FOREWORD

The work described in this report was performed under Task Plan I of the LEAA/LWL Inter-Agency Agreement No. J-LEAA-IAA-014-72. Mr. Marc A. Nerenstone was the LEAA Program Manager for this task. Mr. Donald O. Egner was the USALWL Project Leader.

The work is reported in two volumes. The first volume contains the general methodology, while the second volume describes the application of the technique to the .38 caliber revolver. Although the .38 caliber revolver is not generally thought of as a less-than-lethal weapon, it can be evaluated using crtieria developed for the evaluation of less-than-lethal weapons (Volume I). Furthermore, it provides a common basis for relative comparison with other less-than-lethal weapons and is a weapon which is familiar to all police and law enforcement agencies.

The work described in this report is "pioneer" in nature and thus subject to considerable change in the immediate future. Comments, data and other information which could improve the methodology described herein are welcome and should be forwarded to LEAA or USALWL.

Finally, 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, the following organizations cooperated in the data gathering for this task:

Maryland State Medical Examiner's Office
Baltimore Police Department
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

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I. INTRODUCTION

Early in 1970, it became apparent that an evaluation technique for so-called less-than-lethal (nonlethal, 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 these less-than-lethal weapons. In addition, very little quantitative data on blunt trauma to the body was 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 was available on electrical shock, but not in a form which would be applicable to the evaluation of less-than-lethal weapons.

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 conducted by the Security Planning Corporation on behalf of the National Science Foundation and the Justice Department[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 USALWL survey work, form the underlying premise for the development of a standardized methodology for the determination of less-than-lethal weapon effectiveness and safety characteristics. It was decided to build the first evaluation model around the blunt-trauma type less-than-lethal weapon. The myriad display of blunt-trauma items and concepts for less-than-lethal weapons for which no evaluation had been performed contributed importantly to this decision. Although the methodology described in this report pertains particularly to blunt-trauma devices, the general concepts and techniques will be adapted and detailed for chemical and electrical weapons at a later date.

[1]Wilsnack, R. W., et al, Comprehensive Law & Order Assistance Research and Development (CLOARAD) Program, Technical Report No. 71-04, US Army Land Warfare Laboratory, March 1971.
[2]Nonlethal Weapons for Law Enforcement, Security Planning Corporation, March 1972.

Although it was felt by many attendees that chemical techniques were of prime interest, the USALWL had initiated an earlier effort to develop methodology for nonpenetrating less-than-lethal weapons. Utilization of this work was instrumental in the selection of kinetic-energy weapons for the prime methodology development. Furthermore, it should be noted that many police agencies do in fact have nonpenetrating kinetic-energy-type weapons at their disposal. Thus, a prime interest exists 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 basic problem in evaluating less-than-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 less-than-lethal weapons; however, they are not presently standardized. Of necessity, the over-all measure of less-than-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 termination (death) and irreversible systemic damage. In addition, safety criteria may be specific as to eye damage, skin penetration, head-area impact energy, etc.

There are several measures which should be investigated for desirable effects. One relatively simple measure is the amount of force generated by impacts at various locations on the body 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 are developing these 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."*

In addition to measures of desirable and undesirable effects, certain realistic and convenient conditions for standardized 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.

*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.

Although some work with the evaluation of .38 caliber rounds has been done by Hatcher and further developed by others[3] and some tests have been run on the undesirable effects of blunt-trauma devices, no general evaluation model for less-than-lethal weapons per se has, to our knowledge, been developed before the one presented herein. Though concern for testing the safety of less-than-lethal weapons has been apparent, the approach to safety testing (without an over-all evaluation plan to provide for the inclusion of the "effectiveness" factor) could possibly 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-than-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. Nevertheless, it appears that less-than-lethal weapons developments utilizing the limited test data available is moving more and more in the direction of "powder-puff" devices.

Finally, 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-Than-Lethal Weapons was sponsored by and held at USALWL on 21 June 1972; a list of those attending is given in Appendix A. [This reference is provided to indicate those individuals and organizations that were planning work in this area at that time.] In addition, many different individuals participated directly in the present program and are listed in Appendix B by working group, background and organization represented.

The ultimate use of the evaluation technique described in this report would be by local police agencies, but 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. However, certain findings from this effort, as given in the summary, could be extremely useful in a culling or screening of the numerous candidate less-than-lethal devices now available on the commercial market.

[3]Cooper, J., Stopping Power Revisited, Guns and Ammo Annual, 1973.

II. SUMMARY OF ACCOMPLISHMENTS

In general, an over-all evaluation technique has been proposed and described. The procedure includes the use of standard scenarios, theoretical and experimental determinations of weapon performance data, and determination of physiological and "nonphysiological" effects, both from a desirable and undesirable effectiveness standpoint. A method is given which combines these elements into simple measures of effectiveness or indices for comparison.

Specifically, blunt-trauma less-than-lethal weapons were considered. Four scenarios were established and described to provide a standard basis for comparison. Theoretical and experimental performance data have been gathered for some general items. "Pain" as a mechanism of effectiveness has been briefly examined and considered to ascertain the desirable effectiveness of these weapons. Criteria for grading damage levels of various organs and body regions have been established to help in determining the undesirable effects of these weapons. A definition of undesirable effects has been stated. General damage criteria were suggested where total impact energies of 15 ft-lb would be considered relatively safe, the region of 30 to 90 ft-lb would be an area of mixed damage results, and above 90 ft-lb would be considered quite damaging. A mathematical model was developed to aid the computation of probabilities of achieving desired objectives through the use of less-than-lethal weapons as well as the determination of associated undesirable effects probabilities.

Finally, the standard .38 caliber police revolver (158-gr bullet) was selected as a basis for comparing less-than-lethal weapons. Application of the proposed evaluation technique to the .38 caliber revolver, along with the establishment of the required input data, is reported in Volume II of this report.

III. TECHNICAL APPROACH

Although various approaches to the problem of evaluating less-than-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" for the .38 caliber revolver. 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:

A. Scenario Selection

B. Weapon/Device Performance Data

C. Physiological Effects Data

D. Nonphysiological ("Other") Effects Data

E. Model Application for a Relative Merit Index.

The relationships of these elements to one another provide an evaluation procedure. These relationships are shown generally in Figure 1 and in greater detail in Figure 2. It should be noted from Figure 2 that the user requirements and the established standards developed by the Mitre Corporation and the National Bureau of Standards, respectively, should have input into the evaluation procedure. The relationships shown when mathematically defined thus constitute the mathematical evaluation model. Although it is desirable to use such a mathematical model to briefly summarize evaluation 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, as given in Figure 1, is as follows:

> A particular scenario is chosen from those described in Appendix C. 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-than-lethal weapon is selected and its characteristics identified. Once the scenario is chosen and the specific weapon characteristics identified, the terminal kinetic energies are calculated and the pertinent data are extracted from the data banks.

A General Concept of an Evaluation Procedure for Less-Than-Lethal Weapons

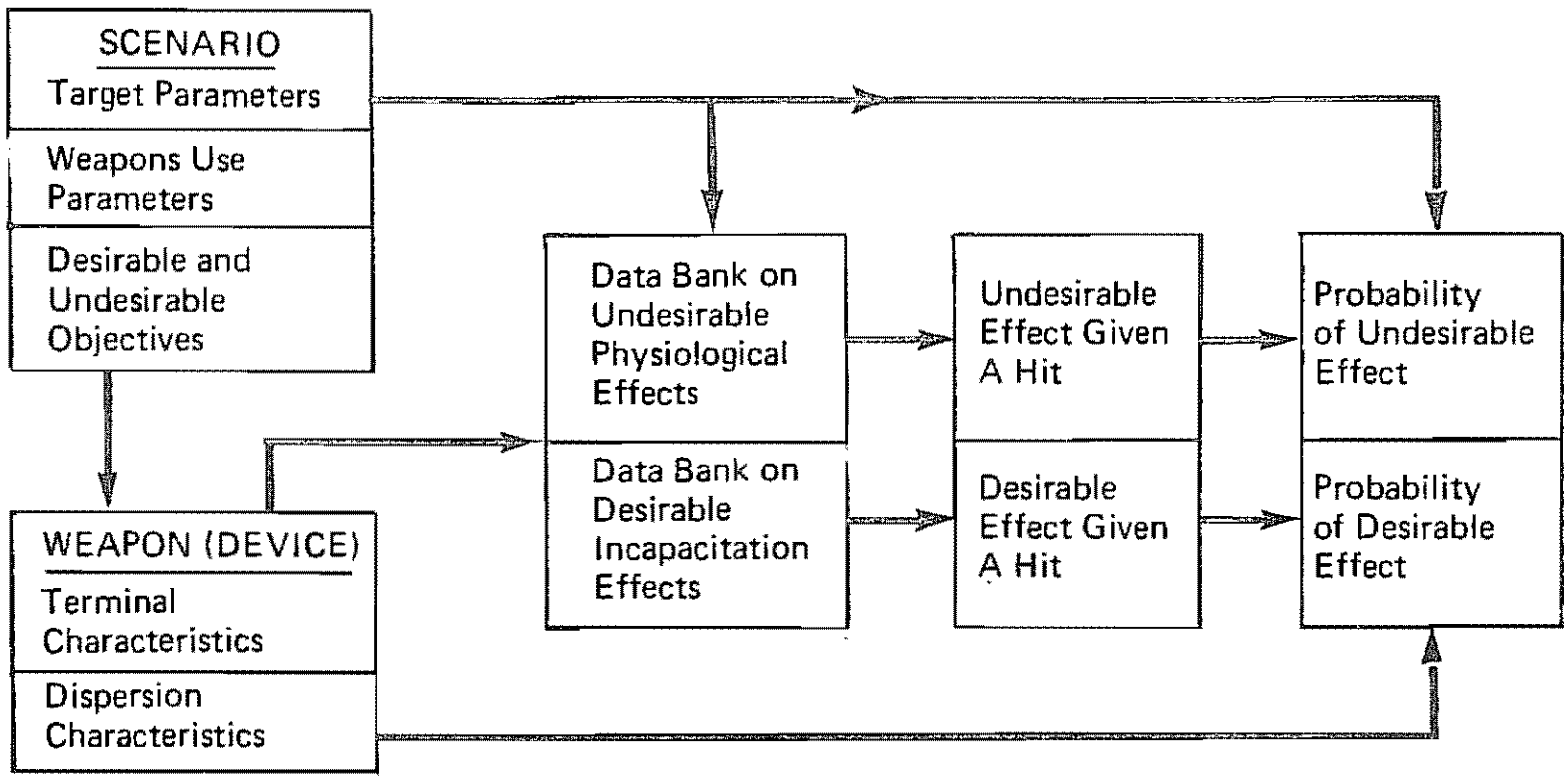

FIGURE 1

DRAFT REPORT

A MULTIDISCIPLINARY TECHNIQUE FOR THE EVALUATION OF LESS-THAN-LETHAL WEAPONS

Volume I

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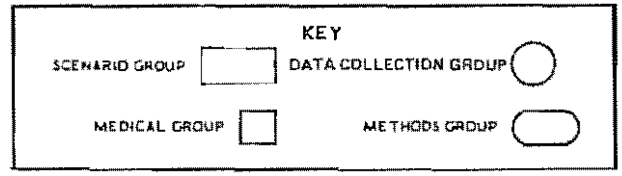
ABSTRACT

The primary program objective was to establish a methodology for determining standardized effectiveness measures of candidate less-than-lethal weapons that utilize kinetic energy damage mechanisms. A two-parameter measure of effectiveness determining desirable and undesirable effects produced when a given weapon is used against a defined target associated with a standard scenario is proposed.

A specific two-parameter data bank was developed for projectiles employing the blunt-trauma damage mechanism and also for the .38 caliber round. The blunt-trauma data bank was generalized for model application and the .38 caliber data was exercised in the evaluation model generated under this program.

A secondary, but equally important, program objective was to point out areas where further effort is required to provide a more comprehensive assessment of less-than-lethal weapons than could be done in the time and funding limitations of this program.

DETAILED CONCEPT FOR AN EVALUATION PROCEDURE FOR LESS-THAN-LETHAL WEAPONS



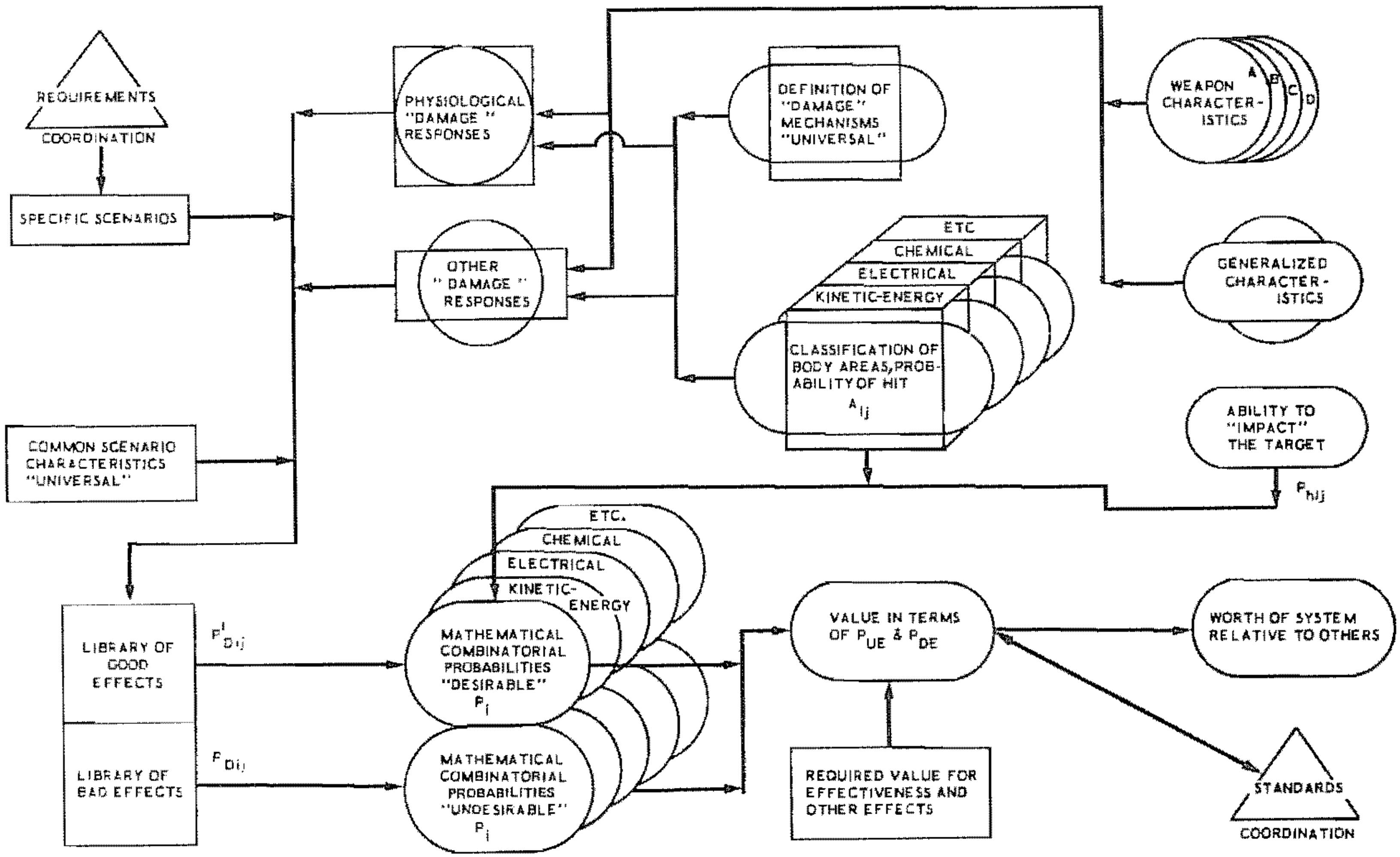


FIGURE 2

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-than-lethal weapons. A summary of the steps of evaluation coinciding with the fund expenditure available for an evaluation is given in Table I.

To assist the development of this evaluation procedure, a Less-Than-Lethal Weapons Evaluation Panel was established (See Appendix B for Panel make-up). Key members of this Panel had prior experience on a similar panel established under an earlier USALWL project[4]. The Panel was responsible for providing:

A. An over-all 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

E. A model for exercising the data in order to obtain quantitative performance estimates of specific less-than-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-than-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 Figure 3. 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 four basic scenarios (details provided in Appendix C) which would depict some situations likely to confront civilian control forces.

The Methods Group originally was primarily concerned with establishing the validity of the basic over-all evaluation technique. As work on this task proceeded, the group's primary objective changed. It then was utilized to

*In terms of probability of a hit (The techniques for determining these are presented in Appendix G.)

[4]Zelina, R. S. and Egner, D. O., Incapacitation Probabilities of Magnesium-Teflon Incendiary Pellets (U), Technical Report No. LWL-CR-08-RAB, US Army Land Warfare Laboratory, July 1970.

TABLE I

STEPS OF EVALUATION AS A FUNCTION OF FUND/EFFORT EXPENDITURES

A. Weapon Performance

1. Theoretical determination of trajectories, velocities, kinetic energies, and target (total and organ system) hit probabilities as a function of range.

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

B. Physiological Effects

1. Estimation of damage levels from similar type data.

2. Tests to determine actual damage levels for various body organ systems.

3. Monitoring of other physiological responses, e. g., by EKGs, 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. Method 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.

Less-Than-Lethal Evaluation Panel Groups

LEAA SCENARIO

Police Consultant
Police Officer
Operations Research Analyst
Political Scientist
Engineer/Lawyer
Physicist

METHODS

Operations Research Analyst
Pathologist (D.V.M.)
Physicist
Psychiatrist (MD)
Research Scientist
Psychologist
Political Scientist
Engineer

MEDICAL

Pathologist (D.V.M.)
Physiologist
Physicist
Forensic Pathologist (MD)
Plastic Surgeon (MD)
Engineer
Surgical Neurologist (MD)

MODEL

Operations Research Analyst
Mathematician
Mathematics Technician
Engineer

DATA COLLECTION

Mathematician
Pathologist
Physiologist
Mechanical Engineer
Mathematics Technician
Bio-Engineer
Engineer
Physicist

FIGURE 3

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. Background information concerning some workings of this group is presented in Appendix D in the form of informal notes from some of the meetings of the group.

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 in test animals were stressed. Some minutes of the Medical Group meetings are presented in Appendix E; however, results applicable to the over-all evaluation technique are summarized in the next section of this report.

The Model Group provided the mathematical portion of the effort. This included 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-than-lethal weapons. The over-all evaluation mathematical model utilized is discussed in some detail in Appendix F. A specific mathematical model used to determine hit probability is given in Appendix G.

The Data Collection Group was of prime importance because so little quantitative data had been generated on less-than-lethal weapons. This group conducted literature searches on blunt trauma effects (Appendix H) and on quantifying pain (Appendix I). The group also organized the data obtained from experiments involving the testing against animals of various weapons used in this project; and they collected, collated and analyzed data from various sources concerning the lethality/nonlethality of so-called nonlethal weapons, including especially the .38 caliber revolver.

IV. DISCUSSION OF THE ELEMENTS OF EVALUATION TECHNIQUES

The study approach lists the five key areas in the proposed evaluation of less-than-lethal weapons. In this section several of these key areas will be discussed in detail.

A. 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-than-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.

Four scenarios have been detailed for use in the evaluation process and are discussed in Appendix C (The initial set of characteristics used to describe all four scenarios are summarized in the last table of that appendix.). By title, the four scenarios are:

1. Scenario I - The One-On-One Situation

2. Scenario II - The Barricade and Hostage Situation

3. Scenario III - The Suspect Fleeing on Foot

4. Scenario IV - The Dispersal of a Crowd.

There were three criteria involved in selecting the inventory of four 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 have been received that the scenarios are too limited and that other situations should be included, e.g., scenarios involving automobiles, prison situations, 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 may be included at a later time. However, the criteria that the scenarios should be limited in number is based upon the Army 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 is not too time-consuming, the over-all 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 was needed, e.g:

1. Distance between the police and the subject

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

3. Allowable 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.

B. Weapon Performance

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

1. Accuracy

2. Muzzle Velocity

3. Projectile Weight

4. Projectile Drag

5. 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 evaluation needs become more stringent, additional information (such as projectile-target compliance) 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) if the target is hit, and those which determine if 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 LWL program has 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 is 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 II 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 III presents the muzzle velocities/energies needed for a 1-inch diameter sphere launched at a 5° 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 four scenarios described in Appendix C. 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 II and III 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 is specific and because the information is of general interest to individuals involved with less-than-lethal weapons. It was suggested by Mr. Burton Katz* 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 IV. The complete test data, including explanation of test procedures, etc., are being published in USALWL Technical Note format; however, some results of the tests are summarized in Table IV.

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 the whole subject of the next section of this report.

*Mr. Katz has been instrumental in establishing the Los Angeles County District Attorney's Less-Than-Lethal Weapons Task Force. The work of this Task Force has been closely coordinated with the LWL effort, primarily through the concurrent participation of several members of the LWL Evaluation Panel on various committees of the Los Angeles Task Force.

56,5

TABLE II

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	205	96	9.1	1.6	315	99	9.7	2.1				
	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 III

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	117	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

TABLE IV

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*
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	--

*Simple experiments performed by another Government agency indicate little penetration damage at these velocities and energies except to the eyes and the ear canals.

C. Measures of Effect - Physiological Basis

Much of the blunt-trauma literature examined by personnel on this project was oriented toward head injuries. Appendix H 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. LWL's rough 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 can, of course, only be studied by more extensive testing. However, it was felt that gross estimates could be given initially.

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. Essentially, it was a policy of "shoot and see." 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 going to the expense of animal tests. It would have been academically honest to use this approach, but it was not done for two reasons: (1) it was difficult to convince a qualified investigator to extrapolate the models and existing data for these purposes, and (2) it was known that confirmatory firings against biological specimens would be needed eventually anyway. Hence, it was decided to pursue the concept that a given weapon could be evaluated with a set of firings. The evaluation plan to be recommended by LWL would state just how extensive such firing tests would be, depending on the allowable effort (both time and money) to be expended on the evaluation.

Once the decision was made to perform these tests, a procedure had to be established for evaluating the results of the firings. During the examination of firing information, two separate but related procedures evolved. The simpler procedure consisted of determining physiological damage grade levels whereby various levels of tissue disruption (resulting from the insult of blunt trauma) were assigned numbers 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 J. For a particular organ, the levels ranged from 0 through 5, where 1 indicated some minimal signature of the insult, 5 represented a massive local disruption of tissue, and 0 represented no signature whatsoever.

To date, different grading scales have been established for the following eight 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).

A ninth grading scale (Heart) has been set up but was not finalized at the time of preparation of this report. It is interesting to speculate on why the Medical Group delayed in establishing heart damage criteria. As noted in the introduction to Appendix J, the purpose of the grade level definitions is to provide a consistent basis for assessing damage to wounded body regions or organs. However, from the over-all 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 received by the test animal. However, the assignment of a grade level to all critical portions of the body after an impact did not 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 was that there was no certainty as to the consistency of a consensus judgment estimate, but 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.

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.

Obviously, the adjectives "less-than-lethal" or "nonlethal" are not well-suited to devices evaluated under this criteria. "Low-hazard devices" would possibly be a better descriptor of weapons in this whole area of interest, but terms once-established are difficult to change. Furthermore, all persons concerned with these devices and the evaluation of these devices should recognize that a real understanding of the area is not achieved by the precision of a title. The real issue is whether undesirable effects of "less-than-lethal" weapons should include loss of functional capability of the subject or should be restricted to the probability of death. It is assumed in the LWL 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 concerned the "effects" data. The problem arose in trying to relate the terminal effects parameter to the probability estimated for obtaining desirable and/or undesirable effects. The probability assignments made to date have been estimated by well-qualified members of both the Methods and Medical Groups. The Methods Group was concerned mainly with the desirable effects, while the Medical Group originally concentrated on the undesirable effects. However, 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. View necropsy slides and tissue samples from animal tests for a particular physiological damage level. (Grade according to the damage criteria given in Appendix J.)

3. Discuss the probable effect of a similar wound on a human target and render 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 animal test.

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 wound was such that it clearly stopped 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 effect, as determined by the Medical Group, were based upon the ability of an individual to function. Hence, 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 tended to be highly effective from a desirable standpoint also tended to produce considerable unwanted, undesirable effects.

Much of the above discussion becomes more meaningful when it is related to the specifics of actual test data described below. But before the specific results of tests are presented, one additional point should be made. It was the intention of all groups of the LWL Less-Than-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.

The LWL test results presented herein were obtained from firings conducted at Hazelton Laboratories, whose primary responsibility was to provide facilities and care and handling of the animal subjects. Experimental Pathology Laboratories, Inc. was responsible for the necropsy work and, together with Hazelton Laboratories, provided the pathology report on each test series. AAI Corporation was the prime contractor on the effort and was responsible for the projectile-launching equipment, its instrumentation, raw data analysis and preparation of tests reports. The entire animal testing effort was under the direction of LWL's staff physiologist.

After a series of deliberations, the Medical Group selected the experimental animals, swine (shoats) for the body tests and baboons for the head tests. The selection was based on the premise that the cranium of the baboon, although somewhat dissimilar to the cranium of a human, was more similar anatomically speaking than the cranium of a goat. Swine (shoats) were chosen in order to observe primarily the effects of blunt-trauma injury on the cutaneous, subcutaneous and underlying muscle areas. At 10 to 11 weeks of age, swine skin and the corresponding reaction to trauma is very similar both from histological and pathological points-of-view to that of a human. The Medical Group felt that goat skin with its various thicknesses, elasticities, and anatomical as well as histological variables did not represent an ideal experimental animal for this type of testing.

