FM 44-1-1

DEPARTMENT OF THE ARMY FIELD MANUAL

U.S. ARMY AIR DEFENSE ARTILLERY OPERATIONS

HEADQUARTERS, DEPARTMENT OF THE ARMY

OCTOBER 1969

FIELD MANUAL
No. 44-1-1

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., *17 October 1969*

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* This manual supersedes TC 44-12, 4 June 1965.

CHAPTER 1
GENERAL

1-1. Purpose and Scope

a. This manual is a guide for air defense artillery (ADA) commanders and staff officers in the techniques of employment of air defense artillery units. This manual complements FM 44-1, FM 44-2, FM 44-3, FM 44-95, and FM 44-96.

b. This manual presents brief nontechnical descriptions of U.S. Army air defense materiel; detailed coverage of Nike Hercules, Hawk, ADA automatic weapons (AW), and Chaparral defense designs; a discussion of manual Army air defense command post (AADCP) personnel, equipment, and procedures; construction of coverage and clutter diagrams; explanation of the World Geographic Reference System (GEOREF); a sample air defense SOP and air defense annex to an operation plan; and English-metric conversion tables.

1-2. Recommended Changes and Comments

Users of this manual are encouraged to submit recommended changes and comments to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons will be provided for each comment to insure understanding and complete evaluation. Comments should be prepared on DA Form 2028 (Recommended Changes to Publications) and forwarded direct to Commandant, U.S. Army Air Defense School, ATTN: AKBAA-S-DL, Forth Bliss, Texas 79916.

CHAPTER 2

ARMY AIR DEFENSE MATERIEL

2-1. General

U.S. Army air defense materiel presently in operation includes surface-to-air guided missile systems, automatic weapon systems, and fire distribution systems. Unclassified system summaries are presented below. System technical manuals and FM 44-1A should be consulted for additional details.

2-2. Nike Hercules System

a. The Nike Hercules system is a long-range, nuclear-capable, guided missile system designed to counter the medium- and high-altitude air threat. The system is designed to operate in an ECM environment and against a highly complicated threat. Nike Hercules battery equipment is deployed in two separate tactical areas.

(1) The launching area contains 12 launchers (it has the capability of controlling 16 launchers), a basic load of missiles, and associated power, test, handling, and missile assembly facilities. Missile selection and firing functions may be accomplished semiautomatically through control circuits originating in the battery control area.

(2) The battery control area includes a Nike Hercules acquisition radar (LOPAR) for target detection; a target tracking radar (TTR) and target ranging radar (TRR) for tracking a selected target; computer equipment for prelaunch computations and generation of missile in-flight steering and burst commands; a missile tracking radar (MTR) for missile tracking and relay of computer-generated orders to the missile being tracked; and associated power, test, and battery control facilities. An additional radar, the mobile or fixed high-power acquisition radar (HIPAR) or the alternate battery acquisition radar (ABAR), may be issued for use with the Nike Hercules system to increase target detection range, provide improved altitude coverage, and improve system operation in an electronic countermeasures (ECM) environment.

b. The Nike Hercules system has demonstrated its effectiveness against targets traveling at speeds in excess of 3,400 kmph (1,836 knots). It has successfully engaged targets at ranges exceeding 139 kilometers and is effective against targets at altitudes of more than 30 kilometers. The system also can effectively engage surface targets with nuclear warheads at even greater ranges. The supersonic Nike Hercules missile may be armed with either a nuclear or high-explosive warhead. The two stage missile-rocket motor cluster combination weighs about 10,000 pounds.

2-3. Hawk System

a. The Hawk missile system is designed to cope with low- and medium-altitude targets, with special emphasis on countering aircraft which attack at low altitude to escape radar detection and attempt to penetrate a defense by taking advantage of the degradation of pulse-type radars caused by ground clutter. Hawk continuous-wave (CW) radars and semiactive homing guidance are not seriously degraded by ground clutter.

b. The equipment in a *towed* Hawk battery includes a battery control central (BCC) for control of battery operations; a pulse acquisition radar (PAR) for medium-altitude coverage; a continuous-wave acquisition radar (CWAR) for low-altitude coverage; two continuous-wave high-powered illuminator radars (HIPIR) for tracking targets; a range-only radar (ROR) to provide range information in an ECM environment; six launchers; and associated power, test, handling, and control equipment. All of the equipment is either vehicular or trailer-mounted, providing excellent ground mobility. Most of the towed Hawk firing battery TOE equipment is air-transportable by fixed-wing transport aircraft and cargo helicopters. Two towed sections are included in the towed Hawk missile battery providing two fire units. An assault fire command console (AFCC), housing the minimum displays and controls needed to conduct engagements with one firing section, provides the towed battery with a means of forming two fire units, each capable of independent tactical operation.

c. The *self-propelled* Hawk battery includes one towed platoon and two self-propelled platoons, providing three fire units. The towed *platoon* contains the same radar and control equipment as a towed Hawk *battery* (*b* above) less one high-powered illuminator radar, three launchers, and the AFCC. The self-propelled platoons are normally deployed forward of the towed platoon, thus extending forward the low-altitude air defense capability. Each self-propelled platoon includes a platoon command post (PCP) for control of platoon operations, a continuous-wave acquisition radar for low-altitude coverage, a high-powered illuminator radar for target tracking, and three self-propelled launchers. The PCP and radars are self-propelled platoon normally engages only low-altitude targets, although the towed platoon, by voice telling over its organic radio, can designate medium-altitude targets for self-propelled platoon engagement.

d. The system is highly flexible, both in its means of attack and method of employment. The Hawk battery, having two fire units (towed battery) or three fire units (self-propelled battery), can fire at two or three targets, respectively, at the same time. Although primarily designed to meet the low-altitude threat, it also provides excellent defense against medium-altitude targets. System effective range and altitude are in excess of 25 kilometers and 11.6 kilometers, respectively. The missile weighs 1,295 pounds. It has a solid-propellant missile motor and is armed with a high-explosive warhead.

2-4. Redeye Weapon

a. The Redeye weapon is a man-transportable, shoulder-fired, low-altitude, all-arms air defense system used in the forward battle area. The Redeye weapon is composed of two basic elements, missile and launcher. The missile is sealed in the launcher and cannot be removed in the field except by firing.

b. The missile is stabilized and steered in flight by control surfaces located on the forward portion of the missile and further stabilized by fins in the tail assembly. It has an infrared homing guidance system, a solid-propellant motor, and a high-explosive warhead. The missile is fired from a launcher approximately 1.3 meters long. The missile-launcher combination, weighing 29.3 pounds, is operated by one man.

c. The organizational unit for the employment of Redeye in the field is the air defense section organic to each divisional maneuver battalion. Each section consists of a headquarters and usually five two-man Redeye teams. Each team constitutes a fire unit with command and control exercised by SOP.

2-5. Chaparral Weapon System

a. The Chaparral weapon system is a highly mobile missile system designed to counter the high-speed, low-altitude enemy air threat to forward elements of the field army. The Chaparral system is composed of three major elements, launching station, tracked carrier vehicle, and Chaparral missile. The system is manned by a crew of five men with each system and crew constituting a fire unit. The organizational unit for employment is the Chaparral battery consisting of a headquarters and three firing platoons of four fire units each.

b. The launching station is mounted on the tracked carrier vehicle and contains all of the equipment necessary to launch missiles. It consists of a base structure and a mount. The base structure contains the master control panel, power unit, air compressor, communications equipment, and stowage space for eight missiles. The mount, containing the gunner's control and sighting equipment, carries four missiles mounted on launch rails.

c. The system is controlled by an operator who sits in an enclosed compartment within the mount. The operator acquires the target by slewing the mount in azimuth and the launchers in elevation, tracks the target using a simple reflex sight, and fires one or more of the four missiles located on the launchers.

d. The vehicle used with the Chaparral system is self-propelled, lightweight, and unarmored. The vehicle is capable of fording streams up to 30 inches deep and swimming when equipped with a flotation kit.

e. The Chaparral missile is 3 meters long and weighs 190 pounds. It is supersonic and homes on infrared radiations.

2-6. Automatic Weapon Systems

a. Twin 40-mm Self-Propelled Gun M42.

(1) The M42 system is made up of two 40-

mm guns mounted on a lightly armored, full-track vehicle of tank-type construction. Each vehicle is a fire unit and includes all facilities required to conduct a series of engagements.

(2) The twin 40-mm gun is capable of being fired at a rate of 240 rounds per minute. The maximum effective range against airborne targets is 1,650 meters. It is primarily effective against low-speed targets. Effective range against surface targets is dependent on the type of ammunition being used and the situation in which it is being used. Using high-explosive ammunition, the maximum horizontal range is approximately 5,000 meters. If no contact is made, the tracer element will burn out between 3,480 and 3,930 meters and the projectile will self-detonate. The principal limitations of the M42, particularly when used as a ground fire support weapon, are its light armor, high silhouette, and the combat service support problems generated by its high rate of fire and fuel consumption.

b. Multiple Caliber .50 Machinegun Trailer Mount M55.

(1) The multiple caliber .50 machinegun trailer mount M55 is composed of a powered quadruple caliber .50 machinegun turret mounted on a two-wheeled trailer. Total system weight is approximately 3,000 pounds.

(2) The M55 mount has four caliber .50 machineguns having a combined cyclic rate of fire of 1,800 to 2,200 rounds per minute. The maximum effective range against aerial targets is approximately 725 meters. It is primarily effective against low-speed targets and as a ground support weapon it is particularly effective against exposed troops. The M55 mount may be towed at slow speeds by a ¼-ton truck or manhandled for short distances. Normally it is transported in a specially equipped 2½-ton truck.

c. Vulcan Self-Propelled Weapon System.

(1) The Vulcan is an automatic weapon system which consists of a turret-mounted 20-mm cannon, an ammunition storage and feed system, a gyro-stabilized lead-computing sight, and a range-only radar. The Vulcan is fielded in two configurations, a self-propelled system which used a full-tracked armored vehicle as the carrier; and a towed system wherein the weapon is carried in a trailer and towed by a Gama Goat prime mover.

(2) Vulcan is designed to deliver effective fire at a very high rate on subsonic, low-flying, aerial targets. It is also effective against moving or stationary ground targets. The gun uses electrically primed 20-mm, high-explosive, incendiary, self-destructing ammunition when employed for air defense and high-explosive, incendiary, point-detonating ammunition when employed for ground fire support.

2-7. Air Defense Artillery Fire Distribution Systems

a. Air defense artillery fire distribution systems are used to enhance the communications capabilities of ADA weapon systems in the distribution of fires, providing early warning, and assisting in the identification of tracks. They also provide an overview of the activities of all fire units of the defense, thus providing the commander with the necessary information to fulfill his mission. These systems collect data provided by radar and other control and coordination systems, present this information on electronic displays at the Army air defense command post, and distribute this data and weapon control information to the fire units.

b. The AN/TSQ-51 (Missile Mentor) system serves certain AADCP established at CONUS vital area defense level and enables the Army air defense commander to supervise defense operations. The system consists of an operations trailer and equipment trailer and can be augmented with one or more remote radar integration stations (RRIS). The operations and equipment trailers are used at the AADCP while the RRIS is used to net remotely located radars and provide supplementary acquisition radar data to the AADCP. The system includes general purpose operating consoles, general purpose digital computers, computer-driven status displays, communications, and automatic data link equipment. The Missile Mentor can receive and process data from the Air Force SAGE (semiautomatic ground environment) system, adjacent AADCP's, RRIS, the local acquisition radars. Data are automatically exchanged by digital data link with Nike Hercules and Hawk fire units. The system is designed on the modular concept, allowing addition or deletion of functions, so that requirements of various defense complexes may be met economically.

c. The AN/GSC-5 (BIRDIE) system serves other AADCP established at CONUS vital area defense level and enables the Army air defense commander to supervise defense operations. The BIRDIE situation display consoles may be shelter-mounted or emplaced in a permanent structure. There are three different configurations of the BIRDIE system. The particular configuration used is determined by the requirements of the defense area and is identified by the number of consoles employed. Each console is capable of coordinating up to four Nike Hercules batteries. A maximum of four consoles may be used. A defense acquisition radar (DAR) or surveillance radar supplies target position information (radar video) to the system. The BIRDIE system is capable of receiving, processing, and transmitting automatic data link information between fire units and semiautomatic ground environment (SAGE) or backup intercept control (BUIC) systems.

d. The AN/MSG–4 (Missile Monitor) system uses standard military vehicles to make it completely mobile for use by ADA units. It is composed of a brigade- or group-level subsystem and a Nike Hercules and/or Hawk battalion-level subsystem.

(1) The brigade- or group-level subsystem is composed of a radar data processing center (RDPC), weapons monitoring center (WMC), defense acquisition radar, and trailer-mounted electronic shops. The weapons monitoring center is the tactical center of the Missile Monitor system.

(2) The battalion-level subsystem, which may operate independently, consists of a battalion operations central. The battalion radar section's electronic search central provides local radar data.

e. The data converter AN/GSA–77, located at each fire unit, integrates the fire unit with the AADCP by performing data modulation and demodulation, data conversion, and auxiliary data encoding and decoding. It is compatible with AADCP's employing the Missile Mentor, Missile Monitor, or BIRDIE fire distribution systems and with Nike Hercules and Hawk missile systems. The system occupies 3.7 cubic feet of space, weighs 135 pounds, and is mounted inside the Nike Hercules director station or the Hawk battery control central.

f. Radar tracking stations, used in conjunction with a radar netting unit, may provide additional radar data for use by ADA units. The radar tracking station obtains data from an associated search radar and semiautomatically tracks and automatically disseminates digital aircraft track data to the field army control and coordination systems. Radar tracking station equipment is compatible with most U.S. Army acquisition radars and certain U.S. Air Force radars although, in some cases, it is necessary to provide connectors and line terminals peculiar to the radar concerned. Radar tracking stations associated with military and civilian surveillance and gap-filler radars can provide additional early warning information to ADA units and overcome blind spots in the radar coverage of a defense.

g. The radar netting unit, when added to the Missile Monitor's battalion operations central, enables the operations central to receive track data from one to four radar tracking stations. It allows synchronized insertion of this data in the battery data link channels making it available to both the battalion operations central and the fire unit. In addition, the radar netting unit transfers the track data from each radar tracking station to others in the net and permits each radar tracking station to receive fire unit track and engagement data. When the radar netting unit has been added, the battalion operations central may receive track data from the radar tracking station or from the brigade/group AADCP, but not from both simultaneously.

CHAPTER 3
ESTABLISHMENT OF NIKE HERCULES AND HAWK DEFENSES

Section I. INTRODUCTION

3-1. General

a. Air defense artillery employment is essentially a problem of deploying fire units and coordinating their fires so that each established defense will maximize the capabilities of the weapon systems against the assumed threat and still provide adequate defense against variations of the threat. Detailed planning is required. A defense maximized against a high-speed, high-altitude, bomber threat may be completely inadequate against a high-speed, low-altitude, laydown attack due to differences in engagement coverages.

b. The task of the air defense planner involves determining the number of ADA units needed to provide a specific degree of protection to an industrial, metropolitan, or military area of strategic or tactical importance, or requires planning the best deployment of a fixed number of ADA units for any of these areas.

c. Defense design should be influenced and evaluated by computer wargaming to take advantage of the large number of threat and defense variations which can be accommodated when using this technique. If time or computer availability does not permit wargaming, the hasty design procedures described herein may be used. It should be noted that the hasty design procedures do not consider aircraft evasive maneuvers or ECM.

3-2. Sequence

The following sequence provides a logical approach to the problem of establishing a Nike Hercules or Hawk defense.

a. Preliminary Phase.

(1) Define the area to be defended.

(2) Determine the characteristics of the threat.

(3) Consider the characteristics of the available defense weapons.

b. Design Phase. Make trial deployments to achieve the optimum defense.

c. Evaluation Phase. Evaluate the trial deployment and redesign the defense, making due allowance for availability of real estate, radar masking, and other terrain considerations. Redesign and again reevaluate, continuing the process until the optimum pattern is established. Advise the commander of the outcome.

Section II. PRELIMINARY PHASE

3-3. Defining the Area To Be Defended

a. General. The commander specifying the areas to be defended may also specify the desired degree of defense for each area. In terms of engagement effectiveness, the specified degree of defense expresses as a percentage the average kill capability of the defense against an assumed raid size (n_a).

b. Defenses. Nike Hercules and Hawk defenses fall into two categories, vital area (VA) and area defense.

(1) *Vital area defense.* Vital area defense is the defense of a limited area or installation, such as a city, military installation, or industrial complex. All Army ADA deployments in the United States are of this type.

(2) *Area defense.* Area defense is the defense of a large area, such as a field army in a theater of operations. This type of defense is normally established for the field army, although certain critical installations within the area may be defended as vital areas.

c. Defining the Defended Area. The planner defines the defended area on a map or overlay.

(1) For a vital area defense, the defended area is defined by the contour of the city or installation to be defended, increased by the radius of

effect of the most likely nuclear weapon that the enemy may use. These contours have been predetermined for CONUS defended areas and include the commander's specifications as to maximum acceptable damage.

(2) For an area defense, the defended area is defined by the area's boundaries; e.g., the field army boundaries define the defended area.

3-4. Threat Characteristics and Bomb Release Line

a. The Threat. The defense planner must make a thorough study of enemy capabilities. The most likely attack speed, altitude, weapons, numbers, and delivery or attack techniques must be determined or estimated. The enemy's attack techniques may include conventional high-altitude bombing, use of air-to-surface missiles, low-altitude laydown bombing, or LABS (low-altitude bombing system). The most likely enemy attack capabilities and techniques are the guide for designing and evaluating the defense. The defense is designed to provide a balanced effectiveness against those combinations of weapons and techniques known to be available to the enemy in meaningful quantity and evaluated as likely to be employed by him.

b. Bomb Release Line—Vital Area Defense. When the threat employs high-altitude (gravity) bombing or the low-altitude bombing systems (LABS), a bomb release line will be circumscribed around the vital area. This line is used in conjunction with the route of approach or direction-of-attack line to define the point of evaluation.

(1) If the expected threat is the manned

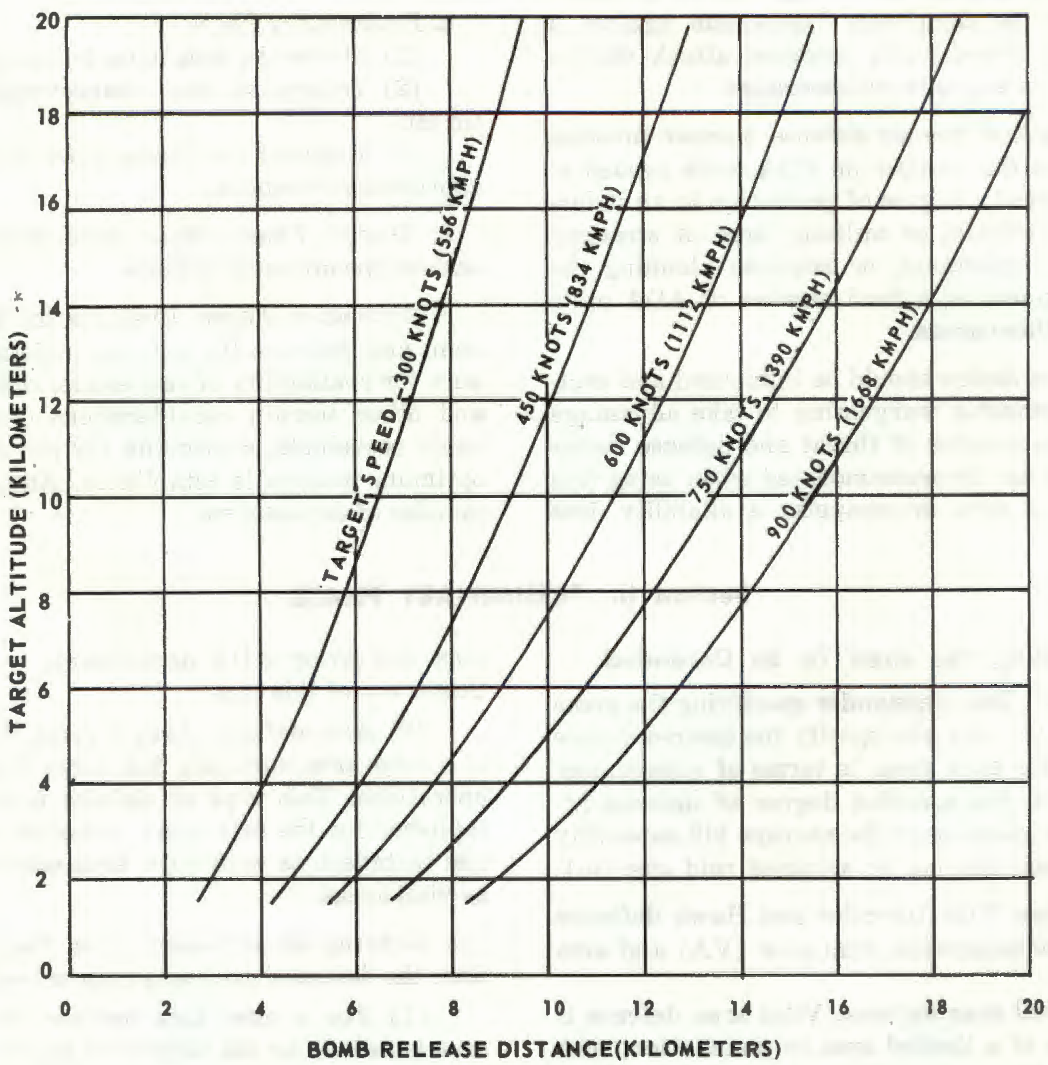


Figure 3-1. Gravity bomb release distance graph.

bomber using conventional gravity bombing techniques, the horizontal distance that a bomb will fall for certain target speeds and altitudes can be determined from a gravity bomb release distance graph (fig. 3-1). This distance is measured outward from the edge of the vital area in order to inscribe the bomb release line (BRL).

(2) For manned aircraft using the low-altitude bombing system (LABS), the BRL can be determined from the assumed altitude, angle, and speed of the enemy aircraft at bomb release, and mathematical computation of the ballistic trajectory of an object released under these conditions. Lacking estimates upon which to base computations, use of a BRL 18,300 meters outside the perimeter of the vital area is recommended.

(3) For air-to-surface missiles or manned aircraft using the laydown technique, no BRL is inscribed. In these cases, the perimeter of the vital area will provide the points needed for evaluation.

(4) Points of evaluation is defined by the intersection of routes of approach and direction-of-attack lines with the BRL or edge of the vital area are critical since the defense must destroy the threat before it reaches these points.

c. Bomb Release Line—Area Defense. A BRL as such is not constructed around the defended area. The intersections of the route of approach and direction-of-attack lines with the FEBA or area boundaries will provide the needed points for evaluation.

3-5. Defense Weapons

a. Allocation. Although the planner's normal mission is to make the best use of a fixed allocation, there may be situations wherein the planner is to recommend an initial allocation of Nike Hercules fire units for defense of a vital area. For this case, an *initial* planning figure can be determined by the following procedure:

(1) Use figure 3-2 to determine the number of attempted missile launches required to provide the desired probability of killing one target. Nike Hercules system effectiveness (SE) figures are obtained from FM 44-1A (para 4*e*).

(2) Solve the following formula to determine the firepower required at the BRL or other point of evaluation:

$$M_t = mn_a$$

wherein:

M_t = Total number of attempted missile launches required to achieve the specified engagement effectiveness.

m = Number of attempted missile launches per target required to achieve the specified engagement effectiveness.

n_a = Assigned number of simultaneously attacking targets.

(3) Determine a planning radius by measuring from the center of the vital area to the farthest point of evaluation. This point may be on the BRL or on the edge of the vital area (para 3-4*b*).

(4) Use the planning nomogram (fig. 8, FM 44-1A) to determine the tentative number of fire units required.

(*a*) Enter column 1 with the planning radius.

(*b*) Enter column 3 with the maximum effective range of the target tracking radar, considering assumed target size and the effects of earth curvature if the threat technique is a low-altitude attack. Table III, FM 44-1A provides the information necessary to determine effective target tracking range as a function of target size.

(*c*) Draw an index mark on column 2 by connecting the points indicated on columns 1 and 3.

(*d*) Enter column 4 with the previously computed quantity M_t.

(*e*) Connect the column 2 index mark and the column 4 point marked. An extension of this connecting line determines the column 6 index mark.

(*f*) Connect the column 6 index mark with a point in column 5 corresponding to the assumed speed of the threat. An extension of this connecting line determines the point on column 7, which is the number of fire units required.

(5) The nomogram may also be used to determine the theoretical capabilities of an existing vital area defense; e.g., given the number of fire units available and the threat characteristics, the M_t capability for a defense can be determined.

b. Defense Characteristics.

(1) *System effectiveness (SE).* (See glossary definition.) Information to determine system effectiveness is contained in FM 44-1A (para 3*g* and 4*e*).

(2) *Engagement effectiveness (EE).* (See glossary definition.) Specific EE figures for a given SE and number of attempted missile launches may be obtained from figure 3-2.

(3) *Operational assumptions.* Certain operational characteristics of the system being employed (e.g., maximum range, rate of fire, reaction

ATTEMPTED MISSILE LAUNCHES REQUIRED PER TARGET

SE \ M	1	2	3	4	5	6	7	8	9	10	11	12	13
99	99	→	→	→	→	→	→	→	→	→	→	→	99
95	95	99	→	→	→	→	→	→	→	→	→	→	99
90	90	99	→	→	→	→	→	→	→	→	→	→	99
85	85	97	99	→	→	→	→	→	→	→	→	→	99
80	80	96	99	→	→	→	→	→	→	→	→	→	99
75	75	93	98	99	→	→	→	→	→	→	→	→	99
70	70	91	97	99	→	→	→	→	→	→	→	→	99
65	65	87	95	98	99	→	→	→	→	→	→	→	99
60	60	84	93	97	99	→	→	→	→	→	→	→	99
55	55	79	90	95	98	99	→	→	→	→	→	→	99
50	50	75	87	93	96	98	99	→	→	→	→	→	99
45	45	69	83	90	94	97	98	99	→	→	→	→	99
40	40	64	78	87	92	95	97	98	99	→	→	→	99
35	35	57	72	82	88	92	95	96	97	98	99	99	99
30	30	51	65	76	83	88	91	94	96	97	98	99	99
25	25	43	57	68	76	82	86	89	92	94	95	96	97
20	20	36	48	59	67	73	79	83	86	89	91	93	94
15	15	27	38	47	55	62	67	72	76	80	83	85	87
10	10	19	27	34	40	46	52	57	61	65	68	71	74

SYSTEM EFFECTIVENESS %

Figure 3–2. Engagement effectiveness expressed as a percentage.

time, and dead zones) will affect the defense. These characteristics must be considered by the defense planner when evaluating the defense.

c. Deployment Guidelines. Hawk and Nike Hercules deployment guidelines are presented in FM 44-1.

Section III. DESIGN PHASE

3-6. Trial Deployments

a. General. Defense design involves trial deployment of fire units consistent with the deployment guidelines. Although the final deployment may vary somewhat from the planner's recommended deployment, his recommendations serve to focus fire unit efforts during reconnaissance, selection, and occupation of position (RSOP).

b. Vital Area Defense. To counter mass attacks from a single direction, and at the same time maintain an effective fire capability against multiple directions of attack, the best deployment pattern is normally several concentric rings of ADA around the vital area with the inner ring on, or just forward of, the BRL or edge of the vital area, depending on the attack variation. Adjacent units should be within mutual support distance. The following trial deployment is recommended:

(1) *Composite defense.*

(*a*) Space Nike Hercules fire units at approximately equal distances apart, unless the vital area has an unusual configuration, and far enough from the center of the vital area to delivery maximum firepower, maintain mutual support, and maintain balance at the points of evaluation.

(*b*) Place Hawk fire units along low-altitude routes of approach according to the priority established for each.

(2) *Hawk defense.* Place Hawk fire units in the most advantageous positions to provide adequate coverage of low-altitude routes of approach and with as much balance as possible.

c. Area Defense. In an area defense, the ADA mission is to provide coverage of the airspace over the entire defended area. Trial deployment criteria for Nike Hercules and Hawk units are—

(1) Deployment of Nike Hercules units is made to provide weighted area coverage. The coverage is weighted toward exposed boundaries and, in some cases, toward priority areas. Mutual support should not be sacrificed. Normally, mission permitting, Nike Hercules units are employed no closer to the FEBA than 40 kilometers.

(2) Hawk fire units are deployed along low-altitude routes of approach. These routes are determined by considering gaps and weaknesses in the Nike Hercules defense and natural low-altitude approaches. Hawk units are then deployed well forward along these routes to exploit system range, normally no nearer the FEBA than 30 kilometers for the towed Hawk system or 15 kilometers for the self-propelled Hawk system. As with Nike Hercules units, Hawk units should provide mutual support.

d. Terrain Difficulties. A map and ground reconnaissance of the tentative positions will frequently disclose terrain difficulties. The two major categories of terrain difficulty are emplacement and masking. Either difficulty will cause changes in the basic defense design.

3-7. Emplacement Difficulty

a. An emplacement difficulty is encountered when a fire unit cannot be placed in the area initially selected because of realty acquisition, nonavailability, nonaccessibility, local security requirements, or other considerations.

b. Those units that would normally be plotted in the unusable area are moved to the nearest usable area. Once it has been necessary to move a unit away from the optimum position, other units may have to be moved to regain balance and maximum capability. The evaluation phase will show whether additional moves are necessary.

c. Emplacement of Nike Hercules units may be complicated by the need to provide rocket-motor cluster impact areas (para 4*j*, FM 44-1A). Such areas should be provided if possible, but not at the expense of defense effectiveness.

3-8. Masking Difficulty

a. General. A masking difficulty is an obstacle which limits required radar-to-target line of sight. Hasty (*b* below) and deliberate (*c* below) methods for determining the effect of the masking difficulty are available. Masking difficulties are countered, using the same technique as for countering emplacement difficulties. For Nike Hercules units, masking problems sometimes can be alleviated by minor adjustments of the relative location of the battery control and launching areas.

b. Hasty Method. When the angle to mask has been measured, detection ranges may be obtained in order to construct a hasty coverage diagram through the use of the horizontal range detection nomogram (fig. 3-3). It is first necessary to determine whether the masking difficulty causes any reduction in the fire unit's maximum effective detection range. This can be done on figure 3-3 by connecting points representing the assumed altitude of the threat above the fire unit (threat altitude above sea level minus fire unit altitude above sea level) and mask angle measured from the unit position, and noting where the connecting line crosses the "range-meters" curve. After range has been determined from the nomogram, a target-size chart should be checked (para 3a and

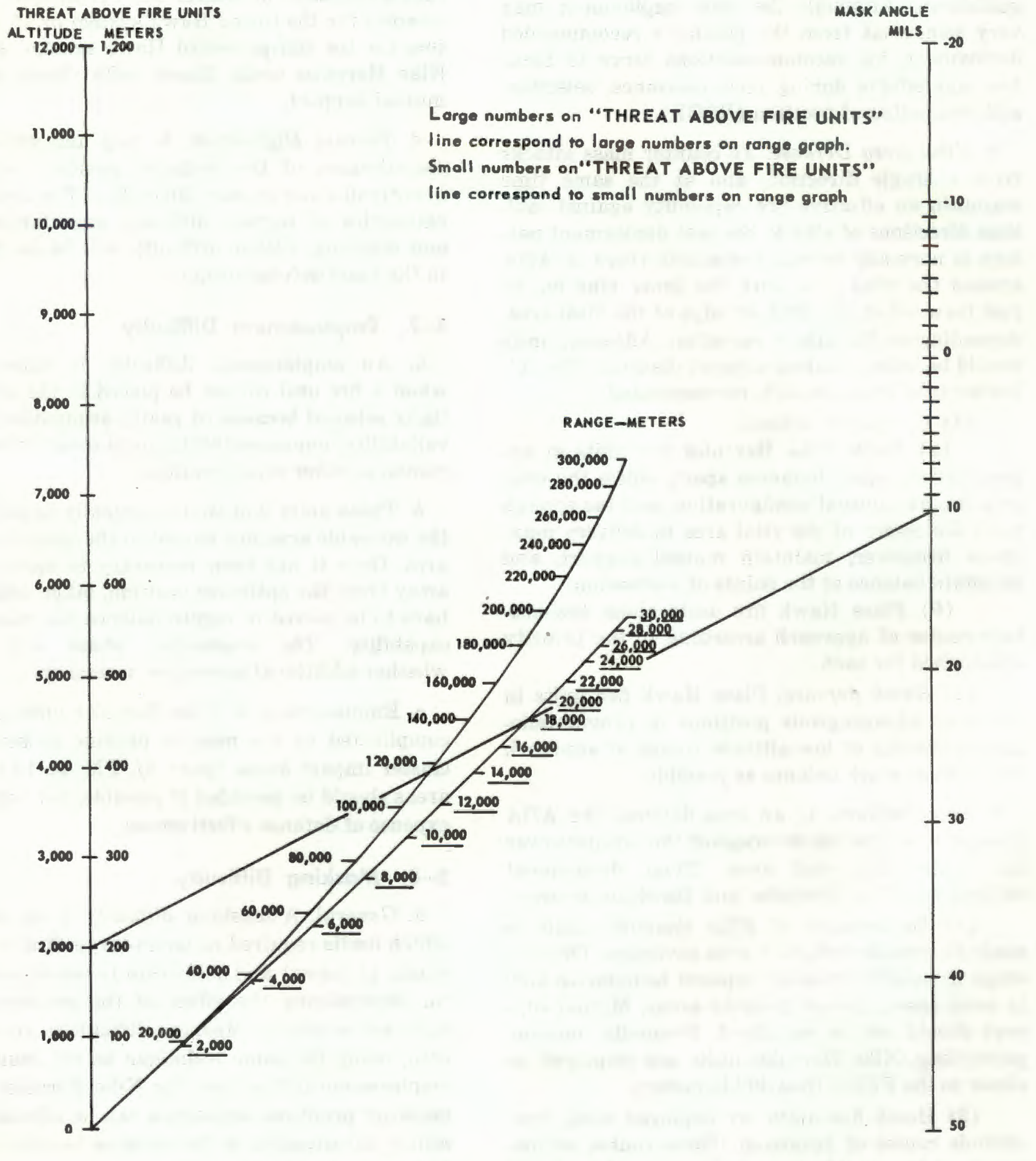
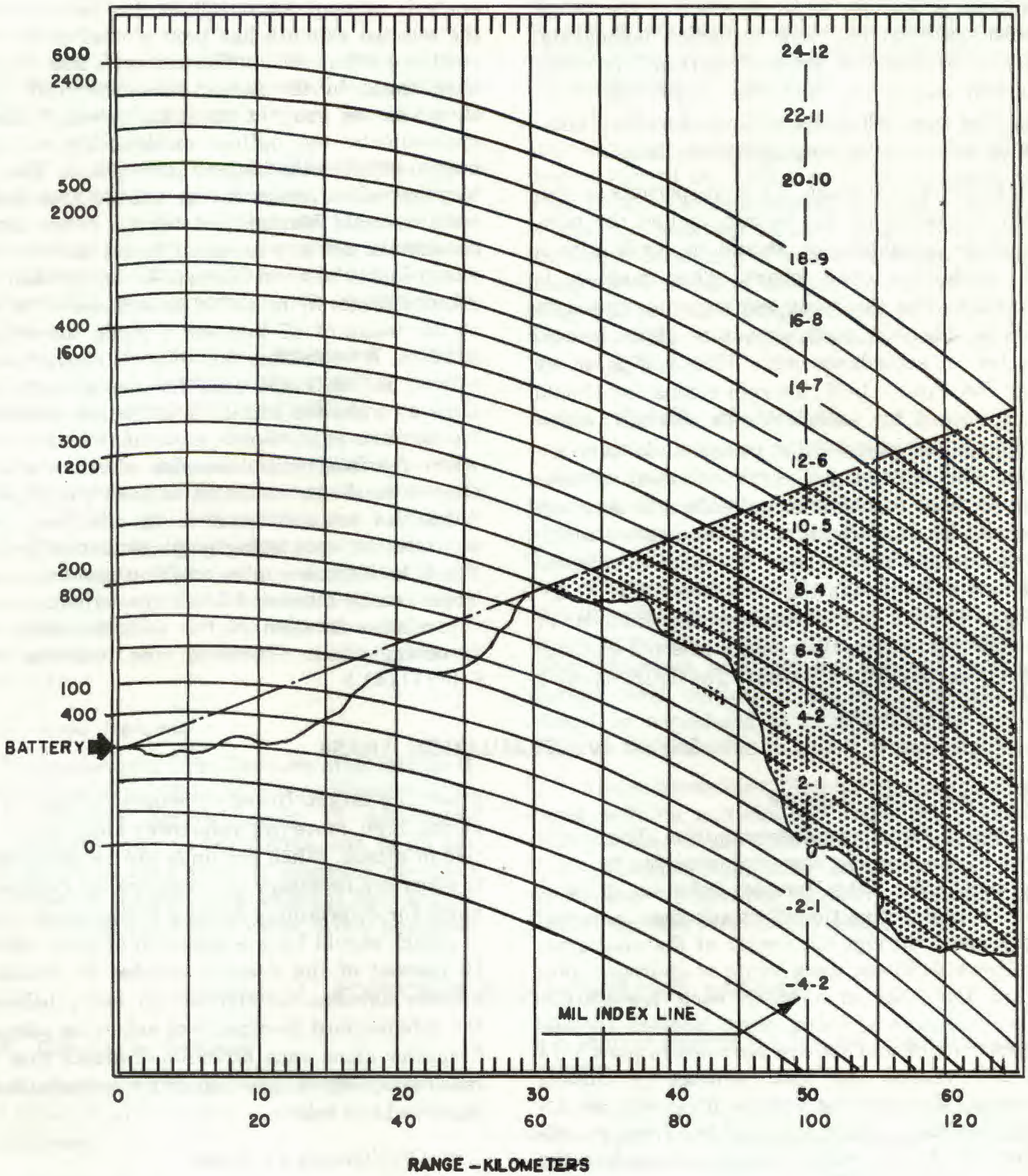


Figure 3-3. Horizontal range detection nomogram.



NOTE:

SMALLER NUMBERS ON THE VERTICAL AXIS CORRESPOND TO SMALLER NUMBERS ON BOTH THE HORIZONTAL AXIS AND MIL INDEX LINE. LARGER NUMBERS ON THE VERTICAL AXIS CORRESPOND TO LARGER NUMBERS ON BOTH THE HORIZONTAL AND MIL INDEX LINE.

Figure 3-4. 4/3 earth curvature chart.

4a, FM 44-1A) to insure that the radar cross section is large enough to be detected at the range determined from the range detection nomogram. The shorter range as determined from the range detection nomogram and the target-size chart should be used when detection cannot be accomplished as maximum engagement range.

c. Deliberate Method. As time permits, a detailed evaluation of the terrain around the position under consideration should be made with a 4/3 earth curvature chart. This method is preferable over the hasty technique presented in *b* above. The 4/3 earth curvature chart is constructed in accordance with TM 11-673, or by using DA Form 11-47. Terrain evaluation should be performed for each 200 mils azimuth, measured from the intended (or occupied) battery position. The detailed 4/3 earth curvature profiles must be used to construct a deliberate coverage diagram. The 4/3 earth curvature method modifies the normal curvature of the earth to compensate for the propagation characteristics of RF energy. Figure 3-4 illustrates the method of showing radar coverage along a selected azimuth on a 4/3 earth curvature chart. The figure shows a battery located 75 meters above sea level. Through analysis of map contour lines, the terrain along the selected azimuth has been plotted on the 4/3 earth curvature chart. The battery's line of sight is indicated by the dashed line. The mask angle shown is the graphic mask angle, which should approximate the optical mask angle normally measured after the battery is emplaced. The battery has no coverage in the shaded area due to terrain mask. Maximum detection range can be determined for any assumed threat altitude. For example, as shown in figure 3-4, the unit can first detect a target flying at 300 meters above sea level at the range of 37 kilometers along the selected azimuth. It is possible that close-in masks, not indicated in the maps used for the analysis, will show up when the battery is emplaced, necessitating position adjustments. Ground reconnaissance, when feasible, will determine the presence of close-in masks in the tentative positions. Masking difficulties are countered, using the same technique as for countering emplacement difficulties. For Nike Hercules units, masking problems sometimes can be alleviated by minor adjustments of the relative location of the battery control and launching areas. (Refer to note following para 6-3*c*(1)(*a*).)

Section IV. EVALUATION PHASE

3-9. Vital Area Defense

a. Initial Firepower Determination. The initial choice of positions is now evaluated for its military worth. For Nike Hercules defenses, draw at least 16 radial direction-of-attack lines at equal angles apart through the center of the vital area. For Hawk defenses, draw route-of-approach lines toward the vital area along each low-altitude route of approach. Using burst locators (details on construction and use are provided in para 3-14 —3-20), record the total number of missile launches (M_t) that the defense fire units can attempt against a target approaching from one direction of attack (route of approach) before the target reaches the BRL or other point of evaluation. Repeat for each direction-of-attack (route-of-approach) line, recording an M_t for each line.

b. Defense Balance. For Nike Hercules defenses, check the balance to see if the defense has approximately the same strength along each direction of attack. In sectors where strength is relatively low, move fire units either closer to that direction-of-attack line or outward toward the approaching target. In sectors where strength is relatively high, move fire units away from that direction of attack. When fire units are repositioned, it is generally necessary to reanalyze the defense. A guide for determining balance is that no direction of attack should have a deviation of more than ± 10 percent of the average number of attempted missile launches. In addition to being balanced, the defense must be capable of achieving adequate firepower along each direction-of-attack line. Defense adequacy is determined by computation as described in *c* below.

c. Effectiveness Formula.

(1) The M_t values indicate the maximum number of missiles that a defense can attempt to deliver against a target before it reaches the BRL or other point of evaluation. These values were used for determining defense balance. The next step is to determine the maximum raid size against which the defense has the specified engagement effectiveness, using the effectiveness formula:

$$n_o = \frac{M_t}{m}$$

wherein:

n_o = The maximum raid size against which the defense has the specified engagement effectiveness, expressed as a whole number (all fractions are dropped).

M_t = The number of missiles that a defense can attempt to deliver along a given direction of attack (route of approach) before the target reaches the BRL or other point of evaluation. (The slight difference herein in definition of the Term M_t, as compared to its definition in para 3–5*a*(2), is intentional.)

m = Number of attempted missile launches required to obtain the specified probability of killing one target (para 3–5*a*(1)).

(2) The quantity n_o must be greater at all points around the defenses than the single raid-size capability credited to the enemy in the initial threat estimate. If defense balance has been achieved and n_o is not greater at all points, the commander must either acquire additional ADA fire units or accept the decreased defense capability. The quantity n_o may also be used as a figure of merit to determine relative defense weighting.

3–10. Area Defense

a. Evaluation of a Nike Hercules area defense is made at area boundaries. Direction-of-attack lines are constructed approximately 15 kilometers apart perpendicular to the FEBA and to all exposed flanks. A field army is normally provided air defense on the flanks by adjacent field armies and to the rear by other theater ADA elements. An isolated field army would require evaluation all around its boundaries. The computed values of M_t and n_o are used to check for overall defense adequacy and relative weighting toward exposed boundaries and priority areas.

b. The Hawk air defense of the area is evaluated along all expected low-altitude routes of approach toward the FEBA and other exposed portions of the field army boundary. The value of n_o is used to check the defense capability of Hawk fire units defending a route of approach. Outlining the first burst contour on the map or overlay will provide a graphic hasty check as to the defense ability to accomplish early destruction of low-flying targets.

3–11. Validity of Analysis

a. Multiple Attacks. If the enemy is assumed to have the capability of multiple raids from more than one direction, fire distribution must be considered when analyzing the defense. Only those fire units which have been assigned to one direction of attack and fall under the burst locator for that direction of attack should be given credit for firing upon the threat. Fire units assigned to other directions of attack are assumed to be engaging their portion of the multiple raid and cannot be considered as contributing to the defense in the direction of attack being considered.

b. Attack Variations. Major variations in threat speed, altitude, and size will make invalid the absolute values of any numerical data produced by the evaluation; e.g., total firepower (M_t). The conclusions regarding relative balance and weighting, however, will remain valid.

Section V. COMPOSITE AND INTEGRATED DEFENSES

3–12. Composite Defense

a. A composite defense, composed of two or more types of ADA weapon systems, is normal in the field army.

b. In a composite defense, the placement pattern of the longest-range system is designed first, according to its deployment guidelines. Other systems are then employed to complement, particularly at low altitude, the coverage afforded by the longest range system. First burst contours, drawn for both Nike Hercules and Hawk, will provide a hasty check to determine if Hawk satisfactorily complements Nike Hercules.

c. Mutual support is measured only between like systems.

d. Each weapon system is evaluated independently. Their individual capabilities are totaled to reflect composite capability.

3–13. Integrated Defense and Defense Complex

a. General. An integrated defense is the defense of two vital areas located close enough together so that the defenses can be combined. A defense complex is the defense of three or more vital areas located close enough together so that the defenses can be combined. Consideration normally should be given to integrating the defenses whenever some of the fire units, deployed in their optimum positions around the different vital areas, are capable of engaging the same target. Integration is rarely complete; i.e., all of the fire units of one vital area will rarely be mutually supporting with each other or with all fire units of the other vital area.

b. Characteristics. An integrated defense will either use fewer fire units or will increase the firepower of an existing defense. Some of the weapons deployed around one vital area will contribute firepower to the other when integrated. The number of fire units required, or the number of fire units that can be redeployed to other defenses without degrading the integrated defense, is determined by a trial procedure. As a guide, initially the total number of fire units allocated to the separate vital areas is reduced by 25 percent. Fire units are increased or decreased until the minimum number is used to establish a common defense as strong as, or stronger than, the individual defenses.

c. Design. To obtain balance with an integrated defense, it is necessary to deploy fire units around the sides and opposite ends of the vital areas except that fire units normally are not deployed between the vital areas. Unless the area between is unusually wide, fire units from both vital areas can fire over it, thereby causing this area to be the strongest within the defense.

d. Evaluation.

(1) *Integrated defense.* The direction-of-attack lines drawn to evaluate an integrated defense are constructed by first defining the vital areas and then drawing a line that connects the centers of the vital areas. Next, draw a line perpendicular to this center line through the center of each vital area. Now draw in an appropriate number of direction-of-attack lines on the outside half of each vital area (not more than 400 mils apart). Direction-of-attack lines normally are not drawn between the vital areas. If such lines are drawn, any common direction-of-attack lines that intersect may be checked for adequacy, but they will not be used in computing figures for balance. When using a burst locator to evaluate on integrated defense, the fire units that do not fall under the burst locator, but which have contributed to the defense because the target has flown through the field of fire of these fire units, must be considered.

(2) *Defense complex.* Connect the approximate centers of the vital areas with straight lines. Draw direction-of-attack lines, approximately 400 mils apart, around the outside of each vital area. The exact number of direction-of-attack lines will depend on the distances between the vital areas and on the commander's guidance. Direction-of-attack lines normally are not drawn between the vital areas of a defene complex but, if required in cases where the distances between vital areas are excessive, the same procedure as outlined in (1) above may be used.

