The Joint Non-Lethal Weapons Human Effects Center of Excellence

Human Effectiveness and Risk Characterization of the Electromuscular Incapacitation Device – A Limited Analysis of the TASER

Part II – Appendices

M26

X26

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March 2005

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Submitted by

Advanced Information Engineering Services
A GENERAL DYNAMICS COMPANY

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In Fulfillment of
PO DSC0263

Graphic on cover adapted from images provided by TASER International (2003).

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Appendix A - Non-Lethal Weapons Conceptual Framework

A.1. NLW Framework Overview

The following is extracted from Risk Characterization of Non-Lethal Weapons: Report of Expert Workshop and Proposed Conceptual Framework (TERA, 2001).

Non-Lethal Weapons (NLWs) are becoming increasingly important assets in nontraditional military operations, such as peacekeeping missions or humanitarian aid operations, where the use of lethal force may not be a desired first response for force protection. NLWs are weapons that "are explicitly designed and primarily employed so as to incapacitate personnel or materiel, while minimizing fatalities, permanent injury to personnel, and undesired damage to property and the environment" (DoD, 1996). Various types of weapons are part of the Department of Defense (DoD) non-lethal weapons program, employing riot control agents, electromagnetic, mechanical, or acoustic technologies. DoD Directive 3000.3 calls for these weapons to "achieve an appropriate balance between the competing goals of having a low probability of causing death, permanent injury, and collateral materiel damage, and a high probability of having the desired anti-personnel or anti-materiel effects" (DoD, 1996).

In an effort to achieve this balance, the Joint Non-Lethal Weapons Human Effects Center of Excellence (JNLW HECOE) requested that Toxicology Excellence for Risk Assessment (TERA) organize a workshop of leading risk assessment experts, who were joined by Subject Matter Experts (SMEs) from the DoD and its contractors, to develop a framework for characterizing the risks from military use of NLWs. The results of risk characterization are to provide decision-makers with the probability of intended target response effects and unintended effects so that the risk could be weighed against the effectiveness and benefits of using NLWs.

The workshop participants met in May 2001 and explored ideas to identify, evaluate, and quantify risks from NLWs for users, targets, and bystanders; ultimately, they developed a proposed conceptual framework (TERA, 2001). The independent external review panel (IERP) recommended that the four steps of the National Academy of Sciences risk assessment approach (i.e., hazard identification, dose-response assessment, exposure assessment, and risk characterization) serve as a foundation for the framework.

This conceptual framework is described in Table A-1 and focuses on the physiological effects and immediate behavioral consequences of those effects caused by the weapons. It allows risk assessment experts to integrate information on intended target effects and risks of unintended effects. Its purpose is to facilitate the organization of available data, to communicate risks and benefits to different levels of decision-makers, and to identify research needs. The Human Effectiveness and Risk Characterization (HERC) that emerges from the framework should integrate information from the dose-response assessment and the exposure assessment to evaluate the level of risk for the population or individual and compare that to the target response effectiveness. Field commanders and mission planners could use the resulting information to make informed choices regarding which NLWs would provide the most appropriate combination of target effectiveness and risk for the particular situation or mission.

Table A-1. Overview of the Conceptual Framework for Risk Characterization of Non-lethal Weapons (from TERA, 2001)

Hazard Effects Identification

- **Initial Evaluation:** Have relevant health effects been identified?
- **Screening Decision:** Are identified health effects acceptable?

Dose-Response

- **Quantify dose-response:** Select risk assessment methods or techniques, depending on the unique aspects of the data for the NLW technology under review.
- **Quality/Robustness of Data:** Present the results as dose-response curves or effective dose estimates as warranted by the nature of the data.

Exposure Assessment

- **Identify scenario(s)**
- **Identify variables:** Identify variables that affect delivery of the dose for the scenario(s) of interest.
- **Quantify exposure:** Select risk assessment methodologies suited to the diverse types of data.
- **Present the results:** Present results as probabilistic estimates of risk or point estimates.

Risk Characterization

- **Integrate the dose-response and exposure assessments**: Using an approach accommodating the nature of the input data and considering the type of decision the results will support.
- **Present the results**: Probabilistic and point estimate methods are suggested as two examples of risk characterization metrics.

The IERP convened by TERA concluded that application of risk analysis tools routinely used in human health risk assessment and elsewhere seems to offer great promise for analysis of effectiveness and risk associated with NLWs, both for existing NLWs and those under development. Risk characterization proceeds in tandem with better understanding of the relationships between the biophysical forces delivered by the weapons, the range of behavioral responses to these forces, and the biophysical mechanisms of potential injury. This proposed effectiveness and risk characterization framework could enhance risk communication with stakeholders who influence the sociopolitical environments in which these NLWs might be developed and deployed.

The framework walks the analyst and decision-maker through a series of steps, which identify the types of human effects anticipated from a particular weapon and the relationship between amount of "dose" (or force of the weapon) and the resulting response. For a given scenario or set of circumstances, the effect of exposure conditions on the amount of force or "dose" received by the person(s) is estimated. These are then combined to describe the potential risk of adverse effects to potentially three groups: the person(s) who is (are) the target, the operator or user of the weapon, and bystanders who are not intended targets. The risk characterization description includes the probability of a type of injury or death given certain circumstances. If the data are more limited, the results may provide an indication of the margin of safety between the amount of exposure likely to result from a given situation and the dose that would induce intended and unintended effects.

As for each step of the framework, Figure A-1 illustrates that if there are not sufficient data to identify the weapon's effects, more research is recommended.

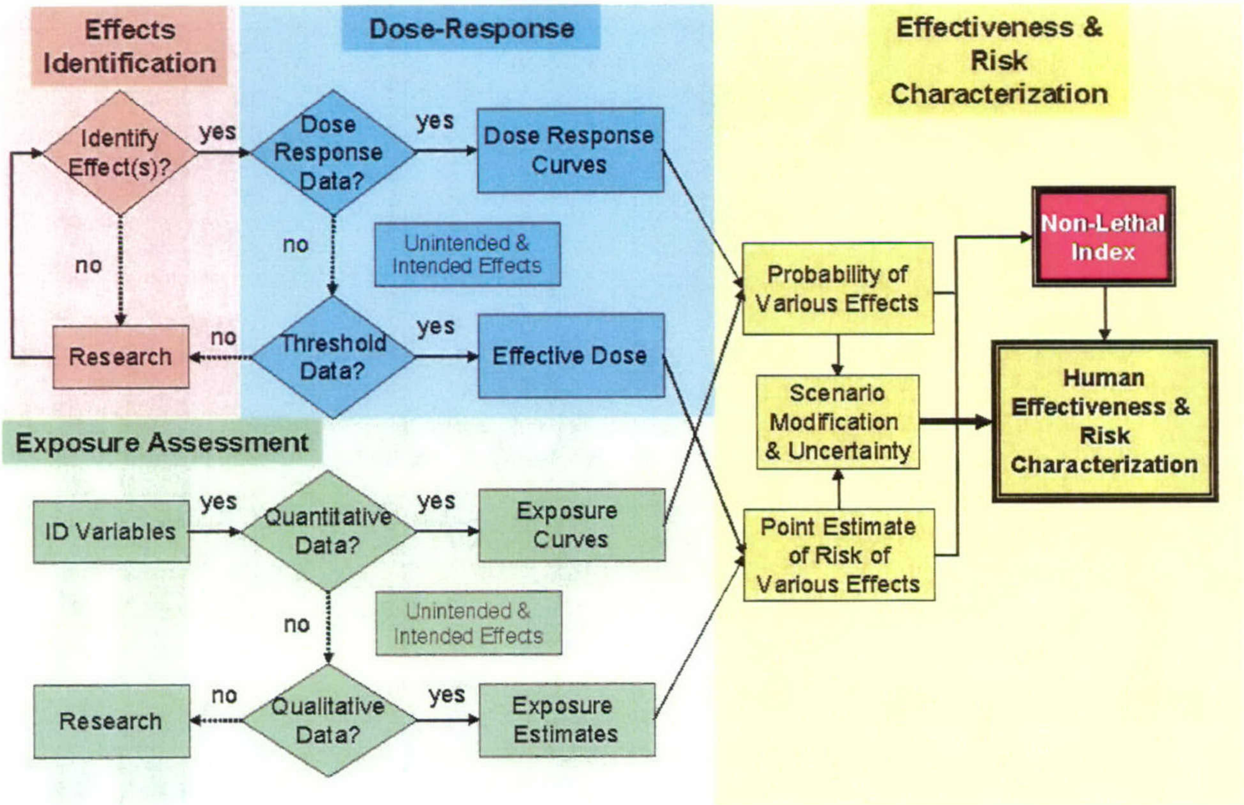

Figure A-1. Conceptual Framework for Effectiveness and Risk Characterization (Revised 2003)

This flow chart outlines the steps needed to characterize effectiveness and risk from use of non-lethal weapons. The effectiveness and risk characterization description is the end result of the process, reflecting the hazard identification and dose-response data incorporated with the exposure assessment. The results in the risk characterization column (either probabilities or point estimate ratios) reflect the type of decision needed as well as data available from the dose-response and exposure assessments.

A.2. Definition of Terms

A number of terms are used in the framework document and are defined as follows:

Users or Operators: in this context, the user or operator refers to the person(s) deploying the non-lethal weapon.

Targets: the target population refers to the individuals against whom the weapon system is being employed.

Bystanders: bystanders refer to all other individuals that may be affected by the use of the non-lethal weapon (collateral individuals).

Human effects: as applied to NLWs, may include any of the following: health effects to the weapon operator, human targets, and bystanders near the target, and effectiveness of the weapon against human targets.

Intended effects: the intended effect of the non-lethal weapon on the target to accomplish specific mission tasks and subtasks. While intended effects may be behavioral responses, generally only the physiological effect (e.g., pain, heat, or eye irritation) is directly measurable. Throughout this report the term "intended effect" is used to indicate the physiological effect.

Unintended effects: effects that produce injury or death to the targeted individuals against which the non-lethal weapon is deployed. Injury may refer to serious irreversible physiological effects that impact on living capabilities, such as blindness, hearing loss, or paralysis. For bystanders, unintended effects may be considered any adverse human effect, including those that would be intended and desired for the target.

Dose: quantity of an active agent (substance or radiation) taken in or absorbed at any one time (Cognitive Science Laboratory at Princeton University, n.d.)

Dose Response: the quantitative relationship between the delivered dose from a non-lethal weapon and the magnitude of an effect in an individual.

Exposure: a scenario-derived estimate of the dose to which a population or an individual is exposed with a specific use of a non-lethal weapon.

SEV0: The lowest effect severity is defined as severity level 0, which corresponds to a no observed adverse effect level (NOAEL). This category includes exposures that evoked no effects or effects of insignificant severity, such as minor cuts and bruises. Effects that fall in this category would not be expected to incapacitate the target.

SEV1: The next higher level of severity corresponds to reversible effects that would not normally require medical treatment for full recovery. SEV1 exposures induce discomfort or evoke involuntary mechanisms that incapacitate. Effects in this category will usually include the intended physiological effect.

SEV2: The next higher severity level includes effects that are more severe and typically require medical treatment, but that are not life threatening nor pose risk of significant disability after recovery. Effects in this category are unintended effects.

SEV3: The highest severity level refers to severe acute life-threatening effects or lethality or effects that pose risk of significant disability after recovery. Effects in this category are unintended effects of the NLW system.

Appendix B - Exposure Data[3]

[3] Appendix B was authored by Paul Price, LINEA, Inc.

B.1. Description of the TASER International Database

The TASER International Database (TI data) was provided by TASER International in July 2003. The TI data consists of 3,459 records submitted by individuals in the U.S. and Canada. The TI data were collected using a reporting form on the TASER International webpage (http://www.taser.com/pages/le/usereport.asp). A copy of the form is attached. The TI data includes information on a specific use of a TASER. The report includes information on the target individual, how and why the device was used, the number of shots fired, and the outcome of the incident. Submission of user reports to the TASER International database is voluntary and encouraged by an incentive program (a free cartridge for each submission). Certain large police organizations do not participate in the reporting process as a matter of policy.

B.2. Strengths and Limitations of the TI Data

The collection of such a large number of records from a variety of users clearly has considerable value in understanding the risks posed by the TASER devices. However, the records were not collected in a statistically representative survey and are potentially influenced by a number of sources of bias.

The TI data are voluntary; thus, they reflect the experiences of those individuals who were disposed to respond. This could lead to either an over sampling of individuals who were positively disposed to the device, introducing a bias toward positive results, or could lead to an over sampling of individuals who had a problem and were motivated to complain, resulting in an over reporting of problems. In addition, if the use of the EMI devices results in injuries that in turn result in lawsuits or internal investigation, police departments may be less likely to allow the submission of a user report. If this occurs, then the number of injuries could be underreported.

The quality of the TI data is also affected by the voluntary nature of the survey. Individuals are more likely to answer questions that are easy to answer than those that require more detailed information or that may not have been measured or recorded during the incident where the TASER was used. TASER International has a program of providing a free cartridge for each report. This will result in a bias towards those police departments that place a higher value on obtaining free cartridges. The implications of this factor are unclear. The TI data are also known to be censored. This censoring occurs by the decision of certain large police departments not to release the data requested and thus not participate in the reporting. Finally, it is not clear that TASER International verifies the reports. If they are not verified, it is possible that individuals could file a spurious report.

Because of these plausible sources of bias, the results of the survey must be viewed with some caution. Factors that related to successful use or the occurrence of adverse effects are of particular concern since these factors are most likely to be influenced by one or more of the sources of bias.

B.3. TI Data Scrubbing

The TI data are messy. Individuals making the reports were often not trained on how to fill out the survey instrument, and the instrument allowed the users to enter partial data and data that are not internally consistent[4]. For example, an individual could fail to enter a number for "darts hit," but indicate two dart hit locations and indicate that darts were removed at the scene. In certain records, the number of shots is recorded as one, but data are entered on more than two dart hit locations. Values are often missing for one or more inputs such as height, weight, age, and location of dart hit. The user's comments are truncated and incomplete. Finally, a small number of records contain extraneous entries that suggest errors of transcription may have occurred in the extraction of the data.

In order to use the TI data, the following actions were taken to revise the information:

- All units of height (unless metric units are specified) are assumed to be in feet and inches.
- When the values of height or weight are not provided, estimates of height and weight are estimated based on the mean height and weight for the reported gender and age of the individual. If no age is available, then no estimates are made for height and weight.
- Records where the number of dart hits were greater than the number of darts fired were eliminated.
- Records that indicate the "Level Deployed" as "Laser Only" or "Stun Gun Application," but also indicated that dart hits occurred and gave locations for the hits, were included in the analysis as "Darts Fired at Subject."
- The number of darts that hit the individual and the number of darts that penetrated the individual's skin are estimated using the following rules.
    - Use reported values if available.
    - Assume that number of darts penetrating skin equals the number hit unless there is indication otherwise in the "did darts penetrate" column or in the "remarks" field.
    - Where the number of dart "hits" is missing and either 1) the submitter reports darts were removed "at the scene" or "at medical" or 2) one or more location for the darts are reported, or 3) the comments section indicates the darts struck, then assume that one or more darts penetrated the skin.
    - Records are deleted where 1) darts are reported to have been removed, 2) no locations are given, and 3) no hits or penetrations are reported.
- Records where one or more of the entries in a field differ from the prescribed options are discarded since these entries suggest that other fields may be incorrect. For example, under the "weapon used", only

[4] Suggestions for improving the report form are attached at the end of this appendix.

three entries are allowed (X26, M26, and Air TASER 34000), yet certain records include the following entries: "Fists," "Yes," "M29," and "Knife."

- A distance between the locations of the dart hits on the person is determined using the individual's height and the grid location. Distances were not determined for records where one shot was to the front of the body and the second was to the back. Note this only affected a small number of records (<100).
- Records with graph coordinates for dart hit locations that do not fall on a body part (such as C0, F1, or F5) were assumed to occur as a result of entry error of this specific data. Therefore, these records are retained in the assessment, but no distances were determined and the records were not included in the determination of the probability of location-specific hits.

B.4. Analysis of the TI data

The TI data were sorted and records reflecting the use of TASERs that did not involve the firing of a dart were eliminated from consideration. This reduced the number of records to 2054 records. The remaining records were scrubbed using the process described above. This reduced the number of records to 2035.

The remaining records were sorted by the number of shots. The majority of records (1,766) involved the use of a single shot. Records reporting multiple shots numbered 269 with shots ranging from two to five shots. Data on incidents where there are multiple shots are more difficult to evaluate since the success of the use could be a function of any one of the shots. Therefore, this analysis focuses on those records where a single shot was performed. (The one exception to this is the interpretation of the reported success rate and its implications for achieving a complete circuit. In this case records involving two shots were also evaluated.) Of the 1,766 records, the distance to the target data were available on 1,667.

B.5. Results

B.5.1. Weapons Included in the TI Data

In the TI data, the vast majority, 98%, of the records are for the M26 with 1% for the AIR TASER 3400 and 1% undefined.

B.5.2. Dart Hit Location Distributions

The location of the dart hits were defined based on the grid described in Figure B-1.

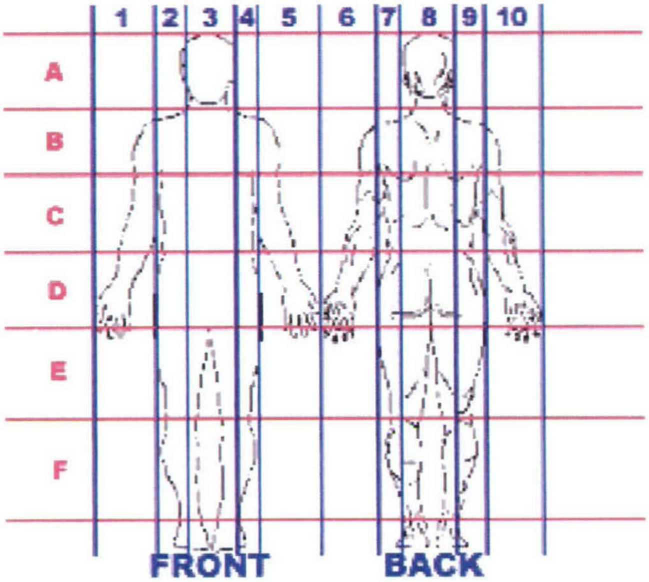

Figure B-1. Grid for Reporting Location of Dart Hits

Each shot potentially results in two dart hits. The data on location of the hits are recorded separately for each dart. When one dart misses, the remaining dart is reported as the top dart (although it is not clear that the shot came from the upper dart of the cartridge). In addition, if a second shot is made, the hit locations of the second set of darts are reported.

Table B-1 presents the distribution of the number of dart hits per grid location from the records where a single shot was fired. The data in this table includes records both with and without distance to target data. Thus, the total number of possible records is 1,766. No location data were reported for 149 records. This results in 1,617 records. For the top dart, locations are recorded for 1,617 records and 1,502 for the lower dart. Since a lower dart is only reported when an upper dart is reported, there are 1,502 records with two dart hit locations.

Not all of these records report a valid location for a dart hit. In a small number of records, the reported coordinates do not fall on the figure of the person's front or back (such as F,1). Eliminating these records reduces the numbers to 1,591 (from 1,617) and 1,448 (from 1,502) records for the top and bottom dart hits.

The TI data indicate that most hits reflect the instruction to place the laser site on the center of chest or upper back. As a result, the two grid locations B3 and B8 have the highest percentage of hits for the top dart.

Table B-1. Number of Dart Hits by Grid Location

Reporting Grid		Top Dart	Bottom Dart	Both
All Reports with Locations		1,617	1,502	3,119
All Reports with Valid Locations		1,591	1,448	3,039
A	3	16	0	16
A	8	7	1	8
B	1	28	1	29
B	2	110	6	116
B	3	345	28	373
B	4	97	10	107
B	5	32	4	36
B	6	12	1	13
B	7	47	7	54
B	8	170	21	191
B	9	52	10	62
B	10	12	0	12
C	1	29	17	46
C	2	62	87	149
C	3	151	312	463
C	4	53	69	122
C	5	20	26	46
C	6	14	11	25
C	7	32	34	66
C	8	137	215	352
C	9	46	58	104
C	10	12	16	28
D	1	8	13	21
D	2	7	62	69
D	3	14	109	123
D	4	10	47	57
D	5	4	24	28
D	6	4	11	15
D	7	6	29	35
D	8	18	68	86
D	9	6	37	43
D	10	6	6	12
E	3	3	18	21
E	4	6	34	40
E	5	0	2	2
E	7	2	8	10
E	8	3	11	14
E	9	5	8	13
F	3	0	2	2
F	4	0	6	6
F	5	0	1	1
F	7	0	4	4
F	8	3	8	11
F	9	2	6	8

B.5.3. Dart Hits and Dart Penetrations

The vast majority of shots resulted in two dart hits, indicating the success of the laser targeting and TASER International training. Of the 1,766 records, 1,666 include a distance to the target using the five distance ranges (1-3 ft, 3-7 ft, 7-11 ft, 11-15 ft, and 15- 21 ft); see Figures B-2 and B-3. For distances under 11 ft, the percentage of shots delivering two darts to a person was 80% and the percentage of the shots having both darts penetrating the skin is 65%.

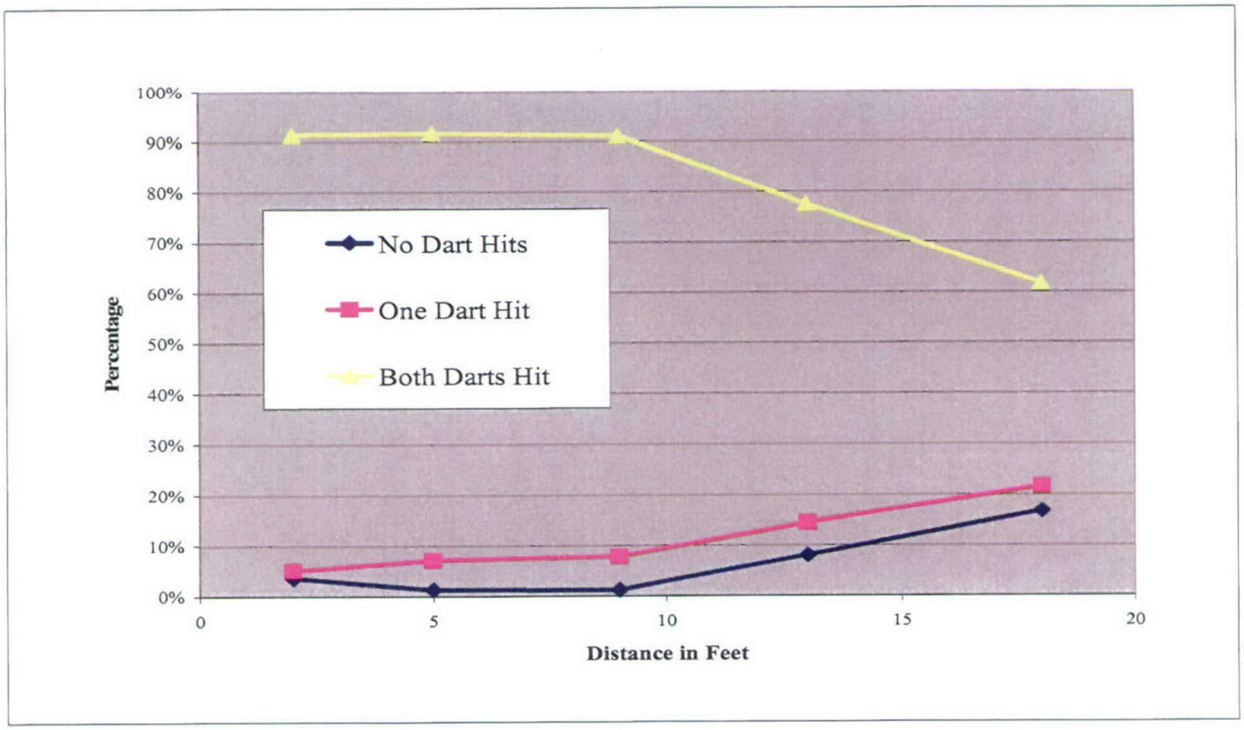

Figure B-2. Percentage of shots resulting in 0, 1, or 2 Dart Hits

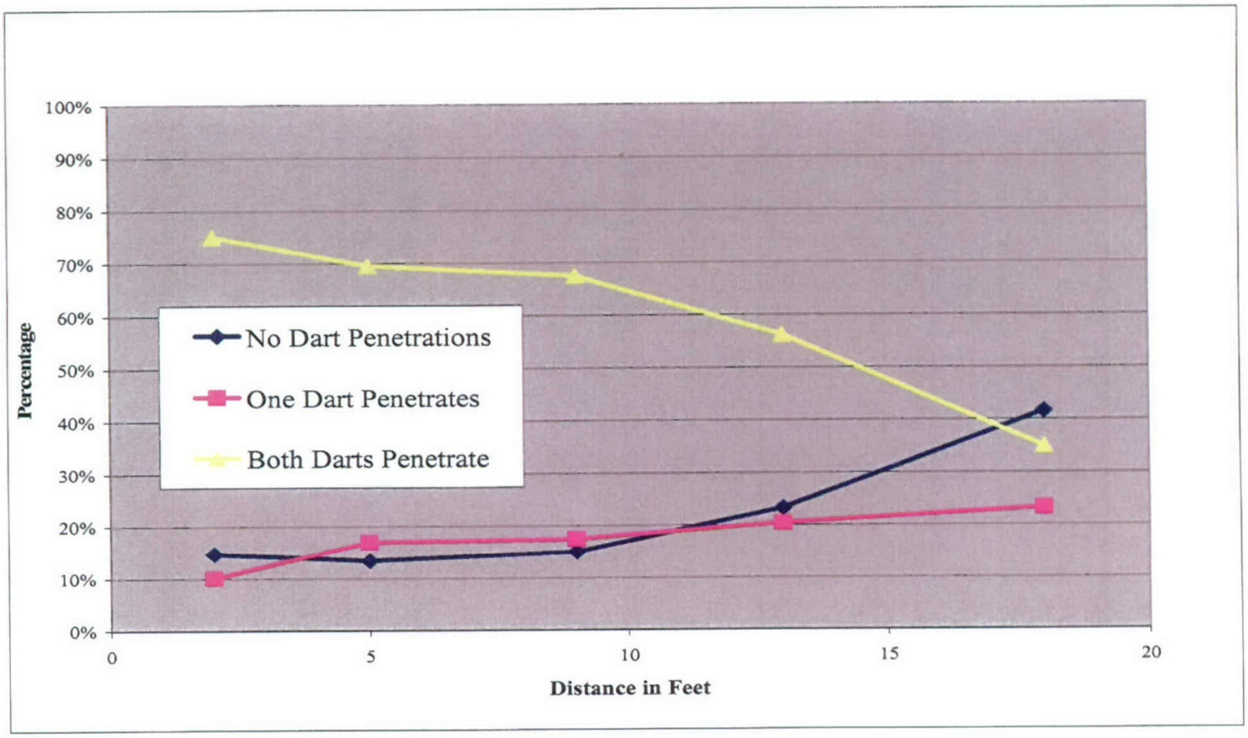

Figure B-3. Percentage of shots resulting in 0, 1, or 2 Darts Penetrating Skin

These findings suggest that the there is a significant drop in the effectiveness of the TASER past 11 ft. The drop is more notable in the percentage of darts that penetrate than darts that hit. The greater decline of the percent that penetrate is likely due to the decline of the dart's kinetic energy. Velocity measurements reported by TASER International indicate that the dart velocity declines from 166 f/s to 98 f/s at 13 ft of travel. This is a 40% decline in velocity. However, the ability of the dart to puncture clothing and skin is determined by the dart's kinetic energy. Since kinetic energy is a function of the square of the velocity, a 40% decline in velocity results in a 64% loss of kinetic energy. The decline would be even larger at greater distances.

B.5.4. Completion of a Circuit

The survey instrument used to create the TI data did not ask the user whether a circuit had been achieved. However, it did allow the user to report a subjective finding of whether the use of the weapon was "successful" or "not successful". Of the 1,766 records where a single shot was fired, 1,758 reported on the success of the shot. The reported success rate was very high. Of the 1,758 records, 1,646 reported the use as being successful. Even in the cases where neither dart struck a person, a large number of the records reported the use as successful.

In this analysis, we assumed that the success rate was a function of two processes: those processes that required an EMD effect (either partial or complete); and processes that do not (startle at being fired at, fear of an additional shot, or fear of higher levels of force). In this analysis, the probability of a circuit being completed is determined based on the following assumptions:

- If a circuit is completed, the user will always report the use as "successful" and
- If a circuit is not completed, then the user will report the use as "successful" X% of the time.

Under these assumptions the following are true:

$$TR = CER + NCER \quad (1)$$
$$SR = CER + NCER * X/100 \quad (2)$$

Where
TR = Total Records
CER = Circuit Established Records
NCER = No Circuit Established Records
SR = Successful Records

If one examined the data from those records where CER = 0 (or is very small) then:

$$TR = NCER \quad (3)$$
$$SR = NCER * X/100 \quad (4)$$

or

$$SR= TR * X/100 \quad (5)$$

and

$$X = (SR/TR)*100 \quad (6)$$

In this assessment, we initially assumed that those records where both darts miss could be assumed to have little chance of a connection. There are two sources of records on individuals who are not struck by either dart. The first source is the records where a single shot is fired and no hit occurred. There are a limited number of these records (58). Of these 58 records, 39 reported success despite no dart hits and thus little or no chance of the completion of a circuit. This suggests that X= 66%.

This estimate is likely to be biased since a user faced with failure from a first shot is likely to make a second shot. Thus, in many instances, a failure of an initial dart was not included in the 58 records because the user went on to shoot a second time and in the second shot achieved success. This could explain the low percentage of "unsuccessful" records. To correct this bias, records indicating multiple shots were reexamined to determine the number of records where the first shot missed and the user made a second shot ("How Many Cartridges Fired" = 2).

All records where this occurred were regarded as incidents where the initial attempt was unsuccessful. This assumption appears reasonable since the user would have to remove the cartridge for the first exposure from the TASER and insert a second cartridge to make a second attempt. Removal of the first cartridge is a clear indication that the first shot was not completely successful. In contrast, if a second shot came from another user, then the second shot may reflect a decision to simultaneously fire two or more TASERs (to insure a quick takedown) and may not be an indication that the first attempt failed.

An additional 154 records were identified that met this criterion. Of these 154 records, 23 reported that the first shot did not involve any dart hits. This raised the total number of records of an initial shot resulting in no dart hits to 99 and reduced the value of X from 66% to 39%.

Once the value of X is determined, the percent of records where a circuit is established (PC) can be determined for the remaining records (where a circuit could have been established) using the following equation:

$$PC = (CER/TR) * 100 \qquad (7)$$

By algebraic rearrangement of equations 1 and 2, the following equations are generated:

$$CER = TR - NCER \qquad (8)$$
$$NCER = (TR - SR)/(1 - X/100) \qquad (9)$$

By substitution:

$$PC = ((TR - ((TR - SR)/(1 - X/100)))/TR) * 100 \qquad (10)$$

Table B-2 presents the values of TR and SR for each of the permutations of dart hits and dart penetrations and the calculated values of PC. Records with no dart hits and the records with one hit (but no penetration) were grouped together and used to estimate the value of X% which was 41%. This value was applied to the equations above to give the results in Table B-2.

Table B-2. Effect of Dart Hit and Penetration on Fraction Successful and Estimated Probability of Circuit Being Established When Dart Hits of 0 and 1 (No Penetration) are Combined

Dart Hits	Dart Penetration	Single Shots		Multiple Shot Records	Total Records	Fraction Successful	Probability of Connection
		Successful Records	Unsuccessful Records	First shot is Unsuccessful			
0 or 1	0	56	27	54	137	41%	0%
1	1	106	17	12	135	79%	64%
2	0	176	29	15	220	80%	66%
2	1	162	5	19	186	87%	78%
2	2	1146	34	53	1233	93%	88%

Using this approach, the percentage of shots resulting in circuit completion increases with the number of dart hits and the number of dart penetrations. However, even with two penetrations of the skin, the prediction that a current has occurred is less than 100%. The reasons for this are not clear but could reflect factors such as battery failure or wires breaking.

It is also interesting to note the effect of skin penetration versus clothing penetration when a single dart hits an individual. The estimated probability of connection when the single dart hits the person, but does not penetrate the skin, is the same as if the dart missed. However, if the one dart does penetrate the skin, then the connection is estimated to occur in more than 60% of the cases. The skin penetration by one dart does imply that the distance to the second dart could be larger and still have an arc form. However, the magnitude of this impact is surprisingly strong.

It is also important to note that these estimates are for single shots. The failure of a single shot can result in the user making a second shot and achieving success. Thus, the rate of successful "uses" including multi-shot uses will be higher than Table B-2 indicates.

B.5.5. Completion of a Circuit as a Function of Distance

The percentage of shots that result in a completed circuit for the five ranges of distance between the target individual and the user can be estimated based on the information in Table B-2 and the number of dart strikes and dart penetrations that occur at different distances. The number of darts hits and penetration occurring at shots at multiple distances are given in Table B-3. The basis for the estimates in Table B-3 is given in Section B.5.3.

Table B-3. Percent of Shots That Hit and Penetrate as a Function of Distance

Hits	Penetration	Distance (ft)				
		1-3	3-7	7-11	11-15	15-21
0	0	4%	1%	1%	8%	17%
1	0	0%	1%	2%	2%	10%
1	1	5%	6%	6%	12%	12%
2	0	11%	12%	12%	13%	15%
2	1	5%	11%	11%	8%	12%
2	2	75%	70%	67%	56%	35%

The resulting percentages for circuit completion are given in Table B-4.

Table B-4. Percent of Shots That Result in a Completion of a Circuit

	Distance (ft)				
	1-3	3-7	7-11	11-15	15-21
Complete Circuit	80%	81%	80%	72%	56%

The effectiveness of a shot is a function of the dart placement. Darts that are too close together may result in partial rather than complete EMD. To evaluate the impact of this factor, the distance between the two dart hits was determined. The distance of the dart separation was determined by assigning locations for the centers of each of the squares in the grid presented in Figure B-1.

These locations were defined in terms of fractions of the individual's height and breadth. Breadth was measured as biacromial breadth (shoulder width distance) as shown in Table B.5.

Table B-5. Location of Centers of Grid in Figure B-1 in Terms of Height and Biacromial Breadth

Locations of Centers of Grid Boxes	
Row	**Fraction of Height**
A	0.94
B	0.815
C	0.68
D	0.495
E	0.25
F	0.06
Width	**Fraction of Biacromial Breadth**
1	-0.625
2	-0.425
3	0
4	0.425
5	0.625

These fractions are then linked to the individual's height using the following equation:

$$\text{Biacromial Breadth (cm)} = (\text{Height (cm)} - 22) / 3.62$$

This equation is based on a regression model of data on biacromial breadth and height data in 24,824 individuals (ages 16-85) collected as part of the National Health and Nutrition Examination Survey III (U.S. Dept of Health and Human Services, 1996). The correlation coefficient R2 for the equation is 0.88.

Once the locations of the centers of the grid boxes are determined as a function of height, then the reported heights for the individuals are used to determine the locations of the centers in cm. Once the locations are determined, the distance between each location is determined using simple trigonometry.

Figure B-4 presents the predicted distances plotted against the means of the reported distance ranges between the user and the target individual. The figure also presents 1) the theoretical separation based on a separation angle of 8°, 2) the mean of the estimated separations for each of the five distance ranges, and 3) the separation reported by PSDB at various distances (PSDB, 2002).

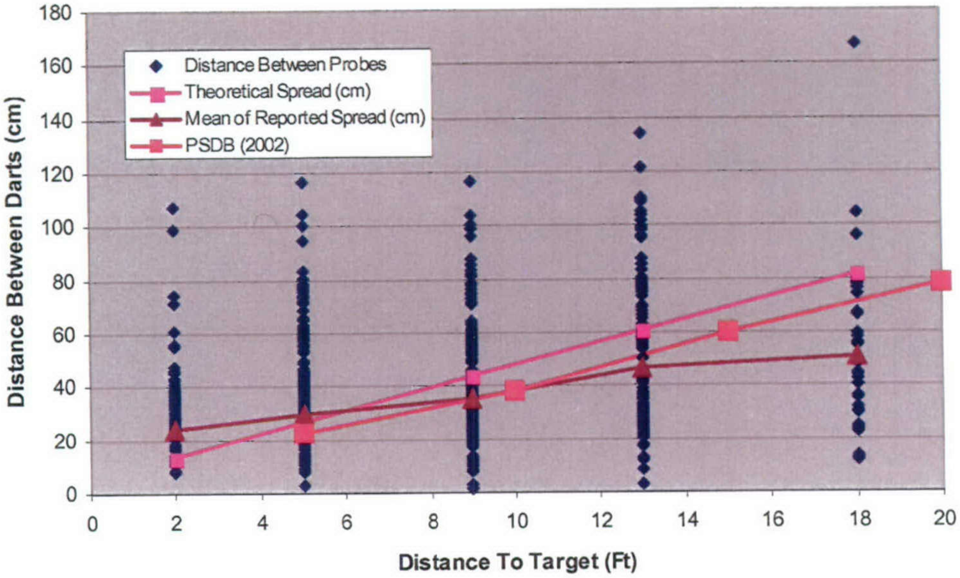

Figure B-4. Plot of Theoretical and Reported Dart Separation as a Function of Distance between the User and the Target Individual

While the data demonstrate a strong trend in the average separation with distance, the range of individual values is similar for each of the distance ranges. It is not entirely clear why there is such a large range in the separations at all of the distances. One explanation may be that individuals may be crouching or sitting when shot. Such position would bring the upper portion of the body closer to the legs. In such a position, closely spaced darts could hit widely separated potions of the body. In addition, if the person were not standing at a right angle to the EMI device (lying in a prone or semi-prone position) the distances would also be increased. It is not clear how the shorter distances occurred. These may be due to errors in entering the data and the imprecision of using a grid.

Finally, the mean calculation of dart separation for each distance range (triangles) is consistently smaller then the theoretical estimates of separation (small squares). This finding is similar to the findings made by the Police Scientific Development Branch in their study of the M26 (PSDB, 2002). The estimates of separation from their trials (large squares) are also smaller than the theoretical estimates.

B.5.6. Determining Risk of Face/Eye Hits

The location information in the records can be used to estimate the risk of eye hits. This risk is evaluated in a two-step process. First, the probability of a dart hitting the face is determined. Then the probability of an eye hit is determined based on the relative sizes of the cross sectional areas of eyes and the face.

The facial area is identified in the location grid used in the TI data as A3. The database reports that 16 of the upper darts had a location of A3. None of the lower dart locations are reported as A3[3]. The total number of records with a valid upper dart location is 1,591. The number of records with both a distance measurement and a valid location for the upper dart is 1,559. This value is used as the denominator for the calculation of the percentage of shots that result in a dart striking the face. While the percentage of eye hits is estimated for the five different distance ranges, the number of facial hits is too small to give a completely reliable estimate of the effect of distance on the risk of a face hit. While not contained in the TI database, there is one known case of permanent vision impairment as a result of a dart strike to the ocular region (Dave Dubay, personal communication, 2004).

Table B-6. Probabilities of Face Hit

	Distance of the Shot				
	1-3 ft	**3-7 ft**	**7-11ft**	**11-15 ft**	**15-21ft**
Number of Records With Dart Location for the Upper Dart and a Distance to Target	185	603	503	222	46
Percent of Records With Dart Location for the Upper Dart and a Distance to Target	12%	39%	32%	14%	3%
Number of Records with Upper Dart Location of A3 and a Distance to Target	1	8	3	3	1
Percent of Records With A Reported Dart Location of A3 and a Distance to Target	0.54%	1.3%	0.60%	1.4%	2.2%

B.5.7. Risk of Groin-Related Injuries

Injuries to the genital organs will occur as a result of hits to cells E3 and possibly E8. The total number of hits to these grid locations from either the top or bottom darts is 35. Of these hits, four did not penetrate the skin. In addition, as many as 10 of the remaining hits may have been stopped by clothing[4]. Finally, one of the hits did not have a distance measurement and was not included in the analysis. Table B-7 presents the number and fraction of shots of the total shots that were reported to occur in E3 or E8. A similar finding was reported by PSDB (2002). The denominator includes all records

[3] Although one shot reported the lower dart as a miss. This suggested that the reported head hit could have come from the lower dart and the upper dart went over the target individual's head.

[4] The reason for this uncertainty is that the reporting form allows the user to specify the number of darts that penetrate the skin. In ten of records, the users reported that one of the two darts had been stopped; however, it is not possible to say which of the two darts were stopped.

where a distance is reported and where a valid location for either the top dart or both a top and a bottom dart is reported.

This analysis also shows a statistically significant increase in the number of groin hits with distance (comparing the number of hits at distances less then 11 ft to the number at distances greater than 11 ft).

Table B-7. Probabilities of Groin Area Hit

	Distance of the Shot				
	1-3 ft	3-7 ft	7-11ft	11-15 ft	15-21ft
Number of Records With at least 1 Dart Location and a Distance to Target	185	603	503	222	46
Percent of Records With at least 1 Dart Location and a Distance to Target	12%	39%	32%	14%	3%
Number of Dart Hits to E3 or E8	3	11	6	7	3
Percent of Records With A Reported Dart Location That Reported E3 or E8	1.62%	1.82%	1.19%	3.15%	6.52%

B.5.8. Risk of Ventricular Fibrillation (VF)

As discussed in section 4 of this report, VF is not expected to occur from the use of the M26 or X26 based on the nature of the electrical charge that the weapons supply. However, it is important to note that not all uses of an EMI device could cause the effect. Only those shots that result in dart placements where both shots hit the front of the individual and one falls on each side of the cardiac region of the chest would put the individual at risk for VF. The probability of this occurring was calculated from the dart hit location information in the TI data. The following sets of locations were assumed to result in a risk of VF.

Top Dart: A 3
Lower Dart: C 1-5, D1-5, E 2-4, and F 2-4

Top Dart: B 1-2
Lower Dart: B 4-5, C 4-5, D 4-5, E 3-4, and F 3-4

Top Dart: B 3
Lower Dart: C 1-5, D1-5, E 2-4, and F 2-4

Top Dart: B 4-5
Lower Dart: B 1-2, C 1-2, D1-2, E 2-3, and F 2-3

Top Dart: C 1-2
Lower Dart: C 4-5

Top Dart: C 4-5
Lower Dart: C 1-2

A total of 323 records were found to have one of the above combinations of dart locations. Since there are 1,502 records where there are two reported dart hit locations, the percentage of shots that result in potential of an electrical dose reaching the cardiac region is 21.5%.

B.6. Recommendations of Improving the TASER International User Reports

The User Reports provide very important data for the evaluation of the intended and unintended effects. However, the current survey instrument could be improved. The following are a list of suggestions for revising the instrument and for improving the value of the data collected.

- Create user ID's to allow an individual to enter his or her personnel information a single time. Then require the ID to be used in all subsequent entries by that user.
- Split the form into multiple windows. This will allow the format and nature of later questions to be tailored to the answers from prior questions. For example, if the user indicates that no shots were fired, then windows asking for dart hit locations will not appear.
- Require that the user complete all of the relevant fields before the record is accepted.
- Prevent the user from entering contradictory data. If the person shot once, then no more than two sets of dart location entries should be allowed.
- Require that the user identify the units for height and weight.
- Explicitly ask if an intended effect occurred.
- Divide the head (grid location A3) into two subareas, above the tip of the nose and below the tip of the nose, to facilitate the assessment of the risk of eye injury and seizures.
- If the person shot twice, then ask why there was a second shot.
- If a stimulation is reported and only one dart struck, then ask if this was the result of a ground connection or the result of a wire "overlay." If a ground connection occurred, ask if the surface was wet or dry and its nature (concrete, asphalt, or soil/grass).
- The first time a user submits a report, ask questions that would help characterize the potential for bias in the reporting of success or injuries. Ask about the policy of their police department for submitting user reports:
    - Does the department report all uses?
    - Does the department sometimes report uses?
    - Does the department report use of TASER instances where any injury has occurred?

- Does the department report uses where a serious injury occurs?
- Does the department report uses where litigation or wrongful actions are alleged?

- Begin a program of selective verification (checking with users who submit reports) to prevent spurious reports from being entered.
- Consider a validation program where TASER International randomly selects a certain fraction of cartridges sold and investigates how the cartridge was used. The results for such an independent survey could be used to validate the data collected by the user reports.
- Use data on cartridge sales to allow an investigation of the impact of biases (departments of a certain size being under or over represented or certain regions over or under reporting).

Appendix C - Disposition of Independent External Review Panel (IERP) Recommendations

DISPOSITION OF INDEPENDENT EXTERNAL REVIEW PANEL (IERP) RECOMMENDATIONS

An independent external review panel (IERP) was convened in December of 2003 to review a draft version of the EMI Human Effectiveness and Risk Characterization document. This appendix summarizes the major comments and recommendations that were made by the IERP, as well as the revisions made to the report in response to those comments and recommendations.

- The IERP recommended that the report be reformatted to include an executive summary, synthesis document, and detailed appendices. The IERP also noted that overall, the document should be revised to enhance transparency in the rationale for conclusions that are presented. For example, more complete documentation of literature reviewed, synthesis of the data, and rationale for the conclusions is needed. Also the IERP noted the need to ensure wording is precise (e.g., statement about use of bioelectrical procedures during pregnancy) and conduct a thorough technical edit.

  Response: The document has been extensively modified to ensure clarity and accuracy of scientific conclusions. For example, a thorough edit was provided for the Effects Identification and Dose-Response section by a medical doctor (Dr. Becky Tominack) and a scientist with extensive background in the mechanisms of bioelectrical response (Dr. Patrick Reilly). In addition, the document was reformatted as suggested by the IERP to include an Executive Summary. The main body of the report retains a similar depth of coverage as in the draft, and presents the synthesis of the data and key conclusions.

- Ensure that precision in numerical effects and risk estimates is well described (e.g., uncertainty around eye strike probability in summary table).

  Response: The uncertainty of eye strike is discussed qualitatively in both sections 6 and 7. The major source of uncertainty in eye strikes (distribution across the face) cannot be characterized quantitatively based on the current data. Other sources of uncertainty such as the potential biases in the TASER International data are not amenable to quantitative estimates. Therefore, no attempt has been made to provide quantitative estimates of the uncertainty in the predictions. The precision in the risk and exposure estimates reflects the uncertainty from the Monte Carlo simulation.

- In the Risk Characterization section discussion of uncertainty, identify important research needs, and indicate whether they are immediate needs or can be addressed through longer-term research programs.

  Response: The discussion of uncertainties and research needs has been included as a separate section (Section 7) of the revised document, and identifies key uncertainties and, in some cases, recommendations for further research. Appendix

B includes recommendations for improving the data collection performed by TASER International.

- Add discussion of comparative risks (lethal versus non-lethal; risk to users when EMI devices are and are not available) to frame the magnitude of potential risks described in the document.

  Response: Several paragraphs of new text on this subject were added to the Risk Characterization section.

- Add a basic discussion of the medical uses of electrical devices (e.g., EMG, pacemakers, defibrillators, etc.) to frame the effects and risk evaluation for the EMI devices.

  Response: This appendix was later deemed to be of little added value, and it was not included per the authors and with later concurrence by the IERP.

- Add discussion of what is known about underlying mechanisms of potential EMI effects (e.g., neuromuscular junction activation, CNS involvement, direct muscle fiber stimulation, smooth versus skeletal muscle excitation) to help the reader consider the biological plausibility of identified physiological effects.

  Response: Where these considerations are informative for the EMI device this has been pointed out in the main body of the report. For example, issues regarding the impact of pulse duration on electrostimulation of the heart and the implications for the proposed dose-response approach were added to the text.

- Make more comprehensive the identification and discussion of potential sensitive populations for each identified effect of potential concern and discuss relative sensitivities (e.g., individuals with implanted electrical devices, those with underlying cardiovascular or respiratory disorders, those prone to seizure, etc.). For exposure data, ensure demographics of population (age, weight, drug use, etc.) are presented. Compare and contrast law enforcement versus anticipated DoD uses of the TASER to support the use of data from law enforcement applications as the basis for the analysis.

  Response: Additional text regarding potential susceptible populations has been added to the document in sections relative to key effects. For example, information on factors that affect susceptibility to seizure or cardiac effects has been added. Additional information on the potential for EMI devices to effect implanted medical devices, such as pacemakers, has been added to the report.

  DoD uses of the EMI devices have yet to be developed in detail preventing any comparison beyond the current text on this issue. The potential differences are discussed in the text, in particular the implicit cut off of ages < 8 and > 60 in the data is highlighted.

- Expand and better document the list of all potential effects and describe the rationale for selecting a subset of effects to carry further into the quantitative risk characterization (e.g., expand the list of effects to include other arrhythmias, decreased blood pressure, CNS effects other than seizures, dart impacts with sinus cavities or the trachea, probabilities of incidents involving flammable substances, etc.).

  Response: The list of potential effects was increased to include those suggested by the IERP, although in some cases they were considered as subsets of existing categories. A summary table was developed to outline clearly the basis for excluding each effect from further consideration in the Risk Characterization section (due to low probability of occurrence, low physical effect severity, or absence of adequate data). We did not develop specific quantitative criteria for excluding effects, although there was general agreement of the authors on the basis for removing from consideration each of the effects that was culled from the overall list.

- Re-evaluate whether sufficient data are available to include induction of seizures among the set of effects included in the dose-response assessment. Consider data from animal models and threshold approaches based on criteria established for other waveforms.

  Response: As recommended, the degree to which seizures should be included in the Risk Characterization was given further consideration. A significant amount of new text was added (in the Effects Identification section) to present the evidence for and against the possibility of a TASER exposure inducing a seizure. Based on this analysis, the report was revised to include an estimate of seizure induction based on the estimated probability of head strikes. It was noted, however, that this approach is likely to yield overestimates (and thus serves only as an upper bound estimate), since the limited number of case reports that involved a head strike did not result in seizures. Additional research approaches needed to resolve this issue were added.

- For ventricular fibrillation dose-response, evaluate waveform characteristics in the available cardiac safety studies in pigs to determine whether these data can be reliably used to build a dose response curve. Make clear in the document that comparison to existing electrical standards (e.g., for electric fences, VF thresholds for household current) is outside the intended use of these standards. Further evaluate the availability of data for longer duration exposures, multiple simultaneous exposures, and human variability in VF thresholds. Discuss more fully the implications and need for developing a program to develop a standard dosimetry approach for TASER-like waveforms.

  Response: A detailed evaluation was made to assess the impact of new data presented by TASER International on the impact of environmental factors (changes in load resistance, arcing, one-dart strikes) on TASER output and waveform characteristics. Based on this review, the approach used for the dose-response *data from the cardiac safety studies in pigs was judged to be appropriate. The basis for this conclusion was added to the text. As recommended by the IERP, comparison of the TASER output to existing electrical standards was removed as a useful approach. Data on the effects of repeated exposures, exposures of long duration, and the degree of human variability to cardiac sensitivity remain areas of uncertainty and are described in the revised section on Data Gaps and Research Needs.*