The over-all test set-up consisted of a helium gas launching system, low-lethality ammunition, velocity-measurement equipment, high-speed photographic coverage, and the test animals in their appropriate restraining harnesses. Details of the conduct of the test, such as preparation, anesthetization, and sacrifice of the animals, will not be discussed in this report; however, the Principles of Laboratory Animal Care were followed. Some detail on procedures of animal handling and other details of test conduct, such as helium gun calibration and velocity data reduction, are available in individual test reports from AAI Corporation and will be issued later as LWL Technical Notes.

Many tests were conducted using a 1-inch rubber ball projectile. Test series I and II were conducted under a previous US Army program; series III was conducted under this project. However, since all test series were conducted in the same manner, the data are treated together. The number of shots in each test series is given below:

Test	Head Shots	Body Shots
Series I	4 (baboon)	21 (goats)
Series II	18 (baboon)	18 (swine)
Series III	7 (baboon)	19 (swine)

Before discussing the results of these tests, a brief discussion of the test analysis procedure is in order. A veterinary pathologist (Experimental Pathology Laboratories, Inc.) was present at the conduct of all tests. If the subject animal died as a result of the impact, the veterinary pathologist performed a necropsy just after the death of the animal. If the animal did not die within 24 hours, then the animal was sacrificed 24 hours after impact and a necropsy was performed at that time. During the conduct of the necropsy, 35mm color photographs were taken at various stages of the surgical intrusion, i.e., photographs were taken of:

1. The surface appearance prior to intrusion
2. The subcutaneous level
3. The muscular level
4. The organ level (organ in place)
5. The organ itself when removed from the carcass
6. Any gross anomalies in the organ.

Also during the conduct of the necropsy, the veterinary pathologist provided a description of the wounded region and made a preliminary grading of all organs/body tissues in the vicinity of the wounded region. The test report was then written based upon all information up to that point. After the test report and 35mm slides were available, a Medical Group meeting was called and the veterinary pathologist who had performed the necropsies discussed each wound.

At this time, the preliminary damage grades were reviewed and final grades assigned and approved by the Medical Group. As time permitted, the Medical Group would then assess probabilities of undesirable effect and probabilities of desirable effect for scenarios of interest.

The results of the rubber ball tests, presented as damage level vs kinetic energy, are given in Figures 4 through 9. Since all tests were conducted with the same projectile, the results could also be presented as a function of velocity. However, since similar test information is available on entirely different projectiles, it appears more meaningful to discuss the response of the various organs in terms of kinetic energy. For example, almost all of the 1-inch ball velocities were in the region of 160-500 feet per second (kinetic energies of 10 to 100 ft-lb), whereas most of the other applicable information is on heavier, lower-velocity projectiles, but which have much the same kinetic energy values as the 1-inch balls.

An examination of Figure 4 (grade level vs kinetic energy for skin, subcutaneous tissue and muscle) indicates a fairly reliable linear relationship between increase of grade level and increase of kinetic energy. For example, there is only one Grade 3 (deep-seated bruise) between 10 and 20 ft-lb of energy. Only three out of 14 impacts were less than severe (Grade 5) for impacts between 90 and 100 ft-lb. A certain amount of caution must be exercised in interpreting the extremely-high-energy impacts with the 1-inch ball; since the energy per unit area is considerably higher than with a larger missile of equivalent total energy, and skin penetration is certainly a function of energy per unit area. However, the pattern of Grades 3 and 4, which preclude skin penetration, also indicates a linear relationship between skin damage and kinetic energy.

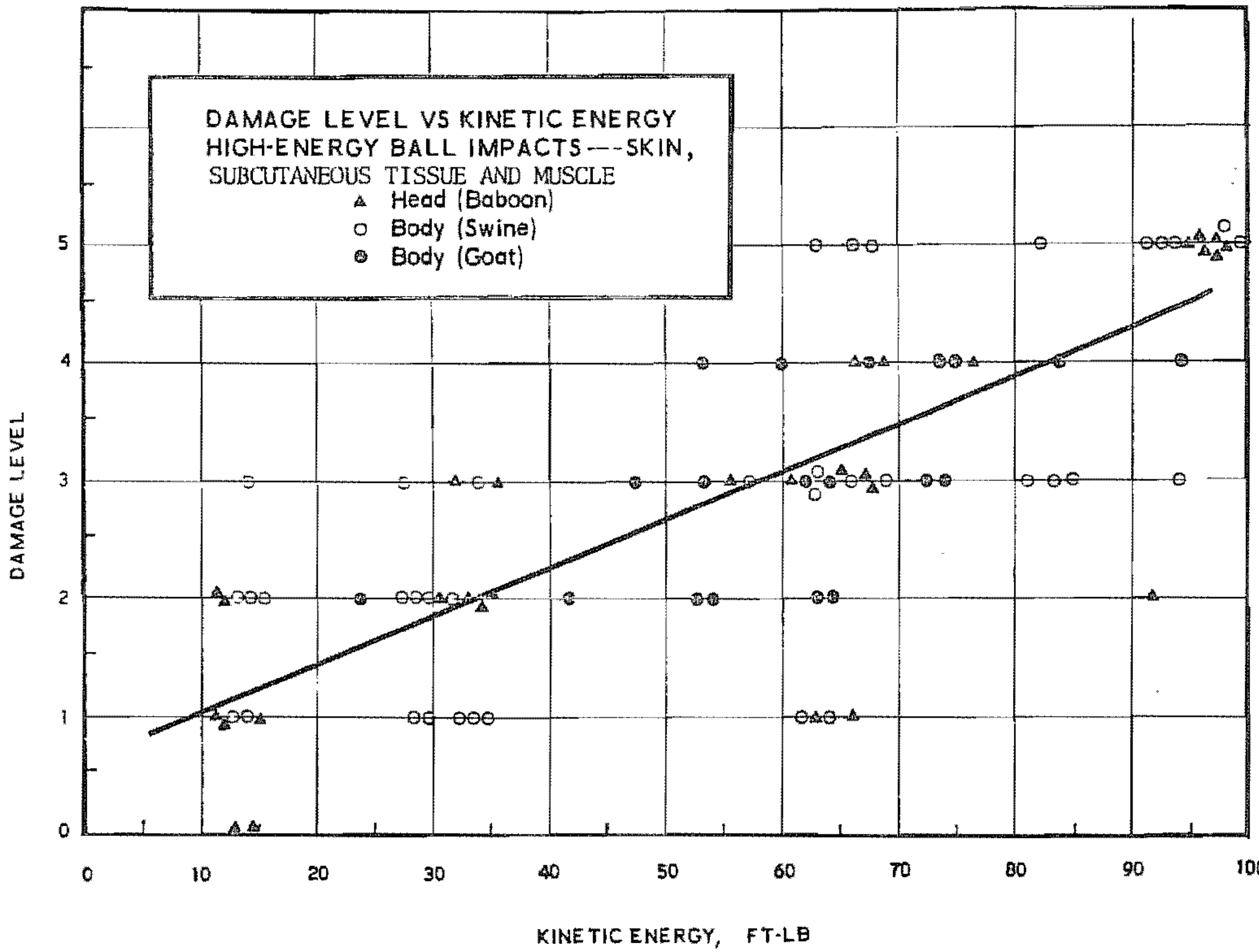
The data on the kidney and the liver (Figures 5 and 6) present a much less clear picture. However, they do present an indication that the kidney and the liver are somewhat less vulnerable than the head (Figure 9). The two Grade 5 liver wounds in the 65 ft-lb region are not sufficient to draw any really meaningful conclusions on extremely hazardous bounds for the energy of missiles impacting on the liver.

The data on the spleen (Figure 7) is obviously much too sparse to draw any but the simplest conclusions. One could infer that the spleen is relatively invulnerable to rubber ball impacts based on the four data points taken to date.

Data on the thorax/heart systems (Figure 8) show a fairly consistent relationship with the exception of the one swine-heart, Grade-3 data point at 28 ft-lb of energy.

The data in Figure 9 on head shots do not present a clear picture of the functional relations between energy and damage, but a rather clear set of bounds are established by this data, i.e., below 20 ft-lb impacts appear to be innocuous and above 90 ft-lb impacts are consistently hazardous.

One can view the data obtained to date as valuable 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.



DAMAGE LEVEL VS KINETIC ENERGY
HIGH-ENERGY BALL IMPACTS---SKIN,
SUBCUTANEOUS TISSUE AND MUSCLE
Head (Baboon)
Body (Swine)
Body (Goat)
DAMAGE LEVEL
0
1
2
3
4
5
0
10
20
30
40
50
60
70
80
90
100
KINETIC ENERGY, FT-LB

FIGURE 4

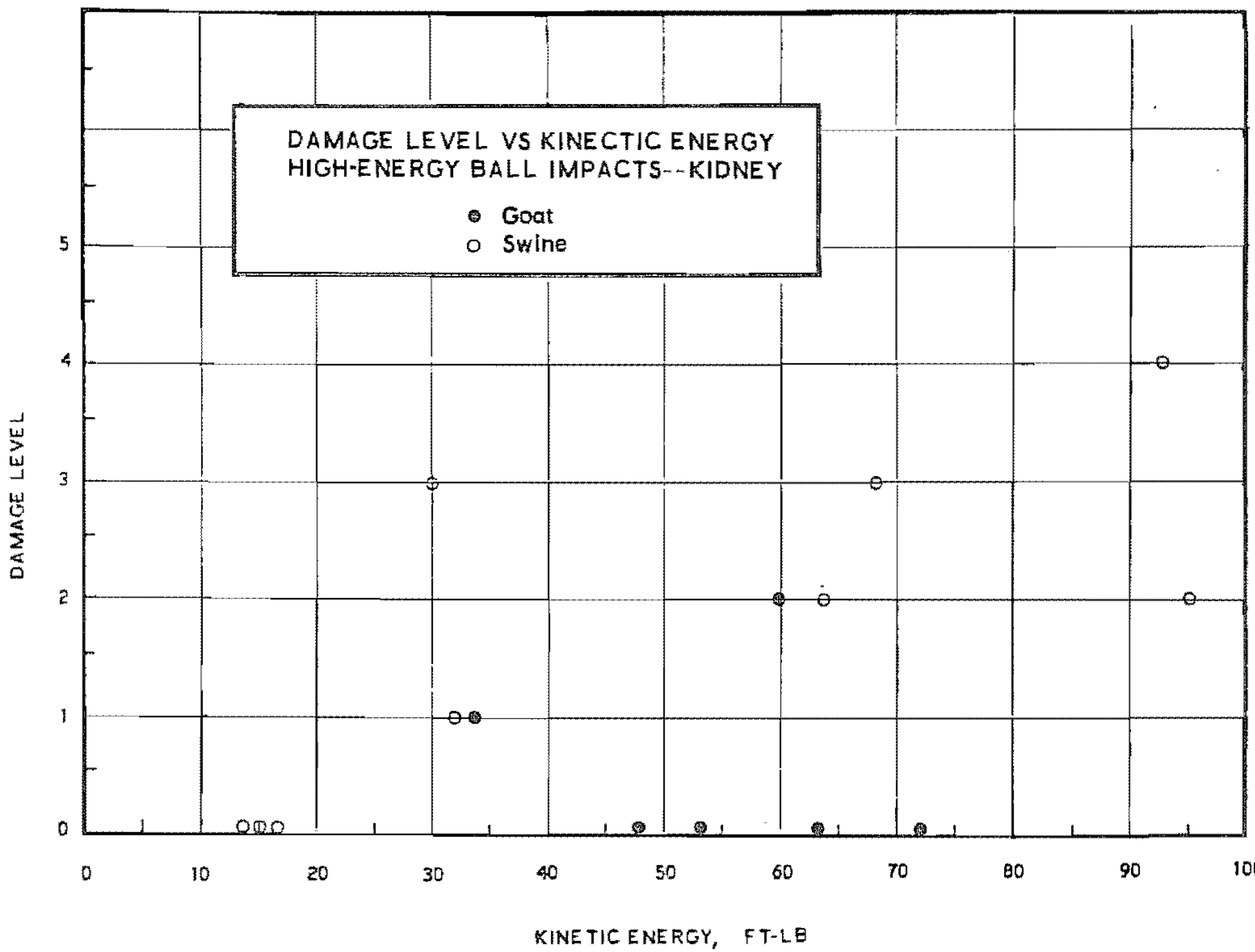

DAMAGE LEVEL VS KINECTIC ENERGY
HIGH-ENERGY BALL IMPACTS--KIDNEY
Goat
Swine
DAMAGE LEVEL
0
1
2
3
4
5
0
10
20
30
40
50
60
70
80
90
100
KINETIC ENERGY, FT-LB

FIGURE 5

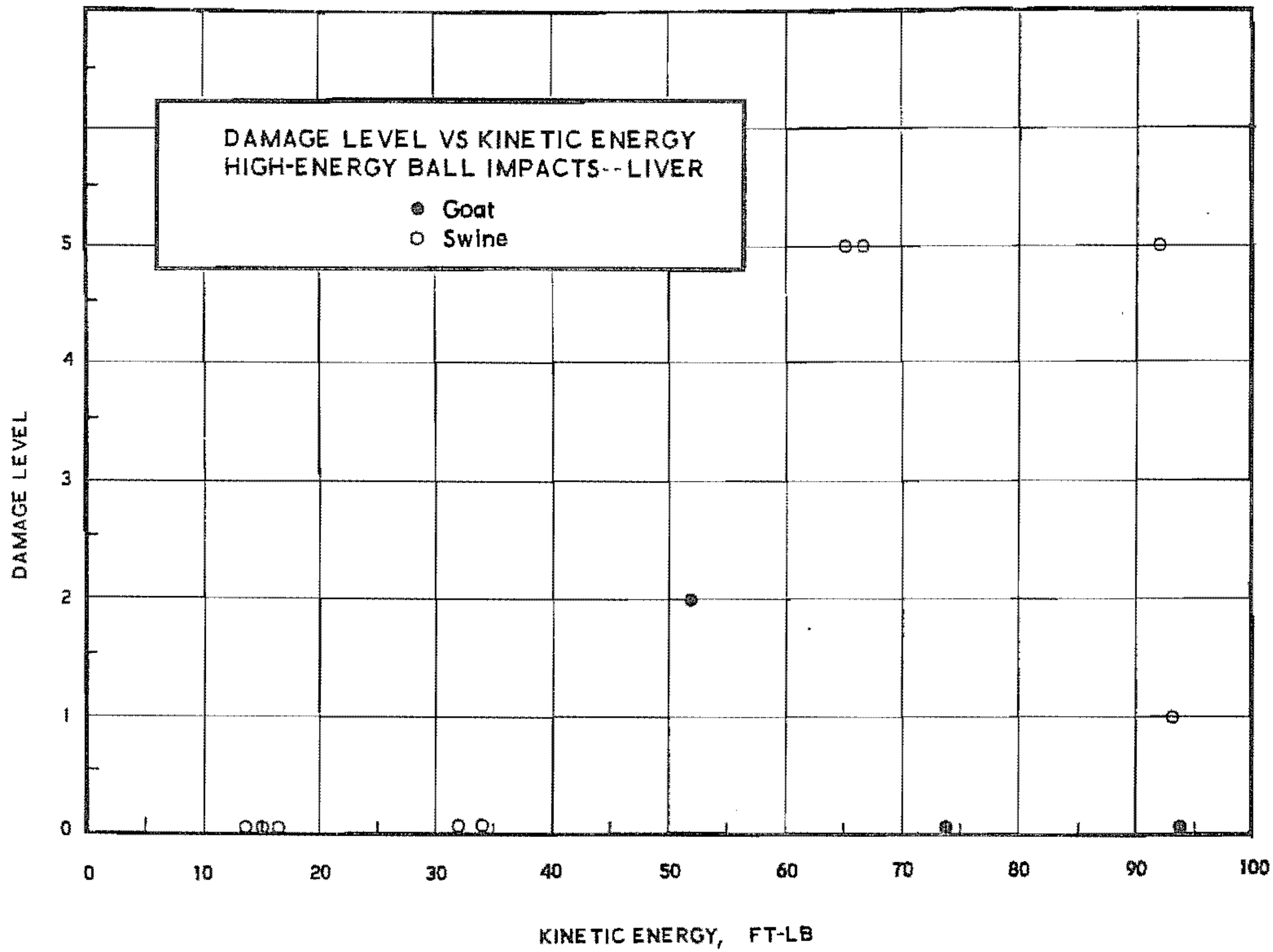

DAMAGE LEVEL VS KINETIC ENERGY
HIGH-ENERGY BALL IMPACTS--LIVER
Goat
Swine
DAMAGE LEVEL
0
1
2
3
4
5
0
10
20
30
40
50
60
70
80
90
100
KINETIC ENERGY, FT-LB

FIGURE 6

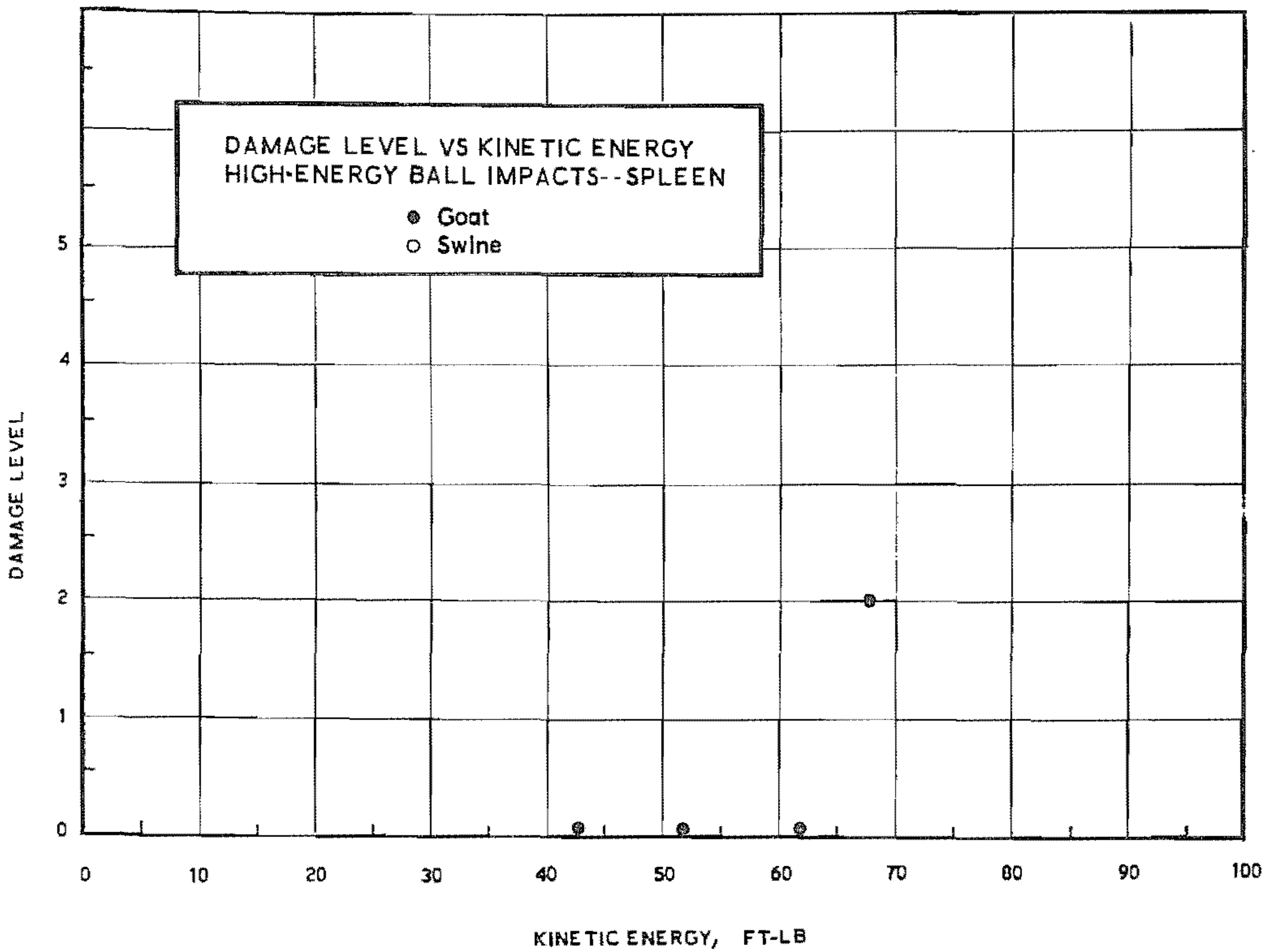

DAMAGE LEVEL VS KINETIC ENERGY
HIGH-ENERGY BALL IMPACTS--SPLEEN
Goat
Swine
DAMAGE LEVEL
0
1
2
3
4
5
0
10
20
30
40
50
60
70
80
90
100
KINETIC ENERGY, FT-LB

FIGURE 7

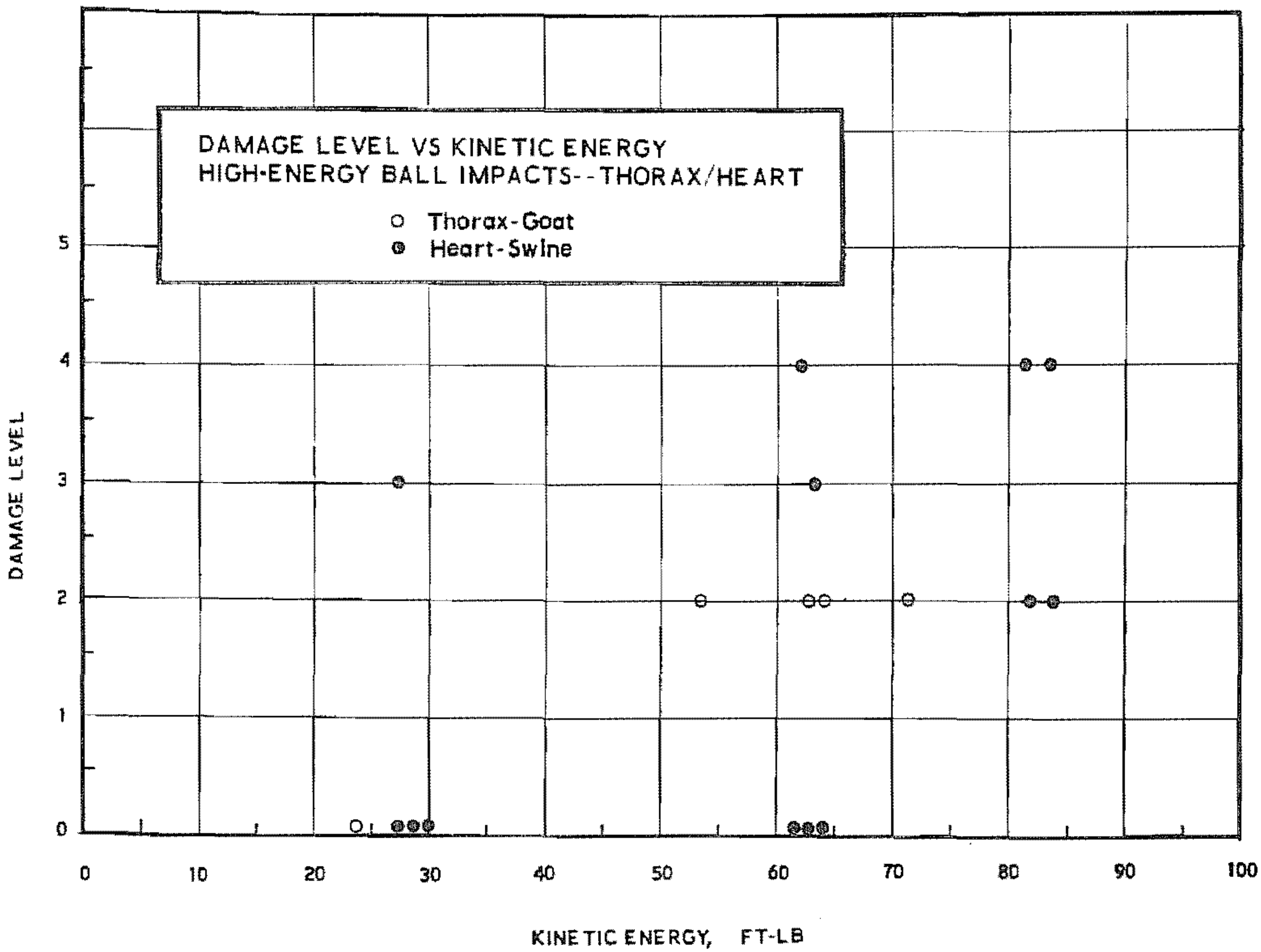

DAMAGE LEVEL VS KINETIC ENERGY
HIGH-ENERGY BALL IMPACTS--THORAX/HEART
Thorax-Goat
Heart-Swine
DAMAGE LEVEL
0
1
2
3
4
5
0
10
20
30
40
50
60
70
80
90
100
KINETIC ENERGY, FT-LB

FIGURE 8

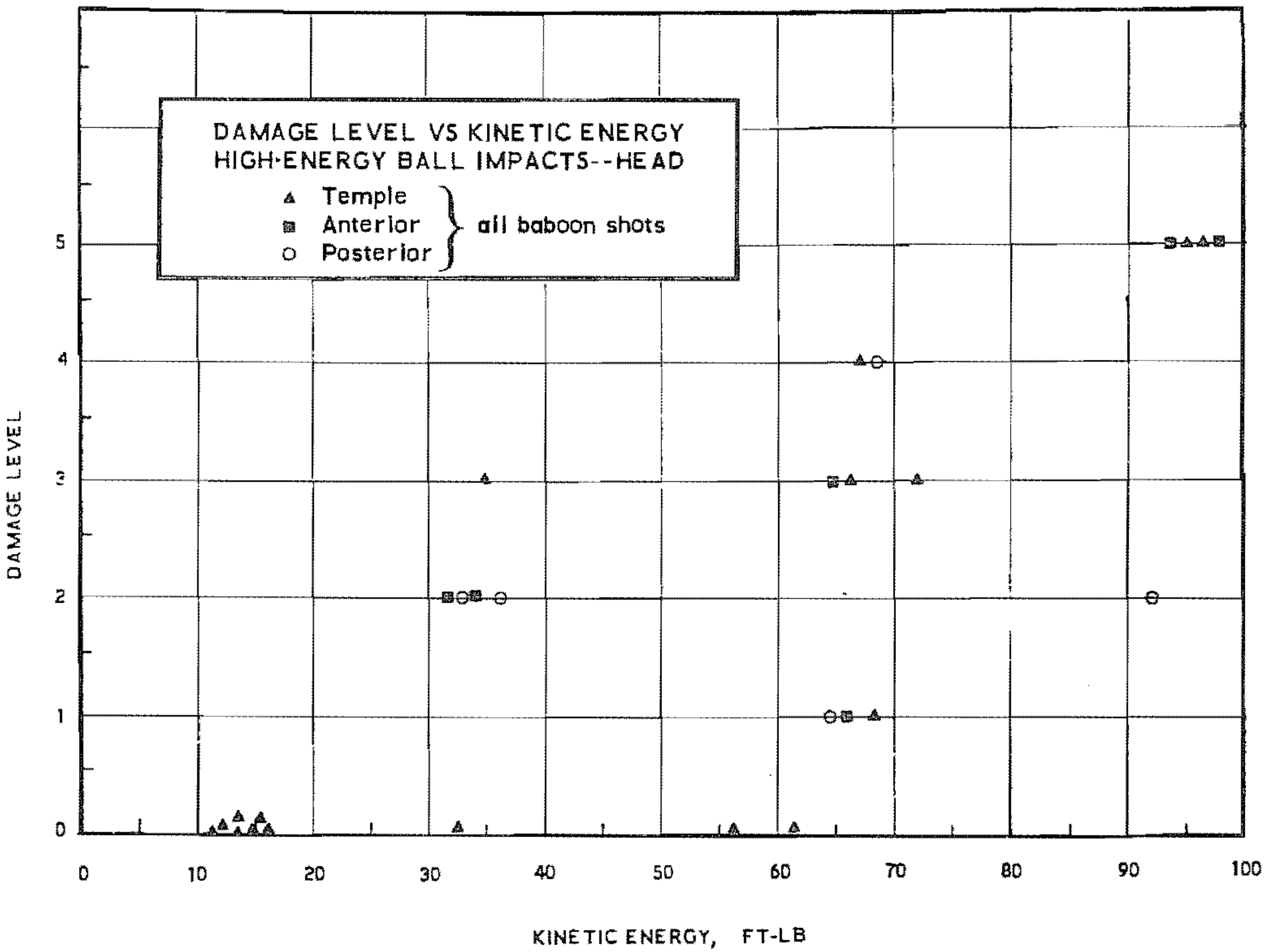

DAMAGE LEVEL VS KINETIC ENERGY
HIGH-ENERGY BALL IMPACTS--HEAD
Temple
Anterior
Posterior
all baboon shots
DAMAGE LEVEL
0
1
2
3
4
5
0
10
20
30
40
50
60
70
80
90
100
KINETIC ENERGY, FT-LB

FIGURE 9

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. However, the most significant aspect of the LWL data is evident when it is examined in conjunction with data from other sources. An example of an additional data source is the work done by the Biophysics Laboratory at Edgewood Arsenal and reported in a letter report entitled "Bean Bag-Hazards Study," released 8 September 1972. LWL had access to the information on the individual shots in this test series and did an approximate grading of these shots according to the LWL grading criteria. It should be noted that the Edgewood tests used a 0.3 pound bean-bag missile, approximately 12 times heavier than the 1-inch rubber sphere of the LWL tests. 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; hence, 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[5].

Considering the lack of simple guidelines on damage due to blunt trauma, therefore, 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. The table below gives these criteria in both the English and metric systems.

	Severe Damage	Zone of Mixed Results	"Safe"
English	90 ft-lb	30 ft-lb	15 ft-lb
Metric	122 joules	40.7 joules	20.3 joules

[5]Clemedson, Hellstrom and Lindgrim, "The Relative Tolerance of the Head, Thorax and Abdomen to Blunt Trauma," Annals of the New York Academy of Sciences, Vol 152, Art 1, pp 187-198, 1968.

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 at this time. 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 are continued, there will undoubtedly be percentage estimates of damage level as a function of kinetic energy such as those given in Figure 10. A presentation such as Figure 10 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 thence the probability of undesirable damage could be determined as a function of range.

Alternatively, the basic data could be used directly by plotting the over-all estimated undesirable effect (using the 24-hour criterion) as a function of impact condition, such as kinetic energy. Again, it is noted that for a particular less-than-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 11 gives the probability of undesirable effect as a function of kinetic energy for the 1-inch ball Series II and III tests. The points plotted on the graph 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 11 tends to give further support to the 15, 30, 90 ft-lb tentative criteria, although some caution should be taken since this data is all from the 1-inch ball tests.

It is fairly obvious that additional tests should be run to better establish the damage level measurements of body response to blunt trauma. Similarly, the judgment 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).

D. Measures of Effect - "Nonphysiological" Basis

A problem which arose in the determination of probability estimates relates to the 'use' of the weapon to be evaluated. The model for evaluating the effectiveness of less-than-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

ESTIMATED PROBABILITY OF A DAMAGE LEVEL AS A FUNCTION OF KINETIC ENERGY
(SKIN, SUBCUTANEOUS TISSUE & MUSCLE)

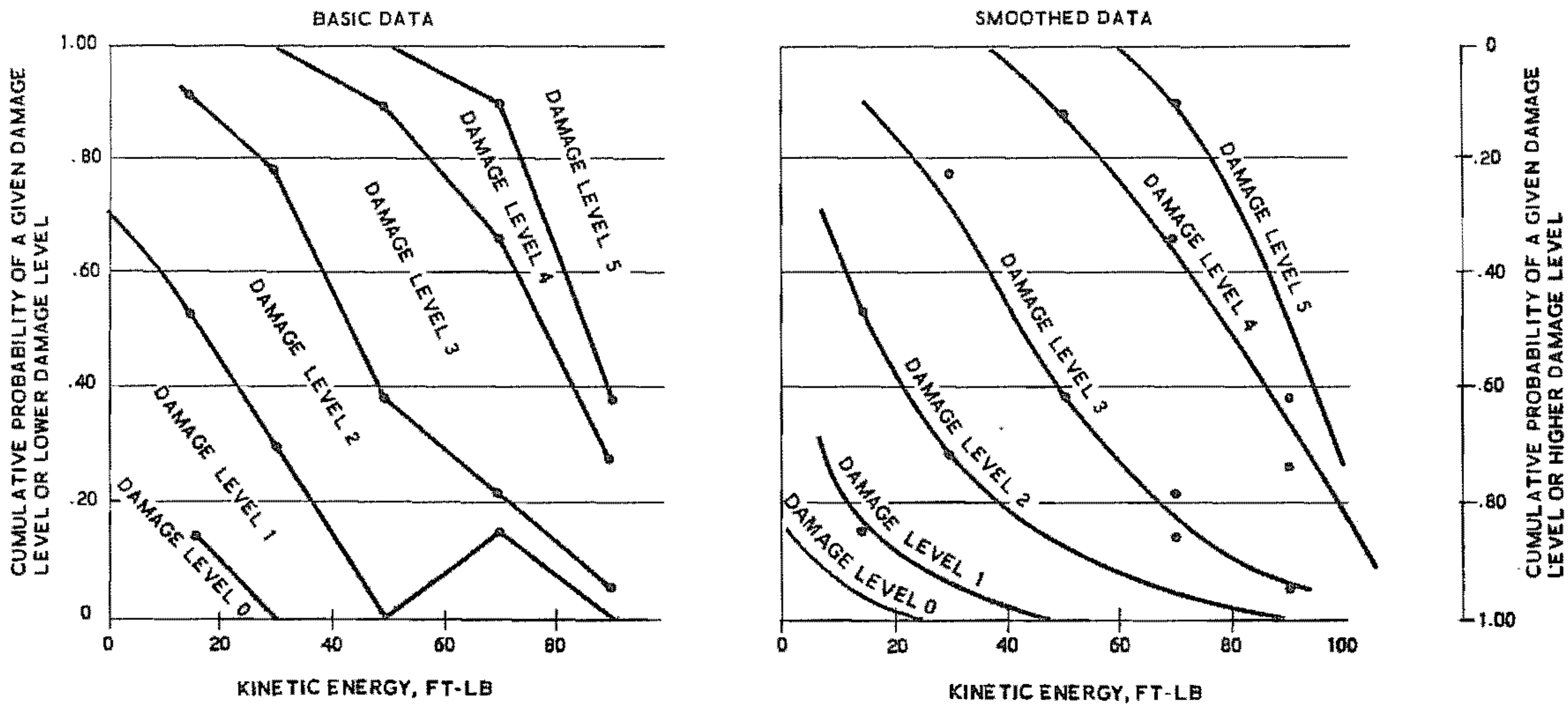


FIGURE 10

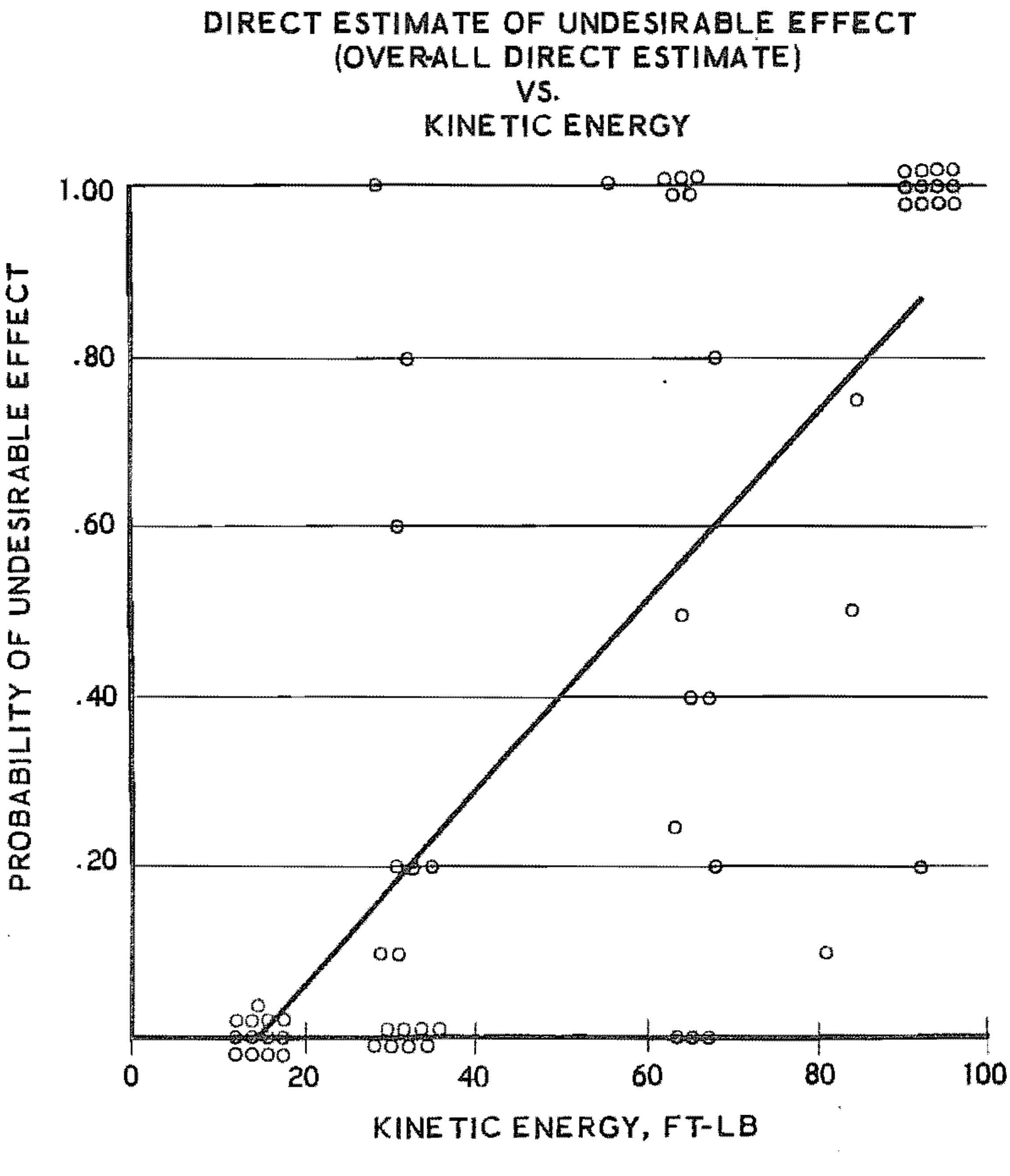

DIRECT ESTIMATE OF UNDESIRABLE EFFECT
(OVER-ALL DIRECT ESTIMATE)
VS.
KINETIC ENERGY
PROBABILITY OF UNDESIRABLE EFFECT
1.00
.80
.60
.40
.20
0
20
40
60
80
100
KINETIC ENERGY, FT-LB

FIGURE 11

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 as targets, the indicated effects also apply to observers. However, 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 (Disposal 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 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 over-all model to include weapon display and threat effects.

There are many terms to describe "nonphysiological" effects of less-than-lethal weapons. Cooper[6] and others in the popular press might call this "stopping power." Still others might call it "shock." 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[7]. 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 <u>desirable</u> 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

[6]Cooper, J., op cit

[7]Block, E., el al, Introduction to a Biological Systems Science, NASA CR 1720, February 1971.

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-than-lethal weapons in terms of behavorial 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 we would further assert 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-than-lethal weapons.

The undesirable effects are discussed in some detail in the previous section 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 LWL evaluation is the establishment of scenarios or "model" situations in which the various less-than-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.

55,1 This initial effort of evaluation, as it relates to a pain mechanism, is oriented toward the assessment of pain induced by impacting, nonpenetrating missiles. However, progress in understanding the nature of MACE, tear gas, etc. has been made by considering the mechanisms of desirable effect through mechanisms which induce discomfort in forms other than 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-than-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-than-lethal weapons investigations. To be more specific, experimental pain rather than pathological pain will be examined. In experimental pain, the direct causal 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.

In this effort, both pain threshold and pain tolerance will be discussed. Geldard[8] describes threshold pain as "the point at which a pressure tap becomes a pricking stab." In the 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% of the time. Pain tolerance is near the opposite end of 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 present program.

The only reason that LWL found a need to conduct any pain experimentation was that no quantitative information in the literature on experimental pain induced by an impact stimulus could be found. A literature survey on "pain" was conducted and the results are presented in Appendix I. Most of the literature on experimental pain is either on pressure stimuli or heat stimuli, with some information on electrical stimuli. Before 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 mc/sec/cm^2 with considerable latitude on the area affected[9]. For a pressure stimulus, the threshold is roughly 2kg/cm^2.[10] There are certain problems associated with electrically-induced pain[11], 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

[8]Geldard, Frank A., The Human Senses, John Wiley & Sons, Inc, 1972.
[9]Hardy, Wolff and Goodell, Pain Sensations and Reactions, Hafna Publishing Co, 1952.
[10]Keele, K. D., The Pressure Algometer, The Lancet, March 1954.
[11]Clark, James W. and Bindra, Dalbir, Individual Differences in Pain Thresholds, Canadian Journal of Psychology, Vol 10, No. 2, 1956.

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.[8,11]

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-than-lethal devices is that the alarm system can be predictably activated with energies that are sub-hazardous.

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 hazard) 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 - .132 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, if an individual is subjected to a graduation of pressure taps, as the intensity of the taps increases,

[8]Geldard, Frank A., op cit
[11]Clark, James W. and Bindra, Dalbir, op cit

the sensation changes from an innocuous pressure and at some point 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 Table V.

TABLE V

RESULTS OF PAIN THRESHOLD TESTS

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

$$v^2 = 2gh,$$

where, v = velocity

g = 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 threshold. 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.

Before addressing the more fundamental problem of pain or threat of pain as a motivational factor, one should recognize some of the limitations of the pain data derived from the LWL experiment. First, 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.

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 Methods Group was asked to make quantitative estimates of the effects of devices whose primary mechanism is pain. At present, very few positive results have been achieved. One of the basic problems is how to invoke a behavior pattern in humans with a simple stimulus (viz., a stimulus that is known to be painful). The Methods 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.[12]

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 Methods 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

[12]Leukel, Francis, Introduction to Physiological Psychology, The C. U. Mosby Co, 1972.

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.[13]

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-than-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 generally 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 has not progressed to the point where this has been set down in a quantitative manner, the deliberations of the Methods 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 Methods Group of the over-all Less-Than-Lethal Weapons Evaluation Panel, it has been 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.

[13]Department of Biological Instrumentation, Incapacitating Criminals by Nonpenetrating Impact, The Lovelace Foundation for Medical Education and Research, Albuquerque, NM, 10 April 1972.

The foregoing is based, of course, on the premise that pain is a readily quantifiable mechanism 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. However, 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 12. (The following notes refer to the circled letters in Figure 12.)

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

2. Note b. One experimenter[14] 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 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 12 might be somewhat 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 12 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).

Although the foregoing discussion indicates the "pain" ballpark to us, its application to a specific device has not as yet been satisfactorily accomplished by the Methods Group, and the estimates of probabilities for desirable effects are based upon the trauma "pain" treated by the Medical Group. When and if the Methods Group can estimate the desirable effects associated with their "pain" data, these probabilities can be revalued at higher levels which include the "pain" effects. Until then, QEF.

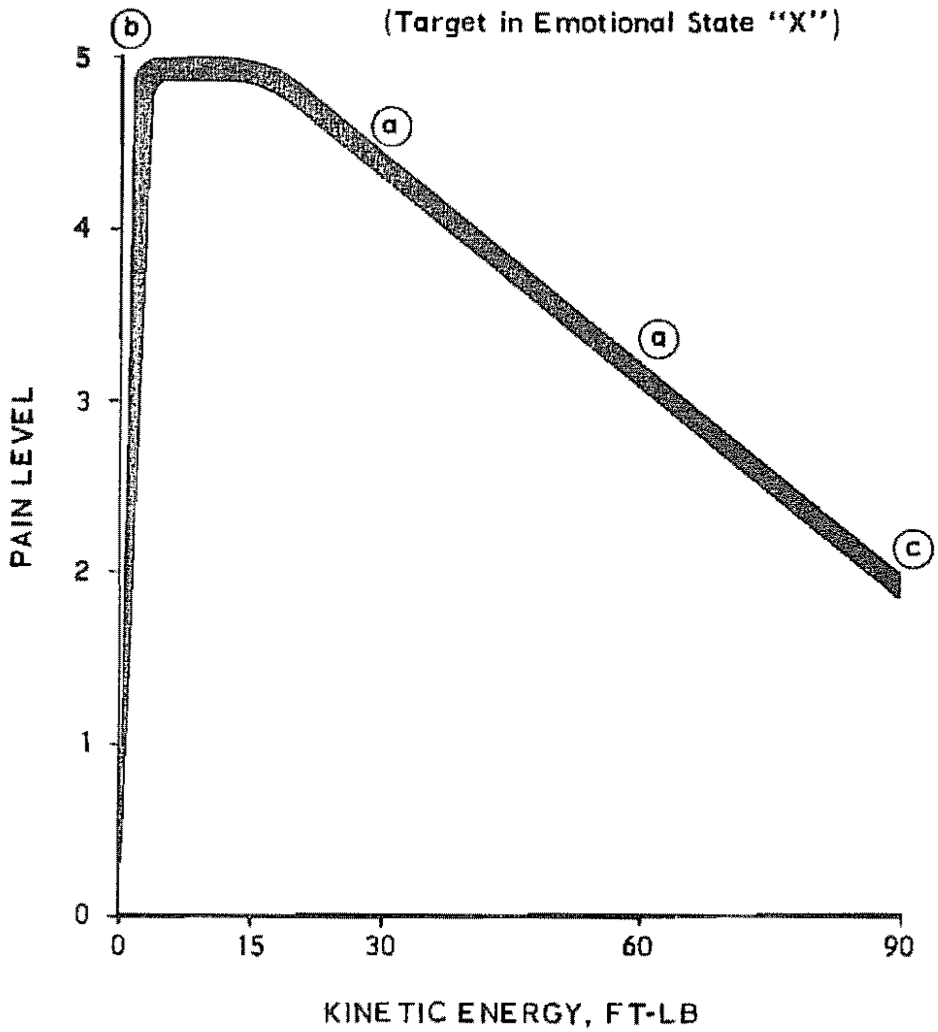
E. Time/Function-Loss Relations

The primary control force objective in imposing some noxious environment* 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.

[14]Clark, James W. and Bindra, Dalbir, op cit

*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, night sticks, handcuffs, etc.

"POSSIBLE" FUNCTIONAL RELATIONSHIP BETWEEN PAIN AND IMPACT-ENERGY, BLUNT-TRAUMA WEAPON



NOTE: Circled letters refer to notes in text

FIGURE 12

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 13. From the military viewpoint, the objectives of three different enemy stress situations* are plotted as regions in Figure 13. 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 designers, 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** concern for the well-being of the enemy soldiers.

Alternately, the applicability/suitability of less-than-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 14 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 by a less-than-lethal kinetic-energy 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 15. 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

*"Stress situations" is used here in lieu of scenarios; the military stress situations given are standard scenarios which describe in general military situations suggested by the titles.
**Obviously, nations have tried to limit the deleterious effects of war by observing the guidelines of the Geneva Convention. Nonetheless, weapon designers are not generally concerned with the well-being of enemy soldiers if the rules of the Geneva Convention are not violated.

ARMY INCAPACITATION CRITERIA

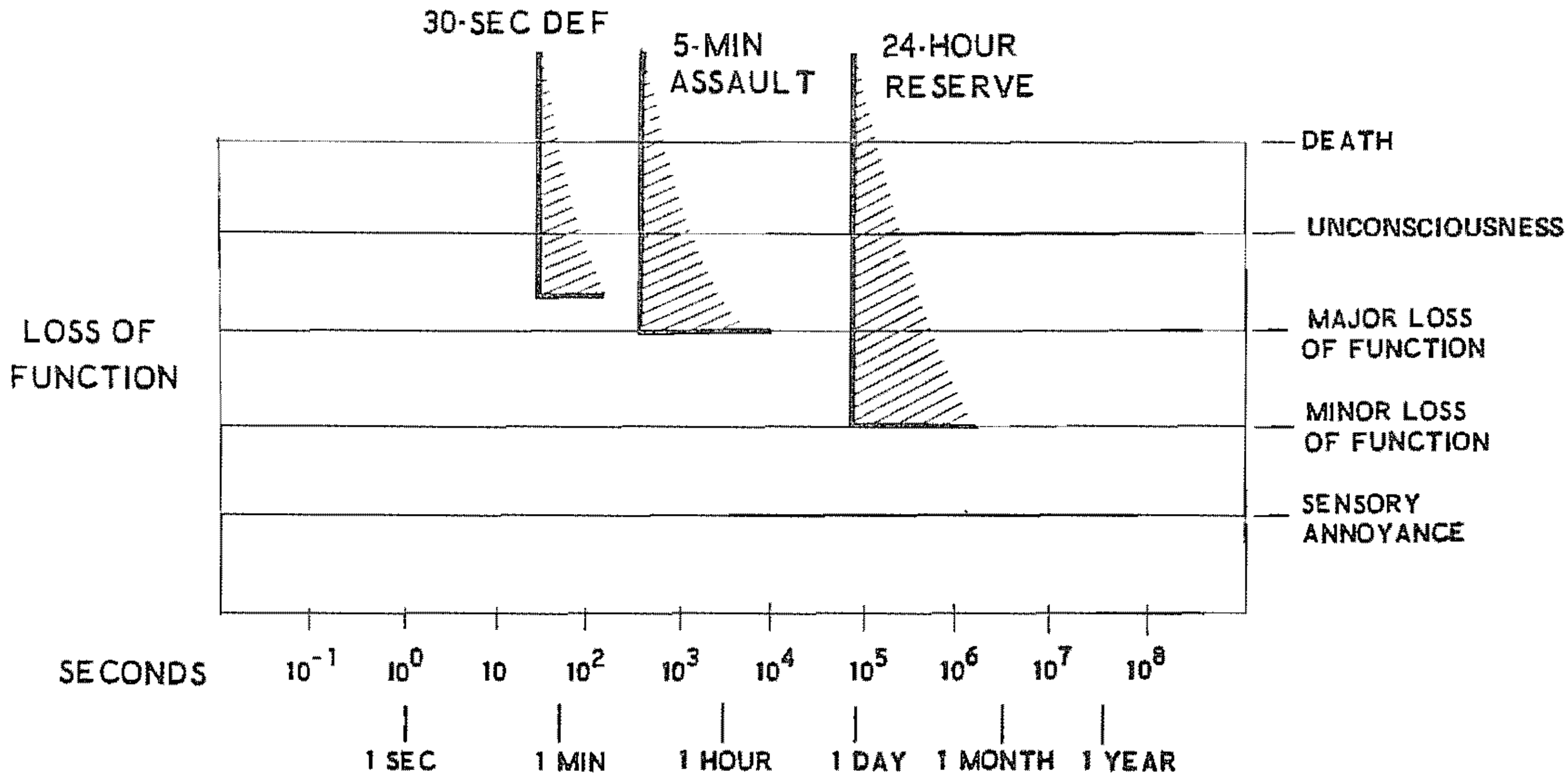


FIGURE 13

THE UNDESIRABLE EFFECTS CRITERIA ON THE FUNCTION-LOSS/TIME PLANE

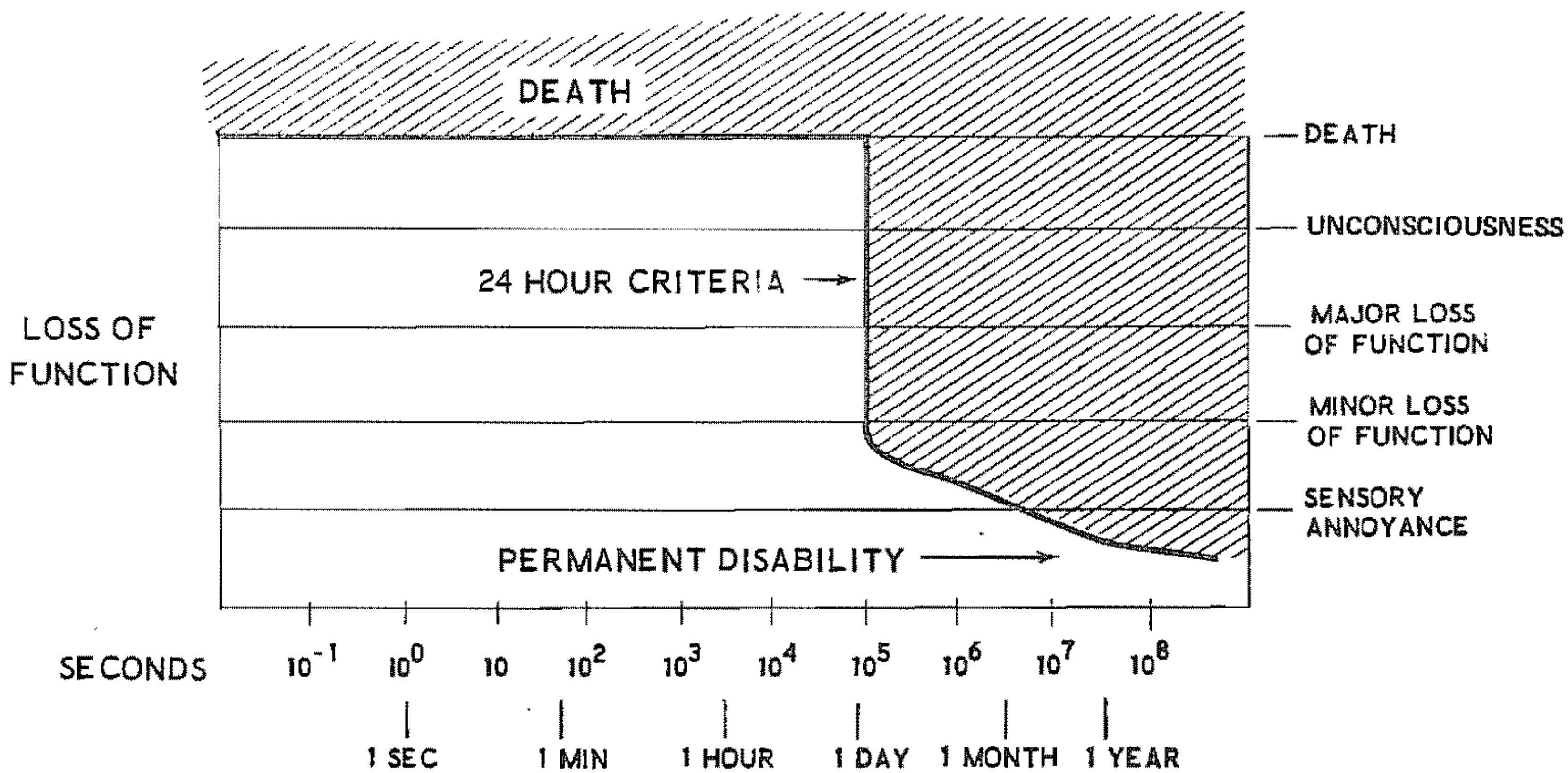


FIGURE 14

DESIRABLE & UNDESIRABLE EFFECTS REGIONS
IN LESS-THAN-LETHAL WEAPONS EVALUATIONS

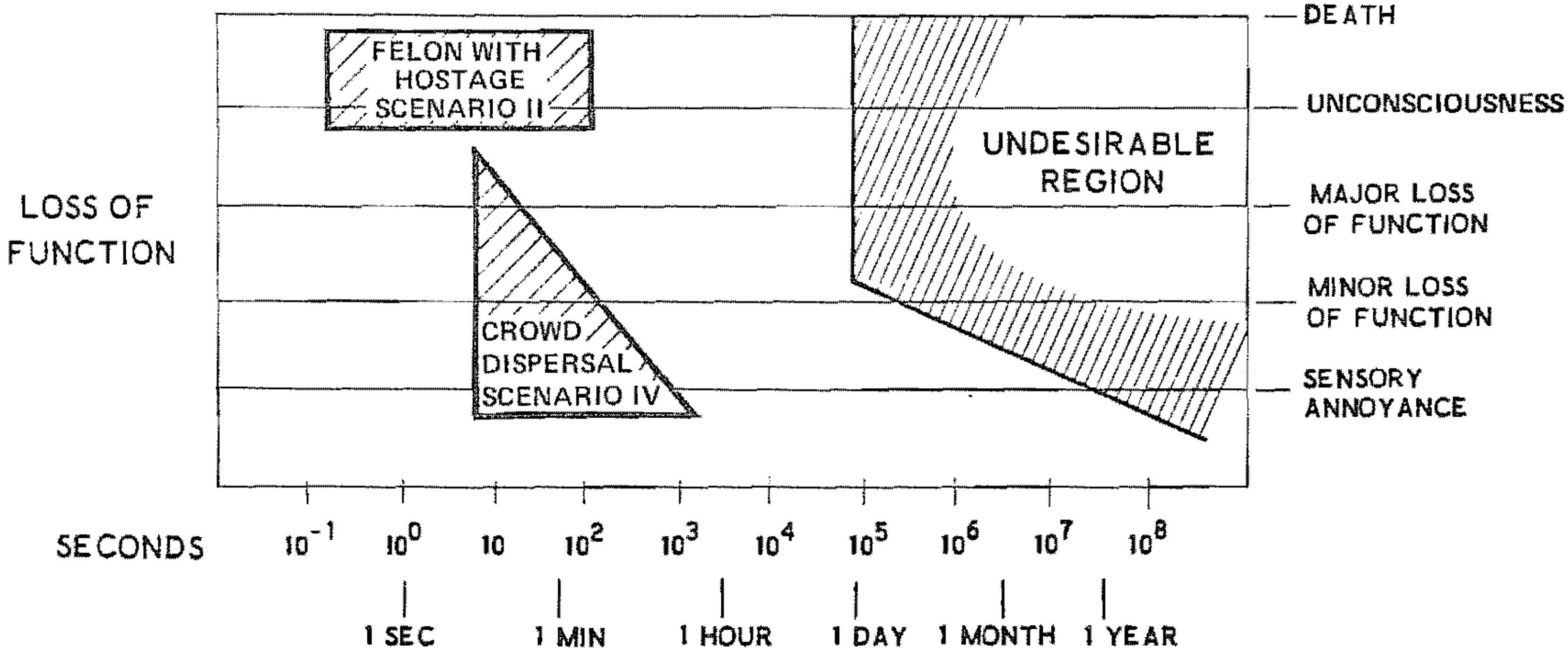


FIGURE 15

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 targgeted 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 14 (and also Figure 15) 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 Figures 14 and 15 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 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-than-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* was not available at the time this report was written, Figure 16 presents a contrived example of the incapacitation history of an individual with a chest wound. The division of the chest wound into a critical and noncritical 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.

*General consideration to the onset and duration times was given at the various Medical and Methods Group meetings. However, no systematic process of constructing these time plots was undertaken.

CONTRIVED EXAMPLE OF THE INCAPACITATION
HISTORY OF A CHEST WOUND

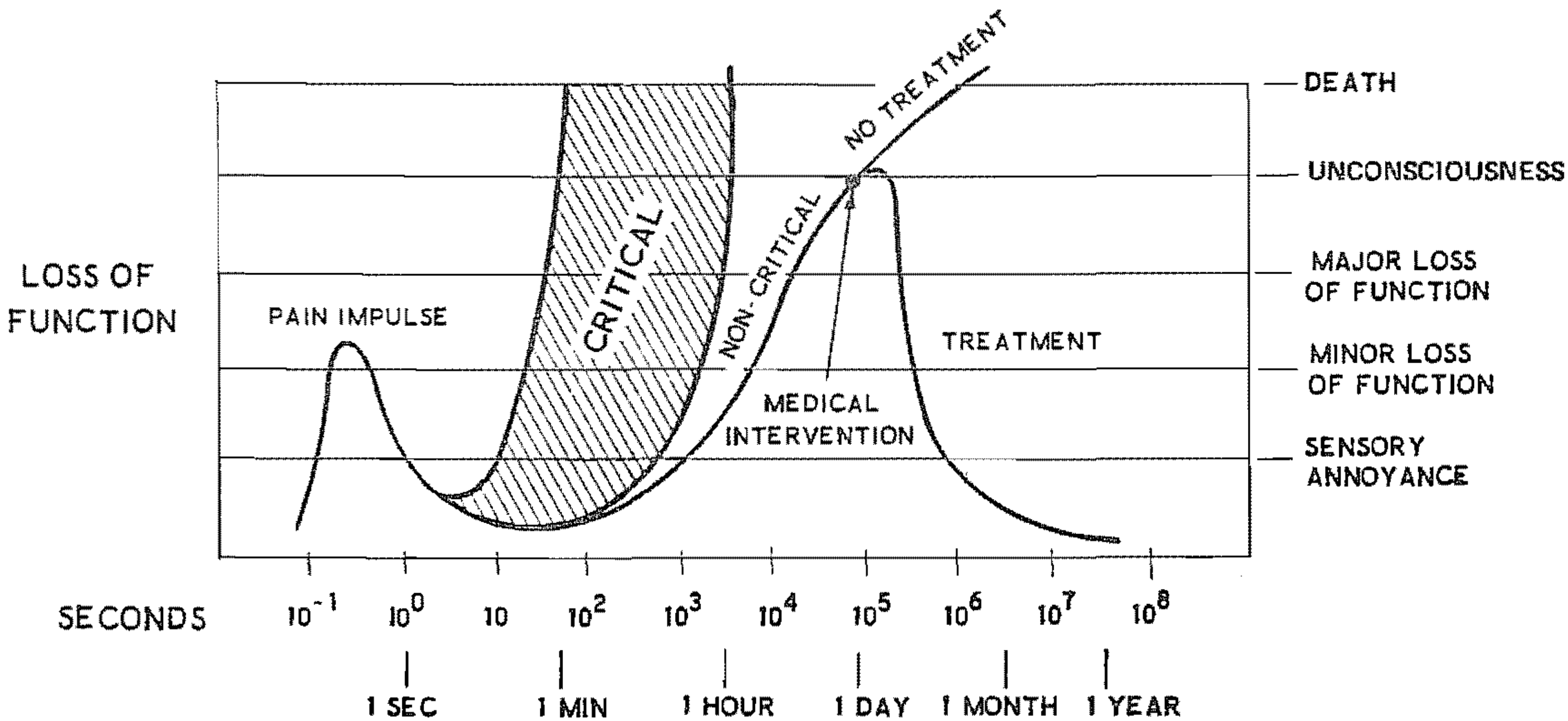


FIGURE 16

If one assumes that the contrived 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 16) is overlayed on Figure 13 (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 15, then there is some evidence that chest wounds tend to violate both the desirable and undesirable criteria. For example, the onset of effects for most chest wounds will not be sufficiently rapid to neutralize the felon with hostage within the desired time frame, and the individual with a chest wound may be too severely injured to disperse within the desired period for this scenario. Almost all chest wounds, critical or noncritical, with or without medical intervention, will violate the 24-hour undesirable criteria. Only the "pain impulse" portion of effects might coincide with the desirable effects to be achieved in the crowd dispersal situation.

In Figure 17, 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 contrived examples of the type of information which would be extremely valuable to a less-than-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 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-than-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-than-lethal weapons evaluation, especially when diverse techniques are used to induce a "noxious" environment.

F. Program Forecast

It would be appropriate to conclude this report with a retrospective analysis of the achievements and shortcomings of the over-all LWL program. Actually, the achievements are sketched in the summary of the report and the shortcomings, or areas needing improvement, are too numerous to treat in sufficient depth in this report. However, proposed future activity which would both expand the less-than-lethal weapons evaluation techniques and remove some of the limitations of the present effort are described by area in Appendix K. That information was previously submitted to LEAA as a proposed follow-on effort to our present activity.

FUNCTION-LOSS PROGNOSIS FOR VARIOUS
"EFFECTIVE" PHYSIOLOGICAL MECHANISMS

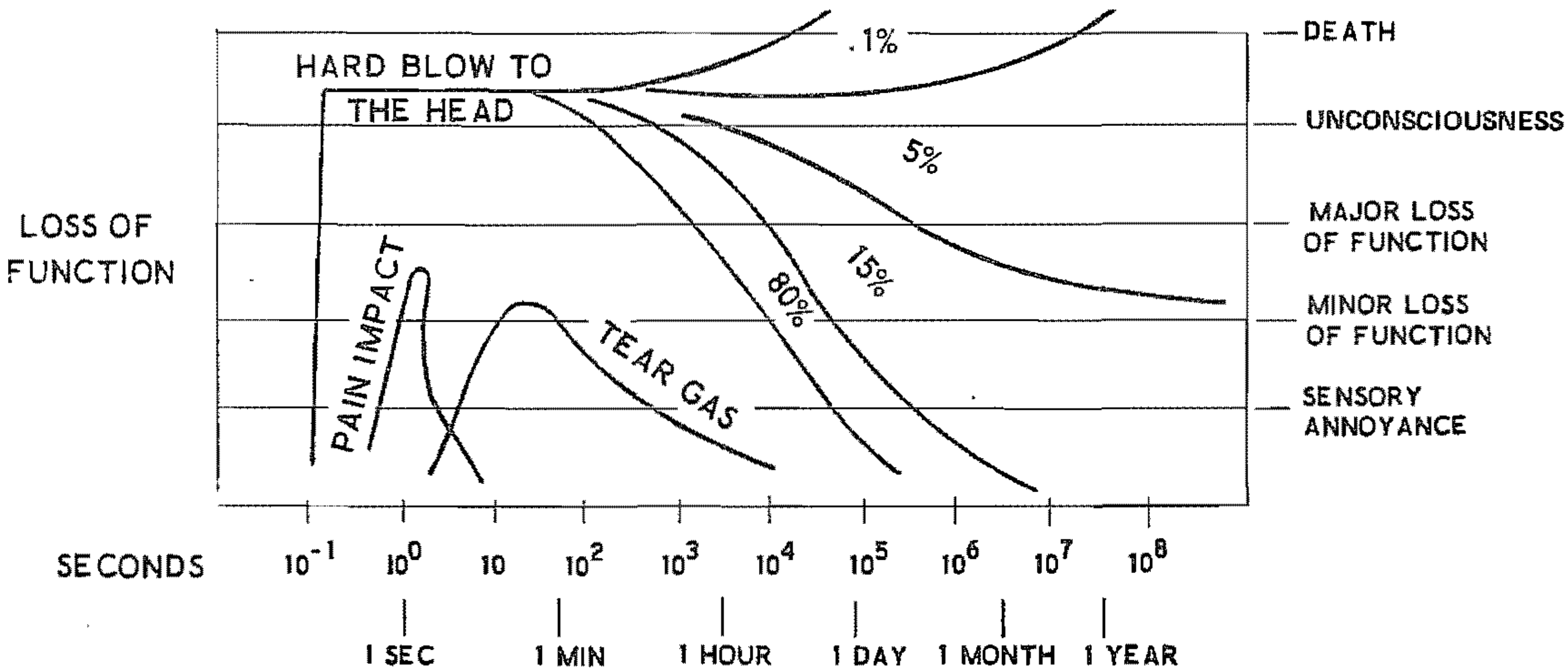


FIGURE 17

APPENDIX A

CONFERENCE ON LESS-THAN-LETHAL WEAPONS AT US ARMY LAND WARFARE LABORATORY (USALWL)

21 JUNE 1972

Name	Title	Organization
M. Nerenstone	Program Manager, Analysis	National Institute of Law Enforcement and Criminal Justice (NILECJ), LEAA*
L. Shubin	Program Manager, Standards	NILECJ, LEAA
C. Maag	Consultant	LEAA
D. Egner	Conference Chairman	Research Analysis Office (RAO), USALWL
J. McNiell	Chief, RAO	USALWL
E. Shank	Operations Research Analyst	RAO, USALWL
J. Sarvis	Weapons Developer	Munitions Branch, USALWL
M. Wargovich	Physiologist	Biological Sciences Branch, USALWL
R. Zelina	Contractor	AAI Corporation
J. Manata	Project Engineer, Graded Lethality Program	Small Arms Systems Directorate, US Army Weapons Command
B. Jezek	General Engineer	US Army Small Arms Systems Agency
F. Essig (CPT)	Physiologist	Wound Ballistics, Vulnerability Lab, US Army Ballistics Laboratories (USABRL)
J. Diamond	Program Manager, Weapons & Protective Equipment	Law Enforcement Standards Lab, National Bureau of Standards
V. Clare	Research Biologist	Biophysics Division, Medical Lab, US Army Edgewood Arsenal
W. DeDufour	Contractor	Mitre Corporation

*LEAA = Law Enforcement Assistance Administration

Name	Title	Organization
W. Bruchey	Observer	USABRL
D. Campbell	Observer	RAO, USALWL
R. Crafton	Observer	RAO, USALWL
B. Thein (Mrs.)	Observer	RAO, USALWL

APPENDIX B

LESS-THAN-LETHAL WEAPONS EVALUATION PANEL

Scenario Group

Name	Background	Organization
Mr. D. O. Egner*	Physicist	Research Analysis Office (RAO), US Army Land Warfare Laboratory (USALWL)
Mr. E. B. Shank	Operations Research Analyst	RAO, USALWL
Mr. L. W. Williams	Political Scientist	Battelle Memorial Institute (BMI)**
Mr. A. Sagalyn	Police Consultant	Security Planning Corporation (SPC)***
LT A. E. Yowell	Police Officer	Washington, DC Police Dept***
Mr. R. S. Zelina	Engineer/Lawyer	AAI Corporation (AAI)**

Medical Group

Name	Background	Organization
Mr. M. J. Wargovich*	Physiologist	Biological Sciences Branch (BSB), USALWL
Dr. W. M. Busey	Pathologist, D.V.M., PhD	Experimental Pathology Laboratories, Inc. (EPL)****
Mr. V. R. Clare*****	Research Biologist	Biophysics Division, Medical Laboratory, US Army Edgewood Arsenal
Mr. D. O. Egner	Physicist	RAO, USALWL
Dr. R. S. Fisher	Forensic Pathologist, M.D.	Chief Medical Examiner, State of Maryland****
Dr. F. G. Wolfort	Surgeon, M.C.	Chief of Plastic Surgery, Cambridge, MA Hospital****
Mr. R. S. Zelina	Engineer/Lawyer	AAI**

Methods Group

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

Model Group

Name	Background	Organization
Mr. E. B. Shank*	Operations Research Analyst	RAO, USALWL
Mr. S. R. Dutton	Mathematician	AAI**
Mrs. B. K. Thein	Mathematics Technician	RAO, USALWL
Mr. A. F. Tiedemann, Jr.	Engineer	AAI**
Mr. R. S. Zelina	Engineer/Lawyer	AAI**

Data Collection Group

Name	Background	Organization
Mr. D. O. Egner*	Physicist	RAO, USALWL
Mr. D. Campbell	Mathematician	RAO, USALWL
Dr. W. M. Busey	Pathologist (DVM-PhD)	EPL****
Mr. J. W. Sarvis	Mechanical Engineer	Munitions Branch, USALWL

Data Collection Group (Cont)

Name	Background	Organization
Mrs. B. K. Thein	Mathematics Technician	RAO, USALWL
Mr. M. J. Wargovich	Physiologist	BSB, USALWL
Dr. R. A. Williams	Bio-Engineer	BMI**
Mr. A. F. Tiedemann, Jr.	Engineer	AAI**
Mr. R. S. Zelina	Engineer/Lawyer	AAI**

*Chairman
**LWL Contractor
***Consultant to BMI
****Consultant to AAI
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APPENDIX C

DRAFT SCENARIOS OF POLICE TACTICAL SITUATIONS FOR THE DERIVATION OF STANDARDS FOR LESS-THAN-LETHAL WEAPONS

This appendix was prepared by Larry W. Williams of Battelle Memorial Institute for the US Army Land Warfare Laboratory. The information contained in this appendix is in essence the output of the Scenario Group of the Less-Than-Lethal Weapons Evaluation Panel; however, the appendix does contain some information generated under previous programs sponsored by the US Army Land Warfare Laboratory.

The Scenario Group of the Less-Than-Lethal Weapons Evaluation Panel (Appendix B) held a seminar at the Washington Office of Battelle's Columbus Laboratories on 6 July 1972. The purpose of the seminar was to bring together a small group of specialists to develop scenarios depicting tactical situations commonly encountered by civilian law-enforcement officers. These scenarios are intended to elucidate factors which might help in establishing guidelines and standards for the design, engineering and testing of less-than-lethal weapons. Particular consideration was given to the constraints which the presence of bystanders, the level of threat to the officer, and general public reaction might impose upon the selection and employment of such weaponry. The scenarios which are presented here are composites of the ideas and observations of the members of the seminar.

Each scenario is accompanied by a summary listing of the desirable and undesirable effects of any less-than-lethal weapons which might be suggested for that situation. In addition, there is a summary of the more salient elements of the four scenarios.

In addition to the scenarios developed for the LEAA evaluation (sometimes referred to as "Civil Scenarios"), there are three "Army Scenarios" which were developed by the USALWL in conjunction with an Army less-than-lethal evaluation effort. Since the next two appendices to this report (Appendix D and Appendix E) frequently refer to the Army Scenarios, descriptions of these scenarios are given as an annex to this appendix.

SCENARIO I

The "One-on-One" Situation

The most common tactical situation in which less-than-lethal weaponry might be employed by a police officer is in the arrest of an individual for some type of misdemeanor. While in many such cases the offender offers no resistance, occasionally the officer must use force in making the arrest. The degree of resistance, of course, poses a varying level of threat to the officer:

1. An unarmed offender might push or shove the officer, attempt to jerk away from him, or strike him.

2. An offender might arm himself by seizing some object at hand:

a. A blunt, nonpenetrating object such as a board or stick.

b. A sharp penetrating object such as a knife, broken bottle, etc.

While in the second case the officer might have to resort to deadly force to protect himself, it is generally preferred to avoid excessive force. In this regard, it is assumed that when confronted with a clearly lethal threat from a firearm, the officer will respond with the use of his own firearm.

The priority of the officer's concern in such situations is:

1. Protecting himself from the threat.

2. Alleviating the threat.

3. Taking the suspect into custody.

4. Moving the offender to the call box, cruiser or patrol wagon.

These encounters most often involve adult males, including the physically mature teenager. A small proportion of cases involve women. It is assumed that young children and older persons can be handled by the average officer without resort to weaponry.

While most of these incidents occur on the street and, hence, out in the open, many take place inside buildings - homes, places of business, bars, etc.

Given the levels of threat to the officer with which this scenario is concerned, the distance between the offender and the officer might extend from arm's length, with the unarmed individual, to the length of a room, when the suspect is armed. Thus, the maximum distance to the offender can be assumed to be comparable to the six or seven meters average range at which most gun battles involving police occur.

In most of these situations, it can be assumed that there will be bystanders. The distances of these bystanders from the officer might vary from arm's length to several meters. It is desired to avoid affecting bystanders in any way, but minimal effect is preferred if a bystander is inadvertently affected by the officer's actions.

These offenders represent a cross-section of society in their mental and physical conditions. In many instances, belligerence is accompanied by a state of intoxication or a "high" brought on by certain drugs. Many offenders are in an excited condition which is other than drug-induced, ranging up to the berserk, and will exhibit increased blood pressure, heart rate and adrenalin flow.

Optimum effectiveness with less-than-lethal weapons would be achieved in this scenario if the officer were able to keep the offender from becoming aggressive, or to dissuade him from continued aggressive action, while at the same time permitting him sufficient mobility to walk to the call box or cruiser. If the offender persists in physical violence, immobilizing his arms does not provide adequate restraint. Likewise, lachrymators in common use induce considerable pain and temporary blindness, but the offender bent on violence can still kick or swing blindly.

The minimal duration of the effect of a less-than-lethal weapon for this application should be 30 seconds to allow enough time to apply handcuffs to the offender. A desirable secondary effect would be minimizing the combativeness of the offender while still allowing him to retain his ability to walk a short distance. In all such situations, it is desirable to minimize the apparent as well as the real damage to the offender in order to avoid alienating observers. Open wounds and blood are absolutely unallowable effects of less-than-lethal weaponry.

EFFECTS ON SUSPECT

Desirable Effects (Short Term)	Undesirable Effects (Short- and Long-Term)
Minimize aggressive behavior	Be lethal
Immobilize for 30 seconds or somewhat longer	Inflict aggression-inducing pain
Permit the suspect to walk a short distance after the initial immobilization	Inflict serious or irreversible damage requiring medical treatment
	Produce bleeding
Reduce states of psychological excitement	Exacerbate existing psychological and physical excitement

EFFECTS ON BYSTANDERS

Desirable Effects	Undesirable Effects
Minimal effects on bystanders	Produce any effects not desired on the suspect

SCENARIO II

The Barricade and Hostage Situation

A recurring problem which confronts police forces is provided by those offenders who have committed a serious crime and who barricade themselves inside a building. This situation probably most frequently involves one offender, but sometimes two or more are involved. In many such situations the police can clear the immediate area, seal possible escape routes, and wait out the criminal. This is possible only in cases where delay in apprehending the offender does not jeopardize innocent persons, i.e., the offender is not holding a hostage with the intention of possibly harming him. In this latter circumstance the police generally feel it is mandatory to subdue the offender(s) before a hostage is harmed.

Normally in these circumstances the police will have a fairly good idea where the offender is located in a building. Sometimes it is possible to isolate the offender on a particular floor, in a single apartment, or even in a specific room. The latter case, where the offender is known to be barricaded in a specific room, is probably the ideal tactical situation for the police. At least the hazards attendant with entering the building are fewer than when the offender is able to move around inside.

While a distance of 10 to 50 meters might typically separate the barricaded man from the police officers outside, there is no line-of-sight technique for attacking the offender. He is careful not to expose himself at windows and doors for fear of being shot. He will only risk exposure with a hostage as a shield. Consequently, ballistic weapons aimed at the offender are essentially useless in this scenario.

In these circumstances, less-than-lethal weapons must either penetrate or circumvent the obstacles (windows, walls, doors, ceilings, floors) which protect the offender from line-of-sight attacks. At the same time, various structural features may offer opportunities to circumvent these obstacles or to get closer to the offender. Consideration should be given here to heating and cooling systems, hallways, attics, basements, crawlspaces and the like.

Some of the persons who barricade themselves with hostages are desperate enough to harm these hostages if it appears the police are moving in. Consequently, it would be desirable to develop less-than-lethal weapons which:

1. Could be introduced without alerting the offender.

2. Would be innocuous in the sense of being colorless, tasteless and odorless.

3. Would have a relatively short onset time so as to minimize the likelihood of the offender harming the hostage*.

4. Would have a high level of reliability so that police personnel could be sure it has worked before they attempt to break into the room.

5. Would have a duration of effect such as to allow the officers two to five minutes to defeat the barricade, secure the offender and rescue the hostage.

These criteria are set forth because the safety of the hostage is the primary concern of the police and they desire to subdue the offender before he is able to harm the hostage. By the same token, the less-than-lethal weapon employed against the criminal must not have any undesirable enduring effects on the hostage. Such less-than-lethal weaponry might also be employed in other situations, such as when the criminal's family is in the building with him and he intends them no harm or in cases where a person is threatening suicide.

*This is not critical if the offender is unaware of any weapon signature, viz., body symptoms, etc.

EFFECTS ON SUSPECT(S)

Desirable Effects (Short Term)	Undesirable Effects (Short-Term)
Instantaneous or undetectable onset of principal effect	Be lethal
Total physical incapacitation for two to five minutes	Inflict serious or irreversible damage
	Excite or alarm the suspect prior to complete onset of the principal effect
	Undesirable Effects (Long-Term)
	Be lethal
	Inflict serious damage or irreversible damage

EFFECTS ON HOSTAGE(S)

Desirable Effects	Undesirable Effects (Short- and Long-Term)
Minimal short- and long-term effects	Be lethal
	Inflict serious or irreversible damage
	Inflict excessive pain or discomfort
	Induce psychological or physical excitement

SCENARIO III

The Suspect Fleeing on Foot

A typical tactical problem for policemen is the apprehension of an unarmed suspect who is trying to escape on foot. Frequently it is impossible for the officer to catch such a suspect - the suspect is often young and unencumbered; the officer may be quite a bit older and wearing a Sam Browne belt loaded with equipment. In many instances the officer is not sure what crime the suspect has committed, or even if he has committed any crime. This, plus the possible proximity of bystanders, precludes reliance on any form of lethal force to stop the suspect.

The most usual setting for this scenario is a public street, in which case it is assumed that the suspect might be up to 70 meters from the officer. It is conceivable that similar situations might occur in hallways and stairways of buildings, in which case the range might be estimated at five to 20 meters. Since the suspect is running away, the officer will see only his back.

The minimal desired effect of a less-than-lethal weapon in this situation is to slow the suspect sufficiently to apprehend him. It is not necessary to stop the suspect instantaneously. He might continue for 20 to 100 meters, but this is of no consequence so long as the officer is able to catch up to him. However, for legal purposes it is not desirable for the suspect to be able to escape the scene, even if he can be identified and apprehended at some later time. In order to maximize the likelihood of successful prosecution, it is best to apprehend a suspect within the context of the crime and in view of the witnesses who saw him commit the offense and attempt to escape.

At the same time, consideration must be given to the apparent effect of the weapon used. Generally, the officer must avoid the appearance of using excessive force, especially against young offenders. Any weapon which causes a flow of blood or otherwise appears brutal cannot be used, considering the emotional reactions of onlookers and the general public and the possibility of bystanders being affected by the weapon.

EFFECTS ON SUSPECT

Desirable Effects (Short-Term)	Undesirable Effects (Short- and Long-Term)
Slow or stop the suspect from running	Be lethal
	Produce bleeding
Relatively fast, but not necessarily instantaneous, onset of effect	Inflict serious or irreversible damage damage
Produce constant effect over ranges of five to 70 meters	Inflict pain appearing excessive to bystanders

EFFECTS ON BYSTANDERS

Desirable Effects	Undesirable Effects
Produce no obvious degrading physical effect	Be lethal
	Produce obvious physical effect
	Inflict serious or irreversible damage
	Motivate to aggression against the officer
	Motivate to take legal action against the officer

SCENARIO IV

The Dispersal of a Crowd

It is frequently necessary for police forces of various sizes to cope with crowds of people intent on blocking a public road, street or park. In order to keep such public facilities open, it is desirable to be able to disperse such a crowd or to move it out of the area. Ideally, it is desirable that the means employed to disperse the crowd prevent them from returning to the area a short time later, and yet leave the area in a suitable condition for routine use by the general public, i.e., the weapon or means employed should not contaminate the area for very long and it should be relatively easy to clean up the after-effects.

The size of such a crowd might vary from 100 to 1,000 or more. Typically there are bystanders near the periphery of the crowd and it is desired to have minimal or negligible effect on these onlookers. There will be both men and women in the crowd and among the bystanders. Normally the distance between the crowd and the police officers would be about 75 meters, but structural features and the tactics of the crowd might shorten this distance to as little as 10 to 15 meters.

The desired effect of a less-than-lethal weapon for this application would be for it to motivate the crowd to move of its own accord. The police do not care to arrest most members of such a crowd. Nor do they desire to immobilize the members of the crowd because of the logistic problems in caring for such persons. The route for dispersal is a tactical consideration.

The time between utilizing such a weapon and the onset of its effect should be relatively brief, though the effect does not have to be instantaneous.

As in other situations where less-than-lethal weapons might be useful, it is preferred that onlookers not get the impression that the police are using excessive force or that the weapon has an especially injurious effect on the target individuals. Here again, a flow of blood and similar dramatic effects are to be avoided.

EFFECTS ON MEMBERS OF THE CROWD

Desirable Effects (Short-Term)	Undesirable Effects (Short- and Long-Term)
Motivate to leave the scene	Be lethal
Desirable Effects (Long-Term)	Produce bleeding or obviously excessive pain
Discourage a return to the scene or reforming at another point	Inflict serious or irreversible damage
	Provoke retaliation
	Immobilize

EFFECTS ON BYSTANDERS

Desirable Effects	Undesirable Effects
No effects desired	Any physical effect
	Provoke to join or defend members of the crowd

SUMMARY OF SCENARIOS

			Scenarios I	II	III	IV
The Target	Sex	Male	X	X	X	X
		Female	X			X
	Age Range	Adult	X	X	X	
		Adults and Children				X
	Number of Persons	Individual	X	X	X	
		Group				X
	Predisposition	Aggressive	X	X		X
		Evasive			X	
	Behavior to be Countered	Fighting	X			
		Harming Hostage		X		
		Running Away			X	
		Resist Moving				X
Primary Objectives of Law Enforcement Personnel		Apprehend or Subdue an Individual	X	X	X	
		Deter Aggressive Acts	X			
		Disperse a Crowd				X
		Avoid Affecting Bystanders	X	X	X	X
Distance to the Target		6-7 meters	X			
		10-50 meters		X		
		5-70 meters			X	
		10-75 meters				X
Obstacles Between the Officer(s) and the Target		Negligible	X			X
		Structural Components of Buildings		X		
		Trees, Lampposts, Cars in the Streets			X	
Location of Bystanders		Possibly Between the Officer and the Target	X		X	
		At the Side				X
		In the Same Room		X		
The Desired Effect of a Less-Than-Lethal Weapon	Incapacitate for Approx	30 seconds	X			
		2-5 minutes		X		
	Slow or Stop a Running Suspect				X	
	Motivate to Leave the Scene					X
Desired Time to Onset of the Effect	Immediately to a Very Few Seconds		X			
	Instantaneously if Agent is Detectable			X		
	A Minute or Two				X	X
Time of Day	Day		X	X	X	X
	Night		X	X	X	

ANNEX TO APPENDIX C

DESCRIPTIONS OF ARMY SCENARIOS

The limited number of scenarios discussed herein were constructed to depict situations most likely to confront military control forces during civil disturbances. It was the intent in establishing these scenarios to identify factors which might help in establishing guidelines and standards for the evaluation of the purported less-lethal weapons*.

The scenarios provide the crucial ingredients of target description and stress situations which are both incident to and necessary for weapon effects evaluations. Perhaps the greatest benefit to be derived from these scenarios to date is that they have provided a reference which has been utilized by the various evaluation groups. In particular, both the Methods Group and the Medical Group have utilized data abstracted from the scenarios (along with the other inputs) to render provisional percentage estimates of undesirable and desirable effects related to pain, various degrees of physiological damage, and nonphysiological phenomena.

In the construction of these scenarios, particular consideration was given to the constraints which the presence of bystanders, the level of threat to the officer, and general public reaction might impose upon the selection and employment of less-lethal weaponry.

Army Scenario I - The Fleeing Suspect

The setting for Scenario I is an urban environment in which military personnel are called upon to assist in controlling a civil disturbance. The disorder has progressed to the point where fires have been set, retail outlets have been broken into and goods stolen, and the rioters have adopted hit-and-run tactics. The rioters include in their number both adults and children of school age (six to seven years) and older.

The mission of the military personnel is to curtail acts of looting and arson and to control curfew violations. Violators of the law are to be apprehended and turned over to civilian law enforcement agencies. The military personnel are in small groups on patrol in jeeps or trucks. Generally, the control force personnel can be expected to have the numerical advantage when one of these confrontations occurs. They are generally 20-70 meters away when they see one or a few individuals engaging in an illegal act. They must dismount and apprehend these individuals who normally attempt to evade capture. It is estimated that an individual who has been immobilized or incapacitated for approximately 30 seconds can be apprehended. Due to the fact that a curfew is in effect and/or because most local residents are trying to avoid trouble, there will normally be few bystanders. It can be anticipated that these few potential bystanders will be randomly dispersed around the individual(s) causing the trouble, perhaps with a few being initially attracted toward the

*Less-lethal weapons are those weapons which (a) have been designed and used with the intention that they would not have fatal or unacceptably injurious effects on an individual, and (b) have exhibited a high probability that such effects will not result from their use.

scene (especially during daylight hours when the curfew might be lifted) but to disperse when control force personnel arrive on the scene (especially during curfew hours).

Army Scenario II - The Moving "H"

The setting for Scenario II is a city street in the early stages of a disturbance or perhaps later when "hard-core" troublemakers try to provoke a re-escalation of tensions.

The tactic of the troublemakers is to block off a street in order to, first, present a challenge to the control forces and, second, provide an incident which will motivate bystanders to join in the troublemaking.

The typical scene involves the troublemakers in the middle of the street, a number of bystanders along the sidewalks, and the control forces confronting the troublemakers in the street. So long as the control forces maintain their distance, the troublemakers hold their ground and throw rocks, bottles, or other objects at control force personnel. It is estimated that a distance of 20-70 meters will generally separate the rock-throwers from the control forces, with the rock-throwers occasionally running forward out of the group blocking the street in order to get within range.

The control forces will be drawn up in standard crowd dispersal formations. After reading the riot act to either those persons blocking the street, or else to everyone on the scene, these formations advance to clear the street. As the control forces advance, the troublemakers will probably hold their ground initially in order to see how bystanders will react. The distance between the control forces and those blocking the street will therefore diminish and objects will be thrown at the control forces from the crowd blocking the street. As the control forces continue to advance, those blocking the street may retreat for a distance; but, if they at some point stand their ground until control forces are quite close, they will either disperse and try to escape (as the control forces hope) or else attack individual control force personnel.

The Major aims of the control forces in this situation are to:

1. disperse the group blocking the street by motivating them to leave the area

2. avoid affecting bystanders or otherwise motivating onlookers to join in the disturbance

Other aims include deterring the rock-throwers and perhaps apprehending individuals who run forward out of the crowd to throw things.

While the troublemakers and onlookers together might outnumber the control forces, the number of bystanders is not significant unless they join in for some reason. If the bystanders do not join in, the control forces may have numerical superiority over those blocking the street. Even if they are outnumbered, the control forces will have training and discipline on their side.

These types of confrontations normally occur in daylight or early evening hours. In some situations, as in certain ghetto areas, the crowd might contain children. If the confrontation is in connection with campus disorders, the crowd can be considered to consist of adults only.

Army Scenario III - The Legal Crowd

The setting of Scenario III is a parade route, the exterior of a building, or the outer periphery of a crowd which is being contained. The crowd is a generally peaceful gathering for any of a number of legal purposes. However, military personnel have been called in to enforce the parade route, to protect buildings, and/or to keep the crowd in a specified area. The major problem involves individual toublemakers who throw things at the control forces either from the cover of the crowd or else by coming out in front of the crowd, throwing, and running back to hide in the crowd.

The disposition of the control forces is generally in a line designed to retain a crowd. "Snatch" teams may move through this line to apprehend individual troublemakers. Among the aims of the control forces are the desires to:

1. avoid affecting the unaggressive bystanders who have a legal right to be present

2. deter aggressive acts by individual troublemakers

3. apprehend those individuals who do engage in acts of violence.

The average distance between the control forces and individual troublemakers is approximately 20 meters. It is believed that troublemakers could be apprehended if they were incapacitated for approximately 15 seconds. The crowd as a whole will probably contain children, perhaps even infants, but the troublemakers will ordinarily be adults. The crowd as a whole will usually outnumber the control forces, but the troublemakers will not ordinarily be concentrated enough to outnumber control personnel at any given point on the line.

Most of the confrontations can be expected during daylight hours, but they might occasionally take place at night.

APPENDIX D

NOTES FROM METHODS GROUP MEETINGS

This appendix contains notes from several meetings of the Methods Group of the Less-Than-Lethal Weapons Evaluation Panel. Although all the notes are not from meetings conducted on this project per se (some are from meetings on a related Army less-than-lethal weapons program), the information included was utilized on this LEAA/LWL project. The actual scenarios discussed in some instances were developed under the Army-sponsored program; however, these scenarios are generally close in content to the scenarios developed under the LEAA/LWL program and are thus presented for general informational purposes.

OBJECTIVES

The primary objective of Methods 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 Army 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 Methods 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 associated with the damage mechanism 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-

*A description of the Army scenarios is given in the Annex to Appendix C.

second immobilization time for the Army scenario. The target consisted of one fleeing suspect whom we 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 likened 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 would 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 to a test animal (baboon head or shoat torso). They were then tasked 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 along 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 mm 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 Level 4 consists of Grades 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 outlined essentially as follows:

> Individuals are swept up into the spirit of the 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 causal 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.

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*.

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 is 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. En route, 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**. In addition, the use of EEGs 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.

*In retrospect, there appears to be considerable evidence to indicate that some dissidents dash up to TV cameras to display their wounds, rather than flee the scene.
**Part of brain concerned with coordinating muscles and bodily equilibrium.

It was proposed that many people develop great anxiety over pain and individual reactions to pain depended 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 Methods 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 Methods Group 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*	Rationale
1	100	5	Note #1
2	-	-	
3	-	-	
4	-	-	
5	100	100	Note #2

*Estimates consider effects on skin, subcutaneous tissue, and muscle only.

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. Scenarios 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, Methods Group, etc.

APPENDIX E

NOTES FROM MEDICAL GROUP MEETINGS

This appendix contains notes from several meetings of the Medical Group of the Less-Than-Lethal Weapons Evaluation Panel. Although all the notes are not from meetings conducted on this project per se (some were generated on related Army less-than-lethal weapons programs), the information included was utilized on this LEAA/LWL project. Thus, the additional related notes are included for the sake of completeness.

APPROACH

The general approach used by the Medical Group in rendering human incapacitation estimates was as follows:

1. Stress situations were stated.

2. Necropsy photos and associated experimental data were viewed and analyzed.

3. The probable effect of a similar wound on a human target was discussed and an estimate of its incapacitation effects as a function of the specific body areas which were impacted was rendered.

The energy associated with specific physiological damage was a part of the data package but was not presented for use by the Medical Group unless specific problem areas developed where its use was dictated. This approach was intended to reduce bias during the assessments.

For the first "cut," all targets were assumed to be identical nude males.

UNDESIRABLE EFFECTS

The principal objective of the Medical Group meetings was to generate provisional estimates of undesirable effect probabilities as a function of apriori graded damage levels for all vital organs and body regions of interest. Also, the graded damage levels were re-examined and a consensus final grading was arrived at by the group as a whole.

These estimates eventually are intended for computer exercise of the weapon effects model. They form a portion of the total basic data bank and are input to the computer in tabular form.

Specifically, the assessment methodology consisted of (1) reviewing necropsy slides of tissue and organ damage of varying grades from the animal tests; (2) agreement and/or modification to the original damage level assessment; (3) estimating probability of the undesirable effect in accordance with the definition, assessment rules, assumption and constraint delineated below.

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.

ASSESSMENT RULES

Use "medical" meeting definition of undesirable effect.

Keep the undesirable effect estimate in perspective with the available animal test data and apriori medical records.

Targets are people [(standard man adopted for meeting) young healthy male, 69" tall, 70-75 kg specimen].

ASSUMPTION

Both baboon data and shoat data correlate with people (this may error on the conservative side).

CONSTRAINT

Injured individuals will recognize the need for medical assistance (such as detecting blood in urine) and seek same within a reasonable amount of time.

The following are summary worksheets for the provisional estimates of undesirable effect probabilities for organs, tissue, bone and other body areas, which were generated during earlier medical meetings. These worksheets represent the so-called raw data of early tests from which other forms of presentation may be rendered; e.g:

1. A straight line could be fitted statistically to the data points.

2. A simple averaging technique could be employed to develop table inputs as below:

Bone	
G	P
0	0.
1	0.
3	0.8
5	1.0

Computer program would do linear interpolation between damage grade levels

SUMMARY WORKSHEETS FOR PROVISIONAL ESTIMATES OF
UNDESIRABLE EFFECT PROBABILITIES BASED ON DATA FROM HIGH-ENERGY RUBBER BALLS

Organ or Body Region	Damage Grade Level	Probability of Undesirable Effect						Sample Size
		0	.20	.40	.60	.80	1.00	
HEAD	0	7						18
	1	2	1			1		
	2							
	3					2		
	4						1	
	5						4	

Organ or Body Region	Damage Grade Level	Probability of Undesirable Effect						Sample Size
		0	.20	.40	.60	.80	1.00	
SKIN	0							36
	1	5						
	2	5	3					
	3		5	5				
	4				1			
	5						12	

SUMMARY WORKSHEETS FOR PROVISIONAL ESTIMATES OF UNDESIRABLE EFFECT PROBABILITIES BASED ON DATA FROM HIGH-ENERGY RUBBER BALLS

Organ or Body Region	Damage Grade Level	Probability of Undesirable Effect						Sample Size
		0	.20	.40	.60	.80	1.00	
L I V E R	0	2						5
	1							
	2							
	3							
	4							
	5						3	

Organ or Body Region	Damage Grade Level	Probability of Undesirable Effect						Sample Size
		0	.20	.40	.60	.80	1.00	
K	0							6
I	1							
D	2		2					
N	3			2	1			
E	4						1	
Y	5							

59,9

SUMMARY WORKSHEETS FOR PROVISIONAL ESTIMATES OF UNDESIRABLE EFFECT PROBABILITIES BASED ON DATA FROM HIGH-ENERGY RUBBER BALLS

Organ or Body Region	Damage Grade Level	Probability of Undesirable Effect						Sample Size
		0	.20	.40	.60	.80	1.00	
LUNG	0							4
	1	1						
	2							
	3					1		
	4							
	5						2	

Organ or Body Region	Damage Grade Level	Probability of Undesirable Effect						Sample Size
		0	.20	.40	.60	.80	1.00	
BONE	0	1						6
	1	2						
	2							
	3							
	4					3		
	5							

59,10

SUMMARY WORKSHEETS FOR PROVISIONAL ESTIMATES OF UNDESIRABLE EFFECT PROBABILITIES BASED ON DATA FROM HIGH-ENERGY RUBBER BALLS

Organ or Body Region	Damage Grade Level	Probability of Undesirable Effect						Sample Size
		0	.20	.40	.60	.80	1.00	
OTHER	0							3
	1							
	2		2*					
	3							
	4							
	5						1**	

*1 stomach
 1 intestine
**heart

DESIRABLE EFFECTS

As a result of facts established early in a Methods Group meeting, it was recommended that the estimation of desirable effects due to purely physiological phenomena be carried out by the Medical Group.

OBJECTIVE

The principal objective of a resulting meeting (discussed below) was to generate provisional percentage estimates of physiologically based desirable effects for both the Fleeing Suspect (Scenario III) and the Moving H/Dispersal of a Crowd (Scenario IV). The data reviewed was generated under a prior Army program.

PROCEDURE

The following methodology was employed:

1. Physiologically based desirable effect for scenarios of interest was defined.

2. Methods for obtaining physiologically based desirable effects were discussed and established.

3. Percentage estimates of the desirable effect were generated along with supporting rationale for the effect quantified.

DISCUSSION

Methods of obtaining physiologically desirable effects were discussed. It was decided that at one end of the spectrum was surprise, and at the other, concussion. In between was something which was more difficult to define. This was considered to be an autonomic effect. Terms used were defined as follows:

1. Surprise - An effect produced by an emotional disturbance such as a a bright light, loud noise or any other sudden change to the target environment, which disturbs, for a finite time, the concentration of the target.

2. Autonomic Component - An effect produced by a near miss, such as when geese are disrupted in flight by a near miss, fall stunned to the ground, regain their equilibrium, and continue on in flight. It was agreed that when all of the nervous system reacts at once confusion results. Nerves have a limit as to how rapidly they can send messages.

3. Concussion - Transient interruption of brain function due to brain acceleration induced by an impact to the head or other body areas. An interruption of cellular membrane activity which causes cerebral function disruption.

Several other effects were considered. These may fit in with some aspects of the surprise-to-concussion spectrum, or they may represent separate effects. In any event, additional effects were defined as follows:

4. Stun - This effect was initially discussed at the previously-mentioned Methods Group meeting. It was noted that a biochemical change causes shock or the stun effect and that this can be caused by a physiological stress (contact) or by a purely mental stress.

5. Pain - The idea of a pain tolerance was discussed. It appeared that common sense would be violated if one fails to include pain as a potential desirable effect*. The phrase discomfort index was coined and defined as that pain level which would induce dissidents to leave the scene in Dispersal of a Crowd (Scenario IV). A sufficient pain level might also induce a fleeing suspect to halt (become immobilized).

*In prior sessions, such as the referenced Methods Group meeting, pain was largely discounted as a desirable effect because people can react so differently to it. However, if the individuals comprising a crowd are truly swept up into the spirit of the crowd and lose their individual identities in it, might they not all be considered to react nominally to some discomfort index with some degree of assurance?

6. Knockdown Force - An effect wherein a target individual is virtually knocked off his feet as a result of sustaining an impact of sufficient force to a body area.

FLEEING SUSPECT - SCENARIO III

The Fleeing Suspect (Civil Scenario III/Army Scenario I) was examined first. The target consists of one fleeing suspect. It is desired to immobilize the suspect for 30 seconds, a time which has been previously established as sufficient for apprehension.

Skin and head (brain) physiological damage levels were used exclusively. The procedure was similar to that used by the Methods Group at an earlier meeting. The group was shown color slides of typical Grade "X" damage* to a test animal (baboon head or swine torso). They were then asked to estimate the desirable effect such an impact would produce on a fleeing suspect. Immobilization increments of 10% were generally 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 along with supporting 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.

Methods generally considered in achieving the desirable effect were stun, concussion, knockdown force and pain.

*The damage level was not stated for this series of estimates. It can be inferred, however, that the members of the group would have a good "handle" on the level for each slide because the slides had been viewed before on two separate occasions by several members of the assessment team.

RESULTS OF MEDICAL GROUP ASSESSMENT OF IMPACTS ON ANIMALS WITH HIGH-ENERGY RUBBER SPHERES (TEST SERIES II)

FLEEING SUSPECT - CIVIL SCENARIO III (ARMY SCENARIO I)

Baboon Shots

Shot No.	Damage Level* Head	Damage Level* Skin	Probability of Desirable Effect	Rationale
2	0	3	.10	Surprise, possible concussion, knockdown doubtful
1	1	3	.90	Concussion
8	4	3	1.00	Cerebral commotion, skull fracture
7	1	3	.10	Sufficient jostling to produce small hemorrhage
13	5	5	1.00	Tearing of tough skin requires a significantly large force to cause damage under the skin
14	5	5	1.00	Ditto
3	0	2	.10	Head jerked - large acceleration resulting in confusion due to stun
4	0	2	.10	Ditto
9	1	1	.20	Ditto
10	0	3	.20	Small subcutaneous hematoma and contusion at impact point
15	5	5	1.00	Large impact force dilated blood vessels and ruptured some blood vessels. Cerebral commotion
16	5	5	1.00	Gross damage, skull fracture
5	0	2	.10	Blood vessels dilated; cerebral lesion
6	0	2	.10	Surprise

*Shown for reference purposes only. Not used directly in making probability estimates.

FLEEING SUSPECT - CIVIL SCENARIO III (ARMY SCENARIO I)
(Continued)

Baboon Shots

Shot No.	Damage Level* Head	Damage Level* Skin	Probability of Desirable Effect	Rationale
11	0	1	.10	Hit above occipital crest; surprise
12	3	4	1.00	Hit below occipital crest; massive damage, knockdown**
17	1	2	.20	Minimum damage to all of brain shown; visual disturbances
18	3	5	1.00	Brain stress damage

Swine Shots

Shot No.	Damage Level Body Region		Damage Level Skin	Probability of Desirable Effect	Rationale
2	Liver	0	1	0	No apparent effect
1	Liver	0	1	0	Some pain in belly, but suspect would probably run faster
3	Liver	5	5	.70	The more he runs, the worse the pain would get; pain & stun effect
4	Liver	5	5	.90	Ditto - only worse
5	Liver	5	5	1.00	Gross organ damage
6	Liver	0	5	1.00	Ditto, ruptured heart left ventricle
11	Kidney	3	2	.20	Quick pain in skin lesion
12	Kidney	1	2	.10	Ditto, but less severe
9	Kidney	2	3	.10	Ditto, but less severe

*Shown for reference purposes only. Not used directly in making probability estimates.
**Brain contusion with force transmitted to brain stem.

FLEEING SUSPECT - CIVIL SCENARIO III (ARMY SCENARIO I)
(Continued)

Swine Shots

Shot No.*	Damage Level Body Region		Damage Level Skin	Probability of Desirable Effect	Rationale
10	Kidney	3	3	.40	A good whack, would smart, pain
7	Kidney	4	5	.80-.90	Pain close to spine
8	Kidney	2	5	.30	Severe skin lesion, almost a punched-out wound; instant blood and pain
13	Thorax	3,4	2	.90	Fractured ribs and lung puncture
(15) - 17	Thorax	5,4	3	.80	Ditto, but less severe
(16) - 18	Thorax	5,4	3	.80	Ditto
(14) - 16	Thigh	0	1	0	--
15 - (14)	Thigh	1	3	.20	Bleeding
14 - (13)	Thigh	1	5	.60	Severe penetrating wound

*Circled value is animal number; otherwise shot number and animal number are synonymous.

NOTES:

Shot No. 6 - Shot missed liver - hit heart and ruptured left ventricle.

Shots No. 13, 17, 18 - First damage levels are for lung.
Second damage levels are for bone.

Shots No. 14, 15, 16 - First damage levels are for bone.

MOVING II/DISPERSAL OF A CROWD - SCENARIO IV

The primary objective with this scenario is to disperse a crowd of dissidents. The approach taken was to estimate the probability that a single dissident would leave the scene because of various effects (stun, concussion, etc.) sustained as a result of being subjected to specific physiological damage associated with high-energy rubber ball impacts. It was desired to mobilize the crowd within five minutes*. A longer time would be undesirable because the crowd may get unruly. A shorter time is inappropriate because the control force will often sit out a situation if the street being blocked is not a critical artery.

As in the Fleeing Suspect (Scenario III) case, skin and head (brain) physiological damage levels were used exclusively. The procedure for evaluation was as previously stated.

Results are shown in the following table along with supporting 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 mobilized in five minutes or less and 90 will not.

Mechanisms generally considered in achieving the desirable effect were stun, concussion, knockdown force and pain**. It was further stipulated that blood flow was a "no-no" (indicative of police brutality as would be inferred by TV viewers). Also, damage grade levels were not announced prior to rendering desirable effect estimates (same as on Fleeing Suspect scenario).

RESULTS OF MEDICAL GROUP ASSESSMENT OF IMPACTS ON ANIMALS WITH HIGH-ENERGY RUBBER SPHERES (TEST SERIES II)

MOVING H/DISPERSAL OF A CROWD - SCENARIO IV

Swine Shots

Shot No.	Damage Level			Blood Flow	Probability of Desirable Effect	Rationale
	Body Region		Skin			
2	Liver	0	1	No	.05-0	
1	Liver	0	1	No	.20	Pain - pit of belly
3	Liver	5	5	Yes	0	Gross damage; diaphragm injured
4	Liver	5	5	Yes	0	Ditto
5	Liver	5	5	Yes	0	Ditto
6	Liver	0	5	Yes	0	Sheared off tip of heart

*It should be noted that a time limit of five minutes was selected for "clearing the area." Therefore, a person unconscious or unable to move within this time period did not meet the desirable criteria of leaving the area, and the desirable effects probability was thus estimated as zero for these cases.
**Generally, these mechanisms are identical to those cited in the Fleeing Suspect work area. However, surprise was not considered to be a significant mechanism in the Moving H/Dispersal of a Crowd scenarios.

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

Swine Shots

Shot No.*	Damage Level Body Region		Damage Level Skin	Blood Flow	Probability of Desirable Effect	Rationale
11	Kidney	3	2	No	.60	
12	Kidney	1	2	No	.50	
9	Kidney	2	3	No	.60	Belly pain
10	Kidney	3	3	No	.50	Some would be disabled
7	Kidney	4	5	Yes	.40	
8	Kidney	2	5	Yes	.40	
13	Thorax	3,4	2	No	.80	Fractured ribs; will get short of breath in a few minutes - some may not make it off the road
(15) - 17	Thorax	5,4	3	No	.90	Fractured rib, punctured lung
(16) - 18	Thorax	5,4	3	No	.80-.90	
(14) - 16	Thigh	0	1	No	.10	
15 - (14)	Thigh	1	3	No	.50	Pain
14 - (13)	Thigh	1	5	Yes	.70	Pain

*Circled value is animal number; otherwise shot number and animal number are synonymous.

NOTES :

It should be noted that most of the above assessments are pain-oriented.

Also, shots 3, 4, 5 and 6 results are keyed to profuse blood flow.

Shot No. 6 - Shot missed liver - hit heart and ruptured left ventricle.

Shots No. 13, 17, 18 - First damage levels are for lung.
Second damage levels are for bone.

Shots No. 14, 15, 16 - First damage levels are for bone.

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

Baboon Shots

Shot No.	Damage Level Head	Damage Level Skin	Blood Flow	Probability of Desirable Effect	Rationale
2	0	3	No	.90	
1	1	3	No	.50	Some will be knocked down - of these, half will get up and leave
8	4	3	No	.10	
7	1	3	No	.80-.90	
13	5	5	Yes	0	Blood
14	5	5	Yes	0	Blood
3	0	2	No	.80	
4	0	2	No	.80	
9	1	1	No	.80-.90	Hit in motivation area of brain
10	0	3	No	.80	
15	5	5	Yes	0	Blood
16	5	5	Yes	0	Blood
5	0	2	No	.80	
6	0	2	No	.80	
11	0	1	No	.80	
12	3	4	Yes	0	Blood
17	1	2	No	.80	
18	3	5	Yes	0	Blood

It was suggested that better assessments could be made, possibly, if the time-on-target (time during which damage mechanism transmits energy to target) could be determined, along with the nature of the impact. The latter might be classed as direct impact, glancing blow, etc.

LEGAL CROWD - ARMY SCENARIO III

The Army Legal Crowd scenario and Civil Scenario III (Suspect Fleeing on Foot) are somewhat similar, in that the emotional level of the individual who comes out of the crowd to throw rocks, etc. can be compared to that of the fleeing suspect. It was agreed that the legal crowd "troublemaker" would be slightly less motivated than the fleeing suspect. Rationale was that the individual in the legal crowd is a "show-off" and that he thinks he will be able to escape into the crowd, whereas the fleeing suspect is a long way from his home and he is usually breaking curfew or looting, etc.

The estimates in the following table were based upon a desirable effect which incapacitates (immobilizes) the offender for 15 seconds. Additionally, the concern here is only with the individual who comes out from the crowd and throws rocks. Moreover, he is the typical young male.

The estimates for this scenario type given in the table were compared to estimates for the fleeing suspect rendered at a previous Medical Group meeting. The purpose of this exercise was to give a spot-check on the consistency of the estimates. It was a good test because in both scenarios a single individual was being dealt with. The motivation levels are different and so are the immobilization times.

Note that for a given impact, damage was typically done to the skin and also to an internal organ. The estimated probability of desirable effect, as stated in the following tables, is based on the over-all physiological damage sustained by the target as a result of one impact.

RESULTS OF MEDICAL GROUP ASSESSMENT OF IMPACTS ON ANIMALS WITH HIGH-ENERGY RUBBER SPHERES (TEST SERIES II)

LEGAL CROWD - ARMY SCENARIO III

Baboon Shots

Shot No.	Animal No.	Damage Grade Skin	Damage Grade Head	P_{DE}*	Remarks
2	2	3	0	.50	Some will be disabled, but not all. The force was sufficient to stun or give concussion to one-half of people. The pain involved in creating this much trauma would be enough to cause subject to hold his head for 15 seconds.
1	1	3	1	1.00	A blow hard enough to cause this much acceleration will cause concussive injury - probable knockout.

*Probability of Desirable Effect

LEGAL CROWD - ARMY SCENARIO III
(Continued)

Baboon Shots

Shot No.	Animal No.	Damage Grade Skin	Damage Grade Head	P_{DE}*	Remarks
8	8	3	4	1.00	A blow hard enough to cause this much acceleration will cause concussive injury - probably knockout.
7	7	3	1	.25	Tangential force accelerated head causing rotational stresses which produce confusion and stun effect.
13	13	5	5	1.00	Massive destruction to head. Instant death. Blew head open.
14	14	5	5	1.00	Ditto
3	3	2	0	.10	Some skull deformation to cause vascular dilation (pain), surprise.
4	4	2	0	.25	Pain, surprise, some skull deformation.
9	9	1	1	.25	Small mark on skin. Slight hemorrhage.
10	10	3	0	.25	Minimal brain lesion. Some demonstrable force transmitted to brain.
15	15	5	5	1.00	Fractured skull (sacrificed immediately).
16	16	5	5	1.00	Fractured skull.
5	5	2	0	.10	Would feel a little blood on top of head. Surprise, startle.
6	6	2	0	.10	Startle, surprise.
11	11	1	0	.10	Occipital depression, surprise.
12	12	4	3	1.00	Concussive injury. Subdural hematoma.
17	17	2	1	.25	Startle. Transmission of force in brain. Subdural hematoma.
18	18	5	3	1.00	Brain stem damage.

*Probability of Desirable Effect

LEGAL CROWD - ARMY SCENARIO III
(Continued)

Swine Shots

Shot No.	Animal No.	Damage Grade Body Region		Skin	P_{DE}*	Remarks
2	2	Liver	0	1	0	No immediate effect probable.
1	1	Liver	0	1	.25	Real pain in belly. Some will double over. Serosal hemorrhage.
3	3	Liver	5	5	1.00	Penetrating wound.
4	4	Liver	5	5	1.00	Ditto
5	5	Liver	5	5	1.00	Ditto
6	6	Liver	0	5	1.00	Ruptured heart, missed liver.
11	11	Kidney	3	2	.50	Rabbit punch. Bruised rib. Painful impact with element of surprise.
12	12	Kidney	1	2	.50	Ditto
9	9	Kidney	2	3	.50	Ditto
10	10	Kidney	3	3	.50	Ditto
7	7	Kidney	4	5	.90	All but the hearty ones will stop. Body wall and kidney damage.
8	8	Kidney	2	5	.50	Most damage occurs at impact point. Similar to Shot No. 11.
13	13	Thorax	3	2	.90	Fractured rib, pain.
17	15	Thorax	5	3	1.00	Fractured rib, pleural tear, and lung perforation.
18	16	Thorax	5	3	1.00	Fractured rib, lung puncture.
16	14	Thorax	0	1	0	Insignificant damage.
15	14	Thorax	1	3	.50	Periosteal hemorrhage.
14	13	Thorax	1	5	1.00	Penetrating wound. Gross skin lesion.

*Probability of Desirable Effect

TEST SERIES III ASSESSMENTS

An additional series of tests employing the high-energy rubber sphere (Test Series III) was run to provide additional data needed in certain areas of this program. The results of a Medical Group assessment of these data, similar to those given above, are presented in the following three tables.

PROVISIONAL ESTIMATES OF PHYSIOLOGICALLY DESIRABLE EFFECTS (HIGH-ENERGY RUBBER SPHERE, TEST SERIES III)

FLEEING SUSPECT - CIVIL SCENARIO III (ARMY SCENARIO I)

Baboon Shots

Shot No.	Animal No.	Damage Grade Head	Damage Grade Skin	P_{DE}	Remarks
3	203	0	1	0	No significant damage.
2	202	0	1	0	Ditto
4	204	0	2	0	Ditto
5	205	0	2	0	Ditto
6	206	0	0	0	Ditto
7	207	0	1	0	Ditto
1	201	0	0	0	Ditto

Swine Shots

Shot No.	Animal No.	Damage Grade Body Region		Damage Grade Skin	P_{DE}	Remarks
3	204	Liver	0	2	0	
1	202	Liver	0	3	.10	Some have belly pain.
2	203	Liver	0	2	0	
6	207	Heart	3	3	.25	Pain due to muscle tear and skin lesion, no significant EKG changes.
4	205	Lung	1	2	.10	Similar to Animal No. 207, but not as severe.
5	206	Heart Lung	0 1	1	0	Lung hemorrhage.
7	208	Lung	2	1	0	

FLEEING SUSPECT - CIVIL SCENARIO III (ARMY SCENARIO I)
(Continued)

Swine Shots

Shot No.	Animal No.	Damage Grade Body Region		Damage Grade Skin	P_{DE}	Remarks
9	210	Heart Lung	3 4	5	1.00	Perforation of thoracic wall.
16	217			No Test		
11	212	Heart Lung	3 4	3	.25	Fractured rib and EKG effects noted.
8	209	Liver	3	1	.50	Liver was fractured. Bellyache. Pain.
10	211	Lung	2	3	.10	Fractured rib.
14	215	Heart Lung	2 3	3	.10	No fractured rib. Muscle lesion. Solar plexus type impact.
13	214	Heart Lung	4 3	5	1.00	Perforation of thoracic wall.
12	213	Heart Lung	2 4	3	.50	Pretty good bruise. Hemothorax pleural tear. Primary cause - lung damage.
15	216	Heart Lung	4 2	3	.50	Possible infarction (muscle probably died). Heart damage.
17	218	Kidney	0	1	0	No significant damage.
19	220	Kidney	0	1	0	Ditto
18	219	Kidney	0	2	0	Ditto

PROVISIONAL ESTIMATES OF PHYSIOLOGICALLY DESIRABLE EFFECTS
(HIGH-ENERGY RUBBER SPHERE, TEST SERIES III)

MOVING H/DISPERSAL OF A CROWD - SCENARIO IV

Baboon Shots

Shot No.	Animal No.	Damage Grade Head	Damage Grade Skin	P_{DE}	Remarks
3	203	0	1	0	There is not enough lesion for positive signs, hemorrhage, etc.
2	202	0	1	0	Ditto
4	204	0	2	.10	Physical pain associated with hemorrhage (muscle).
5	205	0	2	.10	Ditto
6	206	0	0	0	See Animal No. 203 comment.
7	207	0	1	0	Ditto
1	201	0	0	0	Ditto

PROVISIONAL ESTIMATES OF PHYSIOLOGICALLY DESIRABLE EFFECTS
(HIGH-ENERGY RUBBER SPHERE, TEST SERIES III)

LEGAL CROWD - ARMY SCENARIO III*

Baboon Shots

Shot No.	Animal No.	Damage Grade Head	Damage Grade Skin	P_{DE}	Remarks
3	203	0	1	0	No affirmative (positive) signs of effects.
2	202	0	1	0	Ditto
4	204	0	2	.10	Not much damage. Muscle hemorrhage. Pain.
5	205	0	2	.10	Ditto
6	206	0	0	0	No positive signs of effects.
7	207	0	1	0	Very little muscle hemorrhage.
1	201	0	0	0	Ditto

*The desired effect for this scenario is to immobilize the individual for 15 seconds.

GENERAL OBSERVATIONS AND REMARKS

The group noted that effect and/or response times should be added to the scenarios. Some of the scenarios contain these time references, while others do not. The Medical Group has been using stated times in order to facilitate the rendering of effect estimates. Where times are not stated in the scenarios, the Medical Group has evolved and stated their own times while rendering effect estimates.

It was noted that although consideration of pain is a problem, both the Medical and Methods Groups have discussed and used pain in rendering effect estimates. The Medical Group keys on pain which occurs some time after impact and which results from physical damage. The Methods Group keys on the transitory pain associated with an impact.

CIVIL SCENARIO III - SUSPECT FLEEING ON FOOT

The purpose of the latest meetings of the Medical group has been to generate desirable and undesirable physiological effects estimates for the specific civil scenarios given in Appendix C, using the high-energy rubber sphere damage mechanism. Inputs to the assessments include descriptions of the civil scenarios and experimental data. Scenarios to be included are:

1. Civil Scenario I - One-on-One

2. Civil Scenario II - Barricade and Hostage

3. Civil Scenario III - Suspect Fleeing on Foot*

4. Civil Scenario IV - Dispersal of a Crowd.

The group concluded that Scenarios I, III and IV were definitely applicable, and that Scenario II was possibly applicable, for this type of projectile. In the three scenarios of primary interest, spheres may be launched directly against target personnel. In Scenario II, direct-fire launching of spheres is improbable, but they might possibly be bounced off walls of rooms, etc. and affect the target in that way. However, the safety of the hostage(s) must always be foremost in the minds of the control forces.

METHODOLOGY

The working methodology used to derive effects estimates was as follows:

1. The undesirable effect definition was reviewed. It remains fixed for all scenarios.

2. The desirable effect definition was reviewed. The desirable effect will vary with the scenario being investigated. In the scenario of the Suspect Fleeing on Foot, which was the subject scenario for this meeting, the

*Only civil scenario covered in this appendix from a strictly civilian standpoint.

desirable effect is as follows. Desirable effect is that physiological effect which will reduce the suspect's flight speed to a value which would permit a law enforcement officer to pursue, overtake, and apprehend the suspect within a reasonable distance (20 to 100 meters) or time (20 to 30 seconds).

Impact energies are shown in the following tables for convenient reference. These energy levels were not used in the estimation process. As will be noted in examining the table, one impact often produced damage to not only the skin and target organ, but also to other organs. The combinatorial procedure which could be used to assess the over-all effect of such multiple damage was discussed. The following rule was formulated. The over-all effect of multiple damage caused by a single impact of a blunt-trauma-type damage mechanism is equal to the largest individual damage noted, unless complicating circumstances exist in which case a special assessment is made. Typical complications include a fractured bone or a cardiac effect noted on an EKG.

PROVISIONAL ESTIMATES OF PHYSIOLOGICALLY-BASED EFFECTS
(HIGH-ENERGY RUBBER SPHERE, TEST SERIES III)

CIVIL SCENARIO III - SUSPECT FLEEING ON FOOT

Animal		Impact Energy ft-lb (Ref)	Target* Area	Damage Grade	Probability of		Remarks
No.	Type				Desirable Effect	Undesirable Effect	
204	Pig	14.4	(Liver)	0	0	0	No liver damage.
			Skin**	2	0	0	
202	Pig	14.7	(Liver)	0	0	0	No liver damage.
			Skin	3	.1	0	Greater hemorrhage than Shot No. 204.
203	Pig	15.6	(Liver)	0	0	0	No liver damage.
			Skin	2	0	0	
207	Pig	27.7	(Heart)	3	.25	1.0***	Animal died within 15 minutes of impact. Probable cause of death was ventricular fibrilation (heart contracting without pumping blood...system fails). Some percentage of these type hits cause death via arrhythmia.
			Skin	3	0	.25	

*Words in parentheses denotes target organ.
**Includes skin, subcutaneous tissue and muscle.
***This estimate is questioned because of the small sample size involved.

CIVIL SCENARIO III - SUSPECT FLEEING ON FOOT
(Continued)

Animal No.	Animal Type	Impact Energy ft-lb (Ref)	Target* Area	Damage Grade	Probability of Desirable Effect	Probability of Undesirable Effect	Remarks
205	Pig	28.9	(Heart)	0	0	0	EKG record indicates that heart was probably not hit.
			Lung	1	.1	0	
			Skin**	2	0	.1	
206	Pig	29.4	(Heart)	0	0	0	EKG record shows that heart was definitely hit. Possible transient block occurred.. came back in seven beats.
			Lung	1	0	0	
			Skin	1	0	0	
208	Pig	30.7	(Heart)	0	0	0	EKG record indicates that heart was probably not hit. One member requested that microscopic examination be performed on heart at future date.
			Lung	2	0	.1	
			Skin	1	0	0	
210	Pig	62.1	(Heart)	3	0	.1	Animal died. Although cause of death unknown it obviously was related to shot. Penetrating wound. Bruise on heart but no EKG effect.
			Lung	4	1.0	1.0	
			Skin	5	1.0	1.0	
217	- - -	- - -	- - - NO TEST	- - -	- - -	- - -	Probable glancing blow...wound signature distorted.
212	Pig	62.8	(Heart)	3	0 ⎫ ***	.1	Fractured rib and cardiac effect were noted.
			Lung	4	0 ⎬ .25	.25	
			Skin	3	0 ⎭	0	

*Words in parentheses denotes target organ.
**Includes skin, subcutaneous tissue and muscle.
***Over-all effects assessed as greater than the largest individual effect.

X ⎫
X ⎬ X denotes over-all effect.
X ⎭

6,7

CIVIL SCENARIO III - SUSPECT FLEEING ON FOOT (Continued)

Animal No.	Animal Type	Impact Energy ft-lb (Ref)	Target* Area	Damage Grade	Probability of Desirable Effect	Probability of Undesirable Effect	Remarks
209	Pig	63.4	(Liver)	3	.5	1.0	Missed heart. Animal died of anesthesia overdose. Liver damage would cause belly ache in person subjected to this wound.
			Skin**	1	0	0	
211	Pig	63.7	(Heart)	0	0 ⎫***	0 ⎫	Glancing impact missed heart but fractured rib.
			Lung	2	.1 ⎬ .25	.1 ⎬ .5	
			Skin	3	0 ⎭	.1 ⎭	
215	Pig	81.6	(Heart)	2	.1	0	Heart hit very high. EKG record does not indicate a hit. -- It appears normal.
			Lung	3	0	.1	
			Skin	3	0	.1	
214	Pig	82.3	(Heart)	4	.1	.75	Possible necrosis of heart tissue. Large EKG noted.
			Lung	3	0	.1	
			Skin	5	1.0	1.0	
213	Pig	84.1	(Heart)	2	0	0	Hemothorax (collapsed lung).
			Lung	4	.5	.5	
			Skin	3	0	0	
216	Pig	84.1	(Heart)	4	.50	.75	Possible infarction (large consistent EKG changes).
			Lung	2	0	0	
			Skin	3	.1	.5	
218	Pig	13.8	(Kidney)	0	0	0	
			Skin	1	0	0	
220	Pig	14.4	(Kidney)	0	0	0	
			Skin	1	0	0	

*Words in parentheses denotes target organ.
**Includes skin, subcutaneous tissue and muscle.
***Over-all effects assessed as greater than the largest individual effect.

X ⎫
X ⎬ X denotes over-all effect.
X ⎭

CIVIL SCENARIO III - SUSPECT FLEEING ON FOOT
(Continued)

Animal No.	Animal Type	Impact Energy ft-lb (Ref)	Target* Area	Damage Grade	Probability of Desirable Effect	Probability of Undesirable Effect	Remarks
219	Pig	14.5	(Kidney)	0	0	0	
			Skin**	2	0	0	
202	Baboon	13.6	(Brain)***	0	0	0	No gross physiological damage at relatively low energy levels resulted in zero effects.
			Skin	1	0	0	
203	Baboon	13.3	(Brain)***	0	0	0	Ditto
			Skin	1	0	0	
204	Baboon	13.6	(Brain)***	0	0	0	Ditto
			Skin	2	0	0	
205	Baboon	13.6	(Brain)***	0	0	0	Ditto
			Skin	2	0	0	
206	Baboon	13.8	(Brain)***	0	0	0	Ditto
			Skin	0	0	0	
207	Baboon	14.2	(Brain)***	0	0	0	Ditto
			Skin	1	0	0	
201	Baboon	15	(Brain)***	0	0	0	Ditto
			Skin	0	0	0	

*Words used in parentheses denotes target organ.
**Includes skin, subcutaneous tissue and muscle.
***All left-temple shots.

GENERAL

The following observations and recommendations were made:

1. EKG records provide a useful method for determining whether or not a heart target was in fact hit.

2. During future tests, post-hit time should be noted on the EKG tapes.

3. The EKG should be continued for 15 minutes after impact and then be activated at 15-minute intervals for one hour after impact and for a short time just prior to animal sacrifice.

4. More sensitivity (larger signal displacements) on the EKG was requested for future tests.

5. The possibility of utilizing a veterinary cardiologist or MD cardiologist to read test cardiograms was discussed. The veterinary cardiologist was thought to be preferable because it was felt that he would be in the best position to pick out species abnormalities.

6. Also discussed favorably was the possibility of conducting post-hit enzyme (blood) tests to shed further light on damage extent and cause of death.

There was considerable discussion regarding the definition of damage grade levels for heart impacts. The group experienced difficulty in establishing discrete definitions for various levels of damage to the heart, primarily because this meeting was the first actual opportunity they had to see (via color slides) and study heart damage resulting from blunt-trauma damage mechanism impacts. It became apparent that the establishment of damage grade levels for heart impacts should be a separate topic of discussion at a future meeting. With this in mind, the group assigned provisional damage levels to the heart wound studied, using the <u>general</u> level of damage sustained as the overriding assessment criterion. Thus, zero damage level corresponded to no visible effect, Damage Level 1 indicated minimal epicardial hemorrhage and Damage Level 5 indicated gross damage wherein anatomic lesions would probably cause termination.

It was noted that some of the discrepancies in damage grade levels to certain organs impacted at similar velocities may have been due to slightly off-target hits. This is a difficult problem to contend with, but every effort must be made in future tests to attain maximum accuracy. This involves launch accuracy, plus a definite knowledge of target organ location.

Discrepancies in some minutes of earlier Medical Group meetings were clarified. Modifications to several body area classifications were made, and definitions of certain terms were changed.

All estimates for desirable effects generated at this meeting pertain to Civil Scenario III (Suspect Fleeing on Foot) and the series of 25 high-energy rubber sphere shots conducted under this program (Test Series III). These shots should be evaluated against Civil Scenarios I, IV, and possibly II. In addition, the earlier series of 25 high-energy rubber sphere shots (Test Series I, under another program), that were recently regraded in accordance with current damage criteria could also be evaluated against Civil Scenarios I, III, IV, and possibly II.

APPENDIX F

GENERAL MATHEMATICAL MODEL

The model presented herein is the outgrowth of two tasks, one supported by LWL and the other under a LEAA/LWL agreement. A more specific treatment of the evaluation procedure is presented in the basic text of this report.

However, generally, the evaluation procedure begins as shown in Figure 1. 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. At present, the physiological damage data is organized using kinetic energy as a terminal effects parameter.

Figure 2 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 is the area, A_{ij}, associated with each effect in each section (illustrated in Figure 3). 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. This point is illustrated in Figure 4. Incidentally, 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

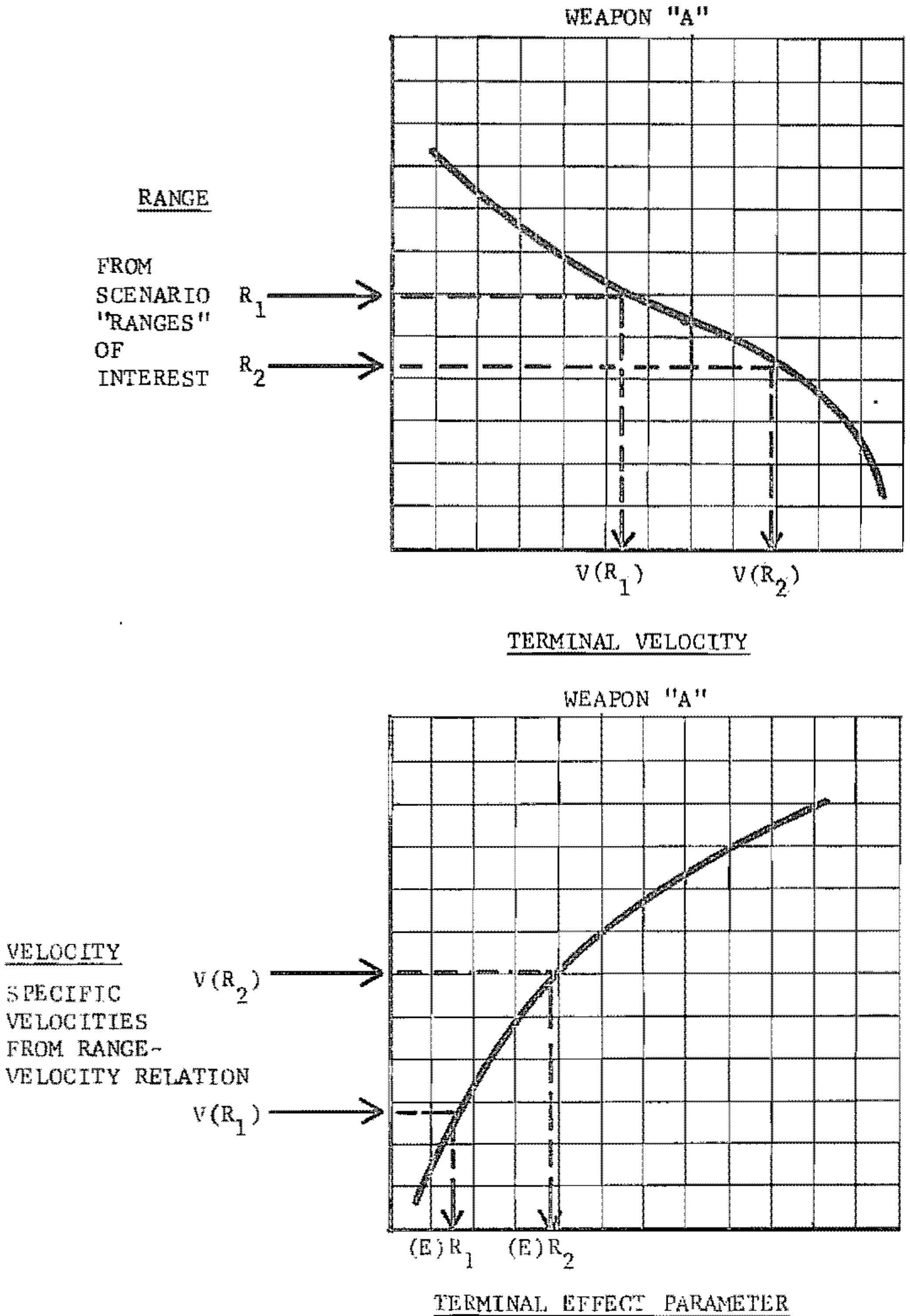


FIGURE 1 - DETERMINING THE TERMINAL EFFECTS OF A PARTICULAR MISSILE (PROJECTILE)

Determining The Undesirable Physiological Effects

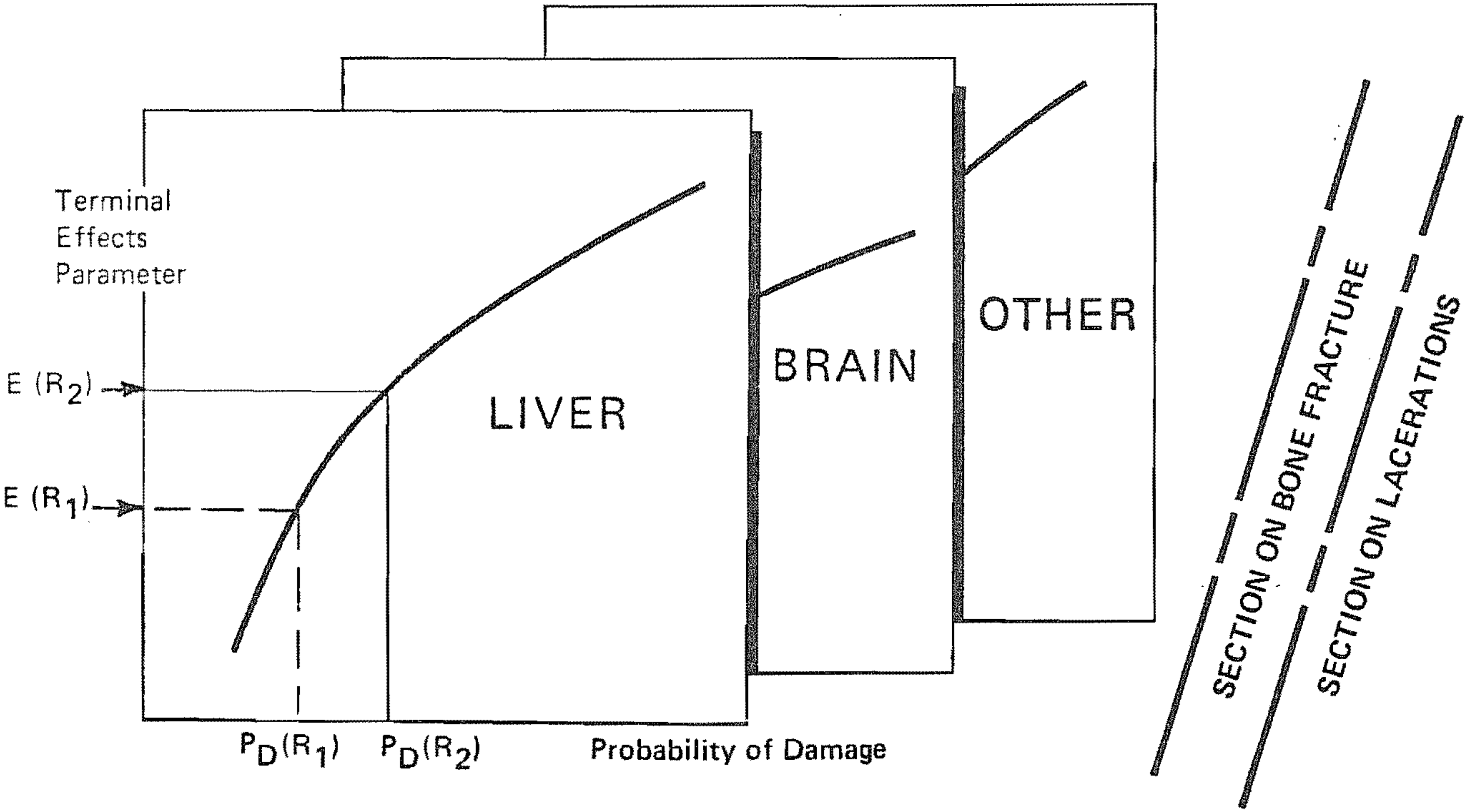


FIGURE 2

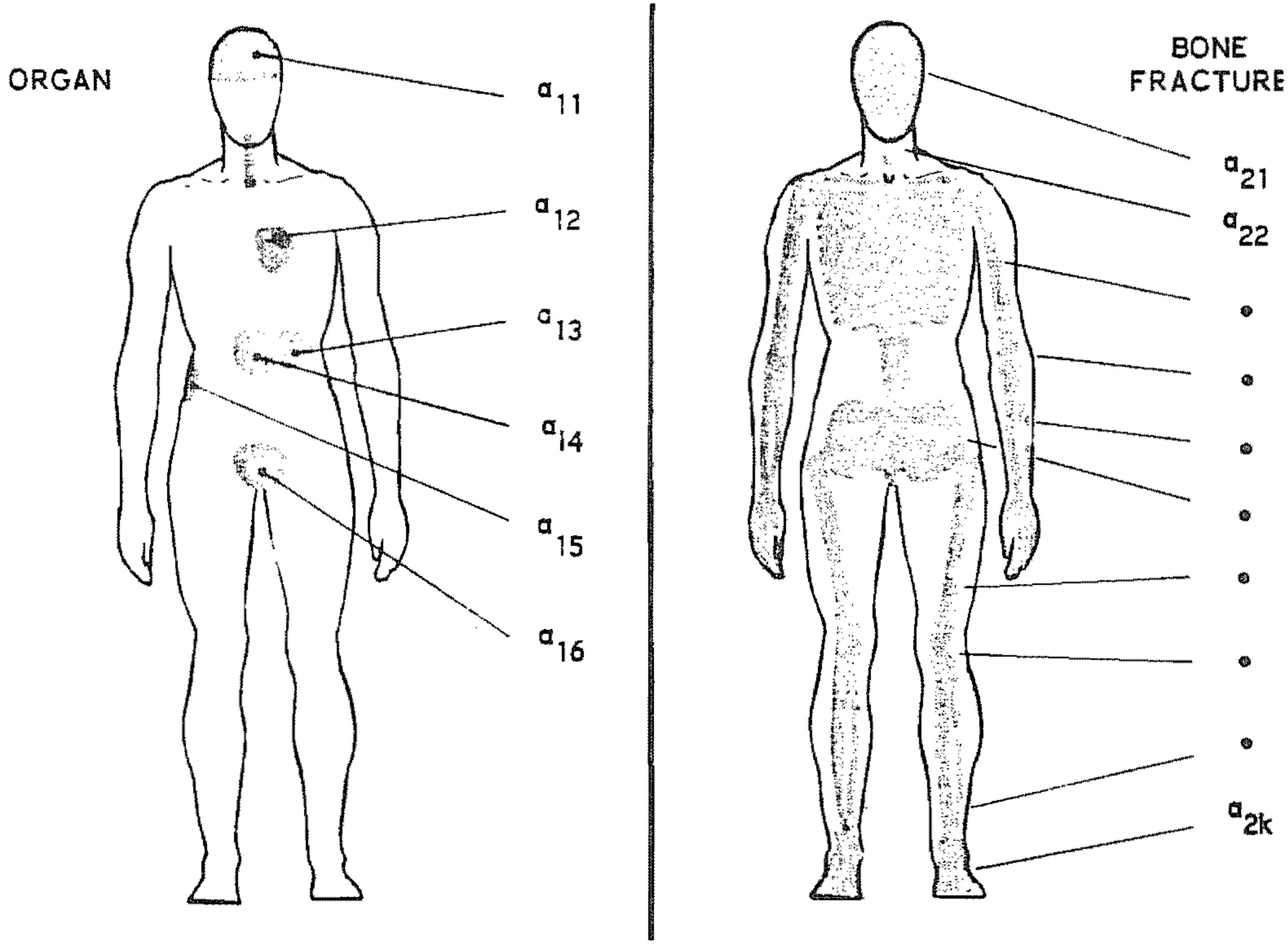


Figure 3 - Areas Associated with Specific Effects

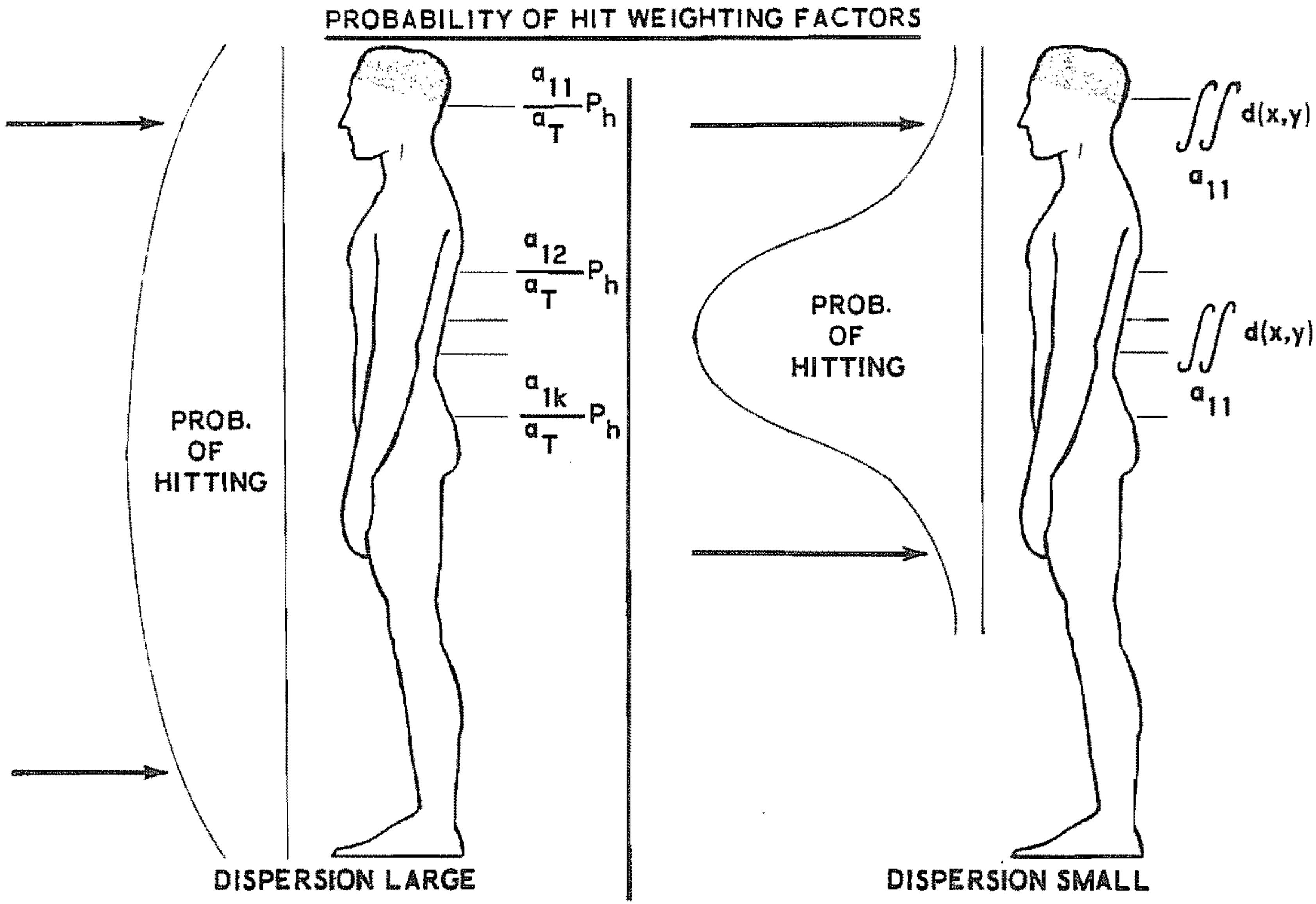


Figure 4 - Determining Probability of Hit

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 $P_{DE} = P_{DE/h} P_h$.

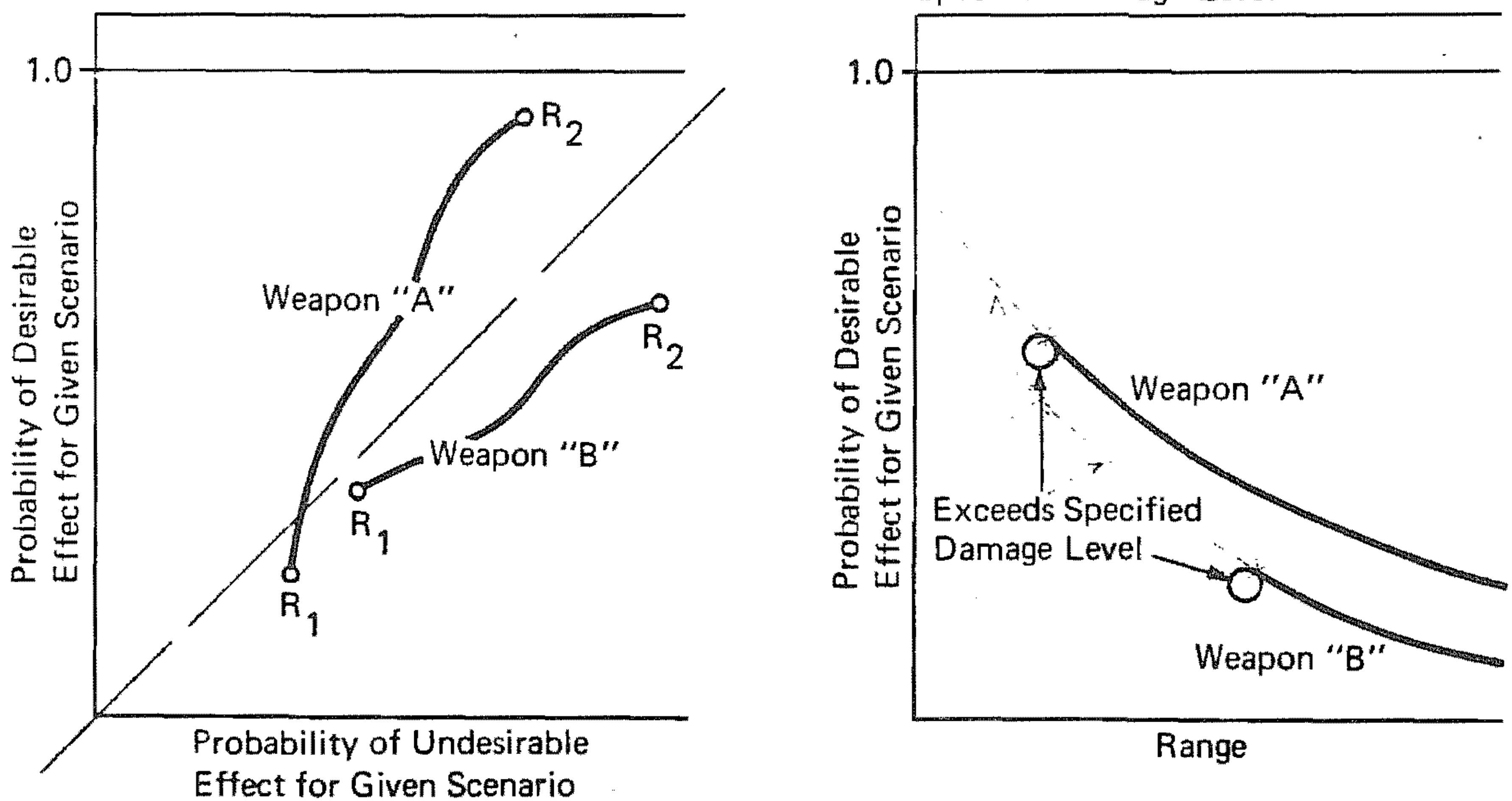
Examples of the possible final presentation of indices of value are given in Figure 5.

Final Presentation Of Evaluation

Figure 5

Simple Two-Parameter Presentation

Constrained by a Specified Damage Level



APPENDIX G

HIT PROBABILITY MODEL

INTRODUCTION

The Incapacitation-Probability Program (IPP) determines the probability of incapacitating one or more targets by firing one or more projectiles of a given type. Incapacitation in this case is synonymous with effects.

The target(s) may be one or more bystanders, a group of rioters or some combination of these, with or without innocent bystanders. A more detailed description is given in Target Identification.

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

PROGRAM ORGANIZATION

1. Inputs - For each run, the program requires the following data:

a. Identity of the run,

b. Area and weight of the projectile,

c. A table of drag coefficients vs. Mach number,

d. A table of incapacitation/hit ratios vs. velocity of impact,

e. The number of projectiles fired,

f. The height from which the projectile is fired,

g. The muzzle velocity of the projectile,

h. The distance to the target(s),

i. Standard deviation of the ballistic and aim errors,

j. The coordinates of the aim point, and

k. The location and size of the target(s).

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

2. 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 IPP. 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 IPP 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.

3. 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.

4. 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 IPP are:

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

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

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

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

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,

and

$$f(X) = \frac{1}{\sqrt{2\Pi}} \int_o^X e^{-\frac{1}{2}u^2} du.$$

The quantity n is computed from the formula,

$$n = 5a/\sigma_{R'}.$$

In formula d, 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 + DEV) · N/A.

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

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

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

TARGET IDENTIFICATION

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 (simplifying assumptions which do not significantly alter results).

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 G-1, their coordinates would be (-5,0), (-1,0) and (3,0), respectively.

As another example, consider the case of firing a less-than-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 4-1/2 feet, then their coordinates are (-1/3, 5) and (0,4-1/2), respectively (Figure G-2).

Figure G-3 which follows shows a flow chart of the computer program for determining incapacitation probabilities.

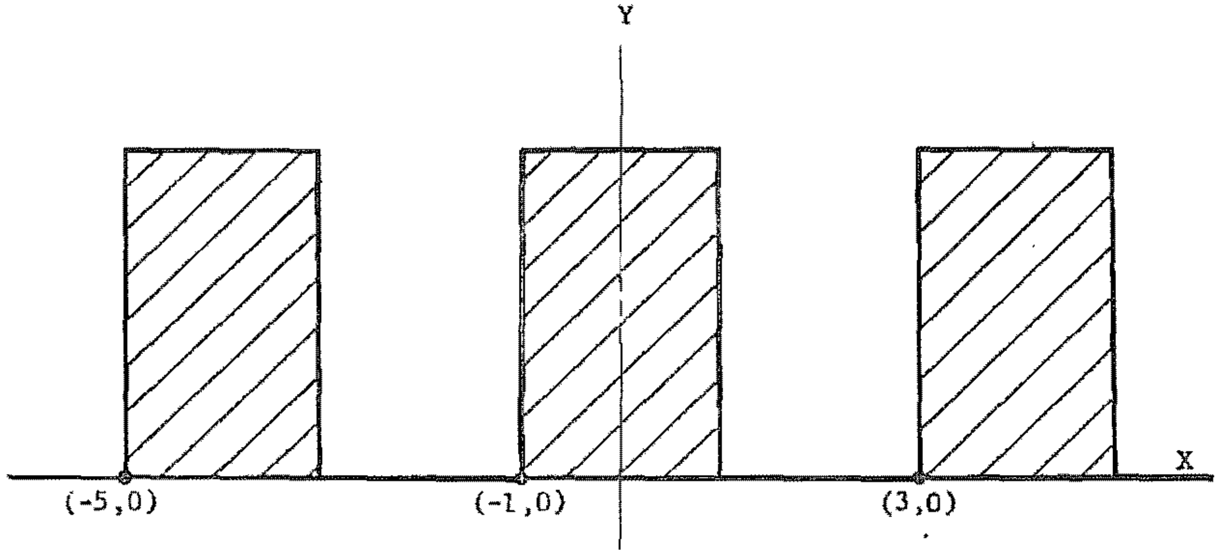


FIGURE G-1 - TARGET IDENTIFICATION, GENERAL

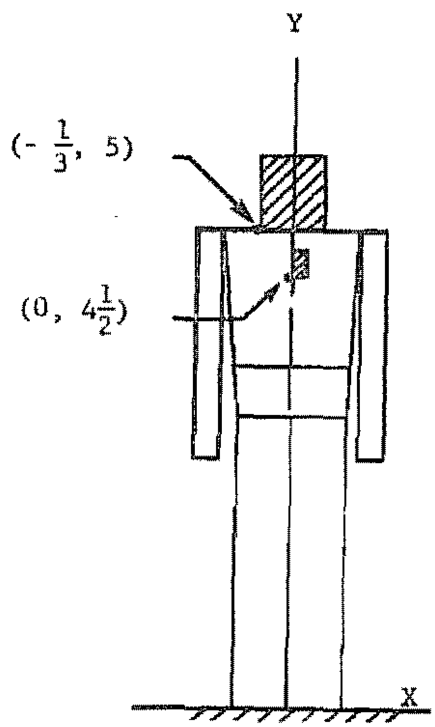


FIGURE G-2 - TARGET IDENTIFICATION, DISCRETE ELEMENTS

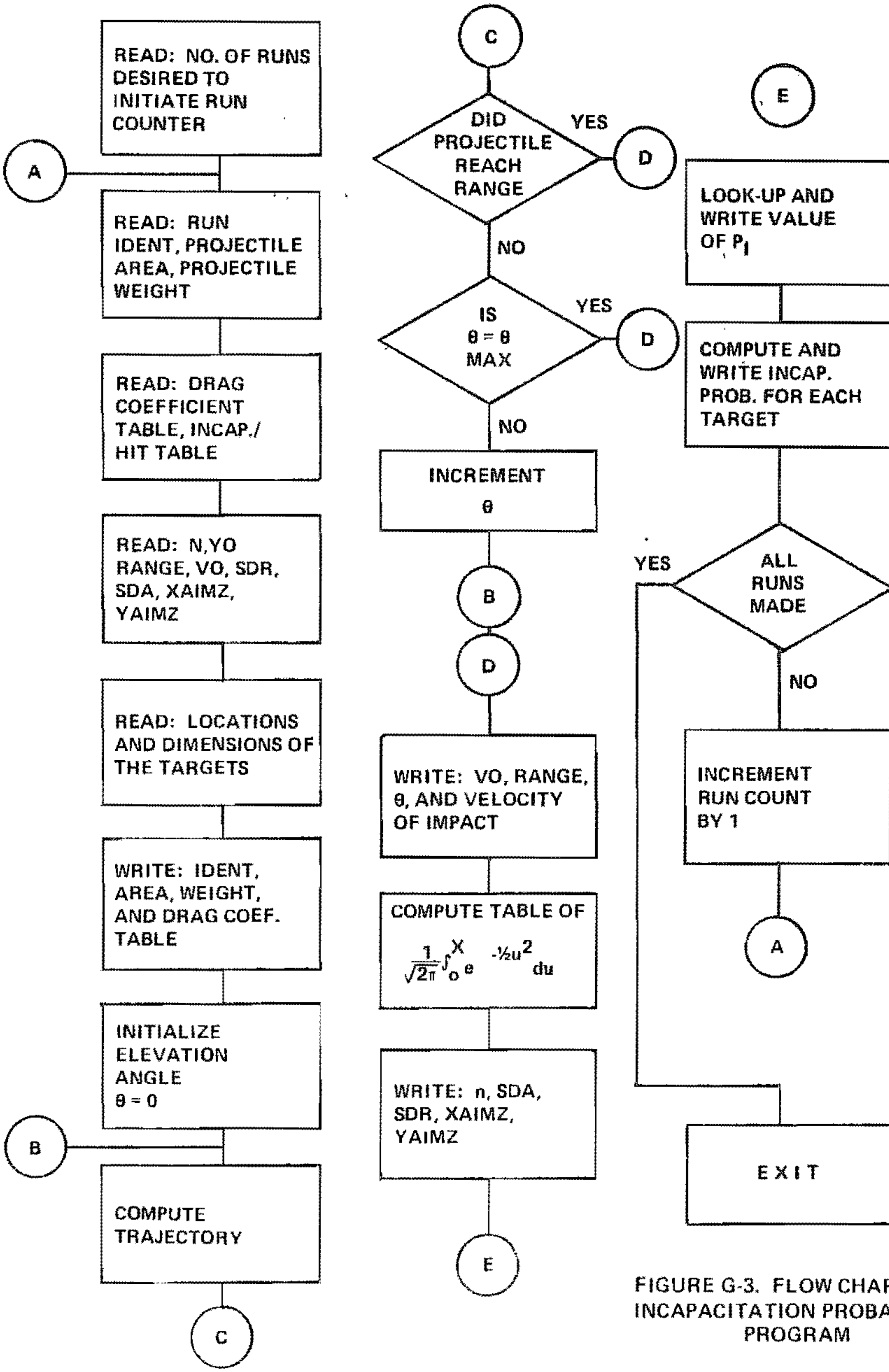


FIGURE G-3. FLOW CHART FOR INCAPACITATION PROBABILITY PROGRAM

APPENDIX H

LITERATURE SURVEY - BLUNT TRAUMA

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 in these papers have not been reproduced herein but are on file at the US Army Land Warfare Laboratory.

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 impacts 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)*] 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.

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

*References are listed at the end of this appendix.

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 relate energy, velocity and deceleration to skull fracture. 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 on file in the Research Analysis Office. 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 because 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 fat-embolism 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 behavior 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.

7.7

This section 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

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

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 properties of the human stomach
2. Shearing properties of human cerebral dura mater
3. Tensile properties of human skin
4. Tensile properties of the 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 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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APPENDIX I

QUANTIFYING PAIN

This appendix was prepared by Dr. Ronald A. Williams of Battelle Memorial Institute for the US Army Land Warfare Laboratory and is essentially a literature search on the subject. Techniques of testing discussed in several of the references served as a basis for the limited pain threshold tests conducted under the LWL less-than-lethal weapons evaluation program.

Quantitative measurement of pain is a very complex and difficult task, since it is basically a problem of trying to quantify a subjective 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 nocireceptors, and accordingly painful sensations may be evoked by many kinds of stimuli, e.g., 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(1). 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[2]. Pain then appears to be a multidimensional space comprising several sensory and affective dimensions.

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 only abstracts were reviewed for these cases. The predominant stimuli employed in most pain quantification work appear 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[4] do not concur with this concept. Further, the sensations perceived are the result of stimulation of the brain cortex by nervous impulses sent by the receptors on the skin. The sensitivity of the receptors can be modified 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 level and weight system[5]. Seevers and Pfeiffer[6] used pressure stimuli on the eyelid to quantify pain while studying drug effects and found wide subject variability for pain thresholds.

According to Davenport[7], 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.,[8] 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[5] discusses material which may be very important to the development of a less-than-lethal weapon. He states with extensive references that "there is no simple, direct relationship between the wound per se and the 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[4]. Further "emotion can block pain; that is common experience. It is difficult to understand how emotion can affect the basic pain apparatus other

APPENDIX J

PHYSIOLOGICAL DAMAGE CRITERIA

Prior to this program a set of physiologically based damage levels for the vital organs and body regions of interest was developed by a consensus of the Medical Group. These defined levels were used and revised during the course of this project. 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 blunt-trauma-producing ammunition of the purported less-than-lethal ammunition. Moreover, the criteria have been 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.

The criteria developed to date are 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 multiple 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

VI. OTHER VISCERA (CONT)

Grade	Criteria
3	Grade 2 plus serosal laceration and/or mesenteric lacerations
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*
3	Depressed fractures of skull with subcritical intracranial hemorrhage and/or limited brain contusion
4	<u>Critical</u> 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

*<u>Critical</u> intracranial hemorrhage is defined by that volume of accumulated blood required to produce coma due to increased intracranial pressure.

APPENDIX K

This appendix consists of a description of eight proposed areas of investigation which constitute a logical extension of the initial USALWL less-than-lethal evaluation effort. The contents of this appendix were forwarded to LEAA under separate cover as a proposed follow-on program. The titles of the eight areas are as follows:

1. Modeling for Less-Lethal Chemical and Electrical Devices
2. Scenario Development and Analysis
3. Weapon Performance Testing and Analysis
4. Testing and Evaluation of Chemical Weapons
5. Blunt Trauma Evaluation of New Weapons
6. .38 Caliber Wound Ballistics, Testing and Analysis
7. Development of a Body Simulator for Blunt-Trauma Testing
8. Utilization of a Stress Range for Performance Testing.

MODELING FOR LESS-LETHAL CHEMICAL AND ELECTRICAL DEVICES

Background: In the past year, LWL has developed a method of evaluating various types of less-than-lethal weapons. The model of evaluation consists of the details of bringing together the various quantitative pieces of information and providing an output measure of the relative value of the devices under evaluation. LWL's interest in less-lethal devices prior to the work for LEAA was oriented primarily toward impact blunt-trauma devices. LEAA also had a high interest in this area because of the proliferation of such devices in the commercial market. Hence, LWL's initial efforts in this area concentrated on a model which was sensitive to impact of kinetic energy devices.

The primary problem in establishing a model is getting the quantitative performance information to relate logically to a desirable end measure of effectiveness or value. For example, in kinetic energy weapons, one critical set of relations is as follows:

1. Relating impact conditions to some measure of tissue disturbance of a particular part of the body.

2. Relating tissue disturbance of a particular part of the body to a lack of well-being of the individual, given that only that part of the body is affected.

3. Relating lack of well-being of a particular part of the body to lack of well-being of the total body system, given a hit on the body.

4. Relating lack of well-being of the body in total, given a hit, to a final measure of lack of well-being.

Although the same general procedure would be used for chemical and electrical devices, specific units of quantification must be established. For the above sequence of relations, it was necessary to establish that total kinetic energy is a measure of impact conditions. Tissue damage grades had to be established in order to have something with which to relate the total kinetic energy of impact. For chemical and electrical weapons, the equivalent of impact total kinetic energy is needed. Undoubtedly, dosage level measured in weight per unit volume is the chemical equivalent, but as a minimum, tissue damage grades will be different for chemical irritants than for kinetic energy weapons. Also it is most likely that tissue damage is not the best dependent variable to associate with chemical dosage level. Hence, the details of quantification must still be worked out for chemical and electrical techniques, and these details depend to a large extent upon the way data has been taken in the past and upon what meaningful cause-effect relations are identified in the process of testing.

Objective: Provide a detailed set of quantitative relations where the units of all intermediate parameters are identified and which will give a relative measure of value as a function of device performance and use conditions.

Scope of Task:

1. Continue the intensive survey and analysis of the quantitative data which presently exists on the relation between chemical and electrical stimuli and physiological, neurological, etc. responses. Where appropriate data does not exist, detail the needs for such data in order that tests can be conducted which will provide the information.

2. Review and analyze all the data forthcoming from new tests for the purpose of determining the most effective way of organizing the model.

3. Update and modify the model to make it suitable for the relative evaluation of kinetic energy, chemical and electrical devices; that is, so different classes of techniques can be compared with each other.

4. Exercise the model in the evaluation of different chemical, electrical and kinetic energy devices.

Schedule:

3 months	Literature survey completed, identification of utilizable quantitative information; identification of quantitative needs for information not included in the literature available.
6 months	Data analyzed and organized in a form suitable for inclusion in the model.
8 months	Model completed; units of quantification identified and limited by the availability of data from tests conducted in response to identified needs (3 months).
10 months	Exercise of the model for specific devices and draft report.

Costs: Estimated cost for this task is $85K.

General Remarks: The value of the modeling effort may not be primarily in the end index of value, but in the "fall-out" of intermediate relations which end in a basic understanding of general principles of using or not using less-lethal devices. The identification of total kinetic energy as an important parameter in causing damage for kinetic energy devices is a good example of such a "fall-out."

SCENARIO DEVELOPMENT AND ANALYSIS

Background: In support of the present less-than-lethal weapons evaluations program, two seminars have been convened for the development of scenarios depicting situations in which less-than-lethal technology might contribute to the efficient resolution of conflicts between civilians and law enforcement personnel, both military and civilian. The results of this research are contained in the reports "Draft Scenarios of Civil Disturbances for the Derivation of Standards for Nonlethal Weapons" and "Draft Scenarios of Police Tactical Situations for the Derivation of Standards for Less-Than-Lethal Weapons."

Objective: Work will be continued in support of the less-than-lethal weapons evaluations program generally, and the police draft scenarios will be further developed in particular. The emphasis will be on:

1. Substantiating and refining the existing scenarios

2. Discover whether other scenarios might be fruitfully developed.

The significance of these scenarios derives from their elucidation of the important parameters of situations in which less-than-lethal weapons might be employed. In addition, they are used as a common basis for determination of probabilities of effects given target parameters.

Scope of Task: In order to achieve the objectives outlined above, two general approaches will be pursued. First, in order to determine the representativeness of the scenarios, police departments will be asked to review these scenarios and advise us as to the commonness of the depicted situations. They will also be asked for suggestions on other situations which might have been overlooked but which merit consideration. The problem is not so much gathering the data, rather the interpretation and assessment of these data. Secondly, in order to determine the accuracy of the scenarios, two techniques will be utilized. Wider distribution of the scenarios will be made and opinions requested as to the validity of the details in these scenarios. More importantly, in order to systematically evaluate the scenarios themselves and establish requirements for less-than-lethal weapons, films of the depicted situations will be acquired and analyzed by the appropriate members of the Less-Than-Lethal Weapons Evaluation Panel. Contacts with police departments, film libraries, private individuals, and other who hold pertinent film footage will be exploited.

Schedule: The schedule for the above research will be coordinated with the requirements of the over-all less-than-lethal weapons evaluations tasks, Task

Plan IV in particular. Emphasis during this six month study will be placed on acquiring the needed film, editing this film to fit the needs of the research, and submitting the resulting footage to the Methods Group of the Less-Than-Lethal Weapons Evaluation Panel for analysis. Concurrently, efforts will be made toward refining the scenarios. The development of new scenarios, further collection of supporting data, writing of reports, and subsequent work will proceed as dictated by previous research findings and/or other over-all study results and requirements.

Costs: This work will be conducted on a level-of-effort basis with total expenditures of approximately $50K.

General Remarks: The majority of the work will be performed under contract with Battelle Memorial Institute in Columbus, Ohio. It is hoped that coordination with Mitre Corporation will provide much of the "gathered" information from the field.

WEAPON PERFORMANCE TESTING AND ANALYSIS

Background: To determine the worth of a less-lethal weapon and ammunition, it is necessary to evaluate its tactical characteristics, ballistic performance characteristics, and physiological effects on the disorderly person(s). In order to compare the performance of certain less-lethal weapons to a familiar standard, the .38 Special Revolver and ammunition were tested under low-stress and nonstress conditions to establish a data base (Task Plan I). Limited tests were also performed with the MBA family of weapons, which use as a projectile a shot-filled canvas bag, and with various hand-launched missiles (Task Plan II).

Objective: To test under low-stress and nonstress conditions and to analyze ballistic performance data for selected weapons, either blunt-trauma-type or electrical devices.

Scope of Task: The objective will be accomplished for several weapon systems, each in two phases as noted below:

1. Phase I

a. As appropriate, a test of the ammunition will be conducted to determine the inherent ballistic characteristics solely of the ammunition (such as pressure, velocity, accuracy), when fired in an accuracy test fixture. Naturally, this will be done predominantly when the subject munition has a configuration which is suitable for firing in a conventional gun chamber.

b. The combination of weapon and ammunition together will be tested for velocity and accuracy. Any unusual weapon and muzzle exit firing effects will be noted.

c. Using a low-stress (time as the stress factor) condition, the man and weapon system together will be tested at representative ranges.

2. Phase II

Utilizing data gained from actual firing tests, an analysis will be performed and comparison drawn to the .38 Special tests. This will permit a critical assessment of the weapon characteristics under controlled conditions.

Schedule:

Subtask for Each Munition	Time Expended on Subtask	Time Elapsed After Authorization
Determine munition test requirements	2 weeks	2 weeks
Order munitions	--	2 weeks
Procure testing services	3 weeks	5 weeks
Conduct test	2 weeks	7 weeks
Provide preliminary data	2 weeks	9 weeks
Analyze test results and write final report	4 weeks	13 weeks

Costs: For planning purposes, assume five items tested for a total of $50K, (Expenditure per Item - $10K).

General Remarks: The proposed contractor for the above testing as applied to kinetic-energy weapons is H. P. White Laboratory. Other expertise will be employed as appropriate.

The cost estimates are subject to change depending upon availability of the subject munitions, unique characteristics of the munitions as they affect the testing program, and extent of data and analysis required.

TESTING AND EVALUATION OF CHEMICAL WEAPONS

Background: The existing chemical dispensing devices which are either already being used by law enforcement agencies or which hold promise as being potential candidate weapons for their use may be grouped into three main categories, viz., (1) dispensers, (2) grenades, and (3) projectiles.

The chemical dispensers are pressurized dispersers and include the hand-held aerosol and liquid dispersers, foggers, smoke cords, chemical wands, etc. These have been looked at briefly under Task Plan III, only to assist in the over-all model development. The chemical grenades dispense their agent by functioning as either burning type agent ejectors, bursting type, or compressed gas type. Some grenades are designed to be hand-held, some to be hand-thrown, some to be gun-launched, and some to permit the option of choosing either of these delivery methods. Projectiles, like the grenades, function as either burning type agent ejectors, bursting type, or compressed gas type. As the name projectile implies, projectiles are impelled to desired target areas by guns or launchers.

Objective: The work proposed under Task Plan III, Testing and Evaluating Chemical Agent CS and/or CN Devices in a Law Enforcement Role, was initiated. Current progress indicates that desired achievements will not be significantly advanced beyond step number one of the efforts listed under Scope of Task (Task Plan III). The objective of this task is to continue the work proposed under Task Plan III in a more comprehensive manner.

Scope of Task: From among those CS and/or CN dispensing devices which have been selected as offering potential as effective law enforcement weapons, at least one representative will be chosen for each device category grouping. These will be tested to obtain estimates of area-coverage/contamination-density relationships for each device tested. This information will in turn be used in the evaluation model developed under Task Plan IV of the over-all project to obtain estimates of effectiveness for each device.

Schedule:

Time	Milestones	Cost
3 months	Select, procure and test devices	$15K
3 months	Analyze data to obtain estimates of area-coverage/ contamination-density relationships	$20K
2 months	Employ evaluation model to obtain estimates of effectiveness and prepare final report.	$15K

Costs: Estimated total cost for this task is $50K.

General Remarks: Items selected for evaluation will be reported to LEAA prior to testing.

BLUNT TRAUMA EVALUATION OF NEW ITEMS

Background: New items are constantly being offered to the public as so-called "less-than-lethal" ammunition, weapons, etc. Very little laboratory testing normally is associated with these on-the-shelf, less-lethal weapons. Some of these items may be desirable for use by law enforcement personnel, while others may be extremely hazardous.

Objective: The objective of this program would be to screen candidate less-than-lethal weapons by in-house laboratory tests (when applicable). Those candidate weapons, ammunition, etc. that meet the standards currently being investigated by USALWL for LEAA will be recommended to LEAA for more comprehensive studies similar to studies completed on such items as the high-Q sphere, .38 caliber bullet, and stun-bag.

Scope of Task: Various candidate weapons, ammunition, etc. (no less than five) will be subjected to screening tests in the laboratory to determine their suitability for further, more comprehensive studies. Included in this study will be laboratory measurement and analysis of such parameters as:

1. Muzzle velocity
2. Striking energy (ft-lb)
3. Effects on gelatin
4. Effects on laboratory animals (at least four)
5. Rationale for recommendation.

Schedule: It is estimated that as items become available, the total amount of time necessary to screen all items will not exceed six to nine months. A typical item would be evaluated according to the following milestones:

1. Procurement of test quantities
2. Establishment of muzzle velocities, striking energies, etc. against 20% gelatin targets
3. Firing of item against laboratory animals (no less than four)
4. Examination of necropsies, pathology, etc.
5. Rationale for recommendation.

Cost: Estimated cost for this task is $40K.

General Remarks: The amount of funding and time necessary for a complete, comprehensive evaluation of all candidate less-than-lethal weapons, ammunition, etc. is prohibitive at this time. Expertise acquired on the present program now enables a laboratory screening program to be established for selection of those less-than-lethal weapons, ammunition, etc. that have promise for use by law enforcement personnel. Items selected for testing will be reported to LEAA prior to testing.

.38 CALIBER WOUND BALLISTICS, TESTING AND ANALYSIS

Background: Previous tests on the current program indicate that the .38 caliber projectile in its present configuration is not ideally suited for use by law enforcement personnel as a less-than-lethal weapon. There are a number of factors, such as striking energies, velocities, accuracy, effect on critical and noncritical organs, etc. that tend to discredit the .38 caliber projectile in its present configuration as a less-than-lethal munition.

Objective: The objective of this study would be to determine if the .38 caliber projectile can be modified (velocities, shape, etc.) in such a way as to enable its use by law enforcement personnel in a more effective and possibly less-than-lethal manner.

Scope of Task: The effects against 20% gelatin targets and laboratory animals (swine and baboons), by varying certain standard characteristics of .38 caliber bullets, will be determined. In these studies, such changes as lowering the initial muzzle velocity and/or modifying the shape of the bullet will be investigated as an aid to insuring that the .38 caliber bullet will have some "stopping" capabilities no matter where it strikes the target. A prime candidate for this laboratory evaluation would be MBA's "Short Stop" per a prior LEAA request. Upon completion of these studies, the most ideal bullet configuration for use in .38 caliber revolvers by law enforcement personnel will be recommended to LEAA. These investigations will be limited to just the bullet, and not include the cartridge case or the weapon.

Schedule: It is estimated that approximately six months will be necessary to complete this task.

Cost: Estimated cost for this task is $75K.

General Remarks: Preliminary results with the caliber .38 special bullet against critical organs of swine and baboons indicate that at an average striking velocity of 870 feet per second, death is either instantaneous or occurs very shortly after impact. In other noncritical areas of the body, it is postulated that the striking velocity of the bullet is so high as to cause the bullet to pass through the body (through-and-through wound) without imparting any significant energies to the body tissue surrounding the passing bullet. Thus, unless law enforcement personnel obtain an accurate first-round hit to a vital area of the target, the bullet could pass through without causing any significant damage. If the striking velocity of the bullet and/or its configuration is altered somewhat, then no matter where the round strikes, it may be possible that energies imparted to the target will cause sufficient physiological damage to incapacitate the target (stopping power). Energy thus used on a target reduces the hazards to other personnel in the area and may even reduce the over-all hazards such as lethality to the target itself.

DEVELOPMENT OF A BODY SIMULATOR FOR BLUNT-TRAUMA TESTING

Background: A number of test vehicles have been used in the past when evaluating kinetic-energy weapons, ammunition, etc. In addition to evaluation of kinetic-energy systems, these vehicles are also used for evaluation of blunt trauma effects. These vehicles include, but are not limited to, laboratory animals, i.e., rabbits, swine, goats, primates, and extensive use of 20% gelatin targets, in addition to instrumented mechanical devices such as accelerometers. The utilization of these vehicles is expensive, and correlation has to be made from animal or 20% gelatin to mechanical to human and vice versa. These correlations and/or extrapolations are also expensive and time-consuming. Therefore, a reasonable, inexpensive device to determine target parameter effects is required in order to provide input data to the general evaluation model developed under Task I of the basic LEAA/LWL agreement.

Objective: The objective of this program would be to develop a body simulator that can be used as a universal testing instrument for use by experimenters in the field of blunt trauma and would be compatible to the evaluation model developed under Task Plan I.

Scope of Work: It will be determined if a human being can be simulated by the use of 20% gelatin, articulated human skeleton, and various mechanical devices such as strain gauges, pressure transducers surgically implanted into the gelatin body, etc. This study would involve the imbedding of human skeletons in 20% gelatin by use of a mold of a standard man, 5 ft 9 in tall and weighing 175 pounds. The 20% gelatin will simulate the specific gravity of human tissue, while the skeleton will provide, in situ, the necessary skeletal support. Various strain gauges and/or pressure transducers can be imbedded in areas where vital organs, such as heart, brain, liver, kidneys, etc., normally exist. The body simulator itself will be transparent, allowing high-speed motion pictures, Micronex, etc. to record such phenomena as temporary cavity, permanent cavity, shock waves, missile impact, bone breakage and/or damage, etc. Using data acquired thusly and correlated with known data resulting from previous animal tests, a comprehensive idea of the missile effect on humans can be directly obtained. In addition to the above, and if necessary, various skin simulators, hair, etc. can be added to the model when and if the experiment warrants. The Medical Group of the Less-Than-Lethal Weapons Evaluation Panel will have primary input to this project.

Schedule: It is estimated that approximately 12 months would be necessary to complete the initial program. This work can be simultaneously accomplished with the blunt trauma evaluations of new items and .38 caliber wound ballistics and analysis programs and should complement each other.

Cost: Estimated cost for this task is $100K.

General Remarks: Initially, the cost of this program would be relatively expensive. However, once the human simulator was perfected, the basic cost would consist of a human skeleton (costing approximately $250), reusable strain gauges and/or pressure transducers and gelatin. Currently the cost of a shoat is approximately $50, plus feeding and care, and of a baboon, $350, plus feeding and care.

UTILIZATION OF A STRESS RANGE FOR PERFORMANCE TESTING:

Background: In the testing of less-than-lethal weapons to identify their ballistic and other performance characteristics, it is generally recognized that regimented range firing does not adequately simulate a tactical situation. In an effort to reproduce more realistically the stresses and decision events in an actual encounter, LWL will utilize a local, unique, stress-type range. This range features pop-up, running, and other dynamic targets. Although this type facility was not utilized previously (Task Plan I), it is a logical extension of past effort.

Objective: To test under stress conditions and to analyze performance data for selected weapons.

Scope of Task: The objective will be accomplished for several weapon systems, each in two phases as noted below:

1. Phase I

Testing on a stress-type course, simulating predetermined tactical situations, will be conducted to obtain data on man/weapon system combinations. A course of fire similar to the Stress and Decision Training Course used by the Bureau of Narcotics and Dangerous Drugs will be employed.

2. Phase II

Analysis of the data derived under Phase I will be conducted. This analysis will evaluate the effect of stress and decision-making on system performance parameters. A comparison of the tested less-than-lethal weapon to the .38 Special Handgun under the same conditions will be made.

Schedule:

Subtask for Each Munition	Time Expended on Subtask	Time Elapsed After Authorization
Assess test requirements and order munitions	2 weeks	2 weeks
Procure and coordinate test services and range facilities	3 weeks	5 weeks
Conduct test	3 weeks	8 weeks
Provide preliminary data	2 weeks (to get prelim rpt)	10 weeks
Analyze test results and write final report.	4 weeks	14 weeks

Cost: Based on the testing of five items, a total of $50K would be required for this task.

General Remarks: It is tentatively planned to conduct the stress range tests at the US Secret Service Training Division range at Beltsville, MD. Although informal contacts indicate concurrence, use is subject to official sanction.

Two approriate weapon systems, at the discretion of LWL, will be tested and analyzed initially to establish base-line data. One weapon would be the .38 caliber revolver since it is a natural follow-on from Task Plan I. The other item would be selected at a later date and would be a less-than-lethal type system. Three other systems could then be selected dependent upon interest and priorities at that time. These would be reported to LEAA prior to testing.