AD-A018 749

AD
A018749

AMSAR/SA/N-25

AN EFFECTIVENESS EVALUATION OF SEVERAL ALTERNATIVE AUTOMATIC CANNON SYSTEM CONCEPTS

RICHARD A. FISCHER

AUGUST 1975

US ARMY ARMAMENT COMMAND

SYSTEMS ANALYSIS DIRECTORATE

ROCK ISLAND, ILLINOIS 61201

DISPOSITION

Destroy this report when no longer needed. Do not return it to the originator.

DISCLAIMER

The findings in this report are not to be construed as an official Department of the Army position.

WARNING

Information and data contained in this document are based on input available at the time of preparation. Because the results may be subject to change, this document should not be construed to represent the official position of the US Army Materiel Command unless so stated.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AMSAR/SA/N-25	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): An Effectiveness Evaluation of Several Alternative Automatic Cannon System Concepts	5. TYPE OF REPORT & PERIOD COVERED: NOTE - FINAL
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Richard Fischer	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Armament Command, Systems Analysis Directorate, Rock Island, Illinois 61201	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Army Armament Command, Systems Analysis Directorate, Rock Island, Illinois 61201	12. REPORT DATE: August 1975
	13. NUMBER OF PAGES: 41
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Automatic Cannons
Attack Helicopter
Long Range
Effectiveness
Target Acquisition
Delivery Error

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

This study estimated both the target acquisition capability of attack helicopters and the effectiveness levels achieved by automatic cannons against targets located beyond 2000 meters range. Line-of-sight, atmospheric visibility, and target detection probabilities were generated in the analyses of target acquisition. Five automatic cannon system concepts were evaluated. The cannon systems are described only by those characteristics affecting their target defeat capability. However, delivery errors were analyzed in detail.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Effectiveness levels against two personnel targets and three materiel targets were determined. The results show that target acquisition capability beyond 2000 meters range is limited. However, if the targets can be acquired each of the five cannon systems can defeat personnel targets at ranges up to 4000 meters. Only one system, a high performance, accurate 30mm cannon, achieves relatively high levels effectiveness against materiel targets.

SUMMARY

This study analyzed the operational environment of the attack helicopter to determine its ability to acquire targets located beyond 2000 meters range. The three primary measures used were terrain line-of-sight, atmospheric visibility, and target detection probabilities. Each measure was correlated to the tactics and engagements geometries expected to be used in a European environment.

This study also analyzed five alternative automatic cannon system concepts to determine their capability to defeat personnel and materiel targets located beyond 2000 meters. Two representative personnel targets--a crew-served weapons emplacement and troop formation; and three materiel targets-- a ZSU-23/4, a BRDM, and a ICV-BMP--were considered. However, attack helicopter survivability was not quantitatively addressed.

Results show that the attack helicopter has only a marginal capability to acquire targets at 3000 meters range and no capability to acquire them at ranges beyond 3000 meters. The two dominating factors which prevent target acquisition beyond 3000 meters are the terrain and weather characteristics of Europe.

The effectiveness analysis shows that each of the five automatic cannons can defeat personnel targets located at ranges up to 4000 meters. However, only one system achieves relatively high levels of effectiveness against the materiel targets.

PREFACE

The author thanks Mr. S. Wasserman and Mr. W. O'Keefe of the Aeroballistics Laboratory at Picatinny Arsenal and Mr. G. Schlenker of the ARMCOM Systems Analysis Directorate for their assistance in defining and analyzing the delivery errors of each of the automatic cannons considered in this report.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Next page is blank.

INTRODUCTION

In recent years, the effectiveness of attack helicopter automatic cannon systems has been evaluated extensively. Nearly all of the evaluations have presented effectiveness as a function of target type and engagement range. However, the ranges considered in these studies were usually less than 2000 meters. In fact, no known study adequately describes system effectiveness for engagement ranges greater than 2000 meters. The Armament Command RDT & E Directorate, recognizing this inadequacy, requested that the Systems Analysis Directorate conduct an analysis of the long-range (beyond 2000 meters) effectiveness of attack helicopter automatic cannons.

This report presents the analysis done in response to the RDT & E Directorate request. The analysis had two objectives: (1) to estimate the ability of the attack helicopter to acquire targets located beyond 2000 meters and (2) to determine the target defeat levels achieved by the automatic cannon systems.

The analysis which estimated attack helicopter target acquisition capability was based on experimental field test data. Only that data which could be directly related to current helicopter operational tactics were used.

Estimates of the target defeat levels were based on one attack helicopter against one passive materiel or personnel target, but the effectiveness estimates represented several alternative hypothetical automatic cannon systems. The descriptions of these alternatives were limited to those characteristics which had a direct correlation to on-target effectiveness. No detailed engineering drawings, specifications, or scale models were developed. The cannon system alternatives were limited to calibers between 20mm and 40mm. Subcaliber ammunition was not considered. Further, the engagement ranges were restricted between 2000 and 4000 meters. Neither attack helicopter attrition or survivability were considered.

APPROACH

Combat Environment

The attack helicopter's operational environment can be characterized by two indices--the geographic location and the enemy force. These two factors influence the helicopter's combat missions, the role of its armament systems, the tactics, and the target acquisition-target engagement sequence. However, it was not the objective of this analysis to evaluate the many possible combinations that could result but to consider only one which is most representative. Therefore, information about the combat environment required for this analysis was obtained from TRADOC documents[1,2] and from informal communications with personnel at the TRADOC schools and the Office of the Project Manager for the 2.75-Inch Rocket.

The attack helicopter has definite applications in low-, mid-, and high- intensity conflicts; however, its usefulness is most vividly portrayed in the mid-intensity European environment.[2] In a European conflict, attack helicopters will be an integral part of the land combat force, providing direct aerial fire support for armored and airmobile divisions. This general role is further defined in the three missions described in The Advanced Attack Helicopter Task Force Report. The three missions--delay, defense, and airmobile--reflect the different stages of a confrontation with an enemy force. The delay mission corresponds to the initial contact with the enemy, the defense mission corresponds to an intense attack by the enemy, and the airmobile mission corresponds to a counterattack action by our forces.

Although the descriptions of these missions define the role of the attack helicopter, they do not specifically define the individual roles of each armament system. However within each mission, each armament system was assigned responsibility for a distinct target. The automatic cannon system, for example, was used in engagements with enemy weapons crews, troop formations, personnel carriers, combat vehicles, and air-defense systems. The BRDM with missles, the ICV-BMP, and the ZSU-23/4 were representative of these types of targets and were used in this analysis to evaluate automatic cannon effectiveness.

In addition to describing the target responsibilities of each armament system, the mission profiles describe the tactics employed by the attack helicopter. Although each mission had a different objective, the tactics used to achieve it were essentially the same. The sequence of events in the mission began when a scout helicopter or ground observer locate and identify the enemy targets. This information was relayed to the division's attack helicopter holding area and the engagement was planned. A flight path to the target area and possible firing positions were predetermined in the planning session. However, since communication links existed between the observer and the attack helicopter, up-to-date information could be provided on target movement

---

[1] AH56A Phase III Study (U), Vol. IV, Appendix I, Annex D, U.S. Army Combat Developments Command, Washington, D.C., November 1967, SECRET.

[2] Advanced Attack Helicopter Task Force Report (U), US Army Combat Developments Command, Advanced Attack Helicopter Task Force, July 1972 CONFIDENTIAL.

[2] Ibid. Appendix I.

while the aircraft was in flight. Thus, the plan of attack could be modified as required. In a typical scenario, the helicopter flies nap-of-the-earth (NOE) from the holding area to one of the possible firing positions; it "pops-up" above terrain mask, acquires the target, and employs its armament. These final steps in the engagement sequence can be repeated until either the helicopter or the target is defeated or until all the helicopter's munition load is expended.

Target Acquisition.

The target acquisition analysis was divided into three parts: (1) the determination of the engagement geometries used in an attack, (2) the investigation of the effects the ambient environment had upon the attack helicopter's ability to engage targets, and (3) the estimation of the attack helicopter's target acquisition capability.

An engagement geometry was defined by two factors: the range from the "pop-up" firing position to the target and the altitude required to establish an uninterupted line-of-sight. Of these two, the limiting factor in an engagement was the maximum effective range of the armament system. In this analysis each automatic cannon system had at least a 4000 meter range.

The altitude used in an engagement was not affected by the characteristics of the armament systems, but terrain features did influence it. There were many possible altitude-range combinations; however, to represent them, two altitudes derived from the environmental data were used as the lower and upper tactical limits in an engagement.

The engagement geometries were also used in the investigation of the environmental factors which influenced the ability of the attack helicopter to engage long-range targets. Data on only two factors were accumulated for the European Environment: (1) the probability of a line-of-sight as a function of range and (2) the probability of having both cloud ceiling and atmispheric visibility suitable for long-range target engagement. These data were analyzed to determine the frequency of long-range engagements when operating, using current tactics and geometries. Additionally, since both measures were statistically independent, a single probability measure was obtained. This measure, which was a function of season and altitude, was the frequency that the attack helicopter could expect to see to a specific range.

