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A "FLASH BULB" APPROACH TO
SOME VIETNAM DEFENSