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THE EVALUATION OF LESS-LETHAL WEAPONS,

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U. S. ARMY HUMAN ENGINEERING LABORATORY

Aberdeen Proving Ground, Maryland

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The primary program objective was to establish a methodology for evaluating the merits of candidate less-lethal weapons. The first portion of the work was done in Fiscal Year 1973 and was concerned with weapons that employ kinetic energy as the effects mechanism. Treatment of other mechanisms (chemical, electrical) was general, with detailed work completed in mid-1975. This report "pulls" this work together and presents the state-of-the-art as of late 1976.

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THE EVALUATION OF LESS-LETHAL WEAPONS

Donald O. Egner

December 1977

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PREFACE

Perhaps some day, someone in an appropriate position of authority will pursue the objective of the development of less-lethal weapons for law enforcement. It is inconceivable that in the space age of today that we provide our law enforcement personnel with the caveman's club and a nineteenth century pistol. We are proud of our system of justice—innocence until proven guilty—law enforcement for apprehension and to prevent violence. Yet the tools we provide do not apprehend effectively, do imply a degree of punishment, and do not provide adequate control and security to those who use them.

The information gathered and developed in the less-lethal program described herein indicates the feasibility of effective less-lethal weapons. Although the efforts described pertain to the evaluation of less-lethal devices,, it simultaneously establishes goals and direction for the development of less-lethal weapons. It is only a beginning, but with the proper dream and effort, less-lethal weapons can be developed which will fulfill the concepts of liberty and justice envisioned by our forefathers.

FORWORD

The work described in this report was performed generally under the Law Enforcement Administration Agency (LEAA)/U.S. Army Land Warfare Laboratory (LWL) Interagency Agreement No. LEAA-J-IAA-014-2. Mr. Marc A. Nerenstone and Mr. Lester D. Shubin were the LEAA Program Monitors for this task. Mr. Donald O. Egner was the U.S. Army Project Officer. This report was prepared under Task 13 of Interagency Agreement LEAA-J-005-4.

The purpose of this report is to "pull together" the less-lethal evaluation work that has been done in the last 5 years. This report essentially is a finalized version of work previously distributed in the following three draft reports along with some final refinements and additions:

1. A Multidisciplinary Technique for the Evaluation of Less Lethal Weapons - Volumes I and II.

2. Analysis of a Bean-Bag-Type Projectile as a Less-Lethal Weapon.

3. The Effectiveness of Less-Lethal Weapons Utilizing Chemical Agents.

The work is reported in six sections. The first section contains the general methodology, while the second section describes the application of the technique to the .38 caliber revolver. Although the .38 caliber revolver is not generally thought of as a less-lethal weapon, it can be evaluated using criteria developed for the evaluation of less-lethal weapons. Furthermore, it provides a common basis for relative comparison with other less-lethal weapons and is a weapon which is familiar to all police and law enforcement agencies. The third section describes the application of the technique to a kinetic energy type less-lethal weapon (the Stun Bag). The fourth section applies the technique to chemical devices. The fifth, electrical devices. The sixth section discusses latest developments.

This report, along with the following reports, make a fairly complete "package" on the evaluation of less-lethal weapons:

1. HEL TM 20-75, "Standard Scenarios for the Less-Lethal Weapons Evaluation Model," Donald O. Egner, Larry W. Williams, August 1975.

2. HEL TM 21-75, "Testing and Evaluation of Chemical Weapons," Donald O. Egner, Donald Campbell, August 1975.

3. HEL TM 2-76, "Modeling for Less-Lethal Chemical Devices," Donald Campbell, Donald O. Egner, January 1976.

4. HEL TM 3-76, "Modeling for Less-Lethal Electrical Devices," Donald O. Egner, Ellsworth B. Shank, January 1976.

5. HEL TM 4-76, "Weapon Performance Testing and Analysis: The MODI-PAC Round, The No. 4 Lead-Shot Round, and The Flying Baton," Brenda K. Thein, Donald O. Egner, Ellsworth B. Shank, January 1976.

6. HEL TM 24-76, "Los Angeles County District Attorney's Less-Lethal Weapons Task Force," Burton S. Katz, Donald O. Egner, June 1976.

ACKNOWLEDGEMENT

The assistance and cooperation of many police departments, hospitals, corporations and individuals helped provide the basis for this report. Although not funded under this task, many organizations cooperated in the data gathering effort. The author wishes to acknowledge all data and technical contributions provided by members of the Scenario Group, the Behavior Analysis Group and the Medical Group, as well as the following organizations which assisted at no cost to the project:

Maryland State Medical Examiner's Office
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Los Angeles County District Attorney's Office
Maryland State Police
Federal Bureau of Investigation
New York Police Department
Miami Police Department
Washington, DC Police Department
Seven Baltimore Area Hospitals
Los Angeles Police Department
Los Angeles County Sheriff's Department
New Jersey Bureau of Prisons
Maryland Penitentiary
Baltimore City Jail

The following personnel of the Military and Civilian Law Enforcement Technology Team contributed to the technical research described in this report and, in fact, wrote portions of the report:

D. Campbell
B. Thein
E. Shank
M. Wargovich

Also the following contractor personnel made major contributions:

W. Busey (Experimental Pathology Laboratories, Inc)
A. Tiedemann, Jr (AAI, Inc)
L. Williams (Battelle Memorial Institute)
R. Zelina (AAI, Inc)

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EXECUTIVE SUMMARY

At the request of the Law Enforcement Assistance Administration (LEAA), the Military and Civilian Law Enforcement Technology Team at the US Army Human Engineering Laboratory, Aberdeen Proving Ground, Maryland 21005, worked on the evaluation of less-lethal weapons for several years. This report "pulls together" much of the work and presents work which was previously disseminated in draft form only. Although the accomplishments are generally described in a scientific language not appropriate for general publications, it seems worthwhile to paraphrase these for more general usage. The following few paragraphs provide a brief background and approach to this work and also summarizes some of the findings.

A multidisciplinary panel of scientific and law enforcement personnel (Scenario Group) developed standard settings or scenarios in which less-lethal weapons are likely to be employed. Once the standard scenarios were established, desired goals or objectives to be achieved by the usage of less-lethal weapons in these scenarios were enumerated. In addition to the goals or desirable effects sought, the proper restraints and/or the effects which would be undesirable to achieve were also listed. Data collected on the results of employing less-lethal weapons, such as tissue damage and physiological response, were then examined by a Medical Group which considered each set of data on each weapon in the context of each scenario. The Medical Team then, based on these considerations, estimated the probabilities of achieving each desirable effect and each undesirable effect in each scenario. Additionally, a Behavior Analysis Group further examined the basic data and viewed available film of actual less-lethal weapon usages and augmented the findings of the Medical Group by making probability estimates for the desirable and undesirable effects due to behavioral responses. This process enabled the comparison of one less-lethal weapon with another. Work on the evaluation of less-lethal weapons is far from complete; however, based on evaluation work done to date, some general comments can be made, particularly for those engaged in the design of less lethal weaponry.

GENERAL

The expected mechanism of effectiveness for a less-lethal munition must be clearly defined; e.g., most projectile (nonchemical) type devices rely on pain as their mechanism of effectiveness. If pain is the primary mechanism and not momentum transfer, the energy transferred to the target can be minimized without a reduction in the induced pain. In fact, increased energy availability not only increases serious damage probabilities, but may in fact decrease the pain induced effectiveness. Other mechanisms of effectiveness have been considered such as entrapment from bola rounds or capture nets. However, much more engineering work needs to be done in these other areas.

Disregarding the psychological effects of "pain," the probability of achieving mission objectives (on scenarios considered to date) through physiological response at these kinetic energy levels is relatively low (10 to 20 percent). First time usage may, of course, provide higher probabilities than will be achieved after several experiences. However, if further evaluation is conducted, the consideration of pain and psychological effects should be considered as they will increase the probability of achieving mission objectives.

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FOR BLUNT TRAUMA

For small (e.g., one-inch diameter rubber ball) relatively hard projectiles, an available kinetic energy level of 15 to 30 foot pounds should not be exceeded unless one is willing to accept some gross physiological damage to critical body organs such as the heart, liver, kidneys, etc.

Considering damage to critical organs, penetration problems, and the size of the eye socket, it appears that for a given kinetic energy level, an object of about two inches in diameter will be the least damaging item. This coupled with the energy limitation suggested above prescribes a muzzle velocity (assume unit density) of slightly over 100 feet per second for a sphere to provide a relatively safe blunt trauma device. Of course, the maximum safe velocity will be different for missiles of other shapes or densities. It may be noted that the maximum range, for the prementioned sphere with a muzzle velocity of 100 feet per second, is about 50 meters. This maximum range will be achieved for a launch angle between 40° and 45°. Consequently, the maximum range prescribed by scenarios utilized to date (7 to 75 meters) will not be reached under these launch conditions.

Certain configurations or packaging may produce "special" types of injuries such as those witnessed in tests of bean-bag type projectiles. These "special" effects can presently only be predicted by adequate testing of the device, to obtain meaningful physiological data.

The relationship of severity of skin damage to critical organ damage is very projectile dependent. This relationship should be well understood for a given item in order to provide correct diagnostic information for medical treatment purposes. Some items tested show very little skin damage associated with rather severe critical organ damage.

FOR CHEMICAL ITEMS

Undesirable effects may be obtained from chemical items not necessarily through the action of the chemical agent itself, but through the delivery system. The delivery system should be designed to minimize hardware induced trauma.

Evidence collected to date on the employment of chemical agents for crowd dispersal indicates that the visual signature of the agent cloud is a major factor in achieving this objective.

It is apparent that effectiveness of hand-held dispensers is due primarily to agent entering the eye, while effective barricade penetrators generally have the undesirable characteristic that the mechanisms used for penetrating barriers are themselves potentially highly dangerous.

FOR ELECTRICAL ITEMS

In terms of minimizing damage and maximizing effectiveness, electrical devices appear to be the most promising. From the practical standpoint, little hardware exists in this area for most scenarios. Further item development appears to depend more on public education than increased technical capabilities.

FOR PENETRATING ITEMS

Although not normally thought of as less-lethal items, penetrating items often are non-lethal. Penetration-type projectiles such as the standard .38 caliber bullet are neither fully effective from the "desirable" nor the "undesirable" viewpoint. This lack of effectiveness was demonstrated in an evaluation of the .38 caliber bullet as a reference point for less-lethal projectiles. It is further emphasized by the continued search by law enforcement agencies for a new ammunition, gun, training, etc. Proper definition of stated objectives and determination of mechanism of effectiveness would allow the development of a weapon system which would maximize effectiveness while minimizing damage.

The above findings are based on the work of the Military and Civilian Law Enforcement Technology Team and are treated in more detail in this and other technical reports and technical memorandums.

THE EVALUATION OF LESS-LETHAL WEAPONS

INTRODUCTION

Early in 1970, it became apparent that an evaluation technique for so-called less-lethal (non-lethal, etc) weapons was required (1). These weapons generally fell into the categories of blunt trauma, chemical and electrical, depending on the mode of energy transfer. Prior to this time, little had been done toward the development of a methodology for the evaluation of this type of weapon. In addition, very little quantitative data on blunt trauma to the body were available, although a fair amount of data was available for head injuries resulting from sports and auto accidents. Considerable work had been done with chemical agents, particularly CS and CN, the most commonly used tear gas agents. Some data were available on electrical shock, but not in a form which would be applicable to the evaluation of less-lethal weapons.

Early in 1971, National Institute of Law Enforcement and Criminal Justice (NILECJ) personnel recognized the need for development of techniques for the evaluation of less-lethal weapons. As a result, negotiations for an agreement to perform this work were initiated with the US Army Land Warfare Laboratory (LWL). This work was later transferred to the US Army Human Engineering Laboratory (HEL).

In November 1971, a conference on "Research Needs for Nonlethal Weapons for Law Enforcement and Related Civilian Applications" was held in Washington, DC. This conference was sponsored by the National Science Foundation and the Law Enforcement Assistance Administration (LEAA), NILECJ (2). Approximately 60 persons, knowledgeable in a variety of fields relevant to the subject matter, participated. The objectives of the conference were:

a. To review the problems and policy issues concerning nonlethal weapons for law enforcement and related uses, and,

b. to develop recommendations for research and development priorities for addressing these technical and policy issues.

The purpose of the conference was not to reach consensus, but to permit the sharing of ideas, knowledge, and insights. A significant finding and conclusion reached by the workshop groups of this conference was that a "systems approach which would take into account the full range of factors affecting a policeman's response to various situations . . . (was) needed to guide nonlethal weapon research and development." Moreover, a need was identified for the development of adequate procedures for nonlethal weapon evaluation.

The above-referenced efforts, together with some earlier survey work, form the underlying premise for the development of a standardized methodology for the determination of less-lethal weapon effectiveness and safety characteristics. It was decided to build the first evaluation model around the blunt-trauma type less-lethal weapon. The myriad display of blunt-trauma items and concepts for less-lethal weapons, for which no evaluation had been performed, contributed importantly to this decision. The methodology described in this report pertains to blunt-trauma devices, chemical and electrical weapons.

Although it was felt by many that chemical techniques were of prime interest, the LWL had initiated an earlier effort to develop methodology for nonpenetrating less-lethal weapons. Utilization of this work was also instrumental in the selection of kinetic-energy weapons for the prime methodology development. Furthermore, it should be noted that many police agencies had nonpenetrating kinetic-energy-type weapons at their disposal at that time. Thus, a prime interest existed for information which would be applicable to their use.

In evaluating conventional weapons, there are no constraints on maximum extent of injury inflicted by the weapon. The basis problem in evaluating less-lethal weapons, on the other hand, is that the area of constraints is highly enmeshed with the area of incapacitation. Furthermore, effectiveness constraints are readily stated for these weapons, however, they are not presently standardized. Of necessity, the overall measure of less-lethal weapons will be at least a two-parameter set, one parameter measuring the desirable effect and the other parameter measuring the undesirable effect.

In the area of undesirable effects, standards must be established as to tolerable probability of death and irreversible systemic damage. In addition, safety criteria may be specific as to eye damage, skin penetration, head-area impact energy, etc.

For desirable effects, one relatively simple measure is the amount of force generated by impacts at various locations on the body (for blunt-trauma devices) and the resultant response of personnel. This must, of course, be translated into a functional disability measure of some sort. One such functional disability is the loss-of-consciousness through blunt trauma in the cranial region. However, the techniques which might provide such effects within reasonable safety constraints may be nonexistent.

The mechanism of effect by which weapon designers developed blunt-trauma type weapons appears to be "pain" rather than pure knockdown force such as obtained by high-pressure water "rods" from fire hoses. The pain-value approach is also of interest since weapon techniques may be optimized to maximize pain while constrained to minimize hazard levels. Although this effect is not directly stated by weapons developers, it seems to be the primary mechanism by which they hope their item will be effective. Therefore, the only "nonphysiological" mechanism of effect treated to any depth in this report is "pain."[1]

In addition to measures of desirable and undesirable effects, certain realistic and convenient conditions for standardization evaluations need to be established. For example, the predisposition of the enforcement personnel, as well as that of the "second force" members, must be classified and identified similar to the combat stress situations formulated for the evaluation of military kinetic-energy "lethal" weapons.

Although some work with the evaluation of .38 caliber rounds has been done by Hatcher (3) and further developed by others (4) and some tests have been run on the undesirable effects of blunt-trauma devices, no general evaluation model for less-lethal weapons, per se, had to our knowledge been developed before the one presented herein. Though concern for testing the safety of less-lethal weapons had been apparent, the approach to safety testing (without an overall evaluation plan to provide for the inclusion of the "effectiveness" factor) could possibly

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[1] It is recognized that pain in fact is a physiological effect; however, due to the qualitative nature by which it is measured, it is considered as a nonphysiological mechanism within this report.

lead to a position where safety is stressed to the exclusion of effectiveness. For example, "marshmallows" delivered by parachutes might be selected as the "best" less-lethal weapon because they are so safe; however, such a weapon's effectiveness for producing the desired effect would have to be considered as practically nil.

It should be mentioned that this work has been coordinated with other agencies which have been working in related areas or which have an interest in this program. A special Coordination Conference on Less-Lethal Weapons was sponsored by and held at LWL on 21 June 1972. In addition, many different individuals participated directly in the program and provided a multidisciplinary approach to the problem.

To assist the development of this evaluation procedure, a Multidisciplinary Less-Lethal Weapons Evaluation Panel was established. The panel was responsible for providing

a. an overall method of evaluation,

b. standardized police-type operational scenarios,

c. damage mechanism effects data,

d. estimates of desirable and undesirable effects produced by the damage mechanism, and

e. a model for exercising the data in order to obtain quantitative performance estimates of specific less-lethal weapon systems.

The establishment of a systemized body of knowledge and a technical approach which can be used to assess the effectiveness of less-lethal weapons involves, of necessity, a number of disciplines representing both the "hard" and the "soft" sciences. In line with the above, the Evaluation Panel was subdivided into several working groups to cover the diverse work areas involved. These groups, with the backgrounds represented, are shown in Appendix A. While the multidisciplinary/expertise requirement was utilized, the number of members on each group was held to a minimum to facilitate the working of the group.

The scenario Group had the responsibility of constructing basic scenarios (details provided in HEL TM 20-75, Standard Scenarios for the Less-Lethal Weapons Evaluation Model) which would depict some situations likely to confront civilian control forces.

The Behavior Analysis Group originally was primarily concerned with establishing the validity of the basic overall evaluation technique. As work on this task proceeded, the group's primary objective changed. It then was utilized to render estimates of desirable effects produced by a spectrum of single damage mechanism impacts against individual target personnel engaged in activities specified in the appropriate scenarios. In these estimates, target effects due to "nonphysiological" effects (e.g., pain) were stressed. An example of some workings of this group is presented in the appendix of TM 20-75, Standard Scenarios for the Less-Lethal Weapons Evaluation Model, in the form of informal notes from one of the meetings of the group. Additional notes from the Behavior Analysis Group are found in Appendix B.

The Medical Group worked with the physiological data and was principally concerned with rendering separate estimates of undesirable and desirable effects produced by a spectrum of single damage mechanism impacts against individual target personnel engaged in activities specified in the appropriate scenarios. In these estimates, target effects based on physiological damage were stressed. Some minutes of the Medical Group meetings were consolidated and distributed; results applicable to the overall evaluation technique are summarized in the next section of this report.

The mathematical portion of the effort includes model formulation suitable for use with scenarios of interest, data presentation, and computer programming. The model served as a provisional standard technique for exercising a weapon/scenario combination in order to generate a quantitative index to be used for comparing less-lethal weapons. The overall evaluation mathematical model utilized is discussed in some detail in Appendix C.

Data collection was of prime importance because so little quantitative data had been generated on less-lethal weapons. Literature searches were conducted on blunt-trauma effects and on quantifying pain and are summarized in Appendix D. Data obtained from experiments involving the testing of various items were collected, collated and analyzed.

Although ideally the ultimate use of the evaluation technique described in this report is to be by local police agencies, the form of the evaluation is not sufficiently complete nor has the evaluation been put in a form such that it can be used on the local level. Certain findings from this effort, as given later, could be extremely useful in a culling or screening of the numerous candidate less-lethal devices now available on the commercial market.

A more scientific summary of results for various less-lethal devices are found in the following publications:

Blunt Trauma- USA Land Warfare Laboratory Technical Report 74-79, "A Comparison of Various Less Lethal Projectiles;" USA Human Engineering Laboratory Technical Memorandum 4-76, "Weapon Performance Testing and Analysis: The MODI-PAC Round, The No. 4 Lead-Shot Round, and the Flying Baton."

Chemical Devices- USA Human Engineering Laboratory Technical Memorandum 2-76, "Modeling for Less Lethal Chemical Devices," USA Human Engineering Laboratory Technical Memorandum 21-75, "Testing and Evaluation of Chemical Weapons."

Electrical Devices- USA Human Engineering Laboratory Technical Memorandum 3-76, "Modeling for Less Lethal Electrical Devices."

In addition, over fifty interim and informal reports were prepared as a basis for the results presented within this report.

SECTION I

GENERAL METHODOLOGY

Although various approaches to the problem of evaluating less-lethal weapons were attempted and several so-called mathematical models were developed, this report outlines only the final technique which was developed and subsequently "exercised." This initial technique does not consider such important parameters as cost, training, reliability, etc., to any extent, since weapon-selection restrictions due to training or costs may be straightforward. Reliability can be at least crudely established by the evaluation procedure described herein.

Essentially, the evaluation procedure presented consists of five key elements as follows:

1. Scenario Selection.
2. Weapon/Device Performance Data.
3. Physiological Effects Data.
4. Nonphysiological ("other") Effects Data.
5. Model Application for a Relative Merit Index.

The relationships of these elements to one another provide an evaluation procedure (Figure 1). The user requirements and the established standards should have input into the evaluation procedure. The relationships given above, when mathematically defined, constitute the mathematical evaluation model. Although it is desirable to use such a mathematical model to briefly summarize evaluations results in a few simple indices for comparison purposes, it is apparent that information gathered in each step of the evaluation procedure can of itself be of immense value. Furthermore, given a dollar limit for an evaluation, the model elements are logical progression steps by which one may proceed along the evaluation "trail," the point of termination being determined by the dollar cost set or by the obvious unsuitability of the items to produce acceptable results.

The general procedure for calculating a numerical index of weapons effects and hazards, is as follows:

> A particular scenario is chosen from those described in HEL TM 20-75, Standard Scenarios for the Less-Lethal Weapons Evaluation Model. It is significant to note that the scenario provides a constant basis for weapon evaluation. Moreover, the choice of scenario determines certain quantitative parameters such as time and geometric relations, but most importantly the chosen scenario defines the undesirable and desirable effects to be used in the particular evaluation. A candidate less-lethal weapon is selected and its characteristics identified. Once the scenario is chosen and the specific weapon characteristics identified, the terminal effects are calculated and the pertinent data are extracted from the data banks. The data extracted from the data banks are the probabilities of effects given a "hit" on the target. Information obtained from the data banks is appropriately combined with the information on weapon dispersion and target geometry to provide a final measure of undesirable

and desirable effects. Thus, the weapon "performance" data are used to determine the probability of a "hit," and the data bank provides the probability of the "effect;" the mathematical combination of this information provides a numerical index which may be used for comparing less-lethal weapons.

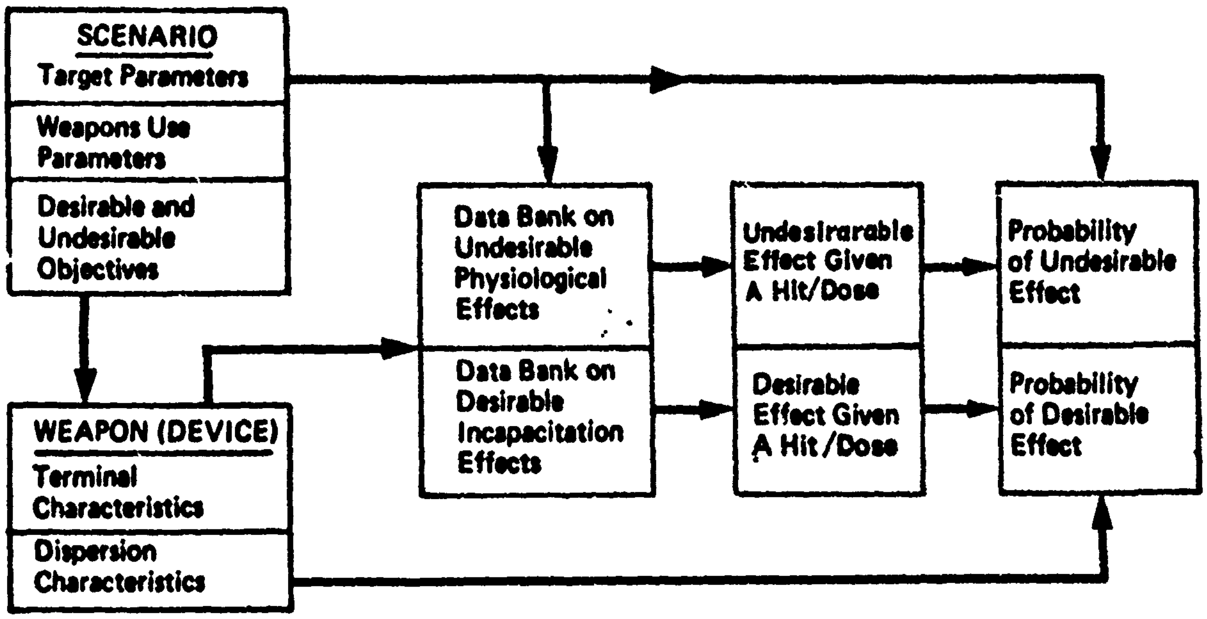

Figure 1. A general concept of an evaluation procedure for less-lethal weapons.

A summary of the steps of evaluation coinciding with the monetary expenditure available for an evaluation is given in Table 1.

TABLE 1

Steps of Evaluation as a Function of Monetary/Effort Expenditures

A. Weapon Performance

1. Theoretical determination of trajectories, velocities, kinetic energies, etc., and target "hit" probabilities as a function of range.

2. Tests to verify total system "hit" probabilities and provide a crude measure of reliability.

B. Physiological Effects

1. Estimation of damage levels or dose response.

2. Tests to determine actual damage levels for various body organ systems, or equivalent dose response relationships.

3. Monitoring of other physiological responses; e.g., by EKG's, changes in blood chemistry, etc.

C. "Nonphysiological" Effects

1. Determination of "effects" mechanisms and estimation of probable responses.

2. Tests to determine effectiveness levels.

D. Probability Estimations

1. Determination of time plot (function-loss history).

2. Medical Group estimates of probabilities of undesirable effects for given conditions (scenarios - independent).

3. Medical Group estimates of probabilities of desirable effects for given conditions and scenarios.

4. Behavior Analysis Group estimates of probabilities of desirable effects based on other than physiological aspects.

E. Math Model

Combination of hit probabilities and effects probabilities into simple indices for relative comparison.

DISCUSSION OF THE ELEMENTS OF EVALUATION TECHNIQUES

As previously mentioned, the first analysis prepared was for the "blunt trauma" type less-lethal weapons. The following discussion therefore is given for these type weapons, but is similar, as will be shown later for other type devices; e.g., chemical, electrical.

The General Methodology Section lists the five key areas in the proposed evaluation of less-lethal weapons. In this section the key areas will be discussed in some detail.

Scenarios Selection

The primary purpose of a scenario is to provide a consistent or standardized basis for comparing different control devices. The scenario can be thought of as a detailed description of how the less-lethal device would be used in a specific situation. There were two main areas of effort in evolving the scenarios; the first involved establishing the different types and numbers of scenarios, and the second was the actual detailing of the scenarios.

Five scenarios have been detailed for use in the evaluation process and are discussed in HEL TM 20-75. By title, the five scenarios are:

a. Scenario I - The One-On-One Situation (Apprehension, Self Protection).

b. Scenario II - The Barricade Person (With and Without Hostage).

c. Scenario III - The Suspect Fleeing on Foot.

d. Scenario IV - The Dispersal of a Crowd (Low and High Violence).

e. Scenario V - Prison (Assault of Officers, Dining Hall Riot, Riot with Hostages).

There were three criteria involved in selecting the inventory of five scenarios; viz., there should be a limited number of scenarios, the scenarios should be representative of frequently encountered situations where police force and/or weapons are likely to be used, and the scenarios should be significantly different in character.

Comments were received during the course of the study that the scenarios were too limited and that other situations should be included; e.g., scenarios involving automobiles, altercations between private citizens, or persons defending themselves on the streets or in the home. It may well be that certain of these situations are sufficiently different to warrant inclusion in the scenario inventory, and certain ones could be included at a later time. However, the criteria that the scenarios should be limited in number is based upon past experience that a large number of situations are never really utilized for evaluation purposes. That is, each time a different scenario is used there is the additional effort required to derive the input data. Even if the development of the input data and the exercise of the model for each scenario are not too time-consuming, the overall evaluations must then somehow employ an "average" over the outcomes for each different scenario. The point is that having many scenarios, although possibly more descriptive of all the police situations which might be encountered, could introduce a decision-making situation where the factors which dominate the decision are obscured.

In detailing the individual scenarios, it became quite evident as the evaluation procedure evolved that certain specific quantitative data were needed; e.g.:

a. Distance between the police and the subject.

b. Allowable maximum elapsed time from actuation of the weapon until onset of weapon effects.

c. Allowabe minimum (and maximum) duration of desirable effects.

Furthermore, it was found that certain details of the situations or scenarios needed to be added as the scenario was used in a particular evaluation. For example, in Scenario IV, is the crowd assembled in their own neighborhood or at some remote public place? In addition, in Scenario II, details of the building in which the hostage(s) is held are important inputs to the estimation of a nominal time needed for the police to get from the street to a particular location (room) in a building.

Weapon Performance

Before a particular device can be evaluated, some basic data on the performance of the device are required. For blunt-trauma (impact, nonpenetrating) devices, the important characteristics are:

a. Accuracy.

b. Muzzle Velocity.

c. Projectile Weight.

d. Projectile Drag.

e. Reliability (chance the "round" will get to vicinity of target).

If performance data are available on each of the above items, there is sufficient information to conduct an evaluation, as the procedure is presently established. If evaluations needs become more stringent, additional information (such as projectile-target resilience) may be required. It should be noted that weapon performance characteristics generally fall into two categories: those that determine the effect on a target (muzzle velocity, projectile weight and drag) given that the target is hit, and those which determine <u>if</u> the target is hit (accuracy and reliability).

For chemical devices, the performance characteristics generally fall into the same two categories. Unfortunately, the distinction between a "hit" and "no-hit" is not nearly so precise for chemical devices as compared with blunt-trauma devices. That is, the noxious environment for most chemical devices is generally well dispersed prior to interacting with the target, and the details of estimating the net effect on the target are more complex.

In order to provide some specifics on performance data, two different uses of performance data are discussed below. Much of the effort in the original program had involved tests with a 1-inch diameter hard-rubber sphere as a vehicle for orientation on blunt-trauma devices. Portions of a parametric investigation of various diameter hard-rubber balls are presented in the next paragraph to give an example of how the device performance data were related to the target impact conditions. The original purpose of the investigation was to determine the impact conditions of a "bore-safe" missile and to examine the relation between muzzle energy and terminal energy at various ranges.

The analysis was performed for four different sizes of spheres; viz., of 0.5, 1.0, 1.5 and 2.0 inches diameter. Trajectory computations were performed to obtain estimates of projectile impact velocity/energy as a function of muzzle velocity/energy, launch elevation, and downrange position. Table 2 presents nominal range impact velocity, impact energy, and time of projectile flight for assumed muzzle energies of 15, 30, 60 and 90 ft-lb; assumed sphere diameters of 0.5, 1.0, 1.5 and 2.0 inches; and assumed launch angles of 5, 10, 15 and 20 degrees. Table 3 presents the muzzle velocities/energies needed for a 1-inch diameter sphere launched at 5^{o} angle to achieve energy levels of 15, 30, 60 and 90 ft-lb at each of three specified downrange positions. These ranges generally represent the close-, medium-, and long-distance ranges of the five scenarios previously discussed. A ballistic drag coefficient, C_D, of 0.4 was used for all computations. Assuming that a direct-fire capability is desired, a small elevation angle should be selected. However, angles of even one or two degrees require very high velocities, due to the effects of gravity, to achieve even the shortest ranges of interest. The significance of the kinetic energy levels of 15, 30, 60 and 90 ft-lb in Tables 2 and 3 will be discussed in a subsequent section of this report. Calculations like those performed on the various spheres can be performed for other individual items of interest when the actual evaluation of such items is desired.

A second set of data involving weapon performance characteristics is included here also because the data are specific and because the information is of general interest to individuals involved with less lethal weapons. It was suggested by Mr. Burton Katz[2] of the Los Angeles County District Attorney's Office that data on ordinary "hand-launched" items, such as those thrown at law-enforcement personnel, would be useful for comparison purposes. In response to this suggestion, some limited tests were conducted using the items indicated in Table 4. The complete test data, including explanation of test procedures, etc., were published in an informal LWL Technical Note; however, some results of the tests are summarized in Table 4.

Both the results of the hard-rubber ball parameter study and the data from the bricks/beer bottle/etc., throwing tests lead to a question of the significance of a given level of impact energy expressed in foot pounds. This is further discussed in the portions of the report pertaining to blunt-trauma effects.

Measures of Effect - Physiological Basis

Much of the blunt-trauma literature examined by personnel on this project was oriented toward head injuries. Appendix D summarizes the literature survey effort. The diverse investigations surveyed were mostly in general terms of physical parameters (e.g., angular acceleration of the head) which are not easily determined from a knowledge of the characteristics of a specific weapon which is to be evaluated. The initial concept was that if biological species somewhat similar to man were impacted with objects which were of particular interest, then at a minimum, examinations could be made of tissue disruption. Medical judgments on the well-being of human subjects which could have been impacted with the same missile and at the same velocities could then be made. The problem of relating animal data to humans, of course, remains. However, it was felt that gross estimates could be given initially.

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[2] Mr. Katz was instrumental in establishing the Los Angeles County District Attorney's Less Lethal Weapons Task Force. The work of this task force was closely coordinated with this effort, primarily through the concurrent participation of several members of the Evaluation Panel on various committees of the Los Angeles Task Force. A final report on the task force work was published as USAHEL Technical Memorandum 24-76, Los Angeles County District Attorney's Less-Lethal Weapons Task Force.

TABLE 2

Nominal Range, Impact Velocity, Impact Energy and Time of Flight as a Function of Initial Energy, Sphere Diameter and Launch Angle for a Sphere of Density 1g/cc

		Initial Energy = 15 ft-lb				Initial Energy = 30 ft-lb				Initial Energy = 60 ft-lb				Initial Energy = 90 ft-lb			
Sphere Diam (in)	Launch Angle (deg)	Nominal Range (ft)	Impact Veloc (fps)	Impact Energy (ft-lb)	Time of Flight (sec)	Nominal Range (ft)	Impact Veloc (fps)	Impact Energy (ft-lb)	Time of Flight (sec)	Nominal Range (ft)	Impact Veloc (fps)	Impact Energy (ft-lb)	Time of Flight (sec)	Nominal Range (ft)	Impact Veloc (fps)	Impact Energy (ft-lb)	Time of Flight (sec)
0.5	5	260	67	0.2	1.5	320	64	0.2	1.7	380	60	0.1	1.9	420	58	0.1	2.0
1.0	5	153	110	3.6	1.0	234	110	3.6	1.3	320	107	3.4	1.6	370	104	3.2	1.8
	10	233	80	1.9	1.9												
1.5	5	70	99	9.7	0.6	125	119	14.0	0.9	207	131	17.0	1.2	270	133	17.5	1.4
	10	125	86	7.3	1.3	295	96	9.1	1.6	315	99	9.7	2.3				
	15	165	76	5.7	1.8	255	82	6.7	2.3								
	20	200	71	5.0	2.3												
2.0	5	32	73	12.5	0.5	62	97	22.1	0.6	113	112	29.5	0.8	158	133	41.5	1.0
	10	60	69	11.2	0.9	110	86	17.4	1.2	192	102	24.4	1.6	255	107	26.9	1.8
	15	89	65	9.9	1.3	153	79	14.7	1.7	250	90	19.0	2.3				
	20	133	69	11.2	1.8	204	78	14.3	2.3								

TABLE 3

Muzzle Velocities/Energies to Achieve Indicated Velocities/Energies at Indicated Distances for a 1-Inch Diameter Sphere of Density 1.3g/cc Launched at a 5° Angle

Muzzle Velocity (fps)	Muzzle Energy (ft-lb)	Distance, R, from Launch (ft)	Velocity at Distance R (fps)	Energy at Distance R (ft-lb)
210	17	16	198	15
251	24	66	198	15
453	79	230	198	15
296	34	16	280	30
355	48	66	280	30
640	157	230	280	30
419	67	16	395	60
502	97	66	395	60
904	313	230	395	60
513	101	16	484	90
614	145	66	484	90
1106	469	230	484	90

Although there was an awareness of the various concepts of damage mechanisms, there was no preconceived idea of how damage would relate to impact conditions other than that energy and/or momentum transfer should be related somewhat to damage. Serious consideration was given to an alternative approach which would take the best available physical models of damage and attempt to forecast the effects of impacts without verification by tests. It would have been academically honest to use this approach, but it was not done for two reasons: (a) it was difficult to convince a qualified investigator to extrapolate the models and existing data for these purposes, and (b) it was known that confirmatory firings against biological specimens was needed for verification. Hence, the model pursues the concept that a given weapon can be evaluated with a set of firings. The evaluation plan recommended suggests just how extensive such firing tests should be, depending on the allowable effort (both time and money) to be expended on an evaluation.

Once the decision is made to perform tests, a procedure has to be established for evaluating the results. During the examination of test information, two separate but related procedures evolve. The simpler procedure consists of determining physiological damage grade levels whereby various levels of tissue disruption resulting from blunt trauma are assigned number proportional to the extent of damage. On examination of the physiological data available, it was found that standard criteria for rating damage was not available in the form required to quantify experimental results. The Medical Group, therefore, established criteria for grading physiological damage resulting from blunt trauma. These criteria were used as the basis for all data analyses of this report and are presented in Appendix E. For a particular organ, the levels ranged from 0

TABLE 4

Average Velocities and Kinetic Energies for Ordinary Hand-Thrown Objects

Item	Velocity (fps) Computed @ 4.5 ft	Velocity (fps) Computed @ 16.5 ft	Kinetic Energy (ft-lb) Computed @ 4.5 ft	Kinetic Energy (ft-lb) Computed @ 16.5 ft
Sling Shot with 1/4" diameter ball bearing (16 grains)	188	184	1	1[a]
1/8 Brick hand-thrown (0.55 lb)	79	65	58	39
1/4 Brick hand-thrown (1.1 lb)	--	45	--	36
Beer Bottle throw-away, full, hand-thrown (19 oz)	59	--	65	--

[a]Simple experiments performed by other investigators indicate little penetration damage at these velocities and energies except to the eyes and the ear canals.

through 5, with 1 indicating some minimal signature of insult, and 5 representing a massive local disruption of tissue,[3] and 0 representing no signature whatsoever.

Different grading scales were established for the following nine vital organ and/or body regions:

1. Skin, subcutaneous tissue and muscle.

2. Kidney.

3. Liver.

4. Spleen.

5. Lung.

6. Other viscera.

7. Bone.

8. Head (skull and brain).

9. Heart

It was interesting to speculate on why the Medical Group delayed until last the establishing of the heart damage criteria. As noted in the introduction to Appendix E, the purpose of the grade level definitions is to provide a consistent basis for assessing damage to wounded body regions or organs. From the overall objectives of the evaluation effort, there is also a need to relate the well-being of the subject to the particular impact damage. So a measure of damage, however consistent, may be of little value if damage level does not correlate consistently with the well-being of the patient. In the case of the heart, it has been observed that relatively minor tissue disruption can result in a serious heart problem, whereas in some instances, rather gross physical disruption of the heart can create a less serious systemic problem. Hence, it is difficult to establish for the heart a set of grade levels of increasing tissue disruption which correlates well with the well-being of the patient.

This type of concern, along with the recognition that the human body is not a set of simply interfacing components, resulted in the second procedure for evaluating physiological damage. When the data from the individual tests were reviewed by the Medical Group, it was highly desirable to make some assessment of the "well-being" of an individual (in terms of probabilities of undesirable effects) who might have received a wound quite similar to that inferred by tests. The assignment of a grade level to all critical portions of the body after an impact does lead directly to the assessment of a human subject's well-being. Thus, in addition to assigning grade levels, the Medical Group made a probability assessment of the patient's lack of well-being. The problem with this procedure is that there is no certainty as to the consistency of a consensus judgment estimate although the consensus estimation of a probability of lack of well-being of a subject has the obvious built-in characteristic that it is correlated with his well-being. Further

[3]Some criteria for heart damage was in terms of conductive disturbances and myrocardial injury as well as physical damage. These criteria are explained further in Appendix E.

analysis of results did, however, show considerable consistency in these estimates. For an assessment of lack of well-being (undesirable effect), some criteria of well-being have to be provided. The criteria are included in the following definition:

Undesirable effect is that anatomical and/or functional effect which persists longer than 24 hours and prevents an individual from performing routine daily tasks and/or produces permanent impairment as defined by the American Medical Association (AMA) ratings.

The real issue is whether undesirable effects of less-lethal weapons should include loss of functional capability of the subject or should be restricted to the probability of death. It was assumed in this effort that loss of functional capability should also be included as an undesirable effect.

Up to this point, the discussion has been oriented primarily toward undesirable effects. The Medical Group also assessed, from a physiological viewpoint, the desirable effects (incapacitation as a result of impact). For assessment of the desirable effects of a device, it is necessary to introduce the objectives of the scenario. Hence, there may be completely different probability assessments for a given impact depending upon the scenario used in the evaluation. The most obvious difference is between Scenario III (Suspect Fleeing on Foot) and Scenario IV (Dispersal of a Crowd). In Scenario III, the objective is to stop a running suspect; and in Scenario IV, the objective is to make the subject run (disperse). The time/function-loss relationship also becomes a significant factor in considering desirable effects.

Another problem concerns the "effects" data. The problem arises in trying to relate the terminal effects parameter to the probability estimated for obtaining desirable and/or undesirable effects. The probability assignments made were estimated by well-qualified members of both the Behavior Analysis and Medical Groups. The Behavior Analysis Group was concerned mainly with the desirable effects, while the Medical Group originally concentrated on the undesirable effects. The latter's contribution to the desirable effects program was also significant during the last half year of the program.

In each group's rendering of the human incapacitation estimates, the general approach followed was to:

1. State the stress situation. This consists mainly of the scenario description, the effect desired, the time to achieve the effect, and the duration of the effect.

2. Review test data. (Graded according to the damage criteria given in Appendix E.)

3. Discuss the probable effect of a similar impact on a human target and give an estimate of its incapacitation effects.

The undesirable and desirable data banks of probability of effect were constructed from the results of item 3 above. One data point was determined by each test result.

In the deliberations of the Medical Group, the procedure was much the same for assessment of desirable effects as it was for the assessment of lack of well-being under the 24-hour criterion (undesirable effects). For example, if the nature of the impact was such that it would clearly stop the fleeing suspect in the allotted time, then for Scenario III the assessment would yield a probability of 1.0 that a desirable effect would be achieved. It should be noted that the bulk of the assessments on the desirable effects, as determined by the Medical Group, were based upon the ability of an individual to function. A high probability of desirable effect indicated a fairly severe physiological change to the body systems and, as might be expected, there was a high positive correlation between desirable and undesirable effect probabilities; that is, impacts which tend to be highly effective from a desirable standpoint also tend to provide considerable unwanted, undesirable effects.

Much of the above discussion becomes more meaningful when it is related to the specifics of actual test data. A complete analysis of such data for blunt trauma devices is given in USA Land Warfare Laboratory Technical Report No. 74-79, "A Comparison of Various Less Lethal Projectiles," June 1974.

It was the intention of all groups of the Less Lethal Weapons Evaluation Panel that the effects of devices on bystanders (involved primarily in Scenarios II and IV) be included. This intent was not achieved, however, and it is important to note that when it is included, the undesirable effects on bystanders will become scenario-dependent, similar to the desirable effects on the intended target subjects.

Although that analysis is not discussed in detail in this report, one can summarize the data obtained in several ways. First, there is some indication that body shots represent approximately the same degree of hazard as head shots, although they are perhaps slightly less hazardous. However, one of the key organs, the heart, is not well understood. Second, the data on the skin, subcutaneous tissue and muscle grouping, together with the data on the organs, provide a lot of information on the relative hazards of a random hit on the body which was not previously available. The most significant aspect of the test data is evident when it is examined in conjunction with data from many sources. An example of an additional data source is the work reported in a letter report entitled, "Bean Bag-Hazards Study," released 8 September 1972 (5). The individual shots in that test series were graded according to the criteria given in Appendix E. It should be noted that these tests used a 0.3 pound bean-bag missile, approximately 12 times heavier than the 1-inch rubber sphere tests previously considered. The bean-bag missile also has considerably different impact orientation and probably quite different compliance characteristics. However, grossly, the results were quite similar; that is, in excess of 90 ft-lb total impact energy frequently caused extensive damage to the impact region, and at 30 ft-lb impact energy, the damage experienced was quite markedly less (dependent upon the impacted area). There were only two shots at the 15 ft-lb level, and one of these provided some small damage to the liver. Therefore, a safety statement at the 15 ft-lb total energy level for the bean-bag would not be so well justified as for the 1-inch rubber ball, which gives no liver damage and nothing more than minor skin, subcutaneous tissue and muscle damage at that level. For a considerably larger missile (34 pounds), 23 ft-lb for minor liver damage and 91 ft-lb as the threshold of severe damage has been reported (6). Further investigation of Bean Bag (Stun Bag) data is considered in Section III of this report.

Considering the lack of simple guidelines on damage due to blunt trauma, it appears reasonable at this time to propose an interim, evaluation criteria for damage which identifies 90 ft-lb or above as a severe damage region; 90 to 30 ft-lb as a dangerous region, and 15 ft-lb and below as a safe or relatively low-hazard region. It must be recognized, however, that the region of 15 ft-lb and below has not been extensively investigated. If the projectile cross-section were sufficiently large, such as to preclude entry into the eye socket, then the 15 ft-lb total energy level appears to be an extremely useful criterion for safety.

While it is recognized that the mechanism of injury may be better understood with criteria other than total impact energy, it is felt that some consideration must be given to the utility of damage criteria. Hence, with a relatively minimal effort, the blunt-trauma effect of various devices can be estimated using the total energy criteria as stated in the previous paragraph.

It may seem both redundant and inconsistent to give both a 30 ft-lb limit on the hazardous region and a 15 ft-lb limit on the "safe" region. However, this summary appears to be a good description of the results. Due to the complex interaction between a projectile and a body region, different mechanisms of energy dissipation are apparently taking place in the 30-90 ft-lb region, and for fixed total energy impacts on a given region, different damage levels may be expected.

If impact experiments and mechanism investigations were continued, there would undoubtedly be percentage estimates of damage level as a function of kinetic energy such as those given in Figure 2. A presentation such as Figure 2 could have direct application to the evaluation of a particular device, since the cumulative probability of a given damage level or lower (or higher) may be determined at any kinetic energy level. In the particular evaluation of a device, any damage level (such as Grade 3) could be established as undesirable; then, the kinetic energy of the projectile could be determined as a function of range and the probability of Grade 3 or higher could be determined as a function of kinetic energy and therefore the probability of undesirable damage could be determined as a function of range.

Alternatively, the basic data could be used directly by plotting the overall estimated undesirable effect (using the 24-hour criterion) as a function of impact condition, such as kinetic energy; e.g., Figure 3. Again, it is noted that for a particular less-lethal device, the impact velocity is just as meaningful a description of impact condition as kinetic energy. Kinetic energy is used somewhat generically as the impact parameter because it does represent a scaling which may be descriptive of projectiles with different masses and velocities.

Figure 3 gives the probability of undesirable effect as a function of kinetic energy for a 1-inch ball. The points plotted on the graph are data points and include head, liver, thorax (lung and heart) and kidney shots. It should be noted that in a few instances the undesirable effects probability was assigned as a result of the skin damage rather than damage to the individual organ target. An examination of Figure 3 tends to give further support to the 15, 30, 90 ft-lb tentative criteria, although some caution should be taken since these data are all from 1-inch ball tests.

It is fairly obvious that additional tests should be conducted to better establish the damage level measurements of body response to blunt trauma. Similarly, the judgement estimates of the Medical Group may be better understood if the underlying rationale used in making estimates is stated more completely and then analyzed (similar to the work done in computer medical diagnosis of symptoms).

Measures of Effect - "Nonphysiological" Basis

A problem which arises in the determination of probability estimates relates to the "use" of the weapon to be evaluated. The model for evaluating the effectiveness of less-lethal weapons should entail quantifying the contributions of the effect of displaying the weapon, the effect of threatening to use the weapon and the effect of actual weapon use. If these effect contributors are independent, a summation of effects yields a measure of weapon effectiveness which is termed the "response." Note also that while the proposed evaluation technique concentrates on dissidents or suspects as targets, the indicated effects also apply to observers. The effects on observers not hit, while pertinent, were not investigated to any extent.

The effect of "display" and "threat" in the work conducted to date has largely been discounted. In retrospect, it appears that these elements are most appropriately applied to Scenario IV (Dispersal of a Crowd) and then only to that fraction of the crowd who are neither would-be martyrs nor die-hards. First-time effects might be overwhelming, especially to the

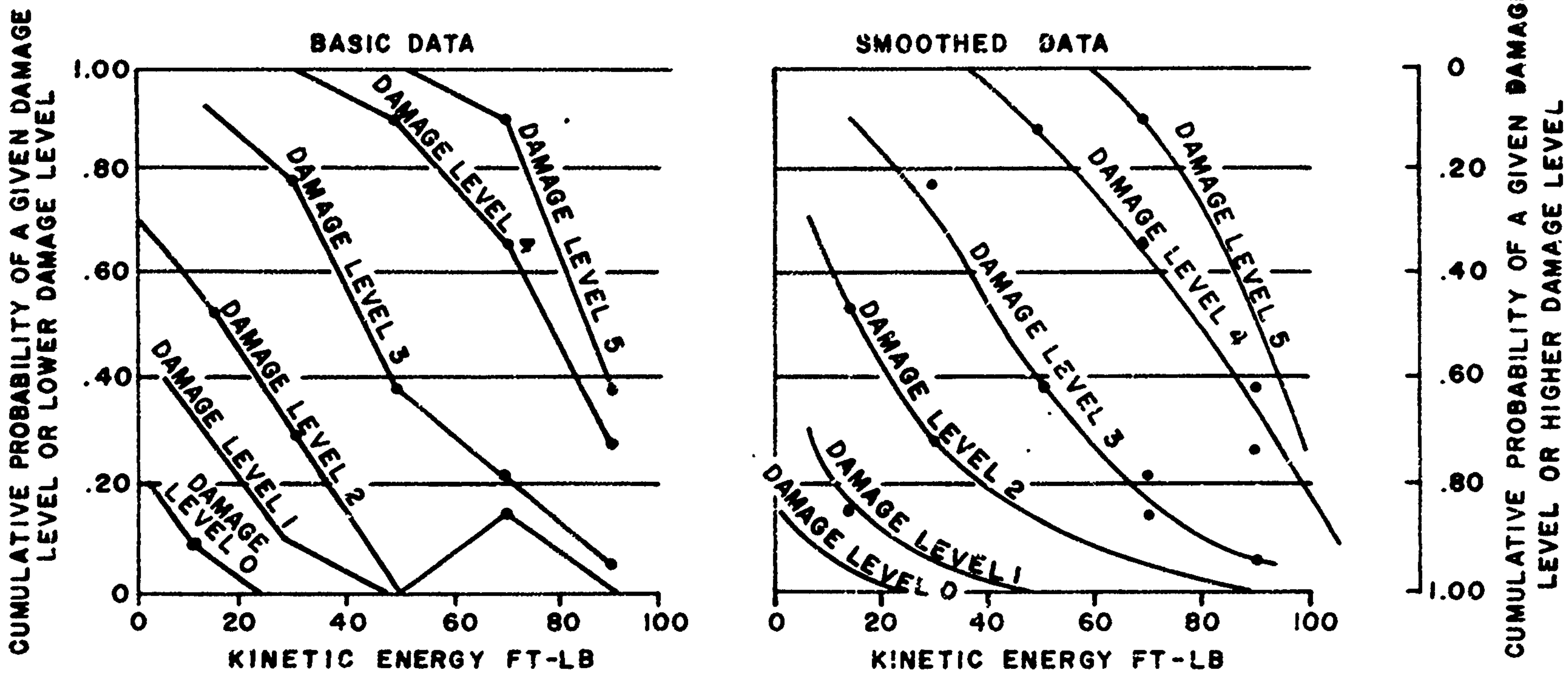


Figure 2. Estimated probability of a damage level as a function of kinetic energy (skin, subcutaneous tissue and muscle).

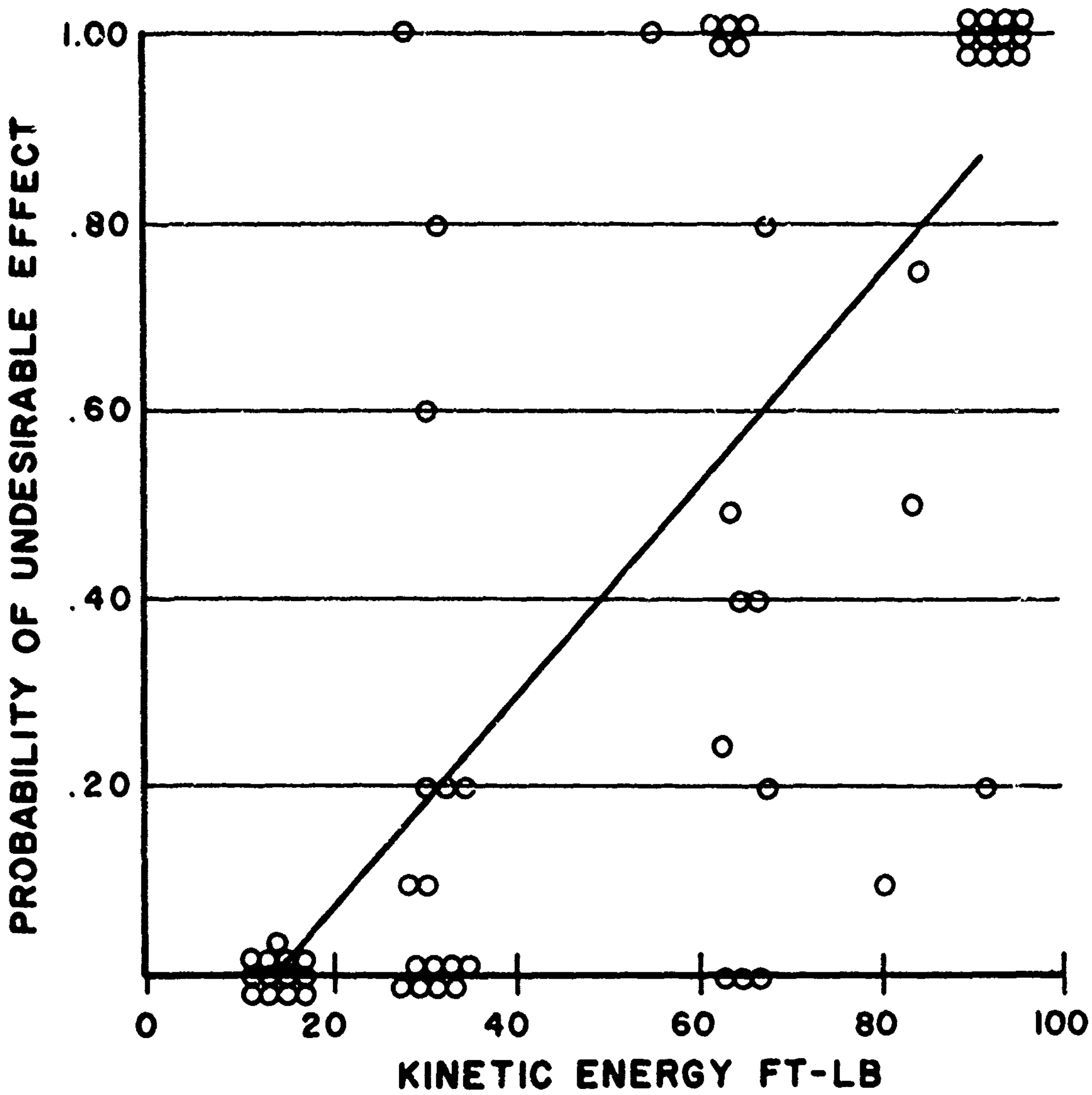


Figure 3. Estimates of undesirable effects versus kinetic energy high energy ball impacts.

fainthearted. However, it is assumed that once the decision has been made to use the weapon, only the "hard core" of the crowd, who apparently are not going to comply with control forces objectives, will remain. Since little work was done on estimation of display and threat effects, weapon comparison techniques presented in this report are primarily based on the premise of actual weapon use. Nevertheless, additional work needs to be done to broaden the overall model to include weapon display and threat effects.

There are many terms to describe "nonphysiological" effects of less-lethal weapons. Cooper (7) and others in the popular press might call this "stopping power." Still others might call it "shock" (not shock in the medical sense). Many people who hunt call it "stun." The following brief discussion is an attempt to identify the mechanisms of effectiveness not normally considered as physiological-produced.

The biological system of the body is complex, but one might break it down into biochemical and electrical systems (8). At least, the hierarchical control systems are chemical and electrical. Bodily control is maintained by chemical flux exchange across the capillary walls, while electrical control is by information flux exchange (both chemical and electrical) through nerve membrane. "General" control messages are transmitted by hormones in the blood, while "specific" control messages are transferred by nervous impulses to specified places. If these control messages are disrupted, altered or tampered with in some manner, the resulting reaction might produce what we could term a desirable effect (without the normal physiological connotation). The primary reasoning behind classifying this as a desirable effect is that the individual's resulting action will deviate from his planned course of action or primary motivation. Although this mechanism of effectiveness, when severe, might lead to undesirable effects, this discussion is primarily concerned with the lower-level mechanism which produces a desirable effect.

As previously stated, time becomes an important factor when measuring effectiveness of a given stimulus (such as impulse from a kinetic-energy device). An interference of function must be related to the body's natural time functioning to give a desired effect. Thus, it should be noted that a cortical task, such as locating a spot of light, requires about 0.1 second. The adrenergic response of the nervous system through the release of norepinephrine at the nerve ends also occurs in the 0.1-second time frame. (This adrenergic response readies the motor system to face the demands which may be placed on it by the command system.) Regulation, such as provided by the hypothalamus, occurs at a time cycle of minutes.

The effects of less-lethal weapons in terms of behavioral and physiological response to a stimulus is a function of time after initiation. From the point of view of the police or control forces, and for the scenarios of interest, the desirable effect has a quick onset time and persists for a relatively short time; i.e., until the objectives of the control forces are achieved. From the point of view of the subject receiving the effects of devices, any discomfort or incapacitation is undesirable; but those effects which persist over long periods of time are unquestionably undesirable from the points of view of both the subject and the control forces. That is, it seems reasonable to speculate that the vast majority of people will consider nausea, temporary blindness and flashes of pain as objectionable, but it may be further asserted that an even greater majority would consider loss of sight, loss of limbs, extended hospital stays, major operations or death as highly undesirable. It should be stated at this point that transitory pain is apparently the only safe mechanism for achieving desirable effects from blunt-trauma, less-lethal weapons. Chemical and electrical devices on the other hand may alter responses in a more physical manner.

The undesirable effects were discussed in some detail in the previous portion of this report, along with a brief description of physiologically-based desirable effects. However, a general discussion of desirable effects is important to properly introduce the subject of "pain."

An essential feature of the evaluation is the establishment of scenarios or "model" situations in which the various less-lethal devices may be used. If the specific scenarios are examined (e.g., Scenario III, the Fleeing Suspect), the desirable effect is to stop the subject within 20-30 seconds from the time of activation of the device. It is not obvious, and this will be discussed below, that a device whose primary effect is to induce pain will stop a fleeing suspect. On the other hand, in Scenario IV (the Dispersal of a Crowd), there is reason to believe that a crowd may be dispersed primarily by the threat of discomfort or pain.

This initial effort of evaluation, as it related to a pain mechanism, is oriented toward the assessment of pain induced by impacting, nonpenetrating missiles. Progress in understanding the nature of electrical devices, tear gas, etc., has been made by considering the mechanisms of desirable effect through ways which induce response in forms other than discomfort due to transitory pain.

If the desirable effects of a device are associated with rapid onset time and relatively short persistence, then it is easy to understand why a pain mechanism of effect through impacting projectiles warrants investigation. Furthermore, there is now a great deal of evidence that impacting projectiles can be launched in such a manner that the resulting impact will cause intense transient pain with little risk of physiological damage to almost any critical part of the body (with some notable exceptions; e.g., vulnerability of the eyes has not been examined, but is assumed). Unfortunately, this does not yet mean that impacting projectiles are obviously a good way to go in less-lethal weapons. That is, as of yet good evidence that intense transient pain for a given stress condition of the subject will result in the desired effect or outcome in a given control force application has not been proven.

At this point, it seems relevant to review what is known about pain as it pertains to pain induced by stimuli of interest in less-lethal weapons investigations. To be more specific, experimental pain rather than pathological pain was examined. In experimental pain, the direct casual relation is understood in the sense that the stimulus is controlled in both time of application, or duration, and intensity. Much of the research on pain is oriented toward the evaluation of analgesics and unfortunately any quantification of pain response that has been found involves an interpretation by the subject as to what pain is and how much pain is experienced.

Both pain threshold and pain tolerance need to be discussed. Geldard (9) describes threshold pain as "the point at which a pressure tap becomes a pricking stab." In a series of tests conducted under the LWL program, the following description of pain was given to the subject: "If you consider taps on the skin with an object, as the force of impact is gradually increased, the feeling changes from an innocuous pressure to a level of discomfort; if an individual tap is at a level of discomfort, call it pain." Statistically, pain threshold is defined as that level of the stimulus for which the subject will call "pain" 50 percent of the time. Pain tolerance is near the opposite end of the spectrum and is related to the amount of pain a subject can tolerate under a given set of conditions. LWL did not investigate pain tolerance because of the relatively greater chance of hazard to the individual during tests. Also, the literal pain and suffering involved would obviously have required a great deal more care, precision and administrative effort than was possible under the sponsored program.

A literature study on "pain" was conducted and the results are presented in Appendix F. Most of the literature on experimental pain is either on pressure stimuli or heat stimuli, with some information on electrical stimuli. Before further discussing the results of the LWL experiments, it is pertinent to review what information from the literature pertains directly to the evaluation.

There are two findings which have a major influence on the evaluation of a pain mechanism. First, pain threshold for a given stimulus is dominated by the impinging energy per unit area. Thus, for a heat stimulus, the threshold pain is roughly 200 millicalories per second per square centimeter (mc/sec/cm^2) with considerable latitude on the area affected (10). For a pressure stimulus, the threshold is roughly two kilograms per square centimeter (kg/cm^2) (11). There are certain problems associated with electrically-induced pain (12), and there is no equivalent unit area statement for an electrical stimulus. If the unit area relation carries over into pain induced by impact, there would be a very important implication on the nature of impacting, nonpenetrating devices; namely, small nonpenetrating missiles at high velocity would tend to provide adequate energy for inducing pain without sufficient total energy to induce physiological damage.

The second finding concerns the relation between threshold pain and pain tolerance. If it is assumed that persons can be motivated to desirable control objectives through pain (a critical assumption), then the levels of stimuli which induce pain tolerance values are fundamentally more interesting than pain threshold values themselves. Fortuitously, for heat, pressure and electrical stimuli, the estimated levels of tolerance run only two to three times the threshold values for mean levels (9, 12).

At this point, it seems appropriate to formulate in layman's terms what has been implied by researchers in pain:

> The body's total somatic, pain-sensing network tends to act as an alarm system where an alarm is triggered for relatively small areal and relatively fixed energy intrusions. This alarm system has a relatively small dynamic range (factor of three in energy).

Hence, the major conjecture in evaluating pain as a mechanism of desired effect in less-lethal devices is that the alarm system can be predictably activated with energies that are subhazardous.

As a result of the literature survey, it was apparent that no quantitative information on experimental pain induced by an impact stimulus was available. As previously mentioned, it was decided that LWL would conduct some simple experiments to obtain such data for pain thresholds. Results of these tests indicated thresholds to be less than 1 ft-lb. A brief description of the test that was given is in Appendix G.

In considering the more fundamental problem of pain or threat of pain as a motivational factor, one should recognize the limitations of the pain data derived from the LWL experiment. It is known that there will be a reduction in pain effect as a result of clothing. A launcher was fabricated that produces a consistent 28 fps muzzle velocity for the 1-inch rubber sphere (the first item in the LWL tests). Numerous firings were made to verify that this velocity was well above the pain threshold, though at 28 fps it is generally not considered to be near pain tolerance levels. However, it was evident that three layers of cloth (shirt, sports coat, and lining of sports coat) sufficiently absorbed the energy such that there were no pain reports at 28 fps for any impacts through clothing.

Relating Measure of Effects to Response

If it is possible to establish that certain impacts can induce pain without causing physiological damage, then the question remaining is, " Will pain or threat of pain produce the disruption to control messages and a resulting desirable effect?" In an attempt to answer this question, the Behavior Analysis Group was asked to make quantitative estimates of the effects of devices whose primary mechanism is pain. Very few positive results were achieved. One of the basic problems was how to invoke a behavior pattern in humans with a simple stimulus (viz., a stimulus that is known to be painful). The Behavior Analysis Group consensus was that the behavioral response in a line of marchers, for example, to a painful stimulus is highly dependent upon the attitudes, the emotional levels, and the emotional stability of the individuals involved. Yet it is known by experience that a person generally acts to move from an environment of discomfort to an environment of less discomfort or that a person will hesitate to leave an environment of relative comfort and move into an environment of discomfort. The basic idea is essentially stated: Pain is the most potent stimulus known to arouse and sustain behavior and is therefore important to the study of drives (13).

A basic problem is that one cannot quantify from any known data sources what to many people is completely obvious. As a specific example, consider the Fleeing Suspect Scenario. The Behavior Analysis Group assessment was that a fleeing suspect would in no way be induced to stop under threat of pain. Furthermore, the fact of pain, if an otherwise noninjurious blow was received, would do little to stop the suspect. It is evident that a person in flight is in a high emotional state and the situation is similar to cases of pain accommodation; i.e., the pain is present but the subject is not paying any attention to it.

It appears at this time that the effect of pain must be accepted as a conjecture, however valid it appears in certain situations. But a relatively clear picture is emerging that impact devices can be built which will induce pain which is transient and at the same time relatively noninjurious. It is also clear that no other incapacitating mechanisms have been uncovered for impacting objects which are reasonable to exploit and which would offer the same level of assurance that there would be no injury (14).

Finally, it seems pertinent to address public acceptance of impact pain as a control mechanism. No one is in a position to reliably forecast acceptance or nonacceptance of impact less-lethal weapons by the vocal public. However, it is felt that the control forces should be quite vocal in the distinction between enforcement measures and punishment as they apply to pain. In a disciplined police force, the enforcement measures are largely the option of the suspect or the persons being controlled; i.e., the police carry weapons for self-protection or as a threatening alternative to nonsubmissive behavior. If the police place a suspect under arrest and the suspect does not submit to arrest, then the police are committed to more physical means of achieving submissiveness. In essence, the suspect has, by option, chosen the nature of the police response. In punishment after conviction, the convicted person has no alternatives, no options and the situation takes on a greater sensitivity as well as the constraints of Amendment VIII of the Constitution in regards to punishment.

There is an interesting parallel in the medical community where relief of suffering is a primary objective but the immediate comfort of the patient is only a concern when no other procedures are applicable. Furthermore, medical diagnosis through pain does not necessarily meet with the willing cooperation of the patient, even though such diagnosis is considered to be in the patient's best interests.

To date, the information gathered on pain can only serve as a general guide to determine the effectiveness of impacting a target at some given energy level. Although the program did not progress to the point where this was set down in a quantitative manner, the deliverations of the Behavior Analysis Group tends to support the conclusion that pain can be obtained at a reasonable and safe level.

Through the expertise of the members of the Behavior Analysis Group of the overall Less Lethal Weapons Evaluation Panel, it was concluded that all persons in a given situation are not in the same emotional state. If it is assumed that each person or group may have any of three different emotional states (an obvious oversimplification), with the highest state ("three") being "extreme motivation," the target in Scenario III (the Fleeing Suspect) would probably be in emotional state "three," while Scenario IV (Dispersal of a Crowd) would probably include some targets in each of the three emotional states. This means then that for this scenario (IV), three different functions would be required to relate energy to pain level and each of these functions would have to be applied in proportion to the percentage of individuals in the scenario who might be in that emotional state.

The foregoing is based, of course, on the premise that pain is a readily quantifiable mechansim of effectiveness. This is a strongly suspect postulation, as we do not have even the necessary qualitative proof. As alluded to previously, there may in fact be other mechanisms, such as "stun," which are of equal or greater significance as a mechanism of effectiveness. Since at this time it must be assumed that pain is the mechanism, then a more realistic relationship between energy and pain level for each of the three emotional states should be determined. Such a relationship might look like that displayed in Figure 4. (The following notes refer to the circled letters in Figure 4.)

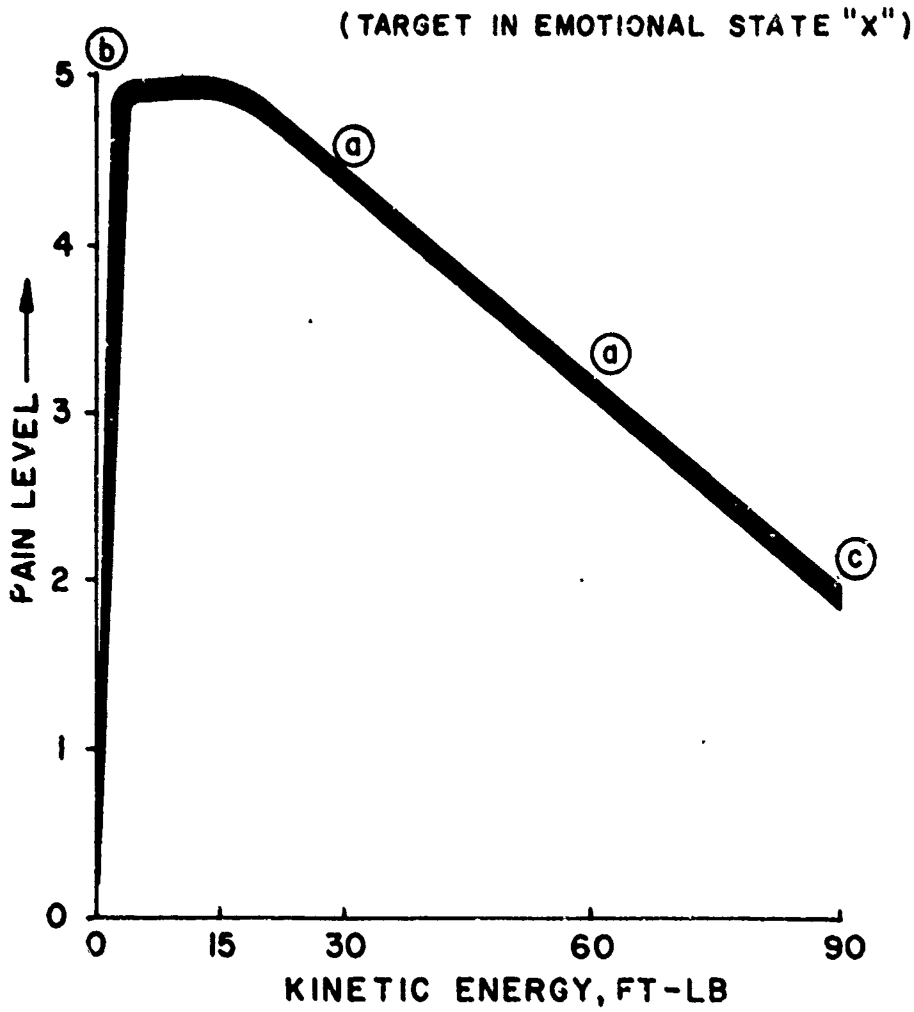
1. Note a. These points are rough estimates based on observed damage levels obtained in animal tests.

2. Note b. One experimenter (12) on pain described the mean mechanical pain tolerance levels to be 2.7 times pain threshold means. Assuming a similar ratio for pain from blunt-trauma devices, gives a tolerance level of about 0.5 to 2.4 ft-lb.

3. Note c. According to a lecture by Dr. Ranck, University of Michigan, pain is a function of many things. It is strongly psychological, since "badly wounded don't feel much pain." (Since damage levels at 90 ft-lb were severe, we might assume a lower pain level.)

It should be noted here that the shape of the curve in Figure 4 might be somwhat different from that which has been depicted if it could be established in a quantitative manner. However, the important point to be made with Figure 4 is that the function is probably not monotonically-increasing and that increased energy does not necessarily mean increased pain, but may mean less pain (at least immediately after the impact). Thus, it appears that after an initial increase in pain with increasing impact energy, pain will tend to decrease as impact energy increases.

Although the foregoing discussion indicates the "pain" ballpark to us, its application to a specific device was not satisfactorily accomplished by the Behavior Analysis Group, and the estimates of probabilities for desirable effects are based upon the trauma "pain" treated by the Medical Group. Had the Behavior Analysis Group estimated the desirable effects associated with their "pain" data, these probabilities could be revalued at higher levels which include the "pain" effects.



NOTE: 1. CIRCLED LETTERS REFER TO NOTES IN TEXT.

2. A QUALITATIVE DESCRIPTION OF THE ABOVE GRAPH IS AS FOLLOWS: THE PAIN LEVEL INCREASES SHARPLY WITH INCREASING KINETIC ENERGY TO THE TOLERANCE LEVEL AT ABOUT 0.5 FT-LBS OF KINETIC ENERGY. THEREAFTER THE PAIN LEVEL DECREASES WITH INCREASING KINETIC ENERGY

Figure 4. "Possible" functional relationship between pain and impact-energy, blunt-trauma weapon.

In addition to relating a measure of effectiveness such as pain level to response, the time/function-loss relationship must be established for the scenario of interest. Additionally, this must be done for both the desirable and the undesirable effects. The importance of this relationship cannot be overlooked in the evaluation model, the significance being evident in the discussion on these relations given in Appendix H.

With all the above factors in mind, we can proceed with a sample evaluation.

SECTION II.

THE .38 CALIBER REVOLVER WEAPON SYSTEM

BACKGROUND

A general concept for the evaluation of less-lethal weapons was presented in Section I of this report. The present section is concerned with analyzing the effectiveness and safety characteristics of the .38 caliber weapon system in a less lethal role. Since no stringent criteria have been developed to distinguish the lethal weapons from the less-lethal weapons, it was somewhat justifiable to consider the .38 caliber weapon system as an element of the set of less-lethal weapons. A general background on the .38 caliber revolver is given in more detail in Appendix I.

Assessment of the peripheral elements of the overall evaluation technique determined that only a few modifications would be required to examine the effectiveness of the .38 caliber weapon system. There were no apparent geometric limitations, so both point and area (line) targets could be addressed. On the other hand, the format of existing human physiological data (obtained from local hospital files and medical examiner records) was not suitable for computer usage (the model, described in Section I, was partially computerized). Additionally, some minor modifications to the input format for the civil scenarios were required.

It was noted, in review, that the model for evaluating the effectiveness of less-lethal weapons necessitated the following quantifications:

- the effect of displaying the weapon
- the effect of threatening to use the weapon
- the effect of actual weapon use.

In prior less-lethal weapons evaluation work, the effect of "display" and "threat" had largely been discounted. However, when considering the .38 caliber weapon system, the elements which may be appropriately applied to it have been stated previously by others: "the physical appearance which the officer presents, coupled with the holstered pistol, is impressive," and it is known that a portion of confrontees indulging in illegal acts submit on a warning shot (15). For the civil scenarios considered in this report, probability of effects for "display" and "threat" for the .38 caliber weapon system were generated by the Behavior Analysis Group. These estimates, presented in subsequent portions of this section, agree closely with some published data (15, 16), especially in the category of "threat of weapon use."

Specific data banks for probability of undesirable and desirable effects (both physiological and nonphysiological) for the .38 caliber weapon system were generated by the Medical and Behavior Analysis Groups. The Medical Group, when rendering estimates of probabilities of effect, took into consideration non-critical wounds (those not involving critical organs) to the chest and abdominal cavities.[4] Moreover, the Behavior Analysis Group established the definition of a nonphysiologically undesirable effect.

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[4]These judgments were based on the Medical Group's experience and expertise.

For the final steps in the evaluation, the scenario was chosen (The Suspect Fleeing on Foot), specific weapon characteristics were identified, terminal effects were calculated, hit probabilities were computed (using the mathematical model described in Section I) and pertinent data were extracted from the generalized data bank. Results were as follows:

- the probability of a physiologically desirable effect = .343
- the probability of a nonphysiologically desirable effect = .174
- the probability of a physiologically undesirable effect = .347
- the probability of a nonphysiologically undesirable effect = 0.

It should be noted that the general evaluation procedures were incomplete but further effort is probably not warranted until sufficient input data; e.g., operational accuracy, is available.

APPROACH

It was inferred that, since the .38 caliber weapon system was in common use (as indicated by survey results in Appendix J), an assessment of its less-lethal characteristics under representative civil scenarios could serve as a baseline against which other less-lethal weaponry could be measured. The objective of the work described in this section was to utilize the evaluation methodology in order to determine the less-lethal weapon effectiveness and safety characteristics of the .38 caliber weapon system. Specifically, this required the development of a data bank by quantifying damage mechanism outputs and estimating probabilities of less-lethal incapacitation and undesirable damage for the .38 caliber weapon system.

In addition to the data given in Appendixes I and J, information relating to the .38 caliber weapon system itself was required. In this regard, the following additional information has been included either as appendixes to this report or cited as references:

- Statistical Analysis of Man-Weapon Test Data Relating to Basic and Time-Stress Tests of the .38 Caliber Special (Appendix K, based on tests reported in LWL Technical Note No. 73-0[illegible] (1[illegible]
- Accuracy Data for the .22, .38 and .45 Caliber Weapon Systems (Appendix L).
- Statistical Analysis and Summary of .38 Caliber Shooting Incidents in the Baltimore Area (Appendix M).
- Analysis of Tissue Damage in Experimental Animals Resulting from the Impact and Penetration of a .38 Caliber Bullet (Informal Report).
- Analysis of Shooting Incidents, Dade County, FL (R.S. Zelina, AAI Corporation, Informal Notes, Miami Police Department, 11 October 1972).

The synthesis of an evaluation technique for less-lethal weapons is not an easy task, and it cannot be claimed at this point that the objective was realized. As the effort progressed during 1972 and 1973, a confidence developed among the personnel involved in the project that the work being accomplished was both significant and useful. It is recognized, however, that additional work is necessary in order to refine both the data collection effort and the logic of the evaluation scheme. It is further realized that this refinement must be accomplished before the technique of the evaluation will be acceptable to both the users of the product information and those agencies claiming to understand what comprises an ideal evaluation.

Many questionable areas remain in this evaluation of the .38 caliber weapon system with regard to its role as a less-lethal weapon. These questionable areas are a consequence of both the incompleteness of the evaluation and the "shotgun approach" used to conduct the evaluation. However, it seems reasonable to present the report in terms of the "shotgun approach" that was used.

It was assumed, prior to this task, that considerable data existed in Army reports on the subject of .38 caliber wound ballistics. It appears that this assumption was incorrect. Two separate approaches were initiated, therefore, to obtain some basic data on .38 caliber woundings. One activity involved the examination of operational data (from hospital files and medical examiner records) on .38 caliber woundings and deaths in the Baltimore area. The second entailed gathering basic wound data. It is recognized that these efforts could not be considered to either encompass all possible study/test conditions or reveal startling new information. The resulting data, however, unequivocably did validate the "critical organ" concept in wounding.

One of the major variables in all weapons or devices is "operational accuracy"—this is the accuracy under actual-use conditions—and it is suspected that this accuracy is quite different from any target range-type accuracy. In the absence of reliable data on either stressed or unstressed accuracy firings, a test series was conducted to obtain this information. The tests were not exhaustive, but they did provide some previously unavailable basic accuracy information on the .38 caliber weapon system. The key elements of the evaluation model discussed in the following paragraphs utilize the basic information gathered as stated above.

Weapon System Performance Characteristics

Since the effort presented in this volume represents only a trial application of a newly established methodology, it was decided to utilize only one weapon/ammunition combination. The weapon selected was a .38 caliber Smith and Wesson revolver with a four-inch barrel[5], and the ammunition used was the Remington .38 caliber special with a 158-grain round-nose lead bullet.

Weapon systems evaluations are generally characterized by at least three types of data: reliability, accuracy, and terminal effects (impact parameters). In this initial evaluation the subject of reliability has not been considered—the assumption has been made that the device functions approximately as intended and presents no hazard to the user. The accuracy data has been addressed in two ways: (1) tests were conducted and analyzed to determine man/weapon system accuracy (Appendix K)[6], and (2) a comparison of accuracy was made with other familiar weapon systems, viz., the .22 caliber and the .45 caliber (Appendix L). The third characteristic, terminal effects, was examined in two parts: first, from a series of wound ballistic test data, and second, an investigation of human medical data. For the first part of this particular phase of the

[5]Information presented in Appendix J influenced this selection.

[6]The accuracy data used in subsequent calculations are based upon the data in Appendix K.

weapon performance evaluation, the terminal effects or impact conditions were held constant; in other words, all targets were the same distance from the muzzle and no attempt was made to vary the impact velocity/energy[7] at the target by, for example, varying the range; for the second part of this phase, impact conditions (e.g., ranges) were unknown.

As noted previously, one of the relatively weak parts of a weapon system evaluation is "operational accuracy" information. Whenever an attempt is made to obtain accuracy data, there is a tendency to fall back to unrealistic match-type firing tests. The best way, however, to obtain operational-type firing accuracy appears to be through expensive simulated firings or by controlled time-stress firings, and this latter technique was used for the .38 caliber accuracy data found in this report (17).

One of the factors assumed in operational accuracy is a degradation which occurs under time-stress. Analysis of the controlled time-stress firings (Appendix K) conducted for this study is based upon 10- and 20-second limits for firing five-round groups.[8] For these firings, although the accuracy degradation is noticeable under time-stress, it is not overwhelming.

Other factors which may contribute to operational accuracy are individual differences in proficiency, motivation, emotional level, decision-making ability, target motion, and unusual target presentation. All these stress factors should be investigated, for future analyses.

An interesting "fallout" from this data is a phenomenon peculiar to handgun shooting, viz., the an[illegible] accuracy seems to improve with range. Since the accuracy information in this report has b[illegible] developed from man-silhouettes without a marked bull's-eye (or point-target), and since the in[illegible]ed aim point is the center-of-mass, it appears that the shooter is not challenged to fire as accur[illegible]y as possible at short ranges against a large target.

It is felt that this information could be used by a well-trained and well-disciplined police group. When, for example, ranges are very short and the policeman's life is threatened, it appears that there would be an advantage in aiming at the head rather than the trunk of the target. In the section on physiological effects it is shown that head wounds cause a much quicker loss of function in the targeted person than do trunk wounds, even when the trunk wounds involve a critical organ such as the hea[illegible]er. (There is also the possibility that noncritical head wounds could induce unconsciousness[illegible] bringing on an immediate loss of function and reduction of the threat to the police in[illegible].) As another example, when ranges are very short and the policeman's life is not imm[illegible] threatened, there would appear to be an advantage in aimi[illegible] at [illegible]critical areas, such [illegible]xtremities—the physiological effects data show that extrem[illegible] wounds alone are not [illegible]y serious. As a third example, if there is a decision to f[illegible], extremity wounds may [illegible]st as effective as trunk wounds in achieving the objectives of [illegible] police and yet not nearl[illegible] hazardous to the targeted subject or to bystanders.

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[7]The only variations in impact velocity/energy were those common to any weapon/ammunition combination, such as 755 fps versus 758 fps or 200 ft-lb versus 202 ft-lb.

[8]The police who participated in the .38 caliber accuracy tests conducted by LWL were well experienced shooters (some were or had been members of marksmanship teams).

Finally, the three-to-four mil accuracy potential of the .38 caliber weapon system will undoubtedly influence any future weapons comparisons. Blunt-trauma devices, for example, will have difficulty when competing for accuracy with the .38 caliber weapon system. Also, in many situations the accuracy of the .38 caliber, together with selectivity and discipline, provides a potentially more flexible response than blunt-trauma weapons.

SCENARIOS

In examining various scenarios (discussed previously) for this .38 caliber evaluation, the following determinations were made:

- The One-on-One Situation (I) required some modifications[9], after which it was considered the most applicable scenario in terms of evaluating desirable effects.

- The Barricade and Hostage Situation (II) was considered not applicable for the evaluation of the .38 caliber weapon system—primarily because of accuracy/range relations involved and the unlikely line-of-sight conditions required for this system.

- The Suspect Fleeing on Foot (III) scenario required no modifications but was considered most applicable in terms of evaluating undesirable effects.

- The Dispersal of a Crowd (IV) scenario also required no modifications; however, it was considered applicable, with some reservations, for evaluating the desirable effects of the .38 caliber weapon system.

It should be recognized that the evaluation of the .38 caliber weapon system as a less-lethal weapon system presents certain problems. For example, if the scenarios are modified to make the situation credible (i.e., realistic situations wherein the .38 caliber weapon system would be used by the police), then the less-lethal consideration may tend to be obscured. Also, if the .38 caliber weapon system is evaluated as a less-lethal weapon system, it is necessary to include situations where the use of the .38 caliber would be socially unacceptable—this latter problem can be seen when examining Scenarios III and IV. In Scenario III, the Suspect Fleeing on Foot, the target is the back of an unarmed suspect—an obviously controversial situation; in Scenario IV, the Dispersal of a Crowd, shooting into the crowd is a part of the conditions examined—another obviously controversial situation.

Physiological Data

At the time that the decision was made to utilize the evaluation of the .38 caliber weapons system as a baseline with which to compare less-lethal weapons, there was no obvious source of statistical wounding data for this weapon system for either organ tissue disruption or an individual's ability to function after being wounded. There had been a great deal of study by the

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[9]The main modification to Scenario I involves the Variation in which the suspect is armed with a knife and the policeman's immediate objective is changed from subduing the suspect for 30 seconds until he can be handcuffed, to disabling the suspect before he can harm the policeman.

military on the general subject of wound ballistics; however, no information had been gathered specifically on .38 caliber wound ballistics. Since a major concern of this program was to understand the total process of evaluation, including tests to obtain data when no data was available, two separate investigations were conducted to obtain data on physiological effects of the .38 caliber weapon system.

One investigation involved wound ballistics data (18) from animals. These test data included the following target areas:

1. Heart
2. Lungs
3. Liver
4. Kidney
5. Thigh
6. Left Temple
7. Anterior Head
8. Posterior Head

These data produced no real surprises—wounds to critical organs produced fatalities, wounds to noncritical areas (e.g., thigh shots) were non-fatal.

Since the original popular concept of less-lethal devices involved the question of a weapon literally being lethal, an additional investigation oriented toward "lethal vs less lethal data" was made. This second investigation involved a survey of .38 caliber shootings in the city of Baltimore during a nine-month period in 1971 and 1972. (Details of this investigation are given in Appendix M.) Although there are only a total of 56 cases in the survey, certain indications appear sufficiently evident to warrant drawing some conclusions. First of all, 32 victims, or 57 percent of the persons wounded, survived. Survival did not seem to depend on how often the person was shot—of the fatalities, 62 percent were shot only once, and of the nonfatalities, 59 percent were shot only once. None of the survivors was shot in either the heart or the lung and only two were shot in the head (but the bullet lodged extracranially). Sixty-two percent of the survivors had wounds of the extremities, whereas only 25 percent of the fatalities had wounds of the extremities. Of these 25 percent, all were shot more than once, with another wound located other than the extremity. It is important to note, therefore, that the data indicated at least three levels of seriousness in .38 caliber wounding; viz., head, heart and lung wounds were almost always fatal; neck, liver and kidney wounds were sometimes fatal; extremity wounds alone were never fatal.

In regard to the first investigation, the wound ballistics test data, the Medical Group reviewed the basic data for the purpose of assessing probability of desirable and undesirable effects. This effort is a key part of the evaluation procedure and involves two activities. The first activity entails grading the wounds for the various organs, according to previously established grading criteria (Appendix E). This procedure is basically nonjudgmental and serves presently as a check on the level of probabilities assigned for the various test shots. All critical organ areas were assigned physiological damage levels of 5. The second activity involves the assigning of probability levels, and it is also divided into two parts; viz., the determination of the probability of an undesirable effect given a hit ($P_{UE/H}$) and the determination of the probability of a desirable effect given a hit ($P_{DE/H}$). This second activity is presently judgmental, but produces information critical to the evaluation, namely, quantitative values (probabilities) which measure the hazard and the effect of an impact. The quantitative assessment of undesirable effect of the .38 caliber weapon by the Medical Group was simply that $P_{UE/H}$ = 1.00 for any impact on the body.[10]

This assessment is based upon the following criterion previously given for undesirable effect.

(It should be understood that the probability of 1.00 does not indicate absolute certainty but simply that 1.00 is a better estimate of the probability of an undesirable effect than .95, for example.)

The second part of the judgmental assignment of probabilities involves the desirable effect. However, when desirable effects are considered, the criteria for a desirable effect must be obtained from the scenario under consideration. For ease of evaluation, the Medical Group chose to examine the Suspect Fleeing on Foot, Scenario III, in which the specific desirable effect is that the suspect should be intercepted before proceeding 100 meters or that the suspect should be completely stopped within 30 seconds.

Physiologically undesirable and desirable effects probability estimates (P_{UE}, P_{DE})[11], for critical organs were each estimated at 1.0 for Scenario III, the Suspect Fleeing on Foot. Estimates for impacts to the extremities and noncritical wounds to the chest and abdominal cavity are given in Tables 5 and 6, respectively.

For Scenario I, the One-on-One Situation (Variation - Suspect with Knife), group members postulated that onset time was the crucial parameter. Therefore, estimates of onset times for this scenario are given in Table 7 below.

The physiological effects data is the most critical information concerning the hazards to those subjected to the weapon. It is therefore extremely desirable that the physiological effects data be organized so that it is quantitatively useful; i.e., such that one can proceed from a quantifiable weapon/projectile impact (dose) to a quantifiable physiological change. The weakness, however, is the inability of the evaluator to quantify the tissue and organ damage resulting from the .38 caliber bullet's impact to the body. (For example, review of wound ballistics data, although limited, indicates marked damage and death; however, it is known from the search of hospital files relating to gunshot wounds that not all persons die when impacted with a .38 caliber bullet. Although actual distances were unknown, it is assumed that the shootings occurred at relatively short ranges.)

Nonphysiological Data

The area of nonphysiological (or "other") effects is the most difficult when evaluating a weapon system such as the .38 caliber which uses a penetrating projectile. In order to achieve

[10] It was determined by the Medical Group that the physiologically undesirable effects would be the same for all scenarios considered.

[11] It should be noted that these estimates are essentially independent of the emotional state of the subject hit, and thus are medical judgments of the ability of the human body to function after having received various types of wounds.

TABLE 5

Probability Estimates for Physiological Effects for Various Impacts to the Extremities–Suspect Fleeing on Foot, Civil Scenario III

Impact	Description	P_{DE}	P_{UE}
1	One arm hit, no bone or nerve hit but Grade 5 damage to the skin and/or muscle with no major nerve or blood vessel severed.	0.25	1.00
2	As in 1 above except major nerve hit	1.00	1.00
3	As in 1 above except major blood vessel hit	0.50	1.00
4	As in 1 above except bone hit	1.00	1.00

TABLE 6

Probability Estimates for Physiological Effects for Noncritical Wounds to the Chest and Abdominal Cavities–Suspect Fleeing on Foot, Civil Scenario III

Impact Zone	P_{DE}	P_{UE}
Chest	0.30	1.00
Abdomen	0.30	1.00

TABLE 7

Onset Times for One-On-One Situation, Variation C(I)[a], Civil Scenario I

Impacted Area	Onset Time (sec)
Head or Cervical Reticular Cord	<1
Heart, Lung, Kidney, etc.	>5
Femur (Thigh)	--
Extremity Handling Weapon (Up to Shoulder)	<1
Solar Plexus	--

[a]Suspect assumed to have knife.

"other" effects, some desirable effect must be produced at a lower threshold than physical damage. Pain sometimes appears quite promising as a desirable effect; however, pain may not be valid when subjects are emotionally tense, or when certain personalities are involved. (It still appears that threat of pain or discomfort has value in certain scenarios, such as the legal crowd.) A quantifiable relationship between the stimulus and the response has not been established; however, some general nonphysiologically desirable effects data based on level of force were generated by the Behavior Analysis Group (Table 8).[12]

With regard to the specific data bank of nonphysiological undesirable effects, it was judged that this effect would be either 0 or not applicable for all levels of force and for all civil scenarios examined.

Exercise of the Mathematical Model

The final level of sophistication of the overall mathematical model for evaluating the effectiveness of the less-lethal weapons was presented in Appendix C. Results of exercising the model, Table 9, are based upon a sample run and, as such, must be considered only a provisional indication of the manner in which the .38 caliber weapon system effectiveness as a less-lethal weapon might be obtained. Complete exercise of the model would entail quantifying the contribution of the effect of display of the weapon, the effect of threat to use the weapon, and the effect of use of actual weapon—among other factors. If these effects are independent, a summation of effects yields a measure of weapon effectiveness in terms of a response.

OBSERVATIONS

In the course of the analysis of the .38 caliber weapon system as a baseline for evaluating less-lethal weapons, the following observations were made:

a. The more frequently encountered situations in which the police revolver might be used require that incapacitation of the target be complete and occur within a few seconds, particularly at short ranges.

b. A brief summary of data on hospitalized persons who have been wounded by bullets fired from a .38 caliber revolver reveals that quite a few of these persons had been shot several times during the incident. This could indicate that the shooter did not believe the target to be incapacitated to the proper degree in the required time period. On the other hand, this may be an invalid conclusion drawn from the small sample investigated. Additional investigation of this question could produce a more quantitative answer.

c. At least three major police departments which were contacted had on their own initiative reviewed the effectiveness of their police weapon system (.38 caliber) and judged it to be adequate. Of significance, however, is the fact that these departments had pressure from individual police members to "increase the effectiveness" of their weapons by going to a more powerful weapon system, such as the .357 magnum, the 9mm, or the .45 caliber. In some

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[12]All entries in Table 8 are averages of the individual estimates by the Behavior Analysis Group voting members and have been rounded to the nearest 5 percent.

TABLE 8

Probability Estimates of Nonphysiologically Desirable Effects - Suspect Fleeing on Foot

Civil Scenario III

Level of Force	P_{DE}
Physical presence of officer	NA
Threat of weapon use	0.25
Weapon use[a]	
Not hit	0.35[b]
Hit (nonincapacitating wound)	0.50[b]

Probability Estimates of Nonphysiologically Desirable Effects - Crowd Dispersal

Civil Scenario IV

Level of Force	P_{DE}
Physical presence of officer	0.10
Threat of weapon use	0.25
Weapon use	
Fire over crowd	0.90
Fire into crowd	1.00

[a]Might not be a warning shot.
[b]Includes those subjected to threat.

TABLE 9

Example Collation of Input Data for Model Exercise

Target Area	Damage Level	P_H[a]	$P_{DE/H}$
A_1 - Head	Grade 1	.000	1.00
A_2 - Arm	Grade 1	.005	0.25
A_3 - Upper Chest	Grade 5	.336	1.00
A_4 - Arm	Grade 2	.006	1.00
A_5 - Lower Body	Noncritical	.000	0.30
A_6 - Leg	Grade 3	.000	0.50
A_7 - Leg	Grade 4	.000	1.00

[a]Exercise of hit probability model is from Appendix C.

instances individual police members attempted to increase their revolver effectiveness by utilizing unauthorized ammunition.

d. As part of the work on Task I under LEAA/LWL Interagency Agreement No. LEAA-J-014-2, some experiments were run using the standard 158-grain round-nose, .38 caliber bullet. Wound ballistics data (.38 caliber - 158-grain), although very limited, shows that the bullet (at 750 fps) generally gives complete penetration with little or no tumbling. According to the scenarios and other statistics, the ranges of interest are short; therefore, complete penetration of a target has no value and may in fact increase the hazard to other nearby persons. Although penetration of a vital organ, such as the liver or kidney, is indeed damaging (or fatal), hits on these organs and/or less critical areas may not produce the desired incapacitation in sufficient time to avoid lethal return-fire on the officer; and although it would appear that a quick incapacitation might be achieved by increasing the force or decreasing the time of action (increased bullet velocity), it may actually be more beneficial to decrease velocity and stability of the bullet which may, in turn, shorten the onset time of incapacitation.

SECTION III.

THE STUN-BAG TYPE PROJECTILE AS A LESS LETHAL WEAPON

BACKGROUND

It was decided to analyze the Stun-Bag[13] as a less-lethal projectile (using the methodology given in Section I), because of its earlier popularity as a so-called "nonlethal" weapon, because of its representativeness of a class of these weapons, and because it would serve as a further test of the methodology itself. The general objective of this section of the report, then, is the evaluation of this class of less-lethal weapons effectiveness and safety characteristics through the application of the stated methodology. The specific item selected for study was a collection of ammunition which utilized the Stun-Bag as the projectile.

The specific goals of the study were to supply:

- Technical and operational analysis of Stun-Bag ammunition/projectile performance.

- Medical evaluation of damage due to Stun-Bag impacts at particular kinetic-energy levels.

- Estimates of probabilities of Stun-Bag hits on targets in various scenarios at various ranges.[14]

- Assessment of the likelihood of desirable and undesirable effects from evaluation of Stun-Bag impacts.

As the analysis progressed, it became evident that it was not possible to completely exercise the methodology because of certain insufficiencies in both the methodology and the data. However, discovery of these insufficiencies did serve the useful purpose of indicating that further work would be required to make the methodology more usable.

APPROACH

The approach taken was to consider the particular items of data necessary to compute simple, useful indices of overall Stun-Bag projectile/ammunition performance. Handling of the data follows the general methodology previously described, with one exception. The exception is that hit probabilities herein were estimated for the head and body directly, and no use is made of the computational model originally intended for this purpose. (Hit Probability Model, Appendix C.)

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[13]Manufactured by MB Associates.

[14]Time and monetary constraints limited the depth of investigation of this goal. The rest of the goals are examined for two pertinent scenarios, (1) Suspect Fleeing on Foot and (2) Dispersal of a Crowd.

The reason for the departure from the established hit probability methodology is that the data bank developed for the Incapacitation Probability Program (IPP) (Appendix C) included parameters which were not available in this study. Among the parameters necessary for this model are standard deviation of ballistic and aiming errors and incapacitation/hit ratios versus velocity of impact. Because of the limited number of Stun-Bag firings made during the study, there was not sufficient data available to reliably predict incapacitation/hit ratios for particular organs and body areas. However, some ballistic error information is available from another Army-sponsored report (19) and from a USALWL-generated study (20). This background is the justification for the more amalgamated approach to probabilities taken in this section of the report.

The indices which are to form the bases for weapon comparisons are indications of the probability of desirable effects versus the probability of undesirable effects for a particular weapon, in a given operational scenario, for a given range. The parameterization of effects by range is oriented toward the eventual user of these weapons, who is usually more thoroughly familiar with ranging variations than with variations in kinetic energy. Range can, at the same time, be usefully and directly included in both scenarios and computations.

The MB Associates (MBA) Stun-Bag ammunition considered in this study does not represent all of the items of this type. Selections of rounds were made to provide a spectrum of ammunition designed to be effective from relatively close to relatively long range. No real attempt has been made to evaluate, in terms of quality, reliability, etc., the various weapons (such as the Stun-Gun, Prowler-Fouler, etc.) offered by MBA for firing the Stun-Bag.

Projectile/Ammunition Performance Characteristics

The Stun-Bag considered consisted of a pancake-shaped, three-inch-diameter fabric bag filled with metal shot. This Stun-Bag was available either by itself for use in reloading Stun-Gun cartridge cases (or for use in MBA devices such as the Prowler-Fouler where cartridge cases per se are not required), or it was available as part of a factory-loaded munition which consists of a 40mm cartridge case, a three-inch Stun-Bag, a plastic wad, a cardboard disk and a predetermined gunpowder charge or load.

In order to illustrate velocity and ranging information, three factory-loaded rounds were chosen and were designated as A, B, and C (Table 10). The difference in rounds is the gunpowder charge or load used to fire the particular Stun-Bag, resulting in different initial velocities and extreme ranges. Due to the limited amount of data available, the velocities given in Table 10 are nominal figures. The rounds chosen covered a maximum range of 355 feet. Results were published in LWL Technical Note 73-06, July 1973.

An additional feature of the three-inch Stun-Bag was that it was to be in two different weights: the first weight to be around .35 lb and was the approximate weight of the Stun-Bag found in factory-loaded ammunition; the second weight to be around .42 lb and was the weight of the Stun-Bag available for reloading, etc. purposes. Variations in these weights were observed in the 65 firings conducted during the program. The mean weight of these bags was .386 lbs, while the standard deviation was .007 lbs (low .295, high .438 lbs). Since variation in Stun-Bag weights affects kinetic energy delivered to a target, Table 11 shows this effect over a spectrum including all observed weights.

TABLE 10

Factory-Loaded Stun-Bag Rounds Tested
(Three-Inch, Circular Stun-Bag - Average Weight = 0.35 Pounds)

Round A - Super Long Range Round

initial velocity - 230 feet per second
extreme range - 355 feet

Round B - Low Impact Round

initial velocity - 150 feet per second
extreme range - 255 feet

Round C - Close Range Round

initial velocity - 100 feet per second
extreme range - 200 feet

The flight characteristics of a projectile depend on its initial velocity, weight, shape, firing cross section, and the density of air. From assumption of typical values for Stun-Bag weights and initial velocities, a numerical integration procedure (see Appendix N) was used to compute trajectories of Stun-Bags fired at different angles.

When discussing projectile/ammunition performance, it is necessary to consider the associated ballistic error and operational accuracy/aiming error. In order to generate some information on the ballistic error associated with the Stun-Bag, a limited number of test firings were conducted by H.P. White Laboratory for USALWL. For these test firings the MBA Stun-Gun and factory-loaded Stun-Bag ammunition were used. The Stun-Gun was clamped firmly into position (bench-mounted) and bore sighted to a reference point on a paper target. Some of the results of this testing are shown in Table 12. While values for mils of error are difficult to estimate with such a limited amount of data available, a horizontal error of approximately four mils and a vertical error of approximately seven mils can be inferred from the data.

Additionally, a few more rounds were fired by an experienced gunner at 7 yards and 25 yards (employing the Stun-Gun in a hand-held position and again using factory-loaded Stun-Bag ammunition) to obtain a rough estimate of the operational accuracy; i.e., including the aiming error introduced when combining the man and weapon system. In this situation the horizontal error showed a minimal amount of increase to five mils; however, the vertical error showed a large increase to 19 mils (21).

If a target is to be hit, it is also essential to estimate the speed and position of the target and to elevate sufficiently the weapon/firing device so that the projectile and the target arrive in the effective impact region at the same time. Since the greatest initial velocity for the factory-loaded ammunition considered (Super Long Range Round) was 230 feet per second (about the speed of

TABLE 11

Kinetic-Energy As a Function of Bag Weight

Range (ft)	Velocity (ft/sec)	Kinetic Energy Per Pound (ft-lb)	Kinetic Energy(ft-lb)as a Function of Bag Weight .30 lb	.35 lb	.40 lb	.45 lb
		A (Super Long Range Round)				
0	230	822.2	246.7	287.8	328.9	370.0
40	190	561.1	168.3	196.4	224.4	252.5
100	150	349.7	104.9	122.4	139.9	157.4
200	99	152.3	45.7	53.3	60.9	68.5
		B (Low Impact Round)				
0	150	349.7	104.9	122.4	139.9	157.4
40	127	250.7	75.2	87.7	100.3	112.8
100	99	152.3	45.7	53.3	60.9	68.5
200	67	69.8	20.9	24.4	27.9	31.4
		C (Close Range Round)				
0	110	188.1	56.4	65.8	75.2	84.6
40	94	137.3	41.2	48.1	54.9	61.8
100	73	82.8	24.8	29.0	33.1	37.3

TABLE 12

Stun-Bag Ballistic Errors

Ammunition	No. of Rounds	Range (ft)	μ_h (in)	σ_h (mils[a])	μ_v (in)	σ_v (mils[a])	σ_t (mils[a])
A - Stun-Bag, Super Long Range	4	75	-3.00	3.39	-29.55	7.33	5.71
B - Stun-Bag, Low Impact	3	21	-1.63	4.68	-5.67	6.07	5.42
C - Stun-Bag, Close Range	3	21	-0.97	3.77	-5.00	8.65	6.67

NOTE: h = horizontal
v = vertical
t = target
μ = mean miss distance
σ = standard devaiation of miss distances

[a]At a range of 21 feet, one mil is 0.25 inches; at a range of 75 feet, one mil is 0.90 inches

a batted baseball), the difficulty of hitting a target at appreciable distances may be appreciated. When using Round A, for example, to hit a target at 175 feet, it is necessary to estimate the position of the target 1.2 seconds from the moment of fire.

SCENARIOS

The Stun-Bag projectile was considered by the members of the Less Lethal Weapons Evaluation Panel to be generally applicable for use in all of the previously mentioned scenarios. However, there was some restriction regarding the use of the Stun-Gun. It was thought that at very close ranges the Stun-Gun would be clumsy to use, particularly in comparison with a handgun. It was also felt that the single-shot restriction of the Stun-Gun would be a serious hindrance to the police officer.

Use of the Stun-Bag projectile was evaluated by the Medical Group and the Behavior Analysis Group for two of the four scenarios; namely, the Suspect Fleeing on Foot and the Dispersal of a Crowd Scenarios.

Physiological Data

Data from two test series was considered. The first series included data from baboons which provided examples of cranial impacts; the second series was from swine which provided examples of body impacts for several major organs. Both series included as part of the results the effects of the impacts on skin, bone and subcutaneous tissue.

Several facts about the data should be mentioned. First, the tests involved using an air-gun type system, a three-inch Stun-Bag of approximately .42 lb, and velocities ranging from about 50 feet per second to 135 feet per second (these velocities were chosen to encompass the "15, 30, 60 and 90 ft-lb" kinetic energy criteria). Second, data from baboons would represent cranial effects of Stun-Bag impacts. Cranial size and armoring of a baboon and of a man have been judged to be closely comparable. A possible exception is the formation of the posterior skull of the baboon, which is shaped differently from that of a man and includes a thickened area not found in man. Data involving the posterior area of the skull may not, therefore, fully represent the nature and extent of damage that can be done to a man by an impact in this area. Third, swine (actually young shoats) represent bodily effects of Stun-Bag impacts on man. Although goats have previously been used in some evaluations, it was the opinion of the Medical Group that the relative weights of the body organs of shoats were more comparable to those of man and the skin of the shoats was considered to be a great deal more comparable to man than that of goats.

The Medical Group performed the assessment of physiological damage due to Stun-Bag impacts. Records of the physiological effects were made first in terms of damage levels on a scale from zero to five; then, estimates were made of the probability of the damage level observed achieving a physiological undesirable or desirable effect for the scenarios addressed. A summary of the data and subsequent evaluations is contained in USALWL Technical Report No. 74-79 (June 1974).

One significant fact that was noted, however, from the Stun-Bag data was that damage to the liver usually dominated the overall physiological effects whenever there was any involvement of damage to that organ.

Nonphysiological Data

Prior to rendering estimates of probability of desirable effect, the Behavior Analysis Group attempted to quantify the emotional make-up of crowd members. At the same time, they attempted to identify the types of crowds that might be encountered.

Following the above discussions, estimates were rendered of probability of nonphysiologically (psychologically) desirable effects for the scenarios under consideration. An account of these deliberations is contained in Appendix B.

Summarization Indices

A particular graphic form was chosen to display the results of the actual test data, and the expected performance of a particular ammunition as a function of range.

The chosen graphic form plots the probability of an undesirable effect (P_{UE}) against the probability of a desirable effect (P_{DE}). Plotting both of these values together for a single impact in effect describes the price paid in terms of P_{UE} in order to achieve a certain level of P_{DE}.

These results are displayed in Figures 5 through 10. The data are broken down according to three levels of kinetic energy; namely, low (10-39 ft-lb), medium (40-74 ft-lb), and high (75-125 ft-lb). The figures show the probable effects (both P_{DE} and P_{UE}) of Stun-Bags if they do in fact reach a target.

Clustering of points in this graphical presentation suggest a number of possible conclusions. In general, head shots in a low-energy range, 10 to 39 foot-pounds, appear to have little effect (Figure 5). From Figures 6 and 7, medium- and high-energy head impacts show roughly equal probability of undesirable and desirable effect (note the fairly even distribution of data points above and below the equal-probability line). Body shot results for the medium kinetic-energy level (Figure 9) make prediction of effects from similar shots fairly reliable. However, based on limited data available, body shots for low- and high-energy levels (Figures 8 and 10) permit less reliable prediction of effects. These areas probably deserve more intensive study.

The second use of this graphic format is to exhibit performance of the three representative types of ammunition as a function of range. These summary graphs are shown in Figures 11 through 13, and are based on calculations detailed in Appendix N. A feature of these graphs is that they take into account the limitation of the ammunition utility due to low probabilities of accurate delivery.

Briefly, computations supporting the summary graphs involve extrapolating probabilities of effect from test shot data; estimating hit probabilities by the formula:

$$P_{hit} = \frac{A_t}{A_t + 2\pi\sigma_h\sigma_v},$$

where A_t is the total presented body area and σ_h and σ_v are the horizontal and vertical miss distances (standard deviations), respectively; and computing the probabilities of effect on the body.

Comparisons of the three rounds considered in this report show that none of these rounds in either scenario at any range for which computations were made have a probability of desirable effects greater than the probability of undesirable effects. This would mean that Stun-Bag rounds may be expected to extract a high price in terms of undesirable effects[15] in order to produce performance in terms of desirable effects.

In the fleeing suspect scenario, for ranges under approximately 75 or 80 feet, Round A has probabilities of desirable effects exceeding .4, but probabilities of undesirable effects range from approximately .7 to .9. Neither Round B nor Round C provide even the .4 level of "stopping power" at any range considered in this scenario.

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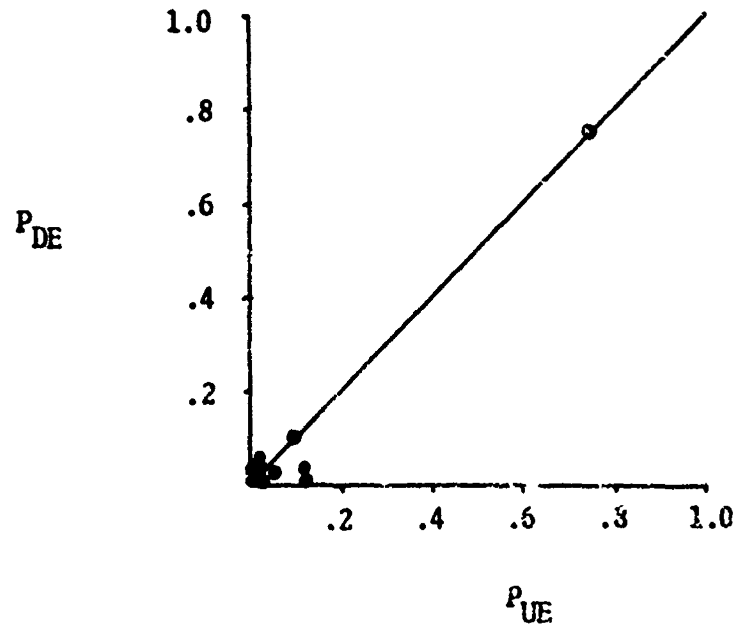
[15]Based on the previously given undesirable effects definition.

Head Shots--Low Energy
[10-39 foot-pounds (10) shots]

Scenario III,
Suspect Fleeing
on Foot



Scenario IV,
Dispersal of
a Crowd

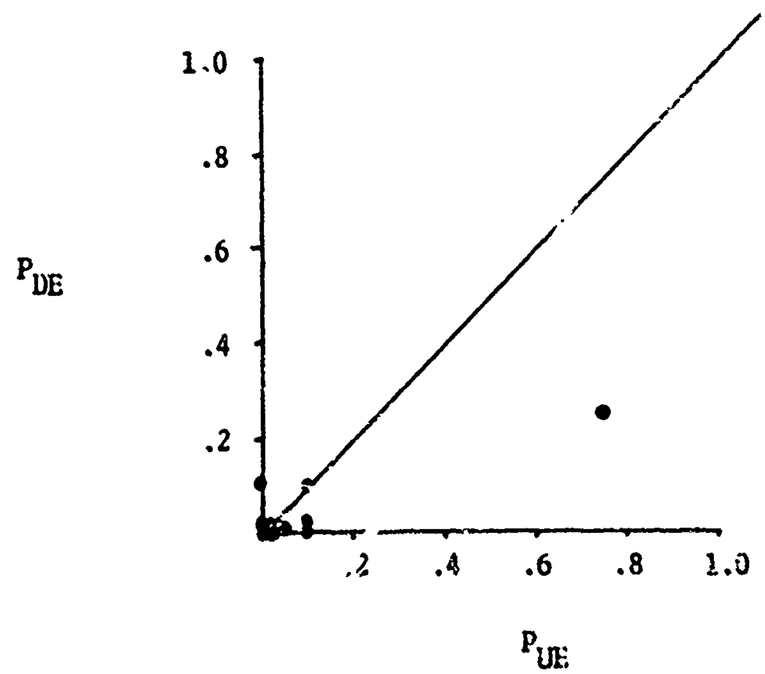
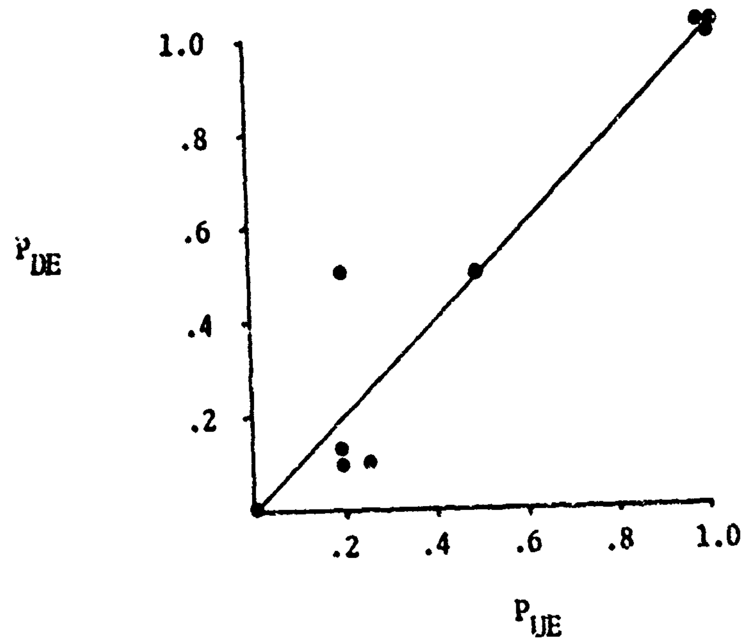


Figure 5. Damage profile graphs (head shots-low energy).

Head Shots--Medium Energy
[40-74 foot-pounds (9 shots)]

Scenario III, Suspect Fleeing on Foot



Scenario IV, Dispersal of a Crowd

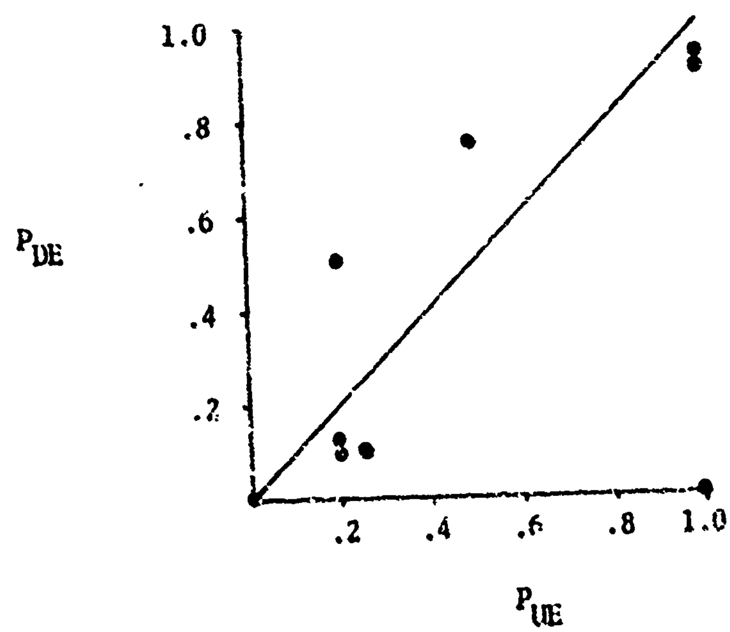


Figure 6. Damage profile graphs (head shots-medium energy).

Head Shots--High Energy
[75-125 foot-pounds (6 shots)]

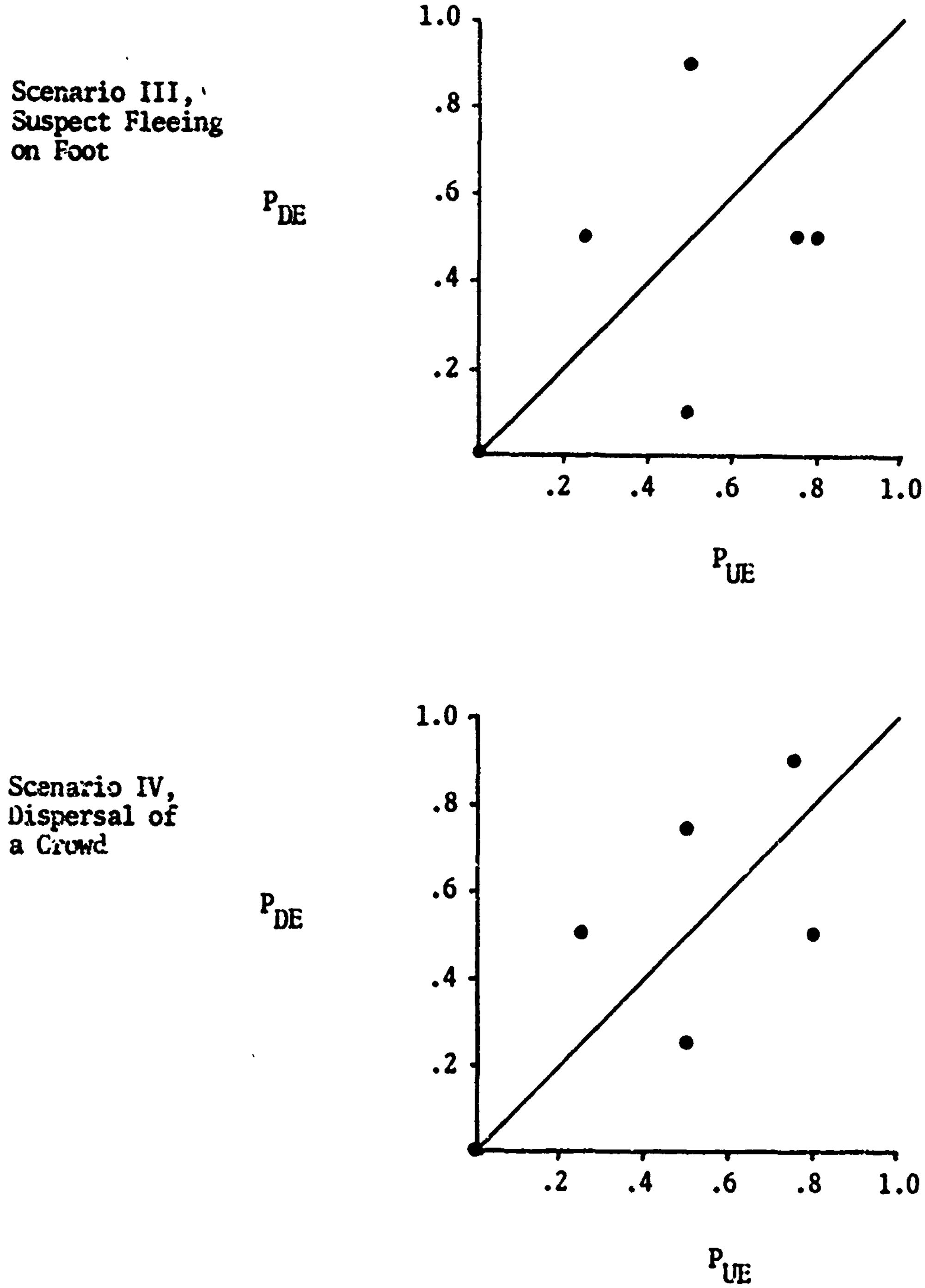


Figure 7. Damage profile graphs (head shots-high energy).

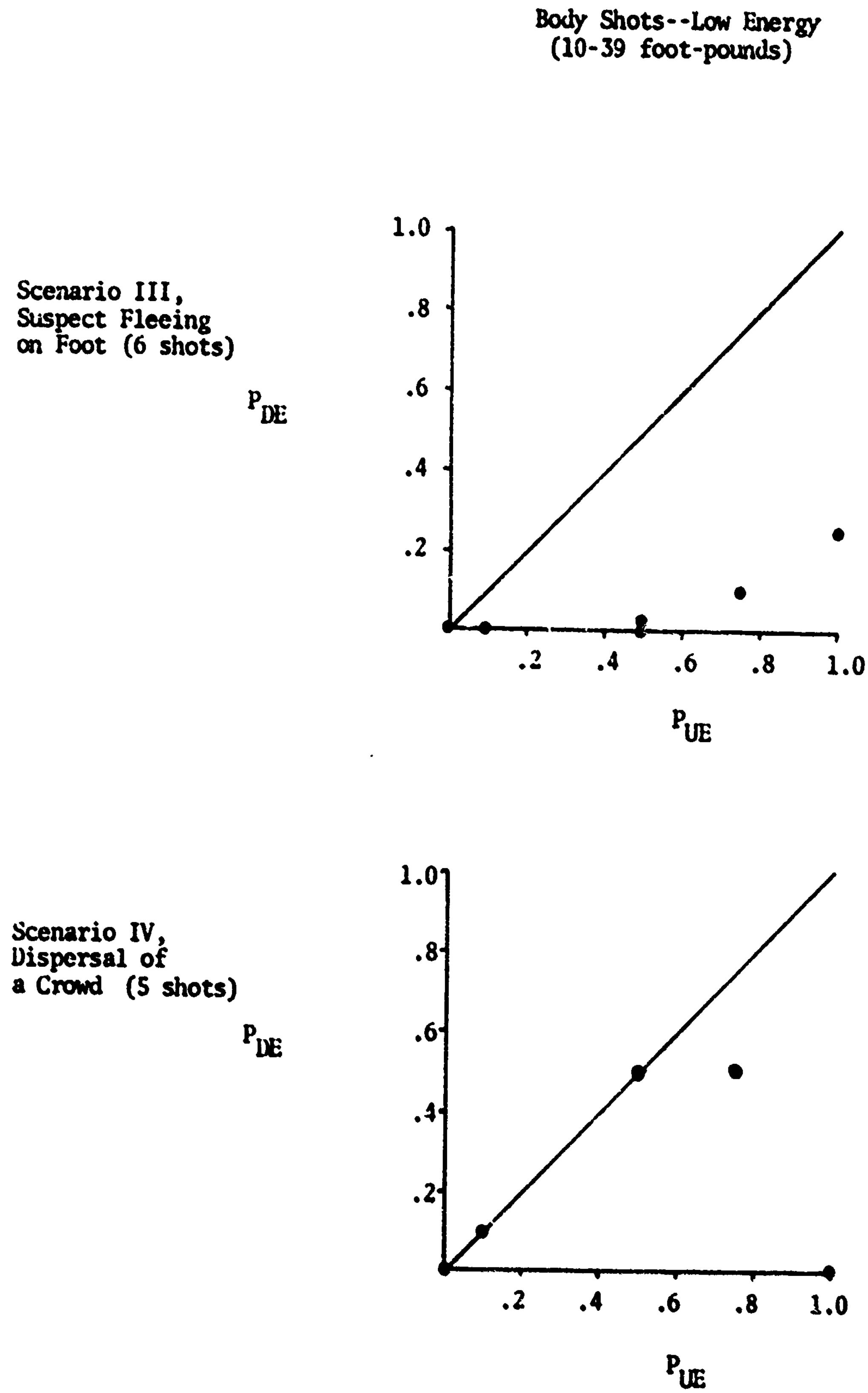
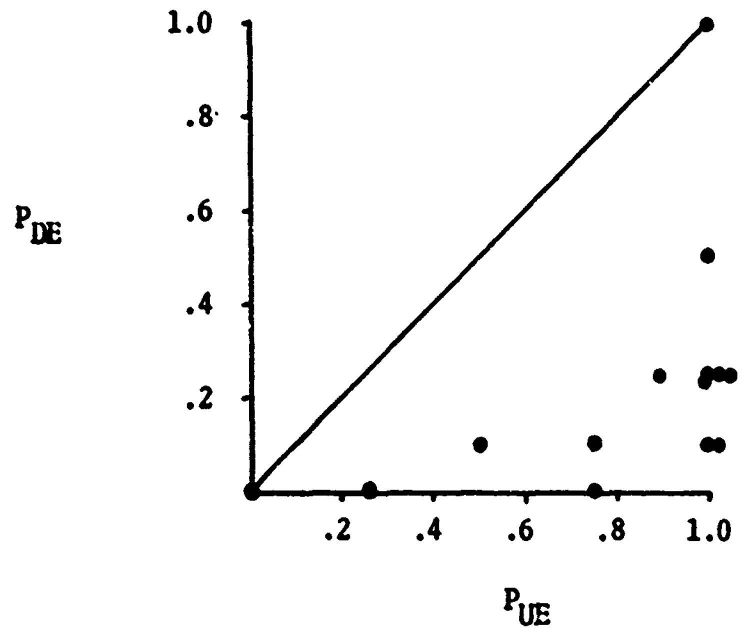


Figure 8. Damage profile graphs (body shots-low energy).

Body Shots--Medium Energy
[40-74 foot-pounds (14 shots)]

Scenario III,
Suspect Fleeing
on Foot



Scenario IV,
Dispersal of
a Crowd

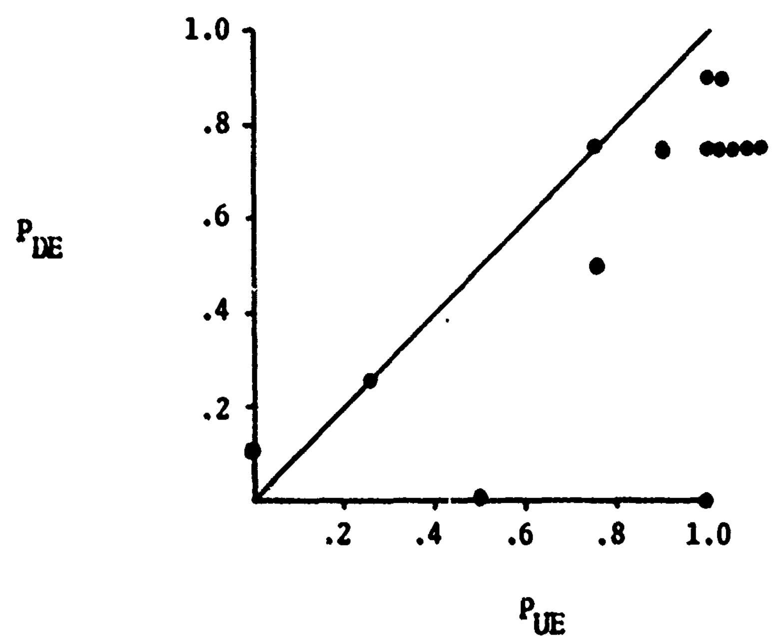
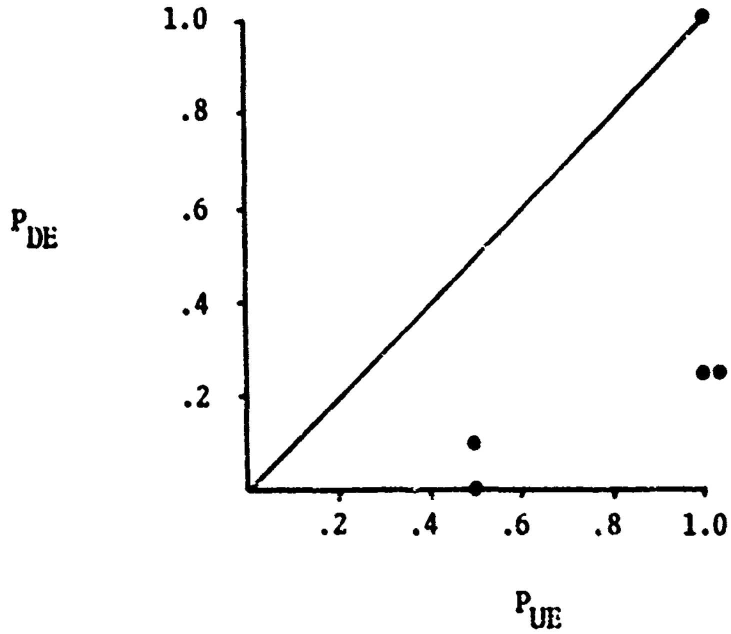


Figure 9. Damage profile graphs (body shots-medium energy).

Body Shots--High Energy
[75-125 foot-pounds (5 shots)]

Scenario III,
Suspect Fieeing
on Foot



Scenario IV,
Dispersal of
a Crowd

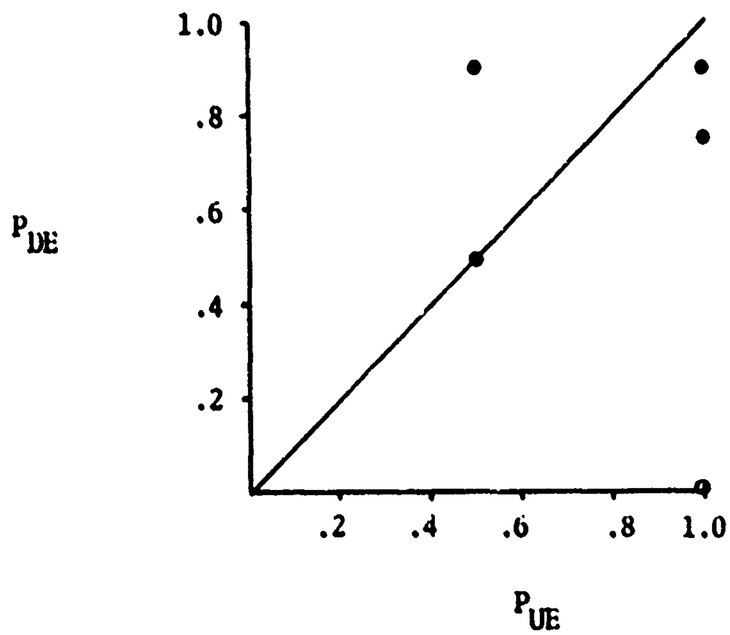


Figure 10. Damage profile graphs (body shots-high energy).

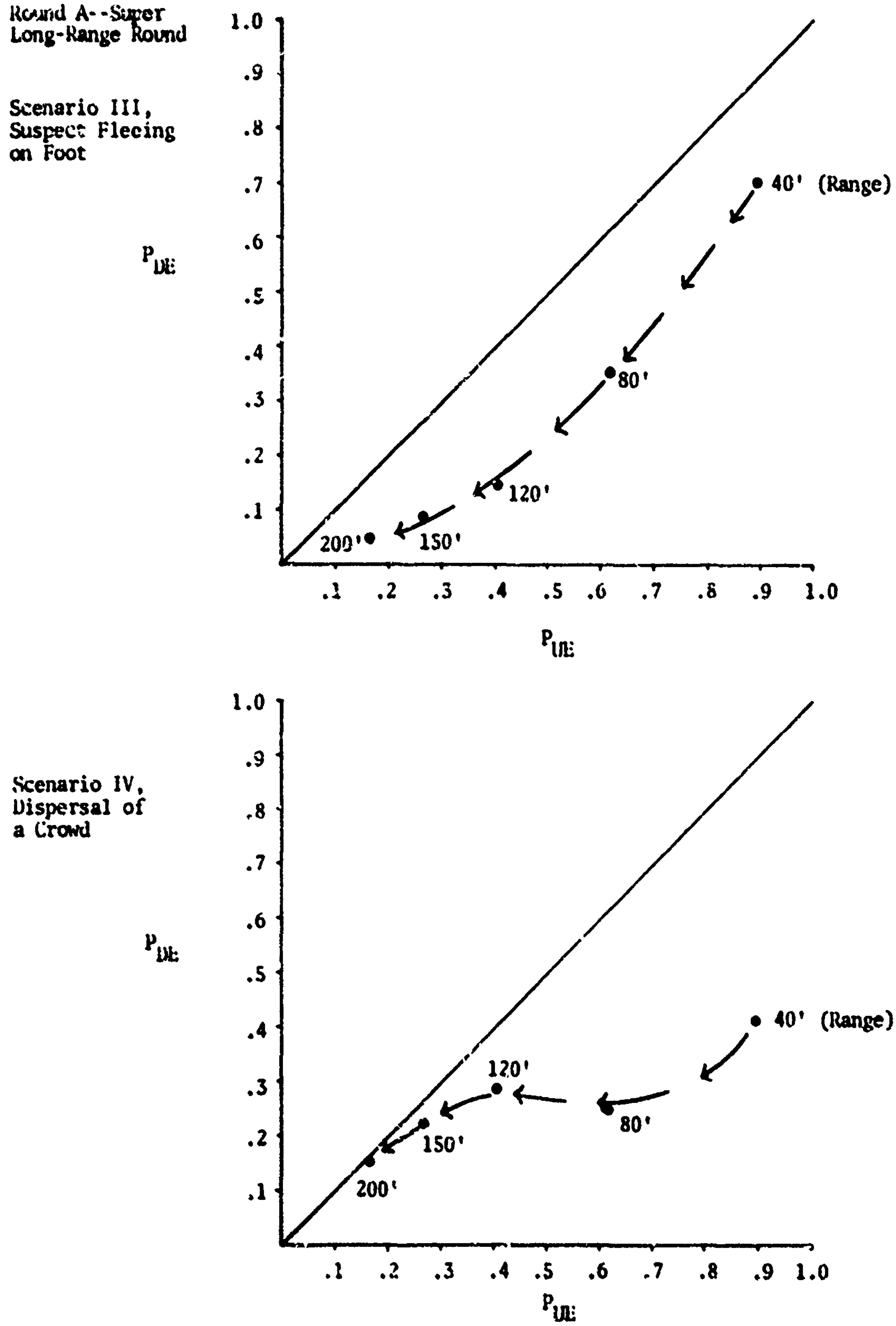


Figure 11. Summary graph (P_{DE} versus P_{UE} as a function of range).

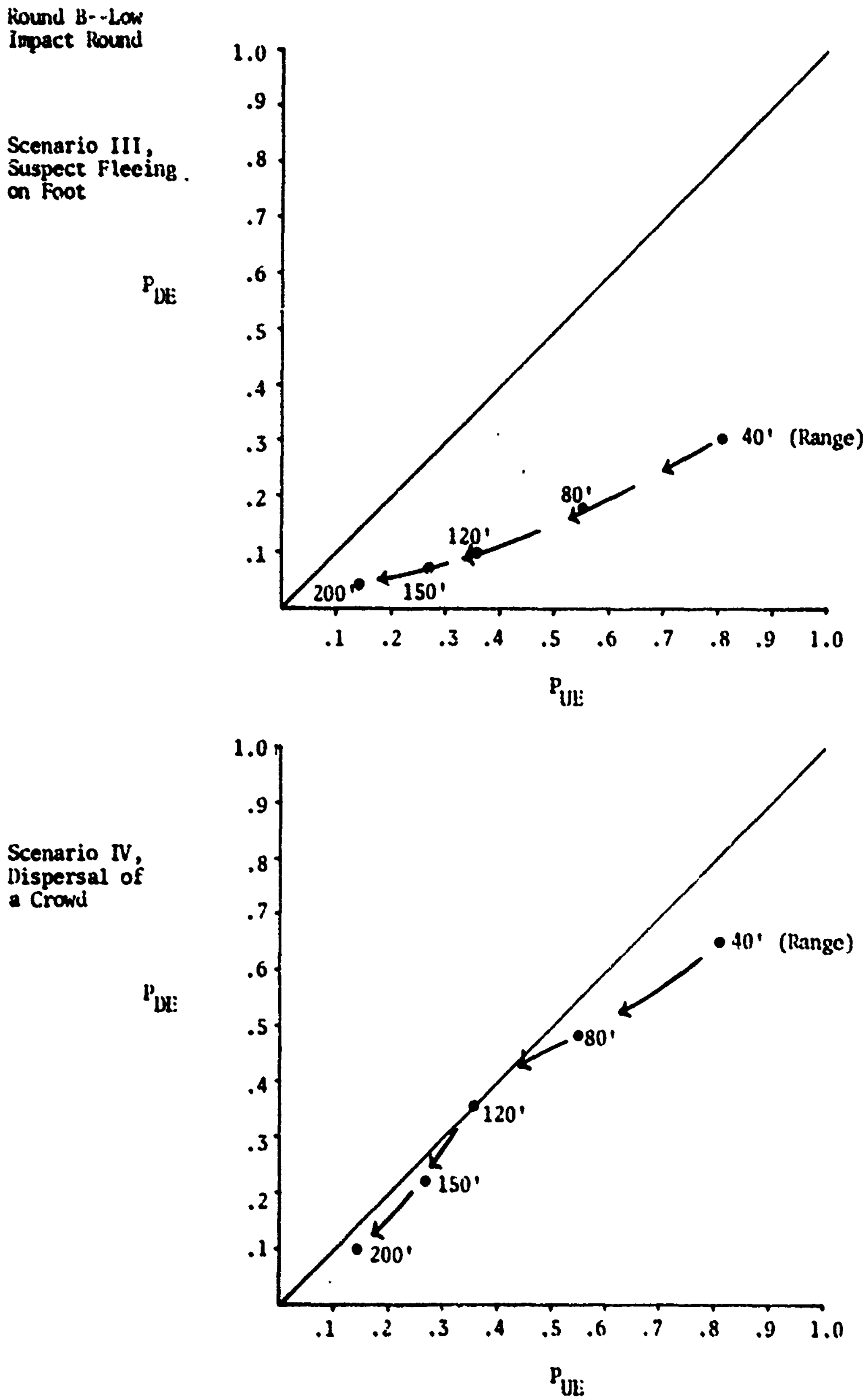


Figure 12. Summary graph (P_{DE} versus P_{UE} as a function of range).

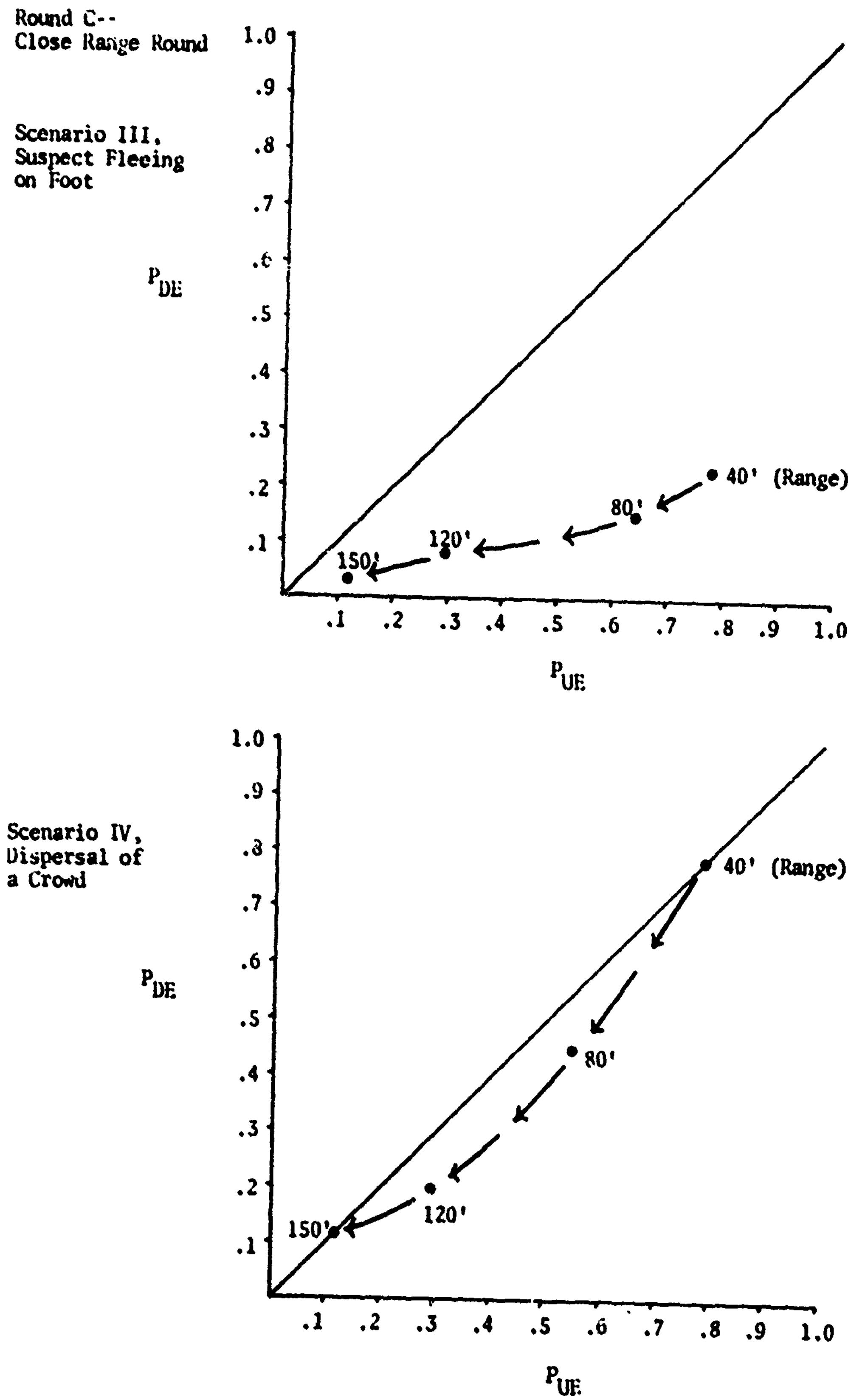


Figure 13. Summary graph (P_{DE} versus P_{UE} as a function of range).

In the crowd dispersal scenario, Rounds B and C both approximate the diagonal line in the summary graphs; i.e., the expected P_{DE} and P_{UE} are roughly equal. Both of these rounds provide a "show of force" with probabilities of desirable effects greater than .4 for ranges up to approximately 90 to 110 feet. The poor performance of Round A in Scenario IV is partially explained by the likelihood that a shot on the head with this round could cause unconsciousness (an undesirable effect), whereas a shot on the head with Rounds B or C (because of their lower kinetic-energy impact) would probably not cause unconsciousness, but would have the generally desirable effect of inducing the individual to leave the scene.

It should be pointed out that in referring to the summary graphs and the damage profile graphs simultaneously, the P_{DE} and P_{UE} figures on the two series of graphs do not mean the same thing. In the damage profile graphs, the probabilities represent the probability of effects given a hit; in the summary graphs, the probabilities include the probability of a hit. Each shot of Round A at ranges under 80 feet delivers considerably more than 110 foot-pounds of kinetic energy. Impacts at even this energy level are almost certain to have an undesirable effect, so any reduction in the P_{UE} from the 1.0 level in the summary graphs is entirely due to hit probabilities.

OBSERVATIONS

In analyzing the Stun-Bag as a less-lethal weapon the following observations have been made:

a. An impact by a Stun-Bag can cause damage to several organs, not all of which are directly under the point-of-impact. In particular, the liver seems to be damaged by impacts on areas of the body remote from the physical location of the liver, and by both low- and high-energy impacts. The Medical Group discussed at length this "liver pheromenon."

b. Stun-Bag impacts may cause damage to internal organs without displaying any gross signature on the skin. This raises the problem of medical treatment for persons hit with nonfrangible projectiles of this type. Since there may be no dramatic skin signature, medical diagnosis may be difficult.

c. In terms of accuracy, at 25 yards a proficient user of the .38 caliber is able to attain a standard error of less than six mils. However, the standard error for the Stun-Bag at 25 yards was about 19 mils, or approximately three times as great as the error of the .38 caliber. These figures are based on less than exhaustive testing, but are reliable to the extent that the Stun-Bag accuracy is much less than that of the .38 caliber.

d. One Stun-Bag round (Round A) provides "stopping power" sufficient to be effective against a suspect fleeing on foot, and two of the Stun-Bag rounds (Rounds B and C) provide a "show of force" sufficient to be effective in dispersing a crowd. However, the cost of obtaining either of these results may be a high probability of undesirable effect (as defined in this report).

SECTION IV.

CHEMICAL WEAPON SYSTEMS

BACKGROUND

The standardized methodology developed for evaluating blunt-trauma-producing less-lethal weapons in law enforcement scenarios was extended to include provisions for evaluating chemical weapons. As will be shown later, the nature of utilization of chemical less-lethal weapons is such that three separate evaluation sub-models are required for evaluation purposes.

The actual sub-models are discussed in HEL Technical Memorandum 2-76, January 1976, and will not be given further discussion in this report. However, some general discussion on the utilization of chemical less-lethal weapons will follow.

Considerable exploratory development and testing of chemical weapons have been completed by the US Government. Some information from this work which is applicable to a chemical weapon evaluation was obtained from the open literature. The latest revised copy of Jones' work is an excellent source of information (22). A perusal of this literature has identified a requirement to better define and establish desirable effects as used in the context of chemical-type less-lethal weaponry.

DISCUSSION

Before a particular device can be evaluated, some basic data on the performance of the device is required. Blunt-trauma (associated with certain chemical delivery systems) devices, is treated in the same manner as if the device were designed for blunt-trauma alone. The total evaluation is then the combined evaluation from both the blunt-trauma and the chemical effects. The chemical factors are treated in the subsequent paragraphs.

Performance Characteristics of Chemical Weapons

The choice of a delivery system depends upon the mission to be accomplished. The differing characteristics of various devices must be considered in relation to risk, cost and effectiveness. Unfortunately, the entire evaluation process is currently hindered by a lack of reliable performance data on chemical munitions.

Over the years, various munitions have been designed to deliver chemical agents to a desired release point. At present no single system has been designed to meet all tactical requirements.

There are three conditions in which chemical agents can currently be disseminated:

- A solid mixed with a pyrotechnic which is burned to vaporize the agent and release it as a submicron aerosol in a cloud of smoke.

- Micropulverized so that the agent can be released as a fine powder or dust.

● Suspended in a liquid which is sprayed at or projected to the target by an expelling force, or vaporized and released as a fog.

Various munitions are commercially available for disseminating chemical incapacitating agents. A survey of the literature on available items was reported in LWL Technical Note No. 74-05 (23). The general types of munitions which are of concern to this study are described below. Much of the information is taken from Thompson S. Crockett's Police Chemical Agents' Manual (24); however, some data was obtained from a series of tests performed utilizing some commercially-available devices. These tests are reported in HEL Technical Memorandum 21-75, August 1976.

Aerosol Projectors

The aerosol irritant projector is designed to project a chemical irritant onto a target subject and was very widely used by law enforcement officers as an alternative to the nightstick. The typical unit is a small cylindrical container about 6-1/4 inches in length and 1-3/8 inches in diameter, with a dispenser assembly in the top. CN is the most commonly used agent in the aerosol. CS is seldomly used, since its effectiveness in aerosol projectors is limited by the need for a direct eye impact to achieve rapid reaction due to the lower vapor pressure of CS relative to CN. The formulation is a liquid containing 0.9 percent CN. This concentration has almost become an industry standard. A typical projector might deliver 40 one-second bursts in which 2.5 grams of formulation or approximately 25 milligrams of CN are dispersed per burst. (The formulation is ideally released in a highly directional shotgun-type pattern of droplets.) Under ideal conditions, this weapon is at best effective up to a range of 15 to 20 feet.

Grenades

Chemical agent grenades are hand-activated containers which with few exceptions are designed to be used against crowds in open areas. Depending on the design they may be hand-thrown or launched from a gun. Grenades may contain either CS or CN although CS has recently become more widely used. Chemical agent grenades are subdivided into two classes; namely, expulsion grenades and pyrotechnic grenades.

Expulsion grenades release their contents instantaneously either by bursting or by using an explosive charge to force the micropulverized powder through exit ports. Due to the instant release, the grenade cannot be returned at police by rioters.

The pyrotechnic or continuous emission grenade releases an opaque cloud of smoke that carries a vaporized agent which recondenses to submicron particles. Since the agent is disseminated by burning, the pyrotechnic grenades present a fire hazard if they come in contact with combustible materials.

Projectiles

Chemical agent projectiles are designed to deliver the agent at relatively long ranges by launching from special riot gas guns or from the standard 12-gauge police riot shotguns. The muzzle velocities of these projectiles allow them to penetrate windows and doors. They may contain either CN or CS and are designed for use against barricaded criminals.

Bulk Dispensers

Bulk or mechanical dispensers are designed to produce large concentrations of chemical agent in those situations where wind condition and field position permit their use. These devices depend to a great extent upon favorable wind currents to achieve a maximum level of effectiveness. Available bulk dispensers employ either the expulsion, liquid or fog dissemination technique.

The expulsion dispensers use a pressurizing gas to project clouds of micropulverized chemical agent for distances up to 50 or 75 feet in a still air. The flow rate is very rapid and controllable only by the length of time that the triggering assembly is depressed.

Liquid dissemination bulk dispensers employ a pressurizing gas in the same manner as an expulsion dispenser to project the chemical agent to the target in a liquid state.

Fog generators disseminate large volumes of inert or irritant fog and have controls to vary the agent concentration. Fog generators operate by rapidly vaporizing a high-boiling-point liquid, which may or may not contain an irritant, exposing it to a hot gas flow, and then mixing the resulting hot vapors with much cooler ambient air causing them to condense into a fog.

In situations where conditions are favorable for their employment, bulk dispensers provide the most economical and effective method for applying agent concentration over large areas. While the devices dispersing micropulverized CS produce a characteristic contamination problem, the newer fog generators create a surprisingly low level of concentration even when the CS formulations are used.

SCENARIOS

Scenarios of interest for application of chemical weapons, along with the associated evaluation sub-models are given in Table 13 below.

TABLE 13

Types of Scenarios Amenable to Chemical Agents' Employment and Applicable Evaluation Models

Scenario Type	Munition	Applicable Model
One-On-One	Aerosol Projector	Projector
Barricade & Hostage	Projectile	Ventilation
Crowd Dispersal	Grenade	Modified Cloud Travel

Physiological Effects

Chemical Agents

Chemical weapons are used by police or control forces, generally in riot control situations, to induce people to behave in a desired manner. For the most part, this means getting rioters and bystanders to leave a particular area or abandon some form of unlawful activity. In some cases, the chemical agent may be used to force the violator to leave a barricaded position and thereby facilitate his capture. Thus, there is a requirement for delivering the agent to the target area and disseminating it in sufficient quantity to produce the desired behavior, while not likely producing permanent injury or undesirable reaction. The chemical agents currently available and generally used in police confrontations act directly on the mucous membranes of target personnel to produce irritation, burning and pain in the eyes, nose, throat and respiratory tract. The action on the eyes also causes tear flow, tightly closed eyelids and redness. The effects in the air passages and lungs causes sneezing, coughing, salivation, congestion of the nose and wall of the pharynx, and a feeling of suffocation.

The symptoms associated with CS and CN exposure are largely the result of irritation produced by extremely small particles that contact moist areas of the skin or are inhaled into the mouth, nose and lungs. The severity of the symptoms is generally related to the concentration of the chemical agent, the duration of exposure and to some extent the physiology of the victim. No matter how discrete the use of chemical agent is, there is always an element of risk of developing a dangerous concentration. Moreover, it is also important to bear in mind that the possibility of death through the development of a lethal concentration is only one of the risks involved in the use of chemical agents; e.g., if an agent produces a high incidence of panic-related unpredictable behavior or causes temporary loss of consciousness in certain types of personnel, it could present an unacceptable injury risk that would be entirely independent of any lethal potential.

Chemical burns and blistering can also result from exposure to the chemical agent. In cases where exposure coupled with the contamination of open wounds inflicted by the delivery system or otherwise are encountered, qualified medical first aid may be essential. The latter suggests that risks reside not only in the characteristics of an agent, but are equally a product of the way in which agents are delivered. Thus, it seems clear that poorly trained control forces or improperly designed delivery systems may increase whatever risk factors may generally be associated with chemical agents.

Of particular significance regarding desirable effects is that the effects cited above are noted immediately and persist 5 to 20 minutes after removal from the contaminated atmosphere. The relevancy of these instantaneous effects becomes apparent upon review of the desirable effect definition(s) which have been developed based on information set forth by the Medical Group as well as the Scenario Group. The definition of course varies with the scenario.

Blunt-Trauma Effects

Various munitions are commercially available for dissemination of the agent. As previously stated, the general types which are of concern to this study are aerosol projectors, grenades and projectiles. Of the three, grenades and projectiles present additional kinetic-energy/blunt-trauma/

fire hazard considerations in the evaluation of chemical weapons. Grenades which disintegrate or shatter create a potential hazard or injury from flying particles of metal or plastic. Burning grenades produce a fire hazard when used in areas in which they come in contact with combustible materials. In outdoor use, the major risk of fire arises in connection with spilled gasoline from overturned automobiles and dry grass or underbrush. Some grenades are capable of being gun-launched. These weapons are characterized by low muzzle velocities and tumbling flight patterns. Errant rounds fired upwind of crowds are less likely to produce serious personnel injury, although the possibility of injury cannot be completely discounted.

Since chemical agent projectiles are designed to deliver the agent at relatively long ranges, the muzzle velocities achieved by these projectiles are sufficient to penetrate windows, doors and even room partitions. The projectiles cannot be classed as totally "nonlethal" in nature because of the likelihood and actuality of injury or death to target personnel who are hit. These projectiles are primarily designed and intended for use against barricaded criminals. Here again, there is the possibility of injury to any hostages from flying projectile fragments or fire or both, since the munition would likely function in an enclosed area.

Nonphysiological Effects

When control forces produce the desired behavior pattern in the individual, other than by inflicting discomfort, there is an effect (nonphysiological) which has something to do with the mind (psychological) and is in most cases not fully understood. A basic problem is that we cannot quantify from any known data sources what to many people is completely obvious. Specific examples of this are: (1) we have observed that when rain falls upon a crowd, the crowd disperses (people just do not like to get wet!); (2) in several of the scenes of tear-gassing incidents reviewed by the Behavior Analysis Group, some impressive evidence was noted that the visual signature of the gas alone was extremely effective in dispersing the demonstrators.

In the case of chemical weapons, it would appear that the individual's knowledge of the agents' attributes would have a marked bearing on his behavior pattern. He could be ignorant, aware, or knowledgeable of its effects. If he were ignorant of tear gas effects, he might allow himself to be engulfed by the cloud; if aware, he might move on if he saw the cloud moving his way; and if knowledgeable, he might leave or be restless just on sight and suspicion of the intentions of control forces to use tear gas weaponry.

Therefore, it is clear that the nonphysiological desirable effects include those effects resulting from such events as display of the weapon, threat of weapon use or observation of the effects of weapon use on someone else. Although it is well-known that these effects do exist, in the case of chemical agents these effects have to date not been quantified.

Application of the Model for Each Scenario

Choosing the Munition and Agent

In considering agent selection, there are two terms which must be kept in mind:

- Median Incapacitating Dosage (ICt_{50}) is the amount of aerosol or vapor which is sufficient to incapacitate 50 percent of exposed personnel within 1 minute. The median incapacitating dosage for CS is 7 milligram-minutes per cubic meter (mg-min/cu m) and for CN is 70 mg-min/cu m.

• Median Lethal Dosage (LCt_{50}) is the concentration multiplied by the time of exposure that is lethal to 50 percent of exposed personnel. The LCt_{50} for CS is 25,000 mg-min/cu m and for CN is 14,000 mg-min/cu m.

The safety factor for a chemical agent is considered to be the ratio of the LCt_{50} to the ICt_{50}. Since the safety factor for CS is much higher than that for CN, there is less risk of developing a lethal concentration of CS. However, one should bear in mind that death is not the only risk in the use of a chemical agent. CS has been known to cause panic-related unpredictable behavior which can cause unacceptable injury. The probability of such injury has not been quantified to date. Some films were viewed by the Behavior Analysis Group which showed people running at the sight of the tear gas cloud. Many people were knocked down and walked upon and, in some cases, even trampled. (Reference: Bridge scene 1968 [video tape].)

Finally, CS can present a contamination problem especially in enclosed areas. CN, being 100 times more volatile than CS, will vaporize relatively quickly, whereas particles of CS will settle on floors, walks, and furniture where they remain for long periods of time and become reactivated whenever the air is disturbed.

With these facts in mind, one may proceed with the munition selection.

For the One-on-One Scenario, the aerosol projector appears to be the logical selection since it can be easily directed at the target individual and the amount of agent dispensed can be controlled. Most aerosol projectors use CN because of its relatively high volatility.

For the barricade and hostage, a projectile is required to defeat the barricade. CS may be the more desired agent because of its high safety factor. Since the barricade situation involves the use of a chemical agent in an enclosed area with little ventilation, considerations of lethal dosage may become a factor of critical importance.

Since grenades have been designed basically for crowd dispersal and are widely used for this purpose, the grenade was chosen as the applicable munition for the Crowd Dispersal Scenario. CS again seems to be the more desirable agent.

In the paragraphs which follow, a generalized application of the model will be explored for each scenario. Specific applications of the model are given in HEL Technical Memorandum 2-76, January 1976, and will not be repeated here.

One-On-One Scenario

Probability of hits were determined experimentally and are reported in HEL Technical Memorandum 21-75, August 1975. Once the hit probability is determined, the effects criteria must be input into the analysis. Some specific devices were tested and reported in the above indicated references, however, most evaluations must rely on the manufacturer's information. There are, at the present time, no completely satisfactory standard tests for aerosol irritant projector formulations. Ideally, the aerosol irritant projector formulations will instantly incapacitate a violent person without permanent injury and with the least possible temporary trauma. Any adequate evaluation of projector formulations would require a series of laboratory tests and field experiments that would include at least the assessment of:

- Injury potential - eyes, skin and systemic toxicity.

- Effectiveness - speed and degree of incapacitation.

- Discomfort level - severity and duration of pain or irritation.

There appears to be at least two effect mechanisms in operation. One is the direct effect of the droplet of agent on the skin and nerve endings. The second is the effect due to the concentration of agent vapor in the air surrounding the target. Knowing this concentration, the probability of incapacitation can be determined.

Based on the symptoms associated with incapacitation via CN tear-gas, we will assume that there is a one-to-one correlation between probability of incapacitation and probability of a desirable effect; i.e., the offender would be sufficiently disoriented to allow the officer at least 30 seconds to apply handcuffs. The probabilities of desirable effect due to the droplet and the vapor would be combined to give the probability of a physiologically desirable effect.

In considering undesirable effects, the possibility of obtaining a lethal dose of agent from an aerosol projector would appear to be remote. Considering the relatively small amount of agent which is dispensed per burst, it would probably be impossible to operate any dispenser fast enough to produce a lethal concentration. However, other undesirable effects can result if the device is improperly used at a range less than two feet and with no post-exposure first aid consisting of flushing the exposed body area with water.

Barricade and Hostage

Application of the model begins at the weapon. Muzzle velocity, along with drag and stability data on the projectile, would be used to determine exterior ballistics information along the trajectory. In this scenario, the target would likely be a door or window which must be penetrated. Probability of hitting the target would be assessed, given trajectory information along with weapon ballistic and aim errors. The projectile would be analyzed as to its penetration ability. After barricade penetration, the agent concentration could be determined from the amount of agent dispensed and the dimensions of the barricaded enclosures. This concentration could be used to determine probability of incapacitation. Of crucial importance in this analysis is the time to incapacitate, which would include the time required to permeate the enclosed atmosphere. The effect must incapacitate the offender before he can harm the hostage. The probability of obtaining the desired effect involves the probability of hitting the target area on the barricade, the probability given a hit that incapacitation occurs, and the probability that this incapacitation occurs before harm comes to the hostage.

Since this munition is to be used in an enclosed area, there is a risk of overexposure. Some determination of human lethal dosage have been made from data provided by animal experimentation. Maximum times allowable for a person to remain in an enclosed area with a specific agent concentration are provided for various devices in Appendix D of HEL Technical Memorandum 2-76.

Other undesirable effects may be injury from flying projectile fragments and possibility of fire, depending on the type of projectile. The projectile itself would pose a high risk of injury if anyone is in its path.

Crowd Dispersal

The grenade most likely would be the munition for use in this scenario. The first consideration is delivery of the grenade to the point of dissemination. The grenade may be hand-thrown or launched from a gun. Data is required on delivery, range and accuracy in order to determine the location of the dissemination source. A series of simple tests were run to determine the accuracy of grenade throwing and the results are given in Appendix O. By using the classical cloud travel model detailed in Appendix B of HEL Technical Memorandum 2-76, time/concentration can be determined as a function of cloud travel. Table 14 gives some normalized data derived from the cloud travel model. Using the range indicated by the scenario, the time the target is subjected to the agent concentration at the target can be determined from the cloud travel model. The time/concentration can be used to extract the probability of incapacitation from the data curves supplied in HEL TM 2-76. The cloud dimensions can be used to determine the fraction of the target covered. The fraction covered and probability of incapacitation within that fraction can be combined to give probability of desirable effect.

There is a need to develop more data to show the probability of an undesirable effect for a given time/concentration of the agent. Other undesirable effects which would depend on the type of grenade would be probability of fire for the pyrotechnic grenade and probability of injury from flying fragments for the bursting grenade.

OBSERVATIONS

Projectors

Desirable effects are not predictable without complete knowledge of the target conditions (emotional condition, drug effects, etc.); the undesirable characteristics are due primarily to the delivery system itself or its improper use rather than the chemical agent per se.

Grenades

The agent dispersed by a single grenade is not usually sufficient in itself to be effective, rather it is suspected that the psychological effect of the visual signature (not taken into account in the general evaluation model) is of greater significance; the primary undesirable effects are due to placement accuracy and damaging effects of the delivery system. (Multiple grenade usage was not considered.)

Projectiles

Subjective analysis of the effects of the barricade penetrators indicate in general that an insufficient amount of agent is injected into the enclosure to be effective, particularly from the 12 gauge variety of devices. The technique for penetration of barriers leads to a potentially highly dangerous device.

TABLE 14

Estimates of Concentration Coverage-Time of Cloud Envelopment

Downwind distance, x, from source meters	Semi-width y, of contour at downwind distance, x, meters	Average normalized dosage, D/Q sec/m^3	Average normalized concentration, C/Q $1/m^3$	Time of envelopment by contour sec	Area m^2
5	16	1.4×10^{-2}	2.8×10^{-3}	5	110
10	20	4.9×10^{-3}	7.2×10^{-4}	7	194
15	24	2.7×10^{-3}	3.2×10^{-4}	8	231
20	26	1.8×10^{-3}	1.8×10^{-4}	10	259
25	28	1.3×10^{-3}	1.2×10^{-4}	11	282
30	30	9.7×10^{-4}	8.2×10^{-5}	12	301
35	32	7.7×10^{-4}	6.0×10^{-5}	13	318
40	33	6.3×10^{-4}	4.6×10^{-5}	14	333
45	35	5.3×10^{-4}	3.7×10^{-5}	14	347
50	36	4.5×10^{-4}	3.0×10^{-5}	15	360
55	37	3.9×10^{-4}	2.5×10^{-5}	16	371
60	38	3.5×10^{-4}	2.1×10^{-5}	17	382
65	39	3.1×10^{-4}	1.8×10^{-5}	17	392
70	40	2.8×10^{-4}	1.5×10^{-5}	18	402
75	41	2.5×10^{-4}	1.3×10^{-5}	19	411
80	42	2.3×10^{-4}	1.2×10^{-5}	19	420
85	43	2.1×10^{-4}	1.0×10^{-5}	20	428
90	43	1.9×10^{-4}	9.2×10^{-6}	20	436
95	44	1.7×10^{-4}	8.3×10^{-6}	21	444
100	45	1.6×10^{-4}	7.5×10^{-6}	22	451
105	45	1.5×10^{-4}	6.8×10^{-6}	22	458
110	46	1.4×10^{-4}	6.2×10^{-6}	23	465

SECTION V.

ELECTRICAL DEVICES

BACKGROUND

The ideal less-lethal device should be capable of either causing an individual to flee or to produce near instantaneous incapacitation of the individual. It should have no incapacitating effect beyond the time required by the control force in the particular situation and should be as safe as can be devised both for the person subjected to the device's effect and to the control officer disseminating the effect. In concept, the electrical device can achieve all of these requirements—whether or not such characteristics can be achieved in practice is unknown since no public funding for the development of such items has been made.

Electrical less-lethal weapons offer many advantages not found with other types of less-lethal devices. Some of the advantages are: Broad spectrum of incapacitation, predictable physiological effect, controllability of dose, rapid incapacitation, etc. However, the duration of incapacitation with the use of an electrical device is critical, since longer durations have an increasingly associated hazard.

The attention given to electrical less-lethal weapons by researchers has been minimal. This was probably the result of the public attitudes on crowd control originating in events where so-called "cattle prods" were used by the police in the early civil rights demonstrations. Recent experiences with electrical devices such as the TASER produce different but still somewhat unfavorable attitudes. The overall less-lethal weapons program described herein has been influenced by this reaction to public sentiment and, as a result, very little has been accomplished in providing a viable model for evaluating electrical less-lethal devices.

It is rather strange that this particular area of less-lethal weapons has been curtailed because as shown above, electrical devices have, in concept, many of the desirable features of less-lethal devices except, of course, the most critical feature of public acceptance.

DISCUSSION OF THE MODEL

In general, the performance and suitability of electric shock for incapacitation of offenders may be affected by several variables which characterize the incapacitating current. The more important electrical parameters are voltage, current, power (or energy) and frequency. The spectrum of physical and physiological effects produced by the variations of voltage, current and frequency is probably familiar to many readers: the tingle of a mild electric shock of low amperage, the appearance of a high-voltage arc discharge, the accidental burn from 110 volt, 60-Hertz "house current" or the painful shock from the high voltage of an automobile ignition system.

In terms of incapacitation and biological effects on living systems, current--not voltage—is the most important variable of electricity. The frequency of the current is also a factor in determining the deleterious effects of electric current, especially with regard to the sensitivity of the human heart.

Electrical devices can be evaluated using the general model for the evaluation of less-lethal weapons. Some parameters for which data must be assembled for the evaluation are thus related to voltage, current, power and frequency. The major parameter for the determination of desirable effects is the so-called no-let-go (NLG) current. Basic data for this parameter has been gathered for certain conditions and is available. The average NLG current for men is 16 milliampere; for women 11 milliampere (60 Hz).

A major parameter associated with the evaluation in terms of undesirable effects is minimum fibrillation current. Unfortunately, most data available is for animals rather than humans, and the human accident data is primarily impulse shocks and is not of much value. However, a reasonable estimate of a maximum nonfibrillation current is around 67 ma. This is at least three times the so-called NLG currents which would produce desirable effects. However, the trade-offs between desirable and undesirable effects have not been established in other than an average or general sense.

An unusual aspect of electrical less-lethal devices is that a considerable body of information (though far from complete) is available on the critical aspects of safety and incapacitating effect. Even though this information is incomplete, it is far more definitive and specific than comparable information on kinetic energy less-lethal devices and possibly superior to the critical information available on chemical less-lethal devices.

A detailed description of the electrical model and its associated parameters is given in USA Human Engineering Laboratory Technical Memorandum 3-76.

APPLICATIONS

Some basic information has been gathered on two commercially available items; viz., the shock baton and the TASER. These data generally show that these items should be effective to some degree, and are relatively "safe." Unfortunately, the public nonacceptance of the shock baton negates its advantages. Simple tests (25) of the TASER have not demonstrated its capabilities.

These tests are the only known independent evaluation of the desirable effectiveness of the TASER.

Although the evaluation model was not used per se for undesirable effects, some general comments can be made. Very often, emotional type statements are made to indicate the unsafe nature of a device such as the TASER, especially when one quotes the 50,000 volt capability of the device.

High voltage, however, is not the prime independent factor in determining safety—as evidenced by high voltage systems of car ignitions. Current is a major factor, and it should be noted that the advertised TASER current of 10 ma is well below the indicated current which causes fibrillation of the heart.

Although, not as a result of using the evaluation mode, one could look at the TASER historically which is in effect the "proof of the pudding." It is our understanding that there have been over 20 firings of the TASER to date, with no fatalities or serious consequences. One can look at an alternative to the TASER, say the .38 caliber revolver. Since there were 20 TASER firings, one can examine some case histories of 20 shootings such as documented in Appendix M.

If the 20 people shot with the TASER had been shot with the .38 caliber revolver, instead of no permanent injuries or death as obtained with the TASER, the estimated results from the use of a .38 caliber revolver would have been: 11 dead, 9 hospitalized for 2 to 25 days.

A comparison analysis from a documented data base thus supersedes results predicted from an electric model and should not be disregarded in reviewing the possibilities of a given less-lethal weapon.

OBSERVATIONS

Although electrical less-lethal weapons appear to show great promise for noninjurious application, little effort has been directed toward their development or evaluation. The basic model developed for the evaluation of less-lethal weapons is applicable to electrical devices, although more basic data needs to be gathered prior to useful evaluations.

1. Research and development efforts should be pursued for less-lethal electrical weapons in that this approach possesses many of the desired features for less-lethal weapon application.

2. Good public relations are essential and must be developed for electrical less-lethal weapons along with the technical development of such items.

SECTION VI.

LATEST DEVELOPMENTS

This section is not intended to be comprehensive, rather it is an update on some of the latest developments on less-lethal weapons.

MILITARY ITEMS

The latest item to be developed by the U.S. Army is the Soft/Sting Rag Munitions.

The Soft/Sting Airfoil Munitions System is designed as a means of controlling civil disturbance situations without requiring close-up confrontation and with a minimum probability of inflicting a serious injury. The system consists of a launcher (XM234), which attaches to the flash suppressor of the M16A1 rifle, and a blank cartridge (XM755) which when fired in the chamber of the rifle supplies gases to propel either an XM742 Soft Ring Airfoil Grenade (Soft RAG) projectile or an XM743 Sting RAG projectile from the launcher at approximately 200 ft/sec and 5000 rpm. A "civilian" type launcher could be designed for this system.

The airfoil cross-section of the annulus-shaped projectile causes the projectile to develop lift during flight, resulting in a relatively flat trajectory and enabling users to engage point targets out to 40 meters and small groups to 60 meters. These projectiles are 2.5 inches in diameter, weight 34 grams, and are made of a soft rubber wrapped with a paper breakband to retain aerodynamic shaping during flight. Upon target impace the Sting RAG (white breakband) utilizes its kinetic energy to inflict pain. The Soft RAG (black breakband) utilizes spin forces needed for gyroscopic stability and impact forces to rupture a peripheral breakband to release its CSI payload in a cloud one to two meters in diameter. For ease of utilization, six projectiles and cartridges are dispensed from a carrier which is clipped to the user. Choice of projectile would depend upon the tactical situation.

Dr. Dennis T. Brennan's (Cleveland, Ohio) report (26), "Riot Control Without Bloodshed," is an excellent article on this device and makes the following important general points which are not always understood:

1. A less-lethal device must be introduced at the proper time in the proper manner (this was also recognized by the Los Angeles Task Force—HEL TM 24-76).

2. The police have a fear that less-lethal weapons will replace their conventional weapons. (This was evident at the California Legislature hearings conducted by Alan Sieroty. Based on the state-of-the-art of less-lethal weapons this feeling is of course understandable.)

3. No weapon can be guaranteed non-lethal (this also was the "findings" of the Los Angeles Task Force).

Standard Army less-lethal devices include:

Dispersers

Riot Control Agent - M5 - Helicopter or Vehicle Mounted

Riot Control Agent - M3 - Portable

Riot Control Agent - M106 - Backpack

Riot Control Agent - XM36 - Hand Held

The M33, when type classified, will replace the M3 and the M106.

Grenades

Hand-Thrown - M-25-A-2

Hand-Thrown - M-7-A-3

The M47 CS grenade, when type classified, will replace the M-25-A-2 and the M-7-A-3.

40mm Cartridge

Riot Control - M674 - CS Round

Weapons

M-16 Rifle (used with the RAG system)

Shotguns

M-79 Launcher

M-203 Launcher

Miscellaneous

36-Inch Riot Baton

COMMERCIAL ITEMS

The MODI-PAC made by Remington is a 12-gauge shotgun shell loaded with approximately 320 lightweight polyethylene pellets weighing about one-quarter ounce. This was a kinetic-energy type less-lethal ammunition which shows some promise. Some tests of this item were performed and results are given in USA Human Engineering Laboratory Technical Memorandum 4-76, "Weapons Performance Testing and Analysis: The MODI-PAC Round, The No. 4 Lead Shot Round, and The Flying Baton."

Jones' book (27) on "Law Enforcement Chemical Agents and Related Equipment," is an excellent source of information on up-to-date chemical less-lethal devices.

The TASER which is mentioned in the previous section seems to be the most active electrical less-lethal weapon on the market today. Apparently over 3500 have been sold since 1975. Public acceptance, laws for regulation and control, and a better understanding of capabilities and limitations will drive the changes and modifications to this device.

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APPENDIX A

LESS LETHAL WEAPONS EVALUATION PANEL

LESS LETHAL WEAPONS EVALUATION PANEL[1]

Scenario Group

Name	Background	Organization
Mr. D. O. Egner[2]	Physicist	US Army Land Warfare Laboratory (USALWL)/ US Army Human Engineering Laboratory (USAHEL)
Mr. E. B. Shank	Operations Research Analyst	USALWL/USAHEL
Mr. L. W. Williams	Political Scientist	Battelle Memorial Institute (BMI)[3]
Mr. A. Sagalyn	Police Consultant	Security Planning Corporation (SPC)[4]
LT A. E. Yowell	Police Officer	Washington, DC Police Department[4]
Mr. R. S. Zelina	Engineer/Lawyer	AAI Corporation (AAI)[3]

Medical Group

Name	Background	Organization
Mr. M. J. Wargovich[2]	Physiologist	Biological Sciences Branch (BSB), USALWL
Dr. W. M. Busey	Pathologist, DVM, PhD	Experimental Pathology Laboratories, Inc. (EPL)[5]
Mr. V. R. Clare[6]	Research Biologist	Biophysics Division, Medical Laboratory, Edgewood Area, US Army Aberdeen Proving Ground
Mr. D. O. Egner	Physicist	USALWL/USAHEL
Dr. R. S. Fisher	Forensic Pathologist, MD	Chief Medical Examiner, State of Maryland[5]
Dr. F. G. Wolfort	Surgeon, MD	Chief of Plastic Surgery, Cambridge, MA Hospital[5]

(Continued)

LESS LETHAL WEAPONS EVALUATION PANEL (Continued)

Medical Group

Name	Background	Organization
Mr. R. S. Zelina	Engineer/Lawyer	AAI[3]
Mrs. B. K. Thein	Operations Research Analyst	USALWL/USAHEL

Behavior Analysis Group

Name	Background	Organization
Mr. E. B. Shank	Operations Research Analyst	USALWL/USAHEL
Dr. W. M. Busey	Pathologist (DVM-PhD)	EPL[4]
Mr. D. O. Egner	Physicist	USALWL/USAHEL
Dr. A. Greenspan	Psychiatrist (MD)	Private Practice[5]
Mr. C. F. Rosenthal	Social Scientist	American Institutes for Research (AIR)[5]
Dr. G. W. Shaffer	Psychologist (PhD)	Johns Hopkins University (JHU)[5]
Mr. L. W. Williams	Political Scientist	BMI[3]
Mr. R. S. Zelina	Engineer/Lawyer	AAI[3]

[1] See Figure 1A for professional affiliation of Group Membership.
[2] Chairman
[3] LWL Contractor
[4] Consultant to BMI
[5] Consultant to AAI
[6] Mr. Clare was succeeded by Dr. A. K. Ommaya, National Institutes of Health (NIH).

(Concluded)

LESS LETHAL EVALUATION PANEL GROUPS

SCENARIO	BEHAVIOR ANALYSIS	MEDICAL
Police Consultant	Operations Research Analyst	Pathologist (D. V. M.)
Police Officer	Pathologist (D. V. M.)	Physiologist
Operations Research Analyst	Physicist	Physicist
Political Scientist	Psychiatrist (MD)	Forensic Pathologist (MD)
Engineer/Lawyer	Research Scientist	Surgeon (MD)
Physicist	Psychologist	Engineer
	Political Scientist	Surgical Neurologist (MD)
	Engineer	Operations Research Analyst

Figure 1A. Less Lethal Evaluation Panel groups.

APPENDIX B

BEHAVIOR ANALYSIS GROUP NOTES

NOTES FROM BEHAVIOR ANALYSIS GROUP MEETINGS

This appendix contains notes from several meetings of the Behavior Analysis Less Lethal Weapons Evaluation Panel. The Behavior Analysis Group assembled five times. The first of these meetings was held on 9 March 1972. This was primarily an organizational meeting.

Topics of discussion included scenario development, candidate less-lethal weapons, and the concept of desirable and undesirable effects produced when these types of weapons are employed in scenarios of current interest. In the second meeting (17 August 1973) there was an attempt to formulate rationale and estimates of probability of desirable effects. Some estimates were rendered but only after some very, very trying discussion. The third meeting was held on 29 December 1973. The estimates of desirable effects came somewhat easier during this meeting. The nature of the weapon addressed; viz., the .38 caliber revolver, may have had a significant bearing on the facility with which the damage mechanism estimates were rendered. Also, some probability estimates for the effect of threat and display of the weapon were made at this meeting. The fourth meeting was held 11 March 1973 and was concerned with the establishment of emotional states for evaluation as well as with an actual evaluation of the Stun Bag. Minutes of the fifth and final meetings of The Behavior Analysis Group are included in USA Human Engineering Laboratory Technical Memorandum 20-75.

OBJECTIVES

The primary objective of the Behavior Analysis Group meetings was to establish a method(s) whereby one could estimate the probable desirable effects produced by kinetic energy damage mechanisms.

A secondary objective was to establish a rudimentary data bank of these desirable effects for a typical blunt-trauma projectile. The projectile considered was a high-energy rubber ball. This was chosen for study of the damage mechanism in general, since some work using this projectile was already available from a related program.

APPROACH

It was established early in the first meeting that the estimation of desirable effects due to purely physiological phenomena should be accomplished by the Medical Group. The Behavior Analysis Group thus concentrated on desirable effects related to ''pain'' and to ''nonphysiological''/psychological or other phenomena.

The general methodology evolved for establishing pertinent effects was as follows:

1. Review the scenario and establish what it is that one would consider to be a desirable effect. This could be in terms of a typical individual's reaction within the target complex and/or in terms of the target complex's reaction as a whole.

2. Establish the demeanor of the target.

3. Establish some baseline assocated with the damage mecha ism which can be used to estimate the degree of the desirable effect attained, if any.

FLEEING SUSPECT-SCENARIO III

The Fleeing Suspect (Army Scenario I) was examined first. This scenario is quite similar to the Civil Scenario III with the prime exception being the 30-second immobilization time for the Army scenario. The target consisted of one fleeing suspect whom it was desired to immobilize for 30 seconds. It was observed that within the context of the scenario, one would only be concerned with the back of the target.

The suspect was assumed to be highly motivated to the extent that pain probably would have no desirable effect. In fact, pain could cause the target to increase his tendency to flee the scene. On the other hand, it was postulated that a degree of desirable effect could be obtained via the imposition of a "stun" effect and/or fear. "Stun" was defined, primarily, as the mental stress (real neurological damage) imposed when the brain is temporarily put out of action as a result of a sharp blow to the head. This was liken to the effect one notes when he inadvertently bumps his head on a door. Some discussion occurred here as to the duration of this effect. In general, it was agreed that the effect could persist for 30 seconds. To some extent, nonhead impacts also can stun.

Physiological damage levels previously established by the Medical Group were used as the baseline for estimating the degree of desired effect attained. These descriptions were reviewed, along with color slides of actual damage classes and the degree of undesirable effects associated with various organs, etc., subjected to these damage levels.

Skin and head (brain) physiological damage levels were used exclusively as baselines. The group was shown color slides of typical Grade "X" damage. They were then asked to estimate the desirable effect such an impact would produce on a fleeing suspect. Immobilization increments of 10% were used. Independent estimates (with supporting rationale) were initially made by the voting group members in the presence of the entire group. After all estimates had been made, they were discussed by the entire group. Modifications to original estimates were permitted. Discussion continued until the group felt reasonably comfortable with posted values and supporting rationale. The procedure was repeated separately for various grade levels of skin and head physiological damage.

Results are shown in the following table with pertinent rationale. Note that the probabilities cited should be interpreted as follows. A .10 probability means that out of 100 people sustaining the impact, 10 will be expected to be immobilized for ≥30 seconds and 90 will not.

DESIRABLE EFFECTS - FLEEING SUSPECT - SCENARIO III

Physiological Damage Level (Grade)	Probability of Attaining Desirable Effect (Immobilizing Target for ≥30 Seconds) Head	Balance of Body (Skin)	Rationale
1	.90	.10	Note #1
2	>.90	.10	Note #1
3	>.99	.30	Note #2
4	>.99	.60	Note #3
5	>.99	.70	Note #3

Note #1- It was observed that based on individual differences (mental syndromes) approximately 10% of the targets impacted on the balance of the body (skin) would be expected to be immobilized. Some people can be counted on to stop when subjected to a mere yell. Physiological Damage Levels 1 and 2 to the skin are very similar and were thought to provide essentially the same desirable effect; i.e., Grade 1 is a superficial blemish or signature in skin; Grade 2 is Grade 1 plus subcutaneous hemorrhage and/or edema. Regarding head injuries, it was thought that a head impact of sufficient velocity to inflict Damage Level 1 would probably stun 90% of the targets thus hit. This damage level is defined as a linear fracture of skull and/or minor epidural or subdural hemorrhage and/or contusion of brain less than two millimeters in diameter.

Note #2- With Grade 3 damage (Grades 1 and 2, plus subcutaneous and/or intramuscular hematoma) to the skin (balance of the body), one encounters damage substantially greater than that previously cited; i.e., intramuscular hematoma. The group estimated that 30% of the targets subjected to this skin damage level would probably be immobilized. Concerning head shots, it was estimated that the probability of immobilization would increase as the physiological damage level increased. Since Damage Level 1 was estimated to produce a relatively high 90% immobilization, the degree of immobilization for higher damage levels would increase rapidly-approaching unity at Damage Level 3 or 4.

Note #3- Higher values for immobilization due to skin (balance of body) impacts were estimated in line with the increased physiological damage levels. Damage Levels 4 consists of Grade 1, 2 and 3, plus laceration of fascia, muscle and/or fat. Damage Level 5 consists of Grades 1, 2, 3 and 4, plus laceration of skin.

MOVING H/DISPERSAL OF A CROWD - SCENARIO IV

The Moving H (Army Scenario II) is quite similar to Civil Scenario IV (Dispersal of a Crowd) and thus is included for general discussion purposes. The primary objective with the Moving-H Scenario is to disperse a crowd of dissidents who are illegally blocking a street.

A profile of distortions characteristic of the crowd was essentially as follows:

> Individuals are swept up into the spirit of a moment and their individual egos merge into the crowd. They may act differently than they would if not a crowd participant. Typical participants are discontented and desire to alter their lives. They may be high school dropouts but are political activists. They are more politically aware than most people. They do not stop and think but go for direct-action solutions. They tend to do what they think other people in the crowd expect them to do. Rumors tend to become firm beliefs. They confuse casual relationships. Pain may become pleasurable at times .... considered to be a badge of courage attained by defending one's beliefs. An individual within the crowd may respond differently to pain during the same incident. Pain may alternately cause displeasure and pleasure. It appears that certain disorders take place, especially on college campuses, which do not entail the political aspects, high school dropouts, etc. noted above. The description nevertheless tends to illustrate the unpredictable character of crowds in general.

It was proposed that many people develop great anxiety over pain and individual reactions to pain depending on life styles. Reaction could include the following:

1. Look how much I suffer!
2. See how brave I am!
3. Look what you do to me!
4. It's really nothing and will go away.

What one requires is an estimate concerning the average effect of pain on an average individual subjected to it. This might be of the form that "X" percent are unaffected, "Y" percent are deterred and "Z" percent take pleasure in it.

Since the control forces would be facing the crowd, one is concerned specifically with the frontal target aspect.

A question arose as to whether the Behavior Analysis Group should work with individuals within the crowd or with the total crowd. What percent of the crowd disperses, if any, when "N" individuals sustain certain physiological damage levels, and what response triggers the movement? These questions could, of course, not be answered directly.

The following table presents data developed during the meeting. Some question exists, though, as to what the table really means. Possibilities include:

1. The approach taken was to estimate the percentage of the crowd that would be mobilized (leave the scene) as a function of the number of individuals within the crowd which sustained a specific physiological damage level.

2. Same as above, but percent of crowd mobilized pertains to those who see targets hit; e.g., 5% of crowd members who see someone else sustain Damage Level 1 are mobilized, etc.

DESIRABLE EFFECTS - MOVING H/DISPERSAL OF A CROWD (SCENARIO IV)

Physiological Damage Level (Grade)	% of Crowd Hit	% of Crowd Mobilized[a]	Rationale
1	100	5	Note #1
2	-	-	
3	-	-	
4	-	-	
5	100	100	Note #2

[a]Estimates consider effects on skin, subcutaneous tissue, and muscle only.

Note #1 - Damage Level 1 (superficial blemish or signature to skin) was estimated to cause 5% of the crowd to disperse; largely, this accounts for individual differences within the crowd. Some people may flee at the threat of being hit.

Note #2 - Damage Level 5 (includes skin lacerations). The group believed that lacerations which produced blood flow would cause essentially all of the subjects thus hit to disperse. In retrospect, there appears to be considerable evidence to indicate that some dissidents dash up to TV cameras to display their wound, rather than flee the scene.

As noted results here are sketchy. No attempt was made to evaluate head hits. Insofar as body hits were concerned, the effects of hits which produced stings but no perceptible physiological damage were not evaluated. Also, Damage Levels 2, 3 and 4 were not evaluated. One must bear in mind that estimates attempted to cover "pain" and "psychological"/"nonphysiological" effects only.

ADDITIONAL NEEDS

The effects of physiological damage levels less than Grade 1 were not estimated, as there appeared to be little basis for doing so.

A meeting of the Medical Group was required to establish desirable effects based on purely physiological effects.

Regarding the given scenarios, several schemes for obtaining needed data were proposed. These included:

1. Pig Deterrent Experiment - Pigs trained to eat at a certain location would be denied food for a sufficient time, then permitted to follow a path to known food. Enroute, they would be subjected to specific impacts with specified damage mechanisms. The degree to which the hit deterred them from food would be noted. Relative deterrence of competing damage mechanisms would be noted. Some extrapolation to human behavior would be made from this data.

2. Human Experiment - A group of volunteers (protected by face shields) would be offered an attractive incentive if they could hold a specified position while subjected to low-level impacts from a damage mechanism, such as the high-energy rubber ball. Statistics could thus be gathered as a function of projectile velocities, etc. The subjects could also be interviewed to determine what caused them to disperse, etc.; i.e., pain, fear, etc.

3. Baboon Head Tests - A neurologist could be utilized to design tests wherein inner ear changes could be monitored as a function of impacts to the cerebellum. (Part of brain concerned with coordinating muscles and bodily equilibrium.) In addition, the use of EEG's on unanesthetized baboons was discounted, as no method exists for interpreting the data. Gel or water-filled skulls would be impacted to measure shock-wave intensity through a simulated brain. This could be correlated with behavior of primates subjected to similar impacts.

None of these programs were, however, pursued.

In the case of the Fleeing Suspect-Scenario III, the objective can be achieved by imposing fear or suggesting fear, stun, and/or pure physiological effects. Scenario such as the Dispersal of a Crowd (Scenario IV) which involve crowds are extremely difficult to handle. One really should know what causes a crowd to band together in the first place, and then attempt to determine forces which cause it to disband. Multiple effects are involved in dispersing the crowd, including the following:

1. Effect of projectile hit to subject (A); i.e., the probability that he personally will leave the scene, etc.

2. Effect on other crowd members (B) who see, or are otherwise aware of subject (A)'s experience.

3. Effect on crowd members (C) who witness the movement or effect on crowd members (B).

In each case one must know why the individual or individuals act as they do and who would be best qualified to render the estimated effect; i.e., Medical Group, Behavior Analysis Group, etc.

The primary purpose of another meeting was to generate desirable effects probability estimated for two or more of the civil scenarios.... based on psychological effects of the .38 caliber revolver and ammunition. This was to serve as a basis for comparison with less-lethal weapons.

In order to establish sufficient background for these estimates, meeting attendees keyed on an agenda as below:

1. Estimation of Psychological Effects

a. Define undesirable psychological effect.

b. Examine possibility of undesirable effects associated with civil scenarios.

c. Review civil scenarios - Discuss most probable emotional level for each scenario, crowd hostility, and crowd breakup and promotion of same.

d. Generate provisional probability estimates of desirable effects of the .38 caliber revolver. Effects examined are to include:

(1) Physical presence of armed law enforcement officer.

(2) Threat of weapon use (verbal order of warning shot).

(3) Weapon Use: Observers (target personnel who do not get hit but see others hit); Hit on target (noncritical flesh wound).

2. Discussion of Other Mechanisms of Effect, Excluding Pain.

3. Discussion of Individual vs Group Desirable Effects.

Emphasis was placed on the applicability of the provisional estimates to be rendered to the general evaluation methodology which had been formulated previously. Physiologically-based probability estimates of desirable and undesirable effects as generated by the Medical Group were discussed, as well as the method employed (slides, etc.) and the rationale used. It was noted that the Behavior Analysis Group should keep in mind when rendering the estimates that desirable effects are characterized by relatively short onset times and lasting effects of less than 24 hours, whereas, undesirable effects are generally thought of as latent (excluding immediate death) and persisting for more than 24 hours. At this juncture, the need for a definition of the psychological effects (similar to Medical Group definition) was stated.

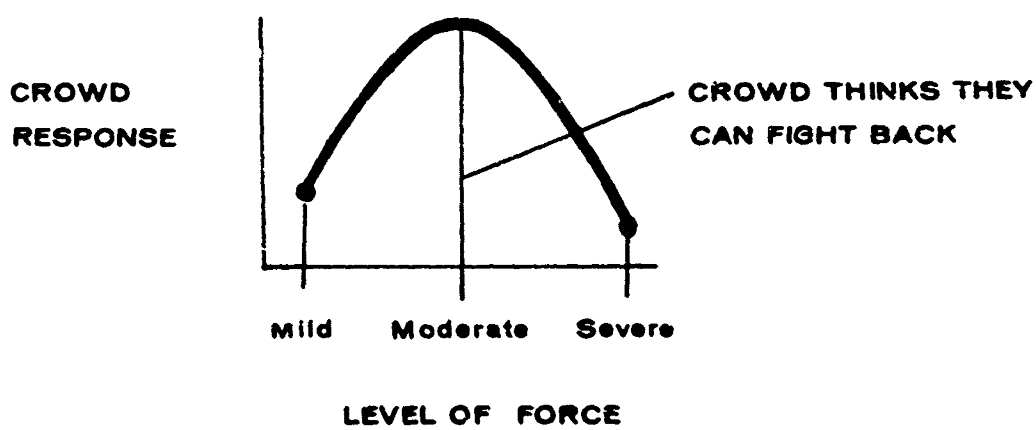
There was agreement among the attendees that a psychologically-undesirable effect could be defined as "an effect which persists longer than 24 hours and prevents an individual from performing routine daily tasks.[1] The desirable effects are defined by the scenarios.

The use of the word "psychological" was discussed regarding its salability. This discussion prompted comments, such as: "Just to find a new word, especially as esoteric term, is pointless" ..."Why not let 'psychological' stand?"...."As everyone knows, it has something to do with the mind which is not fully understood...." These responses were so basic and pure as to illicit no rebuttal from meeting attendees and thus the doctrine of "silence is consent" governed and the term "psychological" stood.

At this juncture, a review of the civil scenarios was initiated. Written descriptions and a simple sketch of each scenario were provided. Most of the discussion dealt with the Suspect Fleeing on Foot and Crowd Dispersal scenarios. The Barricade and Hostage and the One-on-One scenarios were only briefly addressed.

At the request of the other members of the Behavior Analysis Group, one member of the group has conducted some research on crowd behavior prior to this session. Interest in crowd breakup and what promotes it, as well as the emotional state or level of the crowd as it would relate to applicable scenarios, prompted this effort. The member summarized briefly the results of his investigation.

Unfavorable crowd response is maximum when the control forces exert only moderate force on the crowd. When the level of force is mild or severe, the crowd is more easily handled. This is illustrated in the sketch below:



[1]This is similar to the definition agreed upon the Medical Group. It was unlikely that any appreciable number of psychologically-undesirable effects will result in a psychotic episode. It was stated and there was agreement between the psychologist and the psychiatrist that a psychotic episode usually lasts several months and is hardly ever caused by a single event. (This infers that the probability of a psychotic episode for the scenarios of interest would be nil.)

The use of mild force by police is advocated and is evident from police training procedures. It is better to have a few policemen to "talk the crowd down' while the garrisoned troops remain off to the side or around the corner or otherwise out of the view of the crowd; the garrisoned troops can be immediately summoned if the few policemen are not adequate.

Another important consideration relating to crowd response is the indecisiveness of control forces. If the police hesitate, hedge, etc., the crowd will be agressive. If the police exhibit a strong decisive force, the crowd will be passive.[2] Coupled with the credibility of this threat is the physical appearance which the policeman presents to the crowd.(A big, burly officer is impressive.) The holstered pistol is also a good back-up. Once the crowd has the impression that the police mean business, they will be more docile. It is clear that the nonlethal weapon should be used in a "no-nonsense" way or its use may have a negative effect. For example, if the risk to the individual was small, say one or two high-energy Q-spheres (a proposed less-lethal munition), then the crowd would not disperse. It would be better to shower the crowd with the high-energy Q-spheres. The analogy was drawn that one bee would not disperse the crowd, but a whole swarm of bees would. Further discussion of crowds was deferred by the moderator until the Crowd Dispersal Scenario was discussed.

With the foregoing as background, attendees settled down to the business at hand of rendering the psychological effects estimates.

The first scenario considered was the Suspect Fleeing on Foot. Assumptions for the estimates included:

1. The threat is real (the policeman "means business").

2. Fleeing suspect is "average" adult offender.

3. Suspect is unarmed (scenario is written this way).

The desirable effect is to slow down or stop the offender so that he may be apprehended. It was noted that the .38 caliber revolver did not fit the scenario too well, but also that we did not want to rewrite the scenario.

Table 1B summarizes the probability estimates for the psychologically-based desirable effects (P_{DE}).

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[2] Not violent or physical

TABLE 1B

Summary of Probability Estimates of Psychologically-Based Desirable Effects-
Suspect Fleeing on Foot Scenario

Level of Force	P_{DE}[a]	Remarks
Physical presence of officer	NA	Suspect is running away--Probably does not see officer.
Threat of weapon use	0.25	Motivation is key; most will keep running
Weapon Use[b]		
Not hit	0.35[c]	Small percentage might think officer "means business."[d]
Hit (nonincapacitating wound)	0.50[c]	A guess at best.

[a]Probability of Desirable Effect.
[b]Might not be a warning shot.
[c]Includes those subjected to threat.
[d]For our assumptions, panel consensus was that of the 75 out of 100 persons who would keep running after the threat, only 10 would stop on weapon use without a hit. This again depends on local police doctrine and suspect's knowledge thereof.

It is interesting to note that the probability estimates in Table 1B agree closely with some police data. Specifically, Dade County, FL, police records show that 28% of offenders stop when the police fire a warning shot. In those cases where suspects are hit but do not stop, 28% are apprehended later. According to our panel estimates, these numbers would be 25% and 25%, respectively. (Some of the panel members rendering the estimates had access to this information; therefore, some unquantifiable amount of bias might be expected.)

For those suspects in this scenario who escape, the undesirable effects are not applicable. Attendees agreed that the suspects would probably be scared for a few hours.

The attendees agreed that it seemed remote that the single event of capture would cause a psychotic episode. A psychotic episode would, of course, last several months but is a built-up thing which has been compounded on many other things. About the only thing that shooting at these people does.....from the psychological view, is to confirm their view (distorted as it may be) of the world as a mean place that wants to kill them. People will get mad at the police for shooting at them;

and, in particular, the fleeing suspect has a greater anger toward the police if shot at. Moreover, the suspect's desire for retribution may be increased if he is shot at.

Summarizing, then, for all levels of force, the psychological undesirable effect is either not applicable or zero.

The next scenario that was addressed was the Crowd Dispersal Scenario. At this juncture, it seemed appropriate to continue the discussion of crowd behavior. It was related that crowds are an effective way for grieved individuals to "blow-off-steam." A crowd is a homogenous group containing individuals with average or better intelligence. The emotional intensity (EI) of the crowd may lie somewhere between peaceful and hostile. Ordinarily, the crowd will be passive[3] and illegally gathered; however, the crowd has stages. In the beginning, there is purpose. Depending on the display of force, weak members of the crowd may leave and then wander back in. In the early stages, the police are better off not "reading the riot act," for when they do, the threat credibility is challenged as individuals within the crowd are unable to perceive a personal threat. In later stages, the emotional intensity of the crowd tends toward hostility as their purpose is reinforced as they prepare for arrest, jail and bail. It was also noted that clever demonstrators start peaceful demonstrations and that these demonstrations are often well-organized and logistically supported; however, this is not always recognized by law enforcement agencies.

With these additional comments taken under advisement, meeting addendees rendered desirable effects probability estimates for the Crowd Dispersal Scenario. Assumptions for the estimates included:

- Crowd is gathered illegally with purpose.

- Crowd is passive.

The desirable effect is to cause the crowd to leave the area.

Table 28 summarizes the probability estimates for the psychologically-based desirable effect (P_{pE}).

The Barricade and Hostage Scenario received the least treatment. The .38 caliber weapon is inappropriate for this scenario. "Talk" would probably be as effective as any weapon and would represent the least risk to the well-being of the hostage. Many references consulted in preparing for the meeting advocate that tear gas be employed under similar conditions. Panel members tended to agree; therefore, the discussion of this scenario was terminated.

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[3]Not violent or physical.

TABLE 2B

Summary of Probability Estimates of Psychologically-Based Desirable Effects - Crowd Dispersal Scenario

Level of Force	P_{DE}[a]	Remarks
Physical presence of officer[b]	0.10[c]	Authoritativeness of his movements, physical size, etc. "Riot Act" has been read.
Threat of weapon use	0.25	Most do not believe policeman will shoot. Threat credibility is challenged when individuals are unable to perceive threat as a personal threat.
Weapon Use		
Fire over crowd	0.90	If police fire over the crowd, the crowd reacts.
Fire into crowd	1.00	Crowd would be surprised because most riot policemen are armed only with night-stick and possibly tear gas.

[a]Probability of desirable effects.

[b]No obvious weapon, other than nightstick. (If there are a small number of police, the crowd probably would disperse and risk a reassembly.)

[c]0.10 means 10 out of 100 people are expected to leave.

The One-on-One Scenario was examined next. The panel members agreed that Variation A of this scenario was appropriate to consider regarding the psychological effects. In Variation A the unarmed offender pushes, shoves, jerks away, swings, kicks, bites, etc. The offender indulges in this sort of activity to counteract the action of the police. The scenario is one of physical interaction between the police and the offender. (The conditions of Variation A do not normally require the use of a weapon as lethal as the .38 caliber!) Assumptions for the estimates included:

- This is the "average" adult offender.

- The desirable effect is to apprehend (handcuff) the offender within 30 seconds.

Table 3B summarizes the probability estimates for the psychologically-based desirable effects (P_{DE}).

TABLE 3B

Summary of Probability Estimates of Psychologically-Based Desirable Effects - One-On-One Scenario, Variation A

Level of Force	P_{DE}	Remarks
Physical presence of officer	NA	Physical interaction. Presence of officer dictates scenario.
Threat of weapon use	0.70	Policeman is the aggressor.
Weapon Use		
No hit	0.80	
Hit	--	

It should be noted that independent estimates were initially made by each of the voting members of the group in the presence of the other voting members and not by secret ballot as had been their intention. Group members preferred this method. After all estimates had been made, they were discussed by the entire group. Although modifications to the estimates were permitted, none were actually made. A consensus estimate was determined by averaging the individual estimates and rounding to the closest 5%. Thus .282 became .30; .273 became .25, etc.

A few comments were made regarding other psychological effects, exclusive of pain. Two terms which were mentioned but not discussed in depth were "autonomic response" and "endocrine effect."

Individual versus group behavior was discussed only briefly. It was concluded that individually most persons will do what benefits them most; however, in a crowd, they will do what is best for the crowd.

The Group was then asked to comment from their experiences on the best sources of information for the evaluation of human response to noxious stimuli.

It was stated that we are dealing in the realm of an inexact science. We have a problem in choosing the correct word or esoteric term to describe the response; e.g., rainfall on crowd—an observation which we know to cause a crowd to disperse; characteristics of the mob member; i.e., "pain may become pleasurable at times." Under an emotional situation, an individual may be analogous with a black box. You put something in......(noxious stimulus) and you get something out (human response), but you are not certain what has gone on inside the box.

It was further emphasized that data on human behavior is generally, almost universally, taken under very controlled situations — like in a Laboratory. Subjects are ordinarily college student volunteers who have been screened as "normal." (Normal behavior is a situation like the shaking of a hand.) One member of the group believed that laboratory data for well-motivated versus nonmotivated individuals was available. These involved controlled experiments (actually controlled observations). The difficulty, of course, would be to correlate the observed response of normal college student volunteers to various stimuli in a laboratory with the response of an angry, emotional and irrational individual whom we are trying to motivate by the employment of these less-lethal weapons. Although it was reported that some work has been done under real-life situations (candid observation and recording), the results of this effort have not been published.

The Group was confronted with establishing an emotional state(s) for evaluations. It should be noted that the group had not addressed this question to date even though it had been asked in prior meetings. There appears perhaps a missing link in the form of a correct term or terms used when asking the question or, in fact, in answering it. Also, it appears to be the "sin of psychology" that we can say much but convey little.

Perhaps the stumbling block in establishing these emotional levels was that we did not know the emotional background or make-up of the crowd. The individual is more easily defined in terms of make-up. Constituent parameters in establishing the emotional states would be pain and suggestability (hypnosis), yet a great many people cannot be hypnotized. The element of surprise would certainly be important. One of the Group members suggested that another dimension was needed, such as blood flow or no blood flow.

It was very difficult or almost impossible to measure emotional states. The available literature is quite minimal. It was suggested that, for the purpose of our analysis, a number scale of 1-3 or 1-5 be established. Such a scale might be as follows (Table 4B):

TABLE 4B

Emotional Levels of Crowds

Emotional Level of "Mob Member"	Type of Mob Associated with Emotional State
1	Picket line for wage increase
2	Crossing picket line
3	Street gangs
4	Political extremists
5	Lynch mobs

The "trick" in making the weapon effectiveness estimates is the ability of a panel to analogize the levels above in the scenarios.

The question was asked if you could infer emotional levels of the crowd from viewing motion picture films taken of riots. In short, this was felt to be difficult because film editing involves sensationalism. Highly-motivated and highly-intelligent are good terms to describe riot members. It has been observed that riot members cannot be prodded like cattle.

Discussion continued among the Group members as to the information that was required in the conduct of evaluations. The Dispersal of a Crowd Scenario was cited as an example wherein some information is known, but more definition is needed in certain areas; e.g.,

- A large crowd is assembled for a civil disobedience.
- The group members have an act planned.
- The group has formal leadership.
- The group is gathered over a social issue.
- What is the emotional state of the crowd? (e.g., define before police arrive.)
- Can we talk about the crowd in terms of distance?

It was suggested that we, the research team, apply these added definitions to a specific clear-cut crowd, such as a group involved in a rent strike, wherein there is a grievance which may be justified (trash removal, elevator does not work, etc.). An emotional intensity level of 1 or 2 might be characteristic of this crowd.

TABLE 5B

Emotional Levels of a "Rent Strike" Crowd

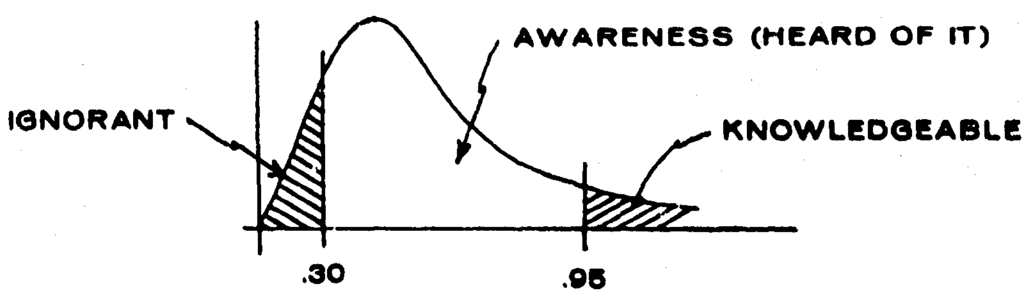
Emotional Level of Crowd	Description
0	Bored I. accidental presence II. disinterested III. annoyed
1	Calm
2	
3	
4	
5	Frenzied, furious, enraged

It was noted that the emotional state is a source of motivation but not the only one. Along these lines, we had a classical presentation of the relation between motivations and emotional state of crowds. This was outlined briefly as follows:

	Emotional State				
			Crowd Outburst		
Motivation	Pre-Mobilization	Mobilization	Passive	Active	Post-Hostility
A	a				
B					
C					
D					

[a] Data for filling in the entries for the table above are fragmented.

Using the rent strike as an example of the Dispersal of a Crowd Scenario, the Group rendered some estimates of effects given that the Stun-Bag was employed against the demonstrators in a confrontation. In this scenario it was assumed that the crowd was middle-aged, with children, and they had gathered at city hall with the purpose of settling their grievance relating to the rent strike. The subtle implication in this scenario is that when the police arrive, the crowd knows that they "mean business." Also, the weapon which will be used has a signature. It was hypothesized that the approximate distribution of consumer wisdom of the weapon's attributes would be as follows:



An order would be given for the crowd to leave. The crowd's response is:

A. Some go home

B. Some remain to deal with the order

- Some will be screaming at the police
- Some will be very quiet
- Some will talk it over with each other
- Some will be angry under these conditions

In general, the fraction of the crowd which remains will be moderately to markedly angry and shouting at the police. The emotional level may be as high as 3.

The Group was asked, "Of the people who do get hit with the Stun-Bag, how many would leave?" Percentage estimates were as follows:

90, 75, 75, 68, 75, 50.

Rounding to the nearest 10 percent, the average percentage of the people that are hit and leave is 70.

The question was then asked, "What happens to the people who observe other people being hit? i.e., of those who perceive the physiological threat, how many leave the area?" Percentage estimates were as follows:

75, 85, 50, 20, 75, 75.

Rounding to the nearest 10 percent, the average percentage of people who leave the area upon seeing other people hit is 60.

The group was asked to comment on their percentage estimates for the case where there was visible physical disruption-say a knockdown-or a severe physical change, such as getting a crushed rib. Some of the members increased their estimate by 10 percent; others more. It was finally agreed that virtually 100 percent of the people would leave if it were apparent that the police "mean business."

Desirable effects percentage estimates for the rent strike confrontation situation are summarized in Table 6B below.

The group then examined a variation of the "Crowd Dispersal" Scenario in which the emotional level would be 3-4. A Vietnam protest gathering was proposed. The typical participant was envisioned to be a college student activist. As a whole, the group would be active and "ready." When told to leave, hardly anyone would go. Spurious groups might go off for more protesting: they may gather a few blocks away for rock-throwing. Participants here are extremely susceptible to crowd influence; i.e., they will act as the crowd would like them to act. Under the conditions of a hard-core element, maybe only two to three percent will leave, because these few people never get caught up in the emotion of the crowd.

TABLE 6B

Summary of Probable Desirable Effects for Stun-Bag in Rent Strike Confrontation, Where P_{DE} = Probability of Desired Effect

(Crowd Disperses and Leaves Scene Within Five Minutes)

Crowd Members	P_{DE}
Observing hit	.60
Hit	.70
Hit or observing hit resulting in severe physical change	1.00

Of the people who stay and get hit with the Stun-Bag, it was estimated that on the average 10 percent would leave the area. This estimate is a rounded-off figure to the nearest 10 percent of the following individual estimates:

10, 10, 5, 25, 25, 10.

For the people who observe a low level of damage to persons being hit, it was agreed that a very small percentage (less than five percent) of these people would leave. The rationale was that there would be no reason to leave if the guy who gets hit does not leave. Individual estimates for this case were:

0, 1, 5, 0, 5, 0.

For the case of individuals observing others being hit at high velocity—sufficient for a knockdown—the estimates were considerably higher for probability of leaving the area. Individual percentage estimates were:

15, 50, 50, 70, 40, 25.

Averaging and rounding to the nearest 10 percent yields 40 percent.

Desirable effects percentage estimates for the Vietnam protest gathering situation are summarized in Table 7B below:

TABLE 7B

Summary of Probable Desirable Effects for
Stun-Bag in Vietnam Protest Gathering

(Dispersal of a Crownd, Scenario IV)

Crowd Members	P_{DE}
Observing hit	<.05
Hit	.10
Hit or observing hit resulting in severe physical change	.40

APPENDIX C

GENERAL MATHEMATICAL MODEL

GENERAL MATHEMATICAL MODEL

This appendix was prepared by
Mr. E. B. Shanks

Generally, the evaluation procedure begins as follows: The specific ranges of interest are obtained from the chosen scenario. The range, together with information on the muzzle velocity, projectile drag, etc., is used to determine the terminal velocity. Using the terminal velocity and other missile characteristics, such as weight, unit area density, etc., a terminal effects parameter is calculated. The physiological damage data is organized using kinetic energy as a terminal effects parameter.

Figure 1C of this appendix illustrates how the terminal effects parameter is used to enter the data bank on undesirable physiological effects. These data within a section are normally mutually exclusive. For example, in the organ section, the heart, brain, kidney, liver, spleen, genitals (and possibly the lungs) will all be characterized by distinct probability of damage, P_D, versus terminal effects parameters relations. Similarly, in the bone fracture section, the body could again be subdivided and distinct relations established for each ''bone region.''

Additional data included in the data bank are the areas, A_{ij}, associated with each effect in each section. Ideally, the individual areas should vary with the terminal effects parameters, but currently the effort was primarily to determine one area for each effect in each section.

The relative weighting of each of these individual effects due to the chance of a hit must also be established. If the dispersion of the projectile is sufficiently large such that unit presented areas of the body are equally likely, then the weighting effect is simply the value $A_{ij}/A_t \cdot P_h$ (where, A_t is the total presented body area and P_h is the probability of hitting the body).

If the dispersion is small (with respect to the area dimensions), double integration over the body area is required to obtain a proper weight for each effect. The value of P_h may be readily estimated from $\frac{A_t}{2\pi\sigma_r^2+A_t}$, where σ_r is the standard deviation of total hitting errors.

If one calls the probability of hitting an individual area (irrespective of how it is determined), P_{hij} (where i is the data bank section and j is the effect within the section), then the probability of an undesirable effect for a given section is $P_i = \sum_j P_{Dij} P_{hij}$ and the probability of at least one type of undesirable effect for a round fired from Weapon ''A'' is $P_{UE} = 1-\prod_i(1-P_i)$.

Similarly, for the probability of a desirable effect (P_{DE}), there must be a data bank representing the probability of a desirable effect given a hit ($P_{DE/h}$) as a function of weapon terminal effects. Then, depending upon the detail of the data bank and the dispersion of the impact device $P_{DE} = P_{DE/h}\, P_h$.

Final presentation of indices can be done in graphical form.

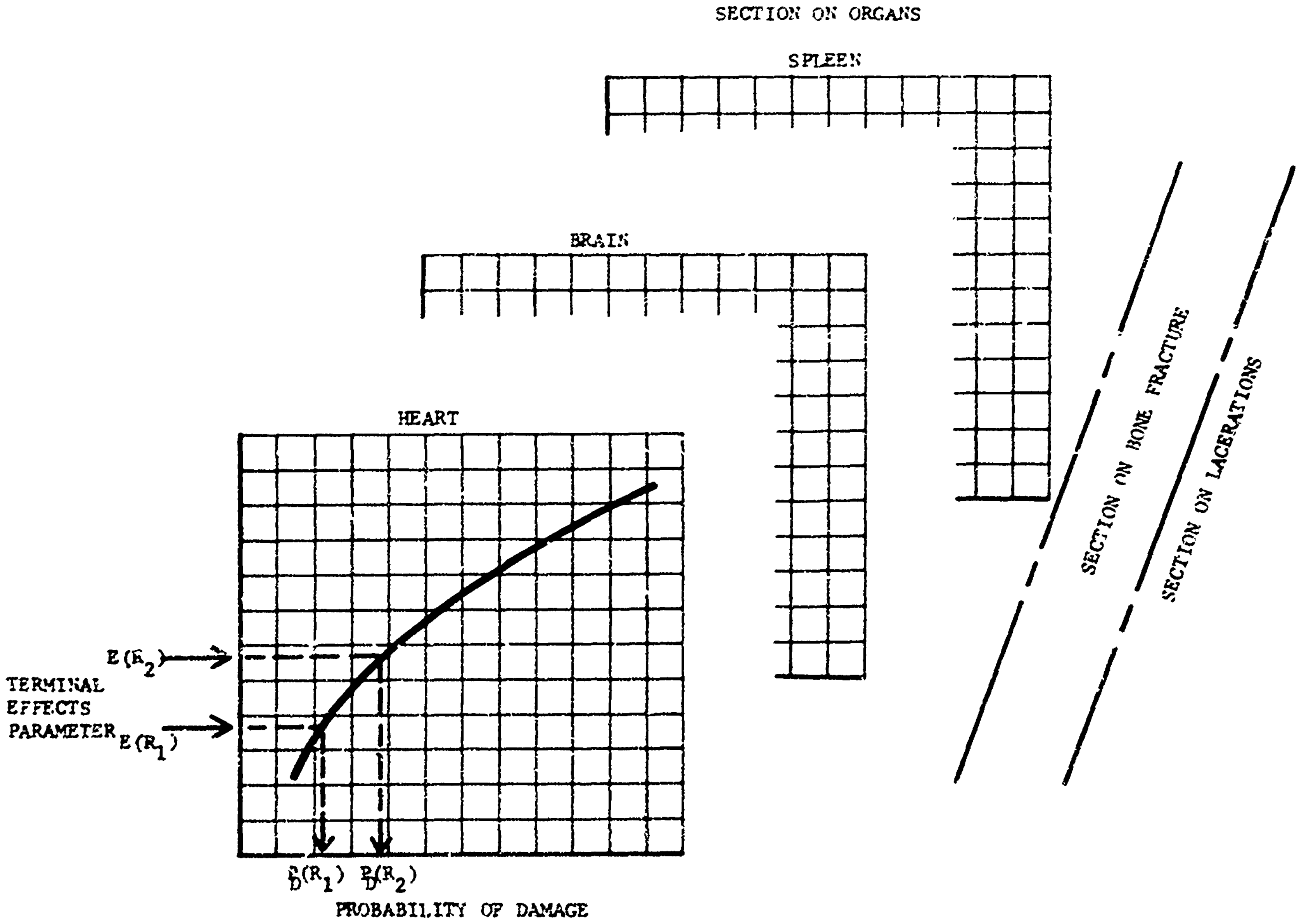


Figure 1C. Data bank utilization.

HIT PROBABILITY MODEL

The Incapacitation-Probability Program (I.P.P.) determines the probability of incapacitating one or more targets by firing one or more projectiles of a given type. The meaning of the term "incapacitation" depends on the effects desired. For example, if the weapon is lethal, then incapacitate means kill. If the weapon is less-than-lethal, then incapacitate may mean "injure slightly" or even "scare away." A less-than-lethal weapon, however, could also seriously injure or kill if a critical area such as the head is struck.

The target(s) may be one or more individuals, a group of rioters or innocent bystanders, or some combination of these.

The program is written in Fortran and can be run on an IBM 1130 computer.

A. Inputs

For each run, the program requires the following data:

1. Identity of the run,
2. Area and weight of the projectile,
3. A table of drag coefficients vs. Mach number,
4. A table of incapacitation/hit ratios vs. velocity of impact,
5. The number of projectiles fired,
6. The height from which the projectile is fired,
7. The muzzle velocity of the projectile,
8. The distance to the target(s),
9. Standard deviations of the ballistic and aim errors,
10. The coordinates of the aim point, and
11. The location and size of the target(s).

All distances are measured in feet. Weight is in pounds and standard deviations are in mils.

B. Computational Procedure

AAI has developed a trajectory program which calculates, among other things, the range and velocity of impact of a projectile for a given muzzle velocity and elevation angle. This program has been incorporated into the I.P.P. In our case, the range (i.e., distance to the target) is known, but the elevation angle θ is not known. As a result, the I.P.P. steps through values of θ until a value is found for which the range is reached. For this elevation angle, the trajectory program then computes the velocity of impact which is used to obtain the incapacitation/hit ratio by a table look-up. This value is then used in calculating the probability of incapacitation for each target.

C. Output

The program prints the input data as well as the computed elevation angle and velocity of impact. The incapacitation/hit ratio obtained by table look-up is also printed, as is the probability of incapacitation for each target. If only one projectile is fired, then the sum of these probabilities, which represents the probability that someone is incapacitated, is also printed.

D. Mathematical Techniques

Equations for the incapacitation probabilities are basically those of the National Bureau of Standards report "Table of Salvo Kill Probabilities for Square Targets." The equations used by the I.P.P. are:

(1) $$PR(i,j) = \left[f\left(\frac{a - \zeta_i}{\sigma_R\sqrt{2}/2}\right) + f\left(\frac{a + \zeta_i}{\sigma_R\sqrt{2}/2}\right)\right]\left[f\left(\frac{b - \eta_j}{\sigma_R\sqrt{2}/2}\right) + f\left(\frac{b + \eta_j}{\sigma_R\sqrt{2}/2}\right)\right],$$

(2) $$Q(i,j) = 1 - [1 - P_I \cdot PR(i,j)]^N,$$

(3) $$PA(i,j) = \left[f\left(\frac{(i+1)a/n - X_o}{\sigma_A\sqrt{2}/2}\right) - f\left(\frac{ia/n - X_o}{\sigma_A\sqrt{2}/2}\right)\right]\left[f\left(\frac{(j+1)b/n - Y_o}{\sigma_A\sqrt{2}/2}\right) - f\left(\frac{jb/n - Y_o}{\sigma_A\sqrt{2}/2}\right)\right],$$

(4) $$PSI = \sum_j \sum_i Q(i,j) \cdot PA(i,j),$$

where

$2a$ = width of target,

$2b$ = height of target,

σ_R = standard deviation of ballistic error,

σ_A = standard deviation of aim error,

N = number of steps over which the summations are made,

(X_o, Y_o) = coordinates of center of aiming distribution,

PR(i,j) = probability of hitting a target aimed at (ζ_i, η_j),

P_I = probability of incapacitation given a hit,

Q(i,j) = salvo incapacitation probability of N projectiles aimed at (ζ_i, η_j),

PA(i,j) = probability that the aim point will lie in the rectangle centered at (ζ_i, η_j).

PSI = salvo incapacitation probability

$$f(X) = \frac{1}{\sqrt{2\pi}} \int_0^X e^{-\frac{1}{2}u^2} du$$

The quantity n is computed from the formula

$$n = 5a/\sigma_R,$$

In formula (4), i ranges from IMIN TO IMAX, where

IMIN = (XAIM - DEV) • N/A,

and

IMAX = (XAIM + DEV) • N/A,

where XAIM is the x-coordinate of the aim point relative to the center of the target and DEV is three times the standard deviation of the ballistic error. Similarly, j ranges from JMIN to JMAX, where

JMIN = (YAIM - DEV) • N/A,

and

JMAX = (YAIM + DSV) • N/A.

For each i and j, ζ_i and η_j are the coordinates of the center of the rectangle whose vertexes are

$$\left(\frac{i}{n} a, \frac{j}{n} b\right), \left(\frac{i+1}{n} a, \frac{j}{n} b\right), \left(\frac{i+1}{n} a, \frac{j+1}{n} b\right) \text{ and } \left(\frac{i}{n} a, \frac{j+1}{n} b\right).$$

The function f is obtained by looking up a table of computed values of the integral.

The program can accept any number of targets. It is assumed that all targets are rectangular in shape and the same distance from the point of fire.

Each target is identified by its height, width, and coordinates of the lower left-hand corner. Thus, for example, if there are three targets each two feet wide and separated two feet apart as shown in Figure 2C, their coordinates would be (-5,0), (-1,0) and (3,0), respectively.

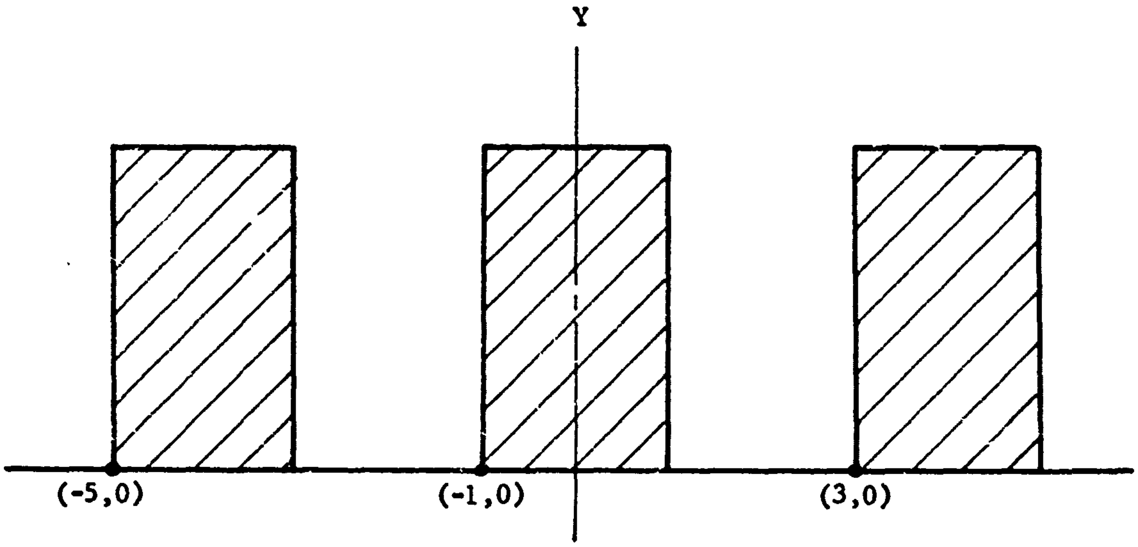


Figure 2C. Target identification, general.

As another example, consider the case of firing a less-lethal weapon at one person. If the intent is not to hurt him, then hitting him, say in the head or heart would be undesirable. To calculate the probability of such a hit, the head and heart are considered as two separate targets. If the head is assumed to be eight inches wide and begins at a height of five feet and if the heart is assumed to begin at $4\frac{1}{2}$ feet, then their coordinates are (-1/3, 5) and (0,4-1/2), respectively (Figure 3C).

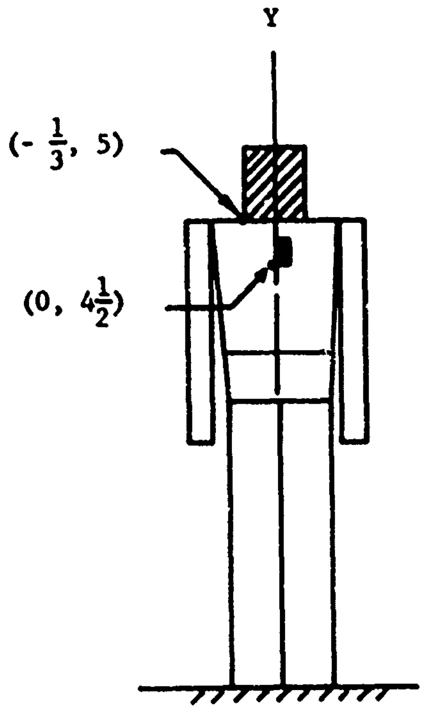


Figure 3C. Target identification, discreet elements.

Figure 4C which follows shows a flow chart of the computer program for determining incapacitation probabilities.

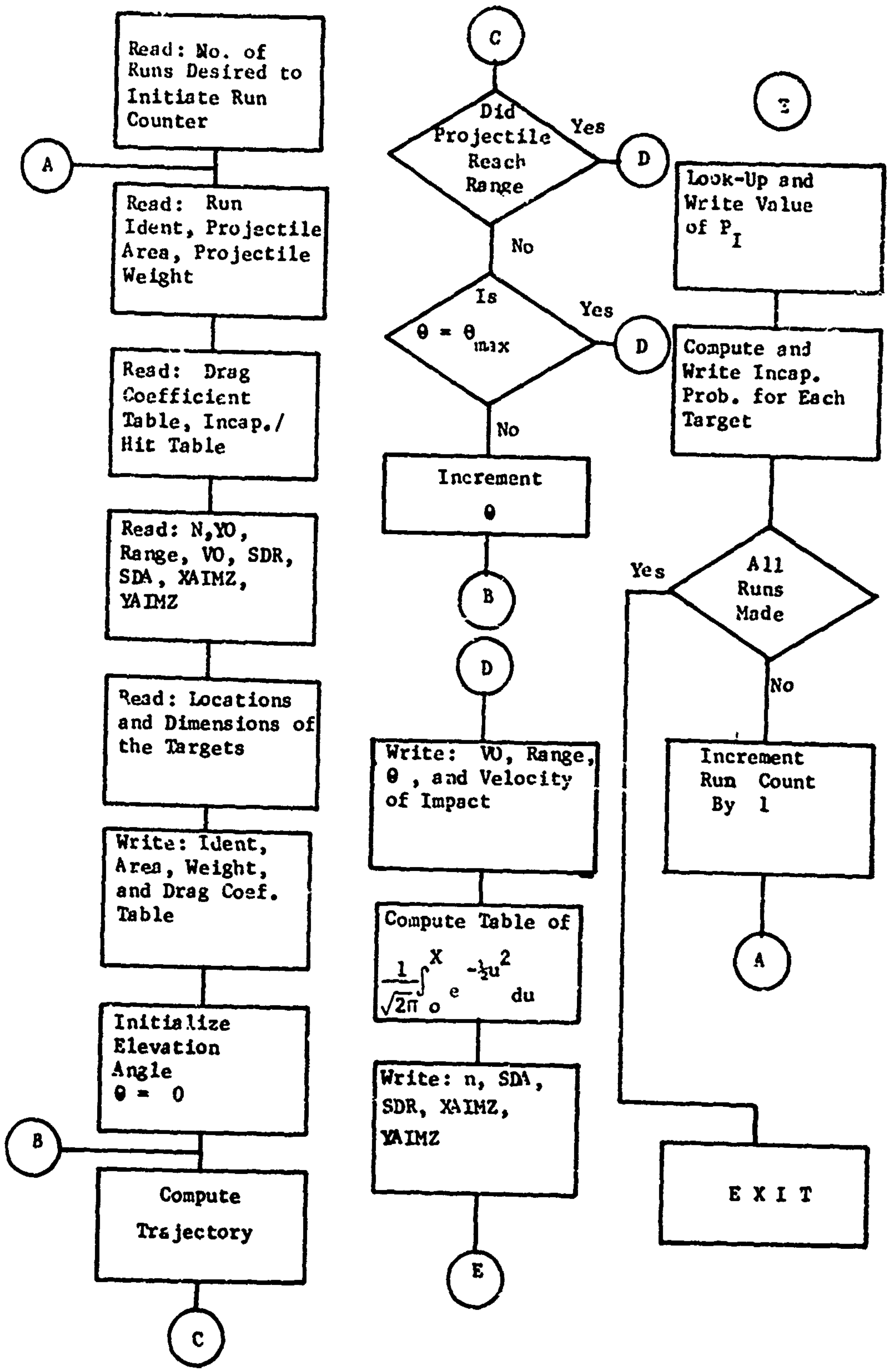


Figure 4C. Flow chart for Incapacitation Probability Program.

APPENDIX D

LITERATURE SURVEY ON BLUNT TRAUMA EFFECTS

LITERATURE SURVEY - BLUNT TRAUMA EFFECTS

This appendix was prepared by Dr. Ronald A. Williams of Battelle Memorial Institute for the US Army Land Warfare Laboratory and deals with two basic but related topics:

1. Physiological Damage Induced by Impacts with Blunt Objects

2. Mechanical and Physical Factors in Physiological Damage Induced by Impacts with Blunt Objects.

Appendices referred to have not been reproduced herein.

PHYSIOLOGICAL DAMAGE INDUCED BY IMPACTS WITH BLUNT OBJECTS

Injuries inflicted by blows from blunt instruments have been prevalent throughout the history of mankind. The club was one of the earliest weapons used for hunting or for defense against an enemy. It was quickly recognized that the most vulnerable portion of the anatomy to impact was the head, and even today protection against head injury is heavily emphasized in sports and combat. The effectiveness of impact on the head is further evidenced by the fact that even in our advanced technological age, many animal slaughtering techniques rely on stunning by a blow to the head.

Other body organs are also susceptible to trauma resulting from impacts with blunt objects, but by far the most sensitive area is the head. While many reports are available which describe blunt abdominal injury, little quantitative data was uncovered. Accordingly, this appendix deals primarily with the tolerance of the head to impact and is intended to provide quantitative information on that problem. Some less quantitative but more descriptive information pertaining to other organ damage resulting from blunt impact is also included.

The best single source of information relating to head injury may be found in a book edited by Caveness and Walker(1)[1] on the proceedings of a Head Injury Conference held in 1966. Several of the contributions to that conference are discussed in this appendix. Ward (2) defines the most common head injury, concussion, as ''the loss of unconsciousness and associated traumatic amnesia that occurs as a consequence of head trauma in the absence of visible damage to the brain.'' He further indicates that even though no morphologic damage is present, concussions can result in death.

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[1] References are listed at the end of this portion of the Appendix.

The critical parameter in head injury resulting from nonpenetrating impact is the acceleration experienced by the brain, and here one finds a fine line between the values which produce only concussion and those producing gross anatomic damage. Acceleration and deceleration result in increased intracranial pressure and mass movements of the brain. The compressive forces resulting from a blow to the head may be manifested by increased intracranial pressure, and in more severe cases, skull fracture. According to Gurdjian, et al (3), a pressure of 40 psi lasting only 0.006-second causes a moderate concussion effect in experimental animals. This work also contains a quantitative ''acceleration-time tolerance'' curve for humans. The curve indicates that based on cadaver tests, the head can withstand 42-g's for several seconds, and they found that the skull fractures with energy levels of about 400 to 600 in. lb.

Hirsch (4) has used the above information to develop a curve of the tolerance of the brain as a function of shock impulse and acceleration. This curve is invaluable in establishing parameters of a device which will inflict only minimal head injury upon impact.

Evans, et al (5), presented very useful experimental results which related energy, velocity and deceleration to skull facture. Their results indicated that the human head can tolerate, without fracture, peak impact accelerations as high as 686-g's and available kinetic energy as great as 577 foot pounds. Further, they found that the approximate energy magnitudes producing fracture ranges between 33 and 75 foot pounds and concluded that the longer the time for energy absorption the greater the magnitude of the energy that can be safely tolerated.

Several additional publications supplied valuable quantitative data on head injury as a function of mechanical variable, but it was felt that the USALWL's needs would be best satisfied by inclusion of copies rather than abstracted information. Accordingly, works by Purvis (6), von Gierke (7), and Ommaya, et al (8-11), were also sent to LWL and are available from the Defense Documentation Center. Other articles of importance were uncovered and reviewed during preparation of this appendix including nearly 100 abstracts of Government reports.

The amount and severity of internal organ damage from blunt abdominal impact has been steadily increasing for many years. These increases are attributed largely to the increase in traffic accidents and the greater speeds of travel on today's superhighways. It is estimated (12) that 50 percent of the cases of nonpenetrating abdominal injuries are caused by motor vehicle accidents, and traumatic rupture of the liver, duodenum, pancreas, spleen, and portal vein are frequently encountered. Without operative therapy most of these injuries will quickly result in the victim's death. Because of the nature of the abdominal wall, very serious injuries to underlying organs may result from blunt trauma without any external evidence. In fact, the mortality rate following blunt abdominal trauma is 20 to 30 percent higher than for penetrating abdominal injuries largely becuase the injuries are less obvious and treatment often delayed (12)

Clinical evaluation of abdominal injuries is frequently reported for various organs. Magee, et al (13), studied 42 cases of blunt traumatic rupture of the spleen; McKenzie (14) discussed similar injuries to the kidney and bladder; Asbury (15) reported on rupture of the diaphragm; and Deodhar, et al (16) reported on rupture of the duodenum.

In an experimental study, Lange, et al (17), investigated thoraco-abdominal strain resulting from sinusoidal vibrations. They found a resonance between five and 7.5 Hz and observed maximum body strain at the resonant frequency or slightly above.

Newton's laws of motion can be used to predict closely the forces, accelerations, and general behavior of the skull and brain during and immediately after a blow of a given energy level. The physical properties of most biological material are fairly well defined (18), and head dynamics can therefore be described readily mathematically in suitable equations of motion. The causes of head injury can usually be associated with the deformation of the skull, with or without fracture, or to the sudden acceleration or deceleration acting upon the head. In general, there is good correlation between theoretical predictions and experimental observations of head injuries. Accordingly, rather precise values can be assigned to the human tolerance to impacts, if the many parameters of the blow are completely described.

Blunt nonpenetrating injury to other body organs can likewise be estimated, but in general there is a considerably greater tolerance to injury than that displayed by the head. Further, injuries of both the head and other portions of the anatomy may have serious and morbid subsequent complications.

Symonds (19) discusses the possibility of increased susceptibility to head injury after concussion, and Sewitt (20) warns of the potential danger of fatembolism after injuries of many kinds. These facts and subject-to-subject variability in response tend to complicate the problem of estimating the tolerance to various impact.

MECHANICAL AND PHYSICAL FACTORS IN PHYSIOLOGICAL DAMAGE INDUCED BY IMPACTS WITH BLUNT OBJECTS

As stated in the previous section of this appendix, Newton's laws of motion can be used to predict relatively closely the forces, accelerations, and general behaivor of the skull and brain during and immediately after a blow of a given energy level. Using suitable scaling techniques and the results of experimental studies which have been carried out on animal subjects, attempts can be made at estimating the degree of physiological damage in humans subjected to similar blows. An analysis of this sort, however, requires a very detailed description of the experiment to be undertaken. That is, the myriad of parameters describing the physical characteristics of both the impacting body and the body to be impacted must be accurately established. Further, if reasonable correlation is to be obtained from previously performed studies, the point of impact, degree of support, impact angles, ranges, etc., must be compatible. Accordingly, any attempts at mathematical modeling and estimation of potential for inflicting physiological damage with a given device must be obtained from an ideal model having a well-defined protocol.

This secion of this appendix is to provide information to describe some of the mathematical relationships which are useful in an analysis of this sort as well as to supply some quantitative information on the mechanical properties of biological materials. The mathematical relationships describing the collision process are not unlike those presented in a number of physics or mechanics tests, and these relationships will not be reviewed in depth.

As was indicated in the previous section, the best single reference on the area of head injury may be found in a book edited by Caveness and Walker (1). In that work, a paper by Goldsmith (21) provides a comprehensive review of the qualitative and quantitative aspects of the collision processes involved in head injuries (including a general mathematical review).

Goldsmith correctly indicates that the mechanics of head injury may be broken into three broad physical processes each of which is described by a separate mathematical analysis. These processes are impact, impulsive loading, and static or quasistatic loading. It must be remembered, however, that while all of these processes may be readily defined mathematically, the actual collision of a less-than-lethal weapon or projectile with any portion of the anatomy represents a complex combination of several of the processes. Accordingly, estimates of the potential for a device to inflict damage, which are derived from theoretical calculations and well-controlled experimental results, may deviate widely from the ''real life'' situation.

In the impact process, two bodies having initial velocities and fixed masses collide. The results of the collision are dependent on not only their initial conditions (velocities, masses, angles) but also upon the properties of each of the materials. Upon impact, stress waves are transmitted throughout the mass of each body and can cause very serious structural damage in addition to that inflicted at the impact point. The damage which can be caused by the pressure and cavitation resulting from these waves is discussed in an excellent article by Unterharnscheidt and Sellier (22) describing closed brain injuries.

One area of concern in quantifying the injury potential of a less-than-lethal device involves the applied stress and resulting strain. That is, what is the force per unit area (stress) and the resulting distortion of the material in question. These terms may be more clearly defined as:

$$\sigma = \frac{F}{A_o},$$

where σ = stress, F = applied force, and A_o =area over which the original force was applied, and

$$\epsilon = \frac{\Delta L}{L_o},$$

where ϵ = strain, ΔL = change in length, and L_o = original length. (Similar relationships may be used to describe compaction, or angular distortion, depending on the type of load applied.)

The mechanical properties of nearly all biological materials are available in a book by Yamada (23). This comprehensive source not only provides good quantitative data and information on measurement techniques but also provides information regarding changes in the properties of biological material as a function of age. Review of these data shows that the strength of fetal materials may be dramatically lower than that of adult materials. Therefore, the possibility of a less-than-lethal weapon striking a pregnant woman and inflicting serious damage to the fetus presents an additional potentially hazardous situation. Other tables of properties included in this reference are:

1. Tensile properites of the human stomach

2. Shearing properties of human cerebral dura mater

3. Tensile properties of human skin

4. Tensile properties of human sclera

5. Stress-strain curves for human limb bones

6. Tensile properties of the human fetus.

Perhaps the most interesting of these data is that which compares the tensile strength of adult human organs and tissues. This compilation provides a quick reference to the varying sensitivity of the components of human anatomy.

One of the major areas of concern in this work involves the area of contact. That is, what are the effects on the biological system at the impact site - penetration? perforation? fracturing? fragmentation? etc. In virtually all collisions, there is a degree of penetration involved, and the degree depends on geometrical shape and bulk properties of the materials involved. Relationships have been developed to provide mathematical expressions relating force and indentation (see Goldsmith (2), Equations 18, 19, 20, and 22).

A recent source of information which provides additional information on the general topic of impact and physiological damage resulted from the Aerospace Medical Panel Specialists Meeting held in Oporto, Portugal, June 23-26, 1971 (24). In this work Ommaya and Hirsch (25) present experimental data obtained from primates which quantify head injury as a function of impact. They found that a combination of head rotation and skull distortion are most injurious for brain damage during both indirect and direct impact. More importantly, they indicate that short-duration pure translational or linear acceleration of the head is not injurious to the brain, and they also provide a scaling scheme to predict injury thresholds for man.

An involved process for modeling the mechanical response to various environmental forces is described by von Gierke (26). These models include whole-body kinematics as well as subsystem models, and a discussion of an attempt at scaling to man is also included.

Mathematical models of impacts with biological systems can be constructed with varying degrees of sophistication and detail. These models in the most elegant state can quite accurately predict the effects of an impact if the many parameters of the blow are rigidly defined and controlled in experimental setups. Validation of these models, however, must be performed using animal subjects for data collection. Accordingly, a scaling procedure must be used to estimate the human response to a similar blow. While these types of analyses can and have been carried out by some investigators, including those on this project, extrapolation to human response under uncontrolled conditions is fraught with complications. However, experimental evaluation of the undesirable effectiveness of a given device should be based on such a comprehensive review of techniques and problem areas within each as to insure that the approach used will fairly portray its characteristics.

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[2] This and other related works was discussed with Dr. Ommaya at the National Institute of Health.

APPENDIX E

PHYSIOLOGICAL DAMAGE CRITERIA

PHYSIOLOGICAL DAMAGE CRITERIA

This appendix was prepared from the works generated by the Medical Group. A set of physiologically-based damage levels for the vital organs and body regions of interest was developed by a consensus of the Group. These defined levels were used and revised during the course of this study. It was the intent in developing these criteria to set a base or standard upon which medical assessments regarding a ''score'' for severity could be rendered given some degree of tissue damage inflicted by the blunt-trauma producing of purported less lethal items. Moreover, the criteria was formulated in such a way as to permit individuals trained in the medical sciences; i.e., pathology, etc., an opportunity to agree, given an opportunity for discussion or defense, on the damage level to be assigned to an observed amount of tissue damage in evidence on post-mortem analysis. In all ratings a 0 (zero) indicates no evidence of damage.

The criteria developed were as follows:

Criteria for the Evaluation of Damage Resulting from Blunt Trauma

I. Skin, Subcutaneous Tissue and Muscle

Grade	Criteria
1	Superficial blemish or signature in skin
2	Grade 1 plus subcutaneous hemorrhage and/or edema
3	Grades 1 and 2 plus subcutaneous and/or intramuscular hematoma
4	Grades 1, 2 and 3 plus laceration of fascia, muscle and/or fat
5	Grades 1, 2, 3, and 4 plus laceration of skin

II. Kidney

Grade	Criteria
1	Superficial contusion with subcapsular hemorrhage and/or perirenal hemorrhage
2	Grade 1 plus superficial laceration of cortex not penetrating more than 2-3 mm
3	Grade 1 plus simple laceration of kidney penetrating to pelvis
4	Grades 1, 2 and 3 plus multiple lacerations
5	Grades 1, 2, 3 and 4 plus rupture of capsule and destruction of kidneys

III. Liver

Grade	Criteria
1	Subcapsular hematoma with no visible fracture of liver
2	Grade 1 plus simple fracture of liver less than 1 cm deep and/or less than 5 cm long
3	Grades 1 and 2 plus rupture of capsule and fracture of liver 1-2 cm deep and/or less than 10 cm long
4	Grades 1, 2 and 3 plus fracture greater than 2 cm and/or greater than 10 cm long
5	Fragmentation of liver

IV. Spleen

1	Subcapsular hematoma less than 5 cm in diameter
2	Subcapsular hematoma greater than 5 cm in diameter and/or minor intrasplenic hemorrhage
3	Grades 1 and 2 plus rupture of capsule less than 1 cm long
4	Grades 1 and 2 plus capsular rupture greater than 1 cm long
5	Disruption of spleen, laceration of substances of spleen-torn capsule

V. Lung

1	Small contusion of lung with subpleural hemorrhage less than 5 cm in diameter and extending less than 1 cm into lung
2	Subpleural hemorrhage greater than 5 cm in diameter and/or muiltiple hemorrhages less than 5 cm in diameter
3	Grades 1 or 2 with pleural rupture and pneumothorax
4	Grade 3 with bilateral pneumothorax
5	Deep tears in lung parenchyma with hemopneumothorax

VI. Other Viscera

1	Less than 1 cm subserosal hemorrhage
2	Greater than 1 cm subserosal hemorrhage
3	Grade 2 plus serosal laceration and/or mesenteric lacerations

VI. Other Viscera (continued)

Grade	Criteria
4	Single rupture of viscera and/or diaphragm
5	Multiple rupture of one or more viscera

VII. Bone

Grade	Criteria
1	Periosteal hemorrhage without visible fracture
2	Simple fracture with no displacement
3	Fracture with lateral displacement without pleural perforation (rib)
4	Grade 3 plus perforation of pleura (rib) or multiple simple fractures or compound fracture of long bone
5	Fragmentation of bone

VIII. Head

Grade	Criteria
1	Linear fracture of skull and/or minor epidural or subdural hemorrhage and/or contusion of brain less than 2 mm in diameter
2	Grade 1 plus subcritical intracranial hemorrhage[1]
3	Depressed fractures of skull with subcritical intracranial hemorrhage and/or limited brain contusion
4	Critical intracranial hemorrhage and/or multiple linear or depressed fractures of skull
5	Massive intracranial hemorrhage with extensive laceration and contusion of brain-immediate death or death prior to animal sacrifice

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[1] Critical intracranial hemorrhage is defined by that volume of accumulated blood required to produce coma due to increased intracranial pressure.

IX. Heart- Three types of grading were considered for the heart; viz.,

PD- (physical damage). This is considered in the same manner as for the other organs and body regions.

CD- (Rhythm and conduction disturbances)

It is well documented that nonpenetrating precordial chest injuries in experimental animals may cause rhythm and conduction disturbances, specifically A.V. block, intraventricular conduction disturbances and extrasystoles.

MI- (Myocardial Injury)

In man, chest trauma is often followed by ST elevation and later pointed inversion of T. Such changes generally are not accompanied by any changes of the QRS complex and are probably due to direct mechanical injury of the subepicardial muscle layers. In other cases deep Q waves are present in addition to the ST and T changes. In such cases traumatic injury of a coronary artery may be found. Infarction may also be found without thrombosis of a coronary artery. If the impact occurs in systole, the myocardium may become injured by stretching at its thinnest point. Less severe injuries may show only depression of ST and T.

Thus, the grading system for the heart is:

PD

1. Epicardial and/or myocardial hemorrhages 2 cm or less in diameter.

2. Epicardial and/or myocardial hemorrhages greater than 2 cm in diameter.

3. Myocardial necrosis less than 2 cm in diameter.

4. Myocardial necrosis greater than 2 cm in diameter.

5. Rupture of the heart.

CD

1. Transient conduction or rhythm changes lasting 10 seconds or less.

2. Electrocardiographic conduction or rhythm changes lasting longer than 10 seconds, but less than 1 minute.

3. Electrocardiographic conduction or rhythm changes lasting longer than 1 minute, but survival for 24 hours.

4. Electrocardiographic changes indicating fibrillation, other marked rhythm changes, or electrical conduction changes severe enough to cause death.

MI

1. Transient ST depression or elevation suggesting relatively mild and reversible myocardial injury.

2. Protracted ST depression followed by T-wave inversion suggesting more severe subendocardial injury possibly accompanied by subendocardial necrosis.

3. Protracted ST elevation followed by T-wave inversion suggesting acute subapicardial injury and probably some degree of subendocardial necrosis.

4. Development of abnormal Q-waves with ST changes suggesting transmural necrosis or infarction; i.e., major heart damage which might well cause death and would be expected to leave permanent residual damage.

APPENDIX F

QUANTIFYING PAIN

QUANTIFYING PAIN

BY Dr. R.A. Williams
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INTRODUCTION

Quantitative measurement of pain is a very complex and difficult task since it is basically a problem of trying to quantify a subject response. Its very definition varies even among scientists working in the broad area of pain. The biologist sees pain as a sensory signal that warns the body of an injury threatening stimulus; the philosopher sees pain as an emotional process having a moralizing influence; to the sociologist pain is a mechanism which can be used as a threat to aid the learning process; the psychologist is interested in the perception and modification of pain; to the physician pain is a valuable tool to aid in his diagnosis. Webster defines pain as "the sensations one feels when hurt mentally or physically; opposed to pleasure; a sensation of hurting or strong discomfort in some part of the body caused by an injury, disease, or functional disorder and transmitted through the nervous system."

On a more scientific approach, it would appear that there are three main groups of pain receptors - mechanoreceptors, thermoreceptors, and noci-receptors, and accordingly painful sensations may be evoked by many kinds of stimuli, i.e., thermal, electrical, mechanical, and chemical. Individual responses to a stimulus and its resulting injury may cover very wide ranges. In addition, certain parts of the body are more sensitive to pain than others; e.g., a very minute particle striking the eye causes instant pain which may be further intensified by the fear of damage to the eye. Further, it appears that superficial wounds are more painful than deep ones; one study shows that bullet wounds are generally relatively painless.[27] Internal pain, on the other hand, has a differing effect on the body. The solid organs, like the kidney and liver, are relatively insensitive, while the tubular organs (ureter, bladder, stomach, intestines, and blood vessels) respond dramatically to stretching, distortion, and inflammation, but do not respond painfully to other stimuli. Muscles do not have the sensitive pain receptors associated with the skin, but when the products of muscular activity accumulate, severe pain can result.

The psychological aspects of pain probably contribute most dramatically to the problems associated with pain quantification. Rage, enthusiasm, and stress are very effective anesthetics as is evidenced by the lack of pain experienced by many injured people during anger, on a football field, in battle, or during automobile crashes. Individual variation in response to similar injuries is also widely different, and variations have even been attributed to cultural differences in addition to age, sex, race, skin temperature, anxiety and fear, training, bias, suggestion, and emotion. Pain thresholds can be raised to nearly twice control values by a loud noise, autosuggestion, hypnosis or distraction.

It has been said that to describe pain solely in terms of intensity is like specifying the visual world in terms of light flux only, without regard to pattern, color, texture, and the many other dimensions of visual experience.[9] Pain then appears to be a multidimensional space comprising several sensory and affective dimensions.

MECHANICAL STIMULATION AND RESULTING PAIN

The primary interest in this search was in the pain generated by experimental mechanical stimulation and, in particular, the relationship between pressure and pain and impact and pain. Accordingly, studies employing other stimuli were only briefly searched and usually abstracts were reviewed for these cases. The predominant stimuli employed in most pain quantification work appears to be thermal, electrical, or chemical. Some few utilize mechanical pressure, but studies of pain resulting from impact were not uncovered.

Because the skin is readily accessible and has a large number of receptor organs, it has been used in experimental work to a much greater degree than internal organs. Some workers [3] feel that tissue damage must be incurred before a painful sensation is perceived but others do not concur with this concept. Further, the sensations perceived are the result of stimulation of the brain cortex by nervous impulses sent by skin temperature and skin moisture content.

Von Frey, a German scientist of the late 1800's, appears to have been the first to attempt to quantify pain by using various sizes of horse hair attached to a lever and weight system.[50] Seevers and Pfeiffer [43] used pressure stimuli on the eyelid to quantify pain while studying drug effects and found wide subject variability for pain thresholds.

According to Davenport,[28] pressure pain thresholds have generally been used to indicate the emotional state of the individual rather than his sensory physiology. Also, he feels that the complex structural nature of the frequently used site (the forehead) for pressure-pain studies is not conducive to obtaining good quantitative information.

Allen, et al.,[22] also point out that experimentally induced pain produced by pressure on the periosteum through the skin has largely utilized the forehead and tibia with uncertain accuracy.

In a discussion of experimental pain versus pathological pain and the psychic reaction component, Beecher[50] discusses material which may be very important to the development of a "nonlethal" weapon for riot control. He states with extensive references that "there is no simple, direct relationship between the wound per se and pain experience. The pain is in very large part determined by other factors, and of great importance here is the significance of the wound, i.e., reaction to the wound." This conclusion was based largely on the reaction of soldiers in battle, as opposed to civilian patients undergoing major surgery.[24] Further, "emotion can block pain; that is common experience. It is difficult to understand how emotion can affect the basic pain apparatus other than by affecting the reaction to the original stimulus." Accordingly, the reaction to such a "nonlethal" weapon under actual riot conditions may be markedly different than that exhibited under experimental conditions.

CONCLUSIONS

The theme which must emerge from a review of the literature on pain is that there is no simple relationship between stimulus and subjective response. Tremendous variation in pain thresholds is found from individual to individual and from one body location to another, even when seemingly identical stimuli are utilized. Without clearly defining what portion of the body is to be considered or the general information about the stimulus, it is difficult to give even "ball park" quantitative numbers for pain thresholds. It would appear that the best approach to determining effects of a given unique stimulus would be to undertake a well-controlled experimental evaluation of the device. Even after completion of this evaluation, however, it should be remembered that the psychological aspects of pain may generate markedly different responses to the stimulus under the uncontrolled and emotional conditions during a riot.

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APPENDIX G

PAIN THRESHOLD EXPERIMENTS

PAIN THRESHOLD EXPERIMENTS

This appendix reports results of the Land Warfare Laboratory (LWL) pain, threshold experiments.

LWL conducted a limited series of tests in an effort to determine threshold pain for impacting missiles. The objectives of these tests were far more modest than most experimental pain investigations, although test procedures were much the same.

The primary objective was to determine if crude estimates of threshold would be of any value in determining whether pain levels were substantially below damage (or hazards) levels for specific missile types.

There were a total of eight different subjects tested on five different days with a total of 639 impacts. Three different missiles were tested having the characteristics given below:

1. 1-inch rubber sphere-.025 lbs.

2. 2-inch rubber sphere-.1[illegible]2 lbs.

3. 2.75-inch circular "bean bag"-.336 lbs.

A preliminary test was conducted on the first day using four subjects to establish the approximate threshold velocities, appropriate procedures, body areas to be tested and the validity of the threshold of pain definition in terms of consistency. The basic procedure used throughout the tests was to drop the missile from fixed heights and record the response of the subject under the explanation of pain threshold noted above. That is, as an individual is subjected to a graduation of pressure taps, if the intensity of the taps increases and the sensation changes from an innocuous pressure to a feeling of discomfort, then this feeling is called pain. For an individual pressure tap, the subject should make a judgment whether or not there has been any discomfort resulting from the impact.