Estimates of the attack helicopter's ability to acquire targets were developed through an analysis of field test data. However, before the analysis was started, the attack helicopter's missions and tactics were reviewed to determine what procedures the attack helicopter would follow to acquire a target. To properly interpret these procedures, it was necessary to define target acquisition. The following definition of the target acquisition process was used in comparing the acquisition procedures.

Target acquisition is the process through which the correct choice of a target is made from a number of possible alternatives. The basic information required to make this decision is usually obtained visually. This information is divided into three levels. These levels are sequential, and each represents an increase in the knowledge of the target's identity and location. The first level, detection, is an awareness that an object is a possible target but unaware of what it actually is. The second level, recognition, is the categorization of the object as a general target type. The final level, identification, is the specific classification of the object, for example, as a Zil-157 truck. Target acquisition is not completed until the object has been identified.

The results of the comparison between this target acquisition process and that process used by the attack helicopter guided the literature search and analysis. Only that data which was directly related to the defined operational tactics were used.

Automatic Cannon System Description.

The alternative automatic cannons and their ammunition were defined only by those functional characteristics which affected their target-defeat capability. In the development of these alternatives, three specific requirements were established: (1) the weight and impulse of the cannon had to be within the limits imposed by the structure of an attack helicopter, (2) the automatic cannon had to have at least a 4000 meter range capability, and (3) the caliber was to be between 20mm and 40mm. The automatic cannon ammunition also had to meet three basic requirements: first, if possible, all rounds had to have both a personnel and a materiel target defeat potential (high explosive, dual purpose); second, each round had to be aerodynamically stable; and third, each round had to be full caliber--no subcaliber projectiles were considered.

Delivery Error.

Personnel at the Aeroballistics Laboratory at Picatinny Arsenal were tasked to investigate the ammunition delivery mechanism of each alternative automatic cannon system. This investigation considered an attack helicopter firing platform equipped with a fire control system reflecting the most recent advances in technology. These advances included a laser range finder which operated in conjunction with a stabilized electro-optical sight, and a wind-sensing device which provided input to the fire control computer to correct the automatic cannon position for environmental winds. It was assumed that the laser range finder had an error of 10 meters (standard deviation) in the estimate of the ground range. However, no error was associated with the wind sensor. Another error, a 5 mil standard deviation in the automatic cannon quadrant elevation was assumed to account for those delivery effects not fully corrected by the fire control systems. These effects included the inability of the gunner to hold the sight setting on the aimpoint, malaignment errors between the sight setting and the actual cannon setting, and cannon movement from round to round due to recoil. Also considered in the analysis were thevariations in the ballistic properties of the different projectiles. The cumulative effect of three ballistic parameters--muzzle velocity, aerodynamic drag, and projectile weight--was determined by successive applications of constant unit effect multipliers. For example, the ammunition muzzle velocity of each alternative automatic cannon was varied by .41% (one standard deviation), and the effect of this variation on the projectile's trajectory was determined. Likewise, the drag of each projectile was varied by .20% and the weight by .25%. The total ballistic error was estimated by root-mean squaring the effects of each ballistic parameter. The total delivery error was determined by combining (root-mean squaring) the individual error components into one.

Automatic Cannon System Effectiveness Estimation.

Three indices were used to estimate the on-target effectiveness of each automatic cannon system: (1) percentage of personnel casualties, (2) percentage of personnel suppressed, and (3) the probability of killing a lightly armored vehicle. The effectiveness estimates were computed by three Monte Carlo computer simulations. The methodology of each simulation followed the same mathematical procedures, departing from the basic logic only to accommodate the different measures of effectiveness.

The computation process in each simulation was initiated by the sequential selection of random normal deviates representing the range estimation, quadrant elevation, and ballistic errors. The first random deviate was chosen from the range estimation error distribution which was centered at the target aimpoint. The point selected to represent the range estimate then became the center of the quadrant elevation error distribution. Likewise, the center of the ballistic error distribution was the coordinates of the point representing the quadrant elevation error. The range estimation error was randomly sampled only once during an engagement. The quadrant elevation and ballistic errors were sampled for each round fired.

The percentage of personnel casualties measured automatic cannon system capability to defeat personnel targets. Casualties were assessed on two circular targets, 5 meters and 50 meters in radius, representing a crew-served weapon emplacement and a troop formation, respectively. Target personnel were randomly distributed in each target area, all in full winter uniform (helmet on). At the start of the attack all troops were standing, but after the arrival of the first burst of ammunition all were prone. In each attack against either target, 200 rounds of ammunition were fired in five bursts of 40 rounds.* These bursts were fired at the center of the 5m radius target and a five different points on the 50m radius target.

The antipersonnel lethality of a single round was computed, using the standard mathematical procedures described in the JTCG/ME Basic Methodology Handbook[3]. The spatial distribution of projectile fragments published in the JTCG/ME Weapons Characteristics Manual[4] were required as input. These computations resulted in munition damage patterns which represented the distribution of the probability of kill as a function of the distance from the center of burst. In the simulation, these damage patterns were superimposed on the target, centered at the projectile's impact point. The cumulative effect of successive rounds were computed by standard mathematical integration techniques.

The percentage of personnel suppressed was estimated by a method quite similar to that used to compute the percentage of casualties. The primary difference between the two methodologies was the inclusion of time in the suppression simulation. Suppression was defined as the probability that an individual soldier becomes a casualty or is forced into a protected position for a specific period of time. The percentage of the target suppressed is the sum of the number of casualties and the number of troops in a protected state. It is expressed as a function of time. To evaluate automatic cannon suppressive capability, an attack against a 100 meter radius target was simulated. A minimum of 200 rounds were fired in bursts of 40 rounds; each burst was fired at a different aimpoint. Initially, all troops were standing; their only protection was to assume a prone position. As in the casualty simulation, the impact point of a round was determined; the damage pattern was superimposed on the target, and the casualty levels were computed. Suppression was then estimated by determining the probability of kill-level sensed by the non-casualty troops. If the troops sensed a probability of kill greater than the threshold value (PK=.001), they were forced to the prone position for a minimum time (minimum time = 5 sec.). Total time suppressed was increased by successive rounds landing close enough to affect the soldier. When the troops did not sense the threshold probability of kill,

---

*Two hundred rounds represents the expected number of rounds that will be fired in any given engagement. This was derived from the AAH Task Force Report Appendix I.

[3]Basic Methodology Handbook (U), TH61A1-3-6, JTCG/ME, Aberdeen Proving Grounds, MD., CONFIDENTIAL.

[4]Weapons Characteristics Manual (U), TH61A1-3-2, JTCG/ME, Aberdeen Proving Grounds, March 1969, CONFIDENTIAL.

they returned to the standing position.

The capability of the automatic cannon systems to defeat materiel targets was estimated, using the probability of achieving a mobility (M) or firepower (F) kill, given a random hit on the target. In an engagement only one materiel target was attacked, with the aimpoint being the center of the vehicle's dimensions. Cumulative vehicle damage was calculated as a function of the number of hits achieved. A projectile hit the target if its impact point was within the boundaries of the vehicle's presented area, which is the total area of the vehicle presented to the incoming projectile. This area varies in size as a function of the projectile's trajectory.

Assumptions.

Effectiveness estimates were based on the following assumptions:

1. A line-of-sight and atmospheric visibility existed to the target area in each engagement.
2. Target acquisition occurred in each engagement.
3. Environmental effects, such as air density and crosswinds, could be sensed and fully corrected by the fire control system.
4. The attack helicopter hovered when engaging targets beyond 2000 meters range.
5. The posture of personnel targets changed from standing to prone after the arrival of the first burst of ammunition.
6. The minimum probability of kill level that could be physiologically sensed by a soldier is .001. When a standing soldier felt that a round was close enough to have at least the .001 level of kill against him, he would assume a prone position and would not attempt to stand for at least 5 seconds.

RESULTS AND EVALUATION

Engagement Geometries and Operational Environment.

The engagement geometry defines the range from the helicopter to the target and the altitude required to establish a line-of-sight (LOS). As stated in the objective, the minimum engagement range to be used was 2000 meters, and the maximum to be used was 4000 meters. In addition, two altitudes, 50 meters and 250 meters, were used as the probable lower and upper limits of an engagement altitude. These altitudes were the height above the target, not above the terrain. Both values were derived from the data shown in Figure 1. The lower limit, 50 meters, represented about a 10% probability of a LOS to 4000 meters range. The upper limit, 250 meters, represented about a 60% probability of a LOS to 4000 meters. The data in Figure 1 shows that at any range, significant increases in altitude above 250 meters only marginally increase LOS probability. Also, it may be inferred that at low

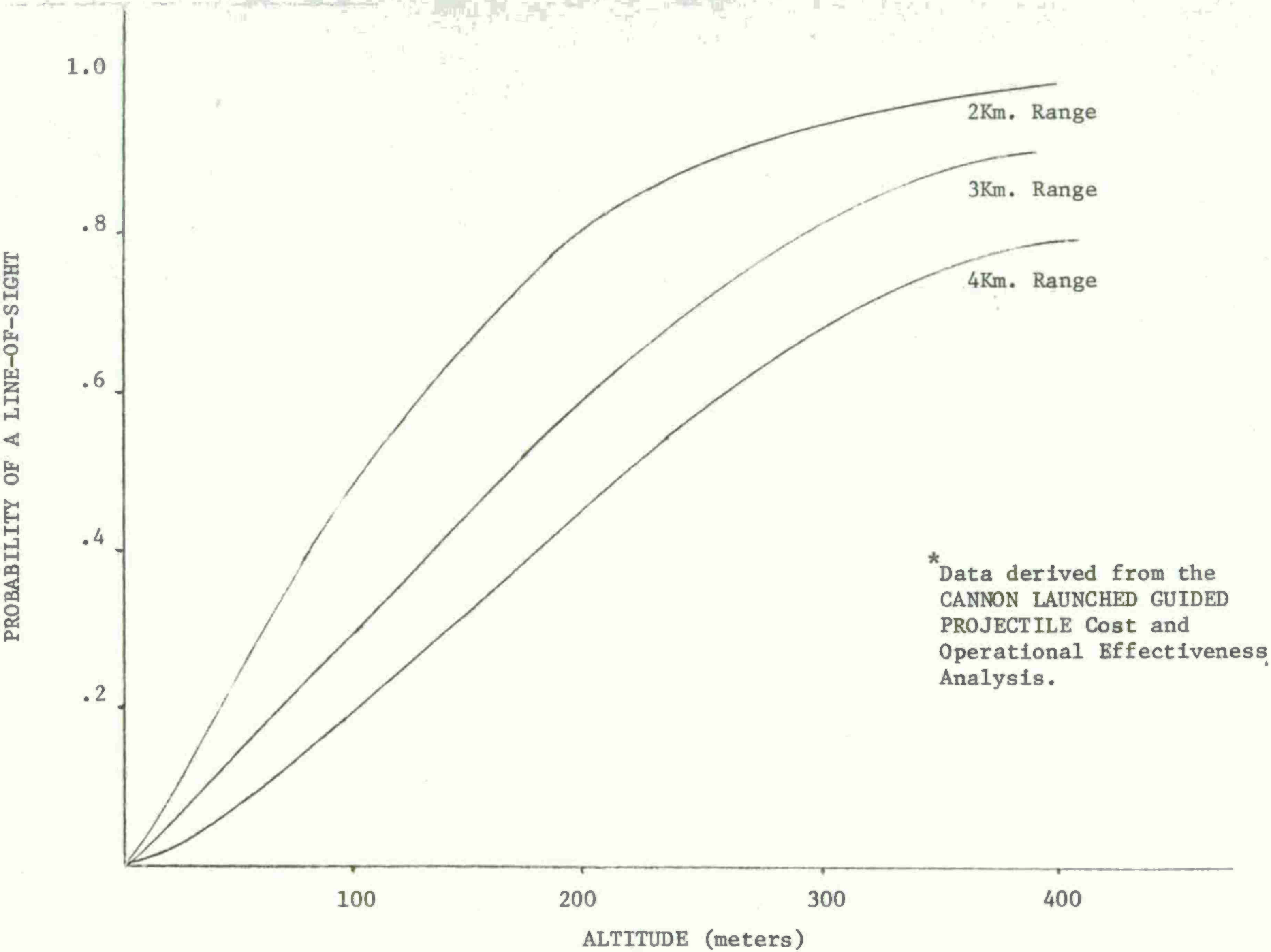

Figure 1. The Probability Of A Line-Of-Sight As A Function Of Altitude*

altitudes (<100 meters), more helicopter manuevers (or greater terrain familiarity) are required in order to find a firing position providing a LOS.

In addition to the affect terrain has upon engagement geometries and engagement frequency, the atmospheric visibility also decreases the ability of the attack helicopter to see to the target area. The data in Figure 2 shows the probability with which one can expect to see through the atmosphere to a point a fixed distance away for a given value of cloud ceiling.* This data indicates that during the winter season in Europe, the probability that conditions would exist that would allow the attack helicopter to see an object at 4000 or more meters is less than 50%.

To summarize the relationship between the environmental factors and the engagement geometries used in this analysis, a joint probability measure was developed which was the probability of both a LOS and atmospheric visibility existing as a function of range. Data pertaining to this measure is shown in Table 1. These data indicate that from any one position at 50 meters altitude, there is only a small likelihood (6%) of seeing to the target, regardless of range or season. However, at the 250 meter altitude this likelihood increases significantly (59%).

TABLE 1. PROBABILITY OF BOTH ATMOSPHERIC VISIBILITY AND A LINE-OF-SIGHT[a] (European Environment)

SEASON	AIRCRAFT ALTITUDE (meters)	PROBABILITY LEVELS RANGE TO TARGET (meters) 2000	3000	4000
SUMMER	50	.06	.04	.03
	250	.87	.70	.55
WINTER	50	.04	.02	.02
	250	.59	.42	.30

[a]Data applies for cloud ceilings ≥ 150 meters only.

*Specifically, visibility distance is the point at which the relative contrast of a perfect black object against a perfect white background (intrinsic contrast = 100%) decreases to 2%. Beyond this range, the object cannot be distinguished from its background.

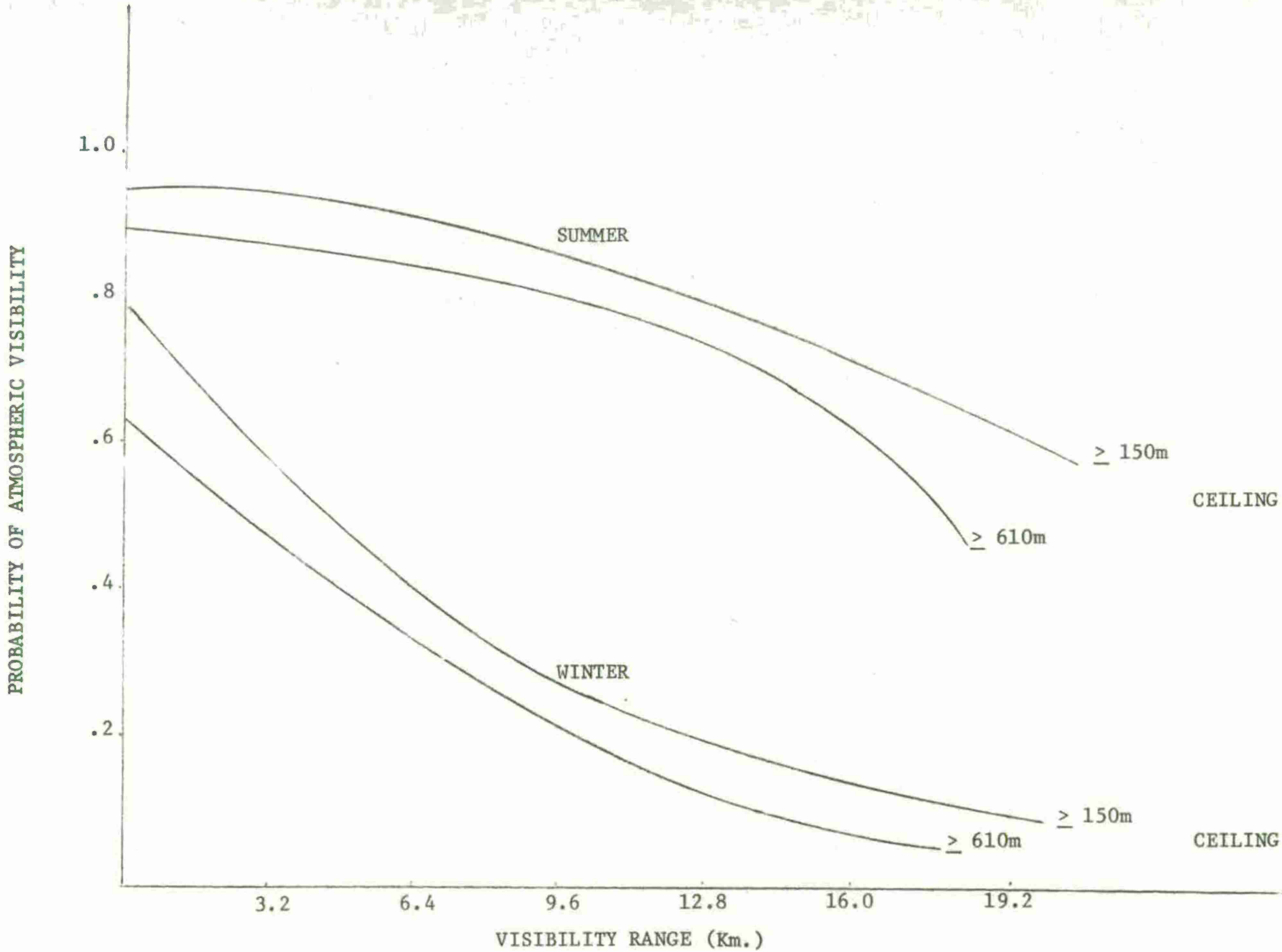

Figure 2. Joint Probability Of Atmospheric Visibility And Cloud Ceiling Combinations (Germany)

Attack Helicopter Target Acquisition Capability.

