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NONLETHAL AND NONDESTRUCTIVE COMBAT IN CITIES OVERSEAS

Joseph F. Coates

May 1970

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FOREWORD

This paper was written in response to a request to the Institute for Defense Analyses from the Office of the Deputy Director for Defense Research and Engineering (Tactical Warfare Programs) for an investigation of the problems confronting military units in overseas urban warfare. The principal response to that request is IDA Study S-345, Promising Areas of Research and Development for Tactical Operations in an Overseas Urban Environment. This paper supplements Study S-345.

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The author is particularly grateful for the extensive, detailed, and valuable reviews of Mr. Arthur Stein, Cornell Aeronautical Laboratory, and Dr. Donald Sheldon and Mr. James Bagnall of the Institute for Defense Analyses. Each of these critics from his special perspective has driven the author to a more perceptive, salient, and, it is hoped, useful effort.

The opportunity to present preliminary versions of this paper to Working Groups at the 23rd and 24th Military Operations Research Symposia has been most useful. The observations and criticisms of several dozen professional colleagues have done much to clarify and guide this paper.

All opinions and judgments expressed in this report are those of the author and do not, either implicitly or explicitly, entail the concurrence of his associates, colleagues, critics, or reviewers, or of the Institute for Defense Analyses or any of its sponsoring agencies.

ABSTRACT

This paper examines nonlethal and nondestructive weapons--both present and potential--for their applicability to military operations in cities overseas. Classes of criteria for evaluation are suggested, and the suitability of various weapons concepts for various kinds of urban operations and missions is considered. The potential nonlethal mechanisms that come under scrutiny include, among others: radiant heating, stabbing and cutting weapons, sound, wind, vortices, animals, plants, manipulation of utilities, light, sticky materials, nets and snares, impact weapons, electrical weapons, and markers. Chemical agents are judged to be uniquely applicable to almost all urban operational missions. The paper concludes that there is a clear need to minimize destruction and fatalities in many of the overseas urban operations in which the United States may become involved. It recommends a number of areas for nonlethal and nondestructive weapons research and development to help fulfill that need.

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I. INTRODUCTION

There is a widespread sentiment that less destructive and less deadly modes of warfare offer promise as a major innovation in the tactics and strategy of limited and low-intensity warfare. The alleged misuse of current capabilities, devices, and tactics is one support for this argument. A second is the partial mismatch between current capabilities and the objectives of present and anticipated operations. The military may be involved more frequently, for example, in benign and quasi-combat roles such as disaster relief, peacekeeping (Ref. 1), and evacuation.

The observation that "nuclear weapons have made the world safe for insurgency" suggests a third closely related point--the continuation of, if not an increase in, stability operations and multilateral peacemaking. Future conflicts generally may have vague, uncertain, or shifting objectives. Consequently, a more intimate interplay of military and political goals, tactics, and implications than has been customary may prevail. There will be both more intermingling of aggressors and civilians and a greater blurring of the distinction between the two in many anticipated types of conflict. This may be especially the case in urban combat. These points all argue for less profligate killing and less wanton destruction of property.

The current doctrine of combat in cities or combat in built-up areas (Ref. 2) is:

1. If possible, avoid such combat.
2. If such combat is necessary, proceed in a three-phase operation: first, isolate the area; second, gain a foothold; and third, systematically clear the area.

The doctrine is extremely flexible and has been applied to many theaters of war and to many scales of operation, and it is elastic enough to integrate and accept changes resulting from experience and technological innovation. Nevertheless, the current doctrine falls short of the anticipated military needs for the three reasons cited in the paragraphs above. The current doctrine is based upon historical experiences of massed uniformed forces in conventional conflict. In traditional conflict, cities have been bypassed where possible. In contemporary conflict, there may be more conflict in cities involving irregular forces in unconventional missions and a high density of civilian population.

This paper, therefore, is concerned with the present state of the art and the potential for future development of less deadly and less destructive weapons. Some of these weapons may find their effectiveness in unusual and new modes of action, directed at unconventional or heretofore neglected objectives. Others may rather directly integrate into established functions. This paper will be limited to the principal, primary definition of a weapon; namely, "an instrument of offensive or defensive combat, that is, something with which one fights." This includes devices and agents that depend on physical, chemical, or physiological effects. The second and broader meaning of a weapon as "any means of contending against another" embraces such a broad range of problems and opportunities as to be beyond the scope of this paper (Ref. 3).

The specific purpose of this paper is to review antipersonnel mechanisms comprehensively and to assess their applicability to nonlethal weaponry in various classes of low-level military operations in overseas cities. While this paper cannot claim to be exhaustive, it is hoped that the relative potential applicability of various antipersonnel mechanisms will be thrown into useful perspective.

A. RELATIVITY OF CONCEPT

To avoid misconceptions or false expectations, it must be borne in mind that "nonlethal" and "nondestructive" are relative, not

absolute terms. This point is particularly important with regard to the term "nonlethal." It seems impossible to imagine any instrument or any agent acting on any physiological system in a significant way that does not have an irreducible and intrinsic risk of death or permanent injury. Even a child's popgun fired into a yawning mouth could cause strangulation. It is appropriate to introduce as a general model for thinking about nonlethal weapons the concept of effective and lethal doses, drawn from pharmacology.

To fulfill the definition of a nonlethal agent, a chemical substance must be effective without in the same dose producing irreversible toxicity or death. Both the incapacitating action and the unwanted toxic or lethal action usually exhibit similar S-shaped curves. The degree of overlap of one with the other expresses the likelihood of an undesirable toxicity.

In the example (Fig. 1), the 50 percent incapacitating dose ID_{50} is measured at 10 dose units, while the mid-lethal dose LD_{50} is 10^4 units. However, if a dose is required to be 100 percent sure of incapacitation (10^3 units), it may be seen that this same dose might cause death in about 15 percent of its victims.

Thus, two important interpretations can be made from dose-response relationships. The first is the "margin of safety," often called the "therapeutic index," or the "safety index." This is the ratio of the dose required for a 50 percent lethal effect to the mean incapacitating dose (i.e., LD_{50}/ID_{50}, or in this case $10^4/10^1$, a ratio of 1000:1). The higher the ratio, the smaller is the chance of death in the use of an incapacitating agent. The second interpretation as to drug safety, derived from Fig. 1, is related to the steepness of the slope of the dose-response curve. If the curves do not rise steeply, there is a greater probability of overlap between doses, yielding incomplete incapacitation in some subjects and yet producing death in others. It is difficult to conceive of drugs which would produce drastic incapacitating action and yet not cause a few deaths among infants or the aged, diseased, or debilitated members of the general population. This last

factor of human variability in drug response is difficult to predict except in a few instances involving widely used (or abused) drugs such as salicylates and barbiturates (Ref. 4). The analogous argument applies to other nonlethal mechanisms such as impact or exposure to cold, heat, or radiation.

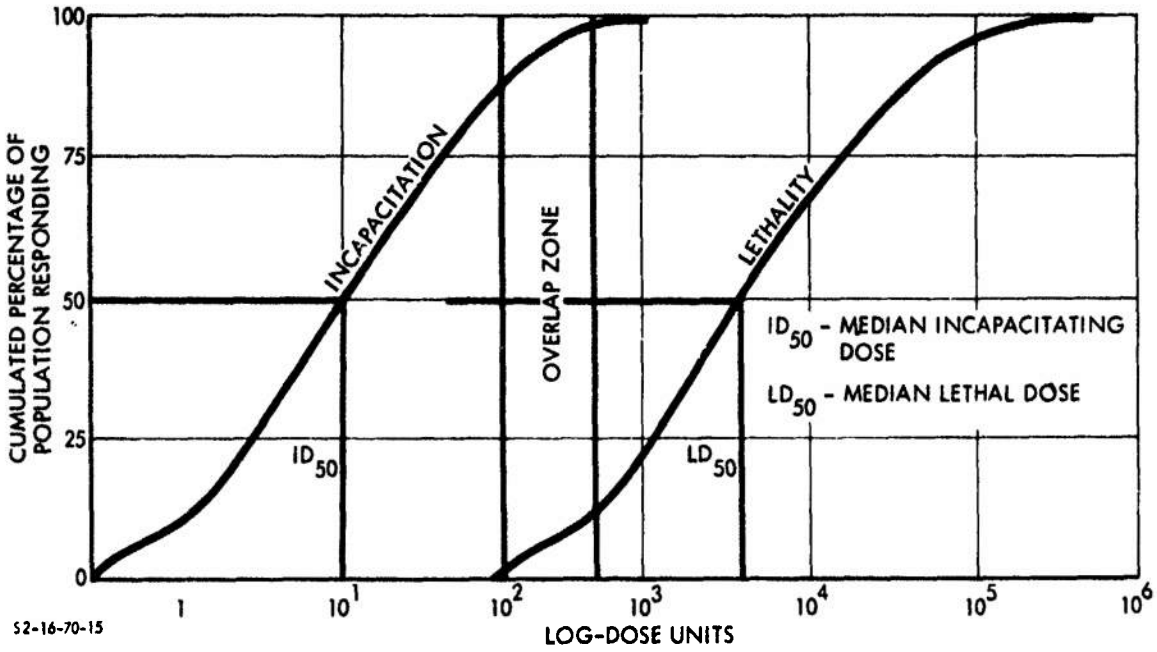


FIGURE 1. An example of the possible relationship of log dose to cumulated percentage of population responding

The lethality curve does not indicate all unacceptable effects. There could also be a curve of irreversible or maiming effects. Furthermore, the effective dose and lethal dose curves need not be so clearly S-shaped. The slopes of the two curves could be different from each other or much less steep.

B. SOURCES AND METHODOLOGY

As far as I have been able to determine, there is no standard monograph, text, or comprehensive basic reference on nonlethal and nondestructive warfare or on the specific subject of nonlethal military weapons. The concept of nonlethality is taken to be relative and elastic,

depending upon the military circumstances and the mode of use, since no device or technique for coercion can be absolutely free of risks or the possibility of irreversible injury. Consequently, this effort should be looked upon as a preliminary study of the broad possibilities and ramifications of the concept of nonlethal weapons. It is hoped that some useful conclusions have been drawn and some appropriate and constructive recommendations made. This effort is by no means the last word--rather, it will hopefully be the early word in a continuing, developing discussion.

Four goals were anticipated for this study:

1. To make a broad survey of the potential applications for nonlethal techniques in overseas urban military operations.
2. To make a comprehensive assessment of physiological mechanisms and effects on which nonlethal weapons may be based, and so to establish some order of priorities.
3. To make the study open-ended in two senses: (1) in that new concepts, new approaches could be integrated into the study without leading to a need for a total re-working; and (2) in that it would invite other investigators to undertake either singularly or in groups a parallel or duplicated effort.
4. To identify some problems which could provide useful basic guidance to RDT&E programs.

This study is a one-man effort. Consequently, it should be looked at not only as preliminary but as reflecting the limitations implicit in a one-man effort on such a comprehensive problem. Limitations of time, knowledge, imagination and analytical skill demand a modest claim for tentativeness in this work. The reader is strongly advised to bear this in mind. On the other hand, this one-man effort may offer the advantage of a uniform perspective or point of view.

1. Sources

The sources of the information contained in this study include:

- A search of the Defense Documentation Center and the Remote Area Conflict Information Center.
- An examination of the military literature and other standard work.
- A brainstorming session.
- An earlier effort to examine nonlethal weapons for law enforcement application (Ref. 5).
- A file of information built up from eclectic sources over a period of years.
- Industrial and safety literature.
- Discussions with military and civilian colleagues and experts in various areas of physiology, safety, and accident research.

It should be recognized that the concept of nonlethal weapons has been most extensively discussed in the literature on the application of incapacitating chemicals and riot-control agents to military operations. The present paper, however, goes beyond the scope of those physiological mechanisms while at the same time narrowing intentions as far as possible to operations in overseas urban areas.

2. Methodology

In the absence of comprehensive prior art in approaching this problem, it was necessary to develop a means of beginning this study that would meet the criteria of being comprehensive and open-ended. The method I have used is one that might be called "backing and filling," in which concepts are proposed and evaluated as to their usefulness and are then accepted or rejected. Those accepted are in turn played off against other concepts, and the process is repeated. The method is described in greater detail in the individual sections. Since the effort is prospective and looks at future military applications, it runs into the difficulty of anticipating what future conflicts would call for nonlethal and nondestructive weapons. Similarly, it runs into the question of what techniques would be appropriate. The methodology therefore relies very heavily upon conjecture, reason, and

judgment and brings to bear only a relatively limited body of experimental and hard observational data, particularly on the problems of employment and military futures.

Since the focus is on urban military operations, the first step was to anticipate or organize a class of activities which we call military operations. These range from disaster relief to the capture or defense of a city in a conventional limited war. "Operations," as used in this paper, are the large-scale military activities reflecting the overall goal of a particular military task force.

The second step was to look at particular firepower missions in a given type of operation. These are the activities that an individual trooper or a small unit might be concerned with, such as mob control, apprehension, the protection of facilities, and the denial of an area. In other words, this is the finer structure of a military operation.

The third step was to attempt to relate each of the specific firepower missions to the various military operations, addressing the question of whether a specific mission is likely to occur in a particular type of operation and whether it is likely to involve firepower. Some military missions do not involve firepower and not every mission is associated with every operation. For example, the neutralization of civilian facilities is not often associated with the protection of a military facility. Similarly, the apprehension of single individuals is not likely to be associated with defending a city or implementing a blockade.

The fourth step was to ask whether in each specific firepower mission a nonlethal weapon capability (of an unspecified sort) would have dominant or major value, some significant but not dominant value, or relatively little value. This involved a gedankenexperiment in which a 46 by 24 matrix was prepared and each cell individually thought about. The details of the thought process are not presented in this paper, but the reader is invited to examine the results and prepare a

matrix of his own for comparison. This step of the analysis provides some assessment of the relative utility of nonlethal weapons in various missions.

The fifth step was to move on to the concept of nonlethal effects, where immediately one confronts the problem of what are the criteria for nonlethal weapons. It is impossible at this stage to lay down quantitative criteria for nonlethal weapons. The attempt to lay down any quantitative criteria would have the effect of falsifying the issues and perhaps stultifying research by being unduly restrictive. It did, however, seem useful to develop what I chose to call "criteria categories." For example, while it was not possible to say what criteria should be employed with regard to the effects of a nonlethal weapon on friendly operations, it was clear that consideration would have to be given to new hazards generated by new weapons and their influence on speed, mobility, and morale. While it was not clear what the limits should be on residual environmental effects of a nonlethal weapon, it was clear that those effects would fall into at least two categories: animate and inanimate effects. In this way criteria categories were established. Some ten major classes or categories of criteria are proposed. Again, this is open-ended, and additions and modification may be made and are invited.

The sixth step was to consider what might be the bases for developing a nonlethal weapon. To do this, I examined physiological mechanisms which might conceivably form the basis for a weapons development. These ranged all the way from blast and foam and whips to use of animals and the deoxygenation of the local atmosphere. The list of mechanisms in some 26 categories was not exhaustive nor logically elegant but rather was assembled in a way that seemed to reflect convenient thought categories. The material obviously could be reworked along other dimensions. It is not claimed to be complete, and new categories may be added without vitiating the subsequent analysis.

The seventh step was to attempt to eliminate some of the mechanisms. This was done by examining each of the proposed antipersonnel

mechanisms against the criteria categories--note that it was not against criteria but against criteria categories. Considering how a particular mechanism might work or what it might involve in some cases sometimes suggested, with regard to a particular category of criteria, a drawback that would eliminate it from further contemplation. So, for example, whips and the manipulation of gravity were quickly dropped from the roster of potential weapons. This led to a shorter list of some 19 categories of tentative potential nonlethal weapons mechanisms (Table 6 on p. 27). At this stage, one loop of analysis was then closed.

Next, each nonlethal weapon concept was examined for its potential application to the proposed list of operating missions. From this was generated some rough qualitative, semiquantitative figure of merit largely reflecting the anticipated versatility of each weapon. For example, the use of vortices (in the nature of smoke rings) seemed to have some tactical versatility. Vortices are potentially applicable to seven operating missions. Nonlethal chemicals have application in all 28 missions (Section IV-B). The tentative figure of merit or value developed for each of the proposed mechanisms gives only a rough order of priority to mechanisms for subsequent development.

The remainder of the report then takes each of the 19 nonlethal mechanisms and presents a more detailed assessment of the state of the art and attempts to throw the potentials for useful RDT&E into some more detailed perspective. From this flows a series of recommendations.

The reader is again cautioned and advised that this is a one-man effort structured to be open-ended, to invite a parallel effort by the reader, and to accommodate the introduction of new technical information and new concepts as they become available.

C. CRITERIA FOR NONLETHAL WEAPONS

No attempt will be made to establish general quantitative or operational criteria for nonlethal weapons, since no practically useful thresholds would be appropriate for all the various combinations of operational missions.

It is useful, however, to consider categories of criteria which would influence the selection of nonlethal weapons for combat in cities. These are laid out in some detail in Table 1, and fall into four major groups and three minor ones:

Major Groups

1. Versatility, that is, the extent to which a particular nonlethal weapon mechanism is applicable under various constraints of urban combat associated with the mission and environmental fittingness, increments of the effect, and environmental limitations.
2. The controllability or predictability of a given effect.
3. Safety--not only of the victims but also of the users and friendly forces.
4. A very large miscellaneous group having to do with operational considerations, including delivery, logistics, unique manpower requirements, countermeasures, and burdens created or intensified by the use of such weapons.

Minor Groups

1. A miscellaneous group having to do with residual effects, both on people and the environment.
2. A group that is rather vaguely designated as "image." It has to do with acceptability to friendly and hostile publics alike.
3. Susceptibility or resistance to abuse or misapplication.

In considering any new nonlethal weapon for urban (or other) operations, specific attention should be given to whether some qualitative, if not quantitative, criteria can be developed from the categories in Table 1. Not all categories are equally applicable to all weapons. Each potential weapon or weapon mechanism must be considered individually.

TABLE 1. CATEGORIES OF CRITERIA FOR NONLETHAL WEAPONS

1. Versatility
   - a. of effects; possible controlled increments of application
     - alone
     - in combination with other weapons
   - b. operational fittingness
     - knockdowns
     - disperse
     - harass
     - immobilize
     - coerce
   - c. environmental fittingness
   - d. environmental dependence, e.g., chemicals depend on weather
2. Controllability - Predictability
   - a. coverage
     - scope
     - accuracy
     - precision
   - b. intensity of effect
   - c. onset time of effect
   - d. duration of effect
   - e. persistence in environment
   - f. percent affected
3. Safety
   - a. to user
   - b. to victim
     - troop protection
4. Effects on friendly operations
   - a. new hazards
   - b. speed and mobility
   - c. morale
5. Residual effects on people
6. Residual environmental effects
   - a. animate
   - b. inanimate
7. Secondary hazards
8. Resistance or susceptibility to abuse
9. Image--effect on:
   - a. victim
   - b. various publics
10. Operational considerations
    - a. convenience
    - b. delivery
      - air
      - vehicle
      - portability
    - c. logistics burden
      - storage
      - handling
      - transportation
    - d. manpower requirements
      - numbers
      - skill
      - training
      - judgment
    - e. reusability
    - f. countermeasures susceptibility
    - g. new burdens created
      - aid to victim
      - mass casualties
      - transport to hospital
      - prison handling
      - clean-up decontamination
    - h. coordination with other operations

II. NONLETHAL FIREPOWER MISSIONS

The intensity of the conflict, the aggressiveness and the deadliness of the violence and force to be used, and the number of combatants and noncombatants influences the choice of weapons and tactics. As background to operational, organizational, and tactical choices, and as guidance to R&D programs, it is necessary to assess the potential use of less destructive techniques.

As a first step toward this, we will compare occurrences of various firepower missions in relation to anticipated types of military operations. Military operations are listed in Table 2 and range all the way from show of force to capture of a city. In the narrow definition we are using, the show of force requires no use of firepower (Ref. 7) but relies on establishing the credibility and the capability of the use of firepower. The operations also include a number of relatively benign activities such as relief and rescue and the supervision of a plebiscite. Two operations do not necessarily occur within a city, but on its perimeter. These are blockade and seige. One group of missions may require a more aggressive use of forces. This group includes civil and conventional limited war to defend, capture, or recapture a city.

Table 3 suggests a wide range of tactical missions in which firepower of some sort could be appropriate. The likelihood of each of these tactical firepower missions occurring in each specific operation was assessed and the results are presented in Table 4. A shaded area indicates that the firepower mission is appropriate with regard to that specific operation. The next step, also illustrated in Table 4, was an assessment of the relative importance of nonlethal weaponry with regard to each cell of the operations-firepower missions matrix. Qualitative judgment was made at four levels:

TABLE 2. OPERATIONS

1. Show of force or show of flag
2. Supervision of a plebiscite
3. Relief
4. Post-disaster restoration and relief
5. Blockade
   - land
   - air
   - water
6. Seige
7. Peace-keeping
8. Rescue
9. Pacification of an area (by an outside force)
10. Evacuation
11. Protection of facilities
    - military, e.g., a base
    - government, e.g., a quay
    - civil, e.g., a refinery
12. Relocation of a population
13. Urban disorders
14. Urban insurgency
15. Urban guerrilla warfare
16. Civil war
17. Conventional limited war
    - defend a city
    - capture a city
    - recapture a city

TABLE 3. FIREPOWER MISSIONS

1. Riot, mob, and crowd control
2. Countering looting
3. Apprehension
   - single individuals
   - small groups
4. Facilities protection against:
   - sabotage
   - theft
   - espionage
   - attack
5. Attack on facilities
6. Neutralization of facilities
7. Clearance of facilities
8. Protection of lines of communication
9. Protection of essential personnel
   - in secure facilities
   - on the street
     - medical
     - repair
     - firefighting
     - food personnel
10. Prisoner handling in compounds
11. Population movement
12. Curfew enforcement
13. Disruption of military activities
14. Disruption of civilian activities
15. Structure control--denial
    - subterranean
    - above ground
16. Area control and denial
17. Route control and denial
    - streets, highways, and alleys
    - rivers and streams
18. Locate hidden personnel
19. Penetrate structures
20. Countering infiltration
21. Static defense
22. Strongpoint clearance--neutralization
23. Countering snipers
24. Roof clearance
25. Structure clearance
26. Counterbattery fire against rockets, mortars, and artillery
27. Countervehicle
28. Countering terror

1. Where nonlethal techniques would be of great value or may even be the only technique to be applied, this is indicated by an X.
2. Where nonlethal firepower could or should be a significant factor, that cell is indicated by a diagonal line.
3. Where nonlethal firepower would have some application but is not likely to be the dominant or significant firepower, a dot is used.
4. In a few cases, nonlethal techniques seem to be inappropriate or of rare application. This is indicated by a blank cell.