Section VI. ANALYZING DEVICES

3–14. Burst Locator

a. General. The burst locator (fig. 3–5) is a graphic portrayal of the summation of bursts as the target approaches and recedes from the range of a fire unit. The burst locator should be used for a hasty analysis only. Computer analysis should be used when time permits. The curved contour lines on the burst locator connect initial points representing an equal number of missiles. The spaces between contour lines represent the horizontal distance that the target travels during crew and system reaction time and missile time of flight. The numbered value of each contour line represents the number of missile launches that a fire unit is capable of attempting against a target by the time the target arrives at the point of evaluation.

(1) The outer contour of the burst locator represents the maximum effective horizontal range of the missile. The center represents the position of the threat. The actual shape of the burst locator outer contour may vary considerably from the example shown in figure 3–5, depending on threat characteristics.

(2) The burst locator is placed with its center on a point of evaluation; e.g., the intersection of a direction-of-attack line and the BRL, and with its direction-of-flight arrow pointed inward along the direction-of-attack line. The battery positions falling under the burst locator are then evaluated.

(3) It is assumed that all target courses are parallel to the direction-of-flight line indicated. With the burst locator properly oriented on the map or overlay, each fire unit receives a numerical burst value as indicated by the number between burst contour lines on the burst locator. ***Do not***

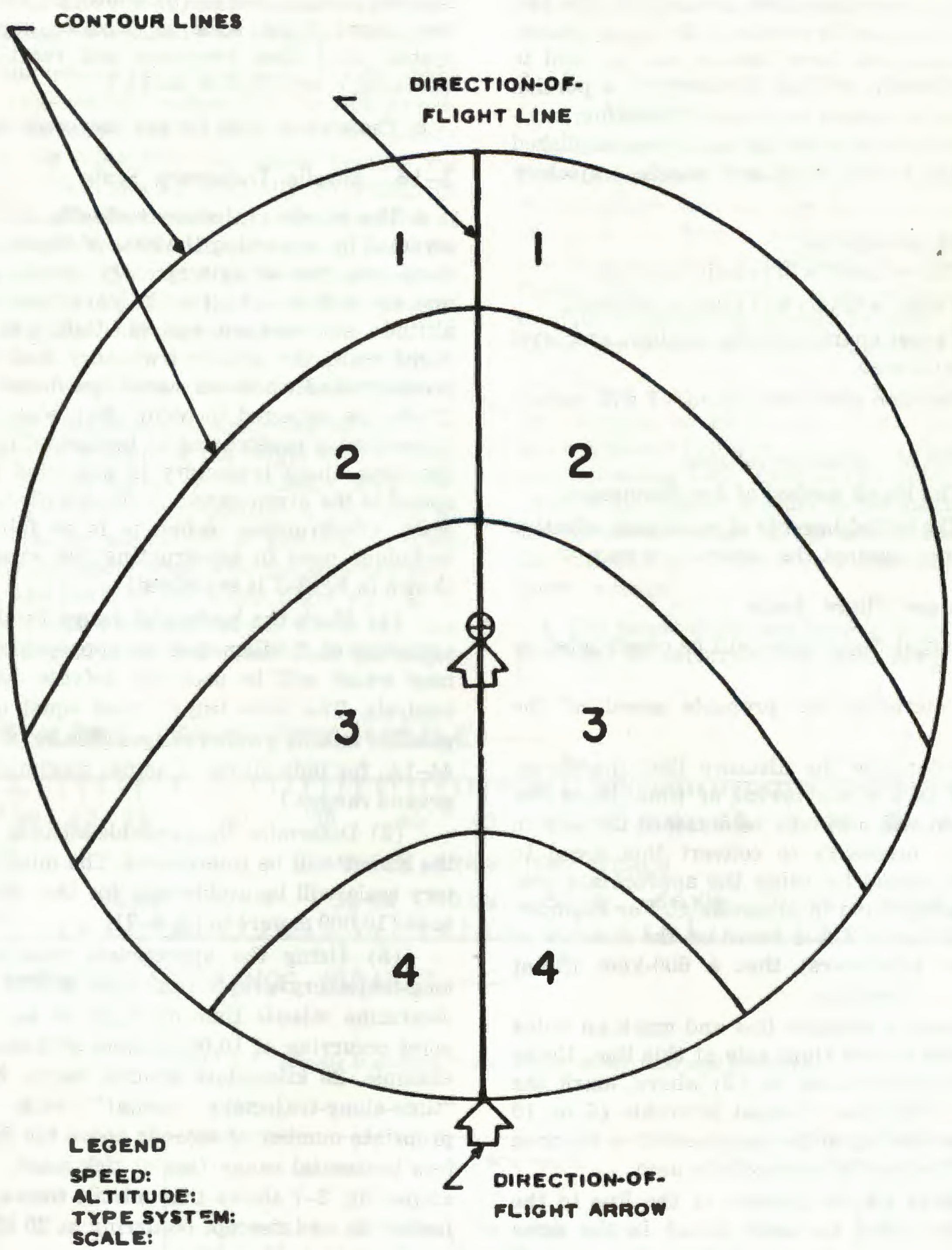


Figure 3-5. Type of Nike Hercules burst locator.

interpolate between contours. A fire unit outside or forward of the outer contour line is indicated as zero since this unit is not yet within range. Conversely, a fire unit to the rear and outside the limits of the burst locator has been within range; therefore, it is given a value by extending a line parallel to the direction-of-flight line from the fire unit location to the circumference of the analyzer and reading the missile value at that point. This is known as tail effect.

(4) It will be necessary to prepare a burst locator for the specific conditions to be encountered. Knowing a specific condition of attack for a particular area, a target flight scale and a mis-

sile trajectory scale are first constructed. The two scales are then used to construct the burst locator. In some cases, one burst locator can be used to analyze an entire defense. However, if a portion of a defense is exposed to excessive masking, analysis of that portion of the defense is accomplished by using the target flight and missile trajectory scales.

b. Design assumptions.

(1) Target speed will remain constant.

(2) Target altitude will remain constant.

(3) Target course will be straight and level toward the defense.

(4) Reaction time (see glossary) will remain constant.

(5) The M_t values are reliable.

(6) The Hawk method of fire is constant.

(7) The initial burst is at maximum effective system range against the assumed threat.

3-15. Target Flight Scale

a. The target flight scale will be constructed as follows:

(1) Determine the probable speed of the target.

(2) Determine the distance that the threat will travel in a given period of time. Since the threat speed will normally be obtained initially in knots, it is necessary to convert this speed to meters per second by using the appropriate conversion factor found in appendix C. For example, the scale in figure 3-6 is based on the distance in meters (or kilometers) that a 600-knot threat would fly in 5 seconds.

(3) Draw a straight line and mark an index or zero point on the right side of this line. Using the distance determined in (2) above, mark the left side of the line in equal intervals (5 or 10 seconds) according to the representative fraction (scale) of the map or overlay to be used.

(4) Mark off the portion of the line to the right of the index (or zero point) in the same manner as indicated in (3) above. This portion of the target flight scale is used to account for system dead time (response and reaction time) (para 3*d*, *e*, and 4*d*, FM 44-1A).

b. The scale is valid for any target altitude.

3-16. Missile Trajectory Scale

a. The missile trajectory scale (fig. 3-7) is constructed by extracting the time of flight (seconds) from the time-along-trajectory graph (para 3*i* and 4*h*, FM 44-1A) for the particular intercept altitude and weapon system. Unlike the target flight scale, the missile trajectory scale must be reconstructed whenever variations in intercept altitude are expected to occur. Map scale range in kilometers is constructed as horizontal range, and the time along trajectory is projected to correspond to the given range on the missile trajectory scale. Construction technique is as follows (the technique used in constructing the sample scale shown in fig. 3-7 is explained):

(1) Mark the horizontal range (scale) in increments of 2 kilometers as appropriate for the map which will be used for defense design and analysis. The scale length must equal maximum possible missile ground range. (See fig. 6 or 9, FM 44-1A, for indications of actual maximum missile ground ranges.)

(2) Determine the probable altitude at which the threat will be intercepted. The missile trajectory scale will be usable only for that threat altitude (10,000 meters in fig. 3-7).

(3) Using the appropriate missile time-along-trajectory graph (fig. 6 or 9, FM 44-1A), determine missile time of flight to an intercept point occurring at 10,000 meters altitude and, for example, 20 kilometers ground range. Mark the "time-along-trajectory (scale)" with the appropriate number of seconds above the 20-kilometers horizontal range (scale) tick mark. (For example, fig. 3-7 shows that missile time-along-trajectory to an intercept occurring at 20 kilometers

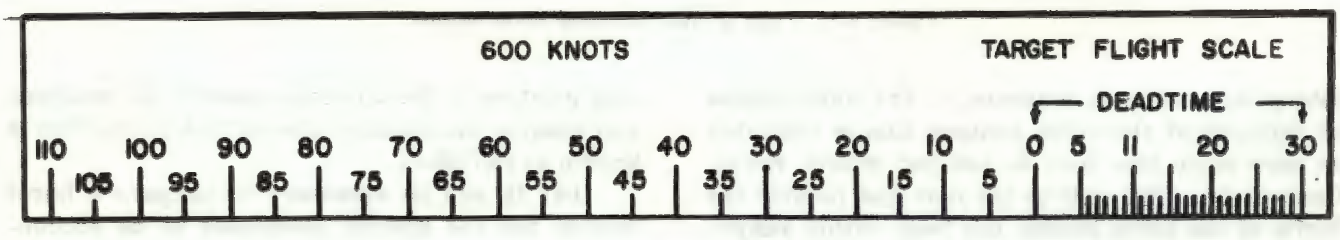


Figure 3-6. Target flight scale.

ground range and 10,000 meters altitude is 30 seconds.) Repeat as necessary to complete the scale.

b. On the missile trajectory scale, the launcher position, or zero time, is shown at the left. Appreciable horizontal movement does not immediately occur for the Nike Hercules scales because the missile initially is moving vertically. Note that the distance the missile travels in a given period of time varies because the missile speed does not remain constant. The number of seconds represented must be equal to the maximum time of flight of the missile being considered.

3–17. Matching Times on the Scales

The principal use of special analyzing devices is to match the time of flight of the target with a corresponding time of travel of the missile. *Example:* A missile is launched from position A (fig. 3–8) at the time that an aircraft is at position B; place the missile trajectory scale with the launcher position at A and the O on the target flight scale at B. The missile will meet the target where the two times correspond (they will meet after the target and missile have each traveled for 60 seconds as shown in fig. 3–8).

3–18. Construction of Nike Hercules Burst Locator

a. In some cases the defense suffers no reduction in maximum effective missile range because no limitations are imposed by the characteristics of the threat. Such a case, although not a normal one, is chosen for convenience in presenting the fundamentals of burst locator construction. The common construction variations which may be required are described in paragraph 3–19.

b. Draw a series of parallel lines to represent the direction of attack (fig. 3–9). An arbitrary point is selected to represent the center of the fire unit launching area. Around this point describe a circle whose radius is equal to the maximum effective horizontal range of the missile system (para 4*b*, FM 44–1A). This circle represents the initial burst contour.

c. The target flight and missile trajectory scales are used to construct the remaining burst con-

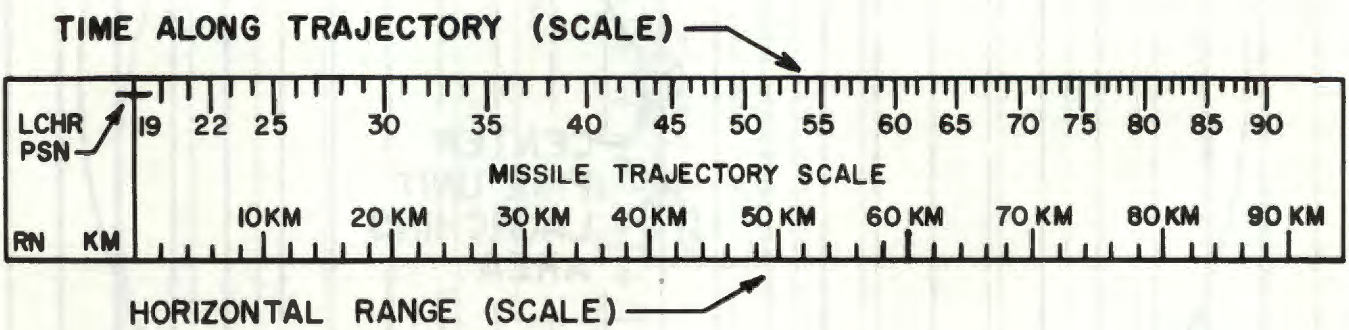


Figure 3–7. Missile trajectory scale (10,000-meter intercept altitude).

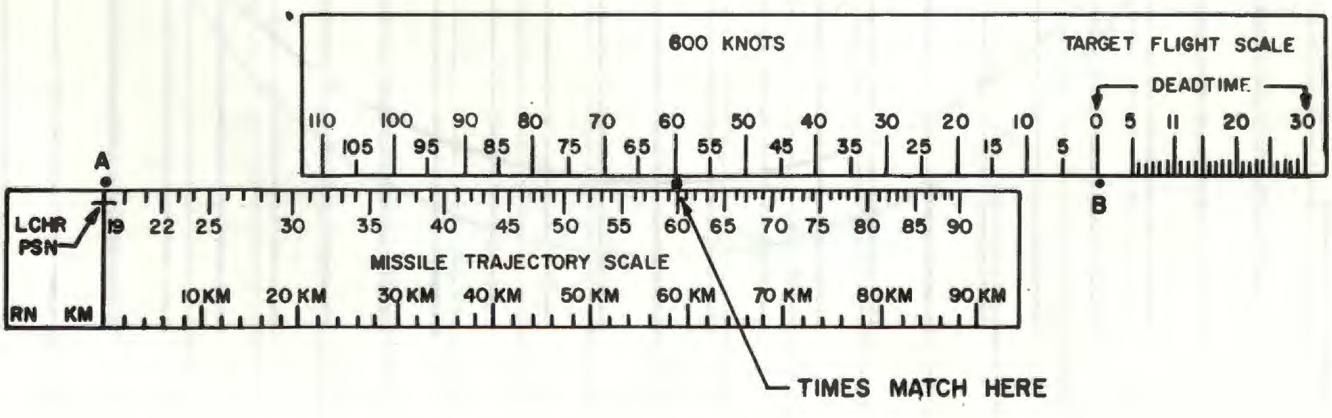


Figure 3–8. Matching times with flight and trajectory scales.

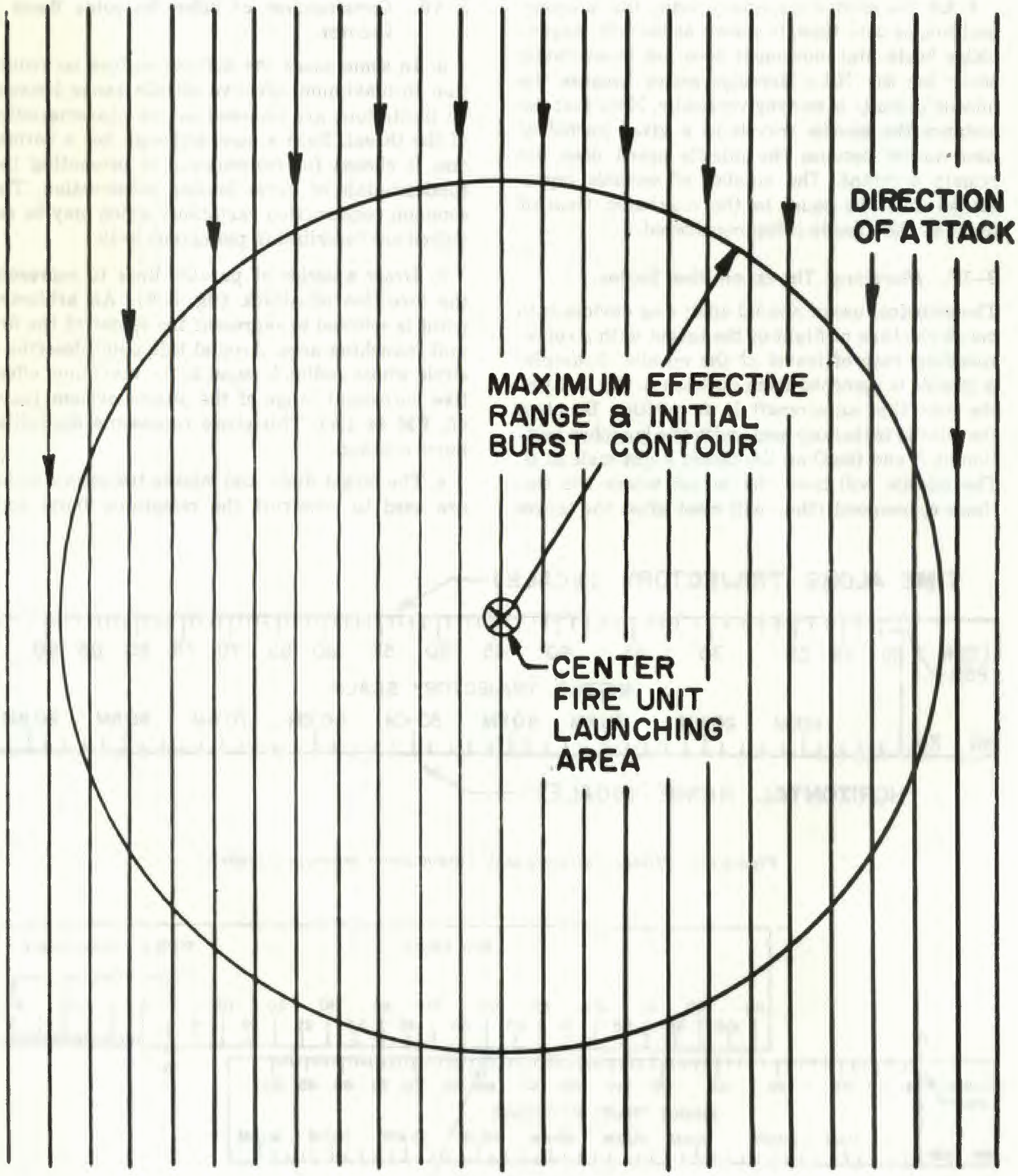


Figure 3-9. Nike Hercules burst locator (initial).

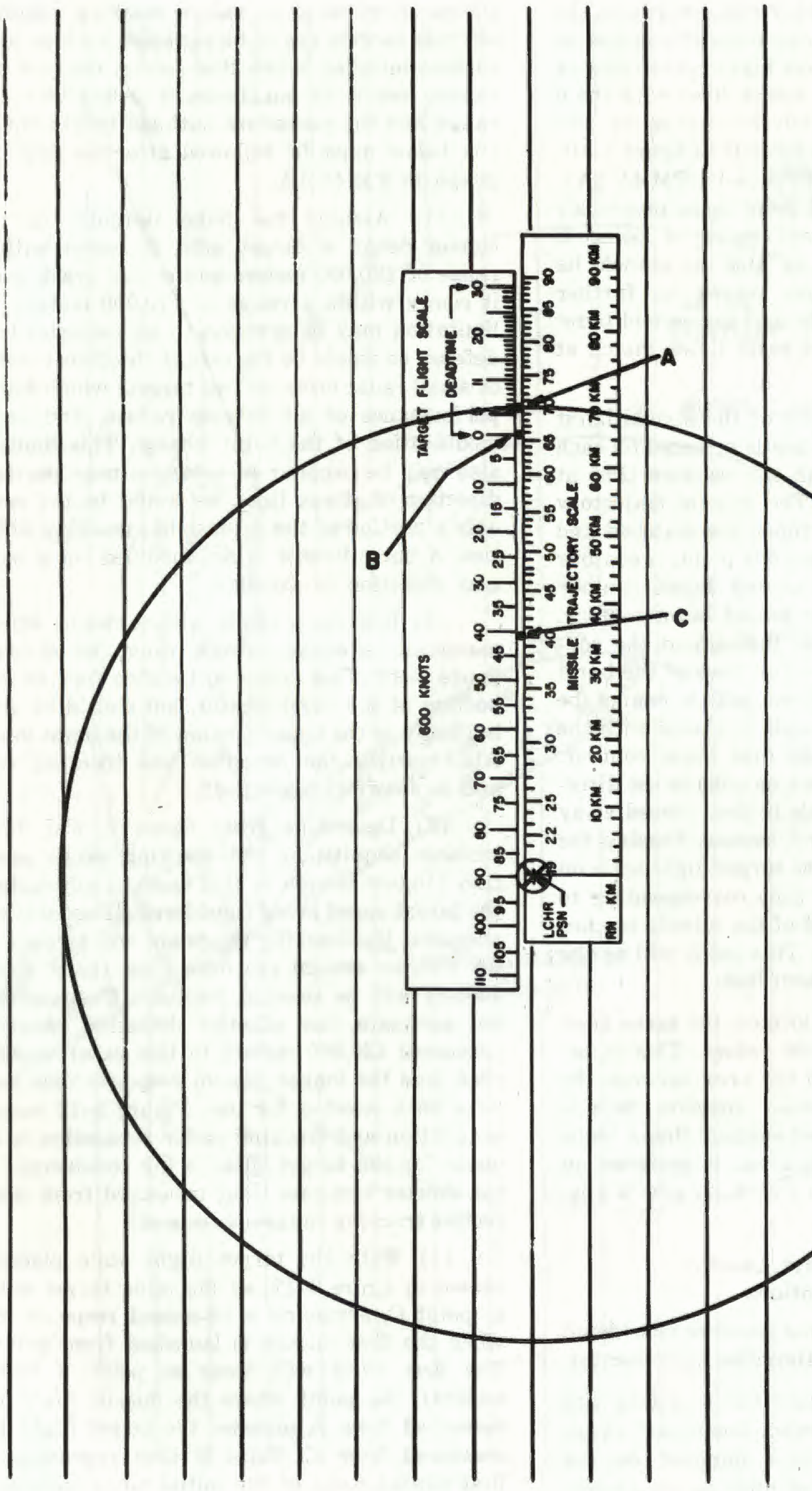


Figure 3–10. Burst locator with target flight and missile trajectory scales.

tours (fig. 3-10). The launcher position (0) on the missile trajectory scale is oriented at the center of the burst locator. The target flight scale remains parallel to the direction-of-attack lines with the 0 mark inside the initial burst contour by the amount of reaction time (6 seconds in figure 3-10; actual figures are included in para 4*d*, FM 44-1A). The initial burst occurs at point A as previously determined. The target will move to point B before the same battery is able to launch its second missile. The target moves in further during missile time of flight and the second burst will occur where the flight scale times match at point C.

d. To locate the remainder of the second burst contour, the target flight scale is oriented on each direction-of-attack line with the reaction time at the initial burst contour. The missile trajectory scale is then rotated until times are matched and marked as a second burst contour point. A contour is drawn connecting the second burst contour points, thus completing the second burst contour. This procedure is continued throughout the construction of the various contour lines of the burst locator (fig. 3-11). If a time match cannot be achieved, the target flight scale is placed with the reaction time set off on the first burst contour. The target flight scale is kept parallel to the direction-of-attack line. The scale is then moved away from the center of the burst locator, keeping the specified reaction time on the target flight scale on the contour line until the time corresponding to the maximum time of flight of the missile touches the periphery of the circle. This point will be the end of the second burst contour line.

e. To complete the burst locator, the areas must be given appropriate missile values. This is accomplished by assigning to the area between the first contour line (maximum effective missile range circle) and the second contour line a value of 1. Each of the following areas is assigned an accumulative higher value; i.e., 2, 3, and 4 (fig. 3-5).

3-19. Nike Hercules Burst Locator Construction Variations

There are two variations that must be considered when constructing a Nike Hercules burst locator.

a. The location of the initial burst contour will often be at less than maximum theoretical range because of range limitations imposed on the system radars, or because of high target speeds. The degradation of effective radar range could be the result of earth curvature masking when low-altitude targets are to be engaged, such as air-to-surface missiles. When this occurs, the first burst cannot occur at maximum effective horizontal range and the procedure outlined in (1) through (6) below must be followed after reading paragraph 4*c*, FM 44-1A.

(1) Assume the Nike Hercules fire unit cannot detect a target until it comes within a range of 120,000 meters and cannot track it until it comes within a range of 110,000 meters. This limitation may be common to all batteries in the defense as would be the case if the threat consists of small radar cross section targets which degrade performance of all defense radars, and require modification of the burst locator. This limitation also may be peculiar to batteries near particular direction-of-attack lines, as would be the case if only a portion of the defense has masking difficulties. A burst locator is not modified for a particular direction of attack.

(2) Inscribe a circle with a radius equal to maximum effective missile range as shown in figure 3-12. This circle will suffice for the lower portion of the burst locator, but should be drawn in lightly in the upper portion of the burst locator. Also inscribe the detection and tracking range arcs as shown in figure 3-12.

(3) Determine from figure 7, FM 44-1A, whether acquisition and tracking range separation (10,000 meters in this case) is adequate for the target speed being considered. If separation is adequate, the tracking range arc will be used, and the shorter system response time (para 4*c*, FM 44-1A) will be selected for use. If separation is not adequate, the effective detection range arc (assumed 120,000 meters in this case) would be used, and the longer system response time would have been selected for use. Figure 3-12 assumes acquisition and tracking radar separation is adequate for the target speed being considered; i.e., the shorter response time, measured from the effective tracking range arc, is used.

(4) With the target flight scale placed as shown in figure 3-12, an incoming target will be at point C, assuming a 12-second response time, when the first missile is launched from point A. The first burst will occur at point B (60,000 meters), the point where the missile flight time measured from A matches the target flight time measured from C. Point B then represents the first plotted point of the initial burst contour.

(5) If acquisition and tracking range separa-

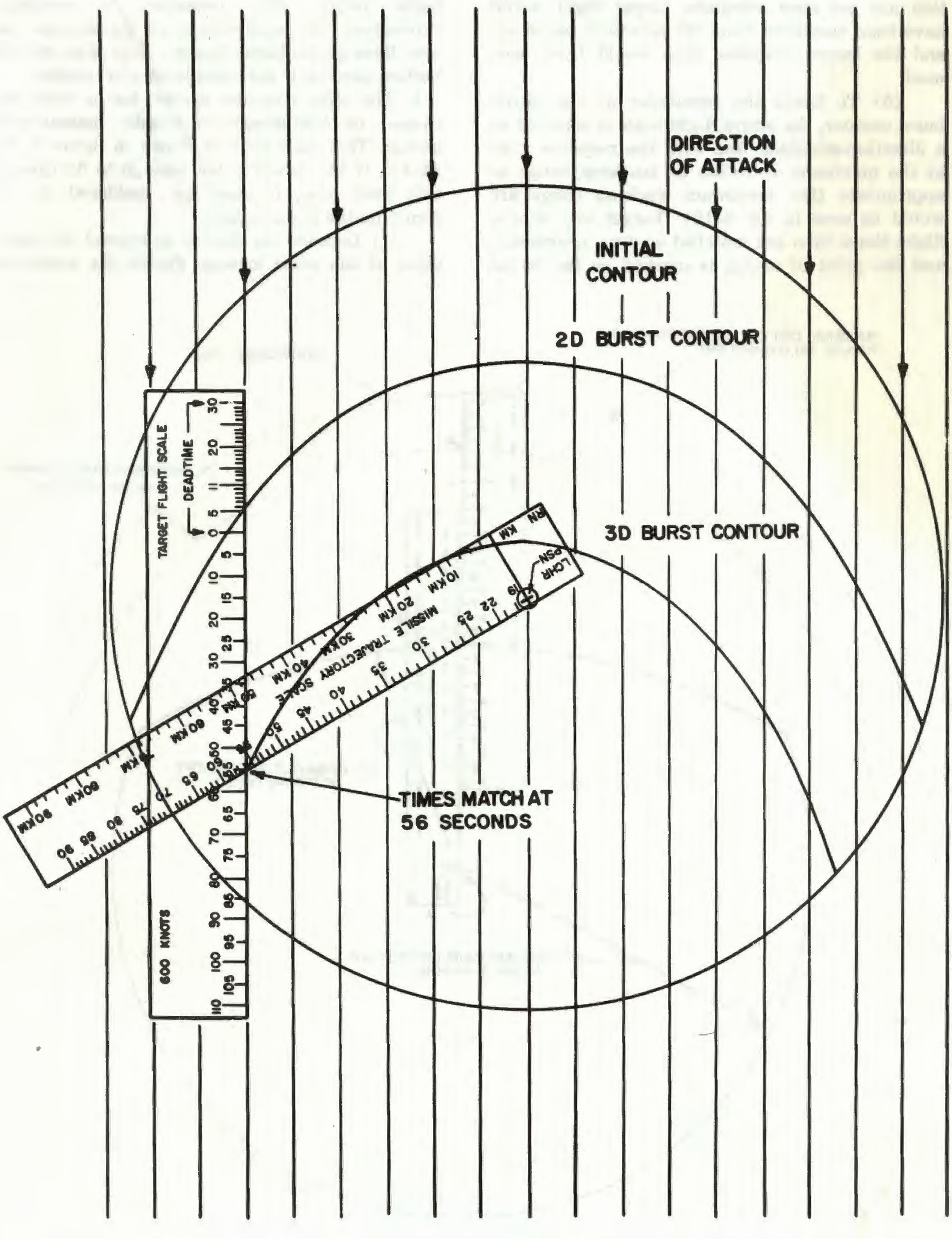


Figure 3-11. Completing burst contours.

tion has not been adequate, target flight would have been measured from the detection range arc and the longer response time would have been used.

(6) To locate the remainder of the initial burst contour, the target flight scale is oriented on a direction-of-attack line with the response time at the maximum detection or tracking range as appropriate (the maximum tracking range arc would be used in fig. 3-12). Target and missile flight times then are matched as done previously, and the point of match is marked as the initial burst point. This procedure is continued throughout the construction of the various contour lines of the burst locator. Note that only the bottom portion of the burst locator is circular.

b. The Nike Hercules system has a dead zone caused by limitations in missile maneuvering ability. This dead zone is shown in figure 9, FM 44-1A. If the threat is low enough to fly through this dead zone, it must be considered in constructing the burst locator.

(1) Inscribe the dead zone around the center point of the burst locator. Follow the usual con-

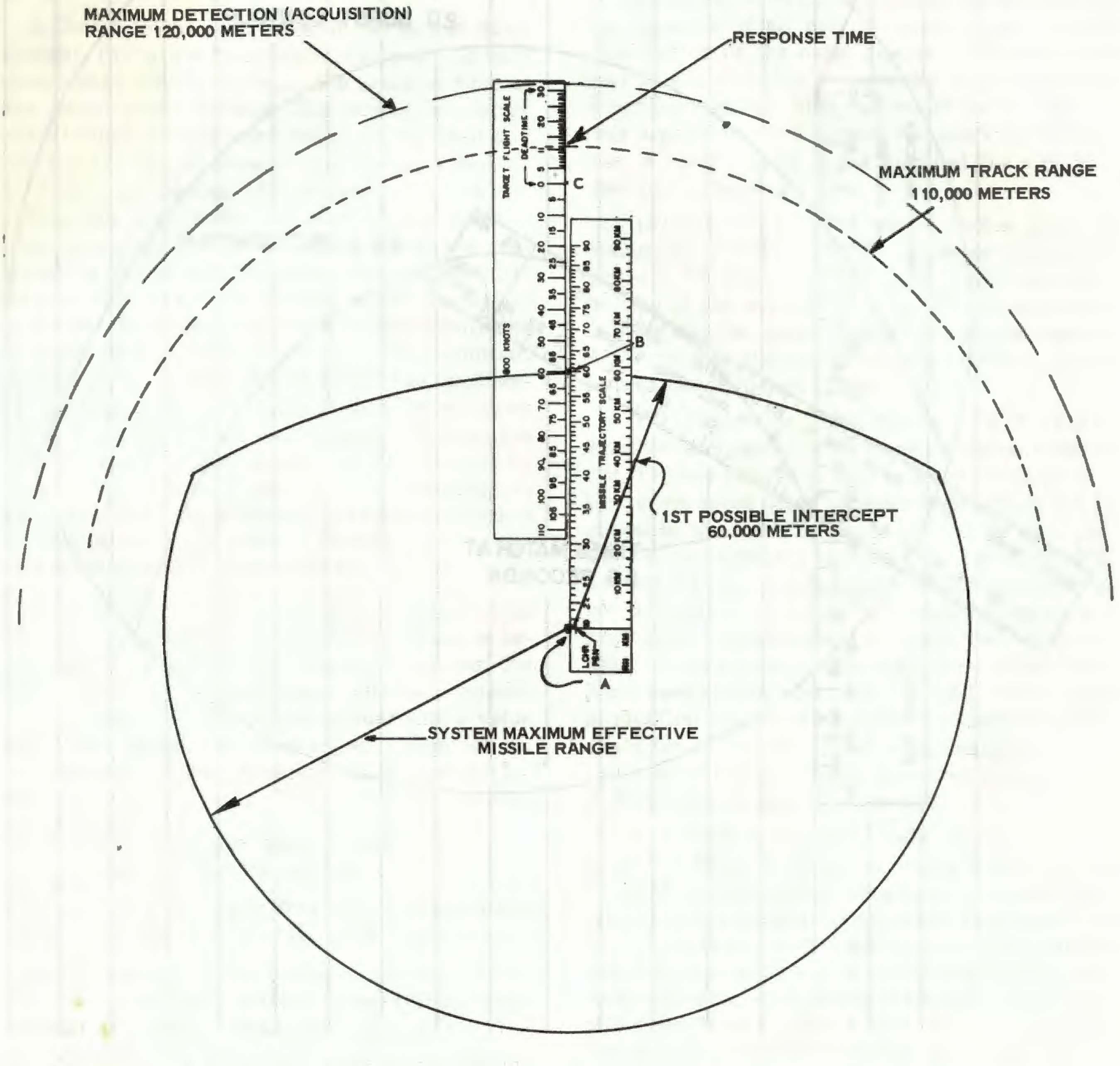


Figure 3-12. Initial burst contour range less than system maximum effective range.

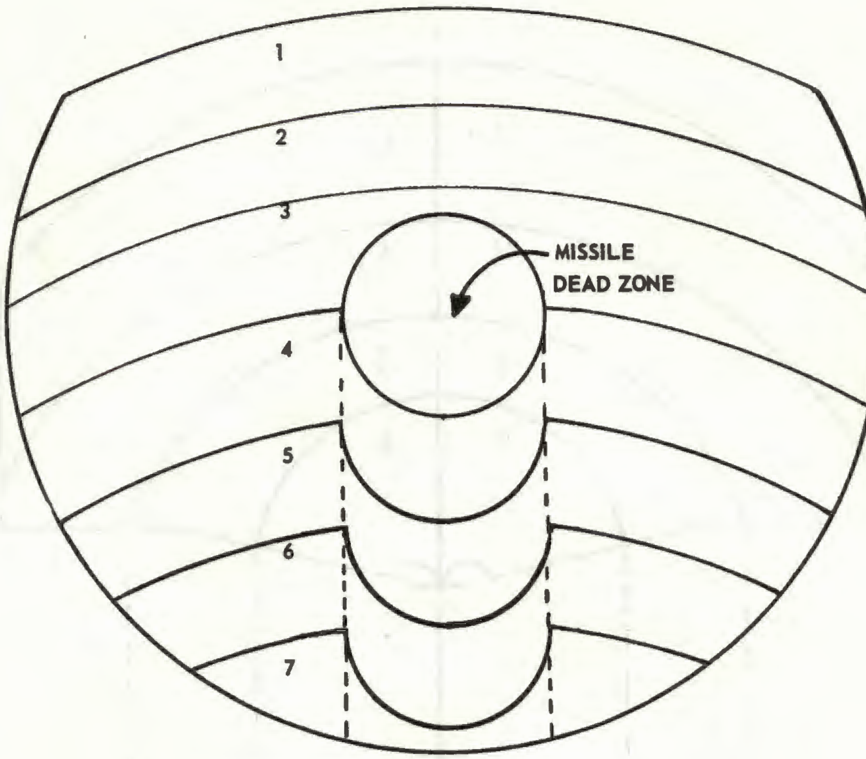


Figure 3-13. Nike Hercules burst locator with missile dead zone.

struction procedure as outlined above. If the burst contour should fall inside the dead zone, the contour line must be altered to skirt around the rear of the dead zone (fig. 3-13). If the air defense planner plots a burst inside the dead zone, he will move this burst to the rear side of the dead zone. This causes the contour to fall behind the dead zone.

(2) Subsequent contours are measured from the preceding burst contour, causing a dip in all succeeding contour lines (fig. 3-13).

3-20. Hawk Burst Locator

a. The Hawk burst locator (fig. 3-14) is a Hawk effectiveness template (fig. 3-15) contoured to reflect specific missile capability of the defense against the specified threat. The outer contour represents maximum effective missile range. The burst locator is used on a defense overlay or map to give a direct reading of missile capability by the time a threat arrives at a particular point.

b. The effectiveness template defines the effective area and dead zone of the Hawk unit. Hawk effectiveness templates are presented in figures 1 through 5, FM 44-1A. The direction-of-flight line and arrow must be added to the templates as shown in figure 3-15. The effectiveness template does not show successive intercepts against the target; these must be determined by using the target flight and missile trajectory scales.

c. In preparation for the construction of a Hawk burst locator, target flight and missile trajectory scales must be constructed, using the pertinent data for the Hawk system (para 3, FM 44-1A) and assumptions regarding the speed and altitude of the threat. The target flight and missile trajectory scales are constructed as described in paragraphs 3-15 and 3-16.

d. If terrain masking is not a limiting factor, the forward edge of the selected effectiveness template defines the first burst contour and the burst locator is constructed by contouring the effectiveness template (fig. 3-16).

(1) On the effectiveness template, draw a number of parallel lines to represent routes of approach. The lines are drawn parallel to the direction-of-flight line which is the center line as shown in figure 3-15.

(2) The outer contour of the effectiveness template represents the first pair of bursts, one per fire unit. The target flight scale is oriented

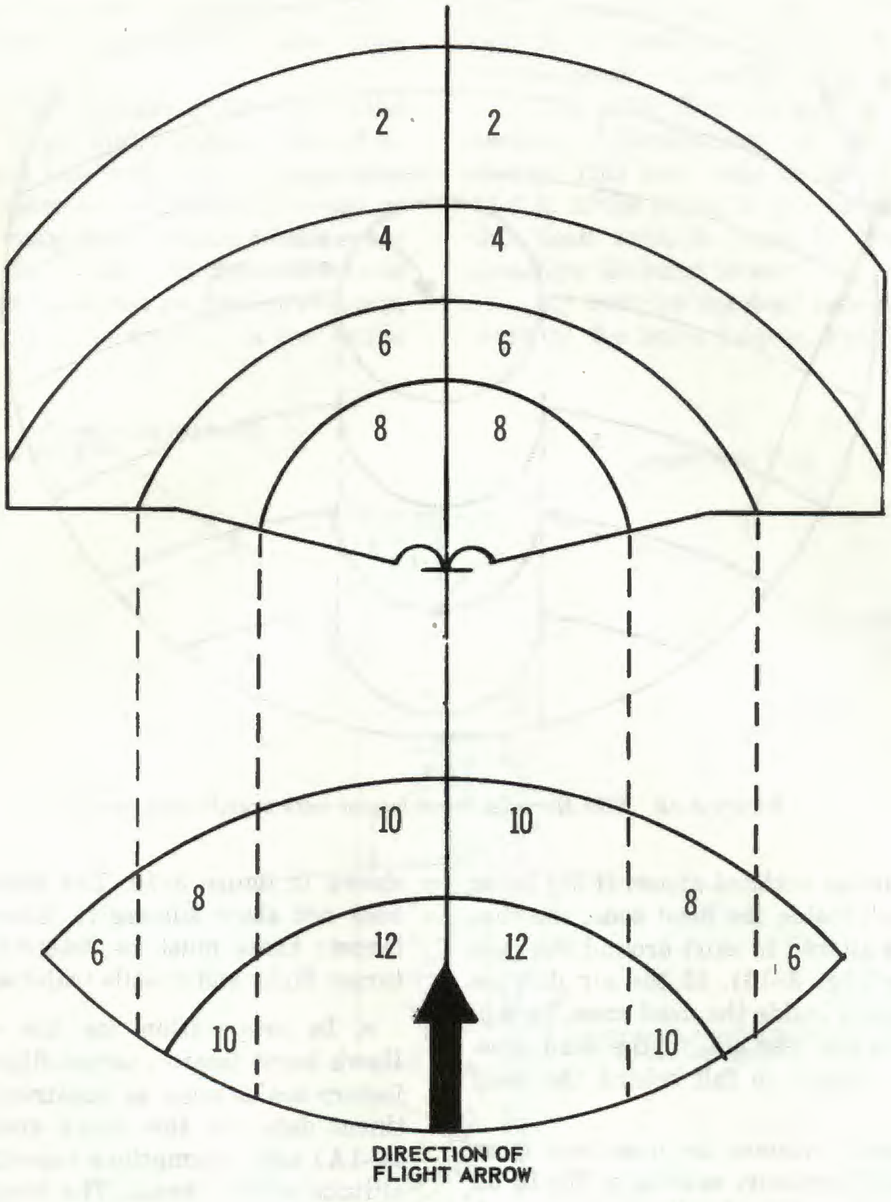


Figure 3-14. Type of Hawk burst locator.

parallel to a route-of-approach line, with the scale moved in from the outer contour by the specified dead (reaction) time, to determine zero time for the target. Place the zero or launch position of the missile trajectory scale at the center which represents the launcher position. Match times and mark this point. Do this along each route of approach line, then connect these points with a smooth line. Label this line as the second burst contour (with a value of 4). Subsequent contours are determined in a like manner. Reverse the direction-of-flight arrow when completing the construction of the burst locator.

(3) In figure 3-16, the dots show points where times matched but have not been connected with a smooth line to form the second burst contour. In this illustration, a sample reaction time of 6 seconds was used.

e. Using the standard Hawk burst locator.

(1) Determine and draw in the low-altitude routes of approach toward the center of a defended vital area, or toward the FEBA and exposed flanks in an area defense.

(2) Plot the BRL or other line of evaluation. The point of evaluation depicts the point that

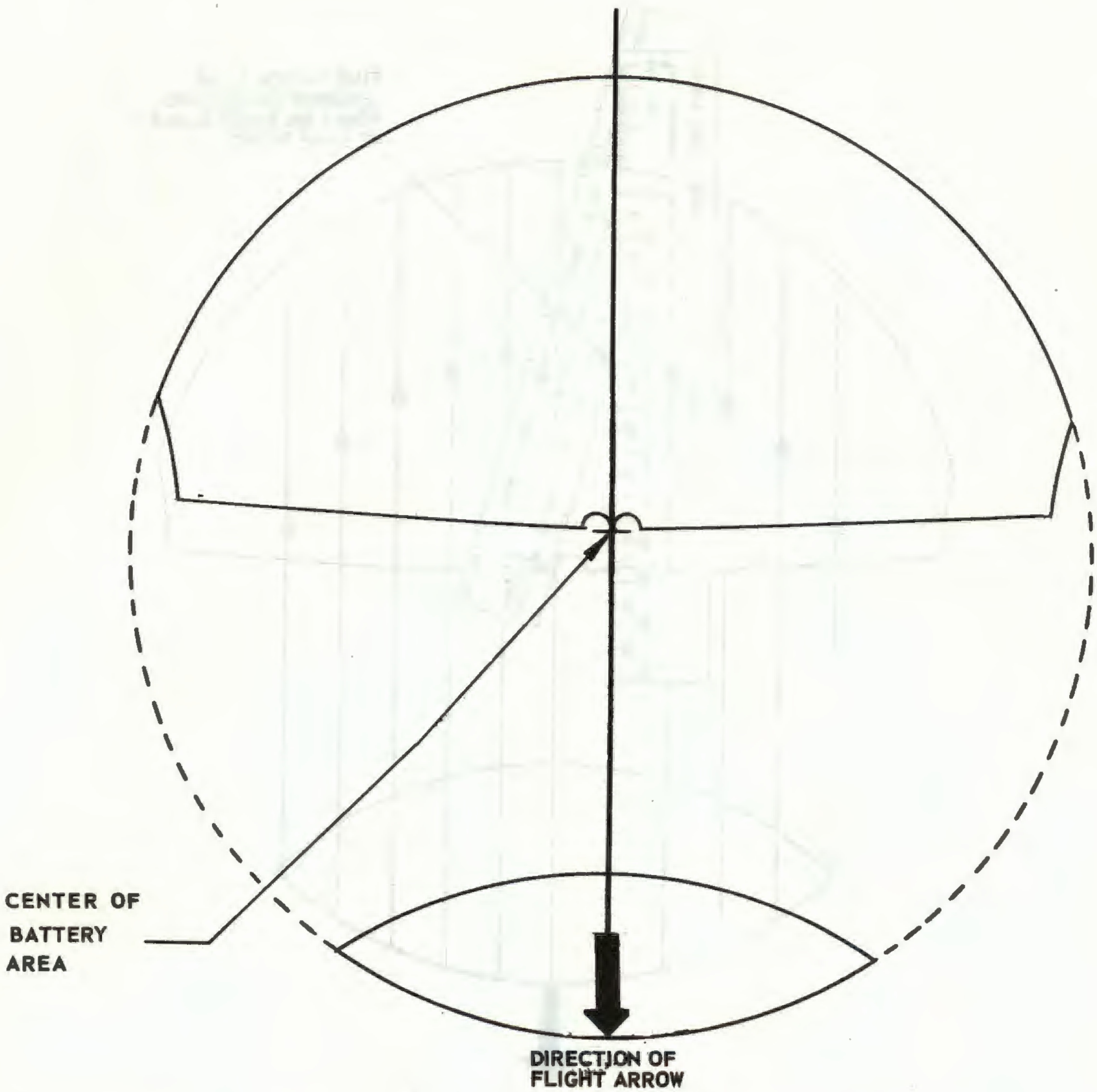


Figure 3-16. Hawk effectiveness template (with direction-of-flight line and arrow added).

must not be reached by the threat if the air defense mission is to be accomplished. For manned aircraft using the high-altitude bombing system (gravity drop) or LABS techniques, this point is where the route of approach intercepts the BRL. When use of air-to-surface missiles or the laydown technique is assumed, there is no bomb release line. The point of evaluation is where the routes of approach intersect the edge of the vital area. In an area defense, the points of evaluation are defined by the intersection of the routes of approach and the FEBA or exposed boundaries. The manned aircraft attacking a vital area will be used for further illustration.

(3) Orient the burst locator with the center point over the point of evaluation (fig. 3-17), the direction-of-flight arrow pointed in the same direction as the threat flight, and the direction-of-flight line superimposed over the route of approach. Read the total missile value for each battery (two-fire-unit capability assumed) falling under the burst locator; e.g., Battery A receives a value of 4.

(4) Record the individual battery readings on the recording form and total them to determine the defense capability.

(5) All target courses are coincident with, or

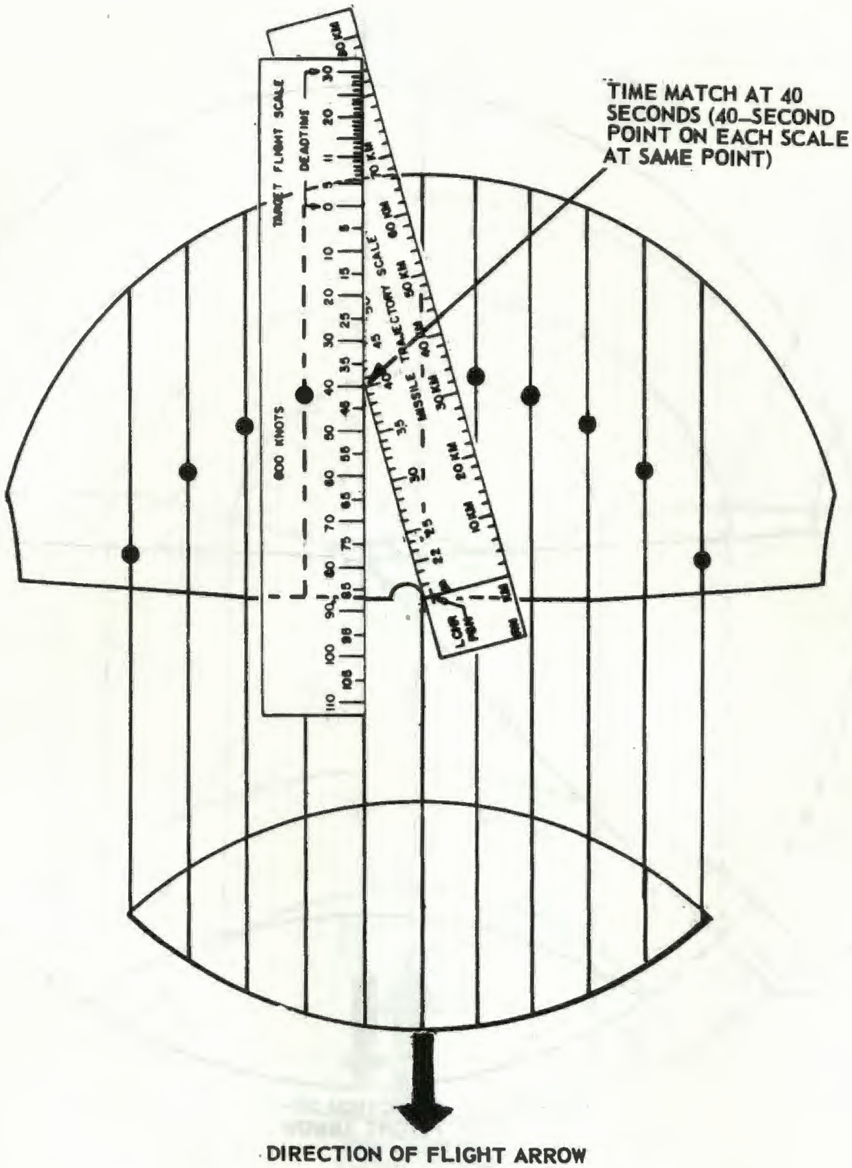


Figure 3–16. Construction of Hawk burst locator.

parallel to, the direction-of-flight line. *Do not* interpolate between contours. If a battery falls in a dead zone between the forward and rear effective zones, give this unit credit for the number of missile launches it would have been able to attempt as it left the forward effective zone and went into the dead zone.

Example: Battery B plots in the dead zone as shown in figure 3–17. Following between the dotted lines back to the forward effectiveness zone, read a value of 6. Therefore, Battery B would be credited with a missile value of 6.

f. If the first burst from a Hawk battery cannot occur at the forward edge of the selected template because of terrain masking, the standard Hawk burst locator techniques cannot be used and the capabilities of the battery must be analyzed separately. Two methods are available for this special evaluation: use of the urgency diagram or use of the target flight and missile trajectory scales with the effectiveness template. The urgency diagram is preferred if its use is valid ((1) below).

(1) *Urgency diagram.*

(*a*) The urgency diagram (fig. 3–18) is a device that may be used for measuring a single battery's missile capability when use of the burst locator is not valid. The urgency diagram is con-

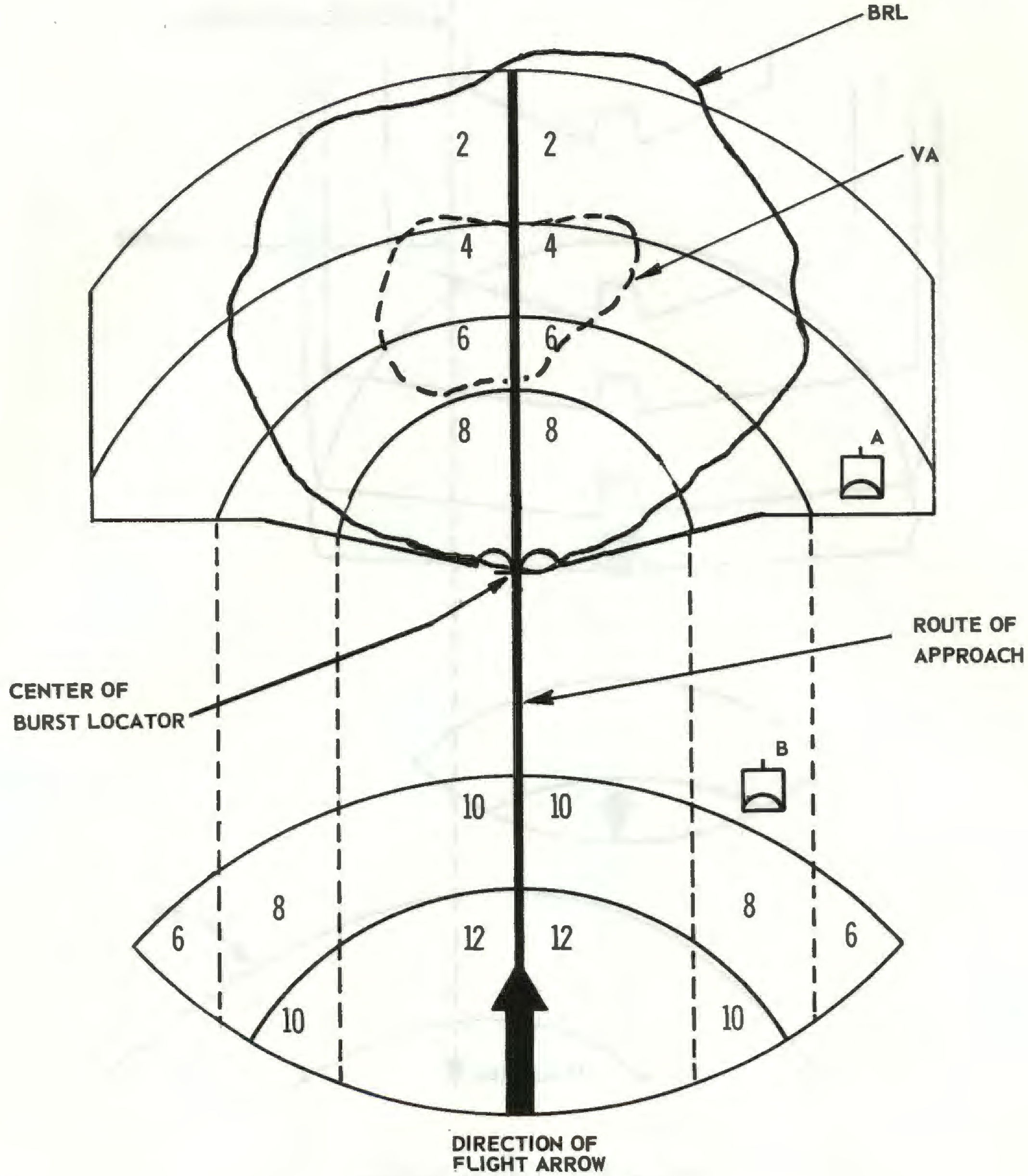


Figure 3-17. Hawk burst locator oriented over point of evaluation.

structed by using the same assumptions as for construction of the burst locator (para 3-14*b*) with the exception of the assumption regarding *initial burst* location. However, two additional assumptions are used.

1. Response time (see glossary) is used to determine the points where acquisition must occur to achieve bursts.

2. Last burst location is assumed to be on the rearward edge of the forward effectiveness zone.

(*b*) The urgency diagram is constructed as follows:

1. Draw a series of lines on the Hawk effectiveness template parallel to the direction-of-flight line. The number of lines drawn is not critical although accuracy will be increased if the lines are no further apart than 5 kilometers. The battery is located in the center of the template.

2. Assume that the last burst against an aircraft flying along each of the parallel lines will occur at the rear edge of the forward effectiveness zone. Measure the missile time of flight to each of these "last burst" points with the missile trajectory scale.

3. Determine the minimum point on each

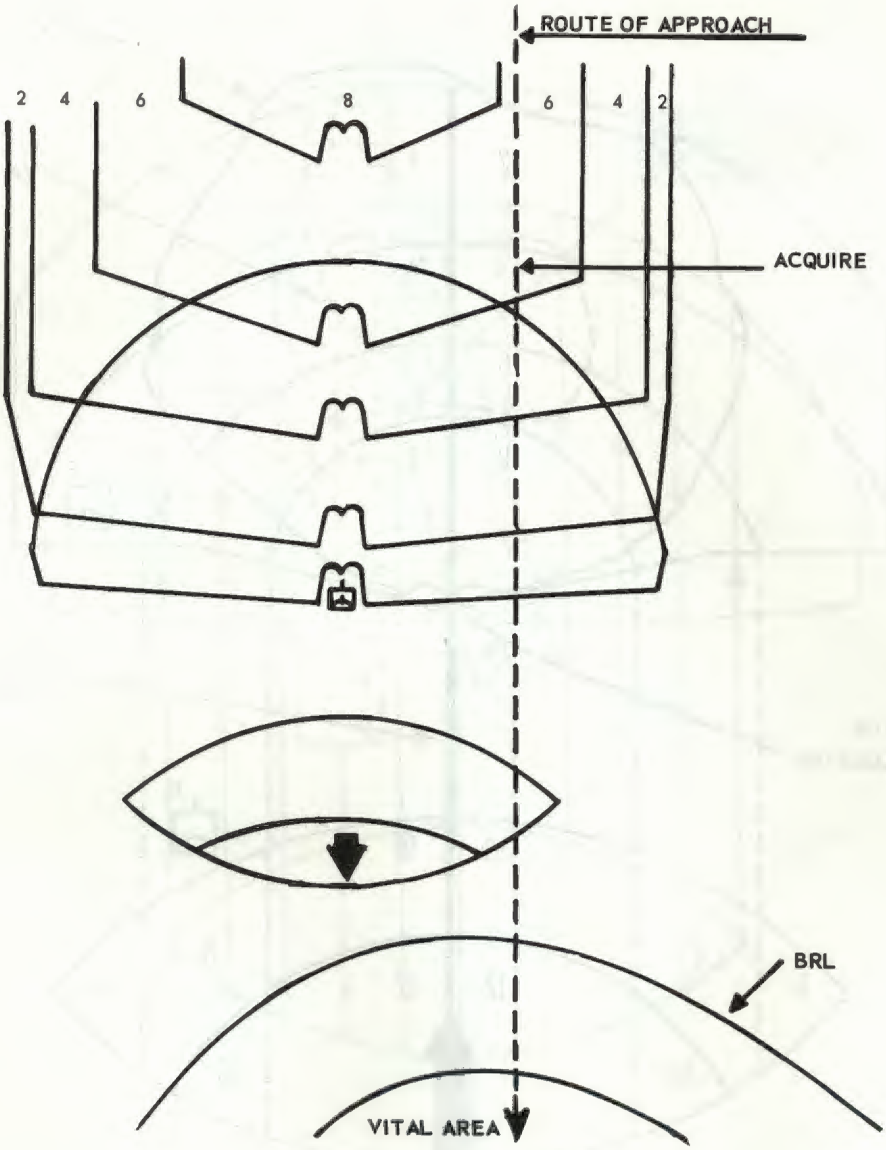


Figure 3-18. Urgency diagram.

parallel line where each aircraft would have to be detected or acquired to obtain "last burst" as indicated in *2* above. This is accomplished by superimposing the target flight scale on each of the parallel lines so that a time match is obtained at each burst point. Then back plot along each parallel line to locate and mark the point (target time of flight plus response time) where acquisition would have to occur. Connect these points with a straight line.

4. Determine the minimum acquisition point on each parallel line that will be required for the battery to achieve two, four, six, or more bursts before the aircraft entered the dead zone (crossed the rear edge of the forward effectiveness zone). This is accomplished by first determining the location of the aircraft on each parallel line when the last missile was launched and back-plotting through reaction time to determine where the "next to the last" bursts could have occurred. Measure the missile time of flight to each of these burst points and, using the same technique described in *3* above, locate and mark the acquisition points required to achieve two bursts before the aircraft reach the dead zone. Connect these points with a smooth line to delineate the second burst bracket. Use the same procedure to determine subsequent burst brackets.

The width of the brackets is determined by the shape of the forward effectiveness zone.

(*c*) The urgency diagram is used to evaluate only one firing battery at a time. To use the urgency diagram, orient its center over the battery symbol of the battery to be evaluated (fig. 3-18). The direction-of-flight line must be parallel to the route of approach. The direction-of-flight arrow is pointed in the direction of the direction of flight of the target. Locate the point at which the target can be acquired (detected). This point must be in one of the numbered brackets at the top of the urgency diagram. The number within the bracket indicates the number of bursts that the battery can deliver by the time the target crosses the rearward edge of the forward effectiveness zone and enters the dead zone. To determine the receding missile capability, count the number of contour lines that the target will cross before reaching the point of evaluation. Each contour line in the rearward effectiveness zone represents a missile burst or a pair of missile bursts, depending on the method of fire. Figure 3-18 shows the firing battery being analyzed with a total missile capability of eight bursts, six in the forward effectiveness zone and two additional bursts as the target crosses the contour line into the rearward effectiveness zone. To determine whether the urgency diagram is a valid analyzing device for a battery, orient it as described above and locate the point of evaluation. If the point of evaluation is to the rear of the rearward edge of the forward effectiveness zone, use of the urgency diagram is valid. If the point of evaluation is forward of the rearward edge of the forward effectiveness zone, the assumption made as to the location of the last burst is violated and the burst indicated cannot be used to evaluate the defense. Therefore, use of the urgency diagram would be invalid for that battery. The effectiveness template and target flight and missile trajectory scales must then be used.

(2) *Use of target flight and missile trajectory scales and effectiveness template.* The target flight and missile trajectory scales can be used in conjunction with the effectiveness template when standard burst locator techniques cannot be used. For example, in figure 3-19, assume that a target can reach point B before a missile can be launched from point A, considering degraded radar range and an assumed response time of 13 seconds.

(*a*) The missile trajectory scale is oriented with the battery position at A, and the target flight scale is placed parallel to the route of approach with the appropriate response time (e.g., 13 seconds in fig. 3-19) at the point of detection. Time matches (point C) when both objects have traveled toward each other for 65 seconds; this point becomes the location of the first outburst. Each time match must occur on or inside the effective area outlined by the effectiveness template. If time matches in the dead zone (point D), the burst will move in the direction of target flight, parallel to the direction-of-flight line, until the rear effective area is encountered (point E). As soon as the rear effective area is reached, the burst point is plotted.

(*b*) Total bursts along the particular route of approach line for this particular battery are obtained only by using the above method. The capabilities of the unaffected batteries are analyzed by using standard techniques (*e* above).

(*c*) Use of this technique is not necessary if radar ranges are only degraded slightly, in which case the standard techniques may be usable. If the plot of the first burst falls forward of the forward edge of the template, it is obvious no significant system degradation has occurred and the battery does not require use of the special analysis technique.

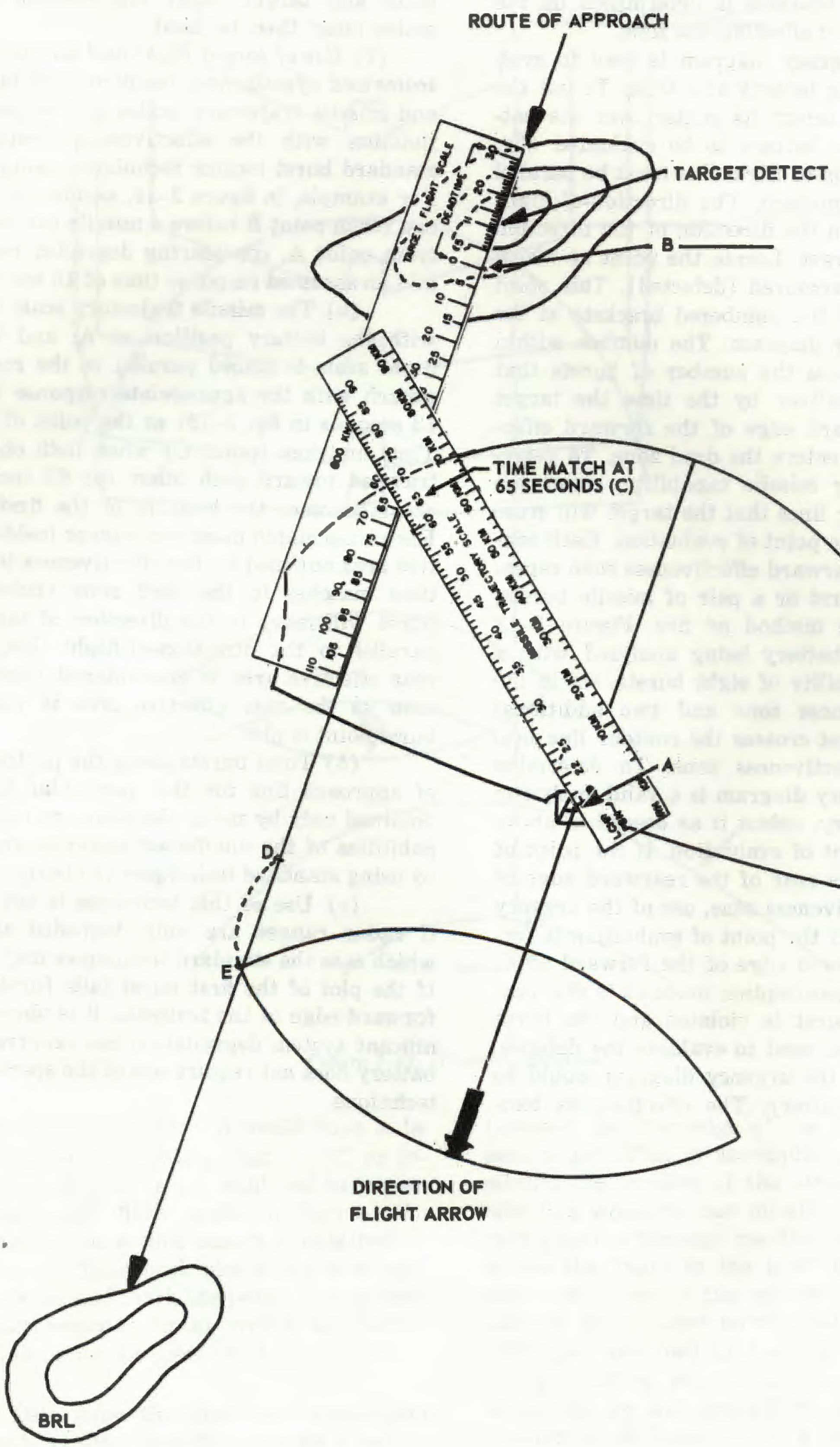


Figure 3-19. Use of effectiveness template with missile trajectory and target flight scales.

CHAPTER 4
ESTABLISHMENT OF ADA AUTOMATIC WEAPON AND CHAPARRAL DEFENSES

Section I. PRINCIPLES AND FACTORS INFLUENCING AIR DEFENSE DESIGN

4–1. Principles Influencing Air Defense Design

a. General. Once air defense priorities are established by the force commander, the ADA commander must determine how best to use his resources. Air defense artillery automatic weapon (AW) and Chaparral squads must be deployed to provide effective air defense for as many of the force commander's assets as possible and in order of priority. Factors such as the expected threat, terrain, number of available weapons, and the size, shape, and proximity of other defended installations tend to arrange the principles influencing air defense design into some order of relative importance. However, it is desirable that each principle be applied to the maximum extent possible. The principles influencing air defense design are covered in *b* through *f* below.

b. Balanced Defense. In general, enemy aircraft are capable of attacking from any direction. The enemy will seek the most favorable direction of attack and will attempt to exploit any weakness in the defense. Therefore, the defense should be balanced to cope with attacks from any direction

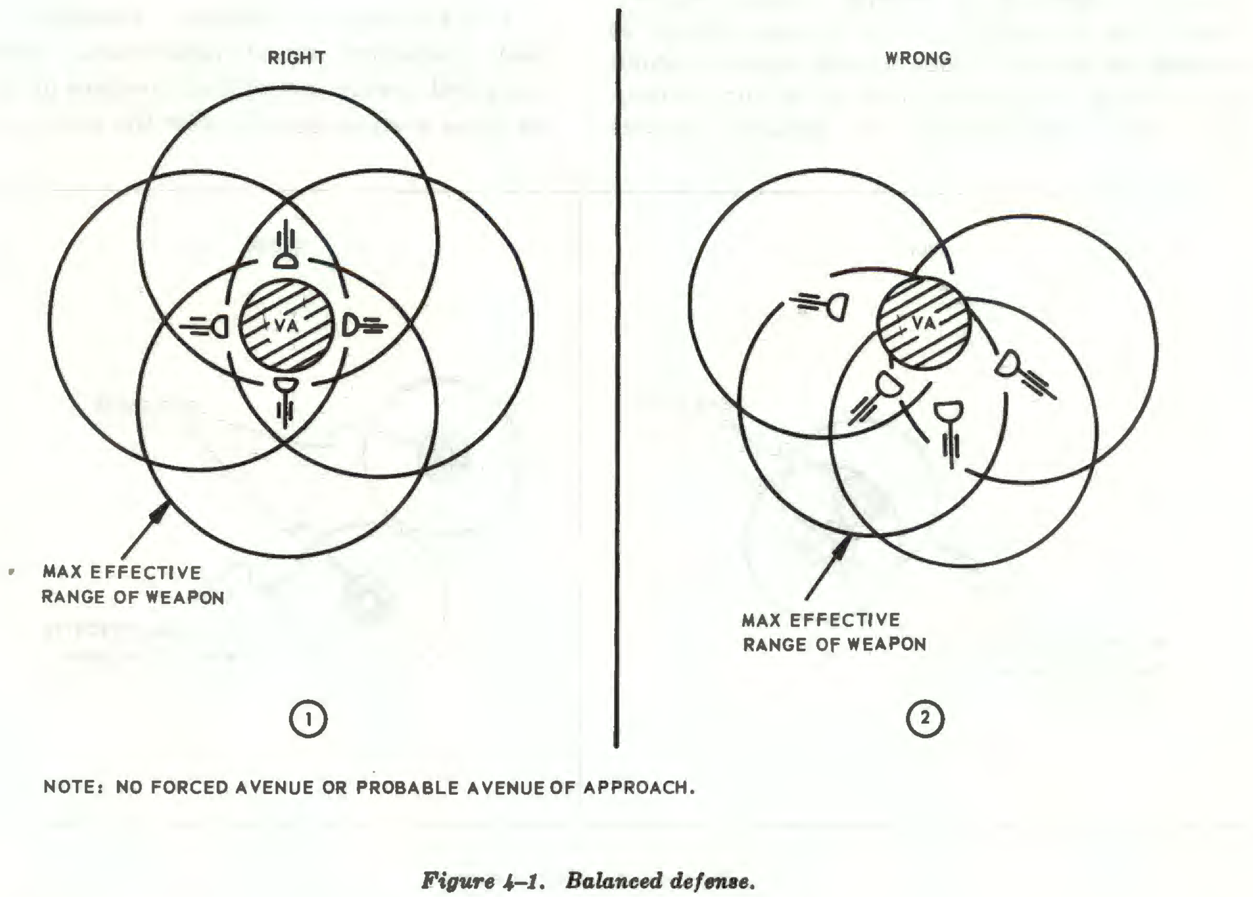


Figure 4–1. Balanced defense.

with approximately the same volume of fire. Exceptions arise in cases where attack along certain avenues of approach is forced or probable (*e* below), during defense of march columns, or in an area defense. Automatic weapon squads sited to provide all-round defense of the vital area are depicted in figure 4-1. A minimum of four AW squads should be employed to defend a small vital area (VA).

c. Mutual Support. The principle of mutual support is applied by positioning each ADA squad so that its dead zone is within the engagement capability of at least one adjacent squad (fig. 4-2). This increases the volume of fire possible in the space mutually covered. To remain mutually supporting, Vulcan, M42, and M55 squads should not be separated by more than 1,000 meters, 1,100 meters, and 480 meters, respectively. As the Chaparral system has a range capability beyond the maximum consistent visual identification range (3,000 meters) for low-flying aircraft, the mutual support distance for Chaparral is determined by using a range of 80 percent of the visual identification range (2,400 meters) as the maximum mutual support distance. Weapon crews must be capable of detecting targets at maximum distances if they are to provide mutual support. Space that is masked to one weapon should be covered by another. When mutual support cannot be obtained, the squads must strive for overlapping fire. Attainment of mutual support throughout the weighted Chaparral area defense frequently will be unattainable.

d. Early Engagement. The object of early engagement is to engage and destroy hostile aircraft prior to the aircraft releasing its ordnance. Since the enemy has such a wide choice of aircraft, ordnance, and attack variations, specific rules for the emplacement of weapons to maximize the principle of early engagement cannot be formulated. The degree of early engagement, therefore, must be determined by the size of the defended VA, number of weapons available, and the need for balance, mutual support, and the other principles discussed herein. Automatic weapon squads should be located as far from the defended VA as practicable to allow for early engagement, yet they should be close enough to provide mutual support and total coverage of the area (fig. 4-3). Chaparral squads should be located as far forward in the defended area as possible, while maintaining the required weighted area defense. Ground aircraft observers and the forward area alerting radar (FAAR) should be situated in advantageous locations which will provide alerting information and further facilitate early engagement.

e. Weighting the Defense. Automatic weapon and Chaparral squad deployments should be weighted toward low-altitude avenues of approach as these avenues usually offer the enemy a higher

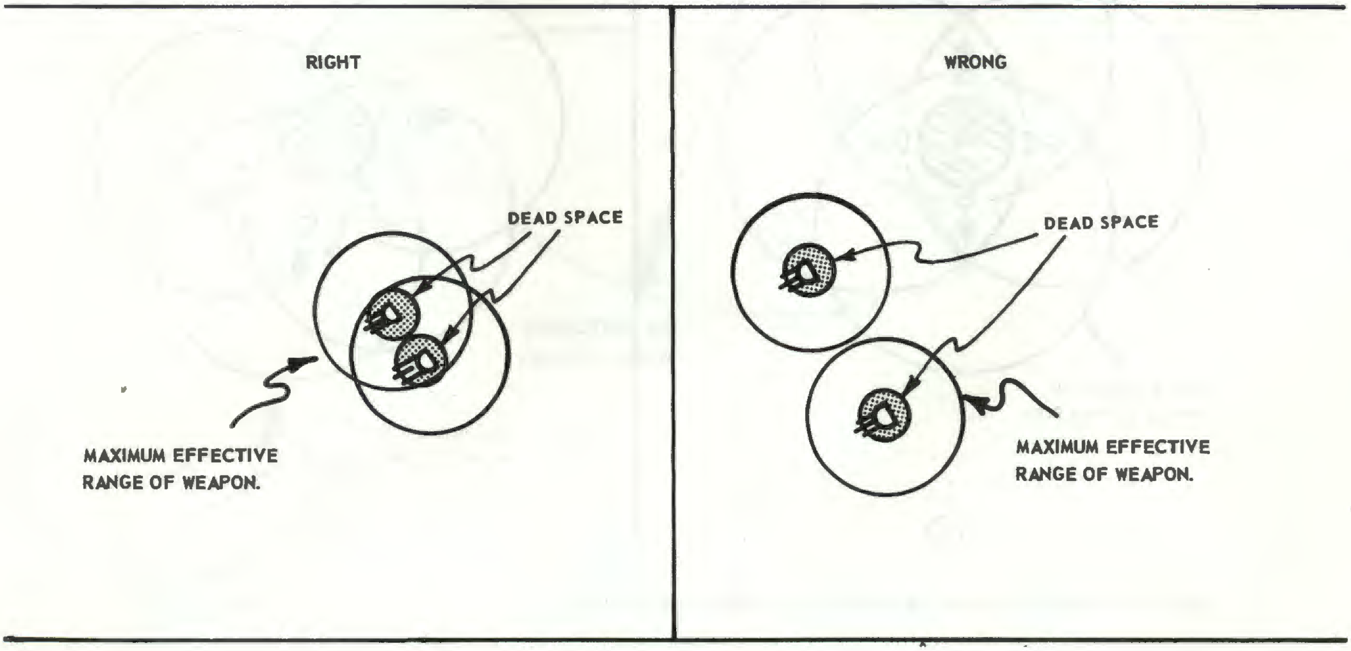


Figure 4-2. Mutual support.

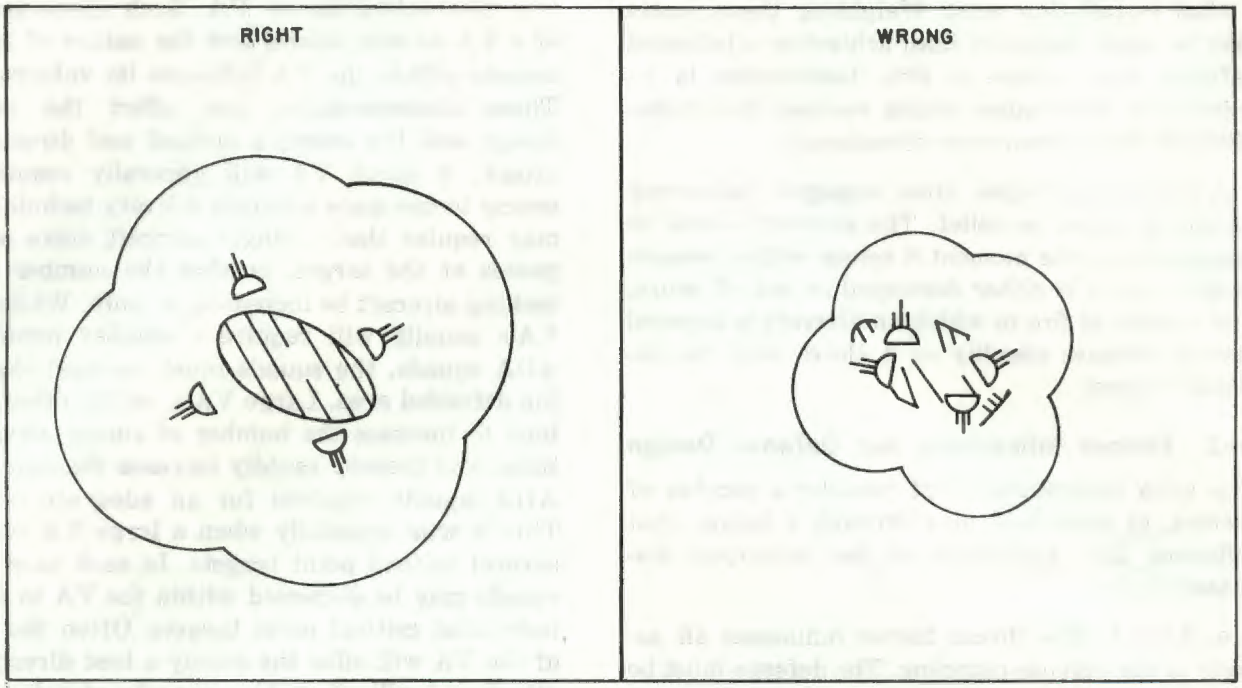


Figure 4-3. Early engagement.

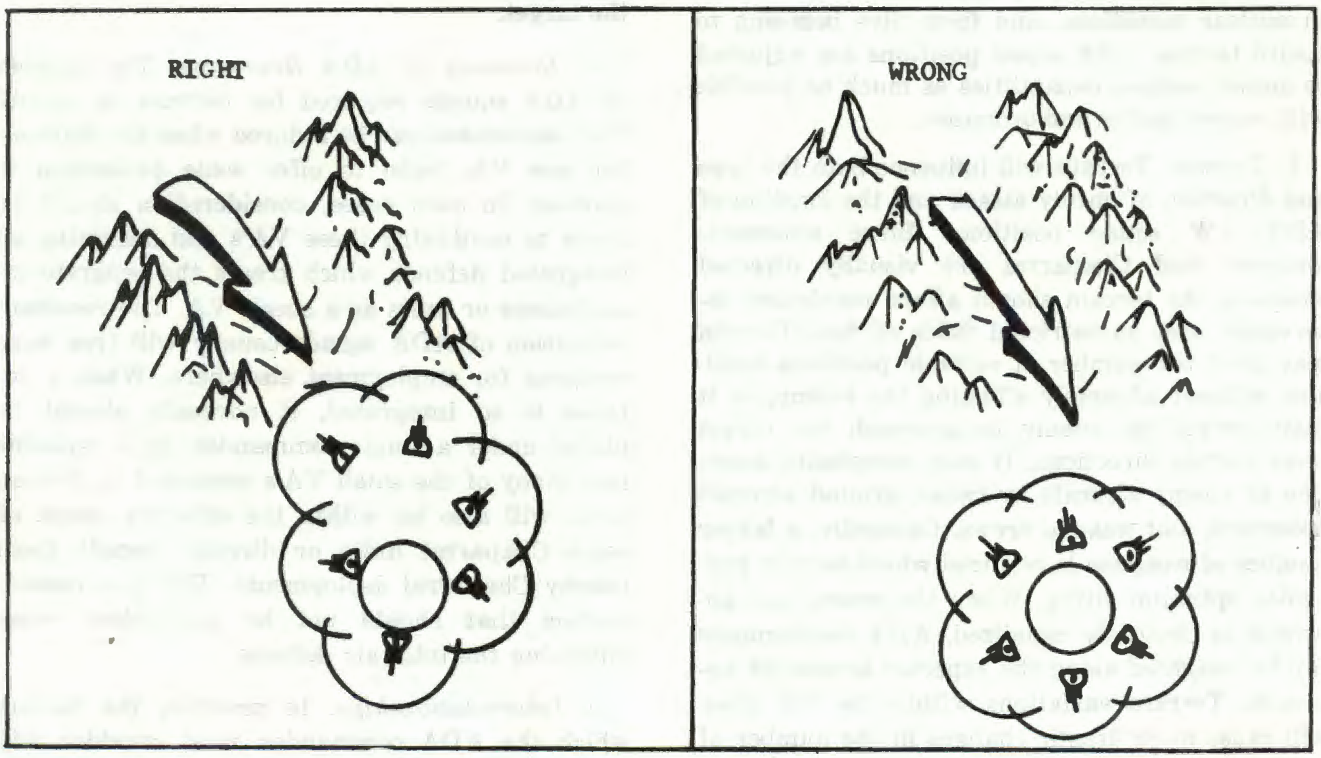


Figure 4-4. Weighted defense.

probability of executing a successful attack (fig. 4-4). The decision to weight the defense must be considered carefully since weighting unavoidably results in some degradation in defense balance. Proper weighting for Chaparral usually will require deployment of fewer fire units, providing balance is not a governing factor. In some cases, probable or forced routes of approach leading into a vital installation exist. Weighting these routes may be more desirable than achieving a balanced defense (e.g., where a vital installation is located in a deep valley which reduces the probability of attack from some directions).

f. Defense in Depth. Once engaged, the enemy should be given no relief. The aircraft should be engaged from the moment it comes within weapon range until it is either destroyed or out of range. The volume of fire to which an aircraft is exposed should increase steadily as it closes with the defended target.

4-2. Factors Influencing Air Defense Design

The ADA commander must consider a number of factors, as explained in *a* through *e* below, that influence the application of the principles discussed above.

a. Threat. The threat factor influences all aspects of air defense planning. The defense must be able to cope with a combination of weapons and techniques likely to be employed by the enemy. Enemy capabilities may range from rotary-wing to high-performance aircraft, from conventional to nuclear munitions, and from dive bombing to LABS tactics. ADA squad positions are adjusted to match weapon capabilities as much as possible with enemy tactics and ordnance.

b. Terrain. Terrain will influence both the type and direction of enemy attack and the location of ADA AW squad positions. Since automatic weapons and Chaparral are visually directed weapons, the terrain should afford maximum observation and unrestricted fields of fire. Terrain may limit the number of suitable positions available without adversely affecting the enemy, or it may compel the enemy to approach the target from certain directions. It may complicate detection of enemy aircraft by radar, ground aircraft observers, and weapon crews. Generally, a larger number of weapons is required where terrain precludes optimum siting. When the enemy air approach is obviously canalized, ADA deployments can be weighted along the expected avenue of approach. Terrain variations within the VA often will cause more drastic changes in the number of weapons required than will variations in VA size. In mountainous areas, ADA positions must not be so high on the terrain that aircraft can fly under ADA AW and Chaparral fires due to either troop safety considerations or the depression limit of the weapons.

c. Characteristics of VA. Such characteristics of a VA as size, shape, and the nature of specific targets within the VA influence its vulnerability. These characteristics also affect the defense design and the enemy's method and direction of attack. A small VA will generally require the enemy to use more accurate delivery techniques. It may require that a single aircraft make several passes at the target, or that the number of attacking aircraft be increased, or both. While small VA's usually will require a smaller number of ADA squads, the squads must be sited closer to the defended area. Large VA's, on the other hand, tend to increase the number of enemy attack options, and thereby rapidly increase the number of ADA squads required for an adequate defense. This is true especially when a large VA contains several critical point targets. In such case, ADA squads may be dispersed within the VA to defend individual critical point targets. Often the shape of the VA will offer the enemy a best direction of attack and will affect the principles of balance and weighting accordingly. To increase the chances of success, air attacks against long, narrow targets may be flown along the long axis or diagonal of the target.

d. Economy of ADA Resources. The number of ADA squads required for defense of several VA's sometimes can be reduced when the defenses for one VA begin to offer some protection to another. In such cases, consideration should be given to combining these VA's and designing an integrated defense which treats the separate installations or units as a single VA. The resultant relocation of ADA squads usually will free some weapons for employment elsewhere. When a defense is so integrated, it normally should be placed under a single commander. It is probable that many of the small VA's protected by Vulcan units will also be within the effective range of some Chaparral units or directly benefit from nearby Chaparral deployments. This is a consideration that should not be overlooked when analyzing the total air defense.

e. Interrelationships. In practice, the factors which the ADA commander must consider will seldom be clear-cut. While each must be judged upon its own merits, it must be considered in comparison with all the others. For example, seldom will the threat be the single factor influencing the air defense design. The threat must be considered in conjunction with the terrain, VA characteristics, and amount of air defense weapons available. The final application of these factors usually will be a justifiable compromise that reflects a certain measure of each.

Section II. METHODS OF AIR DEFENSE DESIGN

4-3. General

The methods and procedures presented in this section provide the ADA commander and his staff with the basic tools for expeditiously determining the desirable number and disposition of ADA squads for each of the force commander's air defense priorities. In general, automatic weapon defenses should consist of no less than four squads. Additional weapons, when required, normally are added in increments of two. Air defense planning factors tables for Vulcan and M42 and initial position templates for Vulcan, M42, and M55 are provided as guides for initial air defense designs. These designs then are adjusted to maximize application of the principles and factors discussed in paragraphs 4-1 and 4-2. Normally, Chaparral squads will be deployed to accomplish an area defense mission. The number of Vulcan and M42 squads necessary to defend a vital area can be determined as described in paragraph 4-4.

4-4. ADA AW Planning Factors Tables

a. Vulcan Planning Factors Table. To assist ADA commanders and staff officers in estimating the number of Vulcan squads for defense of VA's of any shape, the planning factors table (PFT) (table 4-1) is used as a guide. This table does not apply to march columns or targets of similar shape which dictate basically deployments in a line. If a stronger defense is desired, more Vulcan squads may be added as indicated by note 3, table 4-1. This PFT is based on the supposition that Nike Hercules and Hawk provide high- and medium-altitude coverage of the Vulcan defended area and that Chaparral fire units will also complement the overall defense. If the Vulcan is the only air defense system available and a very strong defense is desired, a different method must be used. In this situation, the number of Vulcan squads available is the critical factor because this defense requires a large number of weapon squads. Concentric circles are drawn around the vital area using a radius of not more than successive integral multiples of the effective range of the weapon. Then the weapons are placed on these radii. The number of radii used depends on the number of weapons available and the desired air defense strength (fig. 4-5).

Table 4-1. Planning Factors Table for Vulcan Squads

Perimeter of VA in meters	Number of squads	Perimeter of VA in meters	Number of squads
0-2,460	4	19,600-20,600	36
2,460-5,000	6	20,600-21,600	38
5,000-6,600	8	21,600-22,600	40
6,600-7,600	10	22,600-23,600	42
7,600-8,600	12	23,600-24,600	44
8,600-9,600	14	24,600-25,600	46
9,600-10,600	16	25,600-26,600	48
10,600-11,600	18	26,600-27,600	50
11,600-12,600	20	27,600-28,500	52
12,600-13,600	22	28,500-29,500	54
13,600-14,600	24	29,500-30,500	56
14,600-15,600	26	30,500-31,500	58
15,600-16,600	28	31,500-32,500	60
16,600-17,600	30	32,500-33,500	62
17,600-18,600	32	33,500-34,500	64
18,600-19,600	34		

Notes.
1. Maximum mutual support distance: 1,000 meters.
2. For VA's with perimeters greater than 34,500 meters, two weapons should be allocated for each 1,000 meters (or fraction thereof) increase in VA perimeter.
3. For a stronger defense, additional weapons must be used and the distance between fire units decreased.
4. The shape of the defense should conform generally to the shape of the VA.

b. M42 Planning Factors Table. To assist ADA commanders and staff officers in estimating the number of M42 squads needed for defense of a VA

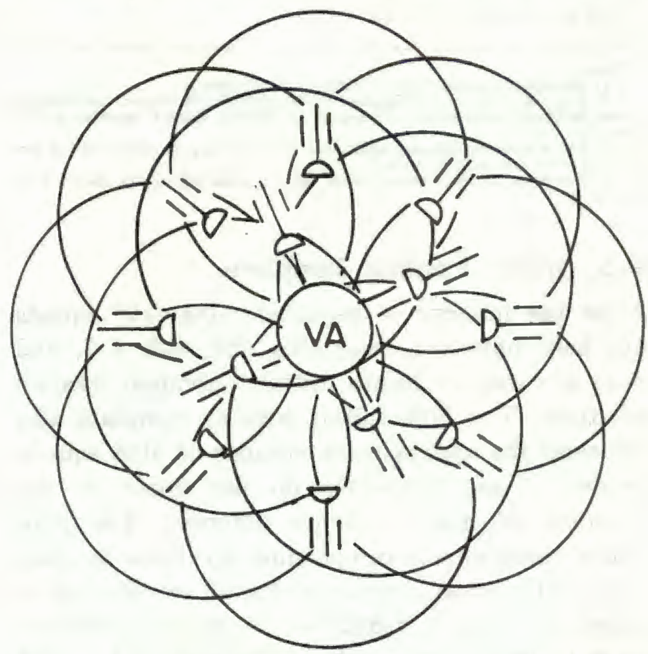


Figure 4-5. Vulcan defense without complementary ADA Weapons.

of any shape, the M42 PFT (table 4-2) is used as a guide. This table does not apply to march columns or targets of similar shape which dictate basically deployments in a line. M42 defenses are not analyzed numerically. If a stronger defense is desired, more squads may be added as indicated by note 3, table 4-2. The PFT prescribes the number of M42 squads required for the defense of VA having a perimeter up to 38,000 meters. For example, 14 M42 squads are required for a VA with a perimeter of 10,000 meters. For larger VA's than those appearing on the PFT, two squads are added for each 1,100 meters or fraction thereof increase in VA perimeter.

Table 4-2. Planning Factors Table for M42 Squads

Perimeter of VA in meters	Number of squads	Perimeter of VA in meters	Number of squads
0-2,700	4	21,600-22,700	36
2,700-5,500	6	22,700-23,800	38
5,500-7,300	8	23,800-24,900	40
7,300-8,400	10	24,900-26,000	42
8,400-9,500	12	26,000-27,000	44
9,500-10,600	14	27,000-28,100	46
10,600-11,700	16	28,100-29,200	48
11,700-12,800	18	29,200-30,300	50
12,800-13,900	20	30,300-31,400	52
13,900-15,000	22	31,400-32,500	54
15,000-16,100	24	32,500-33,600	56
16,100-17,200	26	33,600-34,400	58
17,200-18,300	28	34,400-35,800	60
18,300-19,400	30	35,800-36,900	62
19,400-20,500	32	36,900-38,000	64
20,500-21,600	34		

Notes.
1. Maximum mutual support distance: 1,100 meters.
2. For vital areas with perimeters greater than 38,000 meters, two weapons should be allocated for each 1,100 meters (or fraction thereof) increase in vital area perimeter.
3. For a stronger defense, additional weapons may be used and the distance between fire units decreased.
4. The shape of the defense should conform generally to the shape of the vital area.

4-5. Initial Position Template

After the number of required ADA AW squads has been obtained, templates (fig. 4-6, 4-7, and 4-8) are used to locate initial individual weapon positions. The M55 initial position template also indicates the approximate number of M55 squads needed. These templates do not apply to the planning of march column defenses. The templates place squads in optimum positions for balance and mutual support although no account is taken of terrain features. Normally, positions must be readjusted, both on the map and on the ground, as the principles and factors discussed above are considered.

a. Vulcan Initial Position Template.

(1) *Description.* The Vulcan initial position template (fig. 4-6) is constructed to the scale of the map to be used. Mutual supporting distances for Vulcan range from 100 to 1,000 meters. Figure 4-6 depicts a type template at one specific supporting distance. Dots representing weapons are arranged in a column 1,000 meters apart with each column 850 meters apart. Alternate columns are offset toward the top of the template by 500 meters. This offset will result in a balanced pattern with each weapon being 1,000 meters or less from any adjacent weapon, thereby providing mutual support for each squad from at least two other squads.

(2) *Use of template.* The template shown in figure 4-6 should be used to assist in initially locating Vulcan squad positions. Place the template on a map of corresponding scale and move it about so that the maximum number of squads are in or near the VA. These positions then are individually moved toward or away from the center of the VA as dictated by the need for early engagement, weighting toward avenues of approach, and defense in depth. Due consideration is given to the expected threat, terrain, and nature of the VA.

b. M42 Initial Position Template.

(1) *Description.* The M42 initial position template (fig. 4-7) is constructed to the scale of the map to be used. Dots representing weapons are arranged in a column 1,100 meters apart with each column 900 meters apart. Every other column is offset toward the top of the template by 550 meters. This will result in a balanced pattern with each weapon being 1,100 meters or less from any adjacent weapon, thereby providing mutual support for each squad from at least two other squads.

(2) *Use of template.* The template shown in figure 4-7 should be used in the same manner as the Vulcan initial position template (*a*(2) above).

c. M55 Initial Position Template.

(1) *Description.* The M55 initial position template (fig. 4-8) is constructed to the scale of the map to be used (usually 1:50,000) by placing weapons in a column 480 meters apart with each column 420 meters apart. Every other column is offset toward the top of the template by 240 meters. This will result in a balanced pattern with each weapon being 480 meters or less from any adjacent weapon, thereby providing mutual support for each squad from at least two other squads.

