6 Set t(1)=t(50+2*m-1).
61.61 Set t(2)=t(50+2*m).
61.7 ***Other Values.
61.9 Set N(3)=N(1).
61.91 Set N(6)=1.
61.915 Set N(4)=(u(4)=0:1;2).
61.92 Set N(10)=N(6)/N(4).
61.925 Set d(10)=u(4).
61.93 Set V(1)=6.
61.94 Set s(7)=5.
61.945 Set s(8)=5.
61.95 Set u(1)=0.
61.955 Set u(2)=0.
61.965 Set d(5)=2.
61.97 Do part 62.
61.98 Done if m=1.
61.985 Set m=m+1.
61.99 To step 61.2.

62.02 Line.
62.03 Type m in form 231.
62.04 Type N(1) in form 45.
62.05 Line.
62.07 Set N(55)=0.
62.1 Set N(55)=16 if N(1)=1 or fp(N(1)/2)=0.
62.2 Set N(55)=18 if fp(N(1)/3)=0.
62.21 Set N(55)=20 if fp(N(1)/5)=0.
62.22 Set N(55)=14 if fp(N(1)/7)=0.
62.23 To step 62.4 if 0<N(55)<21.
62.3 Type "N(1) must be less than 21 and divisable by 2,3,5 or 7".
62.31 Stop.
62.4 Set N(60)=[n(14)=1:2*N(55);4*N(55)].
62.5  To part 63.

63.1 Set B(1)=sqrt(B(0)*B(-1))/2.
63.11 Set B(2)=B(1).
63.3 Set A(-1)=2.
63.41 Line.
63.5 Type form 43.
63.51 Type form 44.
63.6  Do part 64 for l=1(1)M.

64.1 Type l in form  230.
64.2 Set A(2)=10**3*sqrt(A(10+1)/A(-1))/2.
64.21 Set A(1)=A(2)*A(-1).
64.3 Do part 65 for N(50)=1(1)6.

65.2 Set X(2)=[N(50)=1:0;X(1)].
65.3 Set N(80)=N(50)*N(60).
65.31 Set N(70)=N(80)/N(1).
65.32 Set N(8)=[N(50)<=2:2*N(50);N(50)].
65.33 Set N(8) =3 if N(1)=12 and N(50)<=4.
65.34 Set N(7)=N(70)/N(8).
65.5 Do part 95.
```

```
65.6 Set X(1)=[n(15)=1:X(15);X(14)].
65.61 Set Y=w(1)*X(1).
65.62 Set U=w(1)*[X(1)-X(2)].
65.7 Type N(70),k(80),X(1),Y,U in form 40.
```

HPV Optimization Routine

File item ALRVPROG, file J0010.A1682

```
95.2 Set d(7)=150.
95.3 To part 96.

96.1 Set d(0)=.1.
96.2 Set q=1.
96.21 Do part 90.
96.22 Set d(8)=q*50.
96.25 Do part 15.
96.26 Set T(q)=[n(15)=1:X(15);X(14)].
96.28 To step 96.4 if q=1.
96.3 To step 96.8 if T(q)<=T(q-1).
96.4 Set q=q+1.
96.41 To step 96.22.
96.8 Set d(8)=(q-1)*50.
96.801 To part 97.

97.11 Set q=1.
97.2 Set d(0)=q*.1.
97.3 Do part 90.
97.31 Do part 15.
97.4 Set T(q)=[n(15)=1:X(15);X(14)].
97.415 To step 97.5 if q=1.
97.42 To step 97.81 if T(q)<=T(q-1).
97.421 To step 97.9 if q=5.
97.5 Set q=q+1.
97.6 To step 97.2.
97.81 Set d(0)=(q-1)*.1.
97.82 To part 99.
97.9 Set d(0)=q*.1.
97.95 To part 99.

99.1 Set q=0.
99.12 Do part 90.
99.2 Set d(7)=50*q.
99.25 Do part 15.
99.26 Set T(q)=[n(15)=1:X(15);X(14)].
99.28 To step 99.4 if q=0.
99.3 To step 99.8 if T(q)<=T(q-1).
99.4 Set q=q+1.
99.41 To step 99.2.
99.8 Set d(7)=(q-1)*50.
99.96 Do part 90.
99.961 Do part 15.
99.98 Do part 16 if n(100)=1.
```

Example 4: RPV Attack with REB-LEKs

```
Recall ABRVIMPT from file J0010.A1682
done

Do part 59.
For single aim, set aim index to 0; if independent, to 1
Aiming Method Index = 1

If dispensers are used, set Weapon Index to 1; otherwise 0
Weapon Index = 1

One to 4 separate targets may be used

Number of Target Areas = 3

        Area 1
Target Area in 10**6 sq ft = 1
Number of shelters in target area = 12

        Area 2
Target Area in 10**6 sq ft = 2
Number of shelters in target area = 12

        Area 3
Target Area in 10**6 sq ft = 4
Number of shelters in target area = 16

Shelter Ground Plane Area, sq ft = 2450
Vulnerability Ratio = .706
Weapon Reliability = .95
Dispenser Pattern Half Length, feet = 200
Dispenser Pattern Half Width, feet = 200
Number of bomblets per dispenser = 16

one to 4 Delivery Vehicle Types may be used
Number of Delivery Vehicle Types = 1

     Delivery Vehicle Type 1
Number of Weapons = 1
Delivery Vehicle Speed, knots = 450
Delivery Vehicle Dive Angle, degrees = 0
Altitude of last weapon, feet = 500
Outboard Station offset, feet = 11
Outboard Rack Throw Angle, degrees = 45

If aiming accuracy is specified as CEP in mils, set
accuracy index to 0; if CEP on the ground, to 1; if REP
and DEP on the ground, to 2; if range and deflection
standard deviation on the ground, to 3
Accuracy Index = 2

REP, feet = 300
DEP, feet = 40
```

Delivery Vehicle Type 1
Weapons/Carrier N(1)= 1

Number of Vehicles	Number of Weapons	Fractional Damage	Expected Damage	Damage Difference
		Area 1		
32	32	.471	5.65	5.65
64	64	705	8.46	2.81
96	96	841	10.09	1.64
128	128	.913	10.95	.96
160	160	.958	11.50	.55
		Area 2		
32	32	.303	3.64	3.64
64	64	.510	6.12	2.49
96	96	622	7.46	1.34
128	128	731	8.77	1.31
160	160.	.609	8.77	93
		Area 3		
32	32	.164	2.63	2.63
64	64	.289	4.62	1.99
96	96	431	6.89	2.26
128	128	[illegible]15	8.23	1.34
160	160	.[illegible]4	9.67	1.44

Appendix D

RPV ATTACK COMPUTATION RESULTS

The modified JOSS Airbase Attack Model, discussed in Appendix C, was used to compute attack effectiveness for the basic RPV weapon attack conditions given in Table 19; results appear in Tables 22 through 25. Tables 26 through 30 give results of variations in two of the pertinent parameters.

RPV ATTACK BASIC RESULTS

This subsection gives the JOSS computer results for the basic RPV weapon-attack conditions outlined in Table 19. Table 20 contains the effectiveness results for the MK-82 bomb, Table 21 for the REB-LEK munition, and Table 22 for the clustered Zuni. Standard conditions are as given in the aircraft-attack case. Note that these results are given by area and not as total damage to the complex. From these tables are constructed the allocation and total damage tables: Table 23 for MK-82, Table 24 for REB-LEK, and Table 25 for clustered Zuni.

The transition from the computer results to the allocation tables is straightforward. For example, consider the REB-LEK attack for the RMS III RPV with four dispensers (Table 21). The largest expected damage (ED) for 32 weapons is 5.17 in Area 1. Thus, in Table 24, the first entry is the allocation 32/0/0 with an expected damage of 5.17. For

Table 19

RPV WEAPON ATTACK CONDITIONS

Weapon	B(0)	Weapons per Dispenser	Loadout			Delivery Conditions			
			RMS II	RMS III	RMS IV	Angle	Velocity	Height	Aiming
MK-82 bomb	1.2		2	6	8	45	450	300	15 mils
Clustered Zuni rocket	1.0	7	1	4	5	0	450	500	300/40[a]
REB-LEK, 40-lb	0.706	16	1	4	5	0	450	500	300/40[a]

[a]REP/DEP.

Table 20

RPV DELIVERIES OF MK-82 BOMBS

(Standard conditions, B(0) = 1.200)

Weapons-Carrier N(1) = 2					Weapons/Carrier N(1) = 6					Weapons/Carrier N(1) = 8				
Number of RPVs	Number of Weapons	Fractional Damage	Expected Damage		Number of RPVs	Number of Weapons	Fractional Damage	Expected Damage		Number of RPVs	Number of Weapons	Fractional Damage	Expected Damage	
			Number	Difference				Number	Difference				Number	Difference
Area 1					Area 1					Area 1				
32	64	0.159	1.91	1.91	8	48	0.119	1.43	1.43	8	64	0.151	1.81	1.81
64	128	0.259	3.11	1.19	16	96	0.216	2.59	1.17	16	128	0.268	3.21	1.40
96	192	0.367	4.40	1.29	24	144	0.311	3.73	1.14	24	192	0.382	4.59	1.37
128	256	0.450	5.41	1.00	32	192	0.382	4.58	0.85	32	256	0.461	5.53	0.94
160	320	0.531	6.37	0.97	40	240	0.393	4.72	0.14	40	320	0.508	6.10	0.57
Area 2					Area 2					Area 2				
32	64	0.083	1.00	1.00	8	48	0.062	0.75	0.75	8	64	0.081	0.97	0.97
64	128	0.159	1.91	0.91	16	96	0.120	1.44	0.69	16	128	0.154	1.84	0.87
96	192	0.229	2.75	0.84	24	144	0.167	2.00	0.56	24	192	0.225	2.70	0.85
128	256	0.293	3.52	0.77	32	192	0.215	2.58	0.58	32	256	0.286	3.43	0.73
160	320	0.352	4.22	0.70	40	240	0.250	3.00	0.42	40	320	0.328	3.94	0.51
Area 3					Area 3					Area 4				
32	64	0.042	0.68	0.68	8	48	0.032	0.51	0.51	8	64	0.042	0.67	0.67
64	128	0.083	1.33	0.65	16	96	0.062	1.00	0.49	16	128	0.082	1.32	0.64
96	192	0.122	1.95	0.62	24	144	0.090	1.43	0.43	24	192	0.116	1.85	0.53
128	256	0.142	2.27	0.32	32	192	0.118	1.88	0.45	32	256	0.151	2.42	0.57
160	320	0.174	2.79	0.52	40	240	0.144	2.31	0.43	40	320	0.184	2.94	0.53

Table 21

RPV DELIVERIES OF REB-LEK DISPENSERS

(Standard conditions, B(0) = 0.706)

Weapons/Carrier N(1) = 1					Weapons/Carrier N(1) = ·					Weapons/Carrier N(1) = 5				
Number of RPVs	Number of Weapons	Fractional Damage	Expected Damage		Number of RPVs	Number of Weapons	Fractional Damage	Expected Damage		Number of RPVs	Number of Weapons	Fractional Damage	Expected Damage	
			Number	Difference				Number	Difference				Number	Difference
Area 1					Area 1					Area 1				
32	32	0.471	5.65	5.65	8	32	0.431	5.17	5.17	8	40	0.496	5.95	5.95
64	64	0.705	8.46	2.81	16	64	0.660	7.92	2.75	16	80	0.731	8.77	2.82
96	96	0.841	10.09	1.64	24	96	0.804	9.64	1.72	24	120	0.862	10.34	1.57
128	128	0.913	10.95	0.86	32	128	0.885	10.61	0.97	32	160	0.927	11.13	0.79
160	160	0.958	11.50	0.55	40	160	0.940	11.28	0.67	40	200	0.951	11.41	0.28
Area 2					Area 2					Area 2				
32	32	0.303	3.64	3.64	8	32	0.286	3.43	3.43	8	40	0.345	4.14	4.14
64	64	0.510	6.12	2.48	16	64	0.485	5.82	2.39	16	80	0.537	6.44	2.30
96	96	0.622	7.46	1.34	24	96	0.593	7.11	1.30	24	120	0.664	7.97	1.53
128	128	0.731	8.77	1.31	32	128	0.675	8.10	0.99	32	160	0.745	8.94	0.97
160	160	0.809	9.70	0.93	40	160	0.754	9.05	0.94	40	200	0.818	9.81	0.88
Area 3					Area 3					Area 4				
32	32	0.164	2.63	2.63	8	32	0.163	2.61	2.61	8	40	0.200	3.20	3.20
64	64	0.289	4.62	1.99	16	64	0.287	4.59	1.98	16	80	0.345	5.52	2.32
96	96	0.431	6.89	2.28	24	96	0.414	6.62	2.03	24	120	0.487	7.79	2.27
128	128	0.515	8.23	1.34	32	128	0.496	7.93	1.31	32	160	0.575	9.20	1.41
160	160	0.604	9.67	1.44	40	160	0.555	8.88	0.95	40	200	0.637	10.19	0.99

Table 22

RPV DELIVERIES OF CLUSTERED ZUNI

(Standard Conditions, B(0) = 1.000)

Weapons/Carrier N(1) = 1					Weapons/Carrier N(1) = 4					Weapons/Carrier N(2) = 5				
Number of RPVs	Number of Weapons	Fractional Damage	Expected Damage		Number of RPVs	Number of Weapons	Fractional Damage	Expected Damage		Number of RPVs	Number of Weapons	Fractional Damage	Expected Damage	
			Number	Difference				Number	Difference				Number	Difference
Area 1					Area 1					Area 1				
32	32	0.334	4.00	4.00	8	32	0.313	3.75	3.75	8	40	0.369	4.42	4.42
64	64	0.569	6.82	2.82	16	64	0.513	6.15	2.40	16	80	0.586	7.03	2.60
96	96	0.713	8.55	1.73	24	96	0.662	7.94	1.79	24	120	0.735	8.82	1.80
128	128	0.814	9.77	1.21	32	128	0.762	9.15	1.21	32	160	0.828	9.94	1.12
160	160	0.868	10.42	0.65	40	160	0.847	10.16	1.01	40	200	0.900	10.79	0.85
Area 2					Area 2					Area 2				
32	32	0.206	2.48	2.48	8	32	0.196	2.35	2.35	8	40	0.235	2.82	2.82
64	64	0.366	4.39	1.92	16	64	0.350	4.20	1.84	16	80	0.416	5.00	2.17
96	96	0.499	5.99	1.59	24	96	0.452	5.42	1.23	24	120	0.522	6.26	1.26
128	128	0.568	6.82	0.83	32	128	0.556	6.68	1.25	32	160	0.603	7.23	0.97
160	160	0.653	7.83	1.01	40	160	0.609	7.31	0.63	40	200	0.684	8.20	0.97
Area 3					Area 3					Area 3				
32	32	0.115	1.83	1.83	8	32	0.108	1.73	1.73	8	40	0.133	2.13	2.13
64	64	0.196	3.13	1.30	16	64	0.195	3.12	1.40	16	80	0.238	3.80	1.67
96	96	0.303	4.84	1.71	24	96	0.290	4.65	1.52	24	120	0.348	5.57	1.77
128	128	0.370	5.92	1.08	32	128	0.356	5.69	1.05	32	160	0.422	6.76	1.18
160	160	0.447	7.16	1.24	40	160	0.431	6.90	1.21	40	200	0.506	8.09	1.33

Table 23

MK-82 RPV ATTACK: ALLOCATION AND DAMAGE

(Standard conditions, B(0) = 1.2; area = $7(10)^6$)

Number of RPVs	Number of Weapons	Allocation	Expected Number of Hangarettes Damaged	Percent of Hangarettes Damaged
I. RMS II (2 weapons)				
32	64	64/0/0	1.91	4.8
64	128	128/0/0	3.11	7.8
96	192	192/0/0	4.40	11.0
128	256	256/0/0	5.41	13.5
160	320	256/64/0	6.41	16.0
192	384	320/64/0	7.38	18.5
224	448	320/128/0	8.28	20.7
II. RMS III (6 weapons)				
8	48	48/0/0	1.43	3.6
16	96	96/0/0	2.59	6.4
24	144	144/0/0	3.73	9.4
32	192	192/0/0	4.58	11.5
40	240	192/48/0	5.23	13.1
48	288	192/96/0	6.02	15.0
56	336	192/144/0	6.58	16.5
64	384	192/192/0	7.16	17.9
72	432	192/192/48	7.67	19.2
80	480	240/192/48	8.18	20.5
III. RMS IV (8 weapons)				
8	64	64/0/0	1.81	4.7
16	128	128/0/0	3.21	8.0
24	192	192/0/0	4.59	11.5
32	256	192/64/0	5.56	13.9
40	320	256/64/0	6.50	16.2
48	384	256/128/0	7.37	18.4
56	448	256/192/0	8.23	20.6

Table 24

REB-LEK RPV ATTACK: ALLOCATION AND DAMAGE

(Standard conditions, B(0) = 0.706, area = $7(10)^6$)

Number of RPVs	Number of Weapons	Allocation	Expected Number of Hangarettes Damaged	Percent of Hangarettes Damaged
		I. RMS II (1 weapon)		
32	32	32/0/0	5.65	14.1
64	64	32/32/0	9.26	23.2
96	96	64/32/0	12.10	30.3
128	128	64/32/32	14.73	36.8
192	192	64/64/64	19.20	48.0
256	256	96/64/96	23.00	57.5
320	320	96/64/160	25.88	64.7
384	384	96/128/160	28.53	71.3
		II. RMS III (4 weapons)		
8	32	32/0/0	5.17	12.9
16	64	32/32/0	8.60	21.5
24	96	64/32/0	11.96	28.4
32	128	64/32/32	13.96	34.9
48	192	64/64/64	20.36	50.9
64	256	96/64/96	22.08	55.2
80	320	96/96/128	24.68	61.7
96	384	128/128/128	26.64	66.6
		III. RMS IV (5 weapons)		
8	40	40/0/0	5.95	14.8
16	80	40/40/0	10.09	25.2
24	120	40/40/40	13.29	33.2
32	160	80/40/40	16.11	40.3
40	200	80/140/180	18.43	46.1
48	240	80/80/80	20.73	51.8
56	280	80/80/120	23.00	57.5
64	320	120/80/120	24.57	61.4
72	360	120/120/120	26.1	65.3

Table 25

ZUNI RPV ATTACK: ALLOCATION AND DAMAGE

(Standard conditions, B(0) = 1)

Number of RPVs	Number of Weapons	Allocation	Expected Number of Hangarettes Damaged	Percent of Hangarettes Damaged
		I. RMS II (1 weapon)		
32	32	32/0/0	4.00	10.0
64	64	64/0/0	6.82	17.1
96	96	64/32/0	9.10	22.8
128	128	64/64/0	11.81	28.0
160	160	64/64/32	13.04	32.6
192	192	96/64/32	14.77	36.9
256	256	96/96/64	17.67	44.1
320	320	128/96/96	20.60	51.5
384	384	128/96/160	22.92	57.3
		II. RMS III (4 weapons)		
8	32	32/0/0	3.75	8.75
16	64	64/0/0	6.15	15.4
24	96	64/32/0	8.50	21.3
32	128	64/64/0	10.35	25.9
48	192	96/64/32	13.87	34.7
64	256	96/64/96	16.79	42.0
80	320	96/128/96	19.27	48.2
96	384	128/128/128	21.52	53.8
		III. RMS IV (5 weapons)		
8	40	40/0/0	4.42	11.05
16	80	40/40/0	7.24	18.1
24	120	80/40/0	9.85	24.6
32	160	80/80/0	12.03	30.1
40	200	80/80/40	14.16	35.4
48	240	120/80/40	15.95	39.9
56	280	120/80/80	17.62	44.1
64	320	120/80/120	19.39	48.5
72	360	120/120/120	20.65	51.6

the next increment of 32 weapons, we find the first 32 weapons against Area 2 results in an ED of 3.43, the largest damage difference among the remaining weapons. Therefore, the second entry for 64 weapons in Table 24 is an allocation of 32/32/0, with a total ED of 5.17 + 3.43 = 8.60. For the next 32 weapons, the largest remaining damage difference is 2.75 from Area 1; the next line is thus 64/32/0 with ED = 8.60 + 2.75 = 11.35.

An example of a complete JOSS run is given in Example 4, Appendix C, for an RPV REB-LEK attack, using the RMS II. The JOSS output is the same as the first part of Table 21.

SENSITIVITY VARIATIONS

As in the aircraft attack case, we consider next the effect of varying some of the pertinent parameters on the RPV attack results. We restrict ourselves here to a variation in just two of the parameters: (a) the vulnerable area of a hangarette and (b) the size of the target complex. (We considered the effect of a variation in attack size in the basic computations of the subsection above.)

Vulnerable Area as a Parameter

We consider the same vulnerable area variations as in the aircraft attack variations of Section III.D, i.e., hangarette vulnerable areas of 1000, 4000, and 6500 sq ft. Equivalently, we use ratios B(0) of 0.408, 1.633, and 2.654, the ratios of the vulnerable areas to the plan area of 2450 sq ft. In addition, we have included the parameter values of B(0) = 1.2 for the MK-82, B(0) = 0.706 for the REB-LEK, and B(0) = 0.706 for the clustered Zuni. These results are contained in Table 26 for the MK-82, Table 27 for the REB-LEK, and Table 28 for the clustered Zuni.

Size of Target Complex as a Parameter

As before, in addition to the standard target complex area of $7(10)^6$ sq ft, we consider two variations with total areas 1.5 and 2 times greater, i.e., $10.5(10)^6$ and $14(10)^6$ sq ft. In each case, the relative sizes and shapes of the three component areas remained the same. Table 29 shows the results of this variation for the MK-82 bomb and Table 30 for the REB-LEK dispenser.

Table 26

MK-82 RPV ATTACK: VULNERABLE AREA VARIATION

Number of RPVs	Number of Weapons	Vulnerable Area, Sq Ft							
		1000 (0.408)[a]		2940 (1.2)		4000 (1.633)		6500 (2.654)	
		ED[b]	PER[c]	ED	PER	ED	PER	ED	PER
I. RMS II (2 weapons)									
32	64	0.70	1.8	1.91	4.8	2.23	5.6	3.32	8.3
64	128	1.34	3.4	3.11	7.8	3.98	10.0	5.64	14.1
96	192	1.76	4.4	4.40	11.0	5.51	13.8	7.66	19.2
128	256	2.25	5.6	5.41	13.5	6.83	17.1	9.42	23.6
160	320	2.78	7.0	6.41	16.0	8.00	20.0	11.09	27.7
	384			7.38	20.7	9.02	23.0	12.49	31.2
II. RMS III (6 weapons)									
8	48	0.52	1.3	1.43	3.6	1.87	4.7	2.69	6.7
16	96	0.98	2.5	2.59	6.4	3.34	8.4	4.62	11.6
24	144	1.46	3.7	3.73	9.4	4.63	11.6	6.40	16.0
32	192	1.85	4.6	4.58	11.5	5.70	14.3	7.90	19.8
40	240	2.31	5.8	5.23	13.1	6.69	16.1	9.21	23.0
48	288			6.02	15.0	7.58	19.0	10.42	26.1
56	336			6.58	16.5	8.28	20.7	11.46	28.7
64	384			7.16	17.9	9.02	22.6	12.44	31.1
III. RMS IV (8 weapons)									
8	64	0.66	1.7	1.81	4.7	2.37	5.9	3.50	8.8
16	128	1.23	3.1	3.21	8.0	4.10	10.3	5.27	13.2
24	192	1.80	4.5	4.59	11.5	5.60	14.0	7.21	18.0
32	256	2.32	5.8	5.56	13.9	6.88	17.2	9.46	23.7
40	320	2.89	7.2	6.50	16.2	8.04	20.1	11.06	27.7
48	384			7.37	18.4	9.17	22.9	12.42	31.1
56	448			8.23	20.6	10.07	25.2	13.69	34.2

[a]Vulnerable area ratio B(0).

[b]Expected number of hangarettes damaged.

[c]Percent of total hangarettes damaged.

Table 27

REB-LEK RPV ATTACK: VULNERABLE AREA VARIATION

Number of RPVs	Number of Weapons	Vulnerable Area, Sq Ft							
		1000 (0.405)[a]		1730 (0.706)		4000 (1.633)		6500 (2.654)	
		ED[b]	PER[c]	ED	PER	ED	PER	ED	PER
I. RMS II (1 weapon)									
32	32	3.78	9.5	5.65	14.1	8.89	24.0	12.60	31.5
64	64	6.52	16.3	9.26	23.2	15.30	38.3	19.12	47.8
96	96	8.84	22.1	12.10	30.3	20.33	50.8	24.33	60.8
128	128	10.67	26.7	14.73	36.8	23.48	61.0	28.52	71.3
192	192	14.11	35.3	19.20	48.0	28.36	70.9	32.91	82.3
256	256	17.0	42.5	23.00	57.5	31.63	79.1	35.46	88.7
320	320	19.66	49.2	25.88	64.7	34.44	86.1		
384	384	21.98	55.0	28.53	71.1				
II. RMS III (4 weapons)									
8	32	3.54	8.9	5.17	12.9	8.81	22.0	11.58	29.0
16	64	5.86	14.7	8.60	21.5	14.28	35.7	18.03	45.1
24	96	8.06	20.2	11.35	28.4	18.69	46.7	23.22	58.1
32	128	9.83	24.6	13.96	34.9	21.82	54.6	27.62	69.1
48	192	13.20	33.0	20.36	50.9	27.16	67.9	32.42	81.1
64	256	15.95	39.9	22.08	55.2	29.62	74.1	35.04	87.6
80	320	18.37	45.9	24.68	61.7	32.78	82.0		
96	384	20.60	51.2	26.64	66.6	34.72	86.9		
III. RMS IV (5 weapons)									
8	40	4.19	10.4	5.95	14.8	10.04	25.1	12.66	31.7
16	80	6.84	17.1	10.09	25.2	16.27	40.7	20.21	50.5
24	120	9.38	23.5	13.29	33.2	21.27	53.2	25.47	63.7
32	160	11.46	28.7	16.11	40.3	24.7	61.7	29.66	74.2
40	200	13.45	33.6	18.43	46.1	27.28	68.2	32.11	80.3
98	240	15.25	38.1	20.73	51.8	29.77	74.4	34.23	85.5
56	280	16.82	42.0	23.00	57.5	32.14	80.4	35.65	89.1
64	320	18.51	46.3	24.57	61.4	33.45	83.6		
72	360	20.88	52.2	26.1	65.3	34.01	85.0		

[a]Vulnerable area ratio B(0).

[b]Expected number of hangarettes damaged.

[c]Percent of total hangarettes damaged.

Table 28

CLUSTERED ZUNI RPV ATTACK: VULNERABLE AREA VARIATION

Number of RPVs	Number of Weapons	Vulnerable Area, Sq Ft: 1000 (0.405)[a] ED[b]	1000 (0.405)[a] PER[c]	1730 (0.706) ED	1730 (0.706) PER	4000 (2.633) ED	4000 (2.633) PER	6500 (2.634) ED	6500 (2.634) PER
				I. RMS II (1 weapon)					
32	32	1.87	4.7	3.02	7.6	5.72	14.3	7.64	19.1
64	64	3.55	8.9	5.41	13.5	9.41	23.5	12.88	32.2
96	96	4.87	12.2	7.24	18.1	12.22	30.6	16.84	42.1
128	128	6.05	15.1	8.91	22.2	14.89	37.2	19.73	49.3
192	192	8.13	20.3	11.75	29.4	19.40	48.5	25.22	63.1
256	256	9.92	24.8	14.39	36.0	23.32	58.3	29.32	73.3
320	320	11.51	28.8	16.63	41.6	26.02	65.1	31.70	79.3
384	384	13.05	32.6	18.90	47.3	28.74	71.9		
				II. RMS III (4 weapons)					
8	32	1.81	4.5	2.87	7.2	5.23	13.1	6.79	17.0
16	64	3.44	8.6	5.19	13.0	9.71	24.3	11.56	28.9
24	96	4.73	11.8	6.94	17.4	11.47	28.7	15.58	39.0
32	128	5.90	14.7	8.39	21.0	14.12	35.3	18.36	45.9
48	192	7.90	19.8	11.02	27.6	18.54	46.4	23.54	59.0
64	256	9.49	23.7	13.40	33.5	22.30	55.8	27.47	68.7
80	370	11.03	27.6	15.62	39.0	24.91	62.3	30.09	75.0
88	384	12.47	31.2	17.70	44.5	26.85	67.1		
				III. RMS IV (5 weapons)					
8	40	2.19	5.5	3.43	8.6	6.01	15.0	7.58	19.0
16	80	4.10	10.2	5.71	14.3	10.21	25.5	13.32	33.3
24	120	5.55	13.9	7.83	19.6	13.46	33.7	18.06	45.2
32	166	6.86	17.2	9.59	24.0	16.28	40.7	21.11	52.8
40	200	8.00	20.0	11.30	28.3	18.69	46.7	23.76	59.4
48	240	8.92	22.3	12.86	32.2	20.94	52.4	26.39	66.0
56	280	10.07	25.2	14.09	35.2	23.23	58.1	28.99	72.5
64	320	11.05	27.6	15.36	38.4	24.79	62.0	30.26	75.1
72	360	11.98	30.0	16.75	41.9	26.31	65.8	31.44	78.6
80	400	12.84	32.1	17.94	44.9	28.72	71.8	32.54	81.3

[a]Vulnerable area ratio B(0).

[b]Expected number of hangarettes damaged.

[c]Percent of total hangarettes damaged.

Table 29

MK-82 RPV ATTACK: TARGET AREA VARIATION

Number of RPVs	Number of Weapons	Hangarette Target Area, Sq Ft					
		$7(10)^6$		$10.5(10)^6$		$14(10)^6$	
		ED[a]	PER[b]	ED	PER	ED	PER
I. RMS II (2 weapons)							
32	64	1.91	4.8	1.30	3.2	1.00	2.5
64	128	3.11	7.8	2.42	6.1	1.91	4.8
96	192	4.40	11.0	3.48	8.7	2.75	6.9
128	256	5.41	13.5	4.35	10.9	3.52	8.8
160	320	6.41	16.0	5.18	12.9	4.22	10.5
192	384	7.38	18.5	5.84	14.6	4.90	12.5
II. RMS III (6 weapons)							
8	48	1.43	3.6	0.97	2.4	0.75	1.9
16	96	2.59	6.4	1.81	4.5	1.44	3.6
24	144	3.73	9.4	2.64	6.6	2.00	5.0
32	192	4.58	11.5	3.28	8.2	2.58	6.5
40	240	5.23	13.1	3.97	9.9	3.09	7.7
48	288	6.02	15.0	4.48	11.2	3.58	8.9
56	336	6.58	16.5	4.96	12.4	4.01	10.0
64	384	7.16	17.9	5.37	13.4	4.46	11.1
III. RMS IV (8 weapons)							
8	64	1.81	4.7	1.25	3.1	0.97	2.4
16	128	3.21	8.0	2.27	5.7	1.84	4.6
24	192	4.59	11.5	3.30	8.2	2.70	6.8
32	256	5.56	13.9	4.05	10.1	3.43	8.6
40	320	6.50	16.2	4.86	12.1	4.10	10.2
48	384	7.37	18.4	5.41	13.5	4.75	11.9

[a]Expected number of hangarettes damaged.

[b]Percent of total hangarettes damaged.

Table 30

REB-LEK ATTACK: TARGET AREA VARIATION

(B(0) = 0.706)

Number of RPVs	Number of Weapons	Hangarette Target Area, Sq Ft					
		$7(10)^6$		$10.5(10)^6$		$14(10)^6$	
		ED[a]	PER[b]	ED	PER	ED	PER
I. RMS II (1 weapon)							
32	32	5.65	14.1	4.51	11.3	3.64	9.1
64	64	9.26	23.2	7.11	17.8	6.27	15.7
96	96	12.10	30.3	9.48	23.7	8.75	21.9
128	128	14.73	36.8	11.55	28.4	10.74	26.9
192	192	19.70	48.0	15.14	37.6	14.35	35.9
256	256	23.00	57.5	17.71	44.3	17.13	42.8
320	320	25.88	64.7	20.00	50.0	19.52	48.8
384	384	28.53	71.1	21.95	54.9	21.41	53.5
II. RMS III (4 weapons)							
8	32	5.17	12.9	4.06	10.2	3.43	8.6
16	64	8.60	21.5	6.60	16.5	6.04	15.1
24	96	11.35	28.4	8.94	22.4	8.43	21.1
32	128	13.96	34.9	10.92	27.3	10.41	26.0
48	192	20.36	50.9	14.31	35.8	13.73	34.2
64	256	22.08	55.2	16.82	42.1	16.07	40.2
80	320	24.68	61.7	19.05	47.6	18.01	45.0
88	384	26.64	66.6	20.95	52.4	19.88	49.7
III. RMS IV (5 weapons)							
8	40	5.95	14.8	4.73	11.8	4.14	10.4
16	80	10.09	25.2	7.78	19.5	7.34	18.4
24	120	13.29	33.2	10.35	25.9	9.66	24.1
32	160	16.11	40.3	12.37	30.9	11.96	29.9
40	200	18.43	46.1	14.27	35.7	14.23	35.6
48	240	20.73	51.8	16.01	40.0	15.76	39.4
56	280	23.00	57.5	17.67	44.2	17.17	42.9
64	320	24.57	61.4	19.10	47.7	18.44	46.1
72	360	26.10	65.3	20.29	50.6	19.54	48.9

[a]Expected number of hangarettes damaged.

[b]Percent of total hangarettes damaged.

REFERENCES

1. Harris, K., R. N. Snow, and J. R. Lind, *FAST-VAL: Target Coverage Model*, The Rand Corporation, RM-4567-PR, March 1966.

2. Snow, R. N., *FAST-VAL: A Theoretical Approach to Some General Target Coverage Problems*, The Rand Corporation, RM-4566-PR, March 1966.

3. Snow, R. N., and M. E. Ryan, *A Simplified Weapons Evaluation Model*, The Rand Corporation, RM-5677-1-PR, April 1970.

4. *Joint Munitions Effectiveness Manual (JMEM): Air-to-Surface* (U), Air Force TH 61A 1-1-1-1, Change 2, 6 July 1971 (Confidential).

5. Bryan, G. E., and E. W. Paxson, *The JOSS Notebook*, The Rand Corporation, RM-5367-PR, August 1967.

6. Dadant, P. M., and J. L. Sibley, *Nonnuclear Attack of Enemy Airbases* (U), The Rand Corporation, R-671-PR, September 1971 (Secret).

7. Lau, J., et al., *An Analysis of Remotely Manned Systems for Attacking SAM Sites* (U), The Rand Corporation, R-710-PR, September 1971 (Secret).

8. Breitsenstein, E. P., and R. C. Ward, *The Wang 700 Users Manual for the JMEM/AS Hand Methods*, Naval Weapons Center, China Lake, California, Technical Note 4072-30, July 1971.

9. Mow, C. C., *The Vulnerability of Aircraft Hangarettes* (U), The Rand Corporation, R-725-PR, November 1971 (Secret).