Using this definition of threshold pain, experiments were conducted on four additional days, the results of which are given in the following Table:

TABLE 1G

Results of Pain Threshold Tests

Item	Target	Estimated Mean Pain Threshold	Estimated Upper Bounds
1-inch rubber sphere(5 subjects)	Forearm	17 fps	23 fps
	Shin	18 fps	23 fps
2-inch rubber sphere(4 subjects)	Forearm	10 fps	13 fps
	Shin	10 fps	13 fps
2.75-inch bean sphere(3 subjects)	Forearm	12 fps	14 fps
	Shin	14 fps	16 fps

The estimated pain threshold was calculated by accumulating the number of "pain" and "no pain" calls at each height and making a linear estimate of that height which would give 50% calls of "pain." The height was then converted to velocity using the formula:

$$v^2 = 2g_n h,$$

Where, v= velocity

g_n = acceleration due to gravity

h = height

The estimated upper bound was determined by taking that height for which all but one subject reported greater than 50% pain response and converting that height to a velocity.

The eight subjects were adult males ranging in age from 19 to 45 years. Six of the eight subjects gave extremely consistent results. One of the eight, the only active athlete, gave consistently lower estimates of pain thereshold. At the other extreme, one of the subjects gave consistently higher estimates of pain threshold. This latter subject was the shortest in height and lightest in weight of all the subjects and a former athlete.

It should be noted that after the preliminary test of the first day, all experimentation was single/blind. That is, the subjects did not know at what height the missile would be dropped. Also, the experimenters did not reveal until after the test that they were using a probing technique.

Although the number of subjects involved was limited and the cross-section of subjects was limited to adult males, it is felt that the experiments provided a reasonable basis for estimating threshold pain resulting from impact and the objectives of the experiments were met. Incidentally, the pain threshold values were much lower than anticipated. Initially, the experimenters were searching for a facility which would provide heights up to 100 feet, whereas the test's actual drop heights were limited to eight feet for the 1-inch rubber spheres and four feet for the 2-inch rubber sphere and the bean bag.

APPENDIX H

TIME/FUNCTION-LOSS RELATIONSHIPS

TIME/FUNCTION-LOSS RELATIONSHIPS

This Appendix was prepared by:
Mr. E. B. Shanks

Time/Function-Loss Relations

The primary control force objective in imposing some noxious environment[1] on a target individual is to alter the behavior of the individual in some desired manner. Unfortunately, for the control forces, there is little they can do to produce a desired behavior pattern in an individual other than inflict discomfort (twist the arm, etc.) or intimidate the individual. Hence, in many cases the general objective of control forces is to reduce the ability of the individual to act by inducing a loss of his coordinative functions.

In military activity, weapons are designed to induce a loss of function in the enemy soldiers and equipment. In order to illustrate the importance of loss of function versus time, a scale of graduated reduction in capability to function is given as the ordinate in Figure 1H. From the military viewpoint, the objective of three different enemy stress situations[2] are plotted as regions in Figure 1H. That is, in the standard 30-second defense situation, the objective is to incapacitate to a degree within 30 seconds so that a soldier cannot function with his weapon, where the soldier in the defense posture need not move about to perform his mission of defense. In the five-minute assault situation, the soldier must be able to move about: hence, the loss of function required to incapacitate the soldier in this stress mode is less than for the 30-second defense mode. It is assumed in the 24-hour reserve situation that the soldier has no critical duties to perform; but the relatively greater accessibility of medical facilities, together with the absence of a key mission at the time of wounding, will tend to make him seek medical aid. Hence, he becomes a casualty with less loss of function than occurs in the 30-second defense and five-minute assault situations. The length of time that the wound affects the function capability of the soldier is generally not an overwhelming concern to military weapon designer, although this factor has been treated by them to some extent. The important point is that for military activity there is a simple, one-region, stress-situation-oriented criterion for weapon wounding effects, and there is little or no[3] concern for the well-being of the enemy soldiers.

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[1]Although the term "noxious environment" may seem pedantic, it is desirable to choose a phrase which includes all techniques of control, such as guns, gas, nightsticks, handcuffs, etc.

[2]"Stress Situations" is used here in lieu of scenarios; the military stress situation given are standard scenarios which describe in general military situations suggested by the titles.

[3]Obviously, nations have tried to limit the deleterious effects of war by observing the guidelines of the Geneva Convention. Nonetheless, weapons designers are not generally concerned with the well-being of enemy soldiers if the rules of the Geneva Convention are not violated.

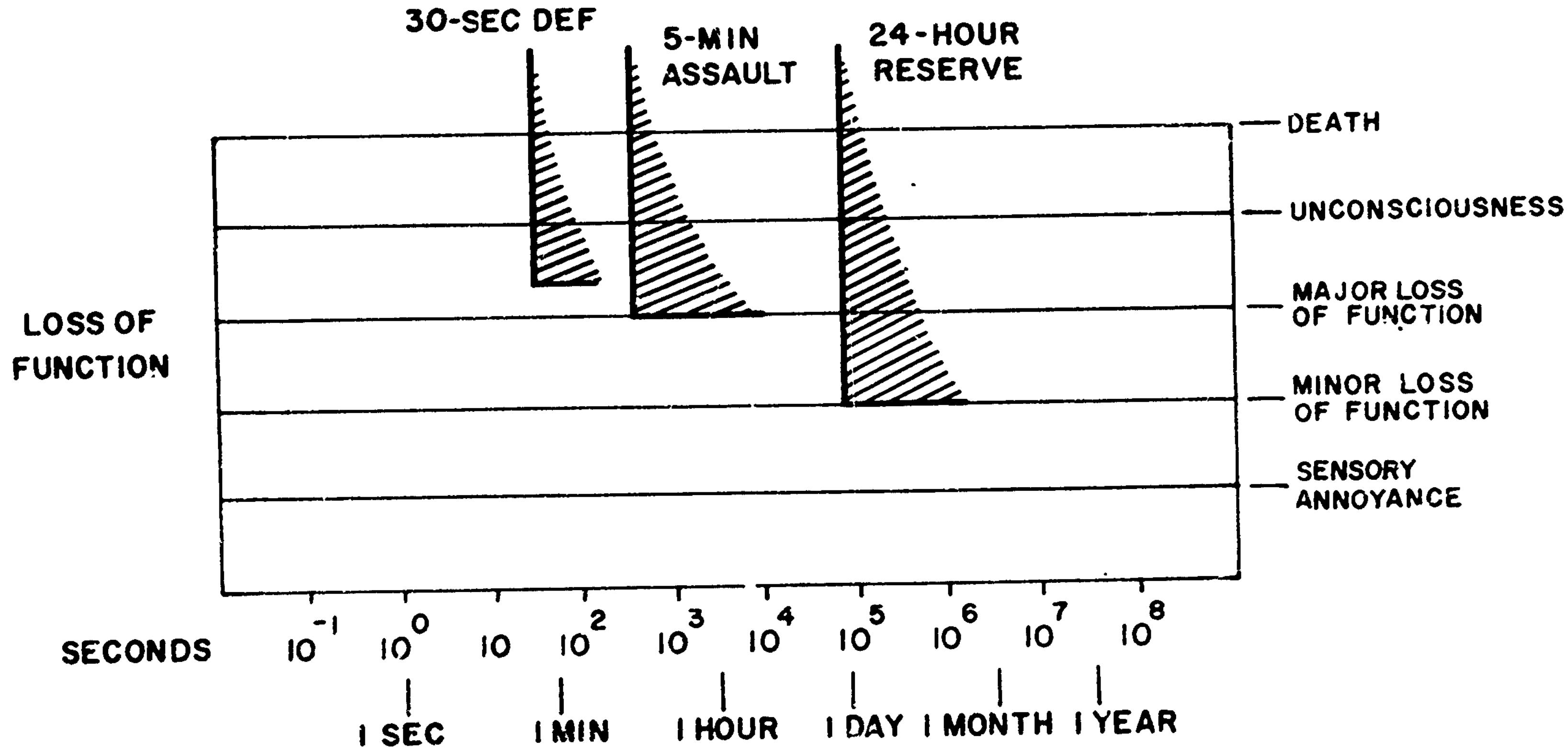

Figure 1H. Incapacitation criteria.

Alternately, the applicability and/or suitability of less lethal weapons is primarily based on two regions, desirable and undesirable, where the effects of the weapon should occur within the former region and the latter region should be avoided. Figure 2H presents the undesirable region for the 24-hour criterion used in the assessment of the probability of undesirable effects in this evaluation. Obviously, if death occurs at any time, it is an undesirable effect. The line at one day is carried down slightly below the minor loss of function level and represents an approximation of the minimum loss of function which will prevent an individual from performing normal duties within 24 hours after being hit or exposed to a less lethal device. The gradual tailing-off toward zero loss of function over a long period represents an estimate of the willingness to accept minor aches and pains over long periods provided such annoyances tend to disappear.

Both desirable regions and undesirable regions are given in Figure 3H. Several scenario concepts are presented with the locations of the bounds of the desirable regions illustrated. In the case of the felon with hostage, the onset time (left vertical line) should at a minimum represent the reaction time of the felon, since it is assumed that the felon will do harm to the hostage if he (the felon) is attacked, or at least is aware that he has been attacked. There is an upper bound, just short of death, because whatever is used against the felon may also affect the hostage. The lower bound to the region is just short of unconsciousness to indicate that it is desirable to completely neutralize the felon. The vertical line to the right indicates a minimum time of a minute or so that the felon should be incapacitated to permit his apprehension. The undesirable region in this case may apply primarily to the hostage, depending upon the policy of the particular control forces involved.

In the case of the desirable region for the crowd dispersal scenario, an entirely different set of bounds are appropriate. There is no extreme urgency for an onset of effect; therefore, the left-hand bound of the region at somewhat less than ten seconds represents a nominal or perhaps arbitrary requirement for onset of effects. The slanted line closes off the region, indicating that extensive loss of function will interfere with the ability of the targeted subjects to disperse as desired. From the point of view of the control forces, an extended period of hours in which the targeted subjects cannot move is undesirable, but the undesirable region of Figure 2H (and also Figure 3H is based upon what is undesirable from the point of view of the targeted individual(s). The dark region within the triangle represents some envisioned minimum time and level of effect which will induce the individual to disperse.

It should be noted that the logarithmic scale of time in Figure 2H and 3H was used as a convenience to illustrate the importance of relatively rapid onset and duration of desirable effects in the same presentation with the longer-term undesirable effects. This scale presents a minor problem because time can represent various things; i.e., time after impact or exposure, time after activation of the device, as well as the duration of certain key events, such as the desired time period that an individual is incapacitated. However, the log-scale also eliminates some difficulties in that boundaries toward the right of a region are virtually independent of

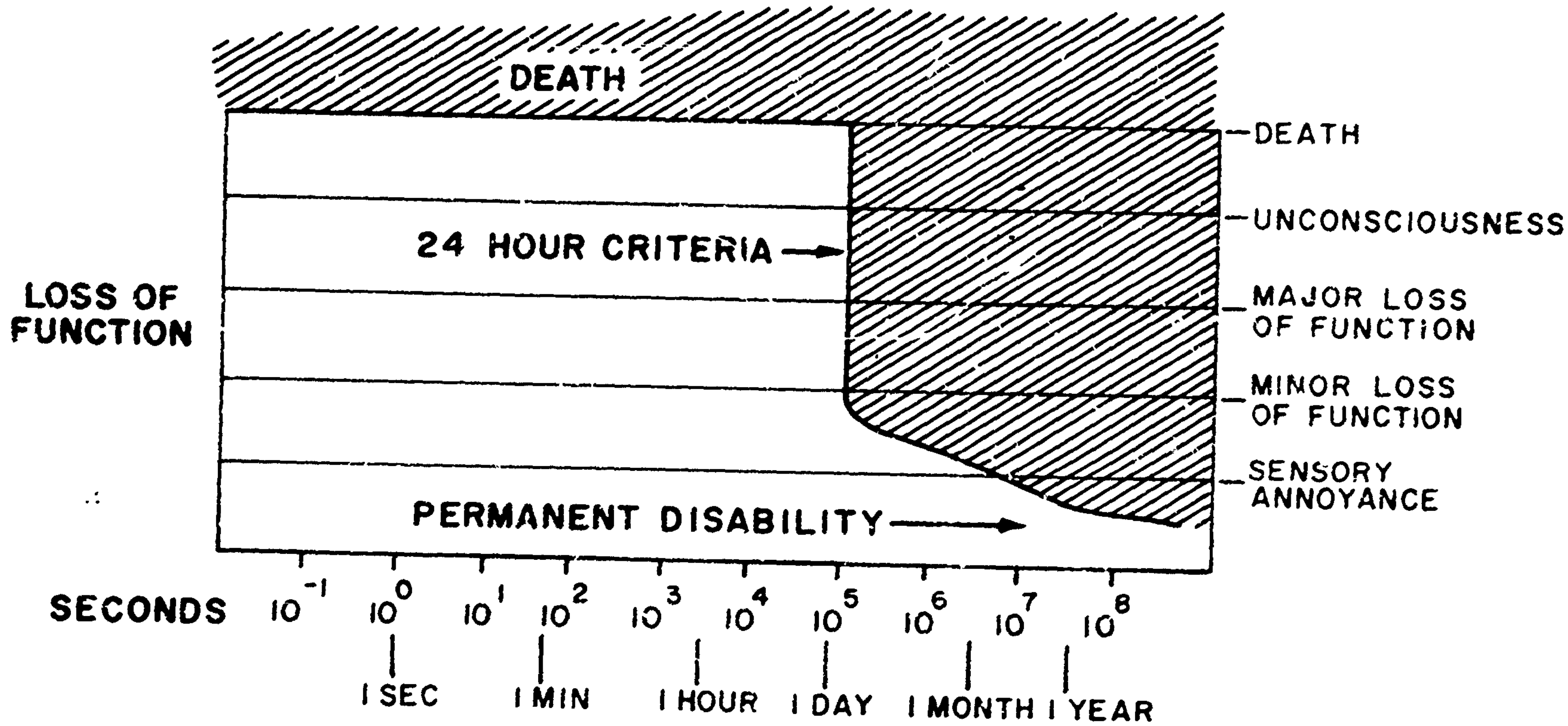

Figure 2H. The undesirable effects criteria on the function-loss/time plane.

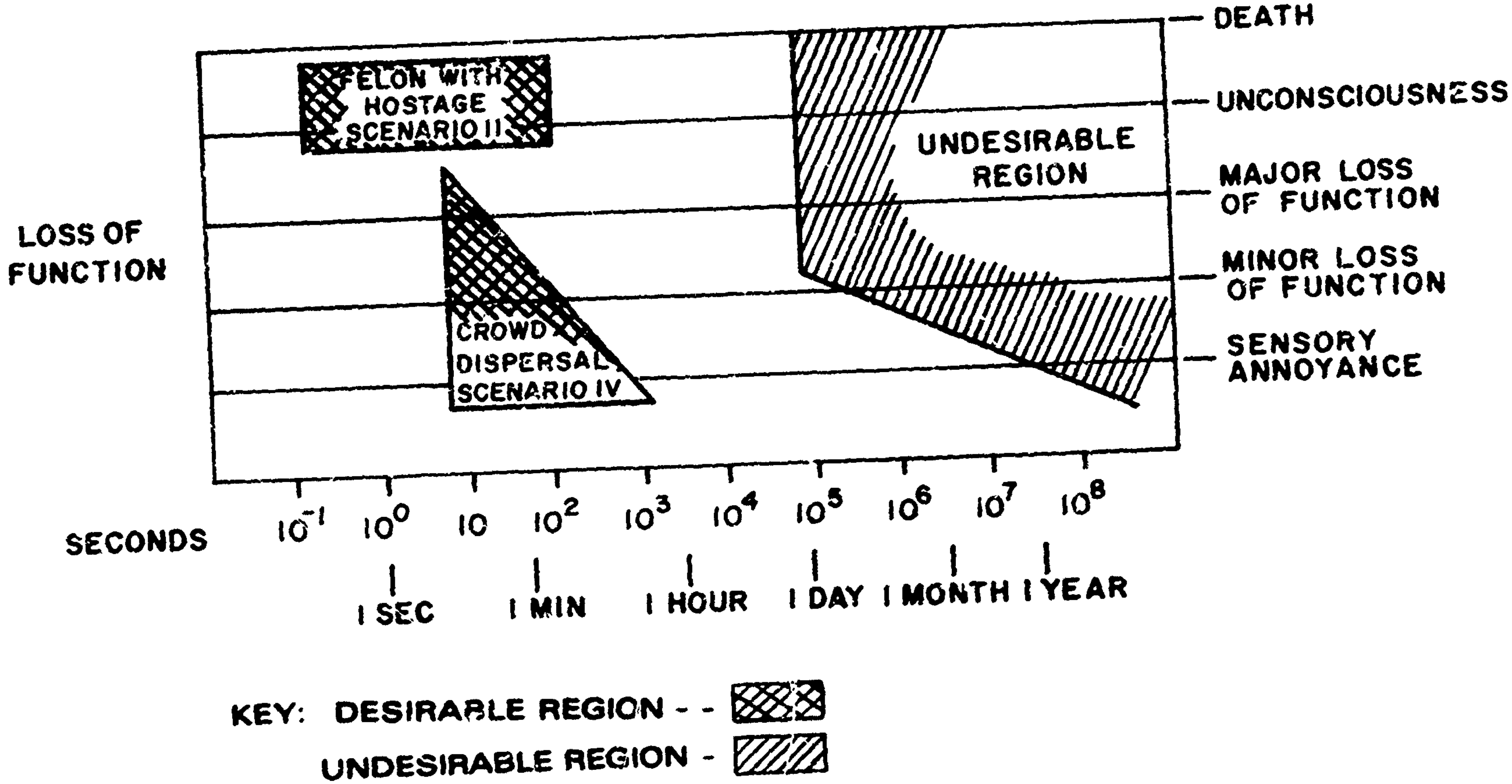

Figure 3H. Desirable and undesirable time-effects regions for two given scenarios.

the left side of the region. For example, whether it takes 10 or 20 seconds for the onset of effects will result in very little difference in the time for the minimum period that the effects should be incapacitating.

But most importantly, it is desirable that the function-loss/time plots present some of the basic concepts of less lethal weapons evaluations in a clearer perspective. The complete utilization of the time plot is made when the incapacitation histories (or function-loss histories) are plotted for different types of less lethal weapons effects. Since specific data[4] was not available at the time this report was written, Figure 4H presents a hypothetical example of the incapacitation history of an individual with a chest wound. The division of the chest wound into a critical and non-critical history is arbitrary. However, the inferred difference is that a critical chest wound can be counted on to give complete incapacitation within a few seconds to minutes; while noncritical chest wounds, without treatment, could take hours or even days before there is a major loss of function.

If one assumes that the hypothetical chest wound history has nominal accuracy, then it is easy to understand why bullet and fragment wounds are militarily useful. That is, if the chest wound history (Figure 4H is overlayed on 1H the military incapacitation criteria), it is noted that chest wounds tend to meet these criteria.

Alternatively, if the chest wound data is overlayed on Figure 3H then there is some evidence that chest wounds tend to violate both the desirable and undesirable criteria. For example, in Scenario II, the onset of effects for most chest wounds will not be sufficiently rapid to neutralize the felon with hostage within the desired time frame, while under Scenario IV the individual with a chest wound may be too severely injured to disperse within the desired time period. Almost all chest wounds, critical or non-critical, with or without medical intervention, will violate the 24-hour undesirable criteria. Only the "pain impulse" portion of the effects might coincide with the desirable effects to be achieved in the crowd dispersal situation (Scenario IV). In Figure 5H three other possible incapacitation histories are presented; viz., an impact pain, a tear gas exposure and a "hard blow to the head" just sufficient to cause unconsciousness. The three examples are alternatives of "noxious" environments as compared to a chest wound. Essentially, the impact pain and the blow to the head are extreme variations of blunt-trauma impact. It should be noted that the percent regions (percentage of target personnel having the indicated time-history plot) related to the "blow to the head" are also hypothetical examples of the type of information which would be extremely valuable to a less lethal evaluation if such data were available. It is felt that the tear gas history presents a vivid picture of the reason why this "noxious" environment is so often

[4]General consideration to the onset and duration times was given at the various Medical and Behavioral Analysis Group Meetings. However, no systematic process of constructing these time plots was undertaken.

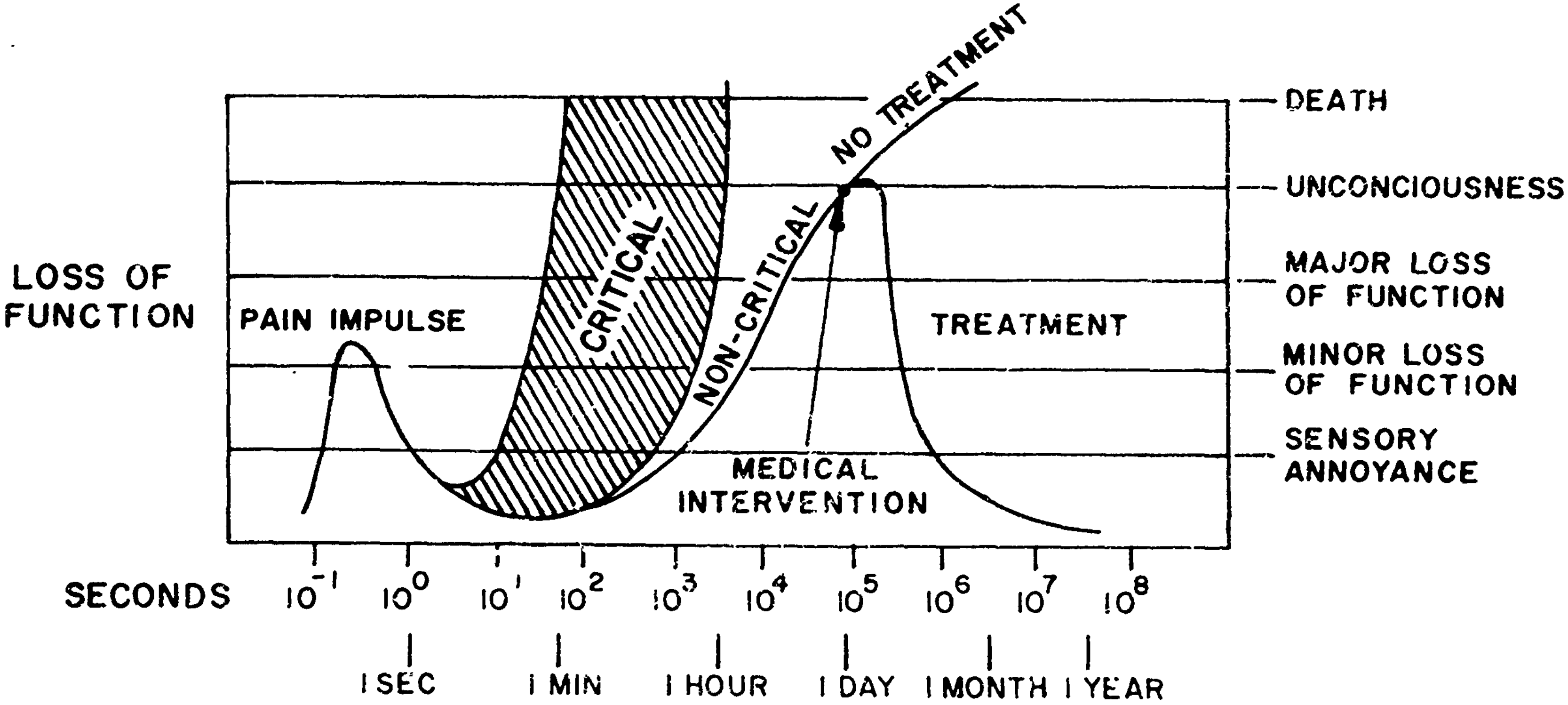

Figure 4H. Hypothetical example of the incapacitation history of a chest wound.

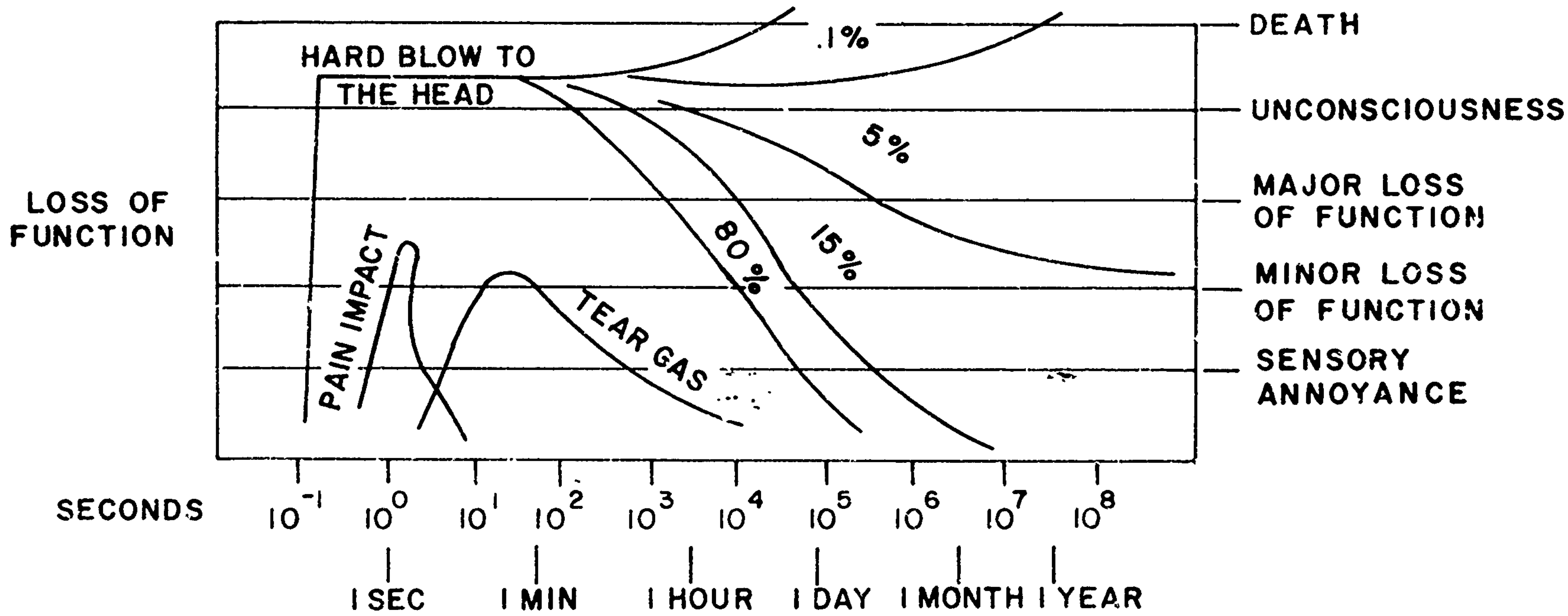

Figure 5H. Function-loss prognosis for various "effective" physiological mechanisms.

utilized in riot control; that is, onset time is not critical in riot control, and the persistence of tear gas is sufficiently long to meet the desirable criteria and the subsidence of effects is well within the 24-hour undesirable criterion.

Essentially, this discussion of function-loss versus time has attempted to put together many of the key concepts involved in evaluating less lethal weapons. Some of the discussion is speculative and inconclusive due to the lack of precise quantification, but such an approach is required in organizing the form of a less lethal weapons evaluation, environment.

APPENDIX I

.38 CALIBER WEAPON HISTORY AND AMMUNITION CHARACTERISTICS

.38 CALIBER WEAPON HISTORY AND AMMUNITION CHARACTERISTICS

This appendix was prepared by:
Mrs. Brenda Thein

The caliber .38 cartridge was first introduced in 1876 in caliber .38 Short Colt and in caliber .38 Long Colt using lead bullets of 130 grains and 150 grains, respectively, and loaded with black powder. The caliber .38 Long Colt was adopted by the US Army in the 1880's. Little, if any, change was made in this cartridge until after the Phillippine Campaign of 1899 against Moro Tribesmen, when the cartridge failed to provide sufficient stopping power to "put down" the enemy. The outcome of this problem was that Daniel B. Wesson began work on improving the cartridge. His aim was to induce the Army to make a change, preferably to a Smith & Wesson product. Although the Army had been using Smith & Wesson revolvers since 1899, they had all been chambered for the caliber .38 Long Colt. Wesson's efforts resulted in the design of the caliber .38 Smith & Wesson Special Cartridge.

At first, this round still utilized black powder loads but the amount was increased by three grains to give a slightly higher velocity. The weight of the bullet was increased by eight grains to what is now the standard 158-grain bullet. The shape of the bullet also underwent a change, that change being a flattening of the base of the bullet. This in turn enabled the relationship between the bullet diameter and groove diameter of the revolver barrel to be held to much closer tolerance limits, eliminating the necessity for expansion by the bullet skirt upon firing, and thus allowing for greater accuracy. However, despite the vast superiority of this round over the Long Colt, the Army declined to consider it, since they had already reached the decision that any future change in handguns would be to a caliber .45 firearm.

In 1902 the Smith & Wesson Military and Police Revolver, Model 1902, was introduced to the general public, and at the same time the caliber .38 Smith & Wesson Special was made available to them. Through the intervening years this cartridge has become the standard round for nearly every civilian law enforcement agency in the country. In very recent years, a slight change in name took place in the form of shortening it from caliber .38 Smith & Wesson Special to just caliber .38 Special. The ammunition is produced by the vast majority of the world's manufacturing companies.

During the last few decades a number of changes to this cartridge have been introduced. These changes have been in such areas as bullet styles and weight, some examples of the various styles being; jacketed hollow point, jacketed soft point, blunt nose, metal piercing, etc, and the weights ranging from 95 grains to 200 grains. There have also been changes in muzzle velocity and muzzle energy thereby causing changes in range, accuracy, penetration, wound-producing capabilities, flatness of trajectory, muzzle blast, recoil, etc. Muzzle velocities now range from approximately 730 feet per second to approximately 1, 542 feet per second, depending on the weight and configuration of the bullet, as well as the weight of the powder charge. Muzzle energies range from approximately 195 foot pounds to 580 foot pounds.

Table 1-I lists various commerical manufacturers of this cartridge and available information concerning it.

TABLE 1-I

Caliber .38 Special

Manufacturer	Bullet		Velocity - Feet Per Second			Energy - Foot Pounds		
	Weight (grains)	Style	Muzzle	50 Yards	100 Yards	Muzzle	50 Yards	100 Yards
Remington-Peters	95[a]	Semi-Jacketed, Hollow Point	985	920	865	205	189	160
	158	Targetmaster, Lead	855	820	790	255	235	220
	200	Targetmaster, Lead/Metal Point[b]	730	695	665	235	215	195
	148	Targetmaster, Lead Wadcutter	770	655	560	195	140	105
	158	Lead (Hi-Speed)	1090	1030	980	415	370	335
	158	Semi-Jacketed, Hollow Point	960	920	880	325	295	270
	125	Semi-Jacketed, Hollow Point	1160	1055	985	375	310	270
	158	Semi-Wadcutter	855	810	765	255	230	205

[a]Only for use in revolvers with 2"-3" barrels.

[b]Different bullet types, same ballistics.

(Continued)

TABLE 1-I (Continued)

Caliber .38 Special

Manufacturer	Bullet: Weight (grains)	Bullet: Style	Velocity - Feet Per Second: Muzzle	Velocity - Feet Per Second: 50 Yards	Velocity - Feet Per Second: 100 Yards	Energy - Foot Pounds: Muzzle	Energy - Foot Pounds: 50 Yards	Energy - Foot Pounds: 100 Yards
Smith & Wesson	110	Jacketed, Hollow Point	1390	1192	1055	472	347	272
	125	Jacketed, Hollow Point	1380	1200	1071	528	400	318
	148	Lead Wadcutter	800	726	662	210	173	144
	158	Lead, Round Nose	910	865	825	289	262	239
	158	Jacketed, Hollow Point	1145	1053	986	460	389	341
	158	Jacketed, Soft Point	1145	1053	986	460	389	341
Super Vel	110	Jacketed, Hollow Point	1370	1240	458	375		
	110	Jacketed, Soft Point	1370	1245	458	380		
	158	Semi-Wadcutter, Lead	855	755	256	199		
	158	Semi-Wadcutter, KOP-PERKOTE	1100	995	423	346		
	148	Hollow Base Wadcutter	775	680	196	149		

(Continued)

TABLE 1-I (Continued)

Caliber .38 Special

Manufacturer	Bullet Weight (grains)	Bullet Style	Velocity - Feet Per Second Muzzle	Velocity - Feet Per Second 50 Yards	Velocity - Feet Per Second 100 Yards	Energy - Foot Pounds Muzzle	Energy - Foot Pounds 50 Yards	Energy - Foot Pounds 100 Yards
Winchester-Western	158	Lubaloy[c], Lead	855		255			
	158	Metal Point	855		255			
	158	Lead, Hollow Point (Police)	1060		395			
	200	Lubaloy, Lead (Super Police)	730		235			
	158	Semi-Wadcutter (Super Speed)	1060		395			
	150	Lubaloy	1060		375			
	150	Metal Piercing	1060		375			
	148	Lead, Super Match Wadcutter	770		195			
	158	Lead, Super Match	855		255			
Federal	148	Lead, Wadcutter	770		195			
	158	Lead (Service)	855		256			
	158	Lead (High Velocity)	1080		415			

[c]Lubaloy is a copper-like coating.

(Continued)

TABLE 1-I (Continued)

Caliber .38 Special

Manufacturer	Bullet Weight (grains)	Bullet Style	Velocity - Feet Per Second Muzzle	Velocity - Feet Per Second 50 Yards	Velocity - Feet Per Second 100 Yards	Energy - Foot Pounds Muzzle	Energy - Foot Pounds 50 Yards	Energy - Foot Pounds 100 Yards
Amron	148	Match	770		195			
	158	Lead, Round Nose	855		255			
	125	Semi-Jacketed, Soft Point	1150		366			
	158	Semi-Jacketed, Soft Point	1150		465			
	200	Lead, Round Nose	730		235			
Norma	110	Jacketed, Hollow Point	1542		580			
	148	Lead, Wadcutter	800		210			
	158	Jacketed, Hollow Point	900		285			
	158	Fully Jacketed, Semi-Wadcutter	900		285			
	158	Lead, Round Nose	870		266			

(Concluded)

APPENDIX J

SAMPLE SURVEY OF REVOLVERS AND AMMUNITION USED BY LAW ENFORCEMENT AGENCIES

Sample Survey[a] of Revolvers and Ammunition Used by Law Enforcement Agencies

Police Department	On-Duty Handgun (Cal & Desc)	On-Duty Ammunition (Cal & Desc)	Remarks on Training
Atlanta	.38 Special Colt or Smith & Wesson, 4" barrel	.38 Special	Practical pistol course
Baltimore City	.38 Special Smith & Wesson, 4" barrel	.38 Special, 158-gr lead, round nose	
Chicago	.38 Special	.38 Special, 158-gr lead, round nose	Part bull's-eye type target, part combat silhouette
Cleveland	.38 Special	.38 Special	Practical pistol course (combat silhouette)
Dallas	.38 Special Colt or Smith & Wesson, 4" barrel	.38 Special	Part bull's-eye type target, part combat silhouette
Miami	.38 Special Smith & Wesson M&P, Model 10, 4"-5" barrel	.38 Special, 110-gr jacketed soft point (Super Vel)	Combat silhouette only
New Orleans	.38 Special	.38 Special, 125-gr semi-jacketed soft point	
New York City	.38 Special	.38 Special, 158-gr lead, semi-wadcutter (Remington)	

[a]1972-1973

(Continued)

Sample Survey of Revolvers and Ammunition Used by Law Enforcement Agencies (Continued)

Police Department	On-Duty Handgun (Cal & Desc)	On-Duty Ammunition (Cal & Desc)	Remarks on Training
Philadelphia	.38 Special	.38 Special, 158-gr lead, semi-wadcutter (Remington)	
Phoenix	.38 Special Colt or Smith & Wesson, 4" barrel	.38 Special, 110-gr jacketed hollow point	Part bull's-eye type target, part combat silhouette
Salt Lake City	.38 Special Colt or Smith & Wesson, 4" barrel	.38 Special	NRA police combat course
St. Louis	.38 Special Colt or Smith & Wesson, 4" barrel (minimum length)	.38 Special, 158-gr lead, hollow point (Winchester-Western)	Combat silhouette
San Antonio	.38 Special Smith & Wesson M&P, Model 10, 4" barrel	.38 Special, 200-gr lead, round nose	Part bull's-eye type target, part combat silhouette
Seattle	.38 Special	.38 Special, 158-gr lead, round nose	
Wichita	.38 Special Smith & Wesson, Model 10, 4" heavy barrel	.38 Special, 158-gr semi-jacketed hollow point	Combat silhouette
Washington, DC	.38 Special Colt, 4" barrel	.38 Special, 158-gr lead, round nose	

(Continued)

Sample Survey of Revolvers and Ammunition Used by Law Enforcement Agencies (Continued)

Police Department	On-Duty Handgun (Cal & Desc)	On-Duty Ammunition (Cal & Desc)	Remarks on Training
Illinois State Police	9mm Smith & Wesson, Model 39	9mm Luger, 100-gr, soft point (Winchester-Western)	
Maryland State Police	.38 Special Colt or Smith & Wesson, 6" barrel	.38 Special, 158-gr, lead, round nose	Part bull's-eye type target, part combat silhouette
Texas Rangers	.357 Magnum and .45 Gov't model Colt, .38 Special	.357 Magnum, .45 ACP, and .38 Special	
FBI	.38 Special Smith & Wesson, 4" barrel	.38 Special, 158-gr lead, roundnose	Practical pistol course (combat silhouette)
US Secret Service	.38/.357 bore Smith & Wesson, Models 19 & 66, 2-1/2" barrel	.38 Special, 110-gr, hollow point (Super Vel)	Practical pistol course

(Concluded)

APPENDIX K

STATISTICAL ANALYSIS OF MAN-WEAPON TEST DATA

This Appendix was prepared by:
H.P. White Laboratory, and
Mr. D. Campbell.

STATISTICAL ANALYSIS OF MAN-WEAPON TEST DATA RELATING TO BASIC AND TIME-STRESS TESTS OF THE .38 CALIBER SPECIAL

Tests were conducted by the US Army Land Warfare Laboratory (LWL) to establish an accuracy and effectiveness data base for: (1) .38 caliber ammunition, (2) .38 caliber weapon systems, and (3) .38 caliber weapon system/user combinations. Shooters from the Harford County (Maryland) Sheriff's Department and the Baltimore (City) Police Department participated in these test firing. The "raw data" for these tests are presented in LWL Technical Note No. 73-01.

This analysis of the man-weapon test data was made by personnel of the Research Analysis Office, LWL. The results of this analysis are condensed into Tables 1K through 5K. Tables 1K through 4K list the individual performances with regard to time spent firing and accuracy achieved, while Table 5K summarized the same information to obtain each team's performance and their combined performance. The labels used to identify the participants are the same as those used in LWL Technical Note No. 73-01; i.e., Shooter A in the tables here is the same individual as the one labeled Shooter A in LWL Technical Note No. 73-01. Shooters A-E were from county police, and Shooters F-J from the city police. It is assumed that the shooters are above-average marksmen, and a greatly expanded test program would be required to determine accuracy data for the "average" law enforcement officer.

From an examination of the results presented in the five tables, the following observations are noted:

1. The dominant source of error differences within police groups is the variability between different individual firers.

2. In general, mil error decreases as range increases.

3. Within range groups, there is some indication that mil error decreases with increasing time-of-fire.This is somewhat noticeable at the 1, 7 and 25-yard ranges for the city police and at the 1 and 25-yard ranges for the county police. However, it is not apparent at the 50-yeard range for either team, nor is it readily apparent at the 7-yard range for the county police.

4. The large time variations and the large inaccuracies at the shorter ranges may well be attributed to the lack of a challenge presented by the short ranges.

5. First-round accuracy appears to be about the same as that of subsequent rounds.

6. The rate-of-fire of the county police was generally slower than that of the city police.

7. The county police were more accurate at the 1 and 7-yard range, but the city police were more accurate at the 25 and 50-yard ranges.