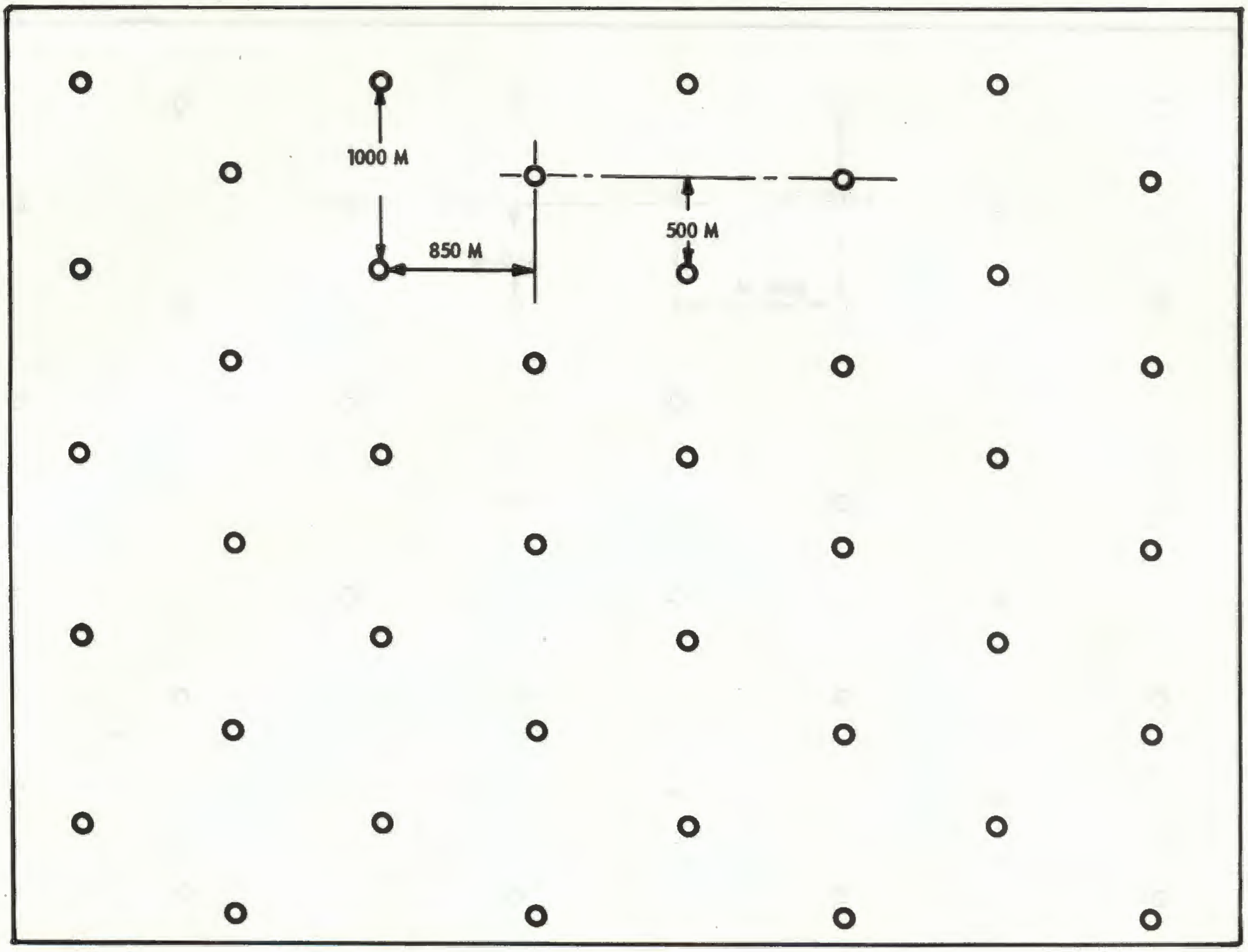


Figure 4-6. Vulcan initial position template.

(2) *Use of template.* The template shown in figure 4-8 should be used in the same manner as the Vulcan initial position template (*a*(2) above).

4-6. ARA AW Defense Design Procedure

a. General. The basic steps in designing fixed or semifixed VA defenses are—

(1) Obtain a suitable map. Generally, a scale of 1:50,000 is best.

(2) Draw the VA on the map and determine its perimeter.

(3) Determine the minimum desirable number of weapons required.

(4) Using the initial position template, locate initial weapon positions.

(5) Considering the principles and factors discussed in paragraphs 4-1 and 4-2, adjust individual positions to meet the situation.

(6) Analyze the disposition of weapons after actual occupation of positions and readjust if necessary.

b. Simple Defense. Figure 4-9 illustrates the design of a simple defense, using the Vulcan initial position template. The steps outlined in *a* above are followed. The same basic procedure is applicable to M42 and M55 defenses to include application to the special considerations noted in *c* through *f* below.

c. Vital Points Within a Vital Area. The first consideration arises when several vital points are within the VA. It is probable that within a fairly large VA there will be certain points of a higher priority than others (fig. 4-10). In such cases, adjust the template initially to favor the vital points. Any weapons that must be moved because of terrain difficulties, or for other reasons, should be moved toward the more important points.

d. Noncircular VA.

(1) The defense of a noncircular VA generally should conform to the shape of the VA. After defining the VA on a suitable map, determine the

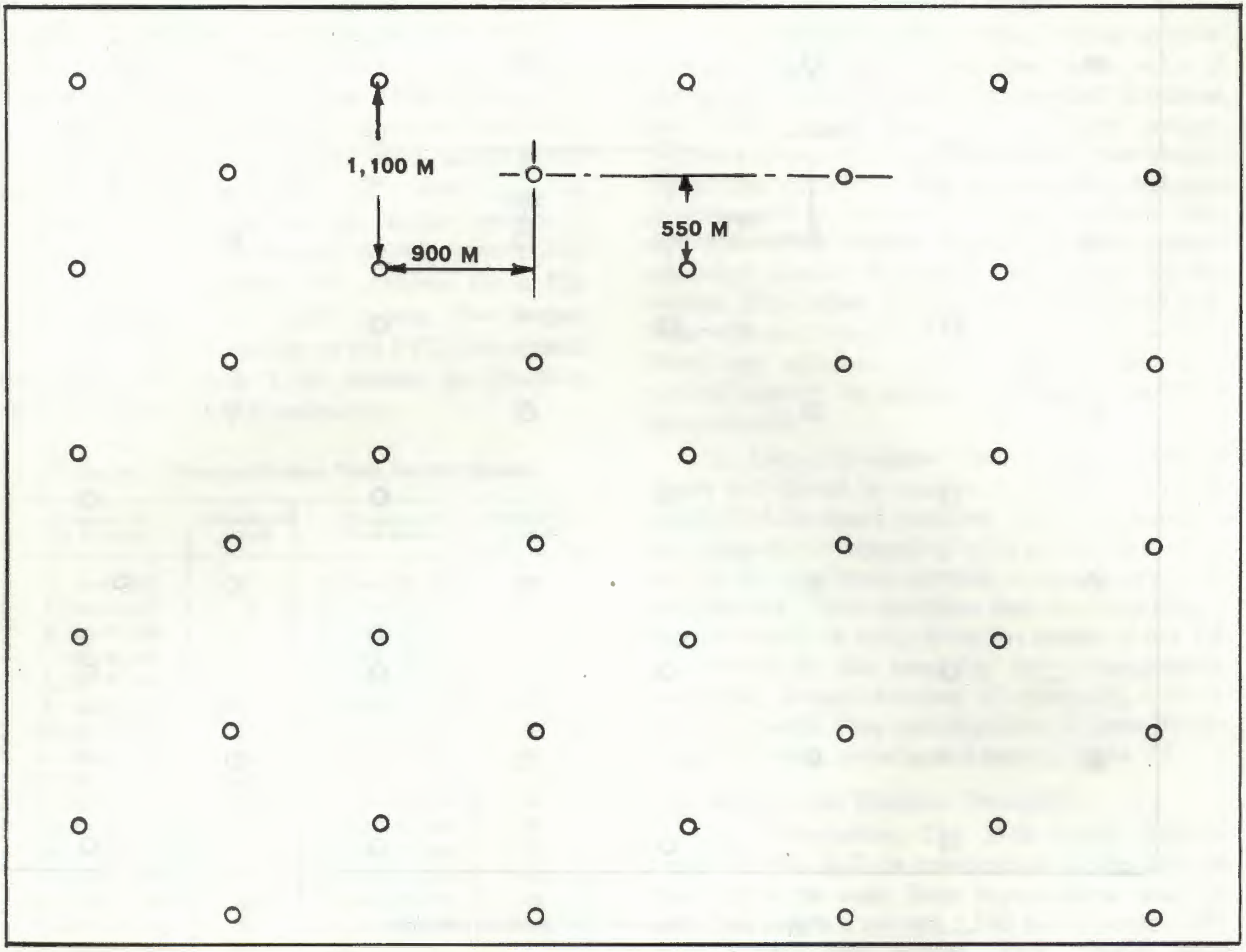


Figure 4-7. M42 initial position template.

perimeter of the VA. If the VA outline has an exaggerated indentation that gives a false picture of the total area to be defended, measure the perimeter, assuming that the indentation does not exist. Using the perimeter so obtained, determine the number of weapons required, using the PFT. Next, place the Vulcan template on the map and adjust the template to provide the best defense for the number of weapons being used as shown in figure 4-11. The same general procedure applies to M42 and M55 defenses.

(2) A long, narrow VA can be defended with fewer weapons that required by the PFT. As an example, consider a VA that is 1,500 meters long and 400 meters wide, with a perimeter of 3,800 meters (fig. 4-12 and 4-13). The PFT calls for six Vulcan weapons while the initial position template suggests that four weapons might be sufficient. (If mutual support and balance are available by placing the fire units around the elongated area, then it is not necessary to attempt to achieve the maximum number of fire units by placing some fire units inside the elongated area.) Thus, the area may be defended adequately by fewer weapons than indicated by the PFT. The same general procedure applies to M42 and M55 defenses.

e. Integrated Vulcan Defense. Vulcan defenses may be integrated when the near edges of separate VA's are within 1,000 meters of each other (fig. 4-14). If the near edges of the VA's meet this criteria, the defense is designed as a single defense by establishing a common perimeter for the VA's. The original VA's may be considered as vital points within the overall VA. The same general procedure applies to M42 and M55 defenses except that the distance between separate VA's

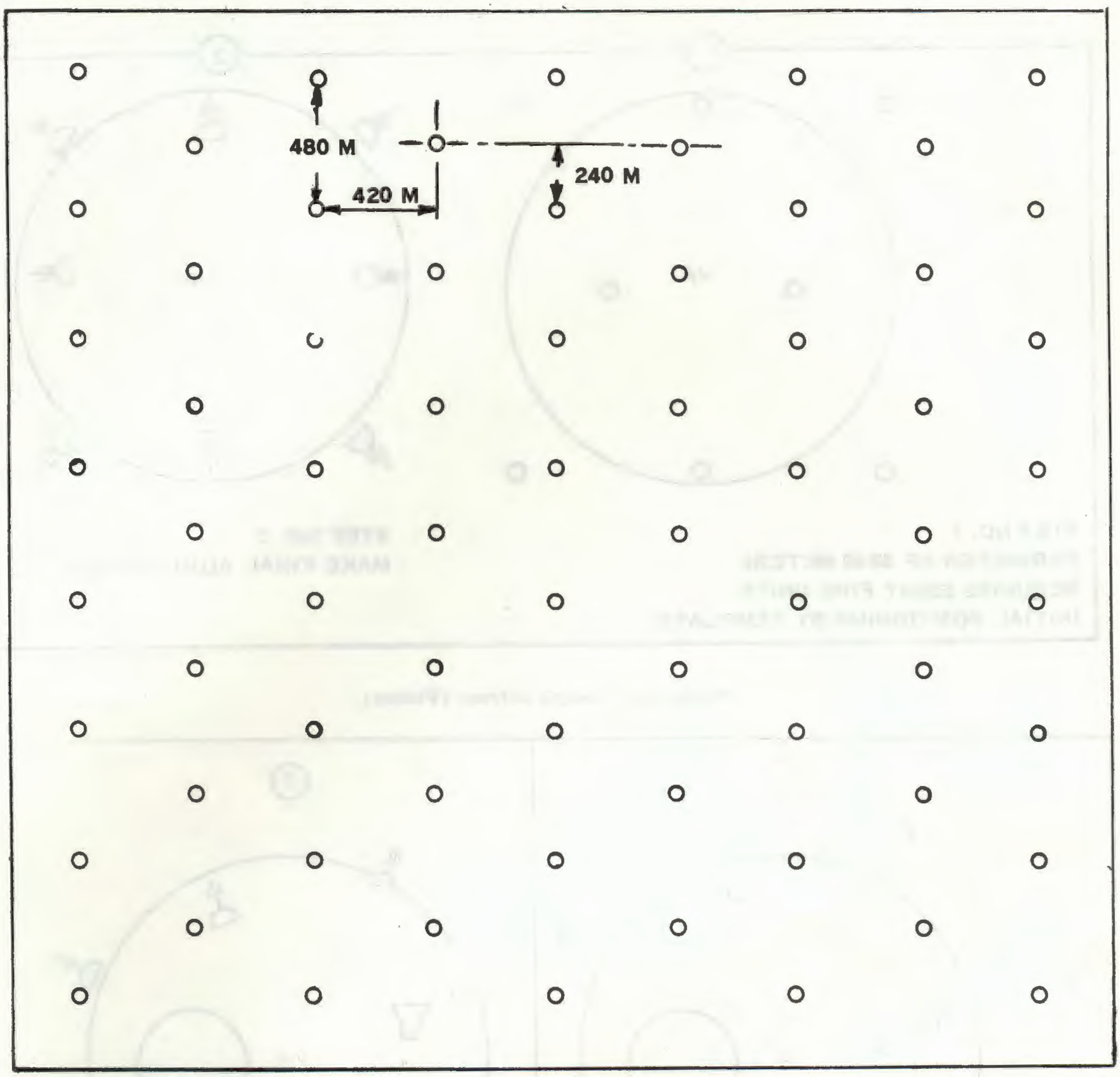


Figure 4-8. M55 initial position template.

must not exceed 1,100 meters and 480 meters, respectively.

f. Routes of Approach. Routes of approach fall into two general categories, probable and forced.

(1) A probable route of approach is one that the enemy is likely to use but is not restricted to use. The pilot of an aircraft traveling at 500 knots at 150 meters above the ground can see little detail on the ground. However, he can see large objects, such as highways, rivers, and mountain ranges, and he may use them to assist in navigation. If such landmarks lead to the VA, they may be considered as in or near the probable routes of approach. In designing the defense, the template should be used in the normal manner except that it should be turned to locate as many weapons as possible toward the probable route. If this process does not provide the desired degree of weighting, more weapons should be provided. Lacking additional weapons, some of the available weapons may be relocated toward the probable route at the expense of a balanced defense.

(2) A forced route of approach is one that the attacker is compelled to use. Balance is disregarded when designing the defense for a forced route of approach and the defense is tailored to fit the situation. Figure 4-5 illustrates a forced route of approach with a typical defense design.

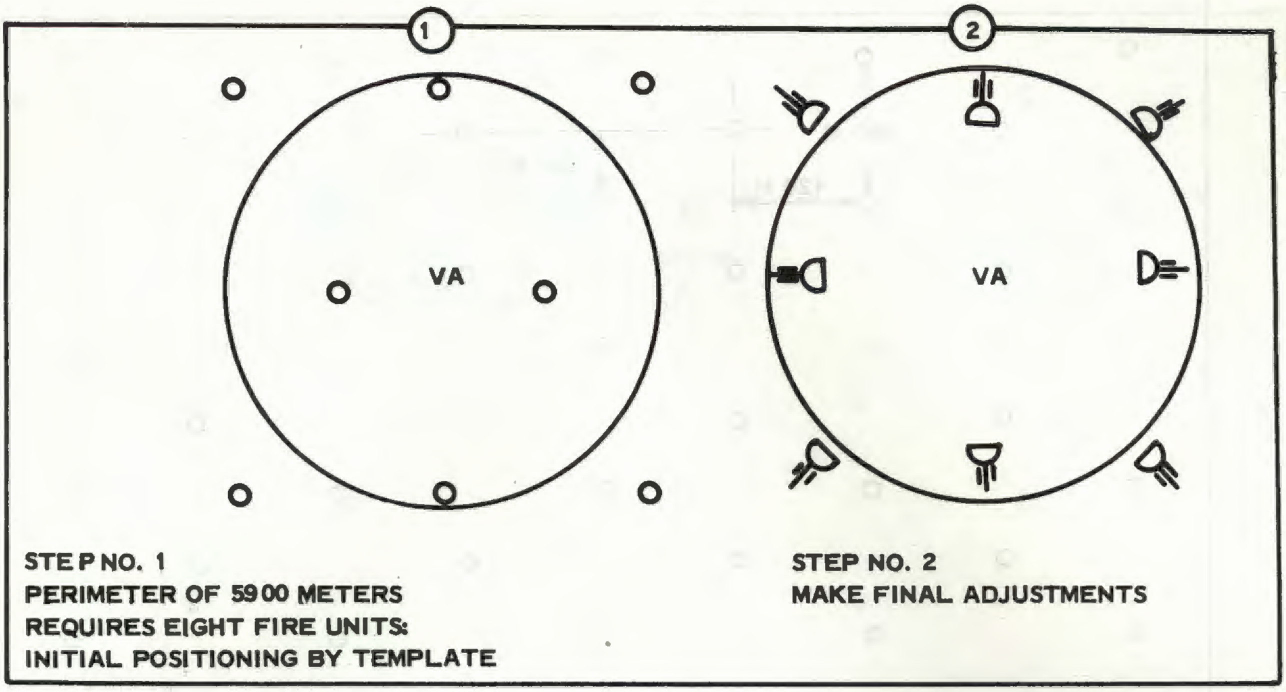


Figure 4–9. Simple defense (Vulcan).

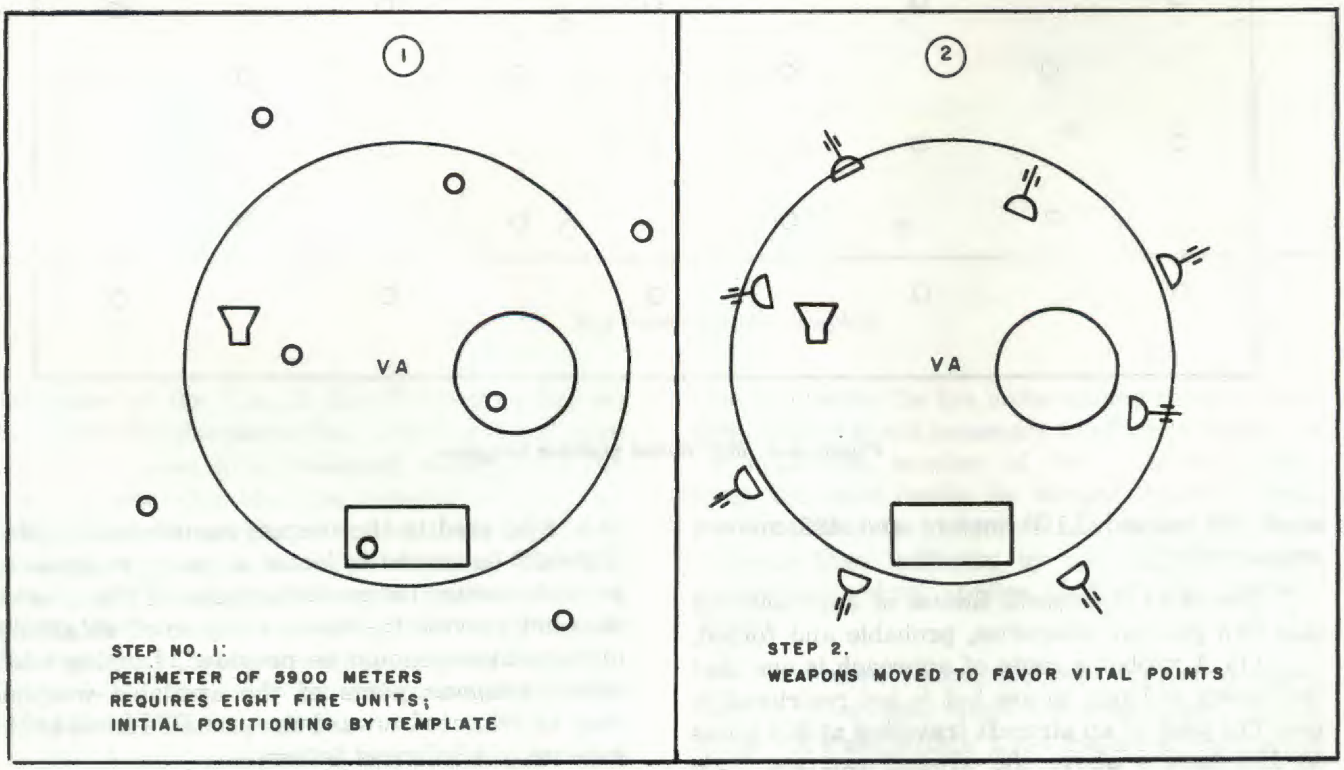


Figure 4–10. Vital area containing vital points.

4–7. Chaparral Coverage Template

To ascertain the number and position of Chaparral squads, a template with the correct coverage and missile characteristics must be constructed. The template coverage will vary with the target speed. Figure 4–16 is a type template and is used for illustrative purposes because of the security classification of specific Chaparral missile

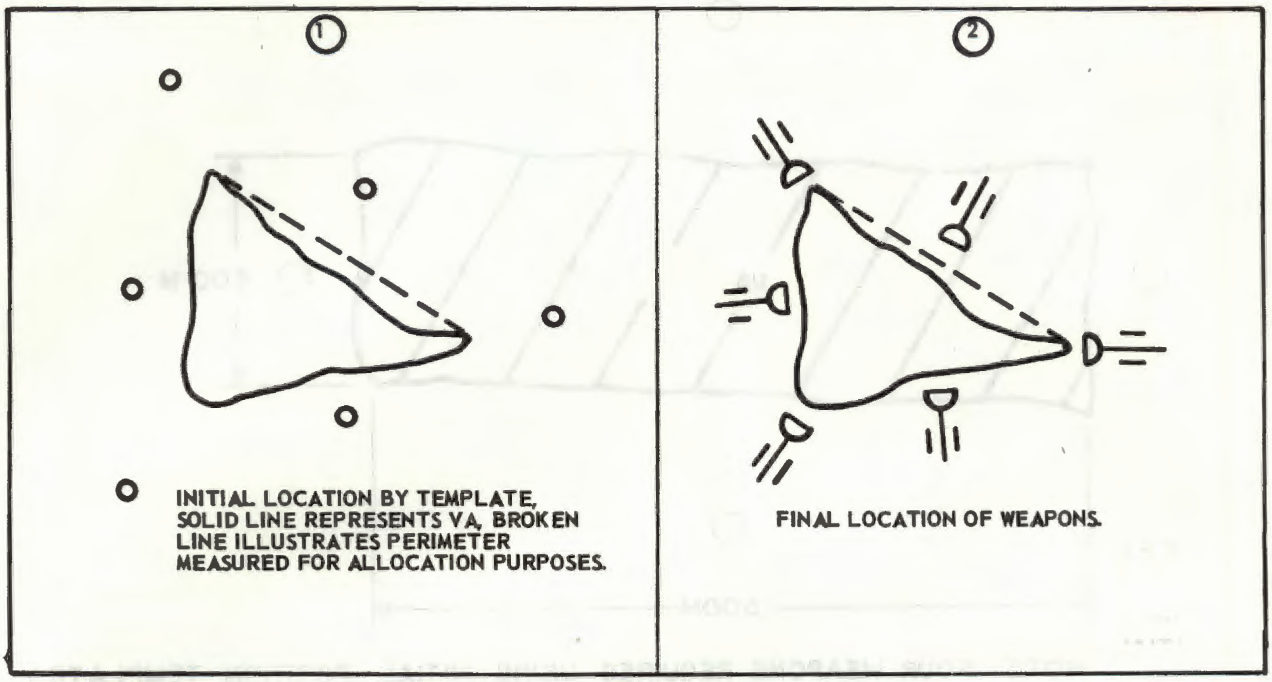
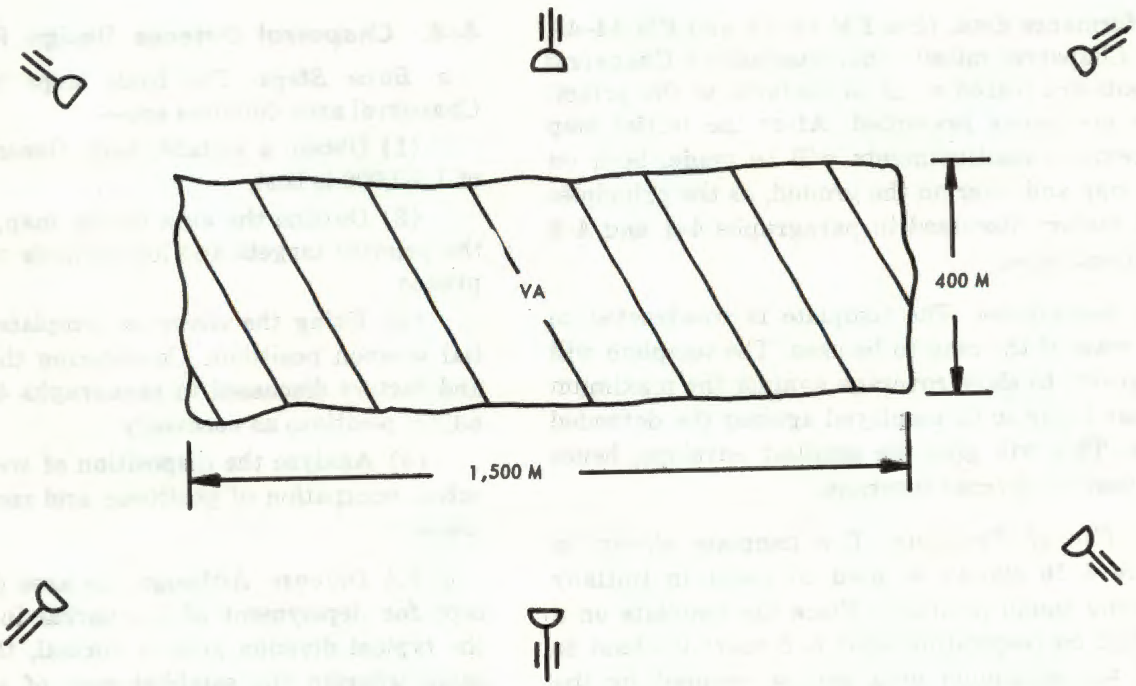
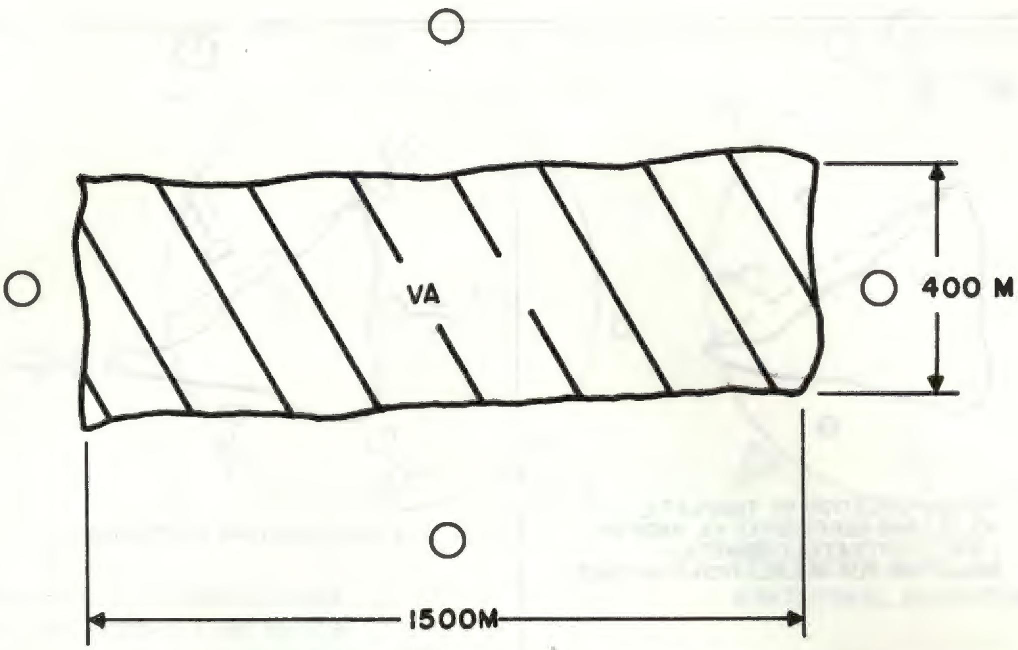


Figure 4-11. Design of defense for noncircular vital area.



NOTE: SIX WEAPONS REQUIRED USING VULCAN PFT.

Figure 4-12. Defense design of an elongated vital area (PFT solution).



NOTE: FOUR WEAPONS REQUIRED USING INITIAL POSITION TEMPLATE

Figure 4-13. Defense design of an elongated vital area (template solution).

performance data. (See FM 44-1A and FM 44-4A for Chaparral missile characteristics.) Chaparral squads are placed so as to conform to the principles previously presented. After the initial map placement, readjustments will be made, both on the map and later on the ground, as the principles and factors discussed in paragraphs 4-1 and 4-2 are considered.

a. Description. The template is constructed to the scale of the map to be used. The template will be drawn to show coverage against the maximum threat likely to be employed against the defended area. This will give the smallest envelope, hence the best air defense coverage.

b. Use of Template. The template shown in figure 4-16 should be used to assist in initially locating squad positions. Place the template on a map of corresponding scale and move it about so that the maximum area can be covered by the number of weapon squads available. Next move the position of the weapon squads as dictated by the need for early engagement, weighting toward avenues of approach and defense in depth. Due consideration must be given to the expected threat, terrain, and commander's guidance.

4-8. Chaparral Defense Design Procedure

a. Basic Steps. The basic steps in designing Chaparral area defenses are—

(1) Obtain a suitable map. Generally, a scale of 1:50,000 is best.

(2) Outline the area on the map, identifying the priority targets and low-altitude routes of approach.

(3) Using the coverage template, locate initial weapon positions. Considering the principles and factors discussed in paragraphs 4-1 and 4-2, adjust positions as necessary.

(4) Analyze the disposition of weapons after actual occupation of positions, and readjust if necessary.

b. VA Defense. Although the area defense concept for deployment of Chaparral in defense of the typical division area is normal, there will be cases wherein the establishment of a Chaparral VA defense is appropriate. For example, Chaparral defends an isolated airhead as if it were a VA. In that case, use of the area defense concept would be impractical.

(1) *Balance.* The principal guideline for deployment of Chaparral units in a VA de-

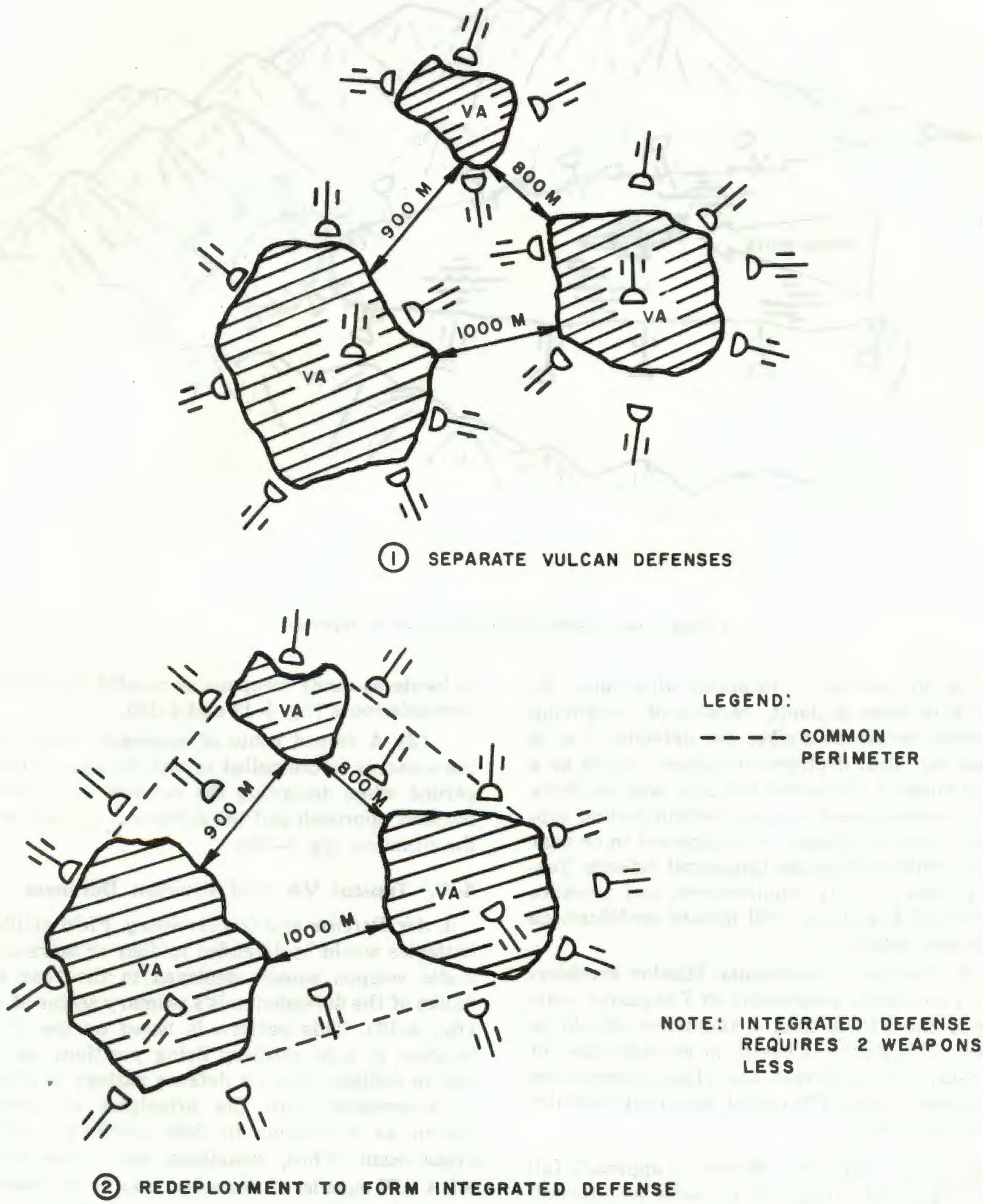


Figure 4–14. Integrated ADA Vulcan defense.

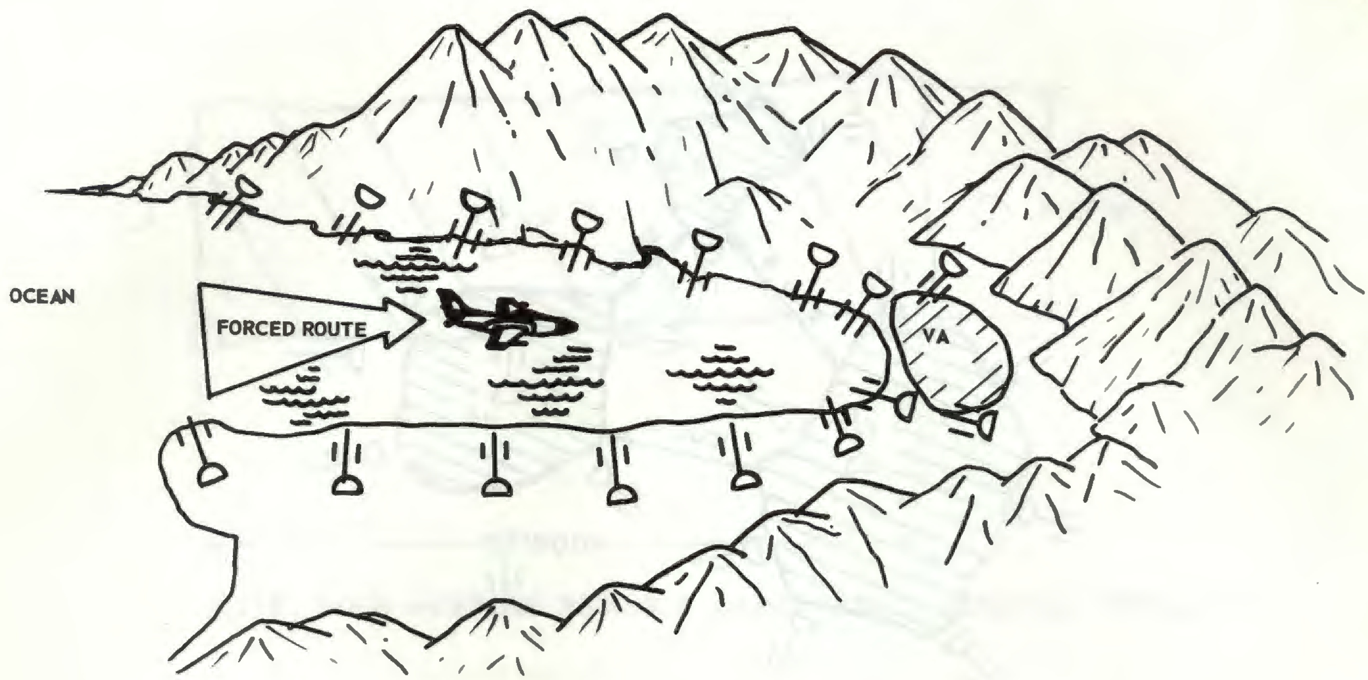


Figure 4-15. Forced low-altitude route of approach.

fense is to provide a balanced all-around defense. A defense in depth, capable of destroying the enemy before he strikes the defended VA, is desired. An ideal deployment pattern would be a ring or rings of Chaparral weapons well out from the VA with adjacent weapons within mutual supporting distance. Vulcan units deployed in or near the VA would back up the Chaparral defense. Terrain, ground security requirements, and presence of other ADA weapons will dictate modifications of the basic pattern.

(2) *Position requirements.* Mission considerations permitting, positioning of Chaparral units closer to the FEBA than 4 kilometers should be avoided. This figure is based on consideration of the enemy ground threat and visual observation capabilities versus Chaparral fire unit mobility and vulnerability.

c. Routes of Approach. Routes of approach fall into two general categories, probable and forced.

(1) A probable route of approach is one that the enemy is likely to use but is not restricted to use. In designing the defense, the Chaparral template should be used in the normal manner, except that the fire units should be shifted slightly so as to locate as many weapons as possible toward the probable route (fig. 4-17 and 4-18).

(2) A forced route of approach is one that the attacker is compelled to use. Balance is disregarded when designing the defense for a forced route of approach and the defense is tailored to fit the situation (fig. 4-15).

4-9. Typical VA and Division Defenses

a. Air Defense of Field Artillery. Field artillery batteries would be defended by four or more automatic weapon squads deployed to the rear and flanks of the defended unit's primary sector of fire (fig. 4-19). This pattern is based on the visual location of field artillery firing positions on line and in defilade. The air defense pattern is altered in accordance with the principles of defense design as variations in field artillery position areas occur. Thus, situations may occur where ADA AW squads, of necessity, may be forward of the field artillery weapon positions. When ADA AW squads are required to emplace forward of the field artillery weapon positions this fact must be made known to the field artillery executive officer or the fire direction officer for his use in com-

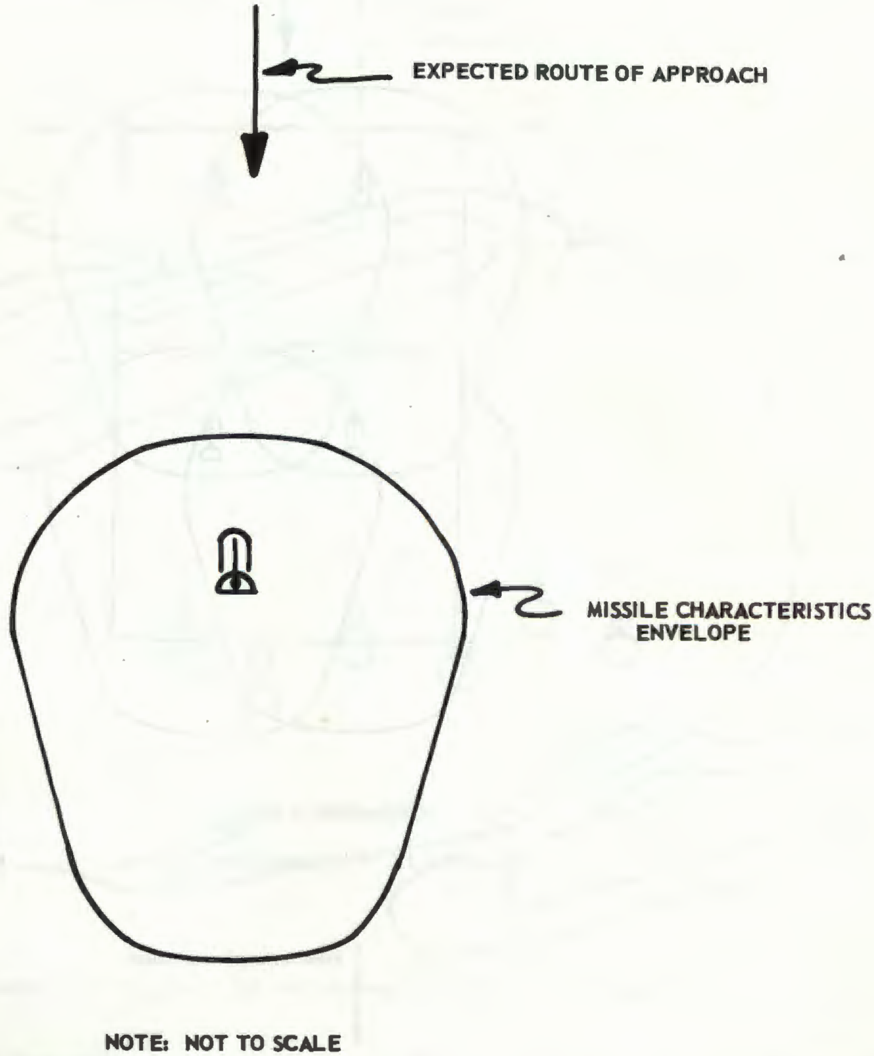
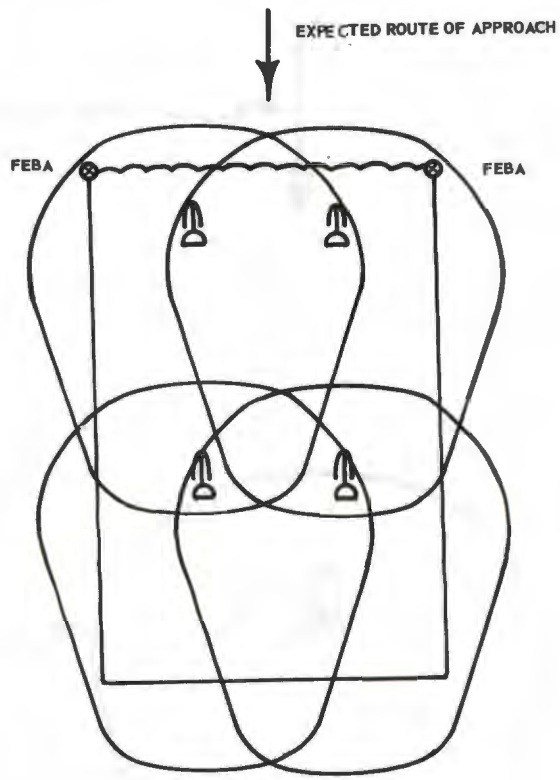


Figure 4-16. Chaparral coverage template.

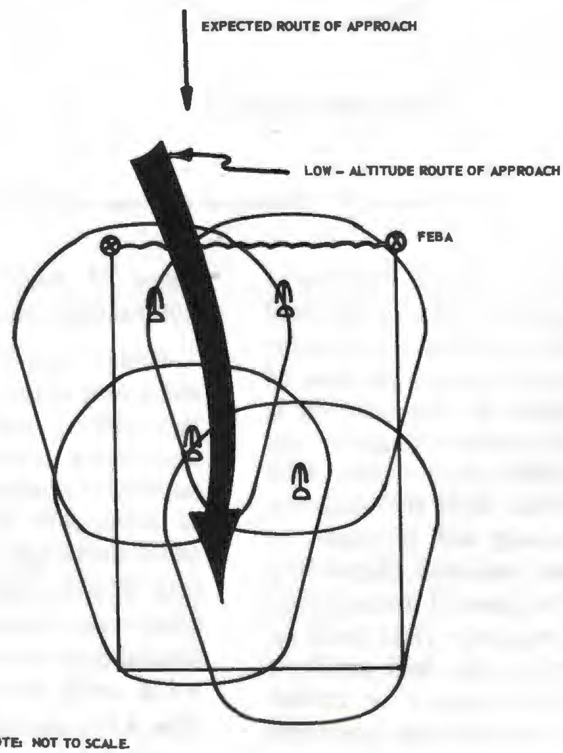
puting safety requirements. The exact location of each ADA AW squad must be known to the field artillery executive officer to coordinate perimeter defensive fires of the cannon weapons in case of ground attack. A type defense of field artillery is illustrated in figure 4-19. If nuclear weapons are involved, the unit commander may desire that both the nuclear ammunition and the delivery means be defended. This usually will increase the number of ADA AW squads required, depending largely on whether or not the special ammunition point must be treated as a separate vital point or can be defended as a part of the field artillery position area. Field artillery missile or rocket launchers may be deployed from hidden positions to firing positions which are vacated after the mission is fired. Plans should be made for the defense of such launchers in each position and during movements between positions.

b. Air Defense of SAM Units (Nike Hercules and Hawk). The combination of enemy tactics, terrain, and the high value of Nike Hercules and Hawk surface-to-air (SAM) units in the air superiority battle may often require employment of ADA AW and Chaparral elements to defend these units against low-level attack. Primary factors determining the number of ADA AW and Chaparral elements assigned this mission are availability of weapons, low-altitude air threat to SAM units, level of defense desired, and terrain. The ADA squads may be deployed to form a balanced defense with the SAM unit being the VA; however, a defense weighted toward probable or



NOTE: NOT TO SCALE

Figure 4-17. Chaparral area defense.



NOTE: NOT TO SCALE

Figure 4-18. Chaparral defense weighted toward low-altitude route of approach.