Target acquisition was defined as the process by which the correct target is choosen. To make this choice, sequential information from the target detection, recognition, and identification processes is required. However, in the operational scenario described by the Advanced Attack Helicopter Task Force Report[2], the use of scout helicopters and ground observers significantly altered the standard information flow of target acquisition. For instance, the observer accurately located the targets and provided the attack helicopter with this information. He also determined the number of targets and followed their movement, keeping the attack helicopter informed. Therefore, these actions allowed the attack helicopter to simultaneously detect and recognize the targets. In addition, since the observer had already identified the object as a target, the attack helicopter need not. So, the normal sequential flow of information in the decision process no longer existed. In fact, the cumulative effect of the observer's actions made target acquisition tantamount to target detection.

The investigation search of the field test literature revealed very few target acquisition tests that address the problem as described by the attack helicopter's operational environment. In fact, only three reports provided sufficient data to estimate target acquisition capability beyond 2000 meters. The first of these was a report of a test conducted by the Combat Developments Command (CDC) in 1969.[5] Target detection data from this test is shown in Figure 3. The helicopter's mean altitude during this test was 50 meters. The helicopter crews had been given general information about target identity and location, but they had no optical aids. The second report described a test done by the British Defense Establishment in 1969.[6] Target detection data from this test is also shown on Figure 3. The helicopter's mean altitude during this test was 250 meters. The helicopter crews had been prebriefed on the target's specific identity and location but they also had no optical aids. The third report summarized a test conducted by the Human Engineering Laboratory at Aberteen Proving Ground (HEL-APG) in 1973.[7] Target detection data from this test is

---

[2] Loc. Cit.

[5] Army Aircraft Survivability: UHIB/M22 Weapon System (U), June 1966, CEDEC Accession #C66 1300, CDC Experimentation Command, Fort ORD, CA., CONFIDENTIAL.

[6] Exercise HELLTANK - An Investigation of the Effectiveness and Vulnerability of Attack Helicopters in European Armored Warfare (U), January 1970, Defense Operational Analysis Establishment, Great Britain, CONFIDENTIAL.

[7] Cheever, J. L. and Horley, G. L., Air-to-Ground Target Identification Test Using Stabilized Optics (U), January 1973, Human Engineering Laboratory, APG, MD., CONFIDENTIAL.

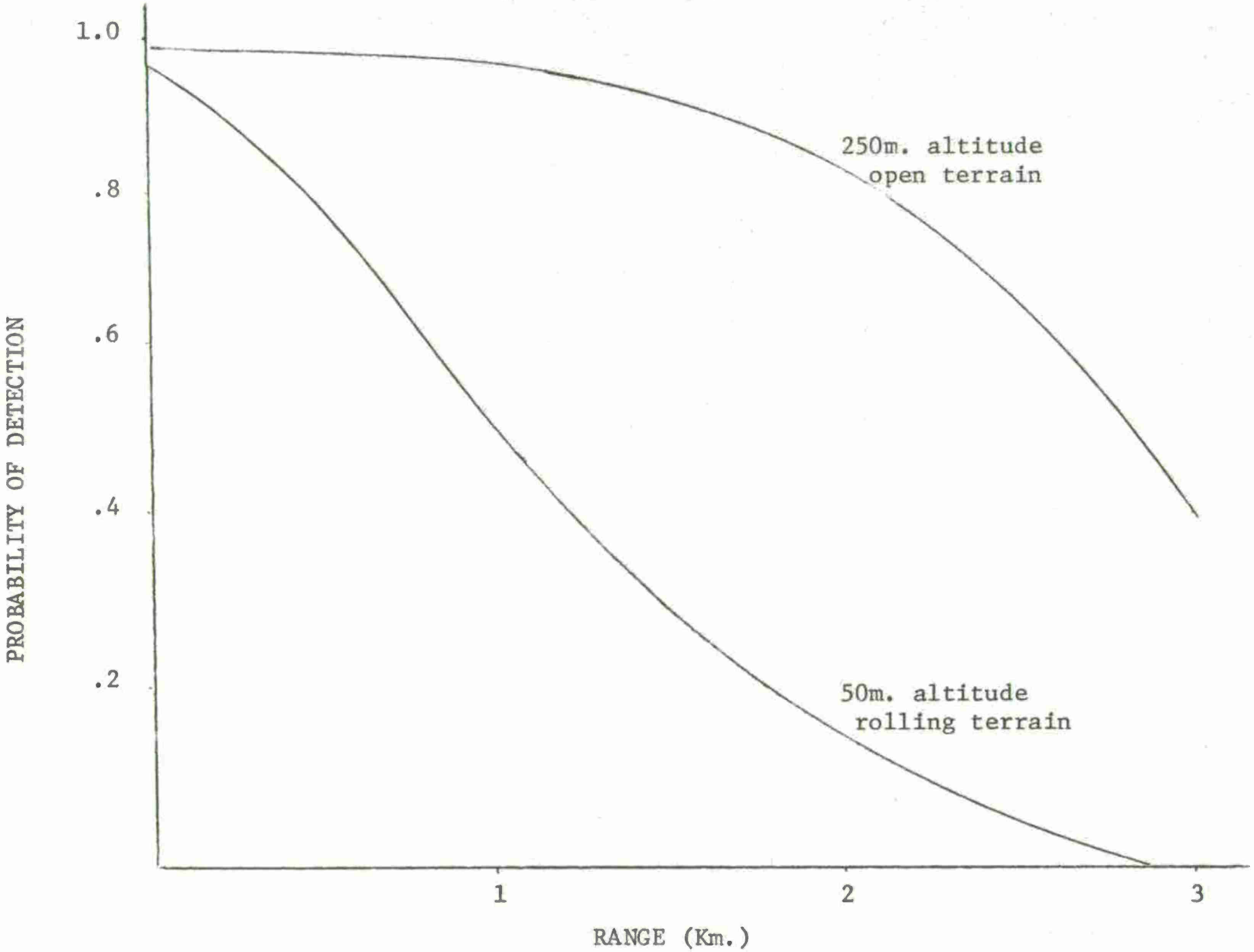

Figure 3. Target Detection Probability (Unaided Vision)

shown on Figure 4. The helicopter's altitude during this test was 610 meters. The helicopter crews were also prebriefed on the target's specific identity and location; but in addition, they were given the best flight path to the target area, and they were given a variable power (5X to 20X) stabilized electro-optical system. As the data in Figure 4 shows, detection probabilities were greatly improved compared to those in Figure 3. However, the individual contributions of increased altitude and optical assistance to this improvement cannot be determined. This is because the probability of a line-of-sight increased significantly as altitude increased. Therefore, it appears that a significant portion of the improved detection capability could be attributed to the increase in the line-of-sight probability. Thus, if the altitude of the last test were lower, the overall improvement may have been smaller, and the contribution of the optical system to target detection may have been only marginal.

<u>Automatic Cannon Characteristics And Delivery Errors</u>.

The characteristics describing the alternative automatic cannon systems and their ammunition are shown in Tables 2 and 3, respectively. A summary of the results of the delivery error analysis done at Picatinny Arsenal is shown in Table 4. These data show that the deflection (azimuth) errors increased linearly with range. Therefore, the deflection errors were expressed as a constant mil value for each system. These values are easily converted to meters at any given range. However, the range (pitch) errors did not follow such a pattern. Generally, the magnitude of the range errors decreased with increasing range. Investigation of this trend revealed a direct relationship between each automatic cannon system's trajectory characteristics and its range errors.

Three trajectory characteristics--quadrant elevation, fall angle, and terminal velocity--had the greatest affect on the range error magnitude. As shown by the data in Table 5, these three effects were not independent--the higher the initial velocity, the smaller the quadrant elevation; and the smaller the quadrant elevation, the smaller the fall angle. Examining the data in both Tables 4 and 5, it can be seen that as quadrant elevation increased, either in a positive or negative direction, the magnitude of the ground range error decreased. In all cases the largest range error was associated with the quadrant elevation closest to zero degrees. Therefore, System 30(B), which had the "flattest" trajectory (caused by its high velocity and small quadrant elevations), also had the largest range errors. On the other hand, System 30(A), which had the most "looping" trajectory (caused by its low velocity and large quadrant elevations), correspondingly had the smallest range errors.

The magnitude of System 30(B)'s range errors was recognized as a possible determent to its effectiveness. Therefore, System 30(C)

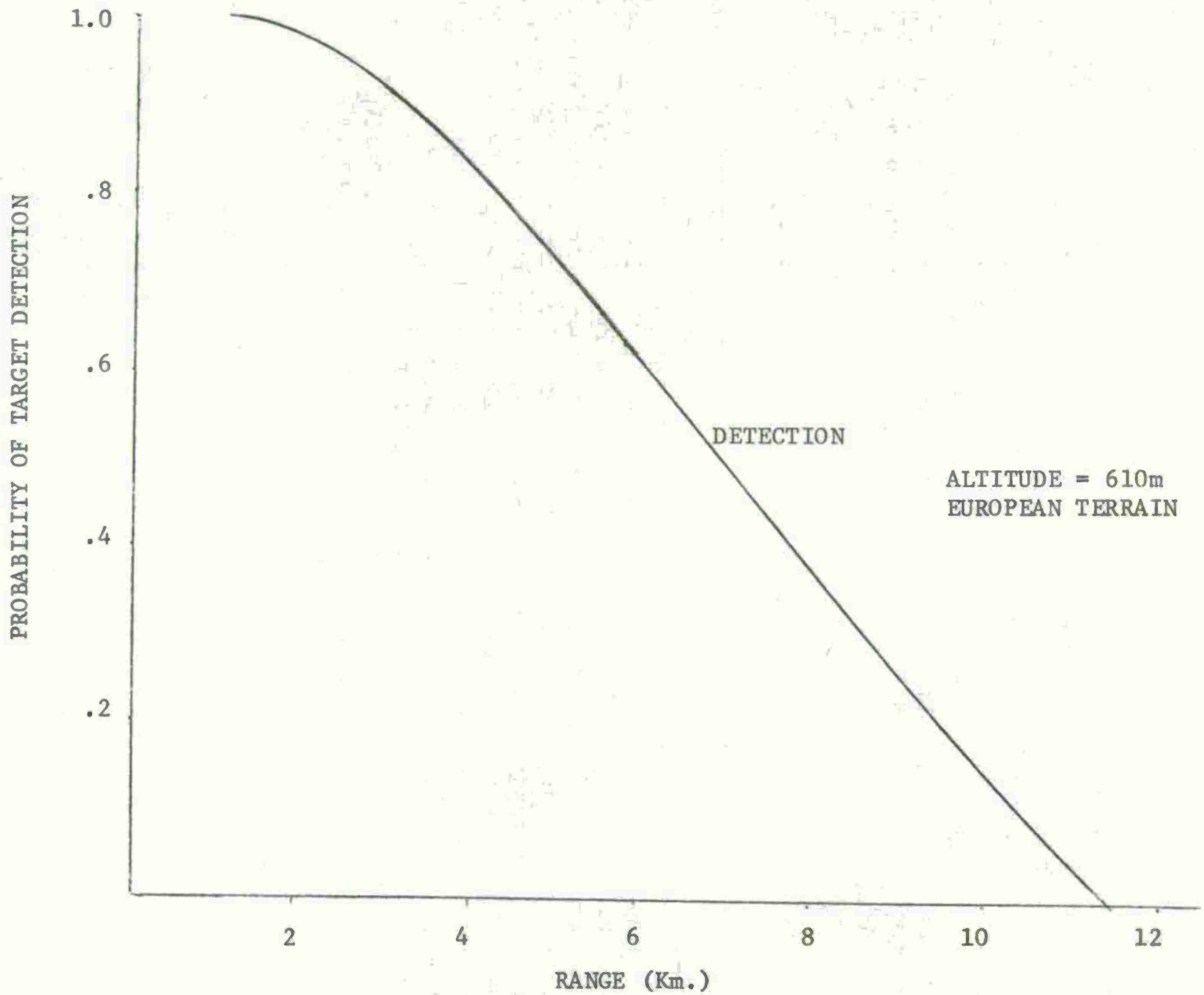

Figure 4. Target Detection Probability (Stabilized Optics)

TABLE 2. AUTOMATIC CANNON SYSTEM CONCEPT DESCRIPTION

AUTOMATIC CANNON SYSTEM CONCEPT	CALIBER (mm.)	RATE OF FIRE (rds./min.)	INITIAL VELOCITY (ft./sec.)	BASIS FOR SYSTEM CHARACTERISTICS Automatic Cannon	Ammunitions
20	20	750	3300.	M39 and M24	Lethal area same as the M56A3 HE projectile. Conditional kill probability (PHK) same as M53 API projectile.
30(A)	30	600	2200.	XM230 (Hughes)	Lethal area and PHK same as XM5[illegible] HEDP projectile. New improved fuze; graze sensitive.
30(B)	30	450	4000.	Advanced Automatic Cannon (Hughes and ARMCOM designs)	Lethal area same as GE/AEROJET GAU-8 HE projectile. PHK values same as GAU-8 projectile's maximum Round fully telescoped with graze sensitive fuze.
30(C)	30	450	4000	Basis identical to concept 30(B).	Basis identical to concept 30(B).
40	40	450	2950	Projected for Advanced Automatic Cannon Designs	Lethal area about 1.6 times that of the 40mm XM430 HEDP projectile. PHK values assumed to be the same as the XM430 HEDP round. The impulse of the round is the same as concept 30(B). Its aerodyamics are the same as concept 30(A).

TABLE 3. ALTERNATIVE AUTOMATIC CANNON SYSTEM AMMUNITION CHARACTERISTICS

SYSTEM CONCEPT[a]	LENGTH (In)	DIAMETER (In)	VOLUME (In^3)	ROUND WEIGHT (Lbs)	PROJECTILE WEIGHT (Grains)	INITIAL VELOCITY (Ft/Sec)
20mm	6.62	1.20	7.54	0.56	1540	3300
30 (A)	6.98	1.40	10.75	0.67	3031	2200
30 (B&C)	6.30	2.06	21.00	1.33	5180	4000
40mm	6.20	2.75	36.80	2.20	7210	2950

[a] See Table 1 for basis of system concepts.

TABLE 4. TOTAL DELIVERY ERROR OF THE ALTERNATIVE AUTOMATIC CANNON SYSTEM CONCEPTS[a]

AUTOMATIC CANNON SYSTEM CONCEPT[b]	AIRCRAFT ALTITUDE[c] (meters)	DELIVERY ERRORS: DEFLECTION STANDARD DEVIATION (mils)	DELIVERY ERRORS: RANGE STANDARD DEVIATION (meters)		
			2Km. Range	3Km. Range	4Km. Range
20	50	5.41	75.8	42.6	20.0
	250	5.31	43.9	37.6	21.3
30(A)	50	5.25	48.5	24.5	16.3
	250	5.19	33.5	23.9	16.4
30(B)	50	5.00	253.0	248.7	152.8
	250	5.00	71.4	122.3	115.0
30(C)	50	2.00	101.2	99.5	61.6
	250	2.00	28.6	48.9	46.0
40	50	5.21	97.3	65.4	39.7
	250	5.14	50.1	52.3	38.3

[a]The total error is the root-mean-square of the round-to-round components which account for variations in drag, weight, and velocity; and aim wander which account for pointing, slight malalignment, and gun movement due to recoil.

[b]See Table 2 for system description.

[c]Aircraft altitude is above the target.

TABLE 5. TRAJECTORY CHARACTERISTICS OF THE ALTERNATIVE AUTOMATIC CANNON SYSTEM CONCEPTS

AUTOMATIC CANNON SYSTEM CONCEPT[a]	AIRCRAFT ALTITUDE[b] (meters)	TRAJECTORY PARAMETERS								
		QUADRANT ELEVATION[c] (degrees)			ANGLE OF FALL (degrees)			IMPACT VELOCITY (ft./sec.)		
		2Km. Range	3Km. Range	4Km. Range	2Km. Range	3Km. Range	4Km. Range	2Km. Range	3Km. Range	4Km. Range
20	50	.95	5.85	16.10	7.30	19.00	44.90	750.	496.	393.
	250	-4.90	1.70	12.10	12.70	21.70	43.30	767.	514.	404.
30(A)	50	3.37	11.60	27.20	11.30	30.60	49.90	598.	407.	320.
	250	-2.50	7.10	21.90	16.60	31.80	56.00	616.	425.	353.
30(B)	50	-.80	.20	1.60	2.30	3.20	7.10	2159.	1405.	894.
	250	-6.60	-3.63	1.04	8.10	7.00	9.70	2179.	1437.	911.
30(C)	50	-.80	.20	1.60	2.30	3.20	7.10	2159.	1405.	894.
	250	-6.60	-3.63	1.04	8.10	7.00	9.70	2179	1437.	911.
40	50	.47	3.90	9.60	5.70	12.60	26.50	899.	654.	495.
	250	-5.30	-.10	6.30	11.30	15.90	27.80	911.	670.	511.

[a]See Table 2 for system description.

[b]Aircraft altitude is above the target.

[c]Quadrant elevation measured from horizontal; helicopter at hover.

was formulated. System 30(C) is identical to System 30(B) in all aspects except delivery error. This new system represents a 60% reduction in the delivery error of System 30(B). The 60% reduction was used because initial effectiveness calculations showed that this level nearly maximized System 30(B)'s target defeat capability.

Automatic Cannon System Effectiveness.

The data in Figure 5 shows the highest and lowest levels of suppression achieved by the alternative automatic cannon systems. The highest values were achieved by the 40mm automatic cannon system at 3000 meters range and 50 meters altitude. The lowest values were achieved by 20mm automatic cannon systems also at 3000 meters range and 50 meters altitude. The suppression levels of the remaining geometries and automatic cannons fall between the curves in Figure 5.

The unique shape of these curves was caused by two factors: (1) the actions of the troops under attack and (2) the continuous attack against the target. The number of troops killed on the target increased monotonically; however, the number of remaining non-casualty troops forced into a protected position flucuated with time. When these non-casualty troops sensed that they were under fire, they assumed a protected position, thus increasing the percentage of the target suppressed. But when these troops sensed that they were not under fire, they returned to their iroginal standing position, thus decreasing the percentage of the target suppressed. The cycle phenomenon illustrated by the curves was a result of engaging the target over and over in sequential attacks.

The suppression levels achieved by each of the automatic cannon systems in an expected target engagement (200 rounds) are shown in Table 6. Analysis of these data revealed that the percentage of the target suppressed increased as range increased. This trend was caused by the relationships between the effectiveness measure, the delivery error, and projectile lethality. First, as the data in Table 4 has shown, the delivery error ground patterns changed significantly as range increased. At the shorter ranges (<3000 meters) these patterns were elongated. However, at the longer ranges ($\geq$ 3000 meters) these patterns were nearly circular. Both pattern shapes were usually centered near the target center, since the error in the estimate of the range to target center was small (10 meter std. dev.). Because of this, the circular pattern, which had the smallest area and highest concentration of rounds per unit area, put the greatest number of rounds on the target. Therefore, if the lethality of the rounds was constant with range, the highest effectiveness levels would correspond to the highest concentration of rounds on the target. However, the lethality of each of the automatic cannon rounds was not constant with range. As discussed, the lethality of each projectile was expressed as a probability of kill grid which was superimposed

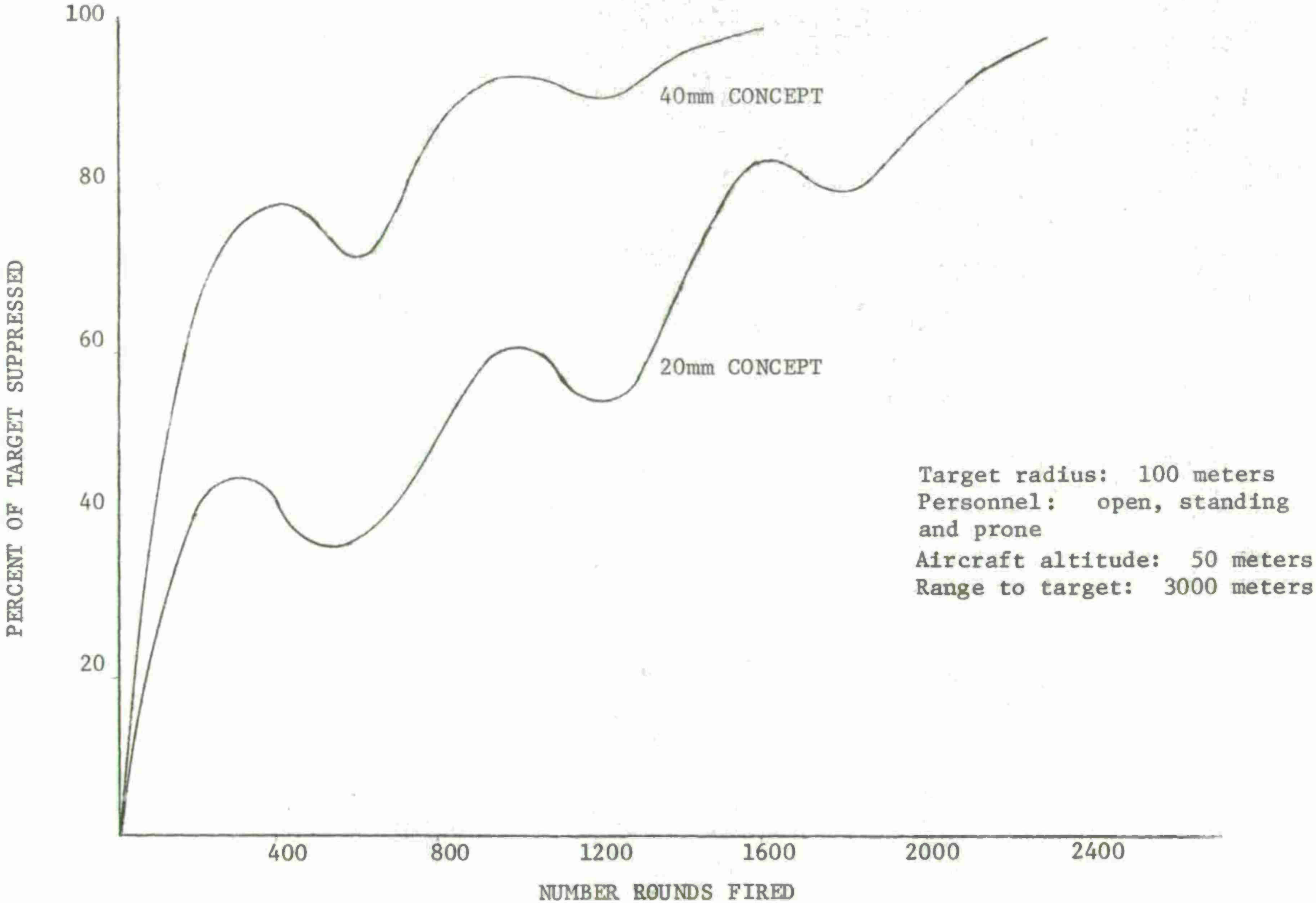

Figure 5. Percent of Personnel Target Suppressed

TABLE 6. PERCENTAGE OF A PERSONNEL AREA TARGET SUPPRESSED DURING A 200 ROUND ENGAGEMENT[a]

AUTOMATIC CANNON SYSTEM CONCEPT[b]	SUPPRESSION LEVEL ACHIEVED (%)[c]					
	AIRCRAFT ALTITUDE - 50 METERS			AIRCRAFT ALTITUDE - 250 METERS		
	2Km. Range	3Km. Range	4Km. Range	2Km. Range	3Km. Range	4Km. Range
20	34	37	39	36	37	39
30(A)	43	47	48	43	47	50
30(B)	38	40	51	49	50	54
30(C)	42	49	51	46	49	52
40	55	62	62	59	63	63

[a]The target radius is 100 meters; personnel are standing and prone.

[b]See Table 2 for system description.

[c]The level of suppression achieved is the sum of the percent killed and the percent forced into a protective posture - from standing to prone.

on the target. These grids differed over ranges because they were a function of the projectile's trajectory. In general, the size of the grid increased with increasing range, and the larger the grid, the more effective was the round. Therefore, if the error patterns of each automatic cannon were constant with range, the highest effectiveness levels would correspond to the greatest lethality. The net effect of combining increased lethality with a greater number of rounds on target was the increased level of suppression shown.

Examining the automatic cannon systems on an individual basis, the 40mm system was the best at all ranges and altitudes. Following in order were the 30(A), the 30(C), the 30(B), and the 20 systems. As the data shows, in a 200 round engagement, each system achieved at least a 30% level of suppression from each geometry.

The data in Table 7 shows the capability of each automatic cannon system to defeat materiel or personnel targets.

The materiel targets considered in the analysis represented three distinct levels of target 'hardness.' Target one, the ZSU-23/4, was a self-propelled air-defense system; and as indicated by the data in Table 7, it was the 'softest.' Target two, the ICV-BMP, was a full-tracked, armored combat vehicle. Target three, the BRDM, was a wheeled armored personnel carrier and combat vehicle; and of the three vehicles, it was the 'hardest.'

When ranking individual system performance against these materiel targets, the data showed that System 30(C) achieved the highest effectiveness levels at all ranges and altitudes. The data also showed that the next best automatic cannon were Systems 40 and 30(A), which were equal in performance but were significantly less effective than System 30(C). The fourth best system, System 30(B), although less effective than the other three systems against the ZSU-23/4, was nearly equal to the 40 and 30(A) systems against the other two targets. The last system, System 20, was ineffective in all cases. First, as discussed, there was a significant change in delivery errors as range increased. Also, since the range estimation error was small, the small circular error patterns usually put a greater number of rounds on the target. But, small circular error patterns are characteristic of "looping" trajectories, which imply large angles of fall; while the larger elongated error patterns are characteristic of "flat" trajectories, which imply small angles of fall. These fall angles are important because they effect the size of the presented area of the target--the larger the fall angle, the smaller the presented area will be. Since it is possible for the presented target size to increase sufficiently to compensate for the difference in the concentration of rounds between the circular and elongated error patterns, a trade-off between error size and target size can occur. When this trade-off is made, the best system is usually the one with the highest conditional kill probability.

Examining the individual automatic cannons again, System 30(C) is the best because its conditional kill probabilities are the highest,

TABLE 7. EFFECTIVENESS LEVELS ACHIEVED DURING A 200 ROUND ENGAGEMENT

SYSTEM CONCEPT[a]	RANGE (Km)	TARGET DEFEAT LEVELS ACHIEVED DURING A 200 ROUND ENGAGEMENT[b] — Aircraft Altitude, 50 meters[c]					Aircraft Altitude, 250 meters[c]				
		Target 1	Target 2	Target 3	Target 4	Target 5	Target 1	Target 2	Target 3	Target 4	Target 5
20	2	0.03	-0-	0.02	0.36	.11	0.06	-0-	0.02	0.46	.12
	3	0.01	-0-	-0-	0.51	.15	0.01	-0-	-0-	0.48	.15
	4	-0-	-0-	-0-	0.57	.20	-0-	-0-	-0-	0.55	.20
30(A)	2	0.37	0.14	0.14	0.88	.29	0.67	0.56	0.43	0.88	.33
	3	0.29	0.12	0.10	0.89	.36	0.30	0.13	0.11	0.89	.36
	4	0.28	0.11	0.09	0.90	.38	0.27	0.11	0.09	0.90	.38
30(B)	2	0.25	0.14	0.13	0.15	.08	0.29	0.23	0.14	0.49	.15
	3	0.15	0.11	0.07	0.20	.10	0.24	0.17	0.09	0.29	.13
	4	0.13	0.09	0.06	0.22	.18	0.16	0.12	0.07	0.28	.14
30(C)	2	0.84	0.73	0.57	0.56	.17	0.88	0.80	0.63	0.93	.25
	3	0.56	0.44	0.30	0.67	.20	0.79	0.68	0.51	0.82	.23
	4	0.48	0.38	0.27	0.69	.21	0.58	0.46	0.32	0.81	.23
40	2	0.50	0.21	0.19	0.80	.38	0.93	0.65	0.58	0.86	.46
	3	0.29	0.12	0.11	0.81	.42	0.32	0.11	0.11	0.83	.45
	4	0.27	0.10	0.09	0.82	.46	0.27	0.10	0.09	0.85	.47

[a] See Table for basis of systems description.

[b] Targets 1, 2, 3, 4, and 5, respectively, are: a ZSU-23/4, an ICV-BMP, a BRDM, a crew-served weapons emplacement and a troop formation. Estimates shown are probabilities of kill.

[c] Aircraft altitude above the target.

the presented area of the targets are the largest, and its delivery error patterns, although elongated, are small enough to permit a large round to hit within the target area. (Remember, this system's characteristics are the same as System 30(B), except that its errors are reduced by 60%). The two next best systems are examples of the tradeoff between presented target area and error pattern size. The error pattern of the 40mm system is larger than the 30(A) system, but the increase in presented target area caused by its flatter trajectory compensates for its larger errors. The conditional kill probabilities of the two systems are about equal; thus the 40 and 30(A) systems achieve about the same levels of effectiveness. In the case of System 30(B), the size of the presented area due to its trajectory is not sufficient to overcome the size of its error pattern. However, because of its conditional kill probability (against the ICV-BMP and BRDM in particular) fewer rounds are required to hit the target to achieve a kill. Therefore, the 30(B) system performs nearly as good as the 40 or 30(A) systems against these two targets but not as good as them against the ZSU-23/4. System 20 is ineffective at all ranges because its conditional kill probabilities are zero. This system's capability was dependent upon the kinetic energy of the projectile, which was not great enough beyond 2000 meters to cause any damage to any of the targets.

The capability of the automatic cannons to defeat personnel is also shown in Table 7. Targets 4 and 5 were a crew-served weapons emplacement and a troop formation, respectively. Examination of this casualty level data showed the same trend that was observed in the suppression data (Table 6). The interaction between delivery error and round lethality caused a general increase in effectiveness as the range increased. However, because the time element of suppression was not considered in the computation of the casualty levels, the effectiveness values were quite sensitive to the delivery errors. For example, the capability of System 30(C) against Target 5 at 250 meters altitude decreased at 3km and then increased slightly at 4km. Referring to Table 4, the delivery errors are seen to follow the same trend.

The relative ranking of each system's capability to defeat personnel targets differs from the suppression rankings in only one case. The 20mm system is better overall than the 30(B) system. The concentrated error pattern of the 20mm system enables it to achieve a much higher level of effectiveness than System 30(B) against the small area target (Target 4).

The data in Table 8 shows the number of rounds required by each automatic cannon system to achieve a 30% level of effectiveness against each target. Generally, the trend in the number of rounds required will be the opposite of the effectiveness trend in Table 7. Since this data was derived by the same methodology used to compute the effectiveness levels in Table 7, the explanations of the trends and the rankings of the automatic cannons are also the same.

The data shown in Table 9 is a summary of the effectiveness data shown in Tables 6 and 7. This data represents the expected performance

TABLE 8. NUMBER OF ROUNDS REQUIRED TO ACHIEVE A TARGET DEFEAT LEVEL OF 30 PERCENT

SYSTEM CONCEPT[a]	RANGE (Km)	NUMBER OF ROUNDS REQUIRED TO ACHIEVE A TARGET DEFEAT LEVEL OF 30 PERCENT[b] — Aircraft Altitude, 50 meters[c]					Aircraft Altitude, 250 meters[c]				
		Target 1	Target 2	Target 3	Target 4	Target 5	Target 1	Target 2	Target 3	Target 4	Target 5
20	2	2200	NA	3372	153	603	1286	NA	1953	93	549
	3	NA	NA	NA	82	526	5596	NA	NA	80	503
	4	NA	NA	NA	69	342	NA	NA	NA	64	346
30(A)	2	152	458	480	24	213	84	115	147	22	182
	3	206	551	616	24	131	200	580	620	21	180
	4	222	625	705	21	120	226	620	700	20	131
30(B)	2	240	305	517	412	1119	220	285	480	74	451
	3	480	640	1060	363	614	260	386	640	208	534
	4	487	699	1120	325	450	404	603	1000	214	530
30(C)	2	38	54	81	68	498	34	43	71	20	242
	3	88	134	200	48	382	46	66	104	29	306
	4	113	152	244	38	351	80	112	186	31	302
40	2	132	405	420	27	149	28	70	85	20	94
	3	209	560	600	24	96	199	560	610	21	122
	4	229	629	720	24	87	224	684	800	21	85

[a]See Table 2 for system descriptions.

[b]Targets 1, 2, 3, 4, and 5, respectively, are: a ZSU-23/4, an ICV-BMP, a BDRM, a crew-served weapons emplacement, and a troop formation.

[c]Aircraft altitude above the target.

NOTE: NA (Not Achieveable). The 30% target level cannon be achieved within a three aircraft-load constraint (>6000 Rds).

TABLE 9. EFFECTIVENESS OF THE ALTERNATIVE AUTOMATIC CANNON SYSTEM CONCEPTS[a]

AUTOMATIC CANNON SYSTEM CONCEPT[b]		EQUAL WEIGHT (134 lbs) OF AMMUNITION FIRED			EQUAL NUMBER (200) OF ROUNDS FIRED		
		Percent of Target Suppressed[c]	Percent Personnel Target Defeated[d]	Probability of Materiel Defeat[e]	Percent of Target Suppressed	Percent Personnel Target Defeat	Probability of Materiel Defeat
ABSOLUTE VALUES	20	44	32	-0-	37	30	-0-
	30(A)	48	62	.17	48	63	.17
	30(B)	31	8	.05	40	15	.11
	30(C)	46	38	.25	49	44	.43
	40	38	28	.05	63	63	.17
RELATIVE VALUES	20	.92	.51	-0-	.77	.48	-0-
	30(A)	1.00	1.00	1.00	1.00	1.00	1.00
	30(B)	.65	.12	.29	.83	.24	.65
	30(C)	.96	.61	1.47	1.02	.70	2.53
	40	.79	.45	.29	1.31	1.00	1.00

[a]Estimates are based on a 50 meter aircraft altitude and a range to target of 3000 meters. This is assumed to be the most representative engagement geometry.

[b]See Table 2 for concept descriptions.

[c]Target radius is 100 meters.

[d]Estimates for the personnel target are the average of the crew-served weapons emplacement and the troop formation shown in Table 7.

[e]Estimates for the materiel target are the average of the three materiel targets shown in Table 7.

of each of the automatic cannons against an "average" personnel or materiel target. Only one engagement geometry is shown because the relative relationship among the systems does not change as function of geometry. Therefore, the most likely engagement geometry to be used by the attack helicopter was selected for summary purposes. Both the absolute and relative effectiveness values are included in Table 9 to highlight the difference among the five automatic cannons systems.

Using System 30(A) as the standard, two comparisons are made in Table 9. The first compares the effectiveness levels achieved by each system if each system were forced to fire an equal weight of ammunition. Since significant weight differences exist among the automatic cannon ammunitions, the amount an aircraft, such as the Advanced Attack Helicopter (AAH), can carry differs considerably. For example, one AAH load of System 30(A) ammunition is 800 rds., one AAH load of System 30(B) or 30(C) ammunition is 400 rds., and a load of System 40 ammunition is 244 rds. Therefore, on an equal weight basis, fewer rounds of System 40 ammunition can be fired; thus the effectiveness levels shown in Table 9 are correspondingly lower.

The second comparison is based on the effectiveness levels achieved when each system fires an equal number of rounds. In this case, weight constraints of the aircraft are not considered. This comparison showed a slightly different picture than the equal weight comparison did. The relative performance of System 40, when compared on an equal weight basis, was significantly less than System 30(A); but when compared on an equal round basis, it was somewhat better than System 30(A). In both cases, however, System 30(C) was always better than 30(A) against materiel targets and was nearly as good as 30(A) against personnel targets.

CONCLUSIONS

One of the two objectives of this analyses was to estimate the ability of the attack helicopter to acquire targets located beyond 2000 meters range. The data shown in Figures 1 through 4, together with the data in Table 1, reveals that the attack helicopter's ability to acquire targets beyond 2000 meters is limited. Further, by following current tactics without optical assistance or an exact knowledge of the target and its location, the frequency of target acquisition and engagements beyond 3000 meters is nearly zero.

The other objective of the analysis was to determine the target defeat levels achieved by the automatic cannon systems. Data pertaining to this objective has been presented in Tables 6 through 9 and in Figure 5. In general, this data has shown that each system does have some capability to defeat both personnel and materiel targets at ranges up to 4000 meters. The highest levels of effectiveness are achieved with the 40(A) and 30(A) systems against personnel targets. Although materiel defeat levels are low, there is one exception, System 30(C), which achieves much higher levels than any of the other systems.

REFERENCES

1. AH56A Phase III Study (U), Vol. IV, Appendix I, Annex D, November 1967, US Army Combat Developments Command, Washington, D.C., SECRET.

2. Advanced Attack Helicopter Task Force Report (U), ACN 20268, July 1972, US Army Combat Developments Command, Advanced Attack Helicopter Task Force, CONFIDENTIAL.

3. Basic Methodology Handbook (U), TH61A1-3-6, Joint Technical Coordinating Group/Munition Effectiveness, (JTCG/ME), Aberdeen Proving Ground, MD., CONFIDENTIAL.

4. Weapons Characteristics Manual (U), TH61A1-3-2, JTCG/ME, Aberdeen Proving Ground, MD., March 1969, CONFIDENTIAL.

5. Army Aircraft Survivability: UH1B/M22 Weapon System (U), CEDEC Accession #C66 1300, June 1966, Combat Development Command, Experimentation Command, Fort Ord, CA.

6. Exercise HELLTANK--An Investigation of the Effectiveness and Vulnerability of Attack Helicopters in European Armored Warfare (U), January 1970, Defense Operational Analysis Establishment, Great Britain, CONFIDENTIAL.

7. Cheever, H.L. and Horley, G.L., Air-to-Ground Target Using Stabalized Optics (U), January 1973, Human Engineering Laboratory, Aberdeen Proving Grounds, MD., CONFIDENTIAL.

BIBLIOGRAPHY

Croyle, Thomas W., Tank Versus Helicopter Re-Identification and Re-Acquisition Time Field Test, AMSAA Tech Report #74, March 1973.

Erickson, Ronald A., Empirically Determined Effects of Gross Terrain Features Upon Ground Visibility From Low Flying Aircraft. NAVWWS Report 7779, September 1961, U.S. Naval Ordnance Test Station, China Lake, CA.

Erickson, Ronald A., Field Evaluation of A 1962 Vintage Visual Detection Model, NWC TP 5057, September 1970, Naval Weapons Center, China Lake, CA.

Erickson, Ronald A., Target Acquisition Studies at The Naval Weapons Center: A Bibliography, NWC TP 5708, September 1974, Naval Weapons Center, China Lake, CA.

Gerald and Bradley, Atmospheric Properties and Their Effect On Target Acquisition Under Flare Illumination, RDTR No. 270, May 1974 Naval Ammunition Depot Applied Science Department, Crane, IND.

Green, Charles and Erickson, Roland, Target Acquisition Model Evaluation, NWC TP 5536, part 3, October 1974, Naval Weapons Center, China Lake, CA.

Jonason, A., A Comparison Between The Threshhold of Detection With A Stationary and Moving Object Against Backgrounds Of Different Complexity, N74-12795, February 1972, Research Institute of National Defense.

Kushnick, S.A. and Duffy, J.O., The Identification Of Objective Relationships Between Small Arms Fire Characteristics and the Effectiveness of Suppressive Fire, Final Report, TR72/002, April 1972, Litton Mellonies, Sunnyvale, CA.

Nichols, Thomas and Powers, Theodore, Task Swingshift: Moonlight and Night Visibility, January 1964, HUMRO Research Memorandum, U.S. Army Training Center, Human Research Unit, Presidio of Monterey, CA.

Thomas, Dr. Frances, Target Acquisition From The Armored Helicopter, April 1962, Visual Search Symposium Paper, U.S. Army Aviation Research Unit, Fort Rucker, ALA.

Winter, R.P. and Clouis, E.R., Relationship of Supporting Weapon Systems Performance Characteristics to Suppression of Individuals and Small Units, TR-73/002, Final Report, January 1973, Litton Mellonies, Sunnyvale, CA.

A Cost Effectiveness Analysis of the SS-11B1/UHIB Weapons Systems (U), Ballistic Research Laboratories Report #1470, August 1963, Aberdeen Proving Grounds, MD - CONFIDENTIAL.

AH-56A Phase III Study, Vols. II and IV, ACN 13640, January 1969, U.S. Army Combat Developments Command, Institute for Special Studies.

Army Aircraft Survivability - Visually Sighted Weapons (U), (Short Title: VISCON), October 1965, Combat Developments Command, Experimentation Command, Fort Ord, CA., CONFIDENTIAL.

AH5614 Phase III Study, Annex K, Volume 13, (SRI Global Model), January 1969, Stanford Research Institute, Menlo Park, CA.

HELHAT II, Scout Crew/Observer Target Detection Flight Tests, HEL-TN-1-74, January 1974, Human Engineering Laboratories, Aberdeen Proving Ground, MD.

Attack Helicopter Daylight Defense (USACDCEC Experiment 43-6), Vols I to VI, ACN 18171, May 1972, CDCEC, Fort Ord, CA.

Estimating the Effectiveness of Future Aerial Weapon Systems, USAMC Report (No number), November 1967, Edited by Capt. B. J. Hamilton.

Estimates of Close Air Support Weapons Effectiveness and Aircraft Survivability (U), JTCG/ME-71-9, September 1971, Joint Technical Coordinating Group for Munition Effectiveness, Aberdeen, MD, SECRET.

Helicopter Armament Program - Air-To-Ground Target Detection and Identification, Human Engineering Laboratories Tech Memo #1-62, CECEC Accession Number U66-634 (U66-1184), January 1962, Aberdeen Proving Ground, MD.

Low Altitude Test 4.4, Target Acquisition, Tactical Air Reconnaissance Data Summary, All Aircraft (U), AD394501, October 1968, Joint Task Force Two, Sandis Base, New Mexico, SECRET.

Visual Target Acquisition: Single Glimpse Probability of Detection, Defense Operational Analyses Establishment Memorandum 7047, G.P. Owen, Minister of Defense, West Byfleet, UK, December 1970.

DISTRIBUTION LIST

Commander
US Army Armament Command
1 ATTN: AMSAR-CG
1 AMSAR-DCG
1 AMSAR-SC
1 AMSAR-RD
1 AMSAR-RDT
1 AMSAR-RDG
6 AMSAR-SA
Rock Island, IL 61201

Commander
Rock Island Arsenal
1 ATTN: SARRI-CO
1 SARRI-LR
1 SARRI-L
1 SARRI-LW
1 SARRI-LS-A
1 SARRI-LPL
Rock Island, IL 61201

Commander
US Army Materiel Command
1 ATTN: AMCPA
1 AMCPA-S
1 AMCRD-WB
Washington, DC 20315

Commander
Edgewood Arsenal
1 ATTN: SAREA-CL-PA
1 SAREA-DE-W
1 SAREA-DE-N
1 SAREA-TD
1 SAREA-TS
Aberdeen Proving Ground, MD 21010

1 Project Manager for Selected Ammunition
US Army Materiel Command
ATTN: AMCPM-SA2
Dover, NJ 07801

Commander
US Army Missile Command
1 ATTN: AMSMI-PI
1 AMSMI-D
1 AMSMI-R
Redstone Arsenal, AL 35809

Director
US Army Materiel Systems Analysis Activity
1 ATTN: AMXSY-C
1 AMXSY-AA
Aberdeen Proving Ground, MD 21005

Commander
US Army Training and Doctrine Command
1 ATTN: ATCD-C
1 ATCD-FA
1 ATLG
Ft. Monroe, VA 23651

1 Commander
US Army Test and Evaluation Center
ATTN: AMSTE-BC
Aberdeen Proving Ground, MD 21005

Commander
US Army Aberdeen Research and Development Center
1 ATTN: AMXRD-BD
Technical Library
Aberdeen Proving Ground, MD 21005

1 Director
Advanced Research Projects Agency
1400 Wilson Blvd.
Arlington, VA 22209

DISTRIBUTION LIST (Cont)

1 Naval Ordnance Laboratory
Chief, Applied Aerodynamics
Division
Silver Springs, MD 20910

1 Commander
Combat Systems Group
ATTN: CDMSD-M
Ft. Leavenworth, KA 66027

1 Commander
Harry Diamond Laboratories
ATTN: AMXDO-PP
Washington, DC 20438

1 Director
US Marine Corps Development
and Education Center
Quantico, VA 22134

1 Technical Library
Arnold Engineering
Development Center
Arnold Air Force Station,
TN 37389

12 Defense Documentation Center
Cameron Station
Alexandria, VA 22134

1 Project Manager for the
2.75-Inch Rocket System
US Army Materiel Command
Redstone Arsenal
Huntsville, AL 35809

1 Product Manager for Advanced
Attack Helicopter Systems
US Army Aviation Systems Command
St. Louis, MO 63166

1 Commander
US Army Armor Training Center
ATTN: AMSTB-CO-MM
Fort Knox, KY 40121

1 Product Manager for AH-1 Cobra
Series Aircraft
US Army Materiel Command
P.O. Box 209
St. Louis, MO 63166

Commander
Picatinny Arsenal
1 ATTN: SARPA-AD-D
1 SARPA-AD-E
1 SARPA-FR-S
Dover, NJ 07801

Next page is blank.