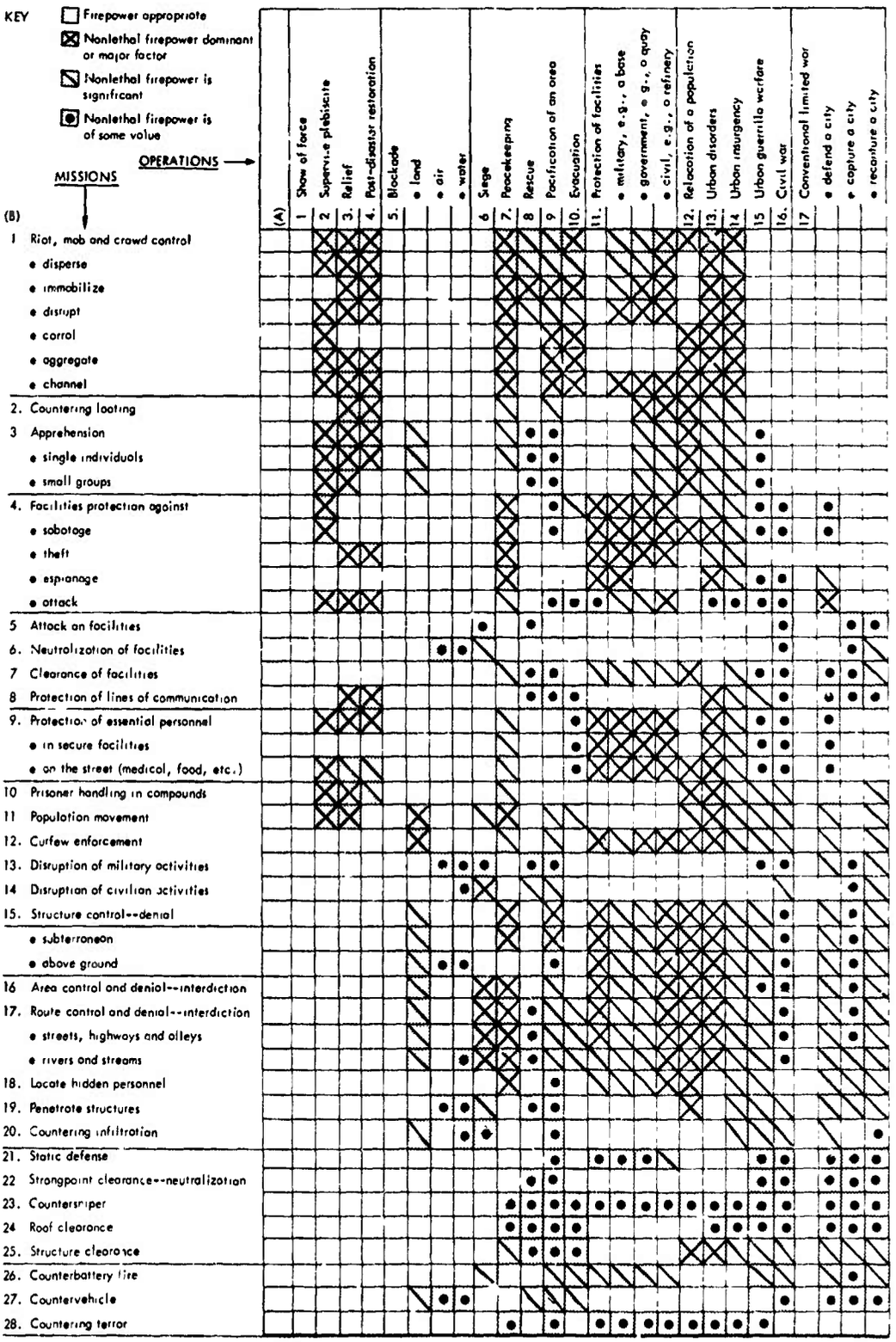
These evaluations are limited to combat in major cities, nominally those over 100,000 in population, or in capital cities.

The point of Table 4 is by no means to define the limitations of the use of nonlethal or lethal firepower unequivocally. Rather, Table 4 suggests in a qualitative way the appropriateness of less deadly techniques as a function of the type of operation. Each judgment reflected in the marks in each cell is open to reevaluation. No claim of finality is made. The overall pattern, however, seems both sound and useful. The reader is invited to prepare his own evaluations for comparison (Annex).

Some points should be noted with regard to both categories: firepower missions and operations.

- With regard to firepower missions, the categories suggested are meant to be of practical value and not necessarily to be taxonomically elegant, nor to reflect the operations of a particular manpower unit. The firepower missions suggested are rather identified for their importance and there is, of course, some overlap among them. With regard to riot, mob, and crowd control, six relatively distinct but not necessarily independent activities are identified. A seventh activity, countering looting, is designated as a separate firepower mission since it is not exclusively associated with mob activities. The concept of apprehension of single individuals

TABLE 4. FIREPOWER MISSIONS IN RELATION TO VARIOUS OPERATIONS



or small groups cuts across both the control of masses of people, where the need may be to apprehend individuals, leaders, or a small band, and more conventional military police operations such as curfew enforcement and facilities protection. In protecting U.S. facilities overseas against pilferage, one can easily precipitate a cause célèbre and an international incident if a foreign national is killed, regardless of the circumstances.

- Mission 6, neutralization of facilities, and mission 7, clearance of facilities, overlap both protection of and attack on facilities, but they represent missions significant enough in themselves to merit separate attention. One could consider, for example, in either attacking or defending a city, that one would wish to neutralize the power plants or the harbor facilities without destroying them.
- Mission 11, population movement, is a broad category encompassing not only police regulation or control of movement in the war theater but the control of masses of refugees following a disaster. Curfew enforcement is subsidiary to this but presents enough special problems that it is singled out as an individual firepower mission.
- With regard to missions 15, 16, and 17, which have to do with the control, denial, or interdiction of structures, areas, and routes, a broad range of applications is encompassed. One may wish to foreclose the use of the facility or route absolutely; on the other hand, one may just wish to regulate traffic to facilitate identification.
- Penetrating structures is a tactical mission that might be associated with a number of other categories, but it seems to occur frequently enough that separate attention should be given to it. Similarly, neutralizing vehicles presents a problem special enough that it can be called out for independent consideration.

With regard to operations (Tables 2 or 4), some points should be noted. In the protection of facilities, the facilities protected can be military, government, or civilian. As shown in Table 4, this suggests different levels of aggressiveness in both defense and attack. On a historical basis, it is questionable whether the protection of civilian facilities alone would ever be the basis for a military operation by U.S. forces. But such activities may be incidental to a larger operation, or of interest to a recipient of U.S. military assistance.

- The protection of a facility for political or other reasons may be restricted in weaponry or movement. For example, defensive measures may be restricted to those measures to be taken inside the gate of a facility, as in the Panama Canal Zone incident where the antisniper measures were restricted to firing by sharpshooters from within the Zone. The protection of facilities may also be strongly influenced by whether that protection is in a friendly or hostile land, or whether it is under relatively peaceful or wartime conditions. The contrast between base protection measures in Japan and Vietnam illustrates this.

- With regard to what might be called benign operations, such as the supervision of a plebiscite, a relief mission, or post-disaster restoration and relief, activities involving the potential use of firepower are likely to be extremely low in frequency and intensity or at most to involve controlling potentially panicky mobs, keeping order, or protecting temporarily abandoned property against looting. It would be important in such matters not to generate a new issue by the misuse or overuse of coercion or firepower.

- The relationship of urban disorder, urban insurgency, and urban guerrilla warfare is unclear in the literature. For present purposes, we distinguish urban disorder from urban insurgency as a phenomenon characterized by civil disturbance

and mass actions, regardless of its spontaneity or ideological or political basis. The concept of urban insurgency includes some urban disorders but has as its unique aspect an organized, systematic attempt to subvert the government. The emphasis in insurgency is on intentions; consequently, insurgency brings to bear a wider range of tactics and techniques than urban disorder alone.

- Urban guerrilla warfare again connotes emphasis on tactics rather than intentions. It complements urban disorders in representing far more aggressive levels of activity. For present purposes, urban guerrilla warfare could be either an accompaniment to an all-out civil war or a behind-the-lines activity in support of a frontal war.

- A civil war can vary widely in method and in some cases could be lumped in with operation 17, conventional limited war. On the other hand, it may evolve out of insurgency, so that the transition phase is of some importance. Limited war in cities is broken out into three distinct operations:

    1. Defending a city
    2. Capturing a city
    3. Recapturing a city

  The presumption is that in defending or recapturing a city substantially more importance will be put on preserving the potential viability of the city as an entity than would be the case in capturing a city. But even in capturing a city, there may be considerable emphasis on saving people and structures.

The applicability of nonlethal techniques, as indicated, depends to a large extent upon the presence of noncombatants. As the number of noncombatants increases, both relatively and absolutely, the requirements for less deadly techniques go up. One might consider a

two-dimensional plot locating the various tactical missions in terms of the mass of the conflict (the total number of combatant and noncombatant personnel involved) and the intensity of the conflict (the appropriateness of deadly versus nonlethal firepower).

A sit-down strike would be an example of a large-mass, low-intensity situation, whereas a sniper terrorist attack would be an example of a high-intensity, low-mass conflict. On the other hand, a massed revolutionary mob in the streets would be an example of a high-mass, moderately high-intensity conflict. Figure 2 qualitatively relates the intensity of the conflict (the appropriateness of the application of more or less deadly force by friendly forces) to the mass of the conflict (the total number of people in the operational area). Figure 2 is only qualitative and is intended to illustrate the complexity of the problem. In general, it would be desirable to move all points to the left.

It is useful at this point to consider some aspects of casualties in urban combat.

A. CASUALTIES

While the general objective in "nonlethal" warfare is to reduce casualties (in the sense of lethal and maiming injuries), it is often unclear what casualties are being spoken of. They may be among friendly forces, enemy forces, or civilians whose affiliations are mixed, unknown, or even fully committed to one side or another. Finally, they may be among neutrals or aliens such as foreign visitors, businessmen, or embassy personnel. In many of the future actions, the safety of civilians, particularly when they are located in the potential field of fire, would be quite important. In other instances, casualties among aliens may have a principal significance, as in a rescue operation. Reducing lethal casualties among enemy forces may have clear and practical values over and above that associated with the general aspiration to humaneness and civility during war. For example, the opportunity to inflict nonlethal casualties may facilitate

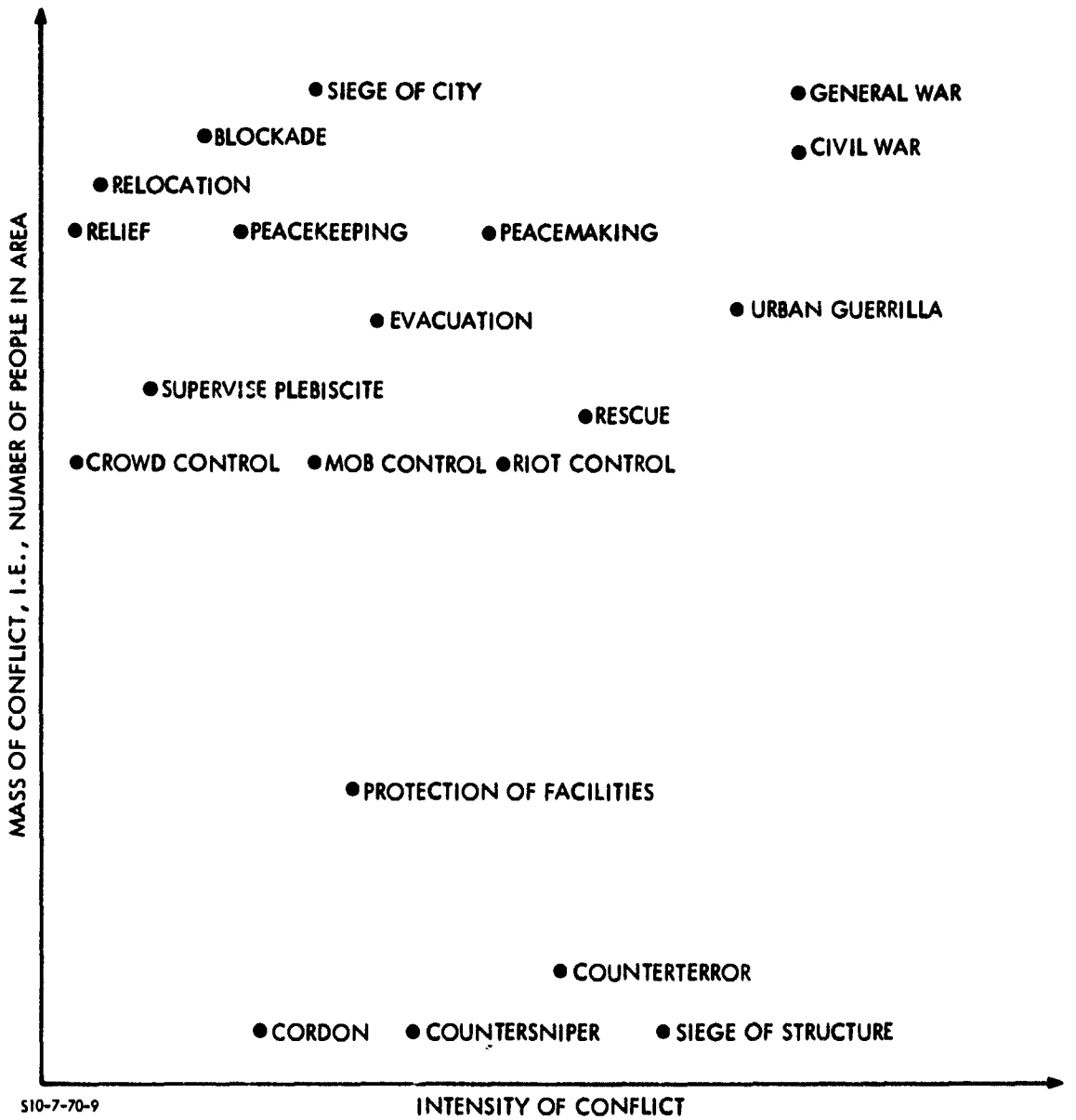


FIGURE 2. Mass and intensity of city conflict

capture and rehabilitation, promote the gathering of intelligence, and even reduce overall violence by reducing the risks in surrender. On the other hand, one cannot discount the possibility that nonlethal weapons might enhance the aggressiveness of the enemy by reducing his deadly risks. These possibilities cannot be evaluated a priori in a generic sense, but only in terms of specific tactics, objectives, and situations. Almost certainly, they require field observations before a conclusive evaluation can be made.

The reduction of casulaties among friendly forces is almost always considered desirable. In fact, most of the destruction currently associated with combat in cities during low-level conflict is directly or indirectly a derivative of the desire to reduce casualties among friendly forces. This is often brought about by neutralizing the enemy position with heavy expenditures of firepower. All other considerations aside, the commander will act to reduce casualties in his own forces. It is clear that discipline, fire control, care to be precise and certain before taking action, and deemphasis on speed can reduce casualties among the enemy and the neutral without necessarily impeding or frustrating the combat objective. This is brought out in very low-level conflict situations in the United States when one compares the civilian casualties in Newark and Plainfield, New Jersey, in 1967 with the general low level of casualties in U.S. cities in the 1968 riots. The principal cause of the relatively high civilian casualties in 1967 resulted from inexperience, fear, and consequent overreaction to alleged sniper fire.

The pattern of casualties varies with the particular kind of operation. Consequently, the emphasis on methods for reducing casualties varies as a function of the military mission. As background to the problem, the reader should consult Payne and Taylor (Ref. 8) for a discussion of casualties in urban combat in limited war and more conventional operations.

B. METHODS OF REDUCING CASUALTIES

Within the framework of present equipment and doctrine, casualties can be controlled or reduced by:

- The choice of tactics.
- Discipline, particularly in the control of firepower.
- Training.
- Better intelligence to earmark the target precisely.
- Evacuation to clear the field. In some situations, areas can be evaculated, particularly if one is dealing with small isolated units whose routes have been cut off.
- Forewarning, which is related to evacuation. It is applicable to a wider range of situations, and allows a wider range of options to all potential victims.
- Care and meticulousness. In some situations, there is a tradeoff between time and accuracy, or care in finding and hitting a target. This may reduce the errors and, consequently, the accidental casualties.
- Accepting greater risks to friendly forces.

The most promising area for a large reduction in the lethality and destructiveness of warfare is in the development of new devices and agents which offer the commander new capabilities or new tactical and strategic alternatives. Obviously, each of the above considerations (tactics, discipline, care in the operation, and evacuation and forewarning) would be applicable to any weapon system in reducing the primary or secondary casualties. But the major decrement in casualties for given types of operations will undoubtedly come about in the development of new devices and agents and, in turn, these will lead to new concepts, new tactics, and new doctrines. In some cases, these may be adapted to old systems; in others, entirely new systems may be required for dealing with particular military situations.

Within the framework of new devices and agents, it is our conclusion that chemical agents hold the greatest promise for new weaponry for combat in cities. The basis for this conclusion will be explained in detail below.

C. ANTIPERSONNEL MECHANISMS AND NONLETHAL WEAPONS

Having established some potential patterns of significance for the employment of nonlethal weapons (Table 4), it is appropriate next to consider nonlethal weapons applicable to such missions. Before proceeding with that, however, consideration must be given to various biological, physical, and other mechanisms which lend themselves to antipersonnel applications and draw from this a potential range of nonlethal weapons mechanisms.

Table 5 is a comprehensive, if not an exhaustive, tabulation of antipersonnel mechanisms. It is from this list that nonlethal mechanisms will be drawn. Table 5 is not taxonomically elegant but presents a roster which is practical and convenient for the tabulation of potential weapons effects.

A number of conventional deadly mechanisms are included since consideration has to be given to the possibility of using a lethal mechanism in an attenuated or modified mode to evaluate whether it can be effectively employed as a nonlethal weapon.

The reader is invited to consider the antipersonnel mechanisms in Table 5 preliminarily for nonlethal weapons potentialities.

The major criteria categories influencing the selection of nonlethal mechanisms were indicated in Table 1.

Of the 26 general antipersonnel mechanisms in Table 6, some immediate preliminary screening can be done on the basis of the criteria categories.

- Blast can be dismissed as a nonlethal weapon because of its well-recognized inherent risks and because its nonlethal effects cannot be predicted reliably. The uncertainty stems partly from the wide variations in human tolerance to blast. Among a dozen people exposed to pressures of 170 to 500 or 600 psi in World War I, there was one fatality at 450 psi. In German tests on dogs during World War II, lethal overpressures ranged from 218 lb/sq in. at a pulse velocity of

TABLE 5. ANTIPERSONNEL MECHANISMS

1. Blast
2. Vortices
3. Mechanical impact
   - bludgeons
   - missiles
4. Foam
5. Snares
6. Whips
7. Stabbing and cutting weapons
8. Modified traction
   - stick
   - slip
9. Sound
   - sonic
   - subsonic
   - ultrasonic
   - sonic boom
10. Wind
11. Penetration
    - fragment and shrapnel
    - tacks, barbs
    - caltrops
    - arrows
    - injector darts
12. Temperature changes
    - flame
    - hot air; hot smoke
    - hot/cold water
    - radiant heat
13. Liquids
    - hose
    - pistols
    - flood
    - sprays
14. Food/water deprivation
15. Light
    - bedazzlement
    - temporary blindness
    - induced seizures
16. Electricity
    - shock
    - ionized air
17. Nuclear radiation
18. Microwave/radar
19. Foreign matter in the air
    - dust
    - smoke
20. Deoxygenation of the air
21. Manipulation of the environment
    - weather
    - gravity
    - earthquakes
    - utilities
22. Chemicals
    - lethal
    - nonlethal
    - stenches
    - markers
23. Biological warfare
    - infections
    - toxins
    - allergens
24. Animals
25. Plants
    - irritants
    - nettles
26. Psychological warfare

TABLE 6. TENTATIVE LIST OF POTENTIAL NONLETHAL WEAPONS MECHANISMS

1. Mechanical impact
   a. Bludgeons
   b. Missiles
2. Foam
3. Snares
4. Vortices
5. Wind
6. Stabbing/Cutting
7. Modified traction
   a. Stick
   b. Slip
8. Sound
9. Penetration
   a. Tacks, barbs
   b. Caltrops
   c. Injectors
10. Radiant heat
11. Liquid
   a. Hose
   b. Pistol
   c. Spray
12. Light
   a. Bedazzlement
   b. Temporary blindness
13. Electrical shock
14. Dust/Smoke
15. Manipulation of utilities
16. Chemicals
   a. Nonlethal
   b. Stench
   c. Markers
17. Biological warfare
   a. Infections
   b. Toxins
   c. Allergens
18. Animals
19. Plants

5.2 ft/sec to 76 lb/sq in. at a pulse velocity of 38.7 ft/sec. On the basis of comparisons of shock pressure versus average body weight for a variety of animals, from mice to goats and men, 50 lb/sq in. has been considered a reasonable estimate for 50 percent lethality for a standard 154-lb man (Ref. 9).

- Whips obviously have extremely limited versatility, require trained users, and it is almost inconceivable that they could ever find an acceptable public image (Ref. 10).

- With regard to penetration weapons, fragment and shrapnel wounds are not always lethal, but they cannot be inflicted with controlled reliability to limit casualties to an acceptable level. Any application that we have been able to anticipate could be better met by other means. The same objection applies to arrows.

- Under temperature changes, flame can be eliminated on the basis of its high risk. The application of hot air or hot smoke to a structure for purposes of flushing people would be plausible in some situations but would be of extremely limited versatility and very dependent on internal building structure, including the availability of fire doors or windows modifying cross currents. While the technique may be useful in driving people out of a building by fear, the mechanical limitations on the application make it unattractive as a standard procedure (Ref. 11).

- Hot and cold water each brings about well-known physiological effects. The margin between achieving a coercive effect from hot water and the temperature at which damage is done is virtually zero. Pain receptors are activated at the same temperature that tissue damage sets in; consequently, one could not expect to apply hot water in a controlled fashion to coerce people without the serious risk of injury.

  Cold water in large quantities definitely produces major physiological effects which will immobilize and arrest

activity. This would seem to have extremely limited applications, however, because of the logistics requirements and the need for special equipment (Ref. 12).

- Food and water deprivation are standard objectives in seige, but they are not antipersonnel mechanisms which lend themselves to weaponization. They are rather consequences of the control of movement of personnel and resources (in urban areas).
- With regard to electricity, it is reasonably well established that the state of ionization of the atmosphere influences attitude; however, there is no evidence that the effect is of any order of intensity that would have military consequences (Ref. 13). Nuclear radiation seems to have no effect applicable to tactical situations of the sort I am discussing. Microwaves and radar are known to induce a number of physiological effects varying from long-term chromosomal damage to transient pain and headache. The present poor understanding of the physiological effects of radar and microwaves and the apparent intrinsic risks in their use place them beyond consideration in the present context. And, as with almost all radiation-type weapons, there appears to be an irreducible risk of abuse (Refs. 14-21).
- Deoxygenation of the atmosphere, particularly in closed structures, could be obtainable either by combustion to form carbon dioxide or metallic oxides or by the burning of sulphur to deoxygenate the air and form the choking sulphur dioxide. The risks inherent in such a tactic, however, seem to be irreducibly great. To bring about oxygen deprivation rapidly enough to be useful and strongly enough to alert the victim to the danger would so narrow the margin of safety that deadly casualties would almost certainly result.
- Manipulation of the environment is conceptually attractive. Such notions as the controlled induction of earthquakes at

arbitrary sites and gravity modification are far beyond the present state of the art. Even the control of weather, e.g., inducing rain, is so uncertain as not to merit consideration as a general tactical device. Manipulation of utilities such as water and electricity may be useful.

- Lethal chemicals do have reversible nonlethal effects at low doses. The general drive in lethal chemical warfare, however, is to find materials which are effective at very low concentration. Therefore, their use in a nonlethal mode, except under the most stringent controls, is not a feasible tactic unless one is prepared to accept substantial casualties. The problems of operational control and the intrinsic risks to the victim knock this out of consideration.

- Flooding may have application in some areas, but it is so dependent on the particular city and situation that it has no general applicability.

- The induction of seizures by high-intensity pulsating light is a phenomenon which occurs in a small percentage of the population and can be induced in a laboratory situation. Its development as a field weapon, however, appears to be infeasible on the basis of the available evidence (Refs. 5, 22, 23).

- Psychological warfare techniques per se are beyond the scope of this paper. However, the effective exploitation of many nonlethal techniques depends upo r could be enhanced substantially by appropriate psychological warfare accompaniments. Show of force, warning, harassment, and induction of fear are all intimately associated with the use of low-intensity weaponry on masses of people. Even voodoo and superstition have been exploited in warfare; for example, in the Congo fighting many of the superstitious natives were cajoled into battle by convincing them that certain ceremonies would cause

their opponents' bullets to turn to water. Other techniques, such as the simulation of lethal effects and the use of various lures (e.g., amnesties, bonuses, and awards), the taking of hostages, and the induction of confusion in the environment may have application to a variety of tactics but are beyond the scope of this paper (Ref. 24).

III. DESTRUCTION IN WARFARE

In general, a destruction of physical property in warfare results from one of three objectives:

1. Attacks on facilities themselves with the objective of making them unavailable to the enemy. This may include knocking out telephone exchanges, electric power plants, munitions factories, road links, or almost any asset physically essential to the war effort.

2. The neutralization of enemy personnel in a strongpoint defense within structures is probably a more significant source of destruction in city fighting. In general, the visual-physical obstacles and the consequent risks and uncertainties presented by structures lead to their destruction, but only as an incidental consequence of neutralizing or killing the emplaced enemy.

3. Demoralization of the enemy by so destroying his war-making capacity that he "no longer retains the ability or the will to wage war." Within the context of this study, strategic warfare, and certainly strategic air warfare involving cities, is a largely irrelevant concept more appropriate to the destruction of Tokyo and Dresden in World War II (Ref. 25). A review and assessment of the efficacy of this technique is beyond the scope of this paper.

The development of reversible nondestructive measures for neutralizing facilities could, in many situations, be of value. The development of new modes of neutralizing enemy personnel could also lead to a major decrement in the destruction of physical assets.

Figures 3 and 4 illustrate the destruction that may accompany conventional small-unit operations in built-up areas. The potential impedance of mobility and the requirements for cleanup are also illustrated.

The relative value of lethal and nonlethal destructive and nondestructive techniques in the kinds of conflict discussed in this paper may be illustrated by a four-cell matrix (Table 7). The highest priority is on innovations in techniques, tactics, and technology that are both nonlethal and nondestructive (i.e., less lethal and less destructive than is now conventional).

TABLE 7. PRIORITY OF NONLETHAL AND NONDESTRUCTIVE TECHNOLOGY IN LOW-INTENSITY CITY COMBAT

	Destructive	Nondestructive
Lethal	tertiary	secondary
Nonlethal	uncertain	primary

There may be some secondary application for improved lethal techniques that avoid destroying physical assets. These might be brought to bear against small numbers of last-ditch resisters holed up in structures. Other techniques, such as employing newly designed stubby firearms to increase maneuverability within structures, may have some promise. In general, however, the more lethal or destructive firepower is beyond the scope of this paper.

Destructive but nonlethal techniques have application in special situations, but all such techniques seem to fall outside the scope of personnel coercion, i.e., they are not alternatives to deadly firepower. For example, in the Kenya campaign against the Mau Mau, the British removed and relocated large numbers of natives from the capital city of Nairobi. They then found it necessary to destroy the shanty towns in which the relocated natives had been living.

FIGURE 3. Along Dong Khanh Street in Cholon, Saigon's Chinese section, blasted houses stand deserted in an early-morning haze. The church was a hiding place for the late President Ngo Dinh Diem during the 1963 coup that deposed him.

All in all, the overwhelming emphasis in firepower improvements for military operations in cities should be placed on far less lethal and far less destructive techniques. Principal emphasis should be on techniques to prohibit or deny enemy movement.

FIGURE 4. Gutted cars litter a heavily damaged street in Cholon, where much of the house-to-house fighting flared. Fragments riddled even the traffic sign.

IV. PRIORITY OF MISSIONS FOR NONLETHAL, NONDESTRUCTIVE WARFARE

Preliminary winnowing of antipersonnel mechanisms resulted in the tentative list of potential nonlethal weapons mechanisms that has been shown in Table 6.

Before continuing with further consideration of nonlethal weapons mechanisms, it is appropriate to discuss more fully the kinds and priorities of targets for which nonlethal firepower is suitable.

On the basis of Table 4, one can establish a tentative order of importance for nonlethal weapons by assigning a figure of merit to each tactical mission in each operational context. By assigning in Table 4 a value of 1 to an X and a value of $\frac{1}{2}$ to a slash, one can rank the priorities of missions for nonlethal firepower as shown in Table 8. Such ranking should be interpreted entirely in qualitative terms.

The priorities shown in Table 8 are based solely on frequency of occurrence as developed in Table 4 and would undoubtedly be modified by many other considerations, such as the availability of alternatives, the effectiveness of the nonlethal techniques, and the relative frequency of various operations.

In general, the mission priorities for nonlethal weapons for combat in cities are greatest where civilians comprise the target or where civilians are intimately commingled with the enemy.

To a surprising degree, the major applications for nonlethal and nondestructive weapons in combat in cities center around civil disturbance and problems closely resembling those of routine police operation.

TABLE 8. PRIORITY OF MISSIONS FOR NONLETHAL FIREPOWER
(Based on Frequency of Occurrence Only)

Riot, mob, and crowd control	11
Curfew enforcement	10
Population movement	9½
Route control and denial	9½
Protection of essential personnel	9
Structure control and denial	8½
Area Control and denial	8½
Countersniper	8
Apprehension	7
Facility protection	7
Prisoner handling	7
Countering looting	6
Locating hidden personnel	6
Structure clearance	5½
Roof clearance	5½
Counterbattery fire	5½
Countering terror	5
Penetration of structures	4½
Clearance of facilities	4
Protection of lines of communication	4
Neutralization of facilities	4
Disruption of civilian activities	3
Attack on facilities	3
Countering infiltration	2½
Strongpoint clearance	2½
Disruption of military activities	1
Countervehicle operations	1
Static defense	½

Nonlethal weapons seem to be at least applicable where the enemy is aggressively violent, most willful, massed, and undiluted by the presence of civilians (Table 4).

A. TARGETS

Possible targets for nonlethal and nondestructive weapons include personnel, inanimate objects such as structures and machines, and living things, both animal and plant. (The most conspicuous example of military destruction of plant life, i.e., the Vietnam defoliation campaign, occurred in nonurban areas.) Looking at the city as an organism, one might consider its various control systems as targets for selective, reversible nondestructive warfare. But these control systems are beyond the scope of this paper.

B. OPPORTUNITIES AND NEEDS FOR NONLETHAL FIREPOWER

After the assignment of nonlethal firepower mission priorities (Table 8), it will be appropriate to point out specific opportunities and needs for nonlethal firepower.

As additional background to the point already made that the presence or prevalence of noncombatants is a main drive requiring new developments, other factors in urban operations should be noted. Crowd, mob, and riot control have a very high manpower requirement. The provision of an overwhelming mass of troops may reduce the need for destructive firepower by affording an intimidating force sufficient to deter extensive mob action. Curfew enforcement, the regulation of checkpoints, and manning barriers and barricades are also high-manpower missions. Techniques for getting around or reducing those burdens need consideration. Similarly, the protection of facilities, either on a standby, low-level basis or with patrols, can require much manpower. The ability to mobilize and move ready forces to augment the protection of a particular site is a problem which is receiving attention in the main report (Ref. 26). To supplement protective forces, it would be useful to have devices that operated automatically or on command to

neutralize intruders or to prevent their access. However, the risks to the innocent in the triggering of such devices may be unacceptable for many applications if deadly firepower is employed. Consequently, the use of automatic and semiautomatic weapons and devices for protection of facilities drives toward a benign, nonlethal weaponry. Such weapons and devices can be used more freely if they are "fail safe," i.e., if they offer low risk and if their effects are reversible.

The denial of structures, the routing of people out of structures, and techniques to prevent their moving back into structures for controlled periods of time would be useful in many operations.

Another class of operations closely resembles more or less routine police apprehension problems. These include some aspects of curfew enforcement such as the apprehension of single violators or small groups of violators, the regulation of population movement, the operation of checkpoints in route control, the apprehension of sneak thieves and pilferers, and the handling of masses of prisoners.

Looting can be countered both by apprehension of looters and by hardening the target, that is, by making access more difficult or chancy. Countering looting strongly resembles the problems of protecting facilities.

Another quite general factor driving toward innovation in combat in cities is the fact that large numbers of casualties result from conventional antipersonnel measures. These antipersonnel measures themselves result from the commander's reluctance to put his men at any higher risk than he judges to be necessary to accomplish the immediate tactical mission. Consequently, techniques that remove the men from the tactical field of fire or which reduce their chances of being exposed to fire may find major applications in city combat.

Semiautomated, remotely controlled, and robot devices could enter the enemy field of fire to deploy nonlethal devices (or lethal ones in some situations), to neutralize an emplaced enemy, to do detailed surveillance, and to drive enemy and civilian personnel from structures.

A reduction in casualties would result from the fact that the devices could take higher risks than men alone.

Conceptually, this suggests the use of robots, man-extension systems, and semiautomated systems that would either precede the movement of human personnel or that would replace personnel in the investigation, search, control, and denial of buildings and the protection of structures and facilities. Robots might be particularly applicable as an alternative to reconnaissance by fire, which is the standard technique applied in the room-by-room, chamber-by-chamber search of a structure. In this case, reconnaissance by fire is either with grenades or semiautomatic weapons. One could picture a robot dispensing incapacitating gas, darts, or even conventional firepower in such a situation.

Countering snipers is generally a problem subsidiary to riot and mob control and to more aggressive city combat. In the first case, there must be a high premium on protecting people in the same building as the sniper from both the primary risks of firepower and the secondary risks of panic and fire. Consequently, techniques for locating snipers (the surveillance aspect of the problem) and for neutralizing the target by nonlethal weaponry would both be useful.

C. NONLETHAL MECHANISMS IN VARIOUS OPERATIONAL MISSIONS

Having established some priority for the importance of nonlethal mechanisms in various operational missions (Table 8), it is now useful to relate various tentative nonlethal antipersonnel mechanisms to specific operational missions, taking into consideration some of the target opportunities mentioned above.

Table 9 presents my assessment of the appropriateness of various nonlethal mechanisms to the 28 operational missions considered in this paper. The assessment again is qualitative. The detailed considerations which entered into making the many judgments in the matrix are omitted as too lengthy for this paper. Table 9 is basically a

TABLE 9. POTENTIAL NONLETHAL MECHANISMS VERSUS OPERATIONAL MISSIONS

	1. Riot, mob, and crowd control	2. Counterlooting	3. Apprehension	4. Facilities protection against:	5. Attack on facilities	6. Neutralization of facilities	7. Clearance of facilities	8. Protection of lines of communication	9. Protection of essential personnel on street	10. Prisoner handling in compounds	11. Population movement	12. Curfew enforcement	13. Disruption of military activities	14. Disruption of civilian activities	15. Structure control--denial	16. Area control and denial--interdiction	17. Route control and denial--interdiction	18. Locate hidden personnel	19. Penetrate structures	20. Counterinfiltration	21. Static defense	22. Strong point clearance--neutralization	23. Countersniper	24. Roof clearance	25. Structure clearance	26. Counterbattery fire	27. Countervehicle	28. Countering terror
1. Mechanical Impact																												
a. Bludgeon	X	X	X	X					X	X	X	X					X			X				X			X	
b. Missiles	X	X	X	X	X	X	X		X	X	X	X					X			X	X			X	X		X	
2. Foam	X	X		X		X		X	X	X	X	X	X	X	X	X	X		X	X				X		X	
3. Snares	X	X	X	X				X	X	X		X					X			X				X			X	
4. Vortices	X			X				X	X	X							X			X	X							
5. Wind	X			X					X	X							X			X	X							
6. Stabbing/Cutting	X		X	X					X	X	X	X																
7. Modified Traction																												
a. Stick	X	X	X	X		X		X	X	X			X	X	X	X	X			X	X			X			X	
b. Slip	X	X	X	X		X		X	X	X			X	X	X						X			X			X	
8. Sound	X			X			X	X		X														X				
9. Penetration																												
a. Tacks-Barbs	X	X		X		X		X	X	X	X	X			X	X	X			X	X						X	
b. Caltrops				X		X		X	X			X	X	X	X	X	X			X	X						X	
c. Injectors	X	X	X	X	X	X		X	X	X		X	X	X	X	X	X			X	X	X	X	X				
10. Radiant Heat	X	X		X																								
11. Liquid																												
a. Hose	X	X		X			X	X	X	X								X		X	X						X	
b. Pistol	X	X	X	X			X	X	X	X	X	X												X	X			X
c. Spray	X	X	X	X		X	X	X	X	X	X	X			X	X	X		X	X		X	X				X	X
12. Light																												
a. Bedazzlement	X			X						X		X					X			X	X			X			X	
b. Temp. Blindness	X			X						X		X					X			X	X			X			X	
13. Electrical Shock	X	X		X		X	X	X	X	X		X			X	X	X			X	X						X	
14. Dust/Smoke	X	X		X	X		X			X			X	X	X	X	X		X	X	X	X	X	X			X	
15. Manip. of Utilities	X	X		X	X	X	X		X	X					X	X	X			X					X			
16. Chemicals																												
a. Nonlethal	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
b. Stench	X	X	X	X		X					X	X	X	X	X	X	X		X	X			X					
c. Markers	X	X	X	X		X			X	X	X	X			X	X	X	X	X	X			X	X	X	X		X
17. Biological Warfare											X																	
a. Infections				X	?	X					X		X	X	X	X	X		X	X		X						
b. Toxins				X	X	X					X		X	X	X	X	X		X	X	X	X						
c. Allergens				X	?	X					X		X	X	X	X	X		X	X		X						
18. Animals	X	X	X	X	?	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X
19. Plants	?	?		X	?	X		X	X		X				X	X	X			X	X							

bookkeeping device to assist me in making and reordering those judgments. The reader may evaluate the mechanisms and the operational missions himself to establish general confidence and concurrence in the conclusions presented in Table 9.

Some antipersonnel mechanisms have a wider range of applicability than others. If one assigns a value of 1 to each X in the cells of Table 9, only one nonlethal mechanism has the maximum value of 28, that is, fits all operational categories. That nonlethal mechanism is chemicals. In descending order of value, i.e., mission frequency, the mechanisms are:

	Value
Chemicals (nonlethal)	28
Animals	25
Injectors	20
Sprays	20
Markers	19
Dust and smoke	18
Foam	18
Missiles	17
Tacks, barbs	15
Electric shock	15
Stenches	14
Slippery agents	14
Manipulation of utilities	13
Caltrops	13
Liquid pistol	13
Plants	13
Biological agents	13
Bludgeons	12
Liquid hose	11
Sticky agents	11
Bedazzlement	9
Temporary blindness	9
Snares	8
Vortices	8
Wind	7
Stabbing and cutting weapons	7
Sound	6
Radiant heat	3

A number of mechanisms in Table 9 are now under investigation as a part of the riot-control research program, which will be described in some detail below. It seems appropriate at this point, however, to make some comments about some of the mechanisms--particularly those

with low mission-frequency scores--so that they can be set aside as totally inapplicable or so that appropriate recommendations for their exploitation can be made.

V. EVALUATION OF POTENTIAL NONLETHAL MECHANISMS

In this section, the 19 classes of potential nonlethal mechanisms (Table 9) will be reviewed for their potential development into useful nonlethal weapons. With regard to each, where appropriate, attention will be given to the present state of knowledge of the physiological consequence of the particular mechanism, the likelihood of striking a useful balance between effectiveness and safety, and the tactical versatility of the weapon which might result. Where it seems possible and useful, the relationship of that mechanism to alternative mechanisms for achieving approximately the same tactical result will be considered. Again, the analysis depends heavily on personal judgment. As far as possible, however, the relevant considerations will be made explicit so that the reader may draw his conclusions. From this will result a series of recommendations for promising areas for RDT&E.

In the presentation below there is a rough ordering from the least plausible or useful mechanisms to those which are of increasing potential application and, consequently, attractiveness for weapons development.

A. RADIANT HEATING

Radiant heating or heat rays are now feasible with the development of the carbon dioxide infrared laser. This device can easily put out enough heat to deliver a mild flush or a severe burn at any line-of-sight target likely to be found in city combat. Such a technique might conceivably have application in crowd and mob control. Let us say, for example, that playing a laser beam for 15 to 30 sec on the target could create enough distress on the face, exposed skin, or even the clothing to cause a person to move away. The arguments against

this, aside from whether such a device would ever have an acceptable image, are (1) the device is now expensive and bulky, (2) it would have applicability to only a few mob and riot-control situations, (3) its safety--particularly to the eyes--is not yet well enough established that one can proceed on the assumption that risks of permanent damage can be kept small and controlled at an acceptably low level.

The work on laser safety should be closely followed to clarify developments in that area (Ref. 27, 28). As things now stand the development of such techniques would assume secondary priority because of high cost, risks, and uncertain outcome; and a better allocation of money can probably be made elsewhere (Ref. 5).

B. STABBING AND CUTTING WEAPONS

Stabbing and cutting weapons are classical military weapons and their use in quite recent military operations is well known. Their principal value in combat in cities these days is in riot control, but they seem to be more a weapon of tradition than that of clear appropriateness, flexibility, and controlled damage. There seem to be few mass or crowd-control situations that could not be handled better with less risks by truncheons or various chemical devices. I see, therefore, no need to promote research on cutting and stabbing devices for crowd and riot control. The applicability of the bayonet is also limited by other factors. Some people, for example, refuse to take the bayonet seriously (Figs. 5, 6). The recent incident in Okinawa (Fig. 7) illustrates a cultural association with the bayonet that appears to have made it particularly offensive (Ref. 29). In other more aggressive military operations, there may continue to be some applicability for the bayonet. I can see no R&D objectives meriting attention now, however.

FIGURE 5. Protesters on the University of California campus at Berkeley taunt armed National Guardsmen as they are called into campus disorders. Guardsmen with fixed bayonets twice turned back marches of several thousand demonstrators who were protesting police use of guns on demonstrating students (Ref. 30).

FIGURE 6. Confrontation with National Guardsmen (Ref. 31).

FIGURE 7. MP's disperse striking Okinawans (Ref. 32).

C. SOUND

For sound, it was concluded in an earlier evaluation that "... there are no physical or physiological effects of sound useful as bases of weapons development in crowd control. Production and control directionally at levels that would be physically distressing or incapacitating and which would not risk permanent injury to the victim are the principal limiting factors on the development of a nonlethal sound weapon.

"The application of noise for harassment, distraction, disruption of crowds is certainly plausible and widely practiced; however, there is a paucity of literature on the efficacy of this technique. A systematic study of the use of noise in crowd control, therefore, would be appropriate" (Refs. 5, 33). Nothing has transpired since this evaluation to modify its conclusions.

D. WIND

Wind machines, basically very large fans, are now used in training parachute troops how to unharness their parachutes on landing. Such fans may have specific application in dissemination of chemical agents in urban areas, particularly under circumstances in which

natural wind conditions are not favorable for dissemination. Whether the development of the specific family of devices for use in urban combat would be justified is yet an open question, inasmuch as the basic dissemination characteristics of chemical agents in city environments are not so sell understood that requirements can be laid down for artificial aids. Nevertheless, the possibility of using wind machines as a field expedient or as an emergency measure should not be overlooked.

The wind generator in current use at Ft. Benning (Fig. 8) is not a standard item of manufacture. It has never been used in riot control (Ref. 34). Its application to riot control, besides disseminating agents such as CS, might also be effective in raising street dust. The wind itself, reported to be as high as 35 mph, could be a deterrent. It may also be feasible in colder climates to use such a device to disseminate water droplets and simulate a chilling rain, or to disseminate marking agents over a wide area at relatively low application rates. Preliminary field evaluations of the Ft. Benning wind generator in a built-up area would be appropriate to estimate its efficacy in (a) rousing and disseminating dust, (b) deployment of CS or other tear agent, or (c) generation of simulated rain.

FIGURE 8. Fort Benning parachute wind machine (Ref. 35).

E. VORTICES

Vortices, most commonly seen as smoke rings, can be generated in quite large size and projected for hundreds of yards. The vortex is an energy-conserving mechanism, that is, it is physically stable. As far as weapons effects go, there is a drop in pressure across the face of the ring. Such a force acting over a total body surface may be enough to tumble a man. The device, therefore, may have application to crowd and mob control, but it would be of limited tactical application.

Vortex rings are rather easily made by the rapid passage of air over a sharp-edged opening. A vortex generator could have two chambers, front and rear. The forward chamber, separated from the rear chamber by a membrane, would have an opening in its forward end. Activation by a powder charge, a modified shotgun shell, or some other device could cause the membrane to rapidly move forward to create a vortex. Its size would depend on the physical parameters of the system. It seems feasible to incorporate irritants such as tear gas or other materials into the vortex to get a secondary effect. This could be done by putting bulk agent in the forward chamber. The vortex might provide a unique and safe means for the remote and controlled delivery of chemical agents. As far as I have been able to determine, no research has been done on this potentially useful application (Ref. 36).

F. ANIMALS

The three candidates for employment in urban combat are horses, dogs, and various kinds of pests such as wasps, bees, mice, rats, and birds. The only two which seem to merit any serious consideration are horses and dogs. The uses of small animals for harassment would not seem to justify the expense in training, logistics, possible adverse effects on friendly operations, the possibly unfavorable attitude of accidental victims, or the risk of introducing an ecological hazard.

1. Horses

Horses are widely used in crowd and mob control in routine police

work and may have value, particularly for local forces, in these applications. Cavalry and other horse-mounted operations seem to be passé for U.S. forces and would have no general mission in military service beyond crowd and riot control. They therefore do not appear to be appropriate candidates for revival.

2. Dogs

Dogs are so versatile, so compatible with people, and have such a distinguished record in military and police operations that their more extensive application to a variety of police and military operations should be systematically investigated. Dogs have been used for messengers, sentry duty, patrol, tracking, surveillance, and the location of lost and contraband items. They seem to be a near-ideal combination of mobile sensor-alarm and weapon. Three basic programs--to consider missions, to breed and select special-purpose dogs, and to reevaluate current training techniques and explore new ones--are the essential R&D requirements to put these animals on an even more effective military basis. Problems of veterinary medicine, maintenance, food requirements, and disease or resistance to disease, would become particularly critical problems in tropical and semitropical areas. Attention to these matters would be an essential part of any major program for military police employment of dogs. Such a program is recommended (Ref. 37).

G. BIOLOGICAL WARFARE

Biological warfare agents may be considered to be of three types: (1) nonlethal infectious diseases; (2) toxic materials, that is, poisons (exotoxins) produced by organisms and otherwise handled as chemical agents; and (3) allergens, materials which induce allergenic responses. In terms of low-level warfare, infectious biological warfare agents--even those of the nonlethal type--seem to have extremely limited application. They could be introduced as a known threat to interlopers in facilities protection, to enfeeble an enemy entrapped in strongpoints, where firepower is undesirable, or where a seige can

be laid for a few days or more. Such situations may seem to be unusual. Nevertheless, they do represent problems for which biological agents may have some potentially useful applications. By and large, however, the effort of R&D development, deployment, and logistics, as well as the strong public antipathy to such weapons would suggest that the development and weaponization of agents for these specific purposes would not be worthwhile since alternative methods, particularly chemical methods, are available for achieving the same objectives.

H. TOXINS

Toxins, particularly staphylococcus enterotoxin, the common nonlethal food poison, have a similar range of potential applications in facilities protection, attacks on strongpoints, area and structural denial (where the threat of exposure to a toxin might be sufficient to proscribe entering) as the infectious organism. In all cases, the applications are useful and feasible and overlap the application of chemicals. Similar remarks hold true for allergens, but their application may be somewhat different in that the allergenic response may have three functions:

1. Deterrence through fear of the effect.
2. Debilitation and harassment because of the effect.
3. Marking and identification by any flare or any other symptom uniquely associated with that allergenic response.

The application of allergens, even though of biological origin, is so remote from the conventional categories of biological warfare as to be subsumed either under chemical warfare itself or under the concept of marking. The principal need at this point is to determine whether allergens uniquely perform a role not already met by alternative means of marking.

I. PLANTS

Plants may be effective in three militarily useful roles:

1. The plants themselves may provide barriers to movement.

2. The plants may contain irritants. Poison ivy plants would augment the effectiveness and the threat of a plant barrier.

3. Plants may be a source of barbs and nettles, to be harvested and used as an irritating or harassing agent. If left in place on the plants or placed on other plants, barbs and nettles can induce itching and can be used as a means of introducing other foreign materials. If harvested and disseminated as separate items, they are another means of chemical agent dissemination.

It is by no means clear that plants would have any practical advantage over concertina-wire fences, chemically treated stakes, or other barriers. But the uses of plants in all three of these roles merit further attention to answer that question. Obviously, the use of growing plants implies static missions such as the protection of facilities. It would hardly require more than minimal organization, horticulture, maintenance, safety precautions, and environmental compatibility. The risk of an ecological disaster because of the introduction of a hardy, environmentally compatible plant should be a major consideration in any anticipated use. By and large, it would seem best to limit applications to indigenous material to avoid this last risk.

Natural nettles and barbs may be imitated with either solid or hollow fiberglass. Irritants may be incorporated in these barbs.

J. MANIPULATION OF UTILITIES

Electricity, illuminating gas, and water are the principal utilities in use in cities. The manipulation of electricity, particularly to moderate crowd and mob behavior, is, at most, worthwhile for tactical purposes. As far as I have been able to determine, no systematic observations of the influence of lights on mass behavior have been made. Similarly, the influence of regulating electric lights on the enforcement of curfews has not been systematically reported, although

it is a widely held opinion in domestic as well as in military policing that lights discourage criminal activities (Ref. 38). Manipulations of gas and water are probably without value as nonlethal tactics.

K. LIGHT

Intense radiation can blind, bedazzle, or heat the eye. The application of bright lights to bedazzle the eye and reduce dark adaptation is practical. The achievement of maximum dark adaptation may take several hours. It is 60 percent completed in 5 min, and virtually completed in 20 min. It may therefore have some applications in controlling mobs and crowds in making any organized effort on their part more difficult. This effect, of course, would be over and above any incidental annoyances caused by bright lights, flickering, flashing, or other manipulated phenomena.

For practical purposes, to achieve a transient blindness safely requires the creation of an afterimage, the familiar phenomenon noted after looking at a photoflash. To achieve illumination on a scale large enough to make it difficult for one to "look around" the blot in the visual field may not be realizable, although efforts in this direction merit some support.

Bedazzling devices as hand-held weapons for the protection of facilities may have some application in temporarily blinding, bedazzling, or disorienting people approaching a checkpoint, curfew violators, or interlopers into a restricted area. It is not clear whether these potentially useful applications can be achieved without substantial new risks to the user.

L. STICKY MATERIALS

Sticky materials would be of use in certain tactical situations, provided that

- Friendly forces will not come into contact with the materials,

- The materials will not present a major cleanup problem in the restoration to normal use of areas to which they have been applied, and
- The potential victims will not be so numerous as to create a major health, cleanup, or handling burden.

The use of sticky materials in urban military operations thus seems to be most appropriate for three purposes (Ref. 39):

1. The protection of facilities. Semipermanent sticky materials might be applied to fences or fence tops and to proscribed areas and routes.
2. Control of mobs. Sticky materials ahead of a mob might impede its movement without creating a major cleanup problem.
3. Denial of vantage points to snipers. Sticky materials might be applied to likely sniper perches.

Sticky materials might serve not only as semipermanent obstacles the way barbed-wire fences do, but they might also be included in remotely or automatically activated devices to be directed at a particular target on signal.

While it is conceptually clear that there are numerous potential applications for sticky materials in the denial and control of movement, and while it is technically possible to prepare extremely sticky materials, it is not clear that they can be prepared, handled, and applied with the speed, effectiveness, safety, and convenience that would be necessary in low-level combat. Nevertheless, modest research in this area should be funded to explore the feasibility of formulating low-cost materials for these special applications.

From a technical point of view, the critical questions are those of: developing a deliverable formulation; field and shelf life; physical cleanup, neutralization, or removal; personnel safety; cleanup of victims and users; and modes of application (Ref. 40).

M. NETS AND SNARES

Nets and snares have some potential application both to controlling mass behavior and to the apprehension of individuals. The use of nets to round up segments of a mob has been reported. Although proposed, no application has been made of dropping nets and snares on crowds to slow them down or immobilize them. This particular technology may achieve some emphasis with the increased availability of helicopters. The application of nets to the apprehension of single individuals has taken a step forward with the invention of the handheld net caster that works within a range of 20 ft (Fig. 9). Nets may be practical for apprehending individuals, but nonlethal chemical projectors would seem to be more satisfactory and flexible for that purpose (Ref. 41).

N. IMPACT WEAPONS

Nonpenetrating impact weapons are probably the most commonly used and the second most important class of police weapons. Little attention has been paid to their military applications, and that has been directed largely at military police functions and riot control.

Increased urban conflict overseas, especially low-level conflict involving mixed military and civil populations, will, as a premise of this paper, entail a wider use of nonlethal weapons. Impact weapons have a potential for filling the needs of such conflict and merit research and development. This should be directed primarily at determining physiological and physical boundary conditions on the risks and effects of impact in traditional and new military missions.

The two principal classes of impact weapons (Tables 9 and 10) are (1) missiles, including modified shotgun charges and special bullets, and (2) bludgeons, truncheons, and other hand weapons, including nightsticks, riot-control sticks, blackjacks, and brass knuckles.

The Hong Kong riot-control police have a device which shoots projectiles resembling short pieces of fluted broom handles. These move

a. Flying through air in London demonstration, net is about to descend.

b. All tangled up.

FIGURE 9. Net caster (Ref. 42).

TABLE 10. IMPACT WEAPONS FOR NONLETHAL USE

Objectives	Targets	Risks	Weapons	Appropriate R&D
To threaten, harass, immobilize, or incapacitate by stunning or injuring.	Head, torso, legs, or the body in general.	Skull fracture, concussion, brain or other neurological damage, eye injury, bruising, internal injury, blood-vessel rupture, neck injury, broken bones.	Bludgeons, truncheons, and other hand weapons, including: Nightsticks Riot Batons Brass Knuckles Blackjacks Saps Nutcracker* Missiles, including: Tether Guns Modified Bullets Modified Shotgun Shells Hong Kong Pellet Guns Conventional Bullets Fired Selectively by Sharpshooters	1. Damage-limiting designs and materials. 2. Improved training aids and procedures. 3. Basic data on medical effects of current practices. 4. Systematic studies of risks and effects of missiles as functions of mass, velocity, material, and target as background for decision on pursuit of hardware development. 5. Impact simulation and modeling to permit better assessment of risks.

*Reference 43.

fast enough that they whistle, and slowly enough that they can be seen coming. The knowledge of the sharp crack and bruise that they inflict and the warning of the whistle are reported to be very effective in breaking up a crowd (Ref. 44).

A variety of other concepts have been investigated. Most of them involve modifying bullets or projecting missiles of somewhat larger size to achieve knockdown, knockout, or neutralization by impact. In general, these devices have not been well received because they fall in the middle ground between deadly force and really low-risk, nondamaging, nonlethal force (Ref. 45).

The principal targets of concern over the safety of such devices are the head, the eye, and the torso. In general, any impact to the eye involves a risk of blinding that cannot be eliminated. Such a risk could only be controlled or governed by the probability of impact, the orientation of the target (whether he is running away from or coming at the user), the intentions and accuracy in aiming the weapon, and the design of the impacting device. General experiences show that no reliability can be ascribed to the ability of the user, unless he is a sharpshooter, to fire selectively at parts of a human target. The risk of eye injury from any missile is therefore unavoidable, even when the user is disciplined and trained.

With regard to nonlethal injuries from impact to the body, relatively few systematic data are available. Therefore, it is difficult to lay out a system of operational or developmental guidelines. In one set of experiments, cylinders of butyl rubber 7 in. long, 1-7/16 in. in diameter, and loaded with mass to a gross weight of 210 grams were fired at goats. In general, the impact damage fell in three categories (Ref. 46):

- Impacts at less than 25 meters per second (69 joules of energy or below) produced only slight or diffused hemorrhage with no measurable free blood flow and no lacerations.
- Impacts at velocities greater than 25 meters per second but less than 35 meters per second (less than 130 joules) gave

mixed results, producing damage at all velocities in this range as serious as laceration of major internal organs or as minor as slight hemorrhage. Free blood was still not found.

- Impacts greater than 35 meters per second consistently resulted in laceration of major internal organs, severe hemorrhage, and measurably free blood flow up to 850 millimeters.

These experiments with goats only suggest that impacts with a mass and consistency of this sort would have to be kept below a velocity of 25 meters per second to avoid causing internal injuries to their targets.

Other experiments to develop a device called a "tether gun"--essentially a bull fired against a target--found that a stunning blow could not be delivered without risk of serious injury to the internal organs of the target.

Risk of injury to the head is in general even greater (Ref. 47). Holbourn, in his extensive studies of physical injury to the skull, has shown that (Ref. 48):

- The adult skull is very rigid and unless fractured does not change shape. But the brain, although not easily compressed, is easily displaced (as by intracranial hemorrhage) and deformed (as by twisting and strains).
- The brain, the circulating blood, and the cerebral spinal fluid are all of about the same density. They all tend to move together when the head is suddenly moved (or decelerated) along a straight line by a direct impact. Only a mild "pile-up" occurs under the force of impact and a mild "rarefaction" on the opposite surface (contre-coup).
- Sudden rotation of the skull is more gradually imparted to the cerebral spinal fluid and the brain. While this inertia is being overcome, the rough interior of the skull-cum-dura

drags along the surface of the brain and stretches, even tears, its arachnoid and perforating vascular tetherings. The rate of change counts most.

The risks from rotational injuries appear to be the greatest when the blow is less severe than that required to crack the skull. Simpson describes these shears, illustrated in Fig. 10, as follows (Ref. 49):

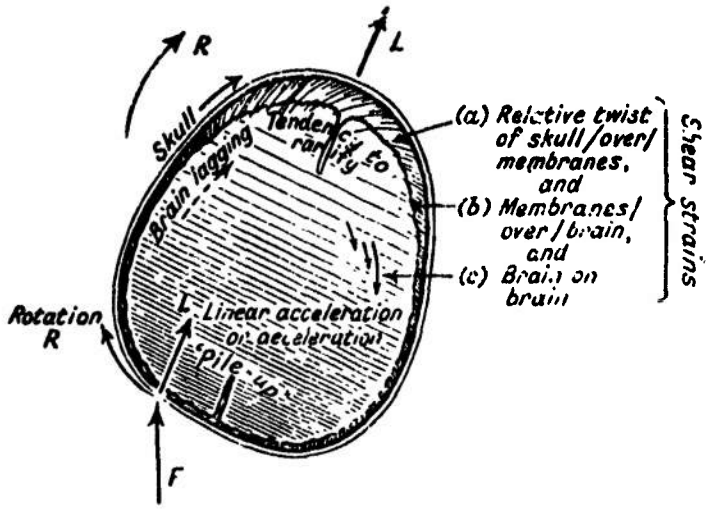


FIGURE 10. Effect of force F on movable head, causing linear (L) and rotational (R) strains (Ref. 50).

- Only when it is free can acceleration/deceleration and rotation (shear) strains develop: the latter cause by far the more serious harm. Not only does the skull chafe over the surface of the brain; the brain undergoes the sort of twisting that you feel when you tighten a roll of paper in the hands, each lamina twisting over that beneath, stretching, shearing, tearing the tissues from the surface to the very core. The brain stem is especially liable to harm as the spinal column fixes it, acting as the pivot on which the head rotates.

- These shear strains operate irrespective of the skull being fractured. Membrane tears causing hemorrhages and surface or deep contusions of the brain occur without fracture in about three-quarters of all fatal cranial injuries.
- "Contre-coup" can be explained on these physical principles. It is a form of brain injury in which an equally--even sometimes more--pronounced surface bruising of the brain is found exactly opposite the site of impact as under the blow itself. The whole surface of the brain suffers chafing injury, but this tends to be accentuated by piling-up of the brain under impact and rarefaction (with stretching of pial vessels and arachnoid tetherings) over the opposite surface. Occipital impacts may thus cause grave injury over the frontal lobes, left-sided blows, right-sided physical signs.

Welch, in his long-term follow-up of over 100 head injuries, points out that the mechanical and accelerative forces alter both the gray and white matter of the brain (Ref. 51). These changes vary in reversibility and manifest themselves in the conscious state in numerous changes: both retrograde and anterograde amnesia, electroencephalographic changes, and changes in neurological, psychological, and vocational statuses.

Even the mildest trauma in the brain may induce irreversible damage. Frequently the effects are not noticed until a number of traumatic insults accumulate. The clearest-cut example of this is punch-drunkenness, a familiar consequence of a boxer's accumulated head injuries. The bulk of evidence now supports the proposition that every substantial blow to the head does some irreversible damage, at least at the micro level, and that risks of serious, permanent injury are cumulative (Ref. 52).

While it would be fairly straightforward to get useful, quantitative data on skull fracture, the most serious problems of concussion and neurological damage will be most difficult to model. Concussion and neurological damage will undoubtedly be functions of the mass,

shape, consistency, and velocity of the missile and the portion of the skull impacted.

Rayne and Maslen (Ref. 53) have reviewed skull fracture from the point of view of designing protective helmets. Some salient portions of their results are summarized in Figs. 11 and 12.

Curve 1 in Fig. 11 shows results obtained by Gurdjian et al. for skull fracture in cadaver heads dropped onto hard flat surfaces. Comparable results have been obtained by workers in France and Germany. In these tests the area of impact was small, probably about 2 sq in. Cadaver skulls are believed to be slightly more liable to fracture than living ones. Hence, since even an inefficient helmet will spread the load over a much greater area, this curve is undoubtedly pessimistic for any one wearing a helmet. It may therefore be reasonable to suggest that this curve could be taken as a limit for helmet performance in protection against skull fracture, if one recognizes that it embodies a moderate factor of safety.

Cases of survival after accidental or suicidal falls from heights up to 175 ft have been recorded by de Haven and Snyder, who have calculated the average accelerations from the depressions made in the impacted surface. These impacts were obviously made on various parts of the body, though 21 persons out of the 137 cases recorded landed head first. From these data and others, several authors have compiled survival and fatal curves referring to the whole body. Curves 2 and 3 in Fig. 11 have been adapted from Thompson and Kornhauser and Gold.

Figure 11 also shows a number of points labeled "tolerable." These have been taken from various sources, and in this context "tolerable" means anything from "the subject endured without complaint" to "causing no permanent injury."

It has been suggested by Holbourn and others that the principal cause of concussion is angular displacement of the brain within the skull. It is clear that almost all linear impacts will cause angular movement of the head unless the neck muscles are deliberately used to hold the head rigid. There appears to be no published data on allowable

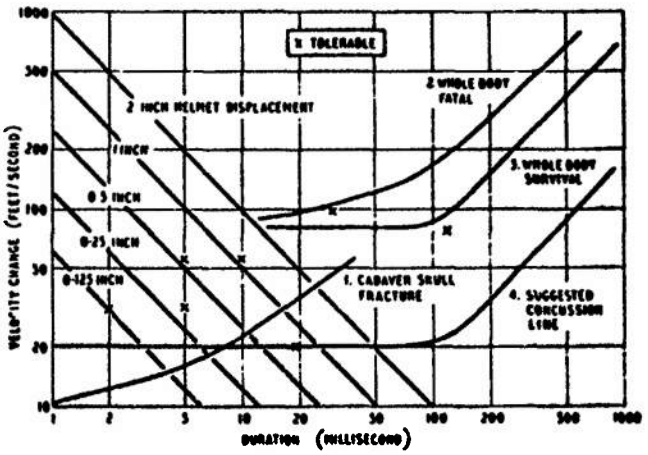


FIGURE 11. Human Tolerance to Impact Acceleration (Ref. 53)

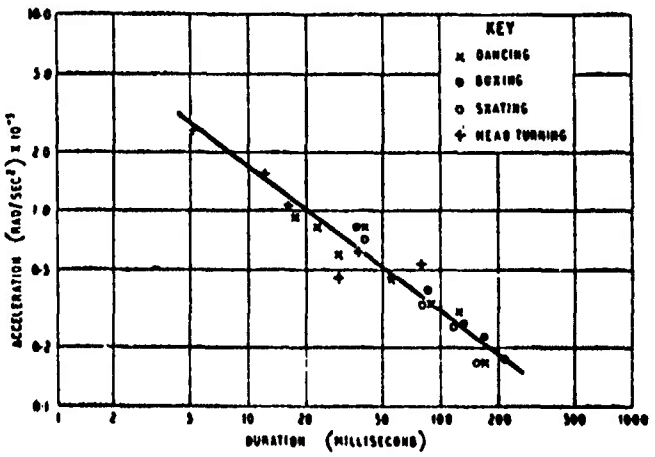


FIGURE 12. Normal Angular Acceleration (Ref. 53)

angular acceleration, however, and it was therefore decided to find out at least what sort of accelerations are tolerated in normal activities. Parker analyzed a number of newsreel pictures of dancers, skaters and boxers, frame by frame. High-speed film taken from above as a ballet dancer pirouetted and as a youth turned his head sharply through 180 deg have also been analyzed. Results are shown in Fig. 12. While the relevance of these results to the onset of concussion is not immediately apparent, it is at least plain that the relationship between tolerable angular acceleration and time is logarithmically linear.

The level of linear impact likely to cause concussion has been estimated by various authors as between 15 and 25 ft/sec change of velocity for short impacts. A mean value of 20 ft/sec is plotted in Fig. 11, curve 4.

In addition to the work going on in military laboratories on the influence of injuries to the skull, mostly penetration injuries, there is an effort under C.E. Bowman of the Department of Theoretical and Applied Mechanics, University of Illinois, on the mechanisms of head injury. He is evaluating stress injury by birefringence patterns developed on impact of a gelatin-filled plastic skull. Particular attention is being paid to sheer stress, acceleration, and cavitation (Ref. 54).

Bowman's and Janssen's two-dimensional modeling of the human head is based on a detailed review of the neurophysiological and modeling work in this field. Their approach could be of major significance in any impact weapons R&D program, especially when extended to a three-dimensional model (Ref. 54).

Other modeling and simulation work expressly focused on impact injuries in auto accidents has been carried on at Cornell Aeronautical Laboratory (Ref. 55). As far as I can tell, none of the modeling work there or elsewhere has addressed the specific issues of the design of impact weapons or the effects of such weapons.

The applications in which impact weapons would be most appropriate are: mob and riot control; the apprehension of single individuals, say, during protection of facilities against theft; a variety of quasi-police and military police functions, including action against curfew violators; and prisoner handling. But the use of impact weapons seems by and large inappropriate, since they imply a risk that is unnecessary in view of the present and potential availability of alternative weapons, particularly chemicals. On the other hand, the availability of modified shot for shotguns or other firearms may present a powerful logistics argument in giving more flexibility to material otherwise available in the field. It is difficult at this point to weigh the value of these alternatives. The variety of nonlethal, allegedly nonlethal, and minimum-damage shot (including salt, rubber bullets, weighted rubber bullets, and blobs of various sorts) available for use in shotguns, 38's, and other modified weapons should be evaluated systematically to better define their safety limits as functions of missile mass, shape, velocity, and consistency (Ref. 56). The weight of the evidence on this point suggests, however, that the risk intrinsic in impact weapons is unnecessary if appropriate chemical weapons can be fielded.

There seem to be no functions or missions for impact devices that cannot be carried out as well or better by chemical weapons at an intrinsically lower level of risk of injury. The universal availability of firearms in the military, however, suggests that the exploitation of damage-limiting impact projectiles merits further exploration, from logistics considerations.

1. Bludgeons and Truncheons

The riot stick and nightstick are so well established as impact weapons that attention must be given to improving them (Ref. 57).

New developments are continually being proposed (Ref. 43), but, as previously noted, nothing substantial in the way of systematic data gathering or evaluation has occurred. For example, a recent report in the New York Times indicates that modern versions of the medieval mace have been proposed for police application. The "mace-like device is a

short steel rod with a short length of heavy metal chain at one end...to be swung like a golf club at the ankles of people in unruly crowds" (Ref. 58).

The nightstick carried by military police is lighter in weight and less damaging than that used by many civilian police. Nevertheless, a systematic study of the effects of various materials and designs of nightsticks would be a valuable undertaking. The establishment of medically and tactically sound standards in this matter would be useful in minimizing damage and maximizing effectiveness.

Careful consideration should be given to the feasibility of employing a breakaway baton--one which, if used too vigorously or improperly, would break apart. A proper balance between achieving a breaking strength that would be damage limiting and maintaining sufficient strength to withstand the stresses of normal use may not be feasible. Attention should also be given to the use of anisotropic material so that the club would have strength when used in one direction but would be relatively weak when used in the other. For example, if a club made of such material were used too vigorously in a slashing stroke it would be likely to break, but it would not break if used in a prod. A detailed study may show too close a margin between the strength requirements for proper and routine use and the breaking strength that would limit damage. In any case, improvements in the design of the nightstick and allied weapons are possible and desirable, as is the establishment of design standards.

While it is obviously difficult to gather field data on the physiology of head injuries, some interesting work along this line has been done in telemetering the effects of head impacts during football games. An extension of this work to head injuries from truncheons may be quite straightforward (Ref. 59).

O. ELECTRICAL WEAPONS

Electrified devices are in use in both military and police situations. The electrified cattle prod has inspired the development of

a variety of electrified police nightsticks and riot batons. One German company is now offering an electrified nightstick, the "Shocker," for private civilian use (Ref. 60). It operates at 12,000 volts, on the principle of a Tesla coil. It is intended principally as a device for mild, nondamaging coercion.

The riot-control forces in West Berlin, according to Hanson Baldwin, have an electrified armored personnel carrier (APC), fitted in front with a fence-like rig that extends a foot past each side of the vehicle. Attached to each end of this fence-like section is a section that can be folded back three-quarters the length of the APC. These folding sections may be straightened to create an electrified boom some 30 ft across, or they may be folded forward to create a roughly U-shaped scoop. The top of the fence is flush with the deck of the APC. It is charged with up to 20,000 volts for use in street clearance or for rounding up a small crowd. The device has not been used in action as far as I know, but it is run through trials every two or three months (Ref. 5).

One of the innovations offered to lawmen for crowd control is a neoprene foam jacket wired to deliver 30,000 volts to anyone who touches the wearer. The "electric defensive jacket" consists of the top half of a skin diver's wet suit and a set of gloves equipped with a grid of tape-covered wires. The wires are charged by a 6-volt battery hooked to an induction coil capable of throwing a spark 1.5 in. long. The suit costs approximately $150. One company marketing it suggests that it lacks the stigma of the shock baton, since "you're not aggressively going after someone when you use this tunic. You're not supposed to put your hands on a police officer and if you do, you're going to wish you hadn't" (Ref. 61).

Electrical devices have also been developed for repelling sharks (Ref. 62). We have no information, however, on their effectiveness. Electrified fences are commonplace for cattle control (Ref. 63).

A number of other concepts have been proposed for employing electricity as a nonlethal weapon, including one patent which proposes

projecting convergent streams of conducting liquid, each of which is attached to an electrode. At the point of convergence the completion of the circuit would induce a shock (Ref. 64).

In general, relatively little systematic experimentation has been done and few codified data are available on the risks inherent in electric shock as functions of voltage, current, frequency, AC or DC, and the resistance of target (Refs. 65, 66). Without better established lines for delineating the safety limits it is difficult to recommend or preclude specific applications.

In broad outline there are five principal effects of electric shock (Refs. 63, 67, 68):

- Heart failure or ventricular fibrillation. In the first case, the heart action is abruptly stopped; in the second case, the normal rhythmic contractions are disrupted and random twitching culminates in failure. After heart failure, there are only about 4 minutes available for resuscitation before irreversible brain damage from anoxia sets in.
- Asphyxia, which results from temporary paralysis of the nervous system controlling respiration.
- Burns--usually at the points where the current enters and leaves the body. This gives no real clue as to the extent of internal injury or the depth of damage.
- Muscle spasms, which may involve erratic motions of the muscles or, in some cases, the inability to let go of the source of the current. Substantial work from a safety point of view has been done on this "let-go" phenomenon.
- Tingling and other sensations associated with the flow of current.

By and large, substantial risks set in as low as 50 volts, but risks are very much greater at 200 to 250 volts in a domestic situation. Low AC frequencies--say, 50 cycles--are more dangerous than very high frequencies. Wet skin is more dangerous than dry skin. In one study,

the resistance from dry hand to dry hand was 6,600 to 18,000 ohms. From hand to wet feet the resistance ranged from 610 to 1,260 ohms. Grounding of the victim plays a factor, and there is some evidence that the expectation of the shock has some influence upon its effect. A detailed analysis of the literature to relate voltage, amperage, victim resistance, AC frequency, and whether the current is alternating or direct to various effects is required as a preliminary step in assessing the feasibility of a number of electrical weapons concepts. Such research would be also of substantial interest in the civilian community, in which familiarity with the effects of electricity on humans and other animals is largely based on anecdotal information, accidents, and a limited number of experiments.

The most extensive work has been done on currents in the frequency ranges of commercial importance. In a very comprehensive review of the literature, Dalziel and Lee attach great significance to the let-go current, that is, the maximum current at which a person is still capable of releasing a conductor. The inability to let go is preceded, at lower current, by sensations of tingling and then contractions or muscle jerks. The everyday significance of let-go current, of course, is that many domestic accidents occur as a result of gripping a source of current (Ref. 67).

Figure 13 shows the relationship between frequency and let-go current for men, based on laboratory experimentation.

Ventricular fibrillation is the principal hazard in electric shock, and in the current state of knowledge the three basic factors governing that phenomenon are:

- Body weight
- Magnitude of current
- Duration of the shock

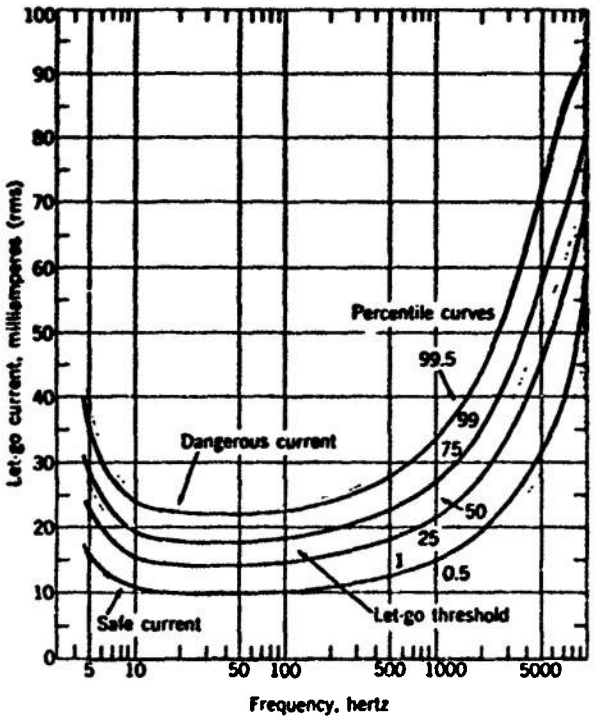


FIGURE 13. Effect of Frequency on Let-Go Current for Men (Ref. 67)

In summarizing their study, Dalziel and Lee estimate that "for a current pathway between major extremities in a 50 kilogram mammal (a small man), the relationship is approximately $116/\sqrt{T}$ to $185/\sqrt{T}$ milliamperes. It is believed that ventricular fibrillation in a normal adult worker is unlikely if the shock intensity is less than $116/\sqrt{T}$ milliamperes, where T is in seconds." These results, based on hundreds of experiments with animals as well as the various studies of accidents for observation, also indicate that currents in excess of let-go current passing through the chest may produce collapse, unconsciousness, asphyxia, and death, while currents through the nerve centers controlling breathing may produce respiratory inhibition that may last for a considerable period even after the interruption of the current.

Cardiac arrest without ventricular fibrillation may be caused by relatively high currents in the region of the heart.

Dalziel and Lee also point out that high currents may produce deep burns and currents sufficient to raise body temperatures which may produce immediate death. For example, in electrocutions, approximately 2000 volts cause 8 to 10 amperes of current to flow through the body. Under these conditions, human body resistance is approximately 200 ohms (Ref. 65). An average body temperature of 138°F following such executions has been observed.

A detailed study by the Underwriters' Laboratory of electric shock centering around the evaluation of hazards in electric fences reports resistance is 40,000 to 50,000 ohms per square centimeter of dry skin and as low as 1000 ohms per square centimeter of wet skin (Ref. 69). Among their conclusions are:

- "The maximum continuance of uninterrupted current to which an individual may be safely subjected to is 5 milliamperes (effective value)."
- The domestic safe requirements relating contact time to allowable current are reported in Fig. 14, based on a two-year-old child, a criterion which is not at all inappropriate for any low-level applications of riot-control or facilities-protection techniques. The values should not exceed those shown in the graph and no single shock impulse should have a duration of greater than 0.20 sec.
- The time associated with peak currents as high as 300 milliamperes should not exceed 0.0003 sec.

1. Research Recommendations on Electrical Weapons

From a technical point of view, there can be no question that electricity is effective in threatening, coercing, incapacitating, immobilizing, deterring, and killing people, depending on the particular complex of variables in a situation. Whether these capabilities could be effectively exploited through the development of useful nonlethal

weapons and devices for low-level conflict remains an open question. The critical issue of public acceptability will not be discussed in this paper, although it would undoubtedly be a major issue should the technical points raised below be satisfactorily resolved. It would be premature to foreclose an investigation and demonstration of the potentialities of electrical weapons because of anticipated total public rejection. Electrical devices may, in fact, have a potential for humane, controllable, extremely low-risk, but effective weaponry.

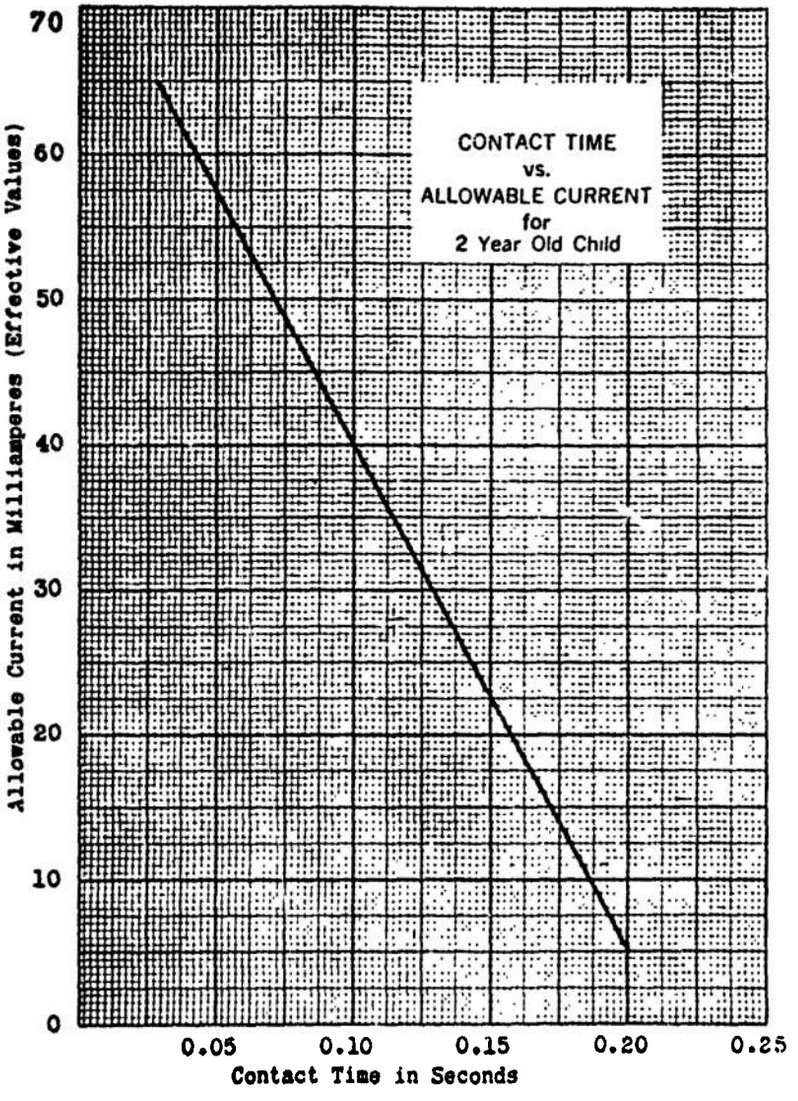


FIGURE 14. Contact time versus "allowable current" for two-year old child.

Technical understanding of the risks and opportunities for the development of weapons based on electrical effects is woefully inadequate. This, in turn, is a reflection of the inadequacy of understanding of electrical hazards over almost the total range of civilian, industrial, commercial, domestic, and medical applications (Ref. 70).

A systematic program, beginning with a collation of the literature and ending with a salient investigation, should be undertaken to determine the human physiological effects and physical risks of electric currents as functions of voltage, current frequency, phase, resistance, health and age of the victim, and other relevant variables. Such a two-phase study should provide a reasonable basis for assessing the possible role of electricity in nonlethal weaponry and for determining the conditions bounding various levels of electrical safety for humans.

The obvious importance of electrical effects on humans in the civilian sector and the widely recognized lack of adequate data on those effects suggest that a very useful program could be undertaken in conjunction with appropriate civilian agencies, both in and out of government.

P. MARKERS

Markers in a military context of low-level conflict can serve three distinct but overlapping functions:

- Identification
- Stigmatization
- Deterrence or punishment

The most straightforward application for markers is in mob and crowd control where it is culturally feasible. A second practical application would be incorporation with nonlethal small arms for use in police and quasi-police functions such as facilities protection, control of pilfering, and the selective marking of individuals in crowds and mobs. A third application would be in automatically activated devices for facilities protection, marking curfew violators so that they can be identified, and so on.

The most promising new application of markers is in more extensive systems of identification to mark trespassers, violators of secure areas, and other malefactors in guerrilla warfare. This application, however, requires that careful attention be given to the development of an appropriate and effective system for its exploitation. The major applications of marking are clearly at the lower levels of urban conflict. Systematic work in this area should be supported.

The application of markers is discussed in greater detail in Ref. 37.

VI. RECENT DEVELOPMENTS IN CROWD-, MOB- AND RIOT-CONTROL WEAPONS

The recent intense interest in the continental United States in riot, crowd, and mob control has stimulated numerous studies of all aspects of these problems, including weapons. Under the sponsorship of the Limited Warfare Laboratory, three studies by contractors were undertaken: the Rosenthal study of the Phases of Civil Disturbances: Characteristics and Problems (Ref. 71); the RACIC Report on the Status of Riot Control Hardware (Ref. 72); and the Christodoulou study of potential weaponry for riot control (Ref. 73). Also, a catalog of selected items to aid in control of civil disturbance has been put out by the Office of the Chief of Research and Development (OCRD), Department of the Army (Ref. 74). These studies, although limited to the U.S. domestic scene, do have potential application to situations overseas. Unfortunately, however, they all suffer from two deficiencies: first, they reflect too much the conventional thinking as to what the problems are, and second, they put too much emphasis on technical gimcrackery. Perhaps more precisely, they neglect the socio-political context in which these devices may be employed. These deficiencies have been recognized, and consequently, to develop a better understanding of technological, tactical, and doctrinal needs, in a new task under the monitorship of the Limited Warfare Laboratory, an intensive study will be made of possible scenarios and actions. Properly carried out, this should be a single major step in developing an improved competence in nonlethal, nondestructive warfare. The study should also provide a better understanding of mass behavior. Rather than duplicate the contents of these catalogs, I refer the reader to them for technical details. I also refer the reader to three of my papers that discuss in some detail the problems of nonlethal weapons for domestic employment and possible new approaches in crowd, mob,

and riot control (Refs. 5, 75, 76). To a substantial degree but not completely, the advice in these reports is transferable to overseas and military situations (Ref. 24).

It would be appropriate at this point to review some of the current and recent developments in nonlethal weaponry. The emphasis in these recent developments is on the application of the chemical agent CS. The weapons that are being pursued in these current activities are drawn together in this section. The next section will discuss more fully the potential applications of nonlethal chemical agents in general to low-level military operations in cities.

Table 11 lists the characteristics of the riot-control agents CS, CN, DM, and smoke (HC).

Many of the new applications center around the exploitation of the properties of the riot-control agent CS. This agent has now become standard in the U.S. military, having completely displaced the agent CN, the conventional riot-control agent that was in use for some 40 years. The agent CS is safer than CN in that CS has a higher ratio between effective and lethal doses. Also, CS is more effective because it affects the eyes and upper respiratory tract at a lower concentration than CN. It may react with the skin to induce first- or second-degree burns. The overwhelming effect, however, is that of inducing ocular and respiratory distress at low concentrations in a relatively reversible and safe mode. The agent CS comes in three forms, frequently designated CS, CS-1, and CS-2.

"CS" is the designation for the material when it is pyrotechnically dispersed. "CS-1" is a prepowdered or micropulverized form. "CS-2" is the same as CS-1, except that it has been waterproofed with silicone, which makes its effects long lasting. It is easily roused up by any mechanical action, such as walking or hosing down. It has been widely used in Vietnam in tunnels and on trails.

A new, not specifically designated form of CS is now under investigation for use in liquid projectors. This is CS in a trioctyl phosphate solvent formulation.

TABLE 11. CHARACTERISTICS OF RIOT-CONTROL AGENTS (Ref. 77) [CS, CN (OBSOLETE), DM, AND SMOKE (HC)]

	CN		CS		CN-DM	HC
	Burning type	Powder type	Burning type	Powder type		
Composition	Chloracetophenone; smokeless powder; magnesium oxide.	Micropulverized chloracetophenone; magnesium oxide.	CS; potassium chlorate; thiourea; magnesium carbonate.	Micropulverized CS; silica aerogel.	Chloracetophenone; diphenylamine-chlorarsine; smokeless powder.	Hexachlorethane; zinc oxide.
Odor	Like apple blossoms.	Like apple blossoms; irritating.	Pungent; pepperlike.	Pungent; pepperlike.	Like apple blossoms.	Like camphor.
Persistency (in open).	Variable according to wind conditions; maximum 10 minutes.	Variable according to wind conditions; persistency greater with lack of wind or in wooded terrain; solid CN may remain several weeks.	Variable according to wind conditions.	Variable according to wind conditions; greater with lack of wind or in wooded terrain.	Variable according to wind conditions; maximum 10 minutes.	Variable according to wind conditions; maximum 10 minutes.
Minimum effective protection.	Protective mask; tight fitting goggles offer limited protection to eyes.	Protective mask; tight fitting goggles offer limited protection to eyes.	Protective mask; field clothing.	Protective mask; field clothing.	Boat commercial mask.	None needed.
Physiological action.	Lacrimation; mild skin itching.	Lacrimation; skin stinging or burning; no permanent irritation.	Extreme burning sensation of the eyes; copious flow of tears; coughing, difficult breathing, and chest tightness; involuntary closing of eyes; stinging action on moist skin areas; sinus and nasal drip; nausea and vomiting on exposure to extreme concentrations (via ingestion).	Extreme burning sensation of the eyes; copious flow of tears; coughing, difficult breathing, and chest tightness, involuntary closing of eyes; stinging action on moist skin areas; sinus and nasal drip; nausea and vomiting on exposure to extreme concentrations (via ingestion).	Lacrimation; irritation of the mucous membranes; viscous discharge from nose; sneezing and coughing; severe headache; acute pain in chest; cramps; nausea with vomiting; involuntary anal evacuation.	Slightly suffocating action in heavy concentration; slightly irritating to nose and throat.
Time required for maximum effect.	Immediate	Immediate.	20 to 60 seconds	20 to 60 seconds	CN: Immediate. DM: 15 to 30 minutes.	Effect negligible.
First aid	Wash eyes with water; if available, use boric or sodium sulfite ¼% solution; keep eyes open and face into the wind, uncontaminated air.	Wash eyes with water; if available, use boric or sodium sulfite ¼% solution; keep eyes open and face into the wind, uncontaminated air.	Remove to uncontaminated area; face into wind; caution against rubbing eyes; keep affected persons well spaced; shower after several hours. Shower first with cool water for 3 to 5 minutes then proceed with normal showering. For gross accidental contamination with CS particles, flush body with copious amounts of cool water, then use a 5% sodium bisulfite solution (except in and around eyes) and finally flush again with water. A 1% solution of sodium carbonate or sodium bicarbonate may be substituted for sodium bisulfite solution.	Remove to uncontaminated area; face into wind; caution against rubbing eyes; keep affected persons well spaced; shower after several hours. Shower first with cool water for 3 to 5 minutes then proceed with normal showering. For gross accidental contamination with CS particles, flush body with copious amounts of cool water, then use a 5% sodium bisulfite solution (except in and around eyes) and finally flush again with water. A 1% solution of sodium carbonate or sodium bicarbonate may be substituted for sodium bisulfite solution.	Wash eyes with boric acid; inhale chloroform frequently; aspirin for headache; uncontaminated air.	None needed.
Type of munitions.	Grenades, hand and rifle.	Grenades, hand	Grenades, hand and rifle	Grenades, hand	Grenades, hand and rifle	Grenades, hand; Pots, smoke
Mechanically dispersable.	No	Yes	No	Yes	No	No.

A. DEVICES EMPLOYING CS

There are a variety of devices employing CS that are at various stages of development or in use including liquid projectors, grenades, and other dispensers. The following summary drawn from a U.S. Army Land Warfare Laboratory Report (Ref. 78) includes the following:

- XM47 CS Riot Control Grenade--This pyrotechnic grenade is housed in a cylindrical rubber container. It can be thrown or rolled by hand and can effectively cover approximately 150 square meters with CS in a 10-15 knot wind.
- CS Mini Grenade--This device, developed by AAI Corp., consists of a small canister approximately 1-1/8 inches in diameter and 1-1/4 inches high. Each unit contains an ignition system, a small fuel block, and several capsules of agent CS. Total gross weight per unit is 1.2 ounces. The unit disseminates agent CS as an aerosol for approximately 6 seconds.
- Spinning Gas Grenade--This anti-riot grenade, developed by AAI Corp., has delivery orifices so designed and placed that high-velocity exit gases cause the grenade to spin wildly and thereby prevent throwback by rioters. Asymetric distribution of weight will randomize motion.
- Hot-Surfaced Grenade--In this grenade the thermal reaction which heats and dispenses an anti-riot gas also heats the exterior surface of the grenades, thereby preventing throw-back by unsuspecting, unprepared rioters. This thermal reaction begins when the grenade is initially released.
- XM674 CS Cartridge, 40mm--This soft rubber projectile is filled with a CS/pyrotechnic mixture. It can be hand-fired, pistol-fired (using AN-M8 pistol), or fired from the M79 Grenade Launcher (using the plastic adapter). The projectile is propelled by a black powder charge in the cartridge barrel. The CS/pyrotechnic mixture ignites and CS is emitted through four holes in the rubber body. It provides a coverage of 35 square yards.

- XM651E1 CS Cartridge, 40mm--This cartridge is designed for use in the M79 Grenade Launcher and with the M16 rifle (with XM148 adapter). The cartridge is equipped with an impact fuze and can penetrate a 3/4-inch pine board at 200 meters, with release of the agent after penetration. Coverage for two rounds is approximately 5000 cubic feet.

- XM33 Dispenser--This back-portable or vehicle-carried dispenser has a 40-foot range in still air. It uses air pressure to dispense micropulverized CS-1 into the atmosphere and can fire in a single burst from one tank for 50-60 seconds. Its pre-pressurized tanks can be replaced in 3-4 minutes. A version using liquid-CS is presently being evaluated.

- MK 17 Pepper Fog CS-Tear Smoke Generator--This generator, powered by a 2-cycle lawnmower-type engine, projects a cloud of agent up to 40 ft; ranges up to 200 ft are possible under ideal wind conditions. It has a formulation capacity of 2 one-quart cartridges at one time and the operator has the option of switching from one cartridge to another. Its output is equivalent to 5 burning grenades per minute and its weight fully loaded is 35 lbs. It was developed by General Ordnance Equipment Corp.

- MK XII--The MK XII is more portable than the MK 17 above, as it weighs less than 25 lbs. Its output is equivalent to 10 burning grenades per minute, and its fuel capacity allows 45 minutes of continuous operation. It was also developed by General Ordnance Equipment Corp.

- Self-Contained CS Dispensing System--This LWL item is intended to be hidden in an inaccessible location in a building and automatically actuated when a window is broken by looters. It would dispense CS for a minimum of 8 hours. A standard burglar alarm could be used to actuate the system, which could be tied to a special telephone circuit to signal the location to a riot control office.

- Controlled Evaporation of Agents--Another LWL concept envisions conversion and utilization of aircraft-mounted, crop-spraying technology and equipment to disperse an encapsulated, noxious compound in areas to be denied. The capsules would be activated at a controlled rate (by wicking).

- Helicopter Riot-Gas Disseminators--These are similar to agricultural aerial fertilizer and insecticide disseminators.

- Hand-Held Pressurized Dispensers--This LWL concept would employ conventional, air-pressurized, water-type extinguishers to disseminate materials, such as food-coloring syrup, stenches, etc., which are identifiable but not harmful.

- CS Sprinkler--Another LWL concept envisions a CS dissemination system, similar to a water-sprinkler system, that can be initiated when a window is broken, door forced open, etc.

- Demountable Anti-Riot Gas Dispenser--Canisters with screw-on adapters to fit sockets inside a commercial establishment could be activated remotely. These dispensers could be used in normal electrical sockets and activated by switching on a light at night. For safety, they could be removed during periods of normal operations.

- CS Canister--This slowly-discharging, thermally disseminating CS canister is placed near a possible target and triggered by a rioter on his way to the target. This is an LWL development.

- XM30 Dispenser--This is the standard 1-1/2 quart M11 decontamination unit modified to spray CS in a slurry solution with water. Nitrogen cylinders provide pressure for a 30- to 35-foot range and one square foot of coverage for a hand-fired burst. The jet stream can be maneuvered by hand.

- XM32 Dispenser--This hand-held dispenser (length: 6-1/2 inches) projects a nitrogen-pressurized stream of 1% CS triocty phosphate (TOF). Its effective range is 15 feet, and its

continuous discharge time ranges from 14 to 19 seconds. A plastic safety cap prevents unintentional discharge.

- Liquid Chemical Dispenser Concept--At present, the US Army utilizes a back-pack flame-thrower device (XM33) which dispenses dry CS for short distances. Disadvantages of this system lie in the fact that a dry agent is greatly subject to wind effects and is quite limited in range. The proposed system would be similar to these flame-thrower type devices except that it would dispense a liquid that contains a non-lethal chemical agent. It would be a man-portable, pressurized, liquid dispenser capable of dispensing liquid up to a distance of approximately 120 feet. The distance of projecting a liquid stream would be controllable for the application at hand. Provision should be made for remote-control operation when mounted on a police van which is used to transport detainees, or on other types of inclosures. This would provide a means of controlling those within. In addition, the device might be mounted on helicopters for overhead control of crowds. A marking agent could be added to the basic liquid to provide a method for identifying rioters.

B. FOAM

Foams are already under investigation for use in Vietnam, and for tunnel denial these foams form solid structures which will fill a tunnel and entrap CS. Similar materials might have application for structure denial, whereas the transient shaving-cream kind of foam would be more applicable to temporary cordoning or blockage.

Grosse, as a result of his extensive work with long-lived soap bubbles, has proposed their use for barriers and barricades in police operations. Grosse has developed a bubble machine containing a tank of compressed air and a quantity of plastic bubble solution which he claims is enough to barricade a street 100 ft wide at a cost of $40 to $50. The bubbles are basically soap bubbles with plastic additives

to increase lifetime (Ref. 79). He claims to have blown bubbles as large as 60 cm in diameter that have lasted as long as two years (Ref. 80). I know of no practical evaluation of this concept, but it certainly merits further investigation. Entraining irritants in the bubbles might increase their effectiveness as barriers.

Foam that would have the consistency of thick shaving cream and that would incorporate CS is under investigation as a barrier.

C. DARTS

An injector dart of the Cap Chur gun type, a variety used in animal trapping, is under investigation for weaponization (Refs. 81, 82).

D. NONCHEMICAL RIOT-CONTROL DEVICES

Among the nonchemical riot-control devices under study, the following should be mentioned:

- A bright-light mob-dispersal technique.
- Marking for riot control. This is under review in several forms. One is a personnel marker grenade that will be approximately the size of a softball. Pressure from a CO_2 cartridge in the bladder of the grenade will force the marking substance to spray out of a sprinkler nozzle and will spin the grenade at the same time.
- A mobility deterrent, essentially a grenade loaded with sticky material, such as has been prepared under contract for the Limited Warfare Laboratory. No evaluation of the effectiveness of this device is yet available (Ref. 39).
- A weapon to produce immediate nonlethal incapacitation by mechanical impact, with a range up to 30 m, under investigation by the Limited Warfare Laboratory.

A systematic review of nonchemical as well as chemical barriers for crowd and riot control is under way at the Limited Warfare Laboratory.

E. DEVICES AND TECHNIQUES FOR SPECIAL PROBLEMS

A very large range of concepts and devices for use in crowd, mob and riot control have been presented in various reports and studies (Ref. 83). The most elaborate of these is a study by Booz-Allen (Ref. 73). As indicated above and as reflected in a new task for the investigation of background conditions and scenarios, the application of proposed techniques is often uncertain. The needs for the devices and techniques proposed are unclear. In addition to that, safety, technical limitations, and other basal considerations are often inadequately treated. An earlier review of the state of the weapons art for crowd, mob and riot control specifically considered a number of these concepts and proposed a systematic program for R&D in the area.

One problem to which the application of technology is particularly appropriate is the neutralization of a sniper inside a room. Tear gas devices, or perhaps devices to disseminate sticky or entangling nets or filaments, would be useful here. A major consideration is eliminating fire hazards and reducing the impact hazard should a "nonlethal" missile hit an innocent person.

Rapidly emplaced barriers and barricades merit intensive consideration. In addition to the foam concepts mentioned above, rapidly emplaced nylon coils of rope and other techniques have been proposed. Their applications are in need of evaluation (Refs. 5, 84-86).

For building clearance, chemical weapons of various sorts have a great deal of appeal. They may be applied by forced drafts or grenades or entrained in bubbles or other media. The optimal method of application is still uncertain, and more study and field evaluation need to be given to the dissemination characteristics of various chemicals in structures as a preliminary to the design of the weapons.

To counter looting, the techniques of apprehension have already been mentioned. Probably the most promising areas of development are chemical injectors and projectors of sprays, globules, and jets. Impact devices, as said before, seem to carry too great a risk of killing

or crippling to provide a basis for major "nonlethal" weapons development. A clearly benign impact weapon has yet to be devised.

One way of countering looting is "hardening the target." Little attention has been given to that, although a number of possibilities seem attractive. Where glass doors or windows provide a potential means of access, a rapidly applied and effective method of impeding, if not preventing, break-in may be to strengthen the glass by spraying it with a mixture of fiber glass and plastic. Iron gates drawn over store fronts are common throughout much of the Middle East. Again, the options need to be proposed and evaluated.

VII. CHEMICAL AGENTS AND COMBAT IN OVERSEAS CITIES

A principal conclusion drawn from Table 9 was that only one nonlethal mechanism, chemicals, was effective across all operational missions. The sections preceding this one have discussed some of the opportunities, limitations, and problems associated with the less generally applicable nonlethal mechanisms for combat in cities. Section VI, on current research on crowd, mob and riot control, reflected an awareness of the value of chemical agents, inasmuch as most of the work in one way or another centers around the exploitation of agent CS.

The purpose of this section is to discuss in somewhat more detail the relationships between operational missions and the effects of various kinds of nonlethal chemical agents, to consider the possible development of munitions to employ these nonlethal agents, and to make some general observations on the problems of RDT&E in nonlethal chemical warfare.

The interplay between tactical applications and weapons characteristics is more intimate and reflexive for chemical weapons than for conventional kinetic or ballistic weapons. The characteristics of the agent, and more particularly the physiological system on which it operates, may open up some new modes of application or make other modes of application inappropriate.

An excellent study of the potential application of nonlethal weapons to low-level warfare has been made by R.H. Ellis and J.C. Kellogg (Ref. 87). While their paper did not focus on combat in cities, their analysis of the use and implications of nonlethal weapons in the context of limited war and counterinsurgency is a most valuable contribution to the literature. This section is not intended

to be a definitive treatise on the development of chemical agents or their application to combat in cities, but only to highlight the relative importance and profound influence chemicals could have on that combat area. An attempt will be made to indicate only some of the classes of chemical-agent effects and their possible application to tactical or operational missions. Table 12 presents a list of various nonlethal chemical effects and assesses their relevance in tactical-operational missions. The roster of nonlethal effects presented in Table 12 includes:

- Irritation of the
  - eyes
  - respiratory tract
  - skin
- Itching
- Pain (Ref. 88)
- Vomiting
- Temporary blindness
- Imbalance
- Paralysis
- Orthostatic hypotension
- Mental effects of disorientation, confusion and hallucination
- Sleep

These effects are by no means exhaustive of the potentially useful chemical-agent effects nor are they comprehensive. They are only meant to illustrate applications to various tactical missions, and the fact that not all effects fit all problems. For example, pain might be generalized, it might be cutaneous, it might be in the form of a headache, or it might center in a particular organ. Temporary blindness, as discussed in another paper (Ref. 4), is a wide-ranging concept. It may range all the way from opacification of the visual field

TABLE 12. NONLETHAL CHEMICAL EFFECTS AND THEIR RELEVANCE TO URBAN OPERATIONAL MISSIONS

MISSIONS	NONLETHAL CHEMICAL EFFECTS														
	1. Irritation of the	a. eyes	b. respiratory tract	c. skin	2. Itching	3. Pain	4. Vomiting	5. Temporary blindness	6. Imbalance	7. Paralysis	8. Orthostatic hypotension	9. Mental effects of disorientation, confusion, and hallucination	10. Sleep
1 Riot, mob and crowd control													
• disperse		•	•	•	•	•	•						
• immobilize						•	•	•	•	•	•		•
• disrupt		•	•	•	•	•	•	•					
• corral		•	•	•	•			•			•		•
• aggregate		•	•	•	•			•			•		•
• channel		•	•	•	•	•							
2 Countering looting		•	•	•	•	•	•	•	•	•	•		
3 Apprehension													
• single individuals		•	•	•	•	•	•	•	•	•	•		•
• small groups		•	•	•	•	•	•	•	•	•	•		•
4. Facilities protection against													
• sabotage		•	•	•	•	•	•	•	•	•	•		•
• theft		•	•	•	•	•	•	•	•	•	•		•
• espionage													
• attack		•	•	•	•	•	•	•	•	•	•		•
5 Attack on facilities		•	•	•	•	•	•	•	•		•		
6 Neutralization of facilities		•	•	•	•	•	•	•	•	•	•		•
7 Clearance of facilities		•	•	•	•	•	•						
8 Protection of lines of communication		•	•	•	•	•	•	•	•	•	•		•
9 Protection of essential personnel													
• in secure facilities		•	•	•	•	•	•	•	•	•	•		•
• on the street (medical, food, etc.)		•	•	•	•	•	•	•	•	•	•		•
10 Prisoner handling in compounds		•	•	•	•	•	•				•		
11 Population movement		•											
12 Curfew enforcement		•	•	•	•	•	•						
13 Disruption of military activities		•	•	•	•	•	•	•	•	•	•		•
14 Disruption of civilian activities		•	•	•	•	•	•	•	•	•	•		•
15 Structure control--denial													
• subterranean		•	•	•	•	•	•	•		•			
• above ground		•	•	•	•	•	•	•		•			
16 Area control and denial--interdiction		•	•	•	•	•	•	•	•	•			
17 Route control and denial--interdiction		•	•	•	•	•	•	•	•	•			
• streets, highways and alleys													
• rivers and streams													
18 Locate hidden personnel		•	•	•	•	•	•						
19 Penetrate structures		•	•	•	•	•	•	•	•	•	•		•
20 Countering infiltration		•	•	•	•	•	•	•	•	•	•		•
21 Static defense		•	•	•	•	•	•	•	•	•	•		•
22 Strongpoint clearance -neutralization		•	•	•	•	•	•						
23 Countersniper		•	•	•	•	•	•	•	•	•	•		•
24 Roof clearance		•	•	•	•	•	•	•	•	•	•		
25 Structure clearance		•	•	•	•	•							
26 Counterbattery fire		•	•	•	•	•	•	•	•	•	•		•
27 Countervehicle		•	•	•	•	•							
28 Countering terror		•	•	•	•	•	•	c	•	•	•		•

to disruption in ability to focus. Similarly, mental effects such as disorientation, confusion, and hallucinations by no means exhaust the range of potentially militarily interesting mental derangements. Other effects of some potential value would be induced susceptibility to fear, amnesia, dyschiria (confusion of touch), indecisiveness, heightened suggestibility, or dyskinesia. Detailed discussions of the possibilities for two classes of effects, influences on the skeletal muscle system and influences on the eye, have been presented elsewhere as a model for a comprehensive program of exploring nonlethal incapacitating chemical agents.

In Table 12, the situation in which the chemical effect could be appropriate is filled in. Obviously many effects and applications depend on effect intensity and the extent to which it is employed. Some effects might be particularly useful if neutralizing agents were available. For example, the use of irritating, itching and pain agents for coralling and aggregating people might have some real value if the victims could be drawn to specified places with the promise of relieving the symptoms. In other instances, an awareness or fear of the effect of a chemical agent might be useful in channeling a crowd. It is clear that for many purposes such as dispersing a crowd, effects such as imbalance and paralysis are likely to work counter to the objective. Then again, a crowd might be disrupted if selected members of it were caused to lose their balance, were paralyzed, or were partially blinded. This would depend on the temper of the crowd and the situation. Such effects might also lead a crowd to panic and trample some of its members. Many otherwise useful chemical effects present problems of control and possible misuse.

It becomes clear that some effects, such as paralysis or temporary blindness, could be disastrous in dealing with a crowd if large numbers of people were affected. But such effects become salient mechanisms for apprehending single individuals and small groups, for spot disruptions in large crowds, and for the protection of facilities in situations in which it would be useful not only to neutralize the trespasser but to apprehend him. However, weapons that render people unable to

exert even a minimum of control over their actions, as in paralysis or blindness, can create a tremendous manpower requirement to handle the victims and a tremendous risk of inadvertent injuries.

In many situations, as in the apprehension of a single man or a small number of men, certain broad criteria apply, such as specificity or selectivity of action. In other situations, as in dispersing a mob, an undifferentiated or generalized effect would be more desirable. That, of course, does not imply that one should not be able to regulate the boundaries over which the agent or technique applies, but rather that the objective is to affect a large number of people in an area at one time.

Generally, the duration of the effect and the speed of its onset are particularly critical. Duration is critical, so that people are left neither helpless nor at specific risks from the environment. The desirable effects themselves will in many cases be quite specific to a given mission. The objective in dispersing a mob is clearly to disperse them, not to paralyze them, to drop them to their knees, or to immobilize them. On the other hand, in apprehending a man who is fleeing, let us say after pilfering a warehouse, the need is to stop him. In other situations, it may be necessary only to slow a person down, neutralize him, or prevent him from going about a cerebral task. For example, it may not be necessary to apprehend a man using a bull horn or giving hand signals to direct a mob. It may be sufficient to neutralize him.

In Table 12 there appear to be no particularly good applications in low-level city combat for agents that have mental effects of disorientation or derangement. To a substantial degree, this follows from the fact that one cannot now achieve useful, reliable effects with predictable outcome. That is not to say that predictable mental effects of the sort mentioned above or others might not have great value. In contrast, useful and reliable effects with predictable results are achievable by means of chemicals such as irritants and tear agents.

It seems clear too that for many purposes, the effects of blinding, imbalance, paralysis, or sleep, which make a person incapable of moving, would not necessarily be productive--they would be of little use, for example, in locating hidden personnel. For many if not most applications one wishes to disrupt, disorient, or break up coherent organized behavior while keeping the victims in a state in which they can act in some coherent way or at least follow simple instructions.

It should be clear that most chemical effects suitable for military application to humans depend upon intensity or scope, and consequently on the modes of delivery and the precision with which they are delivered. In the apprehension of single individuals, whether in the control of pilferage or in neutralizing a group of leaders in a crowd, it is necessary that the agent can be delivered with some precision. This may imply injector darts or directed and narrowly controllable streams. For other purposes, such as flushing a building, the implication is that the chemical material should be deliverable in a form that will allow it to permeate the building. The details of such modes of delivery will not be discussed. It should be noted that general modes of delivery include missiles or projectiles that deliver the chemical agent to a spot whence the agent is disseminated by an explosion or thermally and is then carried to its target by the atmosphere. Other missiles or projectiles that are designed for use against particular individuals may inject, splatter, or explode on contact. Sprays, streams, and jets may also deliver chemical agents, but within a limited range. Clouds of chemical agents may be disseminated from point or line sources on the ground, from vehicles, or from aircraft. Automatically activated devices operating on a variety of dissemination principles may be used in static positions, on vehicles, or at barricades. And finally, agents may be entrained in other materials, notably in foams to be released on attack. Not all the mechanisms above are appropriate for all weapons effects. Agents for the apprehension of single individuals usually could not feasibly be disseminated from aircraft. The matching up of the various desired effects with the appropriate weaponization concepts depends

upon the state of the art of agent development, the alternatives available, and, most critically, on the versatility and the operational missions to be achieved.

Current studies of crowd, mob, and riot control should be supplemented by studies particularly addressing the problem overseas as it may be dealt with by U.S. and indigenous forces. A parallel study should be undertaken to examine more aggressive levels of combat than occur in conventional riot and mob control.

In addition to the agents at various stages of RDT&E, a systematic effort to develop and exploit agents to uniquely meet operational and mission requirements should be undertaken as described in Ref. 4.

The dissemination characteristics of chemical agents, dependent on environment and mode of release, are not understood well enough to provide the necessary degree of precision in the design and development of nonlethal chemical weapons, to establish their logistics requirements, or to formulate doctrine for their use. Much more detailed attention to the dissemination of chemical agents in built-up areas is required to advance the state of the art.

The use of combinations of chemicals and of subtle pharmacologic mechanisms, e.g., the application of slow-release agents, the simultaneous application of agents and antidotes and the application of synergistic agents, has largely been ignored. Such combinations and mechanisms offer many promising opportunities for the development of controllable nonlethal weapons (Refs. 4, 5).

VIII. ROBOTS AND MAN-EXTENSION SYSTEMS

The high manpower requirements of the traditional methods of searching and clearing buildings, as well as the damage resulting from the need to reduce casualties among U.S. and friendly forces, strongly drive toward alternative methods. A most attractive alternative is the use of robots and man-extension systems for a number of specific and combined functions.

The development of automated robots and man-extension systems for use in urban combat may be a significant innovation in reducing destructiveness and casualties. Robots are potentially capable of shielding friendly forces from contact with the enemy while at the same time conducting search and reconnaissance and employing lethal or nonlethal firepower. Furthermore, removing man from the system or at least making man remote from the operating end of the system may allow greater speed, flexibility, and compactness in the operating unit. Robot systems for street surveillance, for manipulating crowds, and for maintaining barriers and barricades all offer great potential. Perhaps the most significant problem to which these devices may be turned would be the internal inspection and surveillance of structures above and below ground, including buildings, sewers, and utility lines.

The narrowness of streets, the close quarters of buildings, and the density of structures and population in cities suggest that robots and remote manipulators would provide a flexible urban mobility which would not be available to a well-armored, well-protected man.

A capacity for remote surveillance by TV or other sensors, remote weapon delivery, and appropriate mobility of the robot or remotely controlled vehicle would meet major needs in urban combat. Mobility requirements could be quite varied and suggest a variety of vehicles.

Search and neutralization in the clearance of tunnels provide one class of problem. Problems involving the searching of rooms may require the capacity to climb or descend stairways.

Man-extension systems may have value in giving an individual superhuman strength. Potentials in this area have recently been demonstrated by the General Electric walking machine known as Hardiman (Ref. 89). Hardiman, precisely controlled by servomechanisms to imitate the motions of a human operator inside, gives the operator great physical power. If the operator were cocooned in appropriate protective suiting, Hardiman might be useful for crowd, mob, and riot control and for breaking into structures. Robots and man-extension systems have applications across the whole range of combat in cities. The capacity to resist hand-tossed missiles, fire, and bludgeons would allow Hardiman to move directly into crowds, rounding up people or apprehending leaders. With resistance to low-intensity firepower, Hardiman might also be useful in search and surveillance. Another use for such a machine might be the quick and selective clearance of rubble.

More fully automated systems of the sort resembling miniature turtles, vehicles operating with insect-type articulation, miniaturized tanks, or armored snake-like vehicles might all have potentials that would be valuable in searching through structures to round up or neutralize the enemy. By minimizing the hazards to the user, it might also be possible to reduce overall casualties and destruction of property. Obviously, a major R&D effort is needed to explore these possibilities, set parameters for the devices, and determine the missions for which they would be useful. All of this is beyond the scope of this preliminary study. The application of robots, however, carries with it the question of who will be using any new nonlethal weapons.

IX. WHO WILL APPLY THE NEW WEAPONS?

In the same way that not all weapons are appropriate for all situations, not all weapons are appropriate for all users. It is anticipated that the principal users of nonlethal weaponry developed and supplied by the United States will be:

- U.S. combat forces and military police
- Foreign military
- Foreign police forces of various types

Considerations of mission, objectives, manpower, and so on must be taken into account in the use of weapons by any force. The potential influence of a given weapon or effect on the attitudes of the indigenous military and civilian populations, as well as on the U.S. domestic and world opinions, must also be considered. This is especially critical if U.S. forces are involved.

Newly developed nonlethal weaponry may eventually be delivered into the hands of foreign military, paramilitary, and police forces. It is essential to consider the appropriateness of a particular weapon for use by indigenous personnel. If the weapon carries a high potential for abuse or misuse once it has fallen outside the control of U.S. forces, preventing its misuse by proscribing its export may become a dominant consideration. Another factor driving in a somewhat different direction is the substantial ignorance of the cross-cultural aspects of coercion, social control, and social violence (Ref. 90). It may be that a level of violence that is completely unacceptable for a given situation in Europe or the United States because of real or apparent risks or dangers would be of very limited consequence in a different culture. The anticipated and expected level of violence

for establishing that the control forces "mean business" may vary substantially from culture to culture. A tactic that is quite effective in one society may be useless in another. As mentioned earlier, spraying colored water for riot control is virtually without effect in Pakistan, where clothes are relatively inexpensive and easily washed, and where on many festive occasions the people are accustomed to pitching colored water at each other. On the other hand, the use of colored water is apparently quite effective in Italy, where demonstrators are likely to have far more of their personal assets invested in their clothes. An illustration of the shifting standards of acceptability was the immediate outcry against the British for their brutishness in moving into Anguilla, while the confrontations between students and control forces in continental Europe, which were often conducted with substantially more physical violence on both sides, were received with scarcely a murmur.

There is an urgent need for cross-cultural study of modes of social control in general, and of the place of organized physical force and violence in particular (Ref. 90). First, this should generate a better understanding of how these problems have been handled and mishandled in different societies, different countries, and different cultures. Second, it should build up a vicarious backlog of experience. Third, it may have substantial influence on doctrine and tactics, at least for export. Fourth, it should highlight the much-needed flexibility in dealing with these problems. Fifth, and most significantly, it should demonstrate or uncover the significance of the misuse, overuse, or ineffective use of force, violence, and social control.

The direct involvement of U.S. combat forces or military police in situations overseas presents other paramount problems. Besides the cross-cultural misunderstanding alluded to above, there is always the possibility that intervention by an outside force may "transfer the issue." If the issue is supervising a plebiscite, peace-keeping, or a relief mission, overreaction or misreaction by foreign forces may move the populace to shift the issue from whatever it was originally

to one of foreign intervention, foreign brutality, and so on. The commonplace situation in which one talks louder than usual to a foreigner may find its analog in more aggressive action than usual where one does not understand the local ground rules.

In any operation in a foreign environment, it is essential that there be an awareness that an action can have calculated or accidental political consequences. The military must be alert to the political aspects of their missions and to the possibility that U.S. intentions will be misread if undue coercive force is applied. It should also be noted that civil violence and disorder in the United States, by all reasonable criteria, offer only the palest images of the extent, duration, planning, aggressiveness, and complexity of urban violence that is intermittent and even commonplace in many parts of the world. Consequently, the lessons learned from U.S. domestic civil conflicts probably cannot be transferred in toto to other countries.

X. THE INFLUENCE OF NONLETHAL WEAPONS ON WARFARE

The potential influence on enemy and friendly forces of the wholesale introduction of nonlethal weapons into combat in cities should be considered in the evaluation of specific weapons concepts.

There is the possibility that forgoing lethal force would enhance the boldness of the enemy by putting him at less deadly risks, but that possibility may be more imagined than real. It is difficult to anticipate a situation in which one could abandon the capability of deadly force entirely and substitute the capability for nonlethal force. Nevertheless, the possibility that an enemy facing nonlethal weapons will become emboldened requires careful evaluation and observation during operations.

A much more significant problem in the introduction of nonlethal chemical weapons is the potential asymmetry of the response of a parsimoniously supplied enemy operating with only limited resources or on a makeshift basis. If the United States introduces a nonlethal weapon that produces a given low level of casualties--say, a tenth of a percent--it would seem quite reasonable that the opposition respond in kind. The kind of weapon with which the opposition may be capable of responding may have a small but substantially higher casualty rate--say, two percent. There is then the risk that the United States may assume that the enemy has escalated the conflict and has justified the U.S. introduction of more vigorous, violent, or risky weapons. Most difficult to anticipate and to throw into proper balance is the friendly-force response to the enemy-force response to the introduction of a new or novel nonlethal weapon. The almost intrinsic asymmetries of the forces could very well lead to rapid escalation of weaponry.

A quite different consequence of the introduction of nonlethal weaponry is that casualties may increase even though the severity of the injuries may decline. There may be new problems in the short-term handling of casualties, especially in the need for therapeutic treatments to deal with real injuries, to allay the fears of the innocently injured, and to reduce the likelihood of their ascribing all their future ills to the effects of the new weapon. The "veteranitis," as it has been called, common among gas warfare victims in World War I, is a very real risk in the introduction of any new, novel, or startling weapon.

A somewhat more complex problem resulting from the use of nonlethal weapons, particularly when coupled with a program of evacuation, would be the handling of the large number of refugees that could be generated.

The introduction of nonlethal weapons would undoubtedly influence tactics, calling for new precision in the use of force in many instances and requiring less precision in others. Troops might have to be differently outfitted and trained. Careful attention would have to be paid to the morale of the troops using nonlethal weapons, particularly if they feel that their weapons are unequal to those of the enemy. And finally there is the problem of developing discipline and skill in the use of nonlethal devices. Virtually every conceivable nonlethal technique is open to abuses that must be guarded against.

A major risk in the use of nonlethal weaponry is failure to keep the nonlethal aspect clean, that is, free of associations with lethal tactics. Such failure is well illustrated in Vietnam now, where a large amount of riot-control chemicals is being used not to achieve casualty reductions but to root the enemy out of his places of cover and concealment so as to make him an easier target for conventional firepower. The basic argument for the use of nonlethal weapons and their practical applicability will be undercut if the rules for their employment remain uncertain. Enemy and friendly forces (and neutrals as well) must be sure whether fighting is in a lethal or nonlethal

mode. If nonlethal weapons are used to augment lethal tactics or strategy, the principal value of the nonlethal weapons may be lost. This proposition has been the subject of much controversy, the settlement of which requires a full-scale assessment of the tradeoffs between the use of nonlethal weapons to enhance lethal capability and their use in a "pure" nonlethal mode.

The basic situation in the employment of the riot-control agent CS in Vietnam has changed substantially since its initial introduction. According to a December 1969 New York Times account (Ref. 91), the following statement was issued by American authorities in response to inquiries:

> This effort can include the use of riot-control agents, either tear gas or CS. These agents have been used in the Republic of Vietnam to drive enemy personnel from caves, tunnels and fortified positions. It has also been used on occasions when the enemy has infiltrated into population centers, built up areas, and is suspected of holding innocent civilian hostages.
>
> Enemy troops who are driven from their bunkers or fortified positions and who do not surrender and who continue to fight are engaged as any dangerous armed enemy would be. Since the effects of the riot-control agents last only a few minutes it is not uncommon for the enemy to resume shooting at our soldiers.
>
> In short, the riot-control agents are employed when they will help save the lives of noncombatants and soldiers of the free-world military forces. The use of riot-control agents also permits rendering the enemy ineffective and subject to capture without taking his life when the situation permits.

While the above statement was not made about combat in cities specifically, riot-control or chemical agents in urban combat present many of the same generic problems. Cities, with their heterogeneity and their greater densities of structures and people, enhance the importance of nondestructive and nonlethal techniques.

The core issue that I see in the use of norlethal agents in warfare is the possibility of establishing a new threshold in low-level conflict that is symmetrical with the nuclear threshold in high-level conflict. If a threshold in low-level conflict could be established (perhaps tacitly, as with the nuclear threshold), it might carry with

it the implication that certain conflicts would be essentially nonlethal and that the forces engaged in them would rely as much as possible on nonlethal weapons. A new class of warfare might thus be established that would have inherent advantages for all parties subscribing to it. While this may seem to be a grandiose expectation, nonlethal techniques might at least lead to a new break between low and intermediate levels of warfare if they were properly scheduled, applied, and backed relentlessly by policy. If that break were sharp and clear, it might tend to keep conflicts at the lower levels. As I see it, this cannot happen if nonlethal techniques are used willy-nilly for whatever purposes the unit commanders see fit, or as mere adjuncts to lethal techniques.

Captain Anthony B. Hamm has pointed out (Ref. 92) that the "...lack of doctrine requires commanders to use their imagination when employing CS."

Restricting and controlling the range of operational innovations could drive the overall conflict in specific directions, even to establishing the ground rules under which nonlethal weapons will and will not be used and giving the enemy to understand those rules fully. As long as a full range of unrestricted options is in the hands of the unit commanders, the establishment of a firebreak or threshold becomes increasingly remote.

XI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Firepower, intelligence, mobility, and communications are the main tactical underpinnings of military operations in cities. There is an urgent need to modify tactics, training, doctrine, selection of personnel, and to provide new weapons for combat in cities. The need for less destructive and less deadly weapons for city combat flows from two major sources: first, the requirements of U.S. military assistance commitments in support of other countries in their urban operation; and second, the need to enable U.S. forces to act effectively in various political-military roles and missions. The general increase in insurgency, coupled with the anticipated increase in benign and quasi-military missions, suggests the requirements for less destructive, less deadly tactics and devices than are now conventional. The widespread destruction and loss of life in recent low-level combat, particularly in Vietnam, suggest a partial mismatch between current capabilities and the objectives of present and future conflicts. It is anticipated that there will be more of an interplay of military and political goals, tactics, and implications than has been customary, and that political-military objectives may be very uncertain and shifting. All of these argue for less profligate killing and less wanton destruction of property.

Cities themselves, as fields for combat in contrast to the countryside, present high population densities as well as high property values, are the depositories of historical and cultural stores, and are the centers of national infrastructures.

The loss of life in urban combat largely results from the need to neutralize enemy personnel sheltered by various structures. The

consequent firepower incidentally destroys property. The availability of nonlethal techniques for neutralizing personnel could go far towards simultaneously reducing the loss of property.

The application of nonlethal techniques is increasingly appropriate as more civilians are placed at risk, and less appropriate as the enemy is more concentrated, violently aggressive, and recalcitrant.

Major missions for nonlethal weaponry also derive from the traditional high manpower requirement in urban operations. In addition to the high risk to friendly personnel because of the protection afforded the enemy by complex structures and buildings, structure-by-structure, unit-by-unit clearance demands many men. The extensive external network of streets, alleys, and other routes also demands much manpower for search, cordon, and patrol. These factors will drive toward more extensive use of automatically activated devices, rapidly emplaced barriers and barricades, and the use of semi-automated, man-extension and robot systems to take the friendly trooper out of the field of fire and to reduce overall combat manpower requirements.

The priority missions for nonlethal firepower include:

- Riot, mob, and crowd control
- Curfew enforcement
- Population movement
- Route control and denial
- Protection of essential personnel
- Structure control and denial
- Area control and denial
- Countersniper
- Apprehension
- Facility protection
- Prisoner handling
- Countering looting
- Locating hidden personnel

By far the most tactically versatile and useful antipersonnel mechanisms for urban combat are chemical. Other techniques relying

on impact, light, sound, and heat, while affording some operational effectiveness and substantial decrements in deadliness, are generally more restricted in their application. They are less versatile and most particularly applicable to riot control. The biological agents, while having much of the versatility of chemicals, lack a rapid onset of effect. Their tactical incisiveness is severely limited so they are less applicable to the class of conflict discussed in this paper. They may, however, have a substantial application in capturing and neutralizing hostile cities at highly intense levels of limited warfare.

Recent experience with crowds, mobs, and riots in the United States has stimulated numerous studies of all aspects of their control. Developments in nonlethal weapons for this purpose have concentrated on exploiting the super tear agent CS. Many of these developments are directly applicable to low-level combat in cities abroad.

The versatility and acceptability of numerous other nonlethal mechanisms are obscured because of the limited number of background technical studies or the limited understanding of social control in other societies. Examples are impact and electrical mechanisms.

Firepower improvements should place overwhelming emphasis on less lethal and less destructive techniques for low-intensity city operations.

B. RECOMMENDATIONS ON NONLETHAL FIREPOWER

1. A systematic field investigation should be undertaken to develop a more comprehensive and precise understanding of the dissemination of chemical agents in cities, the characteristics of those agents, and the limitations on various modes of their delivery. This investigation should deal with dissemination and transport outside of structures, within structures, and from the outside into structures. The results of this study would form the background for

evaluating logistics requirements, for establishing weapons design criteria, and for the evolution of new tactics.

2. Games and simulations of low-level urban conflicts should be systematically undertaken to identify new requirements and to highlight inadequacies in current doctrine, tactics, and weapons, as an exercise to promote innovation and to evaluate new concepts.

3. A systematic RDT&E program to uncover, design, select, and evaluate nonlethal chemical agents with new or improved effects for urban combat reflecting the results of 1 and 2. Among the effects which could be useful for low-level urban combat are disruption of vision or balance, itching, pain, orthostatic hypotension, and disturbances in the skeletal muscle system. In general, effects that would render the victim incapable of any controlled movement are unattractive because of the enormously increased secondary risks.

4. Systematic attention should be given now to protocols, doctrines, tactics, and training associated with the use of nonlethal firepower to elaborate and specify when, where, and how nonlethal weapons will be used.

5. Research should be begun on robots, man-extension systems, semiautomatic systems, and various concepts for remote manipulation and handling for use in urban combat. Among the specific concepts meriting investigation are vehicles incorporating mobility, surveillance, and weaponization (nonlethal or lethal) for patrol and surveillance outside buildings, for search and surveillance, for neutralization within buildings, and for similar functions in tunnels, sewers, and other subterranean structures.

6. Devices to reduce manpower requirements at checkpoints, barricades, and other high-manpower patrol functions, including automatically activated alarms, barriers, and

barricades incorporating nonlethal agents, markers, and alarms, should be more extensively and intensively developed for urban operations.

7. The countersniper problem raises the question of the need for techniques for safely and rapidly penetrating structures to neutralize the occupants. A typical model for this might be firing into a high-rise structure from 100 yards, or perhaps firing into a thick-walled, low-level building at closer range.

8. Marking techniques for identification, harassment, and coercion should be systematically explored, both for individual and mass use in local and area applications, and in covert and overt systems. Particular attention should be given to opportunities to incorporate such agents with nonlethal weapons. Coding marks should be a major consideration. Attention to organizational and administrative requirements for the systematic exploitation of marks in various tactical situations is critical.

9. Techniques for controlled denial of areas or structures would be useful in many cases. It may be necessary, if chemical agents are used, to couple this with active methods for decontaminating or neutralizing the agents. Techniques which may neutralize the use of harbors, roads, physical structures would also have a place.

10. Specific research is needed on injector devices and other means for the apprehension of individuals in a variety of limited-war contexts. Wide attention must be given to reasonable agent effects, durations, and onset times. Systematic search and evaluation of agents and agent combinations are in order. The concept of injectors should not be limited to items now commercially available, such as the Cap Chur concept. Specific attention should be given to weaponizing the nerve-gas antidote Syrette. This self-injector,

if deliverable by small arms and if charged with an appropriate nonlethal formulation, could satisfy several needs.

11. Systematic basic background studies are needed to define the limits of safety of both existing and potential electrical and impact weapons effects. Each of these studies in its way would also be strongly tied to civilian interests. Attention should therefore be given to the possibility of joint or coordinated military-civilian studies. Fire, health, and safety standards in the electrical appliance, power, and communications industries are not now adequately being met in terms of basic knowledge of physiological risks. Civilian police applications of impact and concussion devices are not now well enough understood and are not being systematically researched.

12. A specific weapon needing more intensive evaluation is the truncheon, nightstick, or riot baton. Consideration should be given to the feasibility of damage-limiting construction.

13. Specific devices meriting modest efforts for crowd and mob control are vortex rings and wind-generation machines.

14. New approaches to the concept of building clearance by nonlethal techniques are needed.

15. Dogs are extremely promising and versatile animals suitable for surveillance and tracking, for weapons portage, and for use as nonlethal weapons in urban combat. A comprehensive program directed at the selection, training, and development of general- and special-purpose military dogs would be timely and appropriate.

16. Plants have some potential application to low-level combat. Attractive avenues for research and development include:

- Indigenous obnoxious plants as barriers and barricades.
- Indigenous and nonindigenous plants as sources of irritants and nettles.

- Plants as sources of nettles and barbs for use as harassing weapons, marking devices, and means of delivery of chemical agents. The use of synthetic barbs must also be considered in this context.

17. Particularly with regard to control of mass behavior and the implementation of curfews, and those situations in which military forces are in direct contact with various publics, intensive new attention must be given to:

    - Training aids, both mechanical and theatrical.
    - The wider use of photographic techniques not only for training but for the development of vicarious experience and for the discovery of new tactical factors and elements relevant to the development of new doctrine.

18. The almost total lack of systematic knowledge about social control, force, and coercion in other cultures and even in other nations requires a comprehensive study of these matters, focusing particularly on geographic regions and cultures of anticipated interest. The objectives of such a study should be to:

    - Define limitations on acceptable techniques and weapons.
    - Identify the needs and requirements of U.S. and indigenous forces.
    - Establish a more comprehensive understanding of coercion in general.

19. A closely related but distinct study could include:

    - Crowd, mob, and mass behavior overseas.
    - Foreign practice in dealing with such behavior with a view to assessing techniques, effectiveness, and limitations.

20. Administrative and technical mechanisms for the identification and establishment of research requirements for military and paramilitary, constabulary and police functions in client

countries are urgently needed. There are now no mechanisms whereby the first line of defense against insurgency, namely the forces of the indigenous governments, can adequately be serviced at the RDT&E level. Local responses are inadequate, and the patchwork of present arrangements is totally unsatisfactory.

C. RECOMMENDATIONS ON FIREPOWER OTHER THAN NONLETHAL

1. Means of breaching walls and sapping should be given careful attention for urban combat as a means of making holes for the entrance and exit of personnel, robots, and weapons.

2. Sapping and other means for drilling under structures to facilitate controlled destruction or entrance merit investigation. Recent developments in drilling technology and liquid explosives suggest many useful novel applications.

ANNEX

FIREPOWER MISSIONS IN RELATION TO VARIOUS OPERATIONS

BLANK TABLE. FIREPOWER MISSIONS IN RELATION TO VARIOUS OPERATIONS

KEY
- ☐ Firepower appropriate
- ☒ Nonlethal firepower dominant or major factor
- ▨ Nonlethal firepower is significant
- ◉ Nonlethal firepower is of some value

OPERATIONS →

MISSIONS ↓

(B)	(A)	1. Show of force	2. Supervise plebiscite	3. Relief	4. Post-disaster restoration	5. Blockade	• land	• air	• water	6. Siege	7. Peacekeeping	8. Rescue	9. Pacification of an area	10. Evacuation	11. Protection of facilities	• military, e.g., a base	• government, e.g., a quay	• civil, e.g., a refinery	12. Relocation of a population	13. Urban disorders	14. Urban insurgency	15. Urban guerrilla warfare	16. Civil war	17. Conventional limited war	• defend a city	• capture a city	• recapture a city
1. Riot, mob and crowd control																											
• disperse																											
• immobilize																											
• disrupt																											
• corral																											
• aggregate																											
• channel																											
2. Countering looting																											
3. Apprehension																											
• single individuals																											
• small groups																											
4. Facilities protection against																											
• sabotage																											
• theft																											
• espionage																											
• attack																											
5 Attack on facilities																											
6. Neutralization of facilities																											
7. Clearance of facilities																											
8. Protection of lines of communication																											
9. Protection of essential personnel																											
• in secure facilities																											
• on the street (medical, food, etc.)																											
10 Prisoner handling in compounds																											
11 Population movement																											
12. Curfew enforcement																											
13. Disruption of military activities																											
14. Disruption of civilian activities																											
15. Structure control--denial																											
• subterranean																											
• above ground																											
16. Area control and denial--interdiction																											
17. Route control and denial--interdiction																											
• streets, highways and alleys																											
• rivers and streams																											
18. Locate hidden personnel																											
19 Penetrate structures																											
20. Countering infiltration																											
21. Static defense																											
22. Strongpoint clearance--neutralization																											
23. Countersniper																											
24. Roof clearance																											
25. Structure clearance																											
26. Counterbattery fire																											
27. Countervehicle																											
28. Countering terror																											

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1. Lt. Col. Arnold J. Celick, "Humane Warfare for International Peacekeeping," Air University Review, Vol. XIX, No. 6, pp. 91-93, September-October 1960.

2. Hq, Department of the Army, Combat in Fortified and Built-Up Areas, Field Manual FM 31-50, March 1964.

3. Webster's Seventh New Collegiate Dictionary, G. & C. Merriam Co., Springfield, Mass., p. 1009, 1963, defines a weapon as "an instrument of offensive or defensive combat: something to fight with."

   Army Special Regulation 320-5-1 gives the following definition of a weapon: "Any implement of combat such as a gun, bayonet, grenade, etc., used to inflict injury on enemy personnel or materiel." This regulation is now obsolete and has been superseded by AR 320-5, which does not include a definition of "weapon" alone but gives definitions for such things as "weapons of mass destruction" and "weapons systems."

4. Institute for Defense Analyses, Organ-System Analyses: A Rational Approach for Developing Nonlethal Chemical Warfare Agents, IDA Study S-196, Joseph F. Coates, Cedric Smith, and Edward Truitt, September 1965. (AD 366777)

5. Institute for Defense Analyses, Nonlethal Weapons for Use by U.S. Law Enforcement Officers, IDA Study S-271, Joseph F. Coates, November 1967.

   This study is a comprehensive review of nonlethal weapons for application by domestic U.S. police officers. It includes evaluations of a substantial number of the techniques discussed in the present paper, and it should be consulted for appropriate references where cited.

   Applegate has briefly reviewed the status of riot control developments in "Riot Control 1969," Ordnance, Vol. LIV, No. 296, pp. 180-184, September-October 1969. He has also presented a comprehensive digest of riot control materiel and techniques in his book, Riot Control--Materiel and Techniques, Stackpole Books, 1969. This book is meant to be a practical guide to the organization and techniques for riot control, the use of riot control chemicals, and other special equipment. While valuable in that

respect, the book is not a critical, analytical, or research-oriented volume and presents little material to support the validity of the selections and alternatives that are implicit. The book indirectly highlights the need for a comprehensive RDT&E program in techniques and equipment for riot control.

6. Little analytical material has been presented on the question of acceptability of military or police weapons. Most of the literature is polemical or in other ways forecloses rather than opens up discussion of the subject. Nevertheless, the importance of acceptability has been pointed out by O'Ballance who writes that "...a weapon to be militarily effective, ...also has to be socially and publicly acceptable as well."

   Maj. E. O'Ballance, "The Acceptability of Weapons," Revue Militaire Generale, Vol. 2, pp. 212-223, February 1969.

7. Thomas and Vreeland, in a very instructive paper, define "show of force" more broadly "as the application of military power to influence the alternatives available to other nations or parties by establishing a risk of war and/or punishment and indicating a willingness to assume the risk, if necessary, to achieve one's own political objectives."

   Research Analysis Corporation, Show-of-Force Concepts, RAC-TP-293, John R. Thomas and Mildred C. Vreeland, p. 16, February 1968.

8. Institute for Defense Analyses, Fighting in Cities Overseas, IDA Note N-689(R), W. Scott Payne and Jean G. Taylor, May 1970.

9. Research Institute of National Defense, Medical Department, Sundbyberg, Sweden, Blast Injury, Vol. 36, Carl J. Clemedson, July 1956.

   S. Zuckerman, "Experimental Study of the Blast Injuries to the Lungs," The Lancet, August 17, 1940, cited in AVCO Ordnance Division, Eglin Air Force Base, Antipersonnel Mechanisms, AFATL-TR-67-149, Clever, Barton, and Larkin, October 1967.

10. The only use of the whip by a uniformed force that I know of is by conscript policemen in up-country Afghanistan. A photograph of a policeman so armed may be found in:

    City and Nation in the Developing World: Selected Case Studies of Social Change in Asia, Africa, and Latin America, AUFS Readings, Vol. 2, American Universities Field Staff, New York, 1968.

11. John A. Weaver and Alice M. Stoll, "Mathematical Model of Skin Exposed to Thermal Radiation," Aerospace Medicine, pp. 24-30, January 1969.

    Temperature changes can be induced by radiation or direct contact with hot air or hot liquid. The character of the burn is to some degree influenced by the mode of delivery but is more dependent on

the rate of heat transfer. Weaver and Stoll have done interesting mathematical modeling of skin exposure to thermal radiation. According to one estimate, four calories per square centimeter for one-fifth of a second will induce a second degree burn when the energy is delivered by radiation. (Cited in Effects of Nuclear Weapons, U.S. Department of Defense and U.S. Atomic Energy Commission, June 1957.)

12. Research Analysis Corporation, A Preliminary Feasibility Study of the Cold Liquid Weapon, RAC-TP-178, Emil M. Szten, Harold G. Seeger, and William O. Sprang, May 1965.

13. S.W. Tromp et al., Medical Biometeorology: Weather, Climate and the Living Organism, Elsevier, 1963.

14. Col. George M. Knauf, USAF(MC), "Radiation Hazards and Electromagnetic Test Equipment," paper presented at 20th Meeting of Electronic Test Equipment Coordination Group, Research Division, College of Engineering, New York University, May 6, 1958.

15. "Microwave Tactics Against Birds," New Scientist, p. 558, March 4, 1965.

16. Aerospace Technology Division, Library of Congress, The Biological Effects of Electromagnetic Fields, Annotated Bibliography 1933-1964, ATD-P-65-17, April 1, 1965.

17. A.F. Harvey, "Industrial, Biological and Medical Aspects of Radiation," Chapter 20 of Microwave Engineering, Academic Press, New York, pp. 973-994, 1963.

18. W.W. Mumford, "Some Technical Aspects of Microwave Radiation Hazards," Bell Telephone System Monograph 3865, Proc. IRE, Vol. 49, pp. 427-447, 1961.

19. C. Maxwell Cade, "Wavelengths of Life and Death," New Scientist, pp. 588-590, September 19, 1968.

20. A.S. Presman, "The Biological Effect of Microwaves," Uspekhi Sovremennoy Biologii, Vol. 56, pp. 161-179, September-October 1965.

Soviet research on the effect of microwaves on the nervous system is extensively reviewed in:

Vladimir Mutschall, "Response of the Nervous System to Microwave Radiation," Foreign Science Bulletin, Aerospace Technology Division, Library of Congress, Vol. 5, No. 6, pp. 18-55, June 1969.

21. Institute for Defense Analyses, Review of Information on Hazards to Personnel from High-Frequency Electromagnetic Radiation, IDA Note N-451, Herbert Pollack and Janet Healer, May 1967.

Pollack and Healer review personnel hazards from high-frequency electromagnetic radiation, particularly in the frequency range below 300 MHz. The authors point out that there is universal agreement that electromagnetic radiation increases the thermal load on the body. It is principally a function of average field strength and secondarily a function of wavelength. The longer wavelengths penetrate better than the shorter; the latter result in surface heating. In addition, there are a number of athermal or "specific" effects. These have been described as disturbances of the central nervous system or the vegetative nervous system, including cardiovascular and other changes. In addition, behavioral changes such as tiredness, headache, irritability, loss of memory, and loss of appetite have been reported.

22. James A. Bynum and John A. Stern, "Painted Helicopter Main Rotor Blades and Flicker-Induced Vertigo," Aerospace Medicine, Vol. 40, No. 6, pp. 622-626, June 1969.

23. C.E. Melton, E. Arnold Higgins, J.T. Saldivar, and S. Marlene Wicks, "Exposure of Men to Intermittent Photic Stimulation under Simulated IFR Conditions," Aerospace Medicine, Vol. 38, No. 6, pp. 631-634, June 1967.

24. American Institutes for Research, Washington, D.C., Psychological Phenomena Applicable to the Development of Psychological Weapons, AIR-ES-10/65-TR, Clifford Hahn and staff, December 1965.

Hahn has systematically evaluated psychological phenomena for applicability to weapons development. This report makes it quite clear that once one gets outside the area of physiology and physiological psychology, the variations in human response to stress are largely due to cultural factors. This variability creates uncertainty as to the applicability of various effects as potential weapons. Even in the domain of physiological effects, there are substantial human variations and in some cases the rates of susceptability are so low or the risks so high as to preclude development into useful weapons.

25. Alfred Schwartz, Preliminary Study of Physical Damage to Settlements in South Vietnam--A Methodological Study, IDA memorandum to John Martin, May 23, 1969.

Damage assessment techniques are in need of improvement as well as more extensive application. The self-explanatory proposal by Schwartz for a methodological study of damage assessment is given here because of its extreme value:

Background:

It is proposed that a methodological study be conducted to develop a technique for measuring the amount of physical damage to settlements in South Vietnam.

Common knowledge indicates there has been an enormous amount of physical damage to South Vietnamese settlements resulting particularly from enemy and friendly force actions.

Assuming that the reconstruction of settlements to the early 1965 level is desirable, it would be useful to measure the extent of damage throughout South Vietnam. Damage assessment information would provide a basis for:

1. Establishing priority areas for reconstruction.
2. Checking field reports.
3. Determining how much of what kind of support is required by specific settlements.
4. Planning systematic distribution and control of materiel and services for reconstruction.
5. Checking as to whether materials are being used in the areas designated and for the purposes specified.

Objective:

The objective of this study would be to develop a method for measuring the amount of physical damage to settlements in South Vietnam.

Data and Method:

The study would be based on the interpretation of stereographic aerial photographs, one set for the early 1965 period and another for a recent period. A representative sample of South Vietnamese settlements by Corps area would be selected by examination of the some 585 Army Map Service 1:25,000 scale Pictomaps covering all of South Vietnam. (The Pictomaps derive from aerial photo cover flown in 1965.)

In order to obtain a sample of South Vietnamese settlements, they would be functionally classified (i.e., urban, market town, rural) and a representative number of settlements from each class would be selected from each Corps area.

A damage assessment scheme would be developed progressively assessing damage from undamaged through totally destroyed. Types of structures and facilities damaged would be differentiated according to their function such as residential and general administrative-institutional-commercial transportation-industrial- and military. Special types of structures in the general category would be treated separately if they could be regularly differentiated, such as temples, churches, hospitals, etc.

Damage would be measured in terms of floor space damaged by classes of settlements and by types of structures and facilities. Ground photographs and discussions with field experienced personnel would be used to validate photo interpretations.

The 1965 photography would be analyzed to provide the basic condition and recent photos of the same settlements would be compared with the former in order to measure the extent of damage during the interim. In this analytical process, new construction, including refugee camps, could be separated for special attention. It is estimated that, for the sample, approximately 2000 9"x9" photographs at about 1:10,000 scale would be used for each period.*

Results:

Using data from the sample settlements as a vehicle, the methodological study would present the classification techniques, a format for presenting quantitative data and conclusions regarding the feasibility of extending the study to all of South Vietnam.

Applications of the Methodological Study:

This study would provide a basis for deciding whether the method should be applied to all of South Vietnam. If the product were considered desirable, costs could be estimated on the basis of work completed. Costs could be broken down in terms of staff and materiel (photo procurement, plotting, interpretations, analyses, etc.) required to complete the task within a given time frame.

It is estimated that the study would require the services of three persons for eight months--a total of 24 man-months. The study should include on the order of two months field study in Vietnam.

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*Stereo photo coverage of all of South Vietnam would require about 67,000 9"x9" photographs at 1:10,000 scale.

26. Institute for Defense Analyses, Promising Areas of Research and Development for Tactical Operations in an Overseas Urban Environment, IDA Study S-345, W. Scott Payne, Joseph F. Coates, Herbert L. Goda, Stanley Marder, Michael Muntner, Bernard H. Paiewonsky, and Jean G. Taylor, May 1970.

27. C.J. Bartleson, "Retinal Burns from Intense Light Sources," American Industrial Hygiene Association Journal, Vol. 29, pp. 415-442, September-October 1968.

Bartleson, in his comprehensive review of retinal burns from intense light sources, concludes that "few quantitative data appear to exist in which accurate specifications have been made of the amount of energy, its rate of delivery, time of exposure, and retinal image characteristics involved in the production of such lesions (thermal lesions)." He points out "there is, then, no single value of radiant exposure that can be named as a threshold" (p. 419). While emphasizing the need for more research on the hazards of normal- to high-intensity sources, he suggests that "the prudent course would be to accept the overestimation provided by the power function data based on very intense sources" (p. 423).

28. N.A. Peppers et al., "Corneal Damage Thresholds for CO_2 Laser Radiation," Applied Optics, Vol. 8, No. 2, pp. 377-381, February 1969.

29. "Bayonet Incident Angers Okinawa," New York Times, Pt. C, June 10, 1969.

"To many Okinawans, the most serious aspect of the affair is not that Mr. Asato was slightly wounded but that the Americans, the rulers, used bayonets against Okinawans, the ruled. There is apparently a wide cultural gap on this score. Americans, both military and civilian, say that the bayonet is a recognized riot-cortrol instrument, frequently used as such in the United States.

"To the Okinawans, and even more so to their fellow countrymen in Japan proper, the bayonet is a weapon of war, arousing painful memories most people would rather forget. In prewar Japan, there was a whole mystique about swords and their use, which extended to the bayonet used by infantrymen. There is general agreement that no postwar government could have used bayonets in a riot and survived."

30. Examiner, Washington, D.C., May 22-24, 1969.

31. Time, p. 23, May 30, 1969.

32. "Japan: Winning a Round," Newsweek, p. 50, June 16, 1969.

33. Institute for Defense Analyses, Acoustic Energy as a Nonlethal Weapon, IDA Note N-217, George W. Wood, February 1965.

34. Col. James Van Sickle, U.S.A., Training Section, Office of Chief of Staff for Force Development, personal communications, 1969 (also Technical Manual TM 57-220, June 1968).

35. SFC Carl Martin, "Private Legg Goes Airborne," Army Digest, pp. 60-62, January 1968.

36. Leslie E. Simon, German Research in World War II, John Wiley & Sons, New York, pp. 180-184, 1947.

    Simon's review of German research in World War II reports that a Dr. Zippermeyer investigated explosive powered vortices. An account is given on p. 180 of a wind gun which shot a slug of air. It was designed as an antiaircraft weapon and is reported to have been able to break 1-in. boards at 200 m. It was powered by oxygen and hydrogen. Unfortunately, it is not clear, either from the diagram or the description, on what principle the slug of air was propelled.

37. For more information see:

    Institute for Defense Analyses, Population and Resources Control in Overseas Urban Operations, IDA Note N-690(R), Joseph F. Coates, May 1970.

38. The most extensive review of the influence of light on criminal activities in the U.S. unfortunately reveals effects so confounded by other changes that no definitive assessment of the value of light per se, much less a cost benefit analysis, can be made.

    "Police Chief Interviews - 25 Major Cities," Special News Service, United Press International, Safety Lighting Bureau, 55 Public Square, 12th floor, Cleveland, Ohio, undated.

39. AAI Corporation, Cockeysville, Maryland 21030, Mobility Deterrent, U.S. Army Limited War Laboratory Report No. LWL-CR-06CA68, William H. Collins, December 1968.

40. Among the conceptual applications for sticky material are: (1) the immobilization of individuals or masses as, for example, in laying down a layer of polybutene, the stickum so common in bandages and other adhesives, (2) the deployment of grenades over crowds or in front of crowds to release sticky or adherent strands which would slow down movement and immobilize or neutralize people, (3) the use on edges and tops of buildings to make them unusable by snipers, (4) the deployment of automatically activated devices for guarding facilities which would spray and either immobilize or substantially slow down the victim who either chose to enter or flee, (5) the application to selected denied areas such as streets, alleys, etc., in either a temporary or continuing route control.

In the application of such material to people, not only does toxicity of the adhesive and possible solvents used in formulation become a substantial consideration, but one also has to consider the risks of injury from tearing skin and the potential problems and risks in removal of the adhesive. These could all be major obstacles but, nevertheless, R&D on this unusual weapon effect merits some attention.

41. "Dragnet" Vehicle Safety Barrier System, Van Zelm Associates, Inc., Division of the Entwistle Company, Providence, R.I., no date.

The dragnet system of Van Zelm Associates is a most interesting application of net. This is a rapidly emplaced barrier system which consists of 1/4-in. 7-strand galvanized steel cable loop threaded through a length of 11-gauge galvanized chain-link fencing. The net and the cable are held erect by thin-walled, crushable aluminum tubing which collapses when struck, eliminating danger of injury from debris. Anchor assemblies, either permanent or semipermanent, are available for police roadblocks. Automobiles, trees, light poles, and other fixed objects may be used as emergency anchors. The heart of the systems is the energy absorbers. Each unit consists of a galvanized steel tape enclosed in a steel casing. The tape is manufactured in varying widths and thicknesses according to the breaking force required. When a vehicle engages in the net assembly tape is pulled from its container and is directed to a series of staggered steel pins known as the "torture chamber." As the tape passes through this torture chamber, it is successively bent back and forth and a constant cold working of the steel tape absorbs the kinetic energy of vehicle being arrested. Standard units produced constant breaking force of 2500 and 4000 lb, respectively, for 5000 and 8000 lb per system. This type of system may have some interesting applications in the operation of checkpoints in establishing permanent and semipermanent roadblocks.

42. "Netting a Thief," New York Sunday News, p. 29, April 6, 1969.

The cast net is being developed by Mr. Colin Brown of Mill Cottage, Leighton Road, Neston, Wirral, Cheshire, England. A nylon net of approximately 100 square feet may be shot to a range of about 15 ft in the prototype device, which is spring activated. A limiting factor on development of the greater range may be that to increase the range one needs to increase the propellent force and probably add heavier weights to the edges of the net. The heavier weights would in turn increase the risk of injury on impact.

43. "The Nutcracker," Time, p. 27, February 28, 1969.

They have developed a new $10 weapon known as the "Nutcracker" Flail, which consists of two 3/4-in. square, 2-foot-long plastic sticks joined at one end by four short nylon cords.

> Pointed at the suspect like a dowser's divining rod, the weapon works on two simple principles: speed and pressure. Before the offender can escape, or if he resists arrest, the sticks are clamped around his arm, wrist or hand. The cords act as a hinge. If he resists, the arresting officer merely squeezes the sticks, inducing severe, immobilizing pain. Either way, no permanent injury is usually inflicted because the pain will subdue the offender before any physical damage occurs.
>
> The nutcracker is equally effective in mob control and dispersal. Holding on to only one stick, the patrolman swings the other like a flail. Any attempt to grab the swirling stick results in a broken limb. A blow on the head can fracture a skull. Says a Detroit police official: "With six men carrying the sticks, we can penetrate 50 men and bust up their formation and come back out."
>
> The nutcracker was developed by a suburban Detroit karate expert, Russell Hanke.

The nutcracker, which is distributed by Penguin Industries, P.O. Box 97, Parkesburg, Pa. 19365, seems to be a wrong move in the program of police weaponry. A principal shortcoming of the nightstick is its susceptibility to indiscriminate or careless employment, which leads to skull fractures and other serious injuries. A device designed to facilitate injuries would therefore seem to be a move in the wrong direction of aggravating violence and injury.

44. "Hong Kong Police Trained on Riots," New York Times, March 31, 1968.

    C.D. St. Q. Fletcher, "Riot Control in Hong Kong," FBI Law Enforcement Bulletin, Vol. 38, No. 12, p. 3, December 1969.

    Fletcher describes the Hong Kong projectile or "baton shell" as teak wood with a small lead insert. The projectile is fired from a gas gun. Incidentially, it is instructive to note the sequence of measures used by the Hong Kong police to disperse crowds: (1) verbal request, (2) tear-smoke, (3) the "baton shell," (4) a baton charge, and (5) firepower with buckshot pellets. Revolvers, carbines, and automatic weapons are available to the police in extreme situations.

45. According to the late Theodore Sterne (Systems Evaluation Division, Institute for Defense Analyses), the French used rubber bullets for dueling practice before World War II. The duelers wore masks and slickers for protection. I have no information as to the effect of such a bullet on an unprotected person.

46. Department of the Army, Edgewood Arsenal, Maryland, Impact and Thermal Hazards Study of the E24 (XM674) CS Riot Control Cartridge, EATR 4251, Alexander P. Mickiewicz and Victor R. Clare, October 1968.

47. Capt. Richard L. Simmons, USAR(MC), Capt. Thomas B. Ducker, USAR(MC), and Capt. Robert W. Anderson, USAR(MC), The Journal of Trauma, Vol. 8, No. 5, pp. 800-809, September 1968.

Simmons et al. point out that pulmonary edema may follow head trauma. This illustrates the fact that the consequences of head trauma are numerous, diverse, and dangerous.

48. Cited in Ref. 50, p. 11; see also A.H.S. Holbourn, "Mechanics of Head Injuries," The Lancet, pp. 438-441, October 9, 1943.

49. Ref. 50, pp. 111-112.

50. Keith Simpson, ed., Forensic Medicine, Williams & Wilkins Company, Baltimore, Maryland, 1964.

51. Lauren K. Welch, "Head Injury, A Clinical Perspective," Aerospace Medicine, Vol. 39, No. 11, pp. 1231-1235, November 1968.

52. B. O'Connell, "Postcontusional Syndrome," Journal of Forensic Medicine, Vol. 8, No. 3, pp. 122-130, July-September 1961.

Sir Charles Symonds, "Concussion and its Sequelae," The Lancet, Vol. 1, p. 7219, January 6, 1962.

53. J.M. Rayne and K.R. Maslen, "Factors in the Design of Protective Helmets," Aerospace Medicine, Vol. 40, pp. 631-637, June 1969.

Channing L. Ewing and A. Marshall Irving, "Evaluation of Head Protection in Aircraft," Aerospace Medicine, Vol. 40, pp. 596-631, June 1969.

54. Department of Theoretical and Applied Mechanics, University of Illinois, The Dynamic Response of Two-Dimensional Photoelastic Models of the Human Head, T&AM Report 328, M.L. Janssen and C.E. Bowman, October 1969.

55. Cornell Aeronautical Laboratory, Buffalo, N.Y., Computer Simulation of the Automobile Crash Victim, Interim Report VJ 2492-V-1, D.J. Segal and R.R. McHenry, March 1968.

56. Paul B. Weston, "New Concepts in Police Weapons Systems," Proc. First National Symposium on Law Enforcement Science and Technology, Thompson Book Co., Academic Press, New York, pp. 797-802, 1967.

57. The state of knowledge with regard to truncheons and nightsticks is reviewed in Ref. 5. See also:

Research Analysis Corporation, Nonlethal Incapacitating Weapon: Extensible Billy Club, RAC-TP-194, William O. Sprang, November 1965.

58. "Shield and Mace May be Weapons of Police Future," New York Times, March 24, 1969.

59. "Telemetry Tackles Traumatic Head Blows," J. Am. Med. Assoc., Vol. 210, No. 2, pp. 2175-2176, December 27, 1969.

60. "Shocking an Attacker," New York Sunday News, p. 7, July 16, 1967.

61. "The Latest in High Powered Police Fashions for Crowd Control," Crime Control Digest, p. 12, May 6, 1969.

62. Fred Blumenthal, "Shocking the Shark," Parade Magazine, pp. 10-11, The Washington Post, March 8, 1964.

63. Underwriters Laboratories, Inc., sponsored by National Board of Fire Underwriters, Electric Shock as it Pertains to the Electric Fence, Bulletin of Research No. 14, H.B. Whitaker, December 1939.

64. G.A. Wall, Electrical Anti-Personnel Weapon, U.S. Patent 3,374,708, March 26, 1968.

65. "Electrocution," Encyclopedia Britannica, Vol. VIII, p. 229, 1968.

Electrocution was introduced in New York on June 4, 1888. The first execution by this method was of William Kemmler on August 6, 1890, at Auburn Prison. In a typical execution, 2300 volts, single-phase, 60-cycle AC is employed. The condemned is secured in place and moistened sponges with properly molded electrodes are attached to the head and the calf of one leg. The initial shock of 2000 volts is reduced to 500 volts, then raised and lowered at 30-second intervals for a total application of two minutes, during which peroid, four to eight amperes are applied. Final body temperatures in excess of 120°F have been reported.

66. "Too Many Shocks," Time, pp. 58, 63, April 18, 1969.

Inadvertent electrocutions apparently occur with uncertain but substantial frequency in current medical practice. According to Dr. Carl Walter of the Peter Bent Brigham Hospital, Boston, 1200 electrical shock deaths occur in U.S. hospitals every year. There apparently is a substantial campaign under way for legislation to establish hospital electrical standards.

67. Charles F. Dalziel and W.R. Lee, "Lethal Electric Currents," IEEE Spectrum, Vol. 6, No. 2, pp. 44-50, February 1969.

68. Leslie D. Price, "Codes and Standard Practices," Standard Handbook for Electrical Engineers, G. D. Fink and J.M. Carroll, eds., 10th Edition, pp. 29-2 to 29-3, McGraw-Hill, New York, 1968.

69. Ref. 63, p. 38.

70. A workshop on "Electrical Hazards in Medical Applications," sponsored by the National Research Council, was held in April 1968. A summary of the proceedings will be found in:

Leslie J. Rinder, International Association of Electrical Inspectors News, pp. 36-39, July 1968.

The proceedings of that workshop have been published in:

National Academy of Sciences, Washington, D.C., Electric Hazards in Hospitals, Carl W. Walter, ed., 1970.

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72. Battelle Memorial Institute, Report on the Status of Riot Control Hardware, Report No. LWL-CR-02-RAB, H.J. Hucek et al., January 1969.

73. Booz-Allen Applied Research, Inc., Investigation of Promising New Concepts for Handling Civil Disturbances, U.S. Army Limited War Laboratory Contract No. DAAD 05-68-C--178, January 1969.

74. Office, Chief of Research and Development, Department of the Army, Catalog of Selected Items to Aid in Controlling Civil Disturbances, August 1968.

75. Joseph F. Coates, "Nonlethal Weapons for Domestic Law Enforcement Officers," Law Enforcement Science and Technology, S.A. Yefsky, ed., Thompson Book Company, Academic Press, London, pp. 787-797, 1967.

76. Joseph F. Coates, "Safe Police Weapons," Science and Technology, pp. 52-59, May 1968.

77. Department of the Army, Civil Disturbances and Disasters, Field Manual FM 19-15, March 1968.

78. U.S. Army Land Warfare Laboratory, Comprehensive Law and Order Assistance Research and Development (CLOARAD) Program, Technical Report No. 71-04, Final Report (Revised), pp. 35-41, Richard W. Wilsnack et al., March 1971.

79. "A Scientist Develops Ways to Curb Rioters: Put Them in Bubbles," Wall Street Journal, May 29, 1969.

80. "Soap Bubbles: Two Years Old and Sixty Centimeters in Diameter," Science, Vol. 164, No. 3877, pp. 291-293, April 18, 1969.

81. Carnegie-Mellon University, A Nonlethal Gun, Seminar Project Presentation, Vol. II, May 27, 1969.

The senior chemical engineering thesis group at Carnegie-Mellon investigated the adaptation of the Atropen for use as a nonlethal weapon by modifications that would allow it to be fired from a pistol. The Atropen is a device that is employed for rapid self-injection of a nerve-gas antidote.

82. "Silent," Chemical & Engineering News, p. 101, February 21, 1966.

The crossbow has been modified for use as a nonlethal hunting weapon that shoots hypodermic darts.

83. U.S. Army Advanced Materiel Concepts Agency, Future Warfare in Urban Areas, Ad Hoc Working Group, July 5, 1968.

The Ad Hoc Working Group was concerned with advanced materiel concepts for neutralizing and controlling a defended urban area consisting of high-density, ordered, man-made structures. It was assumed that competent U.S. Army forces and similarly well-trained organized enemy regulars were in conflict and that the mission of the U.S. forces was to be accomplished in a minimum of time, with minimum casualties among friendly forces, at minimum cost, and with minimum damage to the urban area. Thirty-eight concepts were developed by the Working Group, including five leading concepts for exploration in more depth:

1. A small air-mobility device.
2. Foams for obstruction.
3. Foams for area denial.
4. Aerial assault vehicles for urban warfare.
5. An expendable remotely controlled ground reconnaissance vehicle (TURTLE).

No attempt will be made here to duplicate the contents of the report or to comment on the validity or soundness of the Working Group's efforts.

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