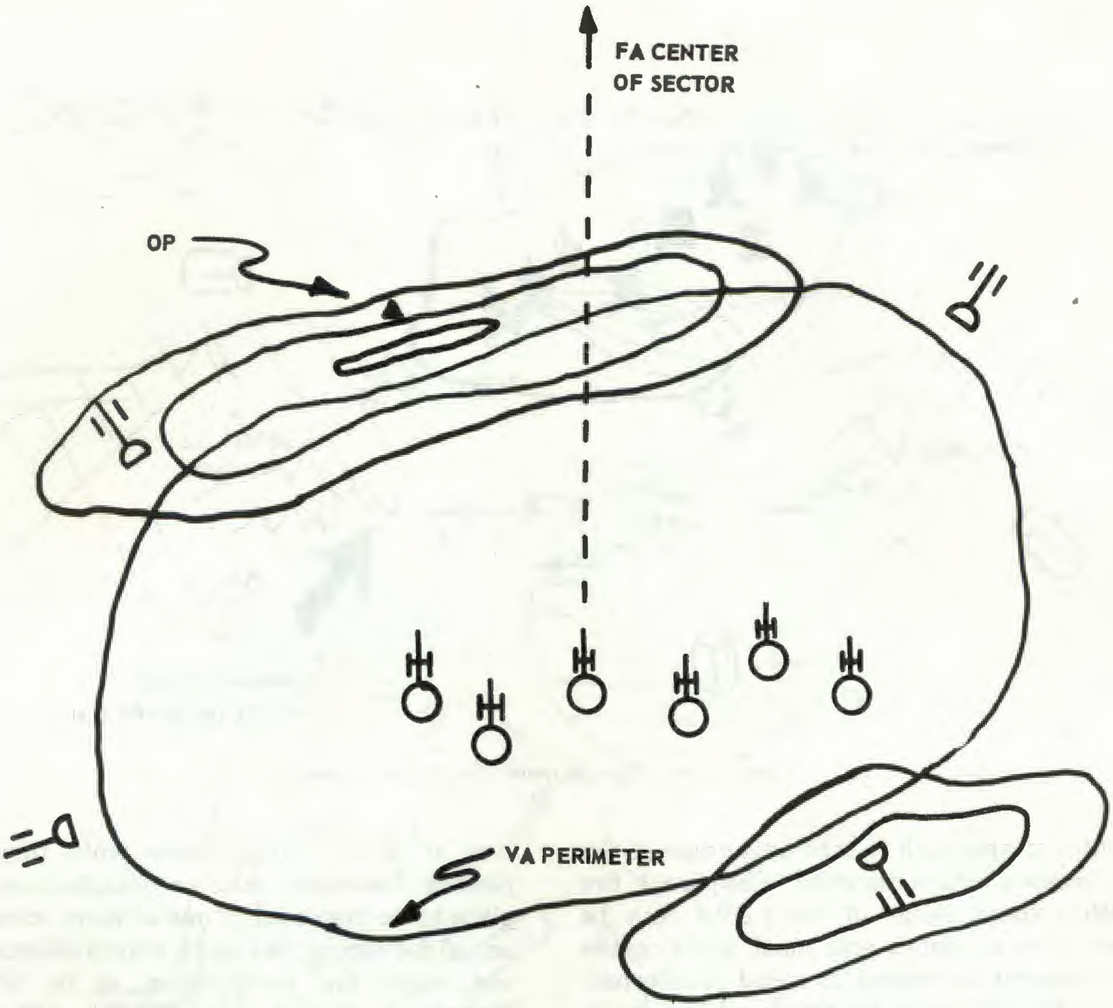


Figure 4-19. Typical ADA AW defense of field artillery position.

forced avenues of approach through areas masked from SAM unit radars may be more appropriate. Care must be exercised not to position ADA AW and Chaparral fire units in or near the booster disposal area of the Nike Hercules units. Figure 4-20 illustrates the latter type deployment, where a Vulcan platoon and a Chaparral platoon are positioned to provide low-altitude defense and to enhance ground security. Exchange of early warning and close coordination between the SAM unit and the ADA AW and Chaparral elements must be maintained.

c. Defense of Airfield. Figure 4-21 depicts an example wherein two Vulcan platoons (eight squads), one Chaparral platoon (four squads), and a Hawk battery are deployed to defend an airfield. A balanced VA defense may be used in this situation; however, this example illustrates utilization of Chaparral squads to cover radar mask areas.

d. Typical Division Defense. Automatic weapon and Chaparral units are preferably deployed in depth throughout the combat zone in accordance with the division operation order. These units are deployed in their respective division sectors, with greatest weapon density in forward areas (fig. 4-22). The corps rear defenses might also be complemented by these types of units. Weighting of the ADA AW and Chaparral defense toward the front serves two purposes—it destroys many attackers before they can reach their intended targets, and it concentrates air defense protection in the region of most concentration of combat power. However, the defense is continuous in depth to insure that an attacker does not enjoy a "free ride" if he breaches the forward zone. Chaparral units usually are deployed in an area defense. The area defense is weighted toward the front along likely low-altitude routes of approach and toward high-value division targets. Chaparral squads should be positioned along the flanks of the low-al-

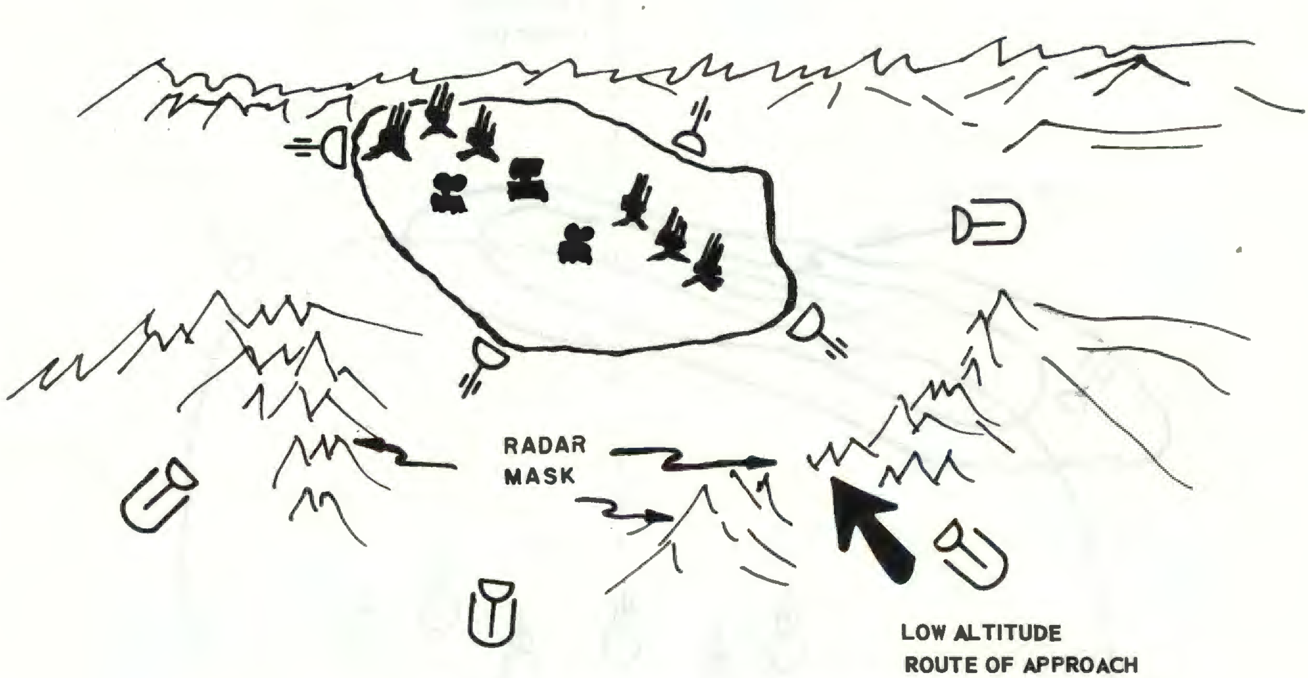


Figure 4-20. Type defense of a Hawk battery.

titude routes of approach to take advantage of the inherent weapon characteristics. Chaparral fire units within visual range of the FEBA may be located on reverse slopes and must practice the tactic of frequent movement to avoid counterbattery fires. ADA AW units are employed in close-in defense of small, high-value targets, such as command posts, signal installations, nuclear delivery artillery batteries, and key bridges. These units realize their highest capability against low-speed, incoming aircraft. They serve to deter an attacker from use of low-speed, multiple-pass, deliberate attack tactics, and encourage aircraft to take evasive maneuvers which detract from their delivery accuracy. Forward area alerting radars (FAAR) are employed primarily to provide alerting information, general target location, and tentative identification information to the visually-directed ADA systems and Redeye. If available in sufficient numbers, they may be employed for complete coverage of the area occupied by the supported ADA systems, provided the primary mission still can be accomplished. They should be deployed as close to the FEBA as the mission and survivability considerations permit.

4-10. Typical Defenses of Moving Units

a. General. Automatic weapon and Chaparral units are capable of providing air defense protection to units or installations while they are displacing. Defended units or installations may displace or be displaced in one or more echelons. The actual movement may be by march column of varying length and composition, or by infiltration. Planning and deploying of ADA AW and Chaparral elements must provide for continuous air defense coverage throughout the displacement.

b. Defense of March Columns.

(1) *Vulcan and M42 planning.* The front and rear of a column is weighted with Vulcan or M42 squads to maximize the principles of early engagement and defense in depth along the most likely and advantageous attack avenues for hostile aircraft; i.e., along the long axis or slightly diagonal thereto. The number of Vulcan or M42 squads required for march column defense is based on the length of the march column.

(*a*) To insure that aircraft approaching the head or rear of the column are engaged as soon as possible with a maximum of firepower, the AD planner should employ three Vulcan squads in the first 1,100 meters of the column or three M42 squads in the first 1,200 meters. One squad is placed about 100 meters behind the lead vehicle. The next Vulcan squad is placed about 500 meters (550 meters for M42 squads) behind the first squad and the third squad is placed 500 meters

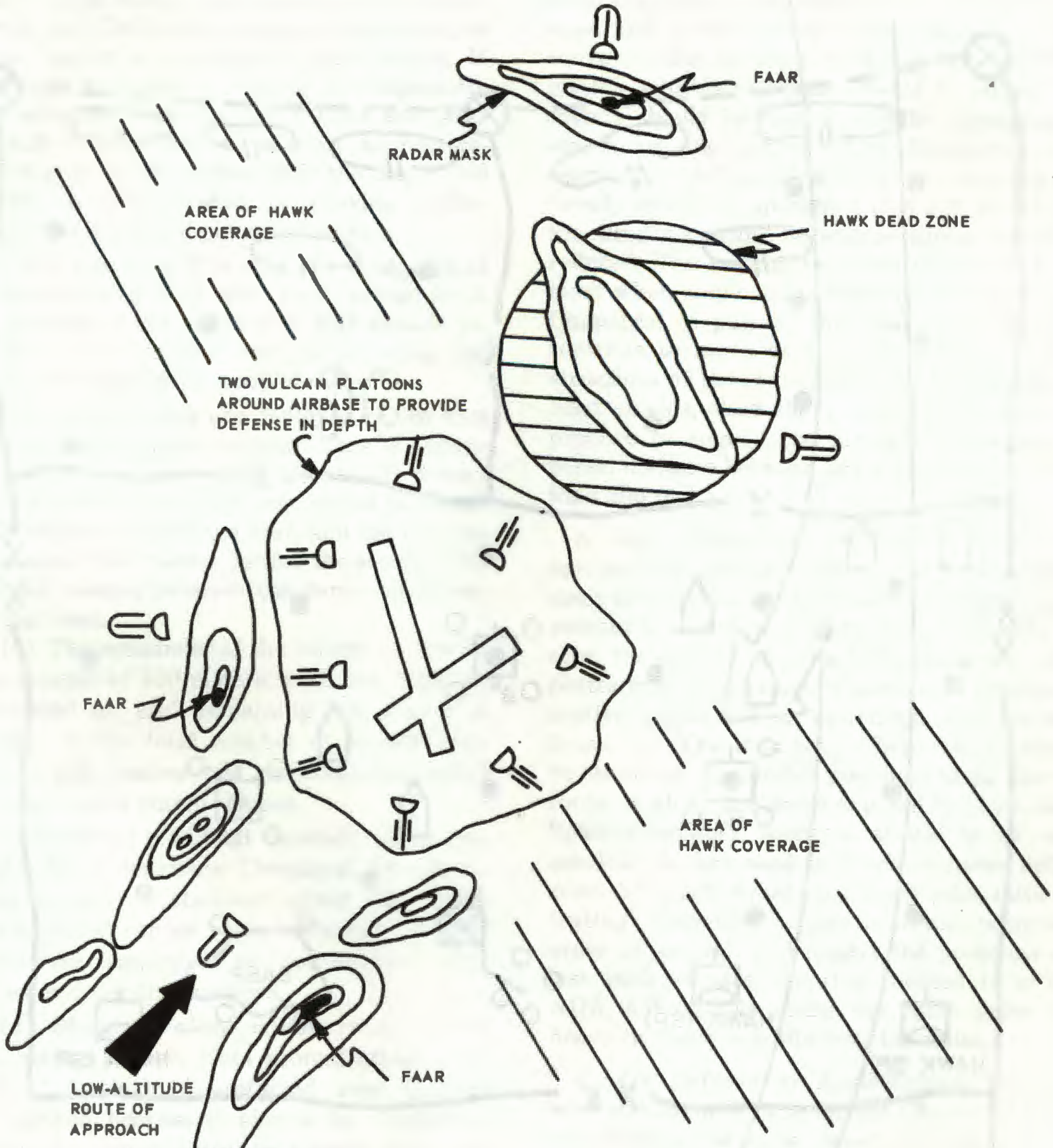


Figure 4-21. Type defense of an airfield.

(550 meters for M42 squads) behind the second squad. The rear of the column receives the same consideration as the front.

(*b*) The remainder of the column is divided into 1,000-meter (1,100 meters for M42) increments with one Vulcan squad allocated for each remaining 1,000 meters (1,100 meters for M42 squads) of road space. If the total number of squads computed is an odd number, add one squad to the center portion of the march column.

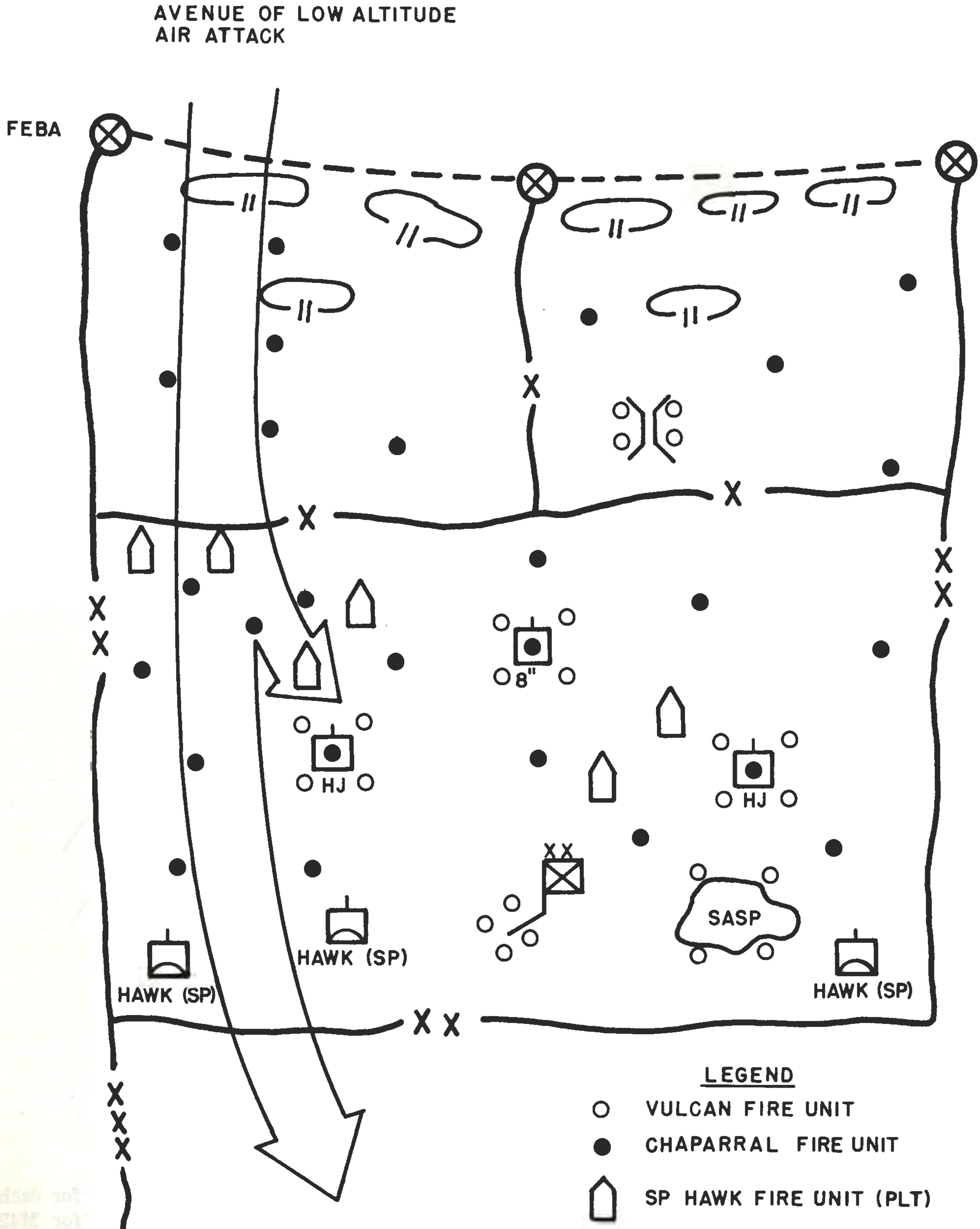


Figure 4-22. Type forward area ADA deployment in area defense.

(*c*) When the column comes under air attack, the column commander may elect to continue movement on the road, or disperse the column on either side of the road. Although the Vulcan and M42 squads are capable of firing while moving, their effectiveness is somewhat decreased. ADA AW units should inform the convoy commander of this limitation in order to determine the proper action to be taken by these squads. If the convoy is to continue moving, a compromise may be arranged whereby the Vulcan and M42 squads halt long enough to conduct an engagement. Complete coordination with the supported unit must be accomplished to provide understanding of prearranged plans and signals.

(2) *M55 planning*. The M55 also is capable of firing while moving. The same basic procedure is used to determine the number of M55 squads required for march column defense, allowing for variation due to the lesser weapon range.

(*a*) Three squads are deployed in the first 600 meters of the march column. This is accomplished by placing one squad about 100 meters behind the lead vehicle, the next squad is placed about 250 meters behind the first, and the last one is placed about 250 meters behind the second. The rear of the column receives the same consideration as the front.

(*b*) The remainder of the column is divided into increments of 500 meters, with one M55 fire unit allocated for each remaining 500 meters of road space. If the total number of squads computed is an odd number, add one additional squad to the center of the march column.

(3) *Chaparral planning*. Basically, there are two methods of deploying Chaparral, in column with the convoy or stationed along the march route. Chaparral cannot replace Vulcan but may be effectively employed in conjunction with Vulcan when defending convoys.

(*a*) *Stationed along march route*. If the route is secure enough from ground attack, this deployment method is preferred over the in-convoy method because it allows the Chaparral fire units the opportunity to situate their observers properly. When utilized in this manner, the fire units should be sited along the march route so that they will have overlapping fires and can provide continuous coverage to the convoy. The Chaparral fire units may be driven or the launching station XM54 may be helicopter-lifted to preselected sites. Figure 4–23 shows a typical Chaparral deployment scheme.

(*b*) *In convoy*. When the Chaparral units cannot be stationed along the march route, they may move within the convoy. When moving within the convoy, Chaparral squads should be spaced evenly throughout the convoy. One squad should be placed about one-third of the distance from the front of the convoy and one squad about one-third of the distance from the rear of the convoy. If the convoy length is greater than 3,000 meters, additional squads should be added. These squads should be spaced equally throughout the length of the convoy. The Chaparral squads cannot fire while moving but they can travel in the "ready mode" of operation (see FM 44–4). Thus, the time necessary to engage aircraft would be reduced. The normal sequence for aerial engagement when employed in this manner would be for Chaparral to pull off the road (the convoy may continue to move or stop, depending on the instructions of the convoy commander), emplace the blast shields, clear the vicinity of personnel, and prepare to engage the aircraft. (Minimum dispersal distance between fire units should be no less than 200 feet.)

c. Air Defense of Infiltrating Units. Units moving by infiltration may not require air defense since this method of displacement usually does not present lucrative targets to enemy aircraft. However, the volume of units infiltrating over certain routes may become heavy enough to produce a lucrative target and an attendant need for air defense. In these instances, Chaparral squads may be stationed in suitable positions along the entire route or along the more exposed sections thereof. Spacing between positions should be as near as possible to that used in march column defenses. Also, ADA AW squads can move with initial infiltrating elements, occupy selected positions in order of arrival, and depart the positions as the last vehicles pass. Another method is to deploy ADA AW squads along the route prior to the heavy increase in traffic over the route.

d. Air Defense of Maneuvering Armor Elements. Automatic weapon and Chaparral elements may be attached to, or placed in support of, armor units to provide air defense. Armor operations are characterized by fire and maneuver. They advance as rapidly as possible, in mass, and by continuous or echelon moves. ADA AW and Chaparral squads may be required to provide air defense for elements serving as the base of fire and for maneuver elements during their advances and consolidation of the objective, or both. Air defense for the base of fire elements is essentially the same as

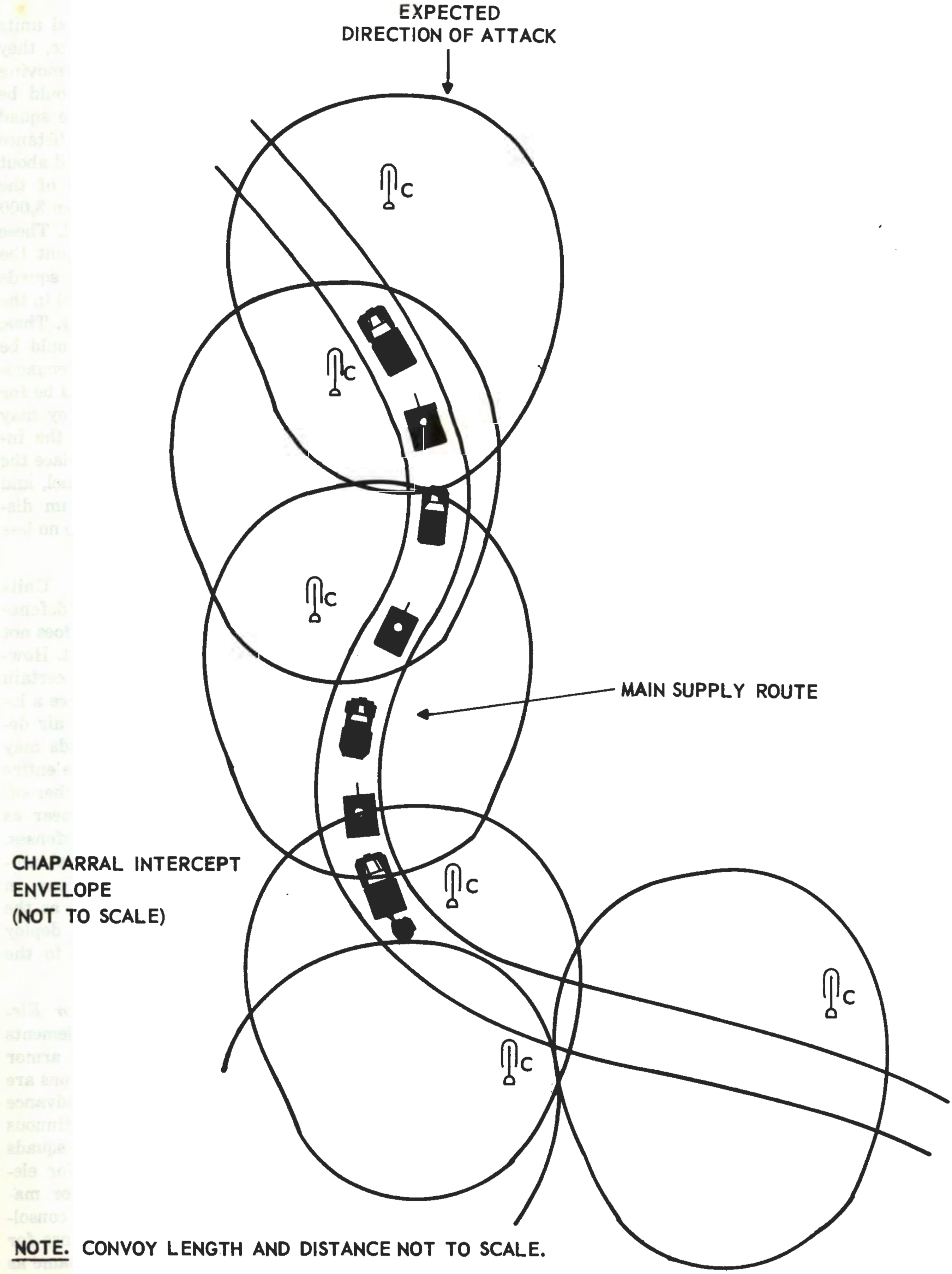


Figure 4-23. Chaparral/Vulcan defense of march column.

the defense of field artillery battery position. Air defense for maneuvering elements is provided as long as possible from positions along the line of departure (LD). The positions permit engagement of aircraft attacking the maneuver elements during the advance to, assault on, and occupation of the main objective. Selected positions beyond the LD should be occupied as soon as possible to maintain and improve coverage. Deployment beyond the LD may incaease the exposure of the ADA units, which are much more vulnerable than tanks to all types of enemy ordnance, especially when in suitable air defense positions. Consequently, the displacement of ADA squads forward to provide air defense for maneuvering elements should be accomplished by echelon a short distance behind the advance. ADA squads may locate in defilade a few meters from good air defense positions to reduce vulnerability to enemy fire. These defense positions are occupied at the first indication of possible air attack. Defilade positions degrade but seldom preclude engagement of aircraft.

4-11. Special Deployment

a. Decoy and dummy positions are designed to lure hostile aircraft into "kill zones" or "flak traps" (fig. 4-24). Dummy positions are "passive." Decoy positions are more elaborate and include "active" devices to fully simulate an ADA position; e.g., a decoy Hawk site would include an electromagnetic energy transmitter operating at Hawk acquisition radar frequency, power, and pulse repetition rate. The decoy site should be located so that attacking aircraft will be canalized into avenues of approach.

b. Decoy and dummy position construction material is obtained from theater resources and is emplaced by engineer and ADA unit labor.

c. Chaparral squads should be positioned a minimum of 4 kilometers from the decoy site and along the low-level routes of approach. By siting the Chaparral 4 kilometers from the decoy site, the Chaparral will have the opportunity to engage aircraft in the "tail-chase" mode before the aircraft reaches the decoy site.

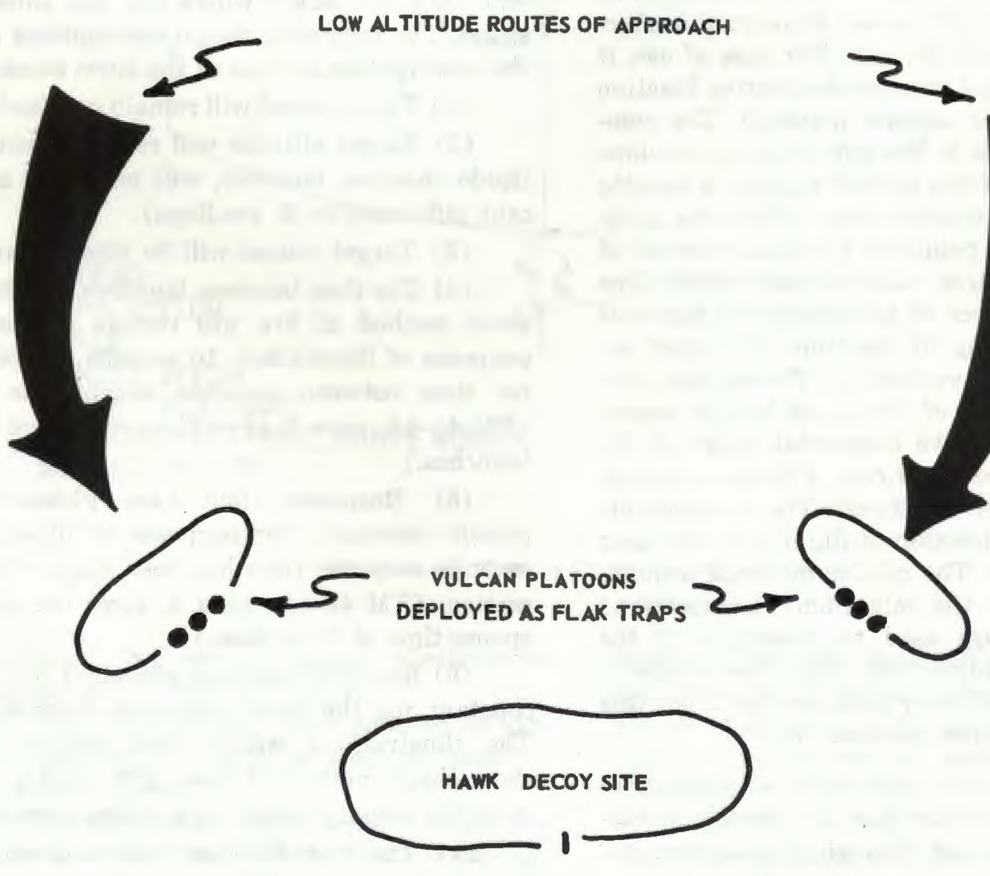


Figure 4-24. Decoy Hawk and Vulcan "flak trap" positions.

d. ADA AW squads should be positioned in a normal vital area defense around the decoy site or dummy position. This will further deceive the enemy into assuming these are actual positions.

Section III. EVALUATION OF CHAPARRAL DEFENSES

4-12. General

This section presents the construction and use of analyzing devices to measure the missile burst capabilities (M_t) of Chaparral fire units in all types of defenses. The procedures parallel those used to evaluate Hawk defenses (para 3-20). Once N_t, the total number of missiles the defense can deliver against the threat prior to the threat reaching the point of defense evaluation, has been measured with an analyzing device, this measured quantity is then used in the defense effectiveness formula to determine the number of aircraft the defense can destroy with a specified engagement effectiveness. System effectiveness (SE) and engagement effectiveness (EE) are used in the same manner as in paragraph 3-9*c*. (Guidance on Chaparral SE is contained in para 8, FM 44-1A.)

4-13. Burst Locator

a. General. The Chaparral burst locator (fig. 4-25) is a graphic portrayal of the summation of burst (M_t) as a target passes through the effectiveness envelope of a fire unit. For ease of use, it should be constructed to a representative fraction of 1:50,000 on clear acetate material. The completely inclosed area is the effectiveness envelope (burst envelope) of the system against a specific threat. The curved contour lines within the envelope connect initial points of an equal number of missiles. The numbered value of each contour line represents the number of missiles that a fire unit is capable of bursting by the time the target arrives at the point of evaluation. The smooth contour line at the rear of the burst locator represents maximum effective horizontal range of the missile against a specific threat. The center represents the location of the threat. The direction-of-flight arrow and direction-of-flight line are used to orient the device. The minimum visual acquisition boundary and the minimum identification/launch boundary are used to determine if the burst locator is valid for use. The actual shape of the burst locator will vary considerably from this example based on threat parameters.

b. Burst Locator Construction. It is necessary to construct a burst locator for the specific conditions to be encountered. Knowing these parameters, a target flight scale and missile trajectory scale are first constructed. It is then necessary to use these scales in conjunction with a Chaparral performance boundary to construct a burst locator. The scales and boundaries used within this manual are academic only, and in no way reflect the true capabilities of the Chaparral system. Several performance boundaries are contained in FM 44-1A. To construct a target flight scale, use the procedures shown in paragraph 3-15, with one exception: use 1-second time-of-flight increments rather than 5 or 10 seconds. Target flight time must be extended to the maximum time of flight of the missile. To construct a missile trajectory scale, use the same general procedures as outlined in paragraph 3-16, except use 1-second missile time-of-flight increments to the maximum missile time of flight. Use the Chaparral time-along-trajectory graph (fig. 17, FM 44-1A) to construct the scale. The use of the scales is to match the time of flight of the target with a corresponding time of flight of the missile. The missile will meet the target where the two times correspond. The following design assumptions apply in the construction and use of the burst locator:

(1) Target speed will remain constant.

(2) Target altitude will remain constant (altitude changes, however, will not make a significant difference in M_t readings).

(3) Target course will be straight and level.

(4) The time between launches for the shoot-shoot method of fire will remain constant. For purposes of illustration, 10 seconds has been used for time between launches within this section. (FM 44-1A, para 8, gives the actual time between launches.)

(5) Response time (see glossary), will remain constant. For purposes of illustration, 5 seconds response time has been used within this section. (FM 44-1A, para 8, gives the actual response time of the system.)

(6) Reaction time (see glossary), will remain constant for the shoot-look-shoot method of fire. The illustrations within this section use the shoot-shoot method of fire. (FM 44-1A, para 8, gives the actual reaction time of the system.)

(7) The missile burst values given by the burst locator are reliable for use in the effective-

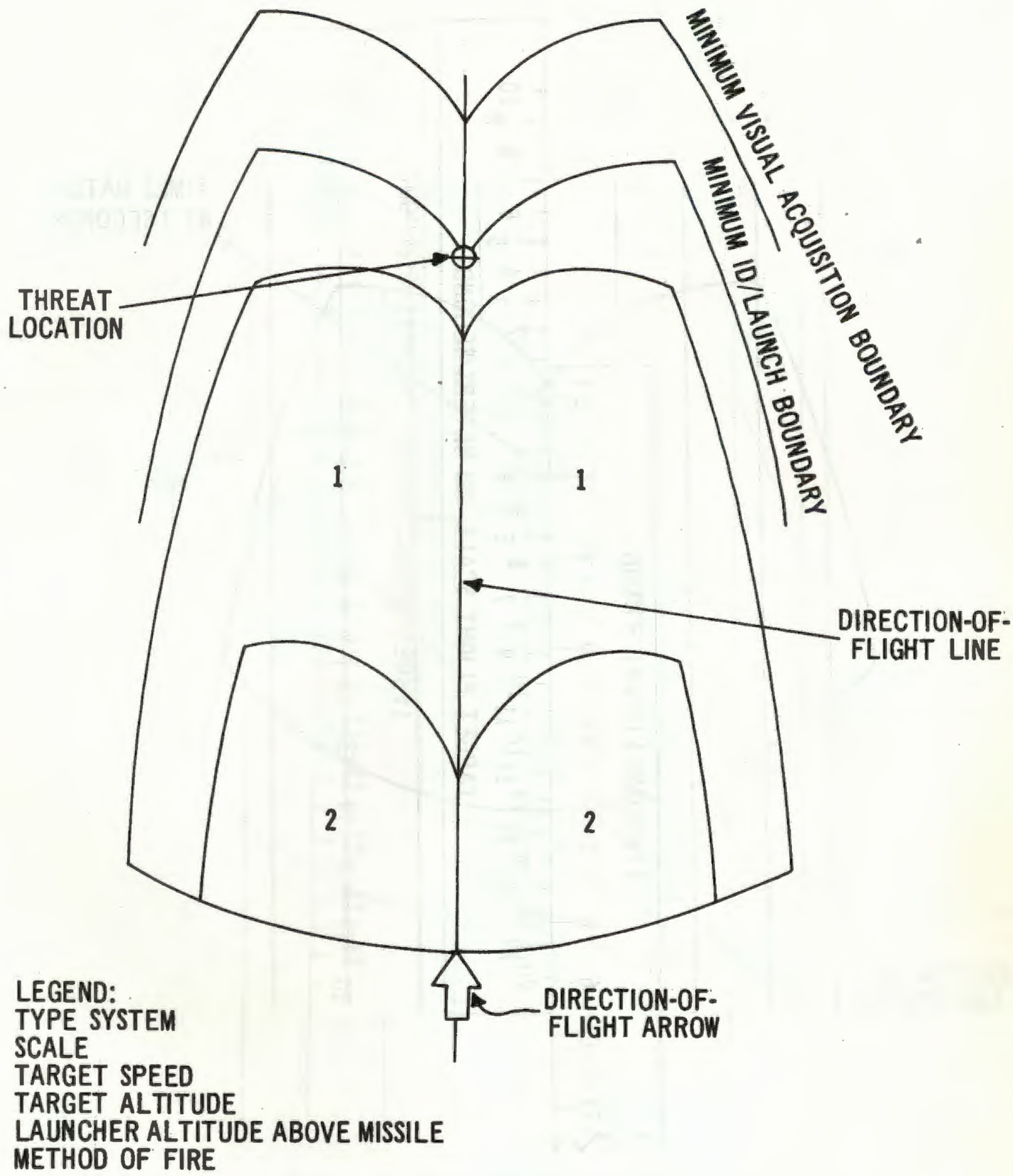


Figure 4-25. Type of Chaparral burst locator.

ness formula; the use of system effectiveness (SE) compensates for system error.

(8) The initial missile launch against an aircraft is assumed to occur as soon as possible within system capabilities.

(9) The burst locator must be constructed for the method of fire that will be used tactically. (Table 5-2, FM 44-3, gives methods of fire.) To construct the burst locator (fig. 4-26), extract the performance boundary of interest from FM 44-1A. Beginning with an azimuth of 0 mils, draw in a series of arbitrary direction-of-attack lines; normally, drawing these lines 500 meters apart gives the desired accuracy. Beginning with an azimuth of 0 mils, orient the target flight scale over this azimuth with time

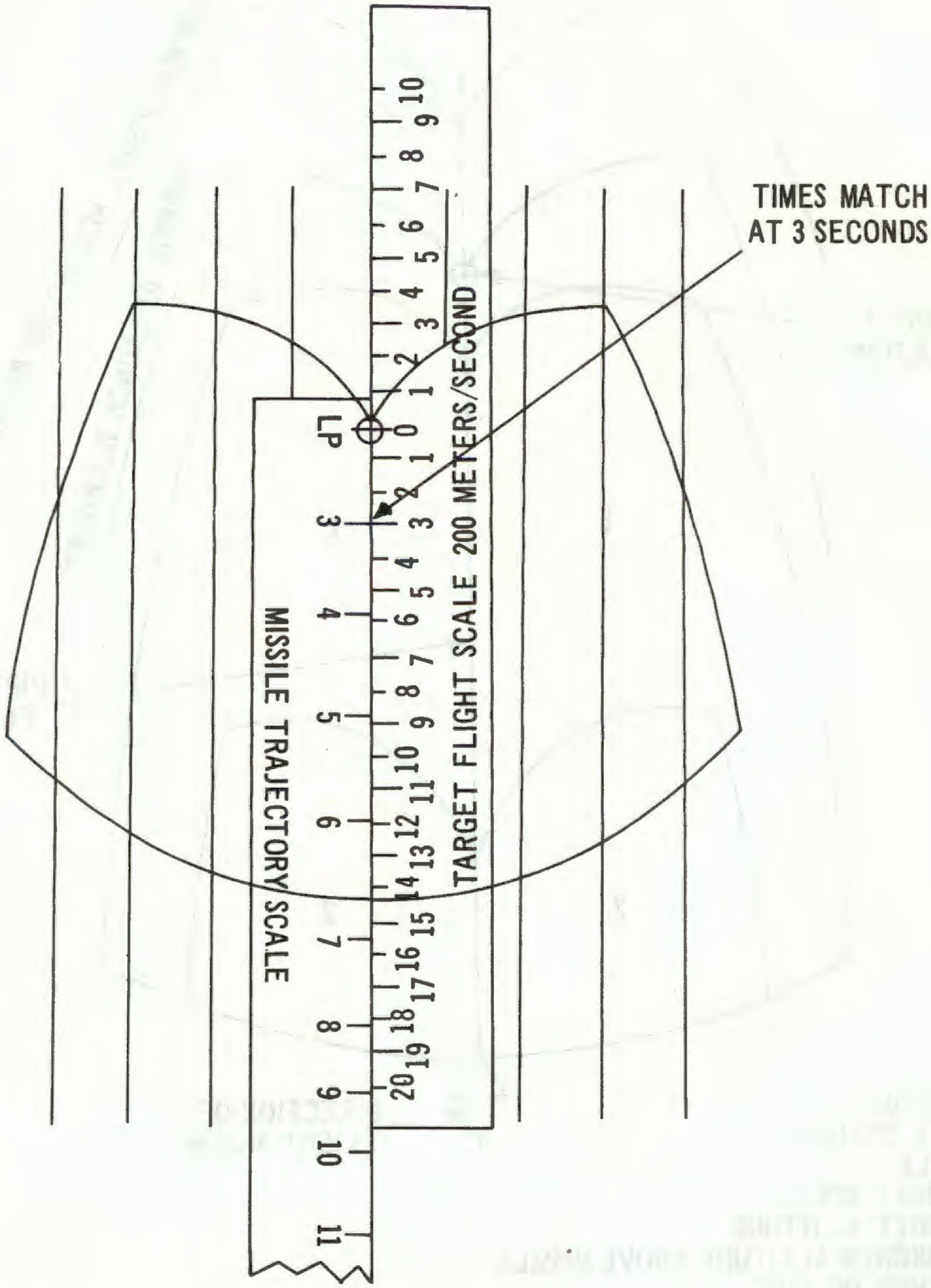


Figure 4–26. Matching times to find first burst location.

zero placed at the first possible launch point. Orient the missile trajectory scale over the fire unit location, and rotate the scale over the target flight scale and note where times on the two scales match; this is the location of the first burst along this direction of attack and is shown to occur at a time of 3 seconds in figure 4–26. To complete the first burst contour, orient the target flight scale along each direction-of-attack line and match times (fig. 4–27). A line is then drawn connecting these points, defining the first burst contour. To determine the second burst contour, first extract the time between launches for the shoot-shoot method of fire from paragraph 8, FM 44–1A. For purpose of illustration, 10 seconds have been used as shown in figure 4–28. On each direction of attack, measure this number of seconds from the first launch locations. Then, placing time zero of the target flight scale over this point (second launch point) on each direction of attack, use the

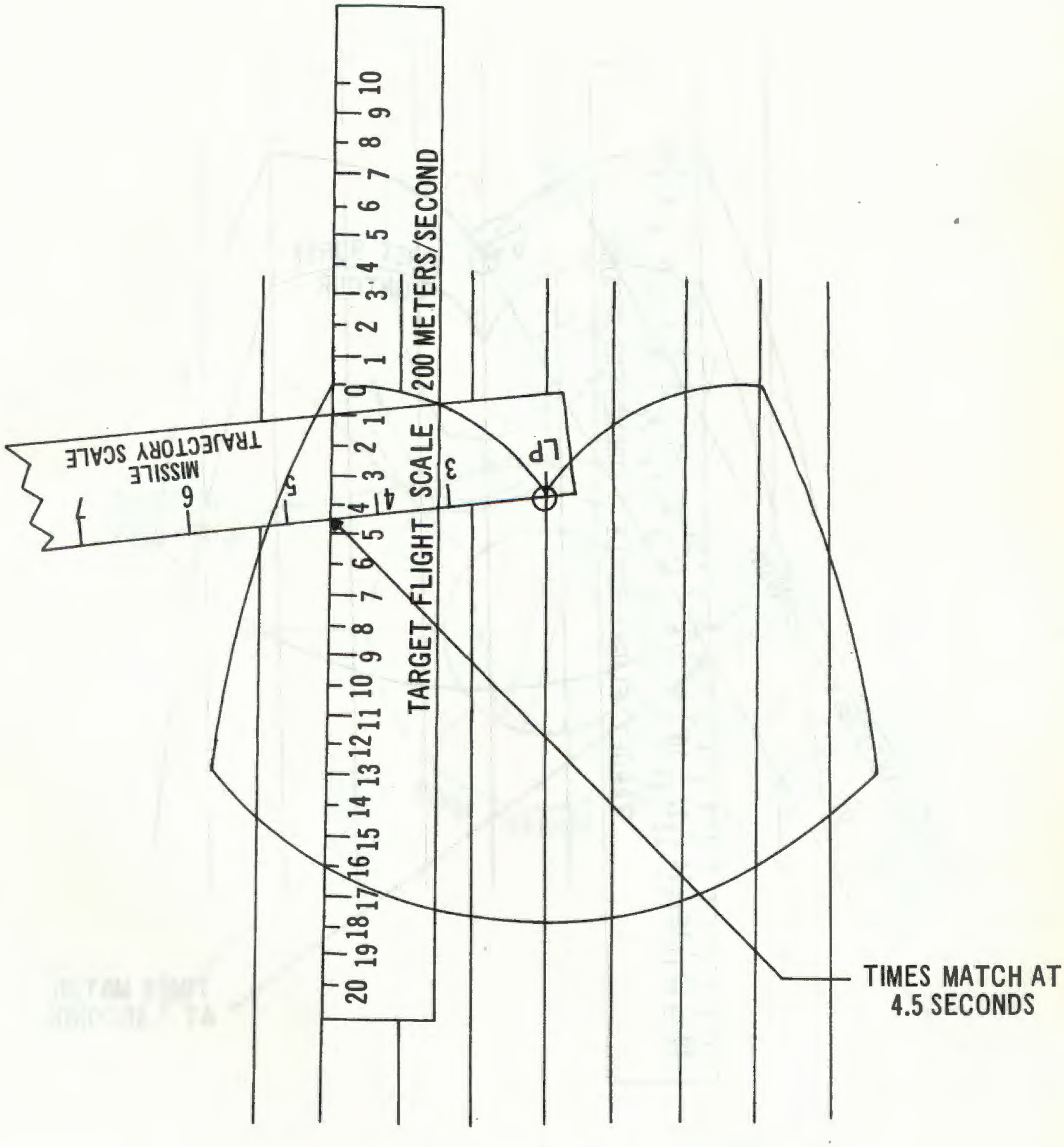


Figure 4-27. Completing first burst contour.

missile trajectory scale and again match times. In figure 4-28, a time match is shown occurring at 7 seconds. Connect these points and the second burst contour is formed. In this example, only two burst contours are possible. The number of burst contours achieved will vary with the speed of the target. To find any subsequent contours, the time-matching procedure is continued. To define the rearward edge of the burst locator, use the scales to determine the last points at which intercepts can occur along each direction-of-attack line. Label the contour defined by the first launch points minimum ID/launch boundary (fig. 4-25). To define the minimum visual acquisition boundary, use the target flight scale to backplot response time (para 8, FM 44-1A) from the first launch locations. For purposes of this example, 5 seconds of response time were used. To complete the burst locator, label the areas between burst contours with their numerical values. Place a direction-of-flight arrow at the rear of the burst locator, and draw a line through azimuth 0 mils on the burst locator (di-

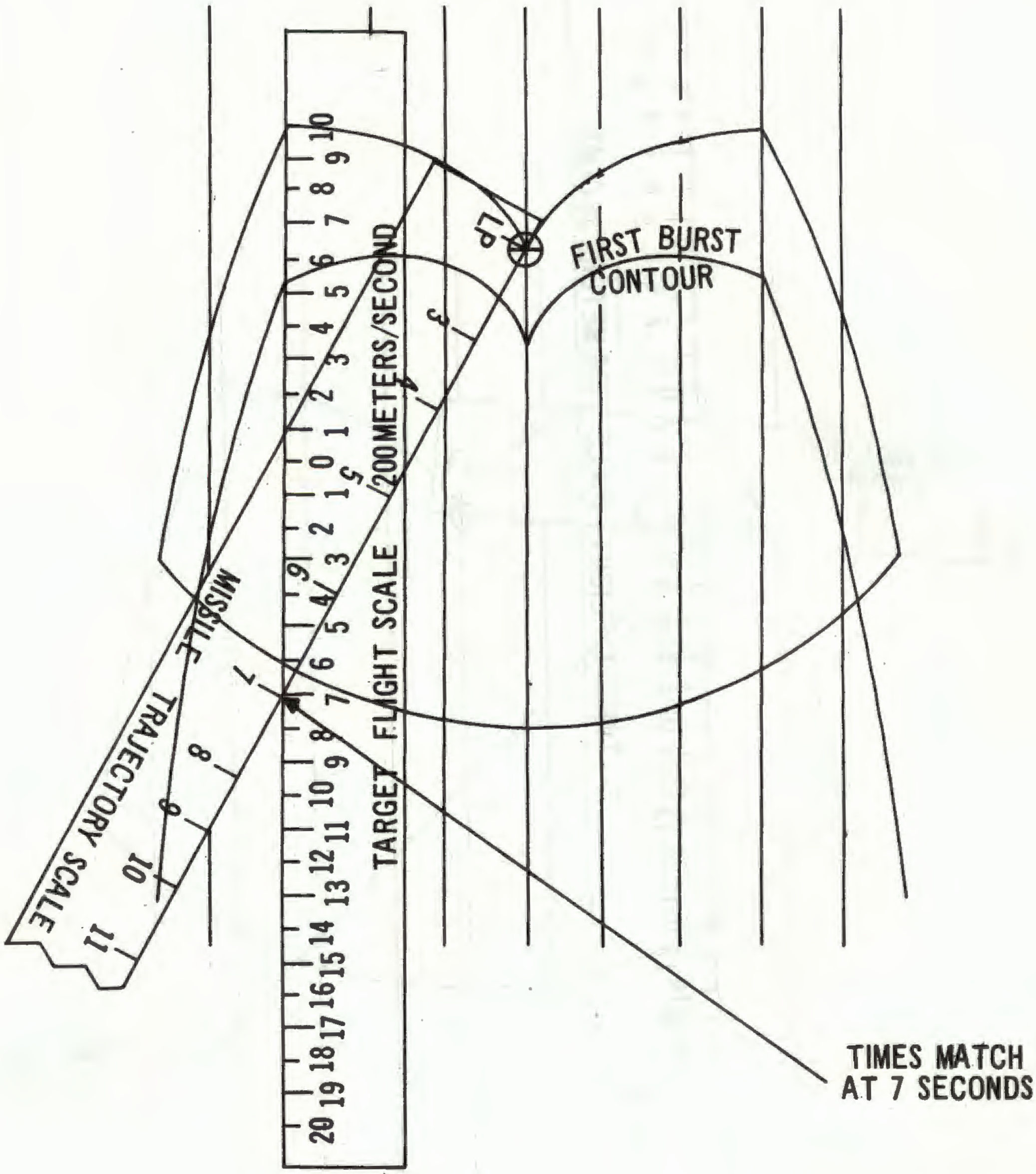


Figure 4–28. Determining second burst contour.

rection-of-flight line). Label the burst locator with type system, representative fraction, target speed, target altitude, launcher altitude above mean sea level, and method of fire.

c. Burst Locator Use. To use the Chaparral burst locator in a vital area defense, first draw in direction-of-attack lines, with origin at the center of the vital area, no farther apart than 400 mils. Plot the bomb release line or, if the laydown attack technique is being analyzed, use the edge of the vital area as the point of evaluation. To measure M_t along each direction, orient the burst locator with its center at the intersection of the direction-of-attack line and the BRL, with the direction-of-flight arrow pointed in the direction of aircraft flight, and with the direction-of-flight line superimposed over the direction-of-attack line being analyzed. In figure 4–29, it can be seen that, with the burst locator oriented properly, one fire unit achieves two bursts while the other fire unit achieves one burst. These values would then be totaled for use in the defense effectiveness formula. If Chaparral fire units are deployed well forward along low-altitude routes of approach

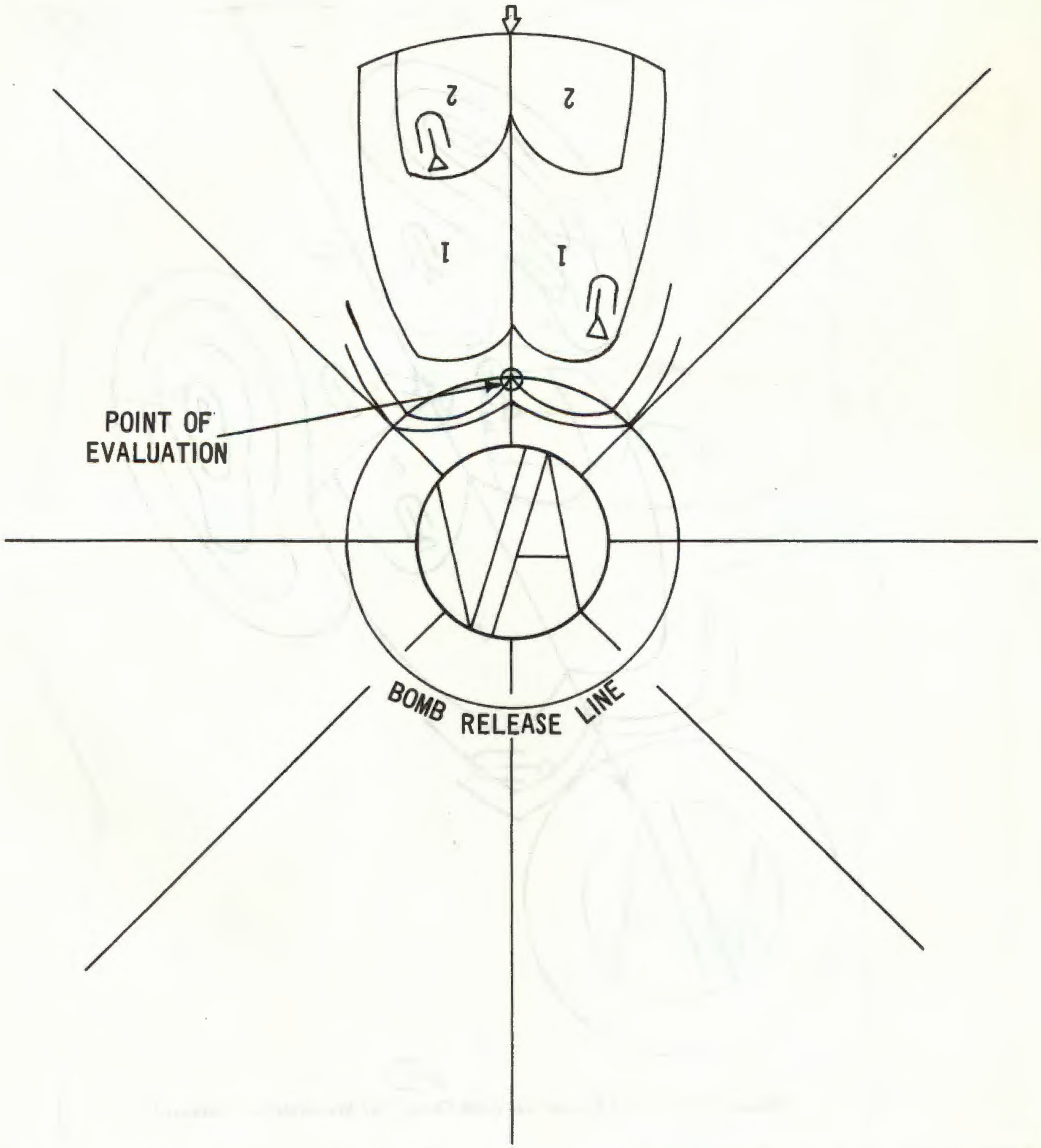


Figure 4-29. Burst locator use in vital area defense.

leading into a vital area, mark the route of approach on the defense overlay and "fly" the burst locator in along the route, recording the missile burst values. In figure 4-30, it can be seen that each fire unit achieves two bursts against the threat. For an area defense, no point of evaluation is used. Mark the low-altitude routes of approach on the defense overlay and simply "fly" the burst locator in along the routes until all fire units are out of range. In figure 4-31, each of five Chaparral units achieves two bursts along the low-altitude route. When using the burst locator, if acquisition, identification, and launch cannot be accomplished at the boundaries shown on the

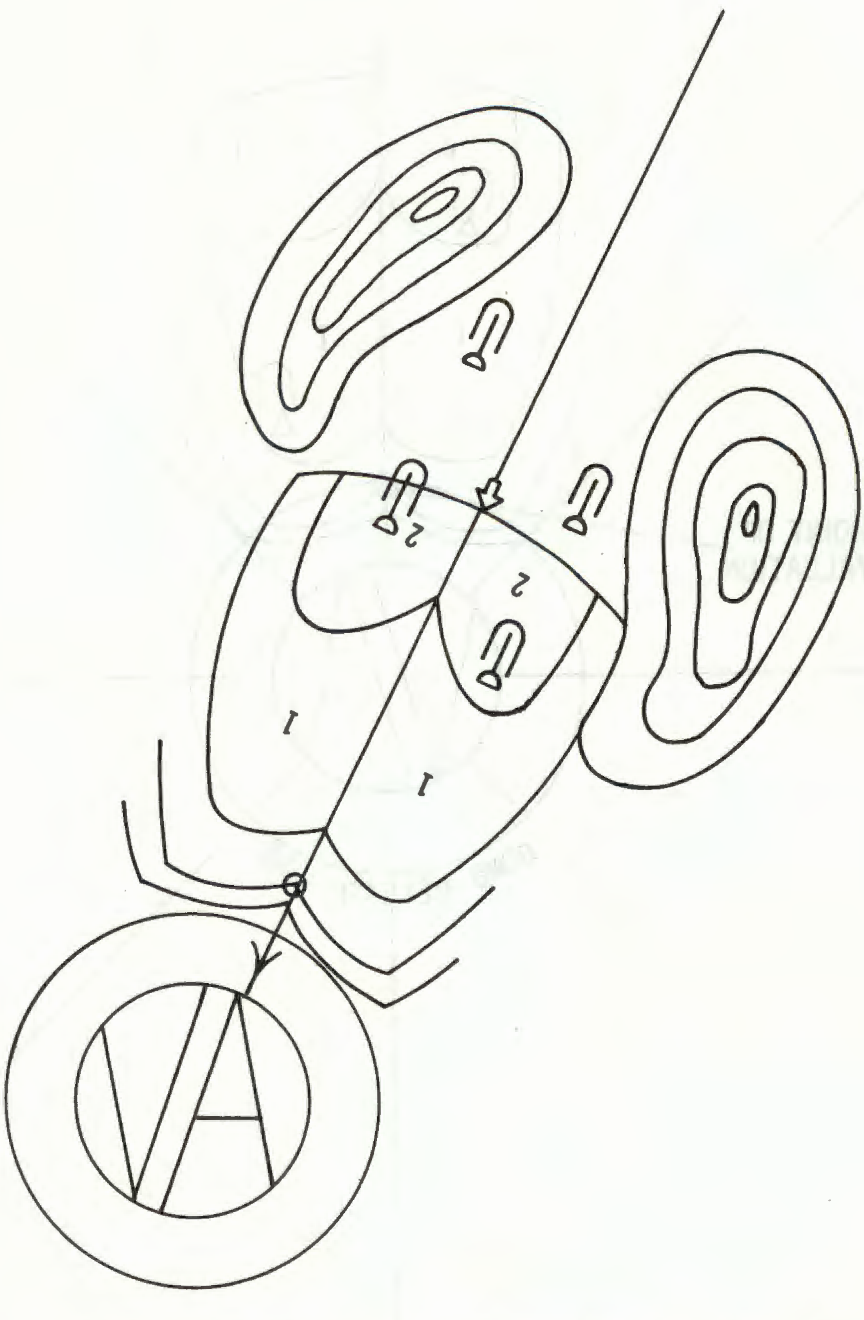


Figure 4-30. Burst locator use with Chaparral fire units well forward.

burst locator, or if any of the design assumptions cannot be satisfied, the burst locator is invalid for evaluation. In this case, two other methods are available for evaluation, use of the urgency diagram or use of the target flight and missile trajectory scales in conjunction with a performance boundary.

4-14. Urgency Diagram

a. General. The Chaparral urgency diagram (fig. 4-32) is a device used to measure Chaparral fire unit missile capability (M_c) when the burst locator is invalid. For ease of use, it should be constructed to a representative fraction of 1:50,000 on clear acetate material. The urgency diagram is especially effective when terrain masking prohibits engagement within maximum system capabilities, a requirement for burst locator validity. The urgency diagram is used separately for each Chaparral fire unit. The bottom,

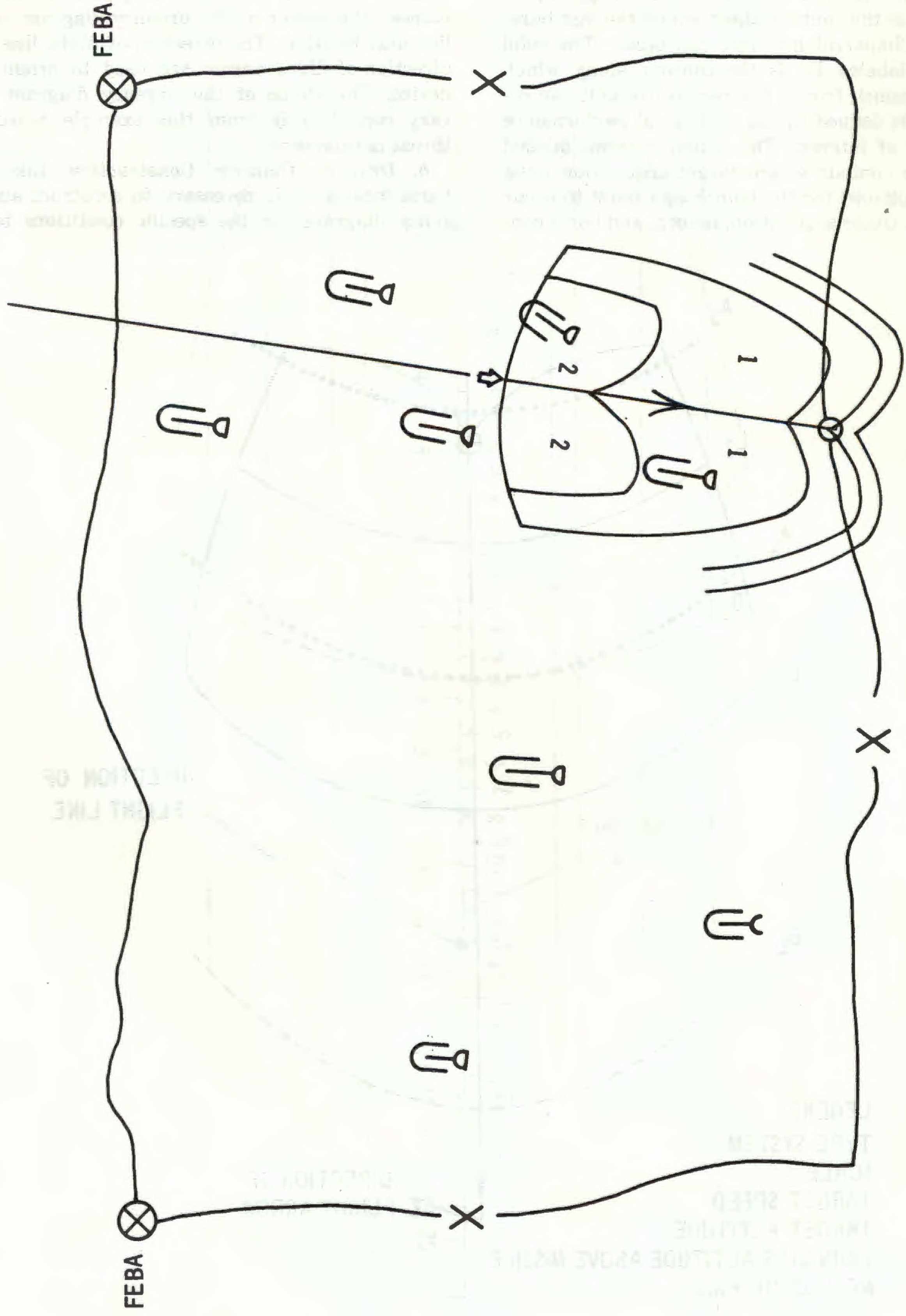


Figure 4-31. Burst locator use in area defense.

or rear dashed line on the urgency diagram, labeled B_L, is the contour along which the last burst from a Chaparral fire unit can occur. The solid contour, labeled L_L, is the contour along which the last launch from a Chaparral fire unit can occur, and is defined by the Chaparral performance boundary of interest. The dotted contour, labeled A_L, is the contour where target acquisition must be accomplished for the launch and burst to occur as shown. Other acquisition, launch, and burst contours are labeled with their respective numerical values. The center of the urgency diagram is the fire unit location. The direction-of-flight line and direction-of-flight arrow are used to orient the device. The shape of the urgency diagram will vary considerably from this example based on threat parameters.

b. Urgency Diagram Construction. Like the burst locator, it is necessary to construct an urgency diagram for the specific conditions to be

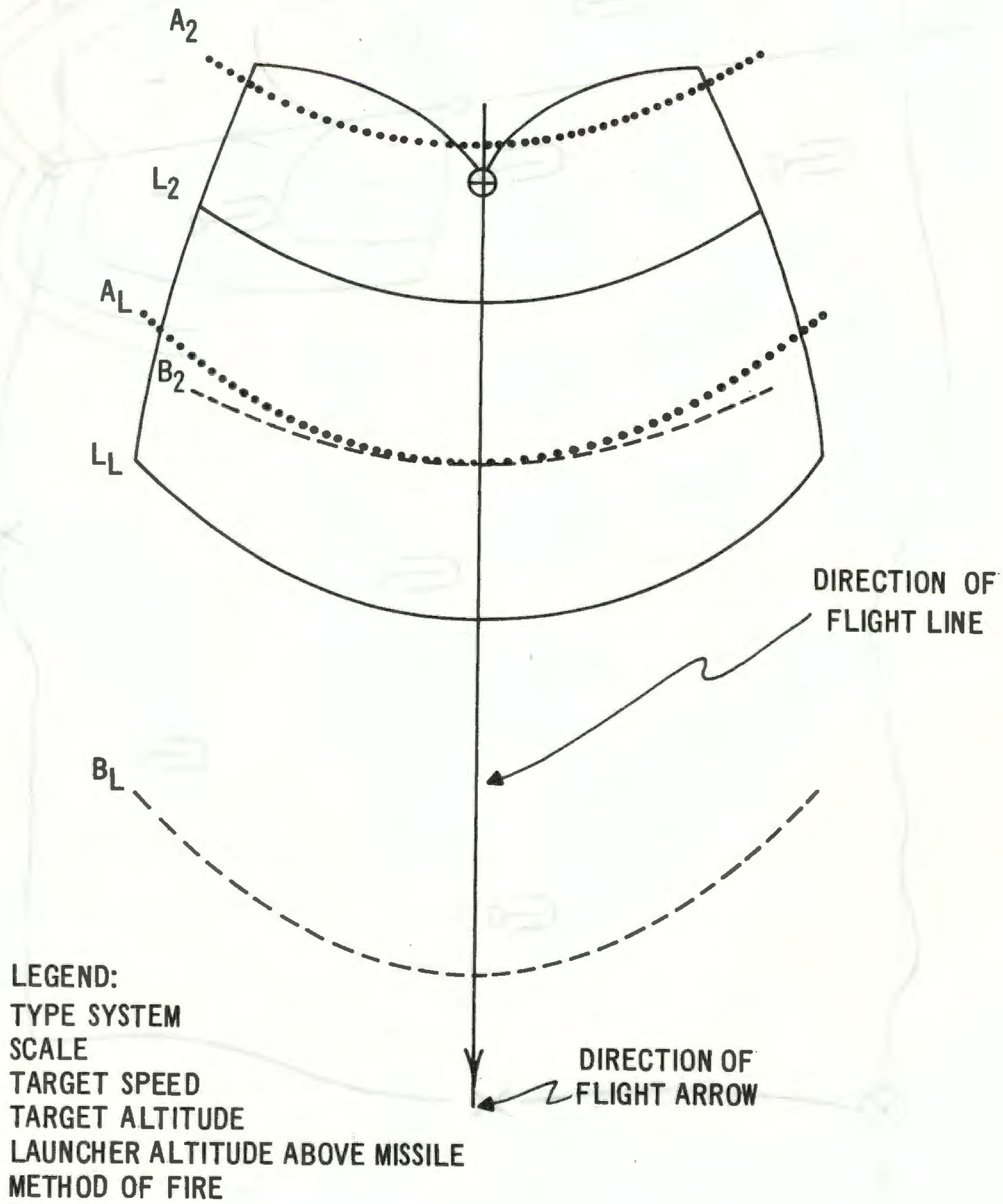


Figure 4-32. Type of Chaparral urgency diagram.

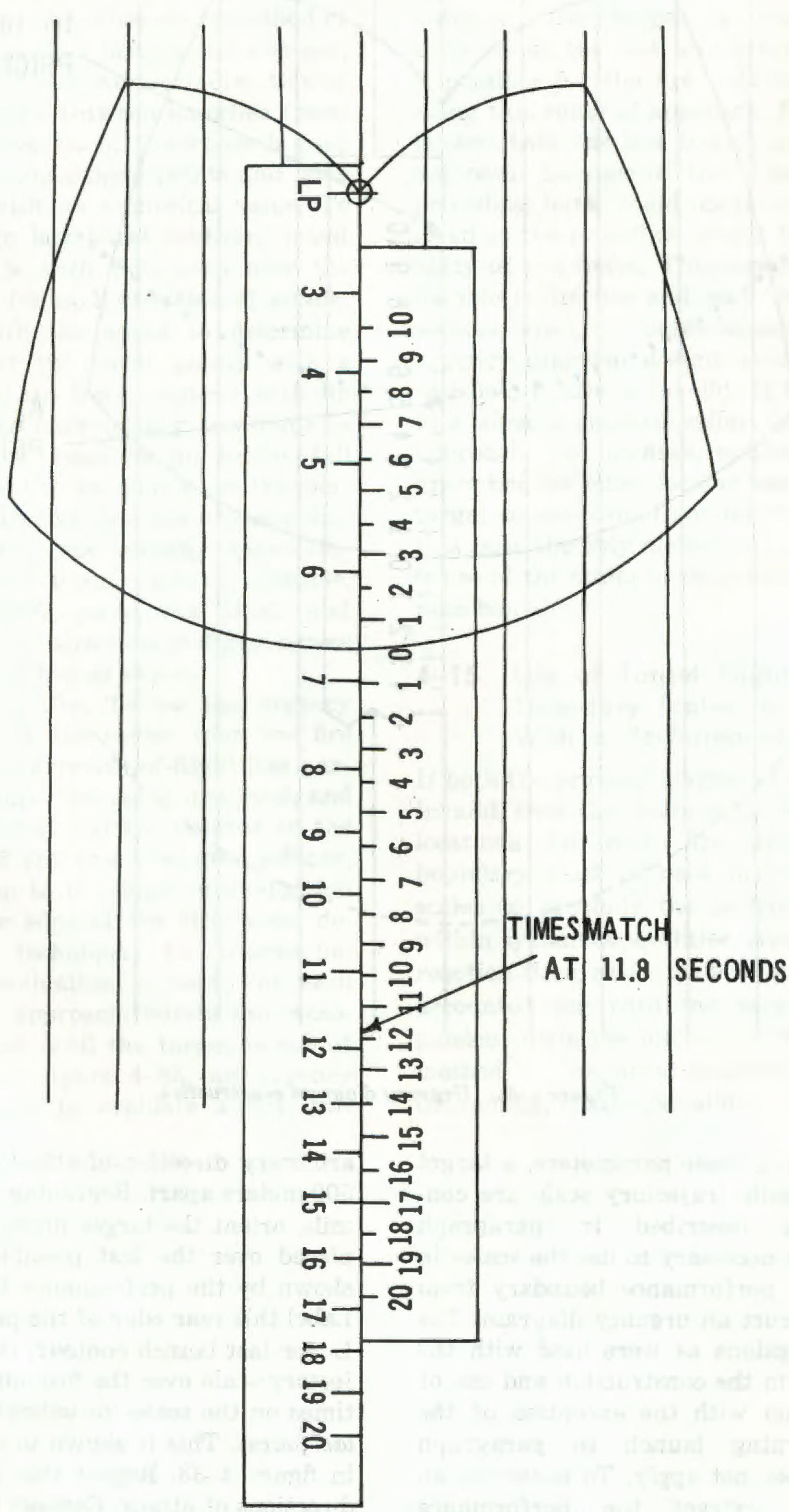


Figure 4–33. Determining last burst location.

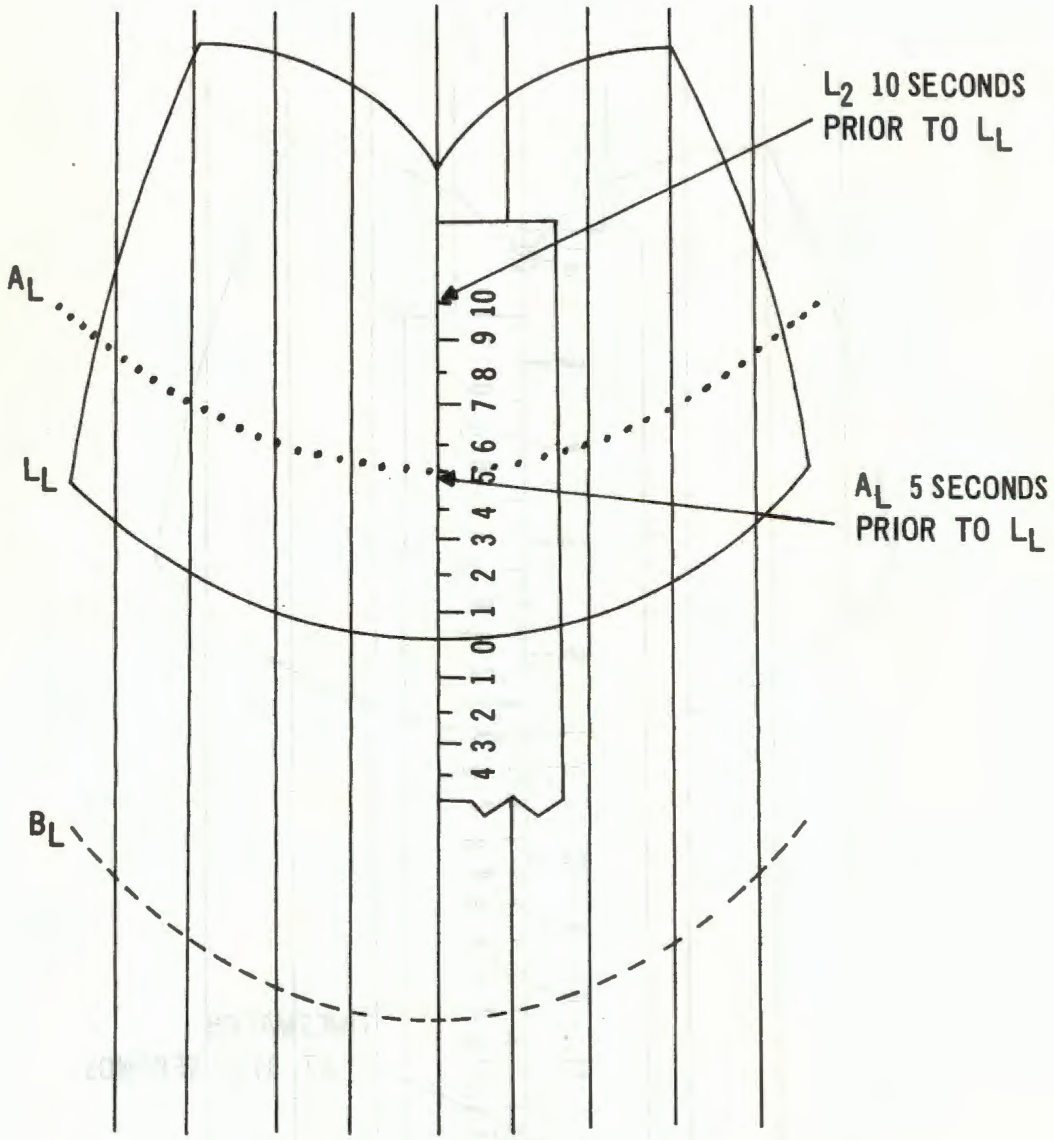


Figure 4–34. Urgency diagram construction.

encountered. Knowing these parameters, a target flight scale and missile trajectory scale are constructed first, as described in paragraph 4–13*a*(1). It is then necessary to use the scales in conjunction with a performance boundary from FM 44–1A to construct an urgency diagram. The same design assumptions as were used with the burst locator apply in the construction and use of the urgency diagram with the exception of the assumption concerning launch in paragraph 4–13*b*(8), which does not apply. To construct an urgency diagram, extract the performance boundary of interest from FM 44–1A. Beginning with an azimuth of 0 mils, draw in a series of arbitrary direction-of-attack lines approximately 500 meters apart. Beginning with an azimuth of 0 mils, orient the target flight scale with time zero placed over the *last* possible launch location as shown by the performance boundary (fig. 4–33). Label this rear edge of the performance boundary L_L for last launch contour. Orient the missile trajectory scale over the fire unit location and match times on the scales to indicate the location of the *last* burst. This is shown to occur at 11.8 seconds in figure 4–33. Repeat this process for all other directions of attack. Connect the burst points with a dashed line, and label this contour line B_L for last burst contour. On all directions of attack, backplot response time (para 8, FM 44-1A), from the last launch location; connect these points with a dotted line, and label this last acquisition contour A_L (fig. 4-34). For illustration, 5 seconds response time is used. For the shoot-shoot method of fire, to determine the next to last launch contour, orient the target flight scale over each direction of attack, and backplot time between launches (para 8, FM 44-1A); for illustration, 10 seconds is used herein (fig. 4-34). Connect these points and label the launch contour with its numerical value. To determine the next to last burst contour, orient the target flight scale with time zero over the plotted launch points for each direction of attack, and match times with the scales to determine burst points. Connect the burst points with a dashed line, and label the burst contour with its numerical value. This backplotting technique is continued until launch locations no longer fall within launch capabilities as shown on the performance boundary. To complete the urgency diagram, label with name, type system, representative fraction, target speed, target altitude, launcher altitude above mean sea level, and method of fire. Add a direction-of-flight arrow and a direction-of-flight line as shown.

c. Urgency Diagram Use. To use the urgency diagram, orient it with the center over the fire unit location, with the direction-of-flight line parallel to the route of approach being analyzed, and with the direction-of-flight arrow pointed in the direction of aircraft flight. In a vital area defense, bursts are counted up to the point of evaluation (bomb release line or edge of the vital area, dependent upon attack technique). In an area defense, no point of evaluation is used; for each low-altitude route of approach, bursts are measured for each fire unit until the target is out of engagement range. In figure 4-35, an urgency diagram is being used to evaluate a fire unit whose capabilities are degraded by two terrain difficulties, a hill mass and a ridgeline. For target path 1, it is seen that the target is behind the hill mass before L_L can be achieved; however, the target is reacquired prior to arriving at the last acquisition contour, making it possible for the fire unit to burst one missile along this route of approach. For target path 2, it is seen that the last launch and last burst could not occur because of the ridgeline; however the preceding burst could occur before the target arrived at the ridgeline, giving the fire unit a capability of one burst. The urgency diagram is very flexible in its use and may be used in many instances when the burst locator is invalid. If the urgency diagram design assumptions cannot be satisfied, it also is invalid. If the planner desired to analyze a crooked valley, low-altitude route of approach, for instance, neither the urgency diagram nor the burst locator would be valid because target course would not be straight and level. In this case, the only method available to the planner is use of the scales in conjunction with a performance boundary.

4-15. Use of Target Flight and Missile Trajectory Scales in Conjunction With a Performance Boundary

If both the urgency diagram and burst locator are invalid, then the scales may be used to plot burst locations for each fire unit; a performance boundary must be used in conjunction with the scales to preclude the plotting of launches not within system capabilities. Against response time, reaction time, and time between launches must be accounted for with the target flight scale, dependent upon the method of fire being used. This method of Chaparral analysis, though very time-consuming, is always valid.

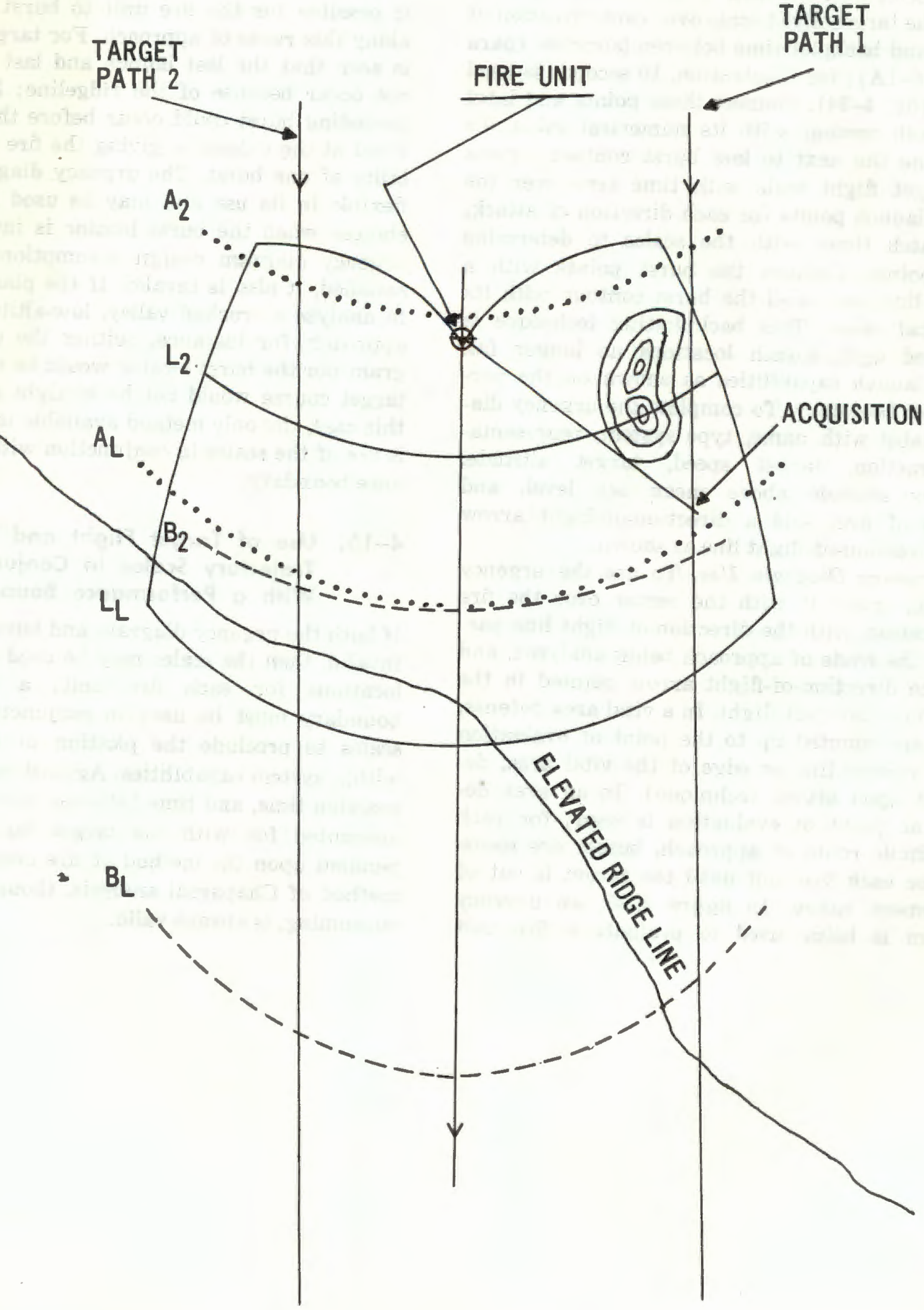


Figure 4–35. Urgency diagram use.

CHAPTER 5

MANUAL AADCP PERSONNEL, EQUIPMENT, AND PLOTTING AND TELLING PROCEDURES

5-1. General

a. The discussion in this chapter pertains to the manual AADCP to be established at ADA brigade, group, and Nike Hercules and Hawk battalion levels as necessary to replace or back up the normal semiautomatic AADCP facilities. Similar requirements exist at the M42 ADA AW and Chaparral/Vulcan battalion level, *but on a reduced scale from that implied in the following discussion* due to the habitually decentralized nature of the operations of these battalions' fire units. These battalions do not employ semiautomatic AADCP facilities nor is it envisioned that plotting and telling of tracks will be accomplished in these units.

b. A manual AADCP receives and transmits air defense information and intelligence by means of wire and radio communications. Information displayed in the AADCP is plotted and posted manually. No automatic display or automatic data transmission means are available. Advantages include simplicity, increased mobility, and probable increased effectiveness in an ECM environment. Disadvantages of the manual AADCP include time loss in plotting and telling procedures, possibility of human error, and lack of complete information on targets under attack by other ADA fire units.

5-2. Requirements

Regardless of the echelon establishing the AADCP, the following minimum requirements exist:

a. Communications. Wire and radio communications must be employed to transmit information, intelligence, and commands between ADA units and as the means to establish liaison with other agencies. (AADCP communication requirements are described in FM 44-1.)

b. Early Warning. Early warning information furnished to the AADCP from Air Force or other external sources should be plotted on early warning plotting boards.

c. Radar Information. Radar information furnished the AADCP from defense acquisition radars normally should be plotted on an operations board.

d. Defense Status. Data regarding equipment operating status, air defense warning, defense readiness condition, and states of alert, weapon control status, and method of control should be displayed on the AADCP defense status boards.

5-3. Air Defense Artillery Operations Personnel

The following personnel are required to assist the Army air defense commander in operation of the manual AADCP:

a. Air Defense Artillery Operations Officer. The operations officer is the senior officer on duty in the AADCP. His duties include—

(1) Conducting the defense in the absence of the commander.

(2) Supervising operation of the AADCP.

(3) Evaluating information received by the AADCP.

(4) Disseminating air defense intelligence.

(5) Exercising tactical supervision and fire distribution as necessary.

(6) Insuring compliance with operational directives of the commander.

(7) Disseminating air defense warnings.

(8) Establishing states of alert for the defense fire units in accordance with published SOP's.

(9) Screening and passing track information to Air Force agencies, and screening and passing track information from the Air Force or other agencies to elements of the defense in accordance with the SOP.

(10) Supervising maintenance of journals.

(11) Coordinating unit maintenance schedules to permit major items of equipment in the defense to become nonoperational for short periods of time without sacrificing the integrity of the defense.

b. Assistant Air Defense Artillery Operations Officer. Assistant operation officers are required for sustained operations, the number depending on the size and type of defense and degree of activity. Their duties include—

(1) Assuming the duties of the air defense artillery officer in his absence.

(2) Assisting the operations officer by monitoring activities of plotters and tellers.

(3) Assisting the operations officer by monitoring activities of fire units.

(4) Assisting the operations officer otherwise as directed.

c. Chief Plotter. The chief plotter supervises the activities of all enlisted personnel on duty in the AADCP. His duties include—

(1) Insuring that the status boards are posted properly.

(2) Supervising the activities of the plotters and insuring that information is plotted properly.

(3) Supervising the changing of enlisted personnel during the change of shifts.

(4) Assisting in reconciliation of early warning information received from other agencies.

(5) Assigning track numbers to tracks originated by the AADCP.

(6) Performing other duties as directed by the operations officer.

d. Plotters. Plotters are provided communications with one or more defense acquisition radars. During periods of hostile air activity, one plotter normally is required to receive information from each defense acquisition radar in operation. During periods of lesser activity, one trained plotter can plot the information received from more than one defense acquisition radar. Duties of plotters include—

(1) Receiving target information from defense acquisition radars.

(2) Plotting locations of aerial activity on the operations board.

(3) Receiving air defense intelligence concerning hostile aircraft from Air Force agencies and updating information on friendly aircraft.

(4) Plotting locations of targets on the early warning board.

(5) Keeping the defense status board current.

e. Missile Teller. The missile teller transmits pertinent track information displayed on the AADCP operations board to the elements of the defense. His duties include—

(1) Transmitting intelligence as directed by the operations officer.

(2) Assisting in maintaining journals.

5–4. Equipment

Display boards for posting and displaying air defense information are required in the operation of a manual AADCP.

a. Operations Board. The operations board, prepared specifically for each defense area, is a plotting board gridded to portray GEOREF coordinates with the defended area displayed in the center. The area represented should extend sufficiently beyond fire unit acquisition radar range to permit detection, identification, and transfer of targets to fire units in time to permit engagement at maximum possible range. Only enough detail should be included on the plotting board to facilitate its use. The range capabilities of individual units and the primary target lines of these units should be included. The board should be large enough so that displayed tracks and track data can be easily viewed from any position in the operations room. Communications outlets must be made available at the operations board for receiving plotting information from radar reporting, early warning, and other air defense information nets. Detailed information on the construction of GEOREF grids is contained in chapter 7.

b. Track Status Board. A track status board is used to display pertinent track information and any tactical action relating to each track.

c. Defense Status Board. The operating status of units in the defense and other pertinent defense data are displayed on the defense status board. The use and design of the board will vary with the individual defense area and particular AADCP requirements. Local defense operations information displayed may include—

(1) Defense readiness condition.

(2) States of alert.

(3) Air defense warning.

(4) Weapon control status.

(5) Method of control

(6) Weapon control case.

(7) Unit and materiel status.

(8) Radar operational schedules.

Note. The terms listed in (1) through (6) above are explained in FM 44-1.

d. Early Warning Board. The early warning board is a plotting board gridded to portray GEOREF coordinates. It contains the area displayed on the operations board and sufficient additional surrounding area to permit display of early warning information.

5-5. Plotting Procedures

a. Color coding of a plot is used to reflect track identity as follows:

(1) Red—hostile.

(2) Orange—unknown.

(3) White—friendly.

(4) Yellow—special interest.

b. A track designator marking indicates the track number, the agency assigning the track number, and the agency reporting the track.

c. The initial plot is marked at the GEOREF grid position by a dot surrounded by a circle. The time of the plot is shown by a two-digit figure (minutes past the hour) placed adjacent to the plot.

d. Subsequent plots are marked at their GEOREF grid position by a dot and line connecting the previous plot, thereby creating a track. Direction is indicated by an arrowhead at the plot and the time of the plot is shown by a two-digit figure (minutes past the hour) adjacent to the arrowhead.

5-6. Telling Procedures

a. The use of standard telling procedures in the manual AADCP facilitates the rapid exchange of information between all air defense levels. The track telling format prescribed by JSC Pub. 12 for interservice telling is described below.

b. Information is disseminated by tellers in the AADCP in the following sequence:

(1) *Initial report.*

(*a*) TRACK CLASSIFICATION—identifies the target as hostile unknown, or friendly, and as an "initial track," if appropriate.

(*b*) TRACK NUMBER—indicates the track number designator, the track number, and the agency reporting the track.

(*c*) POSITION—indicates the GEOREF position of the target in four digits.

(*d*) TIME—indicates the time the target was observed to the closet minute. The time is expressed in minutes only from "zero zero" to "five nine" with the hour omitted.

(*e*) COURSE—indicates target direction of travel.

(*f*) RAID SIZE—indicates the number of objects in the track as one, few, or many.

(*g*) ALTITUDE—indicates the altitude of the target expressed as "angels," ("Angels 4" is 4,000 feet; "Angels 40" is 40,000 feet; below 1,000 feet, altitude in feet is used.)

(*h*) SPEED—indicates the speed of the target in tens of knots.

(*i*) REMARKS—provides additional information as required.

(*j*) Example: "INITIAL TRACK . . . HOSTILE . . . TRACK PAPA WHISKEY THREE ZERO ONE CHARLIE DELTA . . . AT LIMA CHARLIE ONE SIX FOUR ONE . . . TIME FIVE EIGHT . . . SOUTHEAST . . . ONE OBJECT . . . ANGELS THREE ZERO . . . SPEED THREE FIVE."

(2) *Subsequent reports.*

(*a*) TRACK NUMBER.

(*b*) POSITION.

(*c*) TIME.

(*d*) REMARKS—indicates changes in initial report information not already mentioned.

(*e*) Example: "PAPA WHISKEY THREE ZERO ONE CHARLIE DELTA . . . LIMA CHARLIE THREE ZERO THREE TWO . . . TIME ZERO TWO."

c. Information is reported by acquisition radar personnel to the AADCP in the following sequence:

(1) *Initial report.*

(*a*) TRACK—alerts the AADCP plotter. FLASH may be used for high-speed aircraft within an established FLASH line.

(*b*) TRACK SUFFIX—indicates the agency reporting the track. This suffix is reported alone for initial plots only. After assignment of the track designator it is reported as part of the track designator.

(*c*) TARGET POSITION—indicates the GEOREF position of the target in four digits.

(*d*) TIME OF OBSERVATION—indicates the time that the target was observed to the closest minute. Time is expressed in minutes only from "zero zero" to "five nine" with the hour omitted.

(*e*) COURSE—indicates target direction of travel.

(*f*) FORMATION—applies to multiple aircraft carried as a single track. This information is given initial report or when there is additional information.

(*g*) ADDITIONAL INFORMATION—includes amplifying information when necessary. Additional information should be held to the minimum and be brief.

(*h*) Example: "TRACK . . . CHARLIE DELTA . . . LIMA CHARLIE ONE SIX FOUR ONE . . . TIME FIVE EIGHT . . . SOUTHEAST."

(2) *Subsequent reports.*

(*a*) TRACK NUMBER—indicates the track number designator, track number, and reporting radar suffix. The radar personnel are notified of the track designator after it has been established as a defense track. The track designator is abbreviated for radar reporting, but the reporting radar suffix is always given.

(*b*) TARGET POSITION.

(*c*) TIME.

(*d*) FADED—indicates that the track has faded from the radar display screen several times. The track may be visible to another radar.

(*e*) Example: "TRACK . . . ZERO ONE CHARLIE DELTA . . . LIMA CHARLIE THREE ZERO THREE TWO . . . TIME ZERO TWO."

CHAPTER 6
COVERAGE AND CLUTTER

6-1. General

Terrain difficulties are divided into two major categories, emplacement and masking. An emplacement difficulty is one which limits the area within which a fire unit may be physically located. This includes oceans, lakes, rivers, swamps, and mountains. A masking difficulty is one which involves radar masking, such as tall trees, buildings, and mountains. Because either or both of these difficulties may exist in a defense, certain modifications to the basic defense design must be considered.

6-2. Emplacement Difficulty

The preliminary phase in considering a missile defense where an emplacement difficulty exists is exactly the same as for any missile defense. It is in the design phase where the differences occur (para 3-6—3-8).

6-3. Masking Difficulty

a. General. Earth curvature and terrain irregularities have a profound effect on the detection and tracking capabilities of air defense artillery fire units. Degraded detection and tracking capabilities will affect adversely the capabilities of the defense. Additionally, radar energy does not travel in a straight line, but has a certain tendency to follow the curvature of the earth. It is essential to determine the detection range and radar coverage, as affected by earth curvature and terrain difficulties to accurately analyze the proposed defense capabilities and determine if fire unit positions as planned must be moved. There are several methods for determining detection range and radar coverage for a fire unit.

b. Terrain Profile. The first step in determining radar coverage is to prepare a terrain profile. Profiling takes into account the height and irregularities of the terrain.

(1) Select the largest scale map available. Plot the proposed radar location on the map and draw radial lines at least every 200 mils in azimuth, with the radar as the point of origin (fig. 6-1). Identify the radial lines by numbering each with the appropriate azimuth in mils; i.e., north, 0 mils; next radial line to the right, 200 miles; etc.

(2) Inspect each radial line and circle the high, low, and prominent terrain features. The 600-mil radial line shown in figure 6-1 shows several prominent terrain features. For excessive terrain irregularities, additional radial lines may be required. (Notice the 2,300-mil radial line shown in fig. 6-1.)

(3) Prepare a map profile line for each radial line. Beginning at the radar end of the map profile line, record the altitude of the radar. Moving from the radar along the radial line on the map, note the range to the first terrain feature circled. Place a tick mark on the line to represent the distance from the radar to the noted terrain feature. Record the range to that terrain feature and its altitude. Find the range of succeeding terrain features circled on the radial line and mark the map profile line as was done for the first terrain feature. Identify each map profile line with a radial line on the map (fig. 6-2).

c. 4/3 Earth Curvature Diagram. By preparing a terrain profile and using the mil relation formula ($\frac{\text{Width (in yards)}}{\text{Range (in thousands of yard)}} = \text{mils}$), a rough approximation can be made for radar detection. However, this procedure does not account for earth curvature and radar beam curvature. Applying the terrain to a 4/3 earth curvature diagram will account for the other variables necessary to determine true radar detection ranges and radar coverage.

(1) Obtain DA Form 11-47 (4/3 Earth Profile Chart) if available, or construct a modified earth curvature profile as explained in paragraph 6-4. Determine the basic radar capabilities as follows:

(*a*) Plot the altitude of the radar above

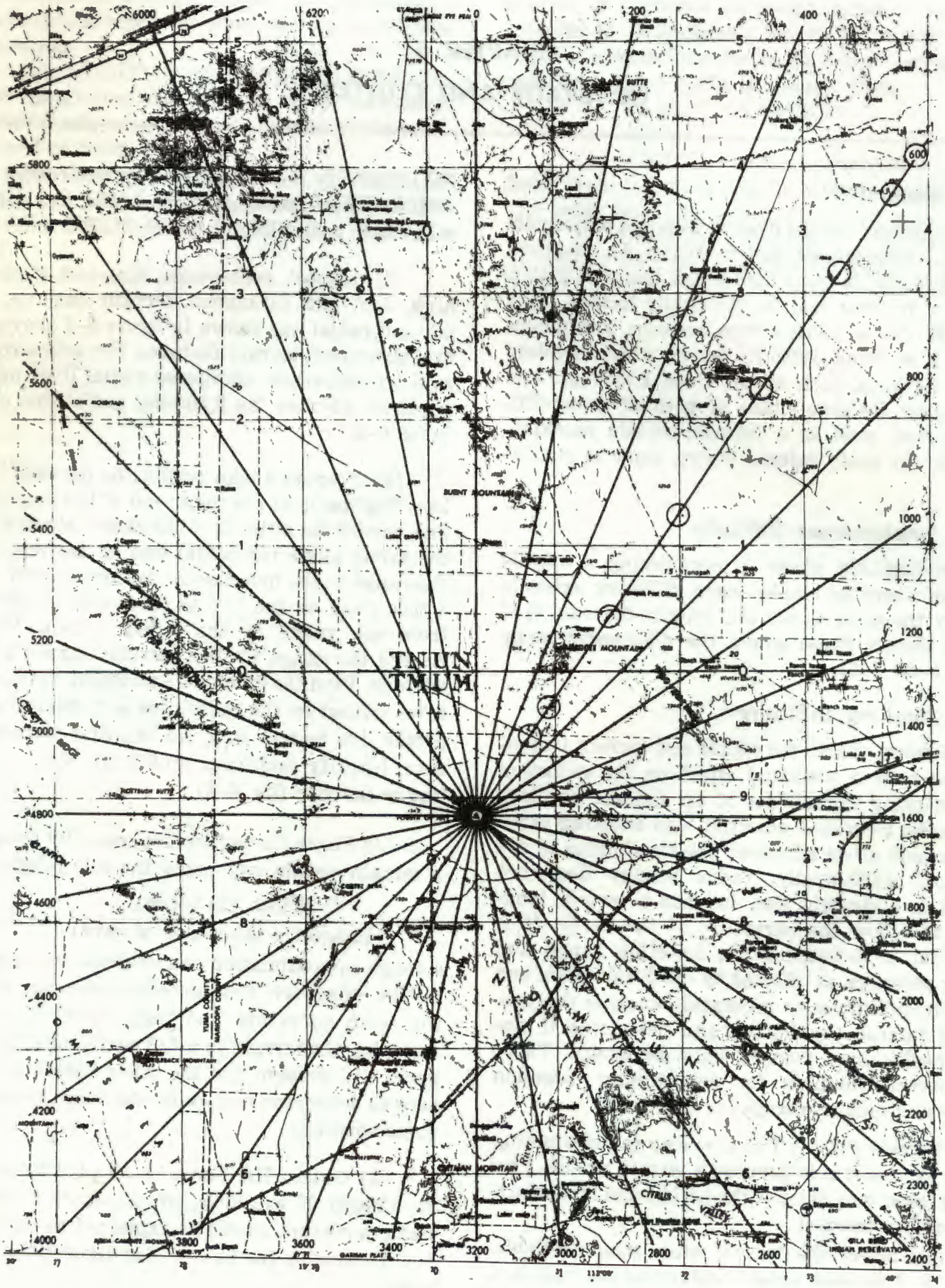


Figure 6-1. Map preparation.

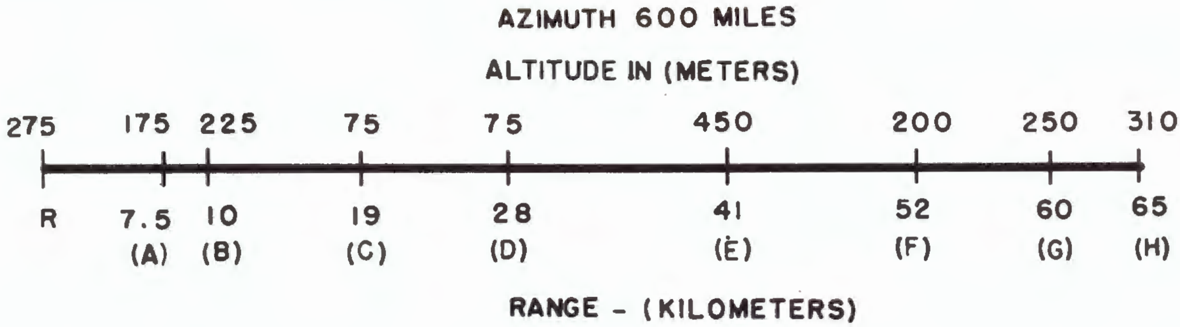


Figure 6-2. Map profile line.

mean sea level (MSL) on the left vertical edge of the 4/3 earth curvature diagram from the information entered on the map profile line (fig. 6-2).

Note. There are two sets of numbers (large scale and small scale) on the 4/3 earth curvature diagram. Use the larger scale (small numbers) whenever possible. However, it may be necessary to use the smaller (large numbers) scale to obtain the desired information. When either scale is used, care must be taken to use the same scale throughout the diagram (altitude, range, and mil index).

(*b*) Plot the information for the first terrain feature noted on the map profile line by beginning at the left vertical line on the 4/3 earth curvature diagram at the appropriate altitude. Move along the arc for that altitude to a range as indicated on the horizontal line at the bottom of the diagram corresponding to the range of the terrain feature from the radar. Do this for each terrain feature recorded on the map profile line (A, B, C, D, E, F, G, and H, fig. 6-3).

(*c*) Connect all points marked on the diagram with straight lines beginning at the left side of the diagram from the radar site to the first terrain feature, from the first terrain feature to the second, etc. (line RABCDEFGH, fig. 6-3). A vertical profile of the terrain is shown as corrected for earth curvature and radar beam curvature (fig. 6-4).

(*d*) Draw a horizontal line from the radar point on the left side of the diagram to a point on the index line on the right side of the diagram. This is the baseline and corresponds to the altitude of the radar (line RXZ, fig. 6-3).

(*e*) Rotate a straight line from the vertical, originating at the radar, down to the right until a terrain feature is intersected. Draw this line from the radar, intersecting that terrain feature (E, fig. 6-3) through the mil index line (line RWY, fig. 6-3). This line represents the radar line of sight.

(*f*) Determine the angle of mask by measuring the angle from the baseline to the line representing the radar line of sight. This is done by measuring the distance from a point found by the intersection of the baseline with the mil index line (X, fig. 6-3) to a point determined by the intersection of the line representing radar line of sight with the index line (W, fig. 6-3). If the line representing radar line of sight is above the base line, the mask angle will be positive; if below, the mask angle will be negative. The distance determined (line XW, fig. 6-3) is plotted on the mil index line with the origin at 0 and the terminal distance plotted above or below the 0 point as determined by a positive or negative mask angle (distance UV equal to distance XW) (fig. 6-3). The mask angle is read directly from the appropriate scale on the mil index line. This is the mask angle for the azimuth. (In the example shown in fig. 6-3, the mask angle is 2 mils.) Identify each 4/3 earth curvature diagram by an azimuth representing a radial line on the map.

(*g*) If the information desired from the 4/3 earth curvature diagram cannot be plotted because of excessive terrain variations, greater ranges, or large mask angles, the diagram may be modified. Assume the altitude on the left side of the diagram is measured from other than MSL; e.g., 0 m is changed to read 1,000 m above sea level with the maximum altitude being 1,600 m or 3,400 m determined by the scale desired. Another method is to change to a smaller scale; i.e., maximum range: 260 kilometers (km); maximum altitude indicated: 9,600 m; maximum angles indicated: +48 mils, —8 mils.

(2) The 4/3 earth curvature diagram can be used to determine detection ranges and radar coverage along particular azimuths by using the information plotted and assuming threat altitudes (optimum attack altitudes) above MSL or terrain.

(*a*) Assuming a threat will travel at a con-

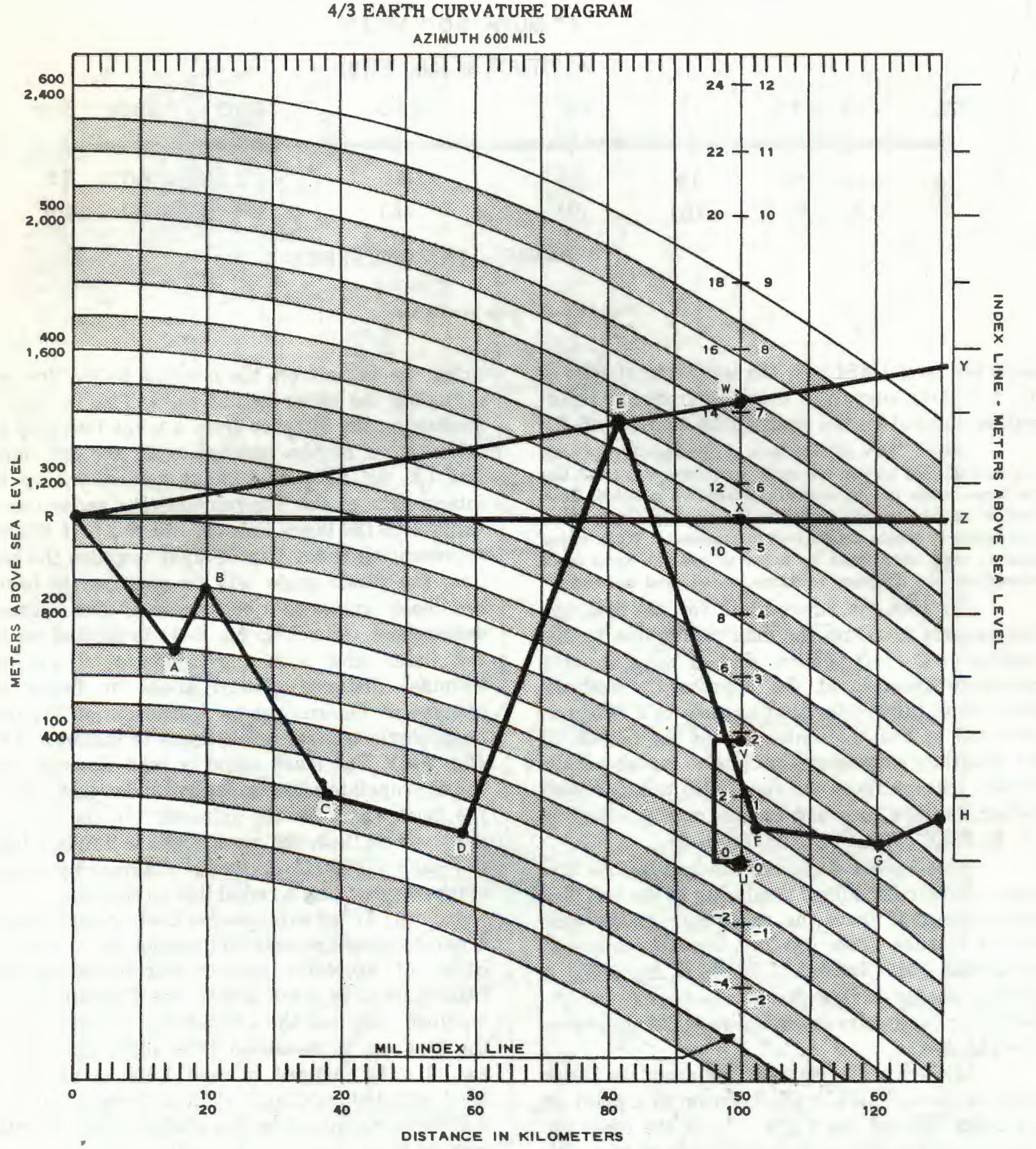


Figure 6-3. Construction of profile and mask angle.

stant altitude above MSL, locate that altitude on the left vertical line of the 4/3 earth curvature diagram. Move along the arc for that altitude to the maximum range on the diagram. Draw an arc representing the altitude of that threat (line MPN, fig. 6-4). The intersection (P, fig. 6-4) of the altitude of the threat with the line representing the radar line of sight (line RPY, fig. 6-4) represents the point at which the threat can be detected. To determine the range to the detection point, draw a line from that point perpendicular to the range line at the bottom of the dia-

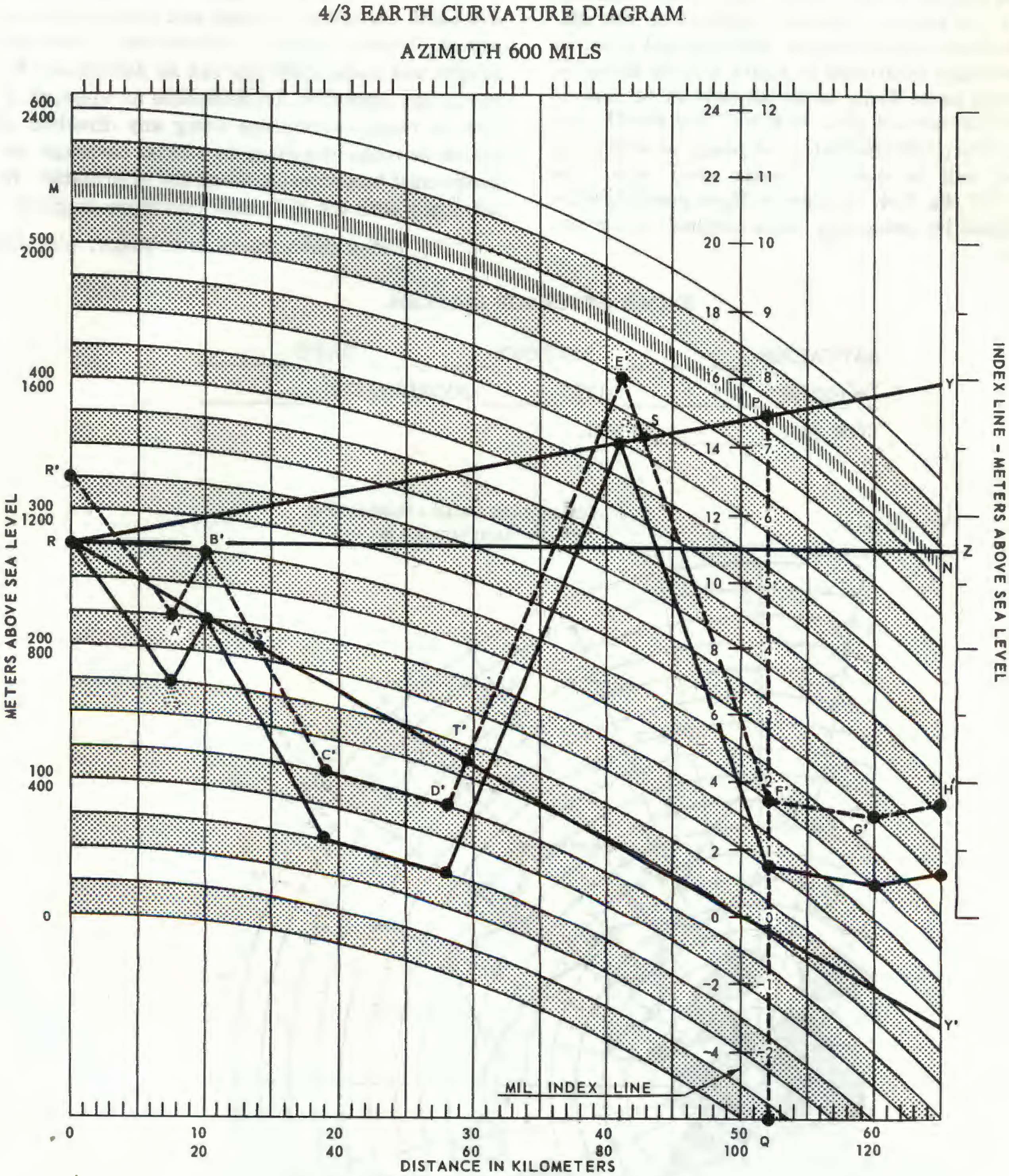


Figure 6-4. Construction of target course.

gram (line PQ, fig. 6-4). The range is read directly from the appropriate scale on the range line.

(*b*) Assuming a threat will travel at a constant altitude above the terrain, determine the distance representing that altitude on the left vertical line of the 4/3 earth curvature diagram. This distance, which represents the altitude of the threat above terrain, is used to plot points directly above the terrain features indicated on the diagram. Connect these points with straight lines. In the example illustrated in figure 6–4 the threat is assumed to be flying at an altitude of 50 meters above the terrain (line R'A'B'C'D'E'F'G'H', fig. 6–4). The profile indicates the points at which the threat will be masked (radar dead zone; line T'D'C'S', fig. 6–4). Ranges to these points are determined by using the same method as in (*a*) above.

d. Radar Coverage Diagram. By completing a 4–3 earth curvature diagram and applying the assumed threat altitude information, detection ranges and radar coverage can be determined for particular azimuths. To determine an approximation of radar capabilities along any direction of attack or route of approach, a radar coverage diagram must be prepared, using the information determined with the 4/3 earth curvature diagram.

(1) Using polar coordinate paper, plot the

RADAR COVERAGE DIAGRAM

BATTALION____________ BATTERY __________ DATE ________

DEFENSE____________ SITE ______ COORDINATES __________

SITE ALT __________M MSL

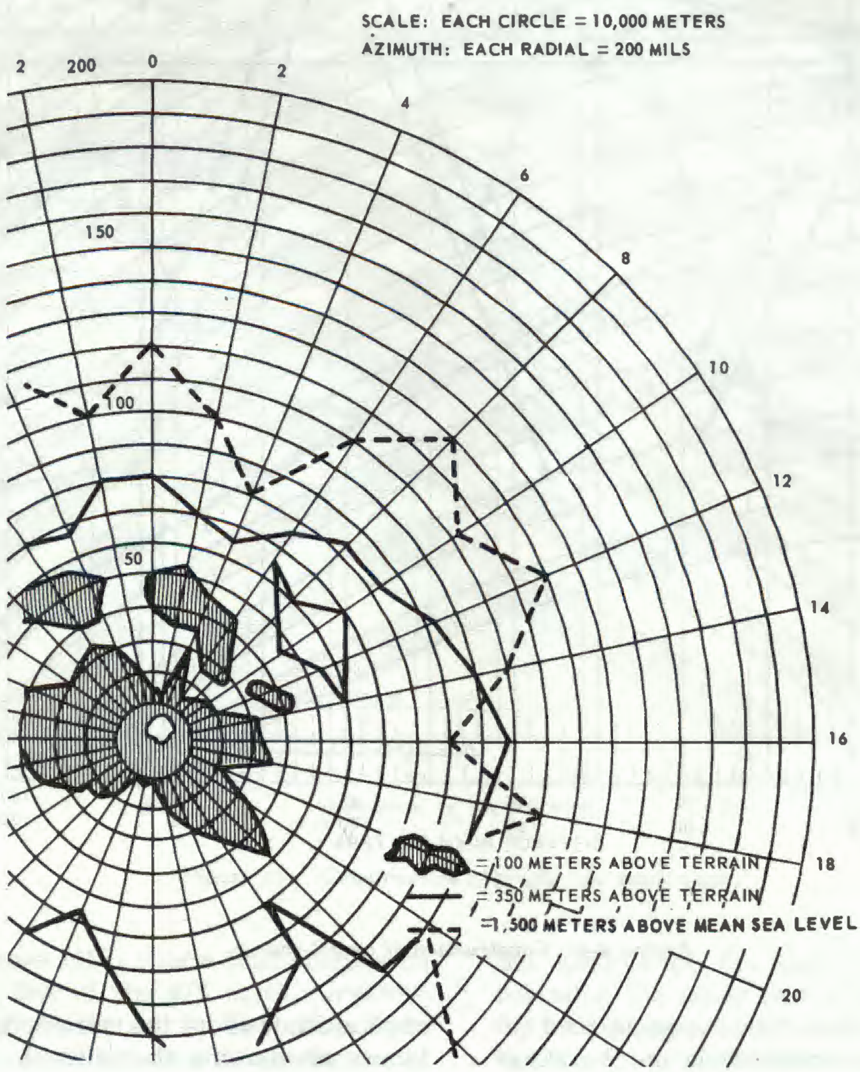


Figure 6–5. Initial radar detection and coverage by map profile method.

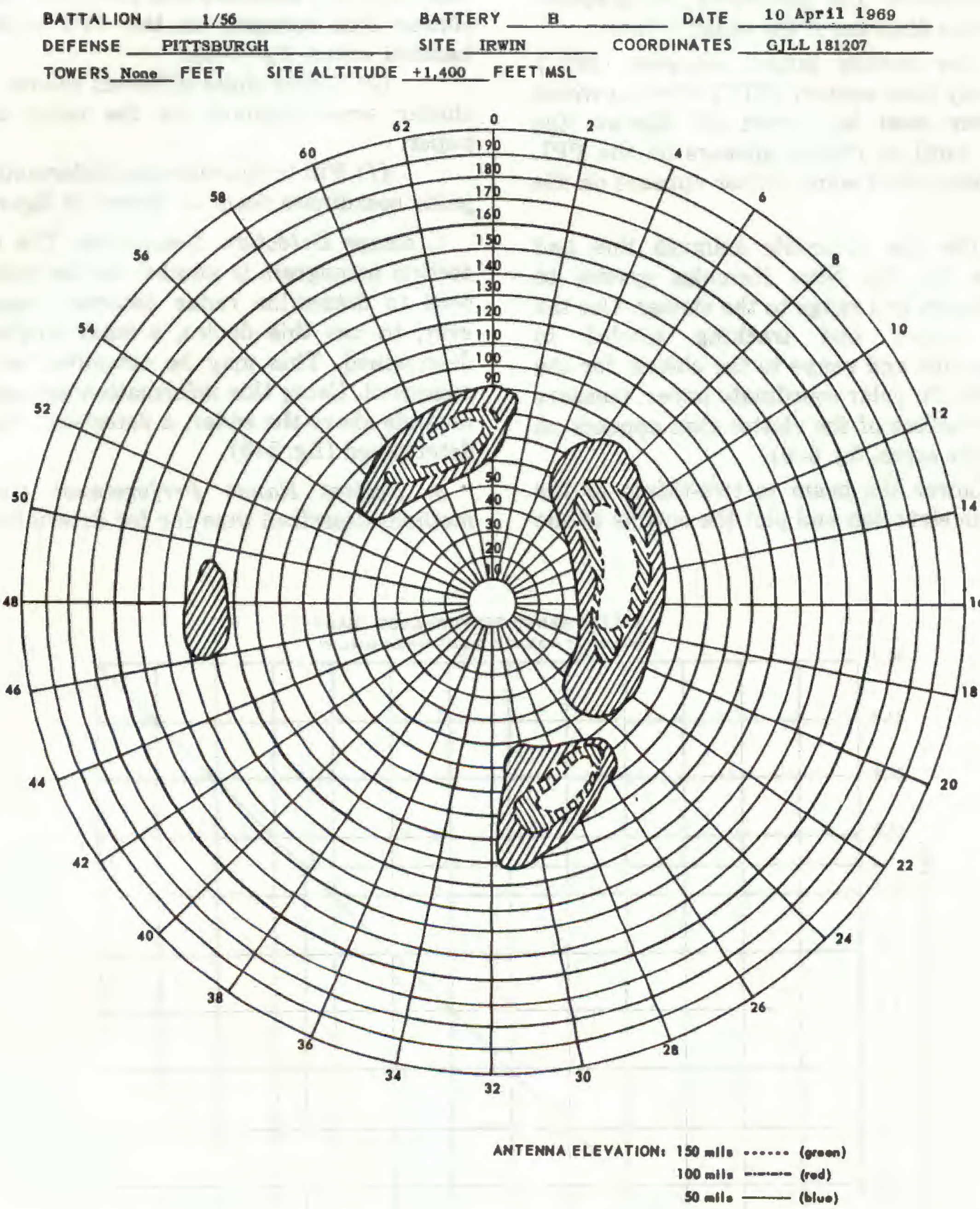


Figure 6–6. Clutter diagram.

detection ranges and radar dead zones for a particular assumed threat altitude on each azimuth for which a 4/3 earth curvature diagram was prepared.

(2) Connect all points plotted for each altitude. Code the altitudes plotted and identify each altitude plotted in the marginal information (fig. 6–5).

e. Clutter Diagrams.

(1) *General.* Clutter and coverage diagrams are used to determine the detection and tracking capabilities of radars emplaced at specific sites and to analyze the detection capabilities of a defense. The clutter diagram is a pictorial representation of video returns from fixed objects plotted on polar coordinate paper. The clutter diagram

also may be prepared as a photograph or as an overlay tracing of the clutter on the PPI; however, these methods are rarely used.

(2) *Procedure.* The procedure for preparation of a clutter diagram of the radar follows:

(*a*) The moving target indicator (MTI) and sensitivity time control (STC) circuits which reduce clutter must be turned off. Elevate the radar beam until no clutter appears on the PPI. Lower the beam until some clutter appears on the PPI.

(*b*) Use the steerable azimuth line and range circle for the Nike Hercules system to measure azimuth and range to the clutter. Use the correlation cursor and tracking symbol to measure azimuth and range to the clutter for the Hawk system. On polar coordinate paper, measure and plot the outline of the clutter that appears on the PPI (white areas, fig. 6-6).

(*c*) Lower the beam to two-thirds of the original beam elevation and plot the outline of the clutter that appears on the PPI (inner cross-hatched areas, fig. 6-6).

(*d*) Lower the beam to one-third of the original beam elevation and plot the outline of the clutter that appears on the PPI (outer cross-hatched areas, fig. 6-6).

(*e*) Using three different colors, fill in the clutter areas outlined on the polar coordinate paper.

(*f*) Fill in the marginal information on the polar coordinate form as shown in figure 6-6.

f. Range Detection Nomogram. The range detection nomogram is another device which can be used to determine radar detection range. However, to use this device, a mask angle must be determined. This may be computed or optically measured. Using this information and an assumed altitude above the radar, a detection range can be determined (fig. 3-3).

g. System Range Performance Chart. The methods described thus far for determining detec-

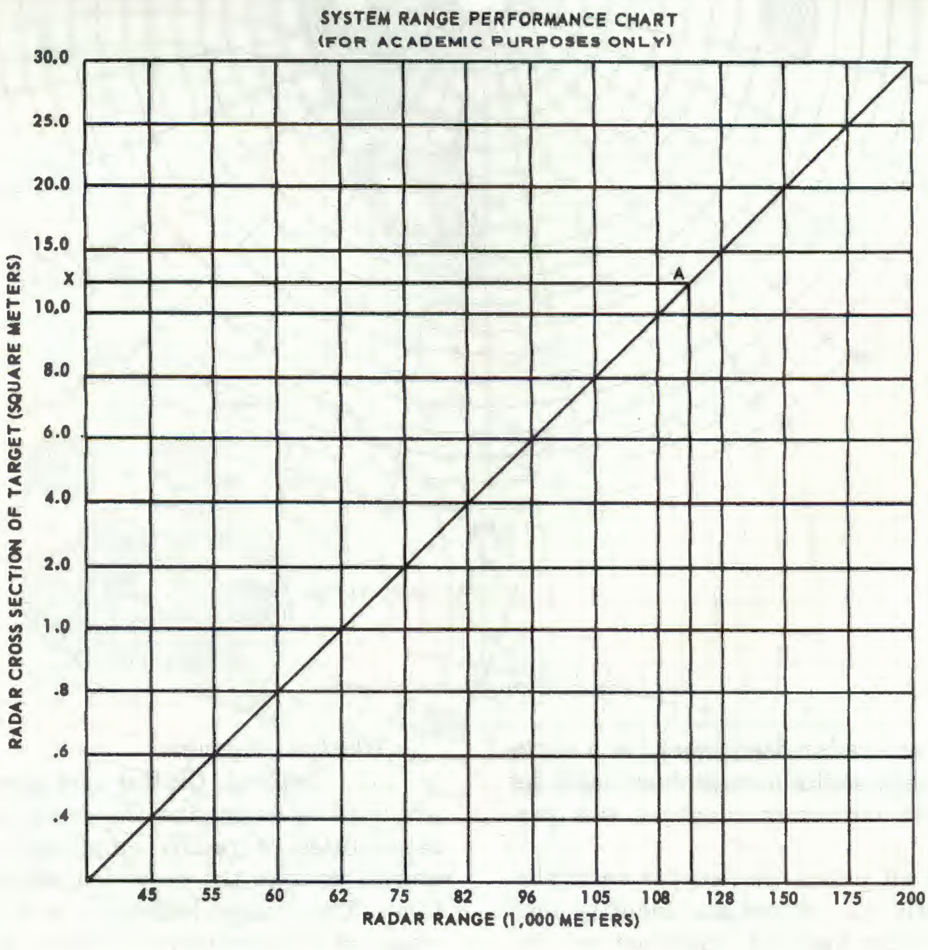


Figure 6-7. System range performance chart.

tion ranges and radar coverage are based on mask angle only. It is possible for a target to be above the radar horizon, but not visible to the radar because of excessive target range, small target size, or both. To determine the true range detection capability of the radar, a comparison must be made between the detection range based on mask angle and the system range performance chart. The smaller distance would be the maximum detection capability of the radar from that position.

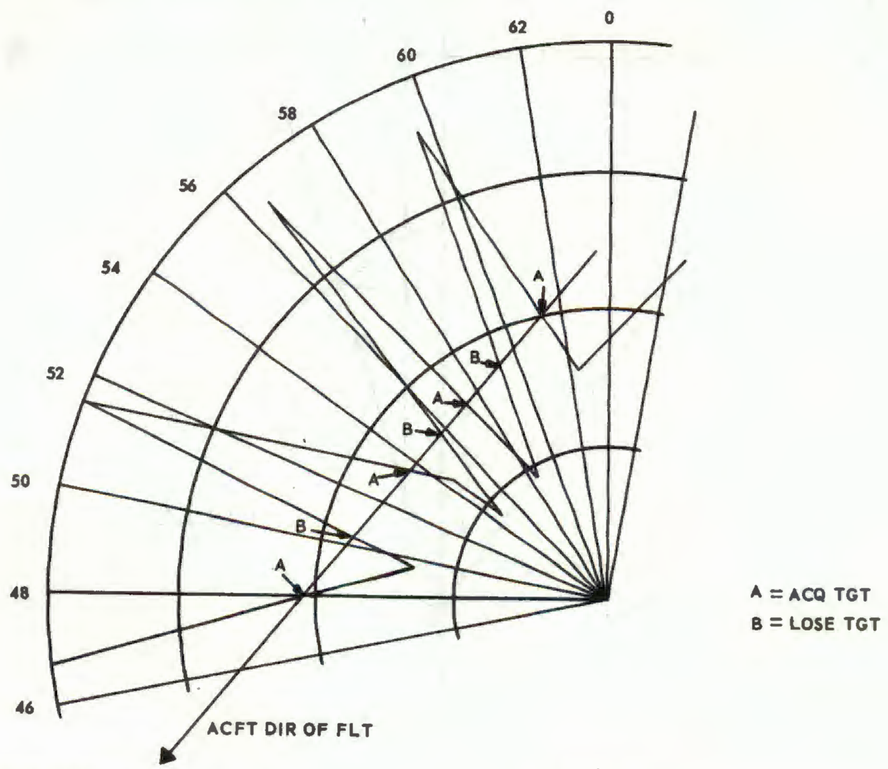
(1) Obtain a system range performance chart for the particular radar. If a chart is not available, it can be constructed as indicated in (2) below. Determine a detection range based on the assumed threat size as follows:

(*a*) Enter the system range performance chart at the left vertical line with the assumed threat target size (radar cross section, 12.5 square meters, fig. 6–7).

(*b*) Draw a horizontal line from the point of entry to a point of intersection with the diagonal line in the chart (A, fig. 6–7).

(*c*) Drop a perpendicular line from the point of intersection to the radar range line at the bottom of the chart (radar range, example 118,000 m, fig. 6–7). The range is read directly or interpolated from the chart.

(2) A system range performance chart is constructed by using the known radar data to derive an approximation of the acquisition capabilities of the radar (FM 44–1A). The known data will be the range detection capabilities of the



ASSUMED THREAT DATA:
TARGET ALTITUDE 1,000 M ABOVE TERRAIN
TARGET SPEED 600 KNOTS
TARGET SIZE 10.0 M²

DEFENSE DATA:
ENGAGEMENT EFFECTIVENESS HIGH

	NIKE HERCULES		HAWK
SYSTEM EFFECTIVENESS	0.80		0.60
RESPONSE TIME:			
ACQ TO TGT TRACK	12 SEC	ACQ TO LAUNCH	20 SEC
TGT TRACK TO COMPUTER SETTLE	4 SEC		
CS TO LAUNCH	2 SEC		
MAX SKIRTING TURN TIME	9 SEC		
REACTION TIME	11 SEC	REACTION TIME	10 SEC

Figure 6–8. Sample coverage diagram.

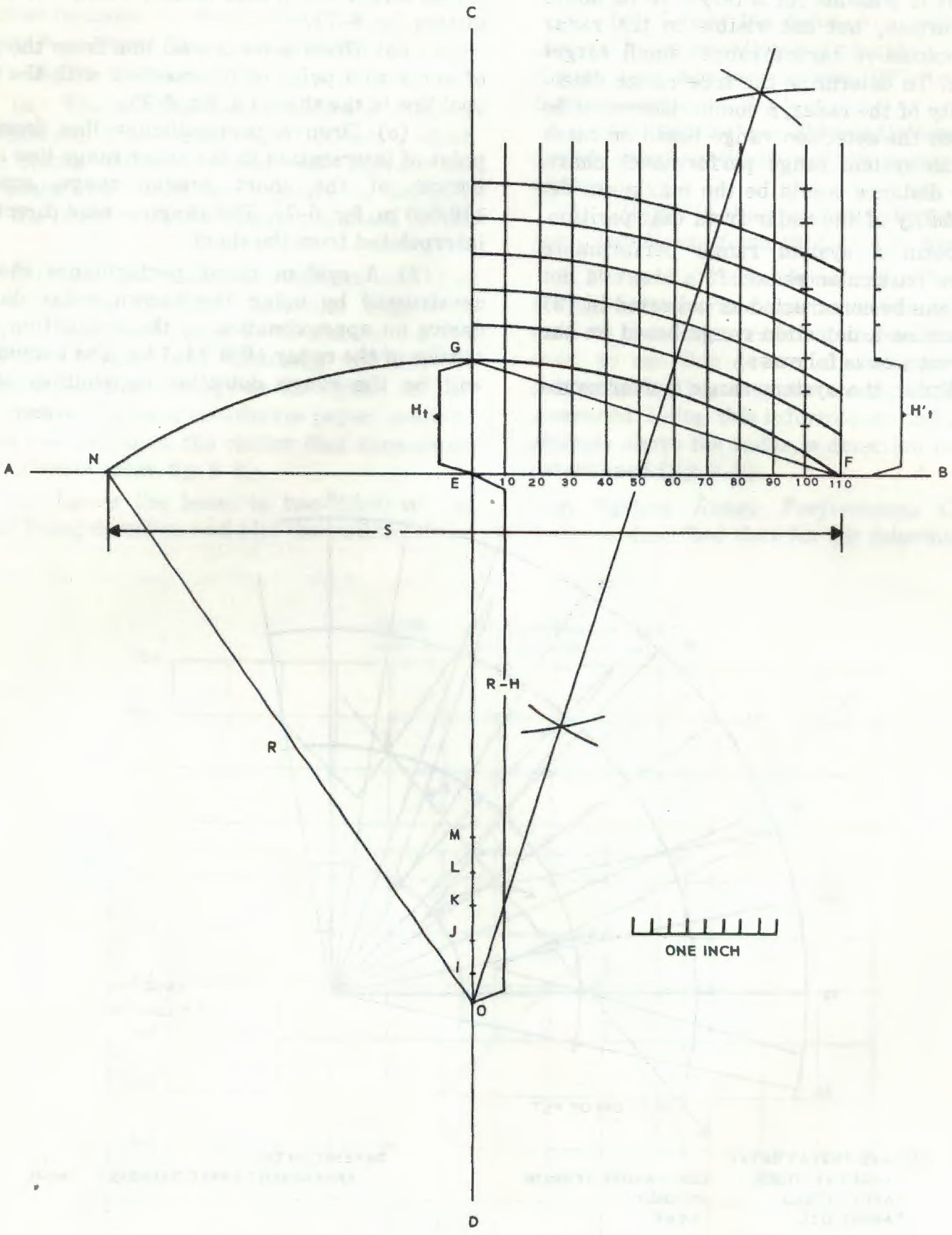


Figure 6-9. Construction of modified earth curvature profile.

radar for three or more target sizes. Construction of a radar range performance chart is accomplished as follows:

(*a*) Using linear graph paper, place the given figures for target sizes on the left vertical line in ascending values, leaving sufficient space to place appropriate values in between.

(*b*) Place the figures for detection ranges beneath the bottom line on the graph paper in ascending values from left to right, comparatively spacing these entries to those for target size.

(*c*) Place points on the graph for the particular target sizes with appropriate detection ranges. Connect the points plotted with a smooth line.

(*d*) Add values for target sizes not given and appropriate values for detection ranges or leave blank for interpolation as desired.

h. Defense Analysis. Analyze the defense unit by unit based on the degraded capability due to masking and assumed target size (fig. 6-8). The validity of the various analyzing devices must be determined and the appropriate ones used. Evaluate the defense capability as discussed for emplacement difficulties and move the fire unit positions as mentioned, if appropriate.

6-4. Modified Earth Curvature Profile Construction

a. General. If a suitable curvature diagram is not available, one must be constructed to portray radar coverage accurately. A formula, $H_t = \frac{S^2}{68}$, is used to account for earth curvature and the bending of the radar wave. (For derivation of this formula, see TM 11-673.)

b. Construction. The method used for construction of a modified earth curvature profile is as follows (fig. 6-9).

(1) Draw a horizontal line AB and a line CD perpendicular to line AB. Any convenient distance scale may be used as long as it includes the range and altitude capabilities of the radar. In figure 6-9, a horizontal scale of 40 kilometers to the inch is used. Point F is 2¾ inches (110 km) to the right of point E (intersection of lines AB and CD).

(2) EF is one-half the baseline (distance S) of the vertical profile of the earth. The height of the arc (NGF) is calculated, using the complete baseline (220 km). Applying the formula, $H_t = \frac{S^2}{68}$, $H_t = 220 \times 220 \div 68 = 48{,}400 \div 68 = 711.8$, or 712 meters. Using a vertical scale of 800 m to the inch, plot point G 0.9 inch above point E on line CD (distance H_t).

(3) Draw a straight line from point G to F. Determine its perpendicular bisector. The intersection of the perpendicular bisector with line CD (point O) will be the pivot for arc NGF. Points I through M are located ¼ inch (200 m) apart and above point O on line CD. Corresponding arcs are drawn with points I through M as the pivot, using the same distance (OG) as the radius. These new pivots are at 200-meter intervals. Additional arcs can be scaled and drawn between the 200-meter intervals if desired.

(4) Draw vertical lines parallel to line CD at ¼-inch intervals with the last line being 2¾ inches from line CD. These lines represent distances from 10 km to 110 km.

(5) Construct an altitude index line parallel to line CD to the right of the maximum range vertical line. The increments indicated on the altitude index line will be the same distances from line AB as those distances indicated on line CD from line AB (distance H_t equals distance H'_t).

(6) Construct a mil scale at any range. For simplicity, the scale was constructed at a range of 100 km in figure 6-9. Applying the mil relation formula ($W/R = m$), an angle of 4 mils at a range of 100 km will produce an altitude of 400 m. Using the altitude index line, a horizontal line drawn from G will indicate 0 mils. Using the second arc up from point G on line CD, draw a horizontal line to the altitude index line. This indicates 4 mils. The same procedure can be used for other increments. Since the curvature of the earth and the bending of the radar beam both have been considered, the radar beam can be plotted as a straight line.

c. DA Form 11-47. DA Form 11-47 (Profile Chart) also may be used to construct a coverage diagram. The form is scaled to plot altitudes in feet and ranges in miles. Conversion factors must be applied to use with the metric system. A mil scale is not provided but can be added as indicated in *b*(6) above.

CHAPTER 7
WORLD GEOGRAPHIC REFERENCE SYSTEM

7-1. General

a. The World Geographic Reference System (GEOREF) is used in all joint air defense operations. Air defense artillery units use GEOREF on early warning plotting boards, for gridding of PPI screens, and for reporting and entering installation and target positions into the air defense system.

b. GEOREF is a worldwide position reference system that may be applied to maps or charts graduated in latitude and longitude, regardless of projection. It is a method of expressing latitude and longitude in a form suitable for rapid reporting and plotting.

7-2. Geographic Coordinates

The geographic coordinate system divides the earth's surface into quadrangles formed by parallels of latitude and meridians of longitude (fig. 7-1). Geographic coordinates are reported as latitude and longitude, respectively.

a. The distance a point is north or south of the Equator is called its latitude, and the rings around the earth parallel to the Equator are called parallels of latitude. Starting at the Equator, the parallels of latitude are numbered from 0° to 90°, both north and south. Thus the North Pole is 90° north and the South Pole is 90° south.

b. The distance a point is east or west of the base line (prime meridian) through the poles is called its longitude. The lines converging at the poles are called meridians of longitude. The prime meridian is the meridian that passes through Greenwich, England. From the prime meridian,

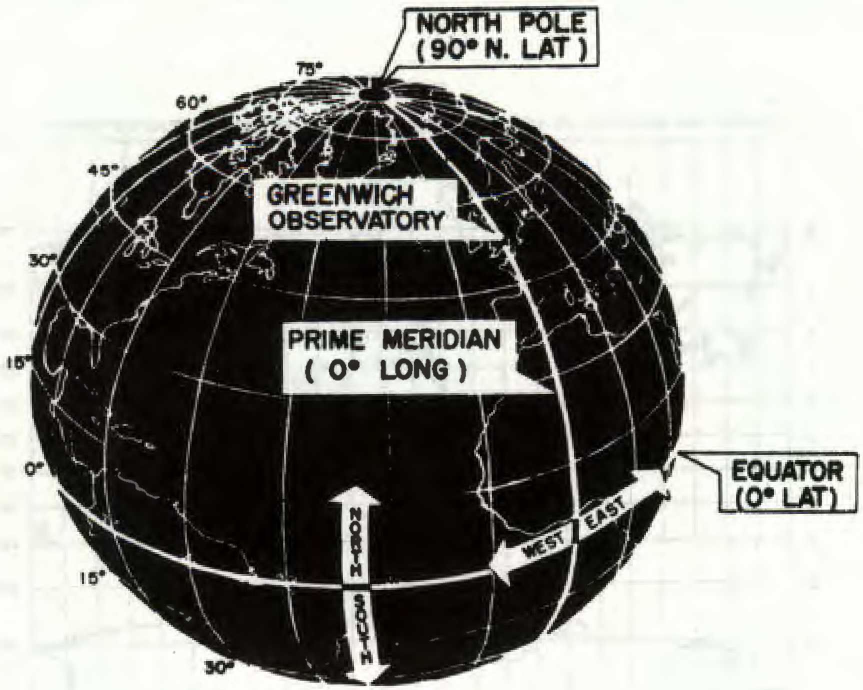


Figure 7-1. Geographic coordinates.

longitude is measured both east and west around the world to the meridian exactly opposite the prime meridian. Lines west of the prime meridian are numbered from 0° to 180° and are called west longitude. Lines east of the prime meridian are also numbered from 0° to 180° and are called east longitude.

7-3. The GEOREF Identification Code

The GEOREF system uses an identification code divided into three main divisions. The GEOREF designations are read by the same rule as military grid coordinates: READ RIGHT—UP. The complete GEOREF coordinate is expressed by combining the identification letters for the first and second divisions with the numbers identifying the third division.

a. First Division. To construct the first division (15° quadrangles) the surface of the earth is divided into 24 longitudinal zones of 15° each and 12 latitude bands of 15° each (fig. 7-2). The longitudinal zones are lettered A through Z (omitting I and O) eastward from the 180th meridian. The first letter of a GEOREF designation signifies in which longitudinal zone a point is located. The 12 bands of latitude are lettered A through M (omitting I) northward from the South Pole. The second letter in a GEOREF designation signifies in which latitude band a point is located.

b. Second Division. To construct the second division (1° quadrangles) each 15° quadrangle is further divided into 1° quadrangles by dividing it into 15 longitudinal zones of 1° east and west and 15 latitudinal bands of 1° north and south (fig. 7-3). The longitudinal zones are lettered west to east from A through Q (omitting I and O). The third letter of a GEOREF designation signifies in which 1° longitudinal zone (within the 15° quadrangle) a point is located. The latitudinal bands are lettered south to north A through Q (omitting I and O). The fourth letter of a GEOREF designation signifies in which 1° latitude band (within the 15° quadrangle) a point is located.

c. Third Division. To construct the third division (1′ quadrangles) each 1° quadrangle is divided into 1′ quadrangles by dividing the 1° quadrangle into 60 longitudinal zones of 1′ east and west and 60 latitudinal bands of 1′ north and south (fig. 7-4). The longitudinal zones are numbered west to east from 00 through 59. The latitudinal bands are numbered south to north from 00 through 59. The first pair of numbers of a GEOREF designation signifies in which 1′ longitudinal zone (within the 1° quadrangle) a point is located. The second pair of numbers of a GEOREF designation signifies in which 1′ latitu-

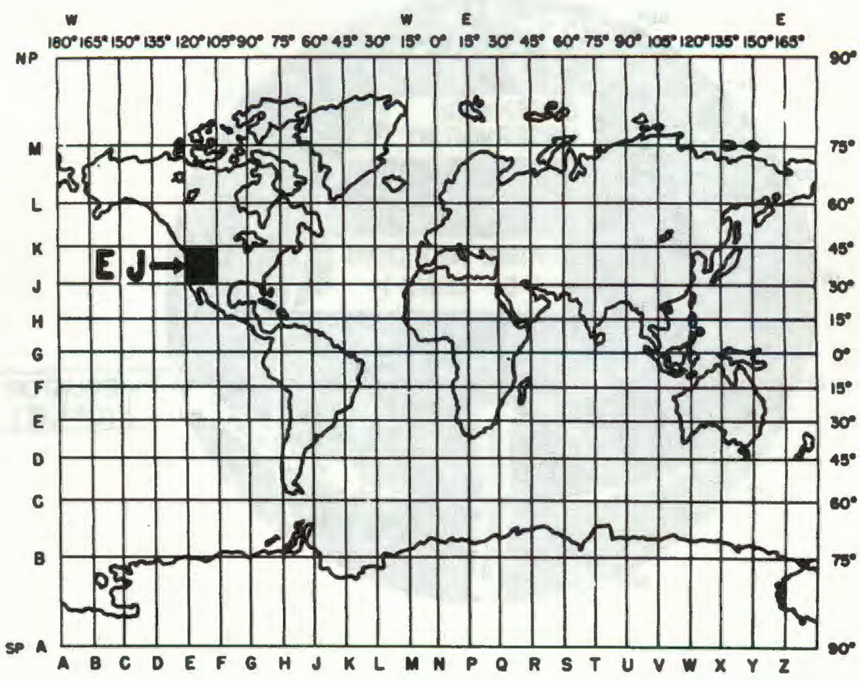


Figure 7-2. First division, 15° quadrangles.

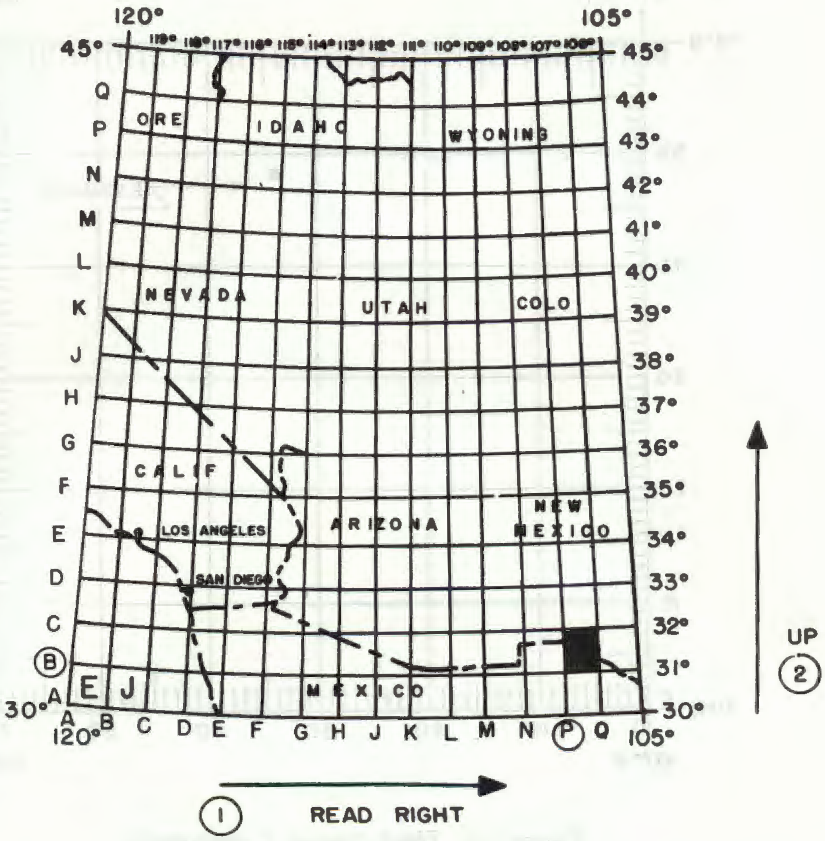


Figure 7-3. Second division, 1° quadrangles.

dinal band (within the 1° quadrangle) a point is located.

d. Quadrangles. The manner of lettering and numbering quadrangles does not vary even though the location may be east or west of the prime meridian or north or south of the Equator. A third division quadrangle encompasses an area approximately one nautical mile on a side. (One minute of latitude is approximately one nautical mile in length at the Equator. The length of 1′ of latitude gradually decreases, going away from the Equator, until it becomes zero at the poles.)

e. Example.

(1) The geographic coordinates of El Paso, Texas, are 31° 48′ 06″ N; 106° 25′ 48″ W. As indicated in figures 7-2, 7-3, and 7-4, the component parts of GEOREF coordinates of the El Paso, Texas area are:

(*a*) First division (15° quadrangle)—EJ.

(*b*) Second division (1° quadrangle)—PB.

(*c*) Third division (1′ quadrangle)—3348.

(2) The complete GEOREF coordinates are EJPB3448.

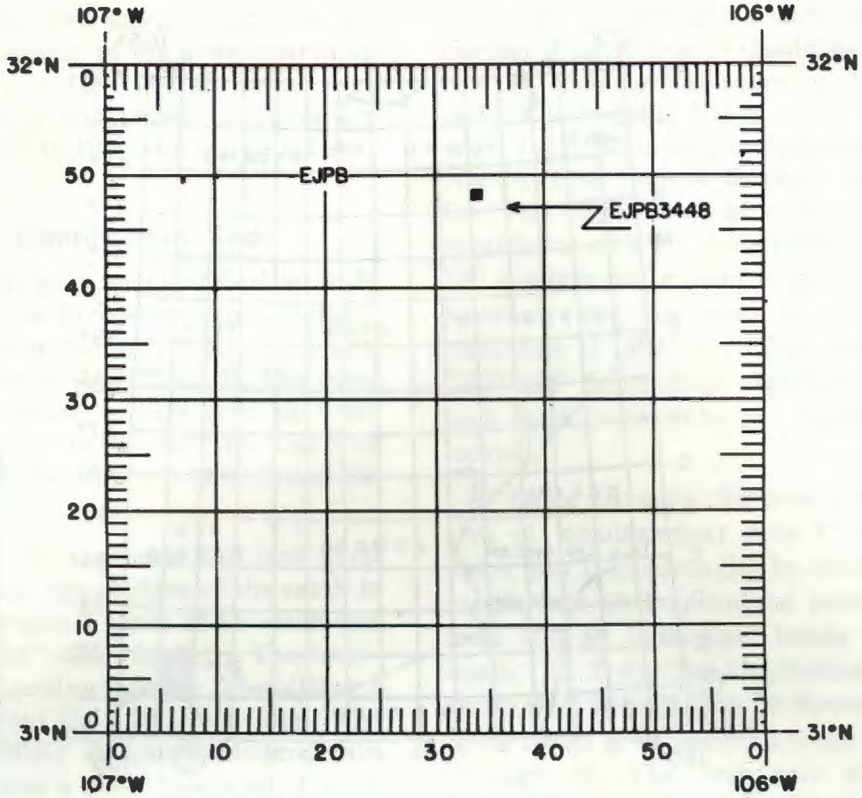


Figure 7-4. Third division, 1' quadrangle.

7-4. Conversion of Geographic Coordinates to GEOREF Coordinates

a. The first division of GEOREF coordinates is converted from geographic coordinates by determining in which 15° longitudinal zone (eastward from the 180th meridian) and 15° latitudinal band (northward from the South Pole) the point is located. *Example:* Geographic coordinates of a position are Lat 29° 13′ 54″ N; Long 104° 21′ 06″ W. Determinations of the first division of GEOREF coordinates as shown in figure 7-5 is FH.

b. The second division of GEOREF coordinates is converted from geographic coordinates by determining in which 1° longitudinal zone and 1° latitudinal band within the 15° quadrangle the point is located. Determination of the second division of GEOREF coordinates, as shown in figure 7-6, is AQ.

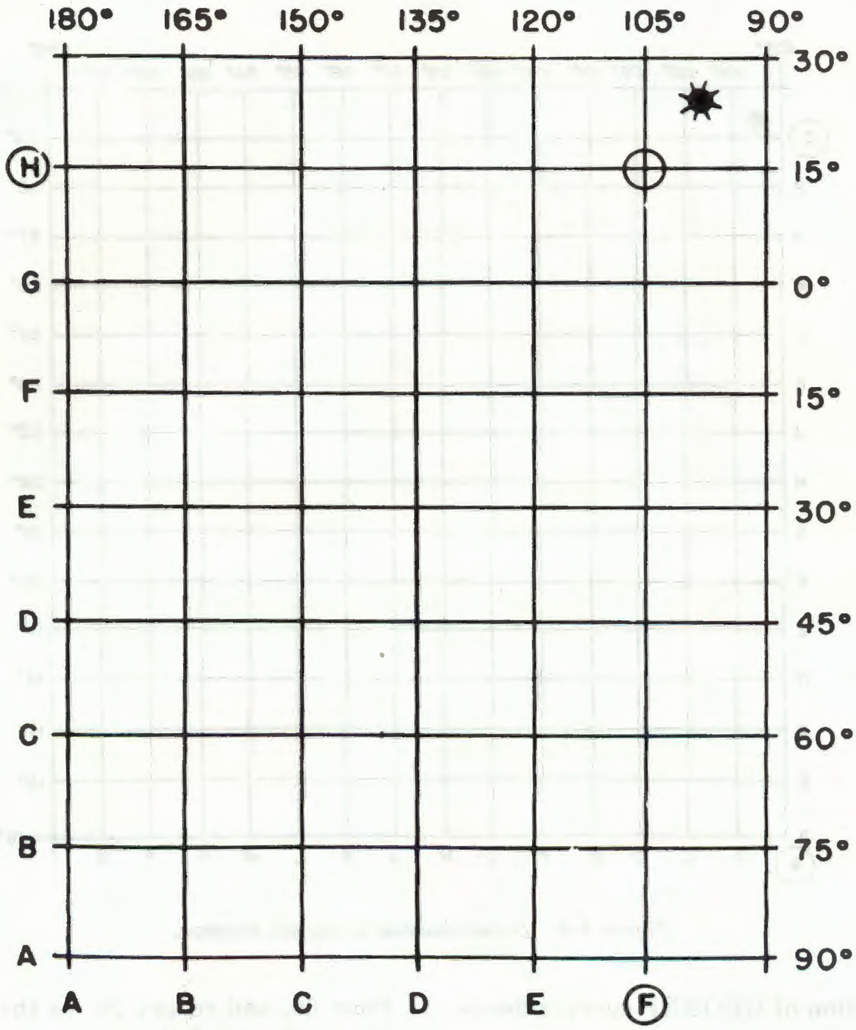


Figure 7-5. Determination of first division.

c. Determination of the third division of GEOREF coordinates is facilitated by the use of the following rules:

(1) *Rule 1.* If a point is located *north* in latitude or *east* longitude, the minute location of the geographic coordinates is the numerical designation of the third division of GEOREF.

(2) *Rule 2.* If a point is located *south* in latitude or *west* in longitude, round the minute location up to the next higher minute, subtract from 60, and record the remainder as the third division of GEOREF.

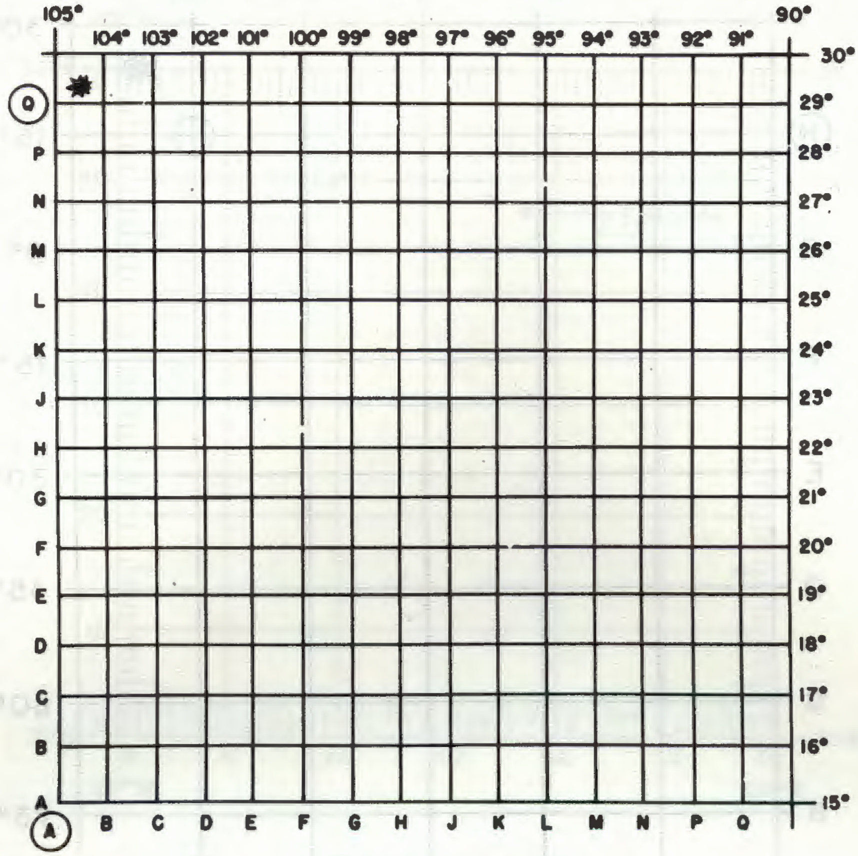


Figure 7–6. Determination of second division.

d. The third division of GEOREF coordinates is converted from geographic coordinates in the above example by using Rule 2 for longitude and Rule 1 for latitude.

(1) *Longitude.* Round 21′ to 22′, subtract from 60, and record 38′ as the longitude designation of the third division.

(2) *Latitude.* Record minute location 13′ as the latitude designation of the third division.

e. The complete GEOREF coordinates for the above example, therefore, are FHAQ3813.

APPENDIX A
REFERENCES

Department of the Army pamphlets of the 310-series should be consulted for latest changes or revisions of references given in this appendix and for new publications relating to material covered in this manual.

A-1. Army Regulations (AR)

310-25	Dictionary of United States Army Terms.
310-50	Authorized Abbreviations and Brevity Codes.

A-2. DA Pamphlet (DA Pam)

39-3	The Effects of Nuclear Weapons.

A-3. Field Manuals (FM)

1-60	Army Air Traffic Operations.
6-2	Artillery Survey.
6-20-1	Field Artillery Tactics.
11-21	Tactical Signal Communications Systems, Army, Corps, and Division.
21-26	Map Reading.
21-40	Chemical, Biological, Radiological, and Nuclear Defense.
21-41	Soldier's Handbook for Defense Against Chemical and Biological Operations and Nuclear Warfare.
23-17	Redeye Guided Missile System.
(C) 23-17A	Redeye Guided Missile System (U).
23-65	Browning Machinegun Caliber .50 HB, M2.
24-1	Tactical Communications Doctrine.
30-5	Combat Intelligence.
(C) 32-5	Signal Security (SIGSEC) (U).
(C) 32-20	Electronic Warfare (Ground Based) (U).
(S) 32-20-1 (Test)	Electronic Warfare (Ground Based) (U).
44-1	U.S. Army Air Defense Artillery Employment.
(S) 44-1A	U.S. Army Air Defense Artillery Employment (U).
44-2	Air Defense Artillery Employment, Automatic Weapons, M42/M55.
44-3	Air Defense Artillery Employment, Chaparral/Vulcan.
44-4	Procedures and Drills for Chaparral Self-Propelled Weapon System.
(C) 44-4A	Procedures and Drills for Chaparral Self-Propelled Weapon System (U).
44-5	Procedures and Drills for Vulcan Self-Propelled Weapon System.
*44-6	Procedures and Drills for Forward Area Alerting Radar.
44-30	Visual Aircraft Recognition.
44-57	Procedures and Drills: Multiple Caliber .50 Machinegun Trailer Mount M55.
44-61	Procedures and Drills for Twin 40-mm Self-Propelled Gun M42 and M42A1.
44-62	Air Defense Artillery Automatic Weapon Gunnery.
44-82	Procedures and Drills for Nike Hercules Missile Battery.

* To be published.

(C) 44-82A	Procedures and Drills for Nike Hercules Missile Battery (U).
44-95	Air Defense Artillery Employment, Nike Hercules.
44-96	Air Defense Artillery Employment, Hawk.
44-99	Procedures and Drills for Hawk Missile Battery (Towed and Self-Propelled).
61-100	The Division.
100-5	Operations of Army Forces in the Field.
101-5	Staff Officers' Field Manual: Staff Organization and Procedure.

A-4. Technical Bulletins (TB)

(C) 380-6-1	Improved Electronic Security for the Hawk Air Defense Guided Missile System (U).
(C) 380-6-2	Improved Electronic Security for the Improved Nike Hercules Air Defense Guided Missile System (U).

A-5. Technical Manual (TM)

11-673	Generation and Transmission of Microwave Energy.

A-6. Joint Chief of Staff Publications (JCS)

Pub 1	Dictionary of United States Military Terms for Joint Usage.
Pub 2	Unified Action Armed Forces (UNAAF).
(O) Pub 8	Doctrine for Air Defense from Oversea Land Areas.
(O) Pub 9	Doctrine for the Unified Defense of the United States Against Air Attack.
(O) Pub 12	Tactical Command and Control Procedures for Joint Operations.

APPENDIX B

SAMPLE AIR DEFENSE SOP AND OPERATION PLAN

B-1. Sample Air Defense Annex to an Independent Corps Standing Operating Procedure

Note. This is a sample SOP for an ADA group composed of one Nike Hercules battalion, two Hawk (SP) battalions, and one Chaparral/Vulcan (SP) battalion. The ADA group is attached to an independent corps in a joint task force that includes the corps and major Tactical Air Force elements.

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1st (US) Corps
Iberian Peninsula
162400 August 19 ___

Annex ______ (Air Defense) to SOP, 1st (US) Corps

Section I. GENERAL

1. References.

a. FM 21-40.

b. FM 44-1.

c. FM 44-1A.

d. FM 44-1-1.

e. FM 44-3.

f. FM 44-95.

g. FM 44-96.

h. FM 101-5.

i. 9th (U.S.) TAF TACSOP: Air Defense.

j. 507th TACON Gp TACSOP 55-2: Air Traffic Regulation and Identification Procedures.

2. Applicability.

a. The provisions of this SOP are applicable to all Army ADA units organic, attached, or assigned to elements of this corps.

b. For use of air defense weapons in ground fire support role, refer to Annex ______ (Fire Support).

c. Passive air defense (refer to unit SOP's).

3. Purpose.

a. Standardize operating procedures of all *Army ADA with the Corps.*

b. Establish internal staff coordinating procedures on matters pertaining to air defense.

c. Provide guidance for air defense coordination requirements with other Services.

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d. Establish rules of engagement, defense conditions of readiness (DEFCON), air defense warning, weapon control case, weapon control status, special control instructions, and states of alert for all Army ADA operating with the corps.

e. Provide a basis for subordinate unit SOP's.

4. Organization.

a. 406th Arty Gp (AD).
2d Bn (Hawk, SP), 72d Arty.
4th Bn (Hawk, SP), 10th Arty.
3d Bn (Nike Hercules), 50th Arty.
1st Bn (Chaparral/Vulcan), 67th Arty.

b. Division ADA Units.
3d Bn (Chaparral/Vulcan), 15th Arty, 8th Inf Div.
5th Bn (Chaparral/Vulcan), 1st Arty, 20th Inf Div.
2d Bn (Chaparral/Vulcan), 18th Arty, 26th Armored Div.

5. Unit Procedures.

a. ADA units, to include divisional ADA, will issue SOP to conform.

b. 1st Bn (Chaparral/Vulcan), 67th Arty, SOP will contain procedures to provide air defense to 19th Armored Cavalry Regiment on order. Procedures will cover actions necessary to effect tactical mission of direct support, or attached status.

c. 2d Bn (Hawk, SP), 72d Arty, and 4th Bn (Hawk, SP), 10th Arty, SOP's will contain procedures to provide air defense to the divisions on order. Procedures will cover actions necessary to effect tactical mission of direct support or attached status.

6. Abbreviations and definitions.

Refer to appendix ________

7. Responsibilities.

a. Corps air defense officer. The Commander, 406th Arty Gp (AD), is designated the corps air defense commander (CADC). The CADC is the principal adviser to the corps commander on air defense matters and for the employment of Army air defense means. Direct coordination with the joint air defense commander (JADC) is authorized for the development, change, and implementation of the joint air defense plan. The CADC, in joint effort with the corps aviation officer, will establish the airspace control element (ACE) in the corps tactical operations center (CTOC) and will establish procedures for the overall coordination of airspace control. He will also establish liaison with the 9th (U.S.) TAF tactical air control center (TACC) and control and reporting center (CRC). He is responsible for informing the CTOC of those air defense rules and procedures applicable to all-arms air defense weapons.

b. Chief, ACE. The chief, ACE, represents the CADC and the corps aviation officer in the CTOC and will function as a member of the corps staff. His primary functions are to coordinate Army ADA operations and

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airspace utilization with other combat and combat support operations. He will advise other elements of the CTOC on capabilities and employment of ADA to include surface-to-surface fires and intelligence gathering capabilities. He is responsible for informing all interested CTOC elements of the current air defense rules and procedures for use of all-arms air defense weapons.

c. ADA liaison officers with Army augmentation elements. The senior ADA liaison officers on duty with the Army augmentation elements at the 9th (U.S.) TAF TACC and CRC will represent the CADC in accordance with prescribed authority, policy, and procedures. They will function as members of the joint air defense staff while on duty and will insure the timely coordination of all Army ADA matters and exchange of intelligence information between the liaison stations and the group AADCP.

d. Divisional ADA commanders. Divisional ADA unit commanders responsibilities are defined by the division commanders (para 12a).

e. All commanders. Commanders at all echelons have the responsibility to insure the protection of their forces and equipment from enemy air attack by taking whatever action is required. Such actions will normally be governed by rules and procedures established by the CADC or JADC. Emergency action deemed necessary, if contrary to established rules, should be carefully weighed for its effect on the operations and safety of other friendly forces and, if taken, reported to the CADC at the earliest practical time. The right of self-defense against air and ground attack and the exercise of the technique of withholding fires of all-arms air defense weapons to preclude position disclosure is not denied.

Section II. INTELLIGENCE

8. General.

a. All corps ADA units function as information collection agencies for the corps G2. The ADA units pass and receive intelligence from the group AADCP. The group AADCP passes and receives intelligence from the ADA liaison officers at the TACC and CRC and from subordinate ADA battalions. The corps ACE exchanges intelligence with the division ACE's. The corps ACE serves as an intelligence coordination center for matters pertaining to air defense and insures that air defense intelligence activities are integrated with other intelligence activities of the corps.

b. ADA intelligence will be disseminated over the ADA group intelligence net to ADA units. The corps G2 will pass air defense intelligence pertinent to all ground units over the corps warning nets.

9. Desired air defense and air threat information.

The following types of information are desirable to provide adequate intelligence:

a. Location of enemy airfields.

b. Expected enemy air tactics.

c. Enemy aircraft including number and type.

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d. Enemy air defense capabilities.

e. ECM and ECCM operations.

f. Warning if impending enemy air strikes and airborne operations.

g. Warning of enemy ground attack.

h. Number, type, and location of downed enemy aircraft.

i. Location of enemy air defense units.

j. Flak analysis information.

k. Weather.

10. Army aviation.

Intelligence data is normally provided from flight operations center (FOC) to the aviation liaison officer at AADCP. It may be provided from FOC to ACE to group AADCP. It may also be received from Army ADA augmentation elements at CRC to group AADCP when flight operations center and the air traffic regulations center (FOC/ATRC) are collected.

11. Operations, corps/division G2 sections.

Intelligence is gathered from all Army sources. Pertinent information is forwarded to the ACE, then to group AADCP. Flash precedence is assigned to initial reports of enemy CBR employment. These reports should be submitted in accordance with the provision of paragraph 14c(5). Warning of airstrikes and airborne assaults are forwarded immediately through operational channels.

Section III. OPERATIONS

12. Air defense.

a. General.

(1) Joint task force (JTF) commander assigns overall responsibility for air defense to the joint air defense commander (JADC).

(2) The JADC (Commander, 9th U.S. TAF) coordinates the JTF air defense effort.

(3) The deputy joint air defense commander (DJADC) (Commander, 406th ADA Group) assists the JADC.

(4) Operational control of organic, assigned, and attached ADA units and Redeye air defense sections is delegated by JADC to the corps commander. Operational control of ADA units organic or attached to divisions is further delegated to division commanders. Operational control of Redeye air defense means is delegated to the using commanders.

(5) Corps air defense commander (CADC) is further delegated operational control of ADA units remaining under corps control. CADC is responsible to coordinate the air defense of the corps, including all divisions assigned or attached and all other elements of the corps.

(6) All elements of the corps are subject to the air defense rules of engagement and coordinating instructions of the JADC and CADC as specified in this SOP and otherwise directed in operations directives.

b. Coordination and responsibility. The CADC exercises his authority and fulfills his responsibility in air defense matters through the corps

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AADCP. He establishes liaison with the JADC at the 9th U.S. TAF TACC and CRC. The CADC advises the corps commander on air defense matters and coordinates air defense operations through the ACE in the CTOC. Together with the corps aviation officer, he coordinates the use of corps airspace through the ACE.

c. Deployment of air defense means.

(1) The CADC plans the Army air defense of the corps subject to JADC rules and procedures for integration of corps air defense into the overall air defense plan.

(2) The JADC will be apprised of impending or accomplished Hawk fire unit movement and Chaparral/Vulcan battalion redeployments in the interest of overall air defense coordination. Coordination of ADA redeployment with ground operations will be affected by the ACE.

d. Exchange of information.

(1) Adjacent ADA groups or Naval forces. Air defense information will be exchanged to extend radar coverage and to coordinate air defense activities.

(2) Tactical Air Force (TACC/CRC). To coordinate the air defense effort, minimum data flow is as follows:

(a) The following information must be passed from the ADA units via intermediate control facilities to the Tactical Air Force CRC.

1. From Nike Hercules and Hawk units.

(a) Weapon system status.
(b) Raid size and direction of threat.
(c) Acquisition and tracking information.
(d) Weapon system location.
(e) Engagement status (to include kill assessment).
(f) Identification (friend, foe, or unknown).
(g) ECM reports.
(h) Nuclear warning message (Nike Hercules).
(i) After-action reports.

2. From Chaparral/Vulcan, M42, M55, and Redeye units.

(a) Major change in deployment and availability for air defense.
(b) After-action reports.

(b) The following information must be passed from the Tactical Air Force CRC to the ADA units via intermediate control facilities.

1. For Nike Hercules and Hawk units.

(a) Weapons conditions of readiness.
(b) Air defense warning.
(c) ADA weapon control status.
(d) Special control instructions.
(e) Identification.
(f) Raid size and direction of threat.
(g) Target(s) position (X, Y, and H).
(h) Initial weapon release conditions.
(i) ADA weapon control case.
(j) IFF codes and modes.

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2. For Chaparral/Vulcan, M42, M55, and Redeye units.
   (a) Air defense warning.
   (b) ADA weapon control status.

e. Control of ADA.

(1) DEFCON's and states of alert will serve as the basis for implementation of air defense rules of engagement that are in effect.

(2) SOP type rules and procedures promulgated by the JADC and CADC relative to aircraft identification and engagement are in accordance with the DEFCON's and states of alert.

(3) Chaparral and Vulcan squads must determine friendly or hostile character of each aircraft based on detailed visual identification criteria.

(4) Identification by forward Hawk platoons and batteries must be based upon speed, direction of flight, and altitude criteria; or electronic identification, friend or foe, response; or a combination of these methods as appropriate.

(5) The group AADCP is designated the primary AADCP for the corps. Alternate AADCP's are designated as follows:

(a) Secondary–3/50 Nike Hercules Bn.

(b) Tertiary–2/72 Hawk Bn (SP).

(6) Radar surveillance within the corps area will be coordinated by the CADC, who will establish and coordinate maintenance and radiation schedules consistent with the announced DEFCON, current threat, and passive air defense plan.

13. Employment of nuclear weapons.

a. Air defense nuclear weapons will be under the control of the corps commander subject to JADC rules and procedures.

b. Release of nuclear weapons will be in accordance with the joint commander's criteria for authentication.

c. MNBA's have been established to conform to FM 44–1A and the directives of the joint commander. (See reference, para 1i.)

d. Diversion of nuclear warheads allocated for surface-to-air employment to a surface-to-surface mission will be coordinated between this headquarters and the JADC. Normally, the contingency provisions in the allocation of warheads will satisfy this requirement.

e. Every effort will be made to warn friendly aircraft of nuclear fires. Refer to annex ______ (Airspace Utilization).

14. Preparation of corps air defense plans, orders, and reports.

a. The CADC is responsible for the preparation of the air defense plan and orders. Use of fragmentary and overlay orders is encouraged.

b. Plans and orders will provide for adequate coordination and intelligent reporting procedures and will contain sufficient guidance to enable subordinate units to operate autonomously when communications with higher echelons are disrupted or when so directed.

c. Operational reports and statistical data are required as follows:

(1) Each ADA battalion will submit after-action report(s) to the group AADCP for consolidation as soon as possible after engagement(s).

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(2) Operational reports will be submitted to the group AADCP and copies furnished to the ACE and Army augentation elements at TACC and CRC. These reports will reflect the following information:

(a) Current locations and status of ADA units.

(b) Dead areas (radar coverage and fires) as changes occur.

(c) Ammunition status and tactical action summary.

(3) Accidents or incidents involving aircraft or missiles of ADA with the corps will be reported through channels to the Iberian Air Force for investigation. Wreckage should be undisturbed and safety zones established as necessary. (Based on STANAG 3531).

(4) Bombing (BOMREP), shelling (SHELREP), and mortaring or rocketing (MORTREP) reports (STANAG 2008) are to be rendered as normal messages by the fastest means available. The following format, preceded by the code word (BOMREP, SHELREP, or MORTREP), is prescribed.

(a) Unit or origin (call sign, address group, or equivalent decoding).

(b) Position of observer (grid references preferred—encoded if it discloses location of headquarters or important observation post, or if method (f) 2, below, is used).

(c) Direction (degrees or mils measured clockwise from grid north).

(d) Time from.

(e) Time to.

(f) Area bombed, shelled, or mortared.

1. Grid reference (in clear), or,

2. Direction in degrees or mils from grid north to impact points and distance in yards or meters from observer (encoded).

(g) Number and nature of methods of delivery (guns, rocket launchers, aircraft, etc).

(h) Nature of fire (registration, harassing, bombardment, etc).

(i) Number, type, and caliber (measured or assumed).

(j) Time of flash-to-bang (omit for aircraft).

(k) Damage (encode, if required).

(5) Nuclear, chemical, and biological attacks are reported in accordance with reference paragraph 1a. Reports cover enemy or unidentified nuclear detonations and resulting radioactive contamination and enemy or unidentified biological or chemical attack and resulting contaminations.

15. Rules of engagement.

a. The following rules of engagement have been approved by the JTF commander and apply to all Army air defense fire units.

b. Aircraft will be identified as hostile or friendly, using the priority of means discussed in reference (para 1j).

c. Nothing in the identification criteria shall preclude a unit from making a hostile identification when an aircraft is committing a hostile act. Unless positive friendly identification has been made prior to the act, the following are considered hostile acts by an aircraft:

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(1) Attacking friendly troops or positions.

(2) Overfly of a restricted area.

(3) Discharging parachutists when aircraft is not obviously in distress.

(4) Engaging in mine-laying operations.

(5) Dropping flares at night over friendly territory.

(6) Violation of battle zone criteria.

(7) Bearing enemy military insignia or otherwise positively identified by visual means as an enemy aircraft.

16. Defense conditions of readiness (DEFCON).

a. Purpose. DEFCON's are used to establish and maintain an adequate state of preparedness commensurate with the intelligence estimate.

b. Dissemination. DEFCON's are announced through air defense channels and reflect the degree of preparedness deemed minimal by the JADC. CADC will respond to the announced DEFCON by adjusting the state of alert (para 21) of all corps ADA units in the defense.

c. Conditions. See reference (para 1i).

17. Air defense warnings.

a. Air defense warning is the means of announcing the JADC's evaluation of the air threat.

b. Air defense warning will be announced through air defense channels except when air attack automatically places air defense warning RED in effect.

c. Air defense warnings are announced as follows:

(1) Air defense warning RED: attack is imminent or in progress.

(2) Air defense warning YELLOW: attack is probable.

(3) Air defense warning WHITE: attack is not considered immediately probable or imminent.

18. Weapon control case. See reference (para 1i).

After a properly authenticated nuclear employment order has been received, the announced case (I, II, or III) will specify how warheads may be employed.

19. Weapon control statuses.

a. Weapon control statuses are used to establish the degree of control necessary, considering the concept of centralized direction and decentralized execution. Air defense commanders down to the group AADCP level may announce changes in statuses according to the air situation. Below the AADCP level, supported commanders may impose temporarily *increased* restrictions, as required.

b. The following weapon control statuses are prescribed:

(1) WEAPONS FREE: ADA units may engage any track not positively identified as friendly.

(2) WEAPONS TIGHT: ADA units may engage only those tracks

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positively identified as hostile. This is established as the *normal* status for divisional ADA, and involves visual determination of hostile character.

(3) WEAPONS HOLD: Do not fire. The right of self-defense is not denied.

(4) DISCRETE FIRE: ADA units may engage only those tracks assigned by the AADCP. Pertains to Nike Hercules and Hawk units only.

20. Special control instructions.

a. Special control instructions are used to modify other rules of engagement and to provide commanders the means to promptly respond to certain contingencies.

b. The following terms may be used to issue instructions to Nike Hercules and Hawk units regarding specific engagements.

(1) HOLD FIRE: do not open fire; stop firing. Missiles in flight will be destroyed. Fire units will cease tracking the target. (HOLD FIRE normally is ordered to protect friendly aircraft.)

(2) CEASE FIRE: refrain from firing on an airborne object. Missiles in flight are permitted to continue to intercept. Fire units will continue to track the target. (The CEASE FIRE command is ordered to permit a friendly interceptor time to complete his run on a hostile track and clear the area prior to a surface-to-air engagement.)

(3) CEASE ENGAGEMENT: disengage the specified track and prepare to engage another. Missiles in flight will be permited to continue to intercept. (CEASE ENGAGEMENT is ordered to divert a fire unit to a target of higher priority.)

21. States of alert.

In accordance with the announced DEFCON, the CADC will prescribe the state of alert for the various segments of the corps defense. States of alert are indicative of the time required for an ADA unit to respond to a fire order or to assume BATTLE STATIONS. States of alert are—

a. BATTLE STATIONS:
b. State I: 5 minutes.
c. State II: 30 minutes.
d. State III: 1 hour.
e. State IV: 3 hours.

Section IV. SERVICE SUPPORT

22. Administration: annex ______

23. Logistics: annex ______

24. 406th ADA group commander will establish ASR for subordinate units in annexes to operation orders.

Section V. COMMAND AND SIGNAL

25. Command. Annex ______ and current operation order.

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26. Signal.

a. SOI-SSI. ADA group SigO extracts information necessary as authorized.

b. Corps SigO provides external communications support when necessary.

(Signature)

Authentication

B-2. Sample Air Defense Annex to Field Army Operation Plan

Copy No. 10 of ____ copies
3d (US) Army
(Note 1) DACHAU (XY5837), GERMANY
031200 February 19____
LD9-K

Annex D (Air Defense Plan) to Operation Plan 3
Reference: Map, Central EUROPE, 1:250,000, Second Edition, AMS, Sheets M51, N51, O51, L50, M50, N50, O50, L49, M49, N49, O49, L48, M48, and N48.
Time zone: A
Task organization: Annex A (Task Organization) to Operation Plan 3

1. SITUATION

a. Enemy Forces.

(1) Annex B (Intelligence) to Operation Plan 3.

(2) Enemy air capable of 55 fighter and 30 bomber sorties daily (by massing aircraft, Aggressor can make a maximum of 340 sorties daily).

b. Friendly Forces.

(1) Air forces. Allied Air forces will—

(a) Continue support of 3d (U.S.) Army with 1st TAF.

(b) Destroy Aggressor aircraft and air installations, interdict Aggressor lines of communications, and deliver nuclear weapons.

(2) Navy forces. Allied Navy forces continue support of 2d (U.S.) Army Gp, with three air groups at RY3020.

(3) Army forces. Allied Army forces destroy Aggressor forces in the CHEMITZ(***)—PRAGUE(***)—BRUNN(***)—OLMUTZ(***) area in accordance with the following plan:

(a) 2d (U.S.) Army Gp attacks in direction CHEMITZ—PRAGUE; secures and defends PRAGUE area to prevent Aggressor movement from the east and to facilitate future friendly offensive operations to northeast; and prevents destruction of vital communication, rail, and airport facilities.

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(b) 3d (U.S.) Army Gp attacks in direction BRECIAV(***)—OLMUTZ—TROPPAU(***); secures, occupies, and defends TROPPAU area; prevents Aggressor movement; and prepares to support advance of 3d (U.S.) Army.

(4) Annex C (Operation Overlay) to Operation Plan 3.

c. Attachments and Detachments. Annex A (Task Organization) to Operation Plan 3.

d. *Assumptions.*

(1) Aggressor Air forces are capable of attacking 3d (U.S.) Army units and installations from any direction and at any time. (Anx D (AD Plan) to OPLAN 3—3d (U.S.) Army).

(2) There will be no major change in enemy air or friendly AD strengths.

2. MISSION

ADA elements available to 2d (U.S.) Army destroy hostile airborne aircraft and missiles or nullify or reduce their effectiveness over the 3d (U.S.) Army zone. ADA elements will attack surface targets on order.

3. EXECUTION

a. Concept of Operation.

(1) Responsibility for AD.

(a) CG, 44th (U.S.) Arty Bde (AD), is responsible to CG, 3d (U.S.) Army, for coordination of overall AD of 3d (U.S.) Army subject to the AD rules and procedures of the regional AD commander (CG, 1st TAF); establishes active AD against low- and medium-altitude air attack for field army service area; and establishes active AD against medium- and high-altitude air attack for entire field army area.

(b) CG, 18th (U.S.) Abn Corps, is responsible for active AD against low- and medium-altitude air attack in zone.

(c) CG, 24th (U.S.) Corps, is responsible for active AD against low- and medium-altitude air attack in zone.

(2) Priority is to the 9th U.S. TAF airfields in zone; SASP's (***, ___): 1st Bn (Persh), 305th Arty; 10th (U.S.) Army CP; FASCOM areas at (***, ___); bridges at (***, ___); and corps-designated priorities.

(3) Coordination measures. A coordinated SAM defense in depth will be established for the army area. AD zones of responsibility will be established to insure maximum utilization and effectiveness of radar surveillance, EW, ECM, and SAM and to minimize restrictive control measures. ADA liaison at CRC will provide EW and ident for army ADA elements and coordinate changes to rules and procedures.

b. 44th Arty Bde (AD):
403d Arty Gp (AD):
1st Msl Bn (Herc), 491st Arty
2d Msl Bn (Herc), 492 Arty
3d Msl Bn (Herc), 493d Arty

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4th Msl Bn (Herc), 494th Arty
5th Msl Bn (Herc), 495th Arty
6th Msl Bn (Herc), 496th Arty
404th Arty Gp (AD):
1st Msl Bn (Hawk) (Towed), 431st Arty
2d Msl Bn (Hawk) (Towed), 432d Arty
3d Msl Bn (Hawk) (Towed), 433d Arty
4th Msl Bn (Hawk) (Towed), 434th Arty
5th Bn (C/V), 451 Arty
6th Bn (C/V), 452d Arty
7th Bn (C/V), 453d Arty
(Anx D (AD Plan) to OPLAN 3—3d (U.S.) Army)

Provide army AD of army area; establish early warning net for army area in coordination with regional AD commander; coordinate defense acquisition radar coverage of army area with regional AD radar coverage; coordinate EW, ident, and ECM with regional AD commander; establish liaison and communications with AD region (CRC); coordinate movement and positioning of AD units for continuous coverage of maneuver forces and priorities subject to rules and procedures of regional AD commander; and provide personnel to ACE of FATOC.

c. 405th Arty Gp (AD):
3d Msl Bn (Hawk) (SP), 434th Arty
4th Msl Bn (Hawk) (SP), 435th Arty
5th Msl Bn (Hawk) (SP), 436th Arty
8th Bn (C/V), 454th Arty

Attached 18th (U.S.) Abn Corps. Group will establish liaison and communications with nearest CRP for EW, ident, and ECM coordination. ACE personnel will be provided to CTOC.

d. 406th Arty Gp (AD):
6th Msl Bn (Hawk) (SP), 437th Arty
7th Msl Bn (Hawk) (SP), 438th Arty
8th Msl Bn (Hawk) (SP), 439th Arty
9th Bn (C/V), 454th Arty

Attached 24th (U.S.) Corps. Group will establish liaison and communications with nearest CRP for EW, ident, and ECM coordination. ACE personnel will be provided to CTOC.

e. Coordinating Instructions.

(1) Appendix 1, AD Operation Overlay.

(2) 1st (U.S.) TAF AD Tactical SOP (not issued).

(3) Requests for restricted areas to this headquarters, attention: AD Section. Requests to include radius of area, altitude restrictions, and effective dates and times.

(4) HERC units be prepared to deliver surface fires within capabilities. Annex C (Fire Support Plan) to Operation Plan 3.

(5) IFF code changed as specified in joint operations instructions.

(6) MNBA: XL–7,000 feet above terrain; XS–5,000 feet above terrain.

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(7) AD nuclear burst warning will be transmitted at burst minus 30 seconds.

(8) This plan is effective for planning on receipt; for execution on order.

4. ADMINISTRATION AND LOGISTICS.

ADMINO. 4.
(Anx D (AD Plan) to OPLAN 3—3d (U.S.) Army)

5. COMMAND SIGNAL

a. Signal.
(1) Appendix 2, Signal.
(2) Current SSI, SOI.

b. Command.
(1) HQ, 44th (U.S.) Arty Bde (AD) (XY5539).
(2) 3d Army AD Section; DACHAU, GERMANY.
(3) Others report loc.

Acknowledge. (Note 1)

TEATOM
GEN (Note 1)

Appendixes: 1—AD Operation Overlay (omitted)
2—Signal (omitted)

Distribution: B

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/s/Wilson
WILSON
G3

Note 1. The heading, acknowledgement, command line, and authentication are required when an annex is issued by separate distribution.

(Classification)

APPENDIX C

CONVERSION TABLES

Table C-1. Conversion Table—Linear Measurements

Multiply number of → By ↘ / To Obtain ↓	Centimeters	Meters	Kilometers	Inches	Feet	Yards	Nautical miles	Statute miles
Centimeters		10^2	10^5	2.540	30.48	91.44	1.852 $\times10^5$	1.609 $\times10^5$
Meters	0.01		10^3	2.540 $\times10^{-2}$	0.3048	0.9144	1852	1609
Kilometers	$\times10^{-5}$	0.001		2.540 $\times10^{-5}$	3.048 $\times10^{-4}$	9.144 $\times10^{-4}$	1.852	1.609
Inches	0.3937	39.37	3.937 $\times10^4$		12	36	7.2918 $\times10^4$	6.336 $\times10^4$
Feet	3.281 $\times10^{-2}$	3.281	3281	8.333 $\times10^{-2}$		3	6076.115	5280
Yards	1.094 $\times10^{-2}$	1.094	1094	2.778 $\times10^{-2}$	0.3333		2025.372	1760
Nautical miles	5.4 $\times10^{-6}$	5.4 $\times10^{-4}$	0.5400	1.3715 $\times10^{-5}$	1.6416 $\times10^{-4}$	4.937 $\times10^{-4}$		0.8690
Statute miles	6.214 $\times10^{-6}$	6.214 $\times10^{-4}$	0.6214	1.578 $\times10^{-5}$	1.894 $\times10^{-4}$	5.682 $\times10^{-4}$	1.1508	

Table C-2. Conversion Table—Linear Velocity Measurements

Multiply number of → By ↘ / To Obtain ↓	Meters per second	Feet per second	Yards per second	Miles per second	Miles per minute	Miles per hour	Kilometers per hour	Knots
Meters per second		0.3048	0.9144	1609	26.82	0.4470	0.2778	0.5144
Feet per second	3.281		3	5280	88	1.467	0.9113	1.688
Yards per second	1.094	0.3333		1760	29.33	0.4889	0.3039	0.5626
Miles per second	6.214 $\times10^{-4}$	1.894 $\times10^{-4}$	5.682 $\times10^{-4}$		1.667 $\times10^{-2}$	2.7778 $\times10^{-4}$	1.726 $\times10^{-4}$	3.196 $\times10^{-4}$
Miles per minute	3.728 $\times10^{-2}$	1.136 $\times10^{-2}$	3.409 $\times10^{-2}$	60		1.667 $\times10^{-2}$	1.036 $\times10^{-2}$	1.918 $\times10^{-2}$
Miles per hour	2.237	0.6818	2.045	3600	60		0.6214	1.1508
Kilometers per hour	3.6	1.097	3.291	5793	96.54	1.609		1.852
Knots	1.944	0.5925	1.777	3128	52.14	0.8690	0.5400	

GLOSSARY

Standard definitions are contained in AR 310-25 and JCS Pub. 1. Standard abbreviations are contained in AR 320-50.

All-arms weapon—A weapon manned and employed by several using arms; e.g., Redeye and small arms.

Bomb release line (*BRL*)—An imaginary line around a defended area or objective over which an aircraft should release its ordnance to obtain a hit or hits on an area or objective.

Engagement effectiveness (*EE*)—The average kill capability of the defense, expressed as a percentage, against a particular raid size. The air defense commander specifies the degree of protection for each area in terms of engagement effectiveness. Values of EE may be obtained from figure 3-2.

Lay-down bombing—A very low-level bombing technique wherein delay-fuzed bombs are used to allow the attacker to escape the effects of his own bomb.

Low-altitude bombing system (*LABS*)—A low-level bombing technique wherein the attacker approaches the target at a very low altitude, makes a definite pullup at a given point, releases the bomb at a predetermined point during the pullup, and tosses the bomb into the target area.

Radar-directed weapon—A weapon system which employs radar for target detection and identification; e.g., Nike Hercules and Hawk.

Reaction time

1. The time delay, *in burst locator construction,* between detonation of one missile (or the last missile of a Hawk salvo) and liftoff of the succeeding missile (or first missile of a succeeding Hawk salvo) fired by the same unit at the same target.
2. The time delay between the time the target is detected and fired on.

Response time—The time delay, in burst locator construction, between the time the target enters detection range and liftoff of the first defending missile.

System effectiveness (*SE*)—The probability, expressed as a percentage, that a fire unit will acquire a single target within system design capability, deliver a single round that will burst within system design accuracy, and achieve the desired degree of target destruction. The numerical value for SE is based on empirical data and includes system reliability, crew performance, maintenance proficiency, and environmental factors.

Visually-directed weapon—A weapon system which depends primarily on the operator for target detection and identification; e.g., Redeye, Vulcan, and Chaparral.

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By Order of the Secretary of the Army:

W. C. WESTMORELAND,
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Chief of Staff.

Official:

KENNETH G. WICKHAM,
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The Adjutant General.

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To be distributed in accordance with DA Form 12-11 requirements for U.S. Army Air Defense Employment.

☆ U.S. GOVERNMENT PRINTING OFFICE : 1969 390-804/6457