TABLE 1K

Individual Performances
(Range = 1 Yard)

Shooter	Rounds	Average Time Per Round, sec	Error, mils
A	All	1.223	27.039
B	All	1.430	14.287
C	All	0.820	15.494
D	All	0.743	17.786
E	All	0.847	14.780
A	First	1.567	10.102
B	First	1.967	18.742
C	First	1.417	12.362
D	First	1.042	21.848
E	First	1.083	16.558
F	All	0.803	25.323
G	All	0.700	21.377
H	All	0.550	29.545
I	All	0.397	46.664
J	All	0.320	48.707
F	First	1.200	26.753
G	First	1.050	16.677
H	First	0.700	40.408
I	First	0.550	42.541
J	First	0.500	62.529

TABLE 2K

Individual Performances
(Range = 7 Yards)

Shooter	Rounds	Average Time Per Round, sec	Error, mils
A	All	1.560	11.999
B	All	1.503	10.337
C	All	0.833	9.797
D	All	0.793	16.854
E	All	1.127	9.709
A	First	1.833	11.742
B	First	2.250	6.454
C	First	1.667	10.298
D	First	1.083	15.718
E	First	1.375	13.428
F	All	1.437	4.997
G	All	0.807	7.509
H	All	1.517	4.166
I	All	0.453	12.266
J	All	0.417	24.023
F	First	1.933	5.806
G	First	0.717	4.236
H	First	2.383	5.863
I	First	0.450	13.108
J	First	0.733	33.839

TABLE 3K

Individual Performances
(Range = 25 Yards)

Shooter	Rounds	Average Time Per Round, sec	Error, mils
A	All	1.750	10.067
B	All	2.550	6.417
C	All	2.253	5.573
D	All	2.127	6.763
E	All	2.330	4.395
A	First	2.208	13.304
B	First	2.958	7.841
C	First	3.708	2.427
D	First	2.333	10.325
E	First	2.000	4.220
F	All	1.440	4.777
G	All	1.183	2.905
H	All	2.133	2.349
I	All	1.213	4.871
J	All	1.463	2.812
F	First	2.283	6.171
G	First	0.567	3.289
H	First	4.017	2.432
I	First	1.017	5.018
J	First	1.517	2.321

TABLE 4K

Individual Performances
(Range = 50 Yards)

Shooter	Rounds	Average Time Per Round, sec	Error, mils
A	All	2.580	5.839
B	All	2.483	4.046
C	All	3.837	3.020
D	All	2.243	3.580
E	All	2.720	3.430
A	First	3.333	2.312
B	First	3.417	6.943
C	First	5.708	2.810
D	First	2.583	3.522
E	First	2.417	3.493
F	All	2.947	3.726
G	All	2.557	5.884
H	All	3.033	1.763
I	All	1.830	3.662
J	All	2.377	1.906
F	First	2.650	4.369
G	First	1.750	3.095
H	First	3.233	1.219
I	First	0.775	2.768
J	First	0.750	2.609

TABLE 5K

Summary of Team and Overall Performances

Shooters	Range, Yds	Rounds	Average Time Per Round, sec	Error, mils
A-E	1	All	1.013	19.023
A-E	1	First	1.415	16.847
F-J	1	All	0.553	41.618
F-J	1	First	0.800	49.275
A-J	1	All	0.804	33.573
A-J	1	First	1.108	43.730
A-E	7	All	1.163	13.593
A-E	7	First	1.642	9.767
F-J	7	All	0.930	20.073
F-J	7	First	1.243	17.642
A-J	7	All	1.047	20.470
A-J	7	First	1.443	21.723
A-E	25	All	2.203	7.143
A-E	25	First	2.642	9.133
F-J	25	All	1.487	4.572
F-J	25	First	1.880	5.092
A-J	25	All	1.845	6.252
A-J	25	First	2.261	10.351
A-E	50	All	2.773	4.385
A-E	50	First	3.492	4.394
F-J	50	All	2.550	4.272
F-J	50	First	1.907	3.743
A-J	50	All	2.661	4.401
A-J	50	First	2.727	4.743

APPENDIX L

ACCURACY DATA FOR THE .22, .38 AND .45 CALIBER WEAPONS

This Appendix was prepared by:
Mrs. Brenda Thein

Accuracy Data for the .22, .38 and .45 Caliber Weapons

Tests Conducted By	Rate of Fire	Firers	Range (Yds)	Cal	Average Aiming Error (mils) σ_x	Average Aiming Error (mils) σ_y	Overall Aiming Error (mils) σ_t
Human Engineering Lab (HEL), APG, MD	Slow	Average (Military)	25	.45	8.7	8.0	8.4
			25	.38	5.7	5.0	5.4
			25	.22	4.6	4.3	4.5
	Slow	Proficient (Civilian)	25	.45	3.5	3.7	3.6
			25	.22	2.5	2.2	2.4
Land Warfare Lab (LWL), APG, MD	Time Stress	Small County Sheriff's Office	7	.38	10.9	12.3	11.6
			25	.38	7.6	7.1	7.3
			50	.38	3.7	3.3	3.5
	Time Stress	Metropolitan Police Dept	7	.38	22.9	16.1	19.8
			25	.38	4.8	4.3	4.6
			50	.38	3.7	3.3	3.5
	Slow	State Police[a]	7[b]	.38	1.4	1.4	1.4
			25[b]	.38	2.7	2.9	2.8
			50[b]	.38	2.7	1.6	2.2
			7[c]	.38	1.7	1.3	1.5
			25[c]	.38	3.4	3.9	3.7
			50[c]	.38	1.0	2.4	1.9
	Time Stress	Government Agency[d]	7	.38	9.0	23.0	17.5
			25	.38	4.7	7.8	6.4
			50	.38	2.9	3.6	3.3

[a]Sample size of 1.
[b]Single action.
[c]Double action.
[d]Practical pistol course.

(Continued)

Accuracy Data for the .22, .38 and .45 Caliber Weapons (Continued)

Tests Conducted By	Rate of Fire	Firers	Range (Yds)	Cal	Average Aiming Error (mils) σ_x	Average Aiming Error (mils) σ_y	Overall Aiming Error (mils) σ_t
Rock Island Arsenal (RIA), Rock Island, IL	Slow	Machine Rest	50	.38	1.3	1.0	1.2
			50	.38	1.1	1.4	1.3
			50	.38	1.1	1.7	1.5
			50	.38	1.0	1.0	1.0

(Concluded)

APPENDIX M

STATISTICAL ANALYSIS AND SUMMARY OF .38 CALIBER SHOOTING INCIDENTS

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STATISTICAL ANALYSIS AND SUMMARY OF .38 CALIBER SHOOTING INCIDENTS

This appendix was prepared by:
Mrs. Brenda Thein

In an effort to obtain a gross estimate of the effectiveness of the caliber .38 weapon system in relation to human beings, the Research Analysis Office (RAO) reviewed current (1971-1972) records from certain hospitals in Baltimore City and from the Office of the Chief Medical Examiner of the State of Maryland. These records (the reduced raw data is presented in Tables 1M and 2M) represent a total of 56 cases of reported caliber .38 shootings which occurred within the city limits of Baltimore[1]. Each group of records that were reviewed; i.e., the hospital records and the Medical Examiner's records, covered a time-interval of nine months.

Before beginning any analysis of the data, however, it is desirable to state briefly the rationale used in limiting the number of cases utilized in the study to 56, as noted above. Since this was an initial effort and was intended mainly to serve as groundwork for a more comprehensive effort in the future, the amount of time expended to obtain the present information was of particular importance. While the information on fatalities could be obtained from one location; viz., the Medical Examiner's Office, this was not the situation for the nonfatalities or hospital cases. The information for these latter cases had to be obtained in a "roundabout" fashion; i.e., first the police records were reviewed to obtain a listing of the caliber .38 shootings, then the hospitals were contacted to elicit their cooperation in extracting the records of interest from the respective files, and finally it was necessary to visit each hospital to review the records. (It should be mentioned here that extensive notes were taken for the various cases reviewed; however, mechanical reproduction of the records was not permitted by any of the hospitals). Since each phase of the data collection required a considerable amount of time, it was necessary at the outset (after reviewing the police records) to assign arbitrary criteria, such as the time interval (nine months) during which the shootings took place and geographic boundaries of the shootings (the city limits of Baltimore). The 56 cases used in this study were the only ones that met the established criteria. Because of the limited sample size any statistics presented in this analysis should be viewed in their proper perspective, as representing possible trends rather than "hard numbers".

An initial point of interest in analyzing the data is the fact that of the 56 reported caliber .38 shootings, 57% of the victims survived. This appears to indicate a lack of lethality on the part of the caliber .38 weapon system.

Several factors, however, should be investigated before making a final judgment on the caliber .38's effectiveness. One point that should be considered is the body area/organ receiving the wound. In the case of head-

[1] It should be noted that since only those cases in which one individual shot another were of interest, all cases involving suicide were excluded.

TABLE 1M

Caliber .38 Wound Data (Based on Medical Examiner Records)

Age Groups			Sex		Race		"T"[a]		Wound Locations																	No. of Times Shot	
0-30	31-60	61-90	M	F	C	N	Hr	Min	HEAD	Neck	Mouth	Eyes	Skull	TRUNK	Abdomen	Lungs	Heart	Liver	Kidney	Spleen	Intestines	Stomach	EXTREMITIES	Legs	Arms	1	>1
X			X			X	1	00	X[1]	X	X															X	
	X		X			X		15						X		X										X	
X			X			X		13	X[2]	X				X		X	X										X
X				X		X		45	X[3]				X													X	
	X		X			X	1	22	X[4]	X																X	
	X		X			X		21						X		X	X									X	
	X		X			X	--	---	X[3]				X													X	
	X			X		X		08	X[3]		X		X													X	
X			X			X		15						X		X	X	X									X
	X		X			X		20	X[3]				X													X	
X			X			X		50	X[3]				X	X[5]									X		X		X
	X		X			X	1	00						X	X				X				X	X			X
X			X			X	--	---						X	X			X	X							X	
	X		X			X		20						X		X	X									X	
X			X			X		05	X[3,6]			X	X													X	
X				X		X		30	X[3]				X										X	X			X
	X		X			X		16						X			X	X				X				X	
	X		X			X		15	X[7]	X																X	
X			X			X		40						X	X	X										X	
X			X		X		--	---	X[3]				X	X		X	X										X
X			X		X		10	43						X		X	X									X	
	X		X			X		22						X[8]		X											X
X			X			X		10	X[7]	X													X	X			X
	X		X			X		15	X[7]					X		X	X						X	X	X		X
12	12	0	21	3	2	22	←TOTALS→		14	5	2	1	8	14	3	10	8	3	2	0	0	1	5	4	2	15	9

[a]Time interval from when shooting occurred until victim was pronounced dead.

[1]bullet lacerated hypopharynx
[2]bullet lacerated esophagus
[3]bullet penetrated brain
[4]bullet lacerated jugular vein
[5]grazed right upper part of back
[6]perforated right orbital plate of skull - eyeball not perforated
[7]superficial scalp wound
[8]bullet wound in right shoulder

TABLE 2M

Caliber .38 Wound Data (Based on Hospital Records)

Age Groups (yrs) 0-30	31-60	61-90	Sex M	F	Race C	N	Δt[a] Hr	Min	"H"[b] Days	HEAD	Neck	Mouth	Eyes	Skull	TRUNK	Abdomen	Lungs	Heart	Liver	Kidney	Spleen	Intestines	Stomach	EXTREMITIES	Legs	Arms	No. of Times Shot 1	>1
X			X			X	--	---	--															X		X	X	
X			X			X	1	30	3															X		X		X
X			X			X	1	05	2	X		X															X	
X			X			X	--	---	7						X	X						X		X	X	X		X
X			X			X	--	---	25	X[1]		X			X	X			X					X	X			X
X			X			X		15	9						X[2]												X	
		X	X			X	1	40	10	X	X				X[3]									X		X		X
X			X			X	2	50	7															X	X		X	
X			X			X		10	<1															X	X		X	
X				X		X		25	12						X	X						X		X		X	X	
X			X		X		1	12	3						X[4]													X
X			X			X	--	---	--															X	X		X	
X				X		X	--	---	--						X[5]	X			X	X								X
X			X			X		29	<1						X[6]												X	
X			X			X		03	14						X[7]	X				X							X	
		X	X			X		35	8	X[8]				X										X		X		X
X			X			X	2	04	6															X	X		X	
X			X			X	1	30	12						X[9]	X			X		X		X				X	
X				X		X	2	55	24															X	X		X	
X			X			X	2	18	9						X[10]												X	
	X		X			X		09	16															X		X	X	
	X		X			X		21	26						X[11]	X			X									X
X			X		X			25	9						X[12]	X											X	
X			X		X			45	14	X	X				X[13]					X				X	X			X
		X	X		X		3	07	<1															X	X		X	
	X		X			X		20	10						X[14]												X	
	X		X			X		15	<1															X	X	X		X
X			X			X	1	40	<1															X	X	X		X
X			X			X	1	00	<1															X		X	X	
X				X		X		35	8						X[15]	X								X	X			X
X				X		X		33	12	X[16]	X	X		X	X[17]					X				X		X		X
	X		X			X	--	---	7						X					X							X	
24	5	3	27	5	4	28	← TOTALS	→		6	3	3	0	2	18	9	0	0	4	5	1	2	1	20	12	11	19	13

(Continued)

[a]Time interval from when shooting occurred until victim received treatment.
[b]Length of time shooting victim was hospitalized.

[1]wound located at mid-forehead at hairline (a grazing-type wound)
[2]two ribs fractured
[3]wound located in soft tissue of left shoulder
[4]chest area wound - bullets did not enter chest cavity (soft tissue trauma)
[5]two ribs fractured; also, large contusion on lung
[6]wound located in left axilla area - no bone damage
[7]bullet transected left gastric artery, lacerated splenic vein and injured adrenal gland - large amount of bleeding
[8]bullet passed from left to right occipital area (lodged extracranially) - no evidence of neurological complications
[9]diaphragm lacerated
[10]wound located in chest area - some accumulation of blood and air in the pleural cavity
[11]wound located in diaphragm; also large amount of bleeding from gastrohepatic omentum and retroperitoneal areas
[12]no penetration of peritoneal cavity; however, a large hematoma in right retroperitoneal area
[13]perforation of splenic flexure of colon, fracture of a portion of the right clavicle, lacerations of right innominate artery, subclavian vein and right subclavian artery
[14]chest wound - pulmonary hematoma; no evidence of pneumothorax
[15]wound in left shoulder and perforation of proximal jejunum
[16]skull area - bullet located extracranially
[17]trunk wounds - hole in left hemidiaphragm, perforation of colon, and wound in left shoulder

(Concluded)

woundings, for example, 30% of the victims survived, but in none of the survival cases were any critical veins (such as the jugular vein) lacerated nor was the skull/brain penetrated. On the other hand, in those cases where people died from head wounds damage to the aforementioned areas appears to have played a prominent part in the cause of death. Other examples of the importance of considering the body area/organs wounded can be shown by the fact that in all those cases reviewed where the individual was shot in the heart, death occurred, while in none of the cases where the person was shot in the extremities only, did death occur.

Another factor that should be considered when examining the data is the influence (or lack of it) of multiple woundings on whether the individual survives. Upon reviewing the data, however, there appears to be no simple correlation between the number of times the individual was shot in the various body areas/organ combinations and whether he lived or died.

A third factor for consideration is the time interval from when the shooting occurred until the individual was given medical treatment or was pronounced dead. While there appears on the surface to be no direct correlation between this time interval and the ultimate well-being of the individual, this may be due in part to an absence of information concerning any medical treatment that might have been given to the nonsurvivors.

A final factor for consideration in evaluating the effectiveness of the caliber .38 weapon system is the scenario-type situations under which the aforementioned shootings occurred. The influence of these situations can be viewed from two aspects: first, the overall relationship between the scenario-type situations and the well-being of the individual(s) involved; secondly, the ability to predict the chance of a fatality by knowing the frequency with which a given scenario-type situation occurs. In regard to the first aspect, Figure 1M depicts the well-being of the individual as a function of the scenario-type situation, while Figure 2M shows the frequency with which the various scenario-type situations occurred[2]. Additionally, using the data illustrated in Figure 1M, it is possible to predict the probability of a fatality as a function of the scenario-type situation, as is presented in Table 3M. When attempting to consider the second aspect, however; i.e., the ability to predict the chance of a fatality (shown in Table 3M) as a function of the frequency with which a given scenario-type situation occurs (as in Figure 2M), it becomes apparent that the small number of cases used in this study precludes establishing whether any correlation exists between the two variables--probability of fatality and frequency of scenario occurrence.

An important conclusion drawn from this initial investigation of the effectiveness of the caliber .38 weapon system in relation to human beings is that a great deal more work needs to be done in this area in order to obtain a large statistical base. A major effort will be required to review hospital and medical examiner records for several other large cities and analyze the data using procedures similar to those used in this study. This

[2]The scenario statistics represent 50 of the 56 cases reviewed--scenario data was not available for the remaining six cases.

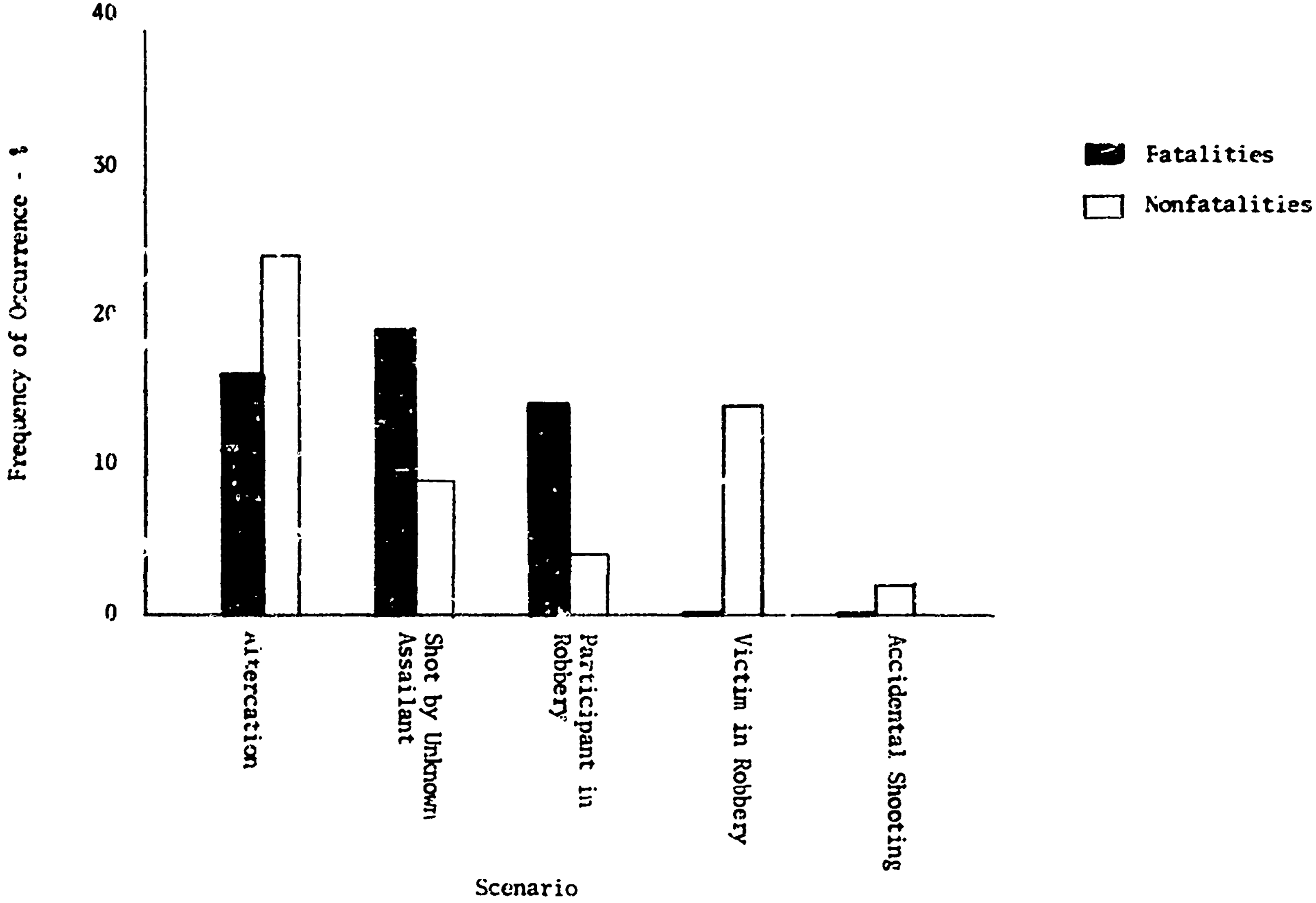


Figure 1M. Fatalities versus nonfatalities as a function of scenario.

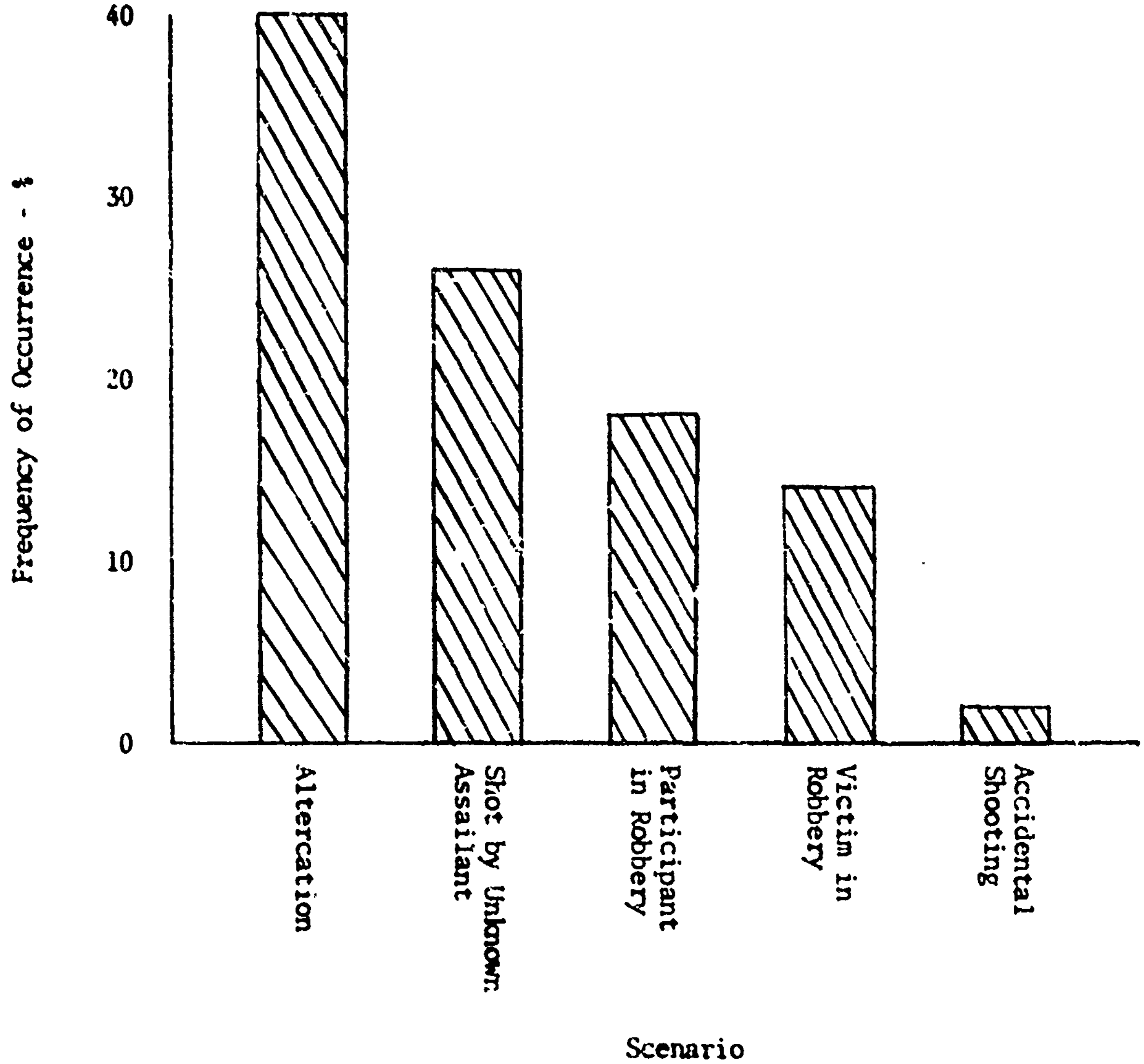


Figure 2M. Distribution of caliber .38 shootings as a function of scenario.

TABLE 3M

Probability of Fatality as a Function of Scenario Type

Scenario Type	Probability of A Fatality	Ratio of Fatalities to Nonfatalities
Participation in robbery	.78	3.5:1
Shot by unknown assailant	.69	2.2:1
Altercation	.40	0.7:1
Victim of robbery	0	-
Accidental shooting	0	-

larger statistical base is necessary before final judgment can be exercised on the effectiveness of the caliber .38 weapon system.

APPENDIX N

SUPPORTING CALCULATIONS FOR THE STUN BAG ANALYSIS

SUPPORTING CALCULATIONS FOR STUN BAG ANALYSIS

A. Trajectory Calculations

The following numerical integration procedure was used to calculate normal trajectories of Stun-Bags (or other similar projectiles), given initial velocities and weights, and taking into account air resistance. The procedure computes range coordinates, $x(t_i)$ and $y(t_i)$, and velocity $v(t_i)$ at time t_i by numerically integrating the differential equations:

$$\ddot{x}(t_i) = -cv(t_i)\, K_D\, \dot{x}(t_i)$$

$$\ddot{Y}(t_i) = -cv(t_i)\, K_D\, \dot{y}(t_i) - g$$

where: $c = -\rho d^2/m$, d = diameter of projectile in feet

ρ = air density = 0.081 lb/ft^3

m = weight of projectile in pounds

$v(t_i)$ = velocity of projectile at time t_i in ft/sec

t_i = time elapsed from time zero in sec

$\dot{x}(t_i)$, $\dot{y}(t_i)$ = rates of change of horizontal and vertical distances with respect to time at time t_i in ft/sec

g = gravitational acceleration - 32.2 ft/sec^2

K_D = drag coefficient - This dimensionless constant may be input as data for use by the program or may be computed as a function of velocity by the program according to the following expression:

$$K_D = c_1 = c_2M + c_3M^2 + c_4M^3 + c_5M^4$$

where: the c's are constants and M is mach number defined as $v(t_i)/v_s$ (v_s is the velocity of sound and is taken as 1,120 ft/sec).

B. Summary Graph Calculations

Calculations supporting the Summary Graphs involve three stages: computation of hit probabilities; estimation of probabilities of desirable and undesirable effects as a function of kinetic energy; and combination of these two sets of probabilities. The data used include estimation of horizontal and vertical standard deviations of miss distance, use of the Test Shot Summary Tables, and estimation of presented areas of the head and the rest of the body for the average male human.

The error value used for the horizontal standard deviation, σ_h, is five mils; the value used for the vertical standard deviation, σ_v, is 19 mils. The areas (in square inches) presented by the head and the rest of the body are 46.5 and 795.2, respectively.

The formula used to combine these data into a probability of hit is:

$$P_{hit} = \frac{A_t}{A_t + 2\pi\sigma_h\sigma_v K^2},$$

where A_t is the presented area of the target, σ_h and σ_v are as defined above, and K is a range-dependent factor for converting mils into inches. (A mil in inches is one one-thousandth of the range in inches.) Now, if $A = 2\pi\sigma_h\sigma_v K^2$, then $A = 190\pi K^2 = 596.90K^2$. Computation of A is summarized in Table 1N below for various ranges of interest.

TABLE 1N

Computation of $A = 2\pi\sigma_h\sigma_v K^2$

(σ_h = 5 mils, σ_v = 19 mils)

Range (ft)	K (inches/mil)	A (square inches)
40	0.48	137.53
80	0.96	550.10
120	1.44	1237.73
150	1.80	1933.96
200	2.40	3438.14

The ranges chosen in Table 1N represent distances at which kinetic energies for the Stun-Bag are estimated. From these kinetic energies and extrapolation from the Test Shot Summary Tables 2N through 4N, estimates are made of P_{UE} and P_{DE} for Scenarios III and IV. (It should be noted here that extrapolations of this nature depend a good deal on subjective evaluation of the cause of damage in the animal test shots. Certain shots have been ignored because it was ascertained through review of high-speed movies taken during the test that these shots produced glancing blows and their effects should be treated separately. Additionally, ''clustering'' of results is taken more seriously than averages.)

The support calculations for the Summary Graphs are displayed in Tables 2N through 4N. Except for the combinations, the numbers appearing in these tables have been explained in the main text. They represent the probability of occurrence of some desirable or undesirable effect.

To explain the process of combinations, consider a column of probabilities of some effect, P_{UE}, P_{DE} (III), or P_{DE} (IV), for a given range/kinetic energy. Let P_{e_1} and P_{h_1} be the probability of effect and the probability of hit, respectively, for the head, and P_{e_2} and P_{h_2} be similar probabilities for the rest of the body. Then the formula for the combination of these probabilities into a total probability of some effect on the body as a whole is:

$$1-[(1-P_{e_1} P_{h_1})(1-P_{e_2} P_{h_2})].$$

TABLE 2N

Summary Graph Support Calculations
(Super Long-Range Round)

Assumed: weight, .35 lb; horizontal error, 5 mils; vertical error, 19 mils

Range (ft)	Kinetic Energy (ft-lb)	Body Area	P_{UE}	P_{DE} III[a]	P_{DE} IV[a]	P_{hit}
40	196.4	Head	1.00	1.00	1.00	0.25
		Rest of Body	1.00	0.70	0.25	0.85
		Combination	0.89	0.70	0.41	
80	144.5	Head	1.00	1.00	0.00	0.08
		Rest of Body	1.00	0.50	0.40	0.59
		Combination	0.62	0.35	0.24	
120	103.6	Head	0.90	0.90	0.10	0.04
		Rest of Body	1.00	0.30	0.70	0.39
		Combination	0.41	0.15	0.28	
150	81.0	Head	0.75	0.70	0.60	0.02
		Rest of Body	0.90	0.25	0.70	0.29
		Combination	0.27	0.09	0.22	
200	53.3	Head	0.30	0.20	0.40	0.01
		Rest of Body	0.90	0.25	0.75	0.19
		Combination	0.17	0.05	0.15	

[a]Denotes number of LEAA Scenario

TABLE 3N

Summary Graph Support Calculations
(Low Impact Round)

Assumed: weight, .35 lb; horizontal error, 5 mils; vertical error, 19 mils

Range (ft)	Kinetic Energy (ft-lb)	Body Area	P_{UE}	P_{DE} III[a]	P_{DE} IV[a]	P_{hit}
40	87.7	Head	0.75	0.50	0.50	0.25
		Rest of Body	0.90	0.25	0.70	0.85
		Combination	0.81	0.31	0.65	
80	60.0	Head	0.40	0.50	0.30	0.08
		Rest of Body	0.90	0.25	0.80	0.59
		Combination	0.55	0.18	0.48	
120	49.1	Head	0.25	0.10	0.20	0.04
		Rest of Body	0.90	0.25	0.90	0.39
		Combination	0.36	0.10	0.36	
150	35.7	Head	0.20	0.10	0.20	0.02
		Rest of Body	0.90	0.25	0.75	0.29
		Combination	0.27	0.07	0.22	
200	24.4	Head	0.00	0.00	0.10	0.01
		Rest of Body	0.75	0.20	0.50	0.19
		Combination	0.14	0.04	0.10	

[a]Denotes number of LEAA Scenario

TABLE 4N

Summary Graph Support Calculations
(Close Range Round)

Assumed: weight, .35 lb; horizontal error, 5 mils; vertical error, 19 mils

Range (ft)	Kinetic Energy (ft-lb)	Body Area	P_{UE}	P_{DE} III[a]	P_{DE} IV[a]	P_{hit}
40	48.1	Head	0.25	0.10	0.20	0.25
		Rest of Body	0.90	0.25	0.90	0.85
		Combination	0.78	0.23	0.78	
80	34.8	Head	0.20	0.10	0.20	0.08
		Rest of Body	0.90	0.25	0.75	0.59
		Combination	0.54	0.15	0.45	
120	24.4	Head	0.00	0.00	0.10	0.04
		Rest of Body	0.75	0.20	0.50	0.39
		Combination	0.29	0.08	0.20	
150	20.9	Head	0.00	0.00	0.00	0.02
		Rest of Body	0.40	0.10	0.40	0.29
		Combination	0.12	0.03	0.12	

[a]Denotes number of LEAA Scenario

APPENDIX O

ESTIMATES OF PLACEMENT ACCURACY

ESTIMATES OF PLACEMENT ACCURACY

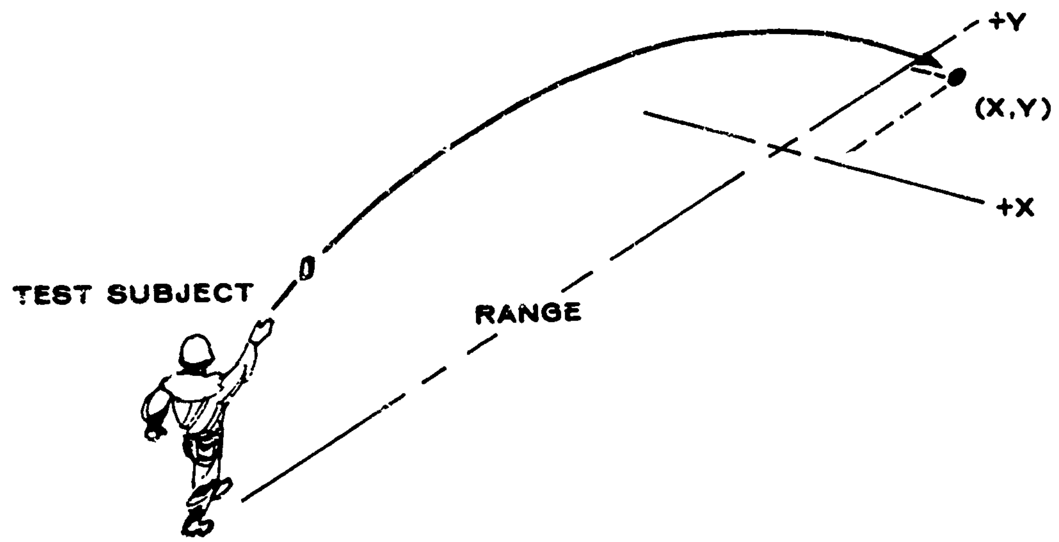
This Appendix was prepared by AAI, Inc.

A. Hand-Throwable Grenade Tests

The hand-throwable tear gas grenades used for these tests were inert (no agent) practice types. The grenades chosen for test were:

- S&W Practice Grenade No. 81
- AAI MPG Grenade No. T-100

A test range and target area were set up as shown in the diagram below.



A group of six test subjects was chosen to perform the throwing tests. The test design indicating number of grenades, grenade type, and distance thrown is shown below.

Quantity	Grenade Type	Range (ft)
6	No. T-100	60
6	No. 81	60
6	No. T-100	100
6	No. 81	100

Thus, each of the test subjects was scheduled to throw a total of 24 grenades, 12 for each of two ranges-60 and 100 feet-giving a total of 144 trials for the entire test. The results of these tests are shown in Tables 1-0 and 2-0.

To further simulate a realistic situation, during performance of the throwing tests, the test subjects wore gas masks. The grenade-throwing tests were performed as described below:

- Each test subject conducted a few practice throws with each type grenade for familiarization.

- After donning the gas mask, the test subject threw six grenades of one type at the target area from the 60-foot marker.

- After each throw, the final resting position of the grenade was marked on the target area.

- At the completion of the six throws, the x and y coordinates were measured.

- The test procedure was then repeated using the other type grenade.

- The throwing range was then increased to 100 feet, and the test procedure repeated.

B. Gun-Launch Grenade Test

The types of tear gas grenades used for the gun-launched tests were inert (no agent) practice types. The grenades chosen for test were:

- S&W Practice Grenade No. 86 (using 37mm [Lake Erie] tear gas gun).

- AAI MPG Practice Grenade No. T-100 (using 12 gauge shotgun launcher [adapter] No. L-110).

A test range and a simulated window target were set up as shown below.

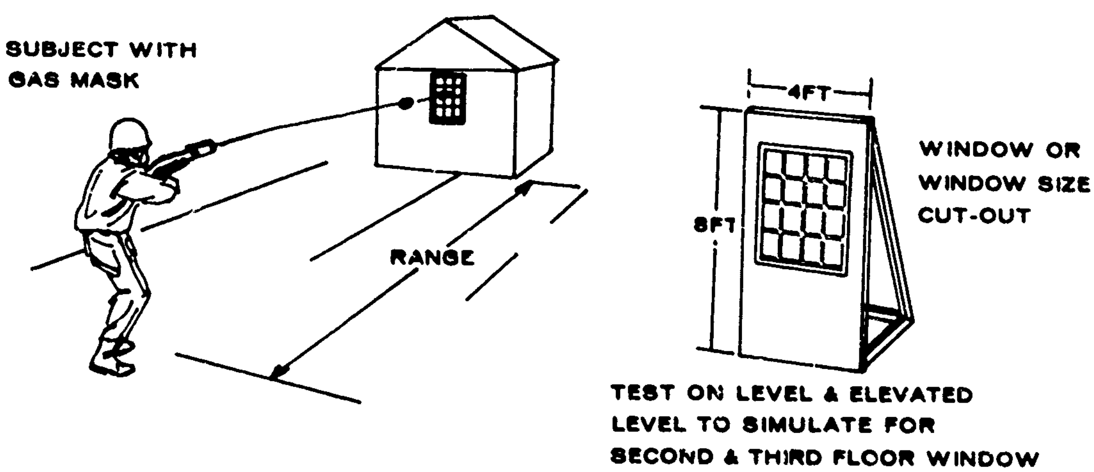


TABLE 1-O

Hand-Throwable Grenade Test Results at 60 Feet
(Distance from Aim Point in Feet)

Subject			1		2		3		4		5		6	
Coordinates			x	y	x	y	x	y	x	y	x	y	x	y
Trial														
Grenade B	1		0.25	7.75	6.00	4.00	- 4.00	5.25	- 4.50	7.50	- 4.25	-13.50	- 2.00	8.75
	2		1.00	- 3.00	- 2.00	- 0.50	- 5.00	5.25	- 2.50	10.00	- 2.00	- 0.50	1.00	- 7.00
	3		2.00	9.50	- 0.75	- 4.50	5.25	7.25	-10.75	4.00	8.50	- 2.50	1.50	- 9.00
	4		3.75	7.50	- 5.00	8.25	- 5.00	0.00	1.75	6.75	6.75	2.00	- 3.00	0.25
	5		1.50	15.25	7.25	4.00	- 5.25	6.00	- 4.50	3.25	3.50	5.75	- 0.50	0.50
	6		- 6.00	2.50	0.25	- 6.75	4.00	9.00	- 3.75	2.00	3.50	- 9.00	- 2.25	6.25
		μ	0.42	6.58	0.96	0.75	- 1.67	5.46	- 4.04	5.58	2.67	- 2.96	- 0.88	- 0.04
		σ	3.35	6.23	4.75	5.71	4.91	3.03	4.04	3.01	4.93	7.13	1.84	7.01
Grenade A	1		- 5.00	17.00	3.00	10.75	3.00	9.00	5.25	8.25	4.75	9.75	0.75	11.75
	2		- 3.00	7.00	1.00	1.00	- 5.75	14.25	0.25	- 3.00	- 3.50	- 3.50	2.25	5.50
	3		- 4.50	8.00	0.50	8.75	2.75	11.00	- 4.00	- 0.75	8.50	- 2.50	0.25	1.00
	4		9.25	- 3.75	- 2.00	8.50	0.50	13.75	8.50	- 3.75	1.75	12.75	4.25	12.75
	5		- 0.75	3.00	- 1.75	10.25	- 3.25	1.25	- 3.50	- 6.50	4.00	-12.25	1.75	- 3.75
	6		- 0.50	1.50	1.25	10.75	3.25	2.50	1.25	1.00	1.25	-15.50	0.25	- 4.25
		μ	- 0.75	5.46	0.33	5.42	0.08	8.63	1.29	- 0.79	2.79	- 1.88	1.58	3.83
		σ	5.24	7.05	1.91	7.87	3.77	5.58	4.89	5.12	4.02	11.36	1.54	7.43

TABLE 2-O

Hand-Throwable Grenade Test Results at 100 Feet

(Distance from Aim Point in Feet)

	Subject	1		2		3		4		5		6	
	Coordinates	x	y	x	y	x	y	x	y	x	y	x	y
	Trial												
Grenade B	1	-10.00	- 4.50	- 8.50	7.75	- 2.50	- 5.50	9.50	- 9.50	2.50	1.75	1.50	-20.25
	2	- 1.25	- 8.25	-12.50	3.75	5.25	- 0.25	- 5.75	- 4.00	5.00	3.75	2.50	14.25
	3	21.25	- 2.50	2.25	-18.50	10.25	-16.25	- 5.00	6.75	- 4.00	1.50	3.50	- 8.75
	4	3.50	- 1.00	8.25	6.25	1.00	8.25	3.50	- 0.75	0.00	0.00	3.00	- 9.00
	5	9.00	- 3.00	- 2.75	5.50	10.50	- 1.00	- 4.25	1.75	5.50	8.00	2.75	- 0.25
	6	1.00	- 4.75	0.50	-16.50	5.25	0.50	5.00	-19.25	3.00	4.75	6.00	- 7.25
	μ	3.92	- 4.00	- 2.13	- 1.96	4.96	- 2.38	0.50	- 4.17	2.00	3.29	- 3.21	- 2.21
	σ	10.54	2.49	7.51	12.12	5.10	8.12	6.36	9.19	3.54	2.86	1.52	12.60
Grenade A	1	- 1.00	-17.25	10.50	-11.50	1.75	1.25	4.50	14.75	16.50	- 5.00	4.75	- 0.75
	2	7.50	- 4.00	- 3.25	- 8.00	- 4.25	0.25	1.25	- 1.00	- 2.25	- 6.00	0.50	1.75
	3	- 1.50	14.00	12.00	-15.25	- 9.25	- 0.75	0.25	3.00	1.75	-16.00	- 1.50	7.50
	4	- 1.75	15.00	0.75	- 6.25	- 3.50	-13.50	14.25	0.25	- 1.75	- 4.00	2.25	9.50
	5	0.25	- 1.50	1.00	- 7.50	- 1.00	6.25	- 0.50	6.00	1.50	3.00	- 1.00	- 4.75
	6	- 8.00	9.00	1.50	- 6.25	- 1.00	0.50	-12.50	7.00	- 3.25	-14.00	-12.75	15.00
	μ	- 0.75	2.52	3.75	- 7.04	0.21	- 1.00	1.21	5.00	2.08	- 7.00	- 1.29	4.71
	σ	4.96	12.48	6.07	7.29	4.91	6.60	8.63	5.70	7.35	6.99	6.06	7.28

A group of five test subjects was chosen to perform the gun-launch tests. Each of the test subjects was scheduled to fire a total of six of each of the two types of grenades at the simulated window target for each of the two different ranges-60 feet and 100 feet. The firing tests were discontinued for one of the practice grenade types due to the extreme inaccuracy of the practice projectile. The modified test design, giving the series of tests actually performed by each firer, is shown below:

Quantity	Grenade Type	Range (ft)
6	Type A	60
6	Type A	100

The gun-launched grenade tests were performed as described below:

- Each test subject conducted a few practice shots for familiarization.

- The test subject fired six grenades of the one type at the simulated window target from a range of 60 feet.

- After each grenade was fired, impact position on the target was noted. Of primary consideration was whether or not the grenade passed through the simulated window.

- The test procedure was then repeated from the 100-foot range.

- A tally of the results was made (See Table 3-0) giving the ratio of successes-grenade passing through window-to total shots for each test subject, as well as for the combination of shooters, for each test range.

TABLE 3-0

Results of Gun-Launched Grenade Tests for the Practice Grenade

Subject	Range (ft) 60	100
1	5/6	3/6
2	6/6	1/6
3	2/6	2/6
4[a]	-	-
5	5/6	2/6
6	4/6	1/6
All (1-6)	22/36	9/36

[a]Test Subject 4 did not participate in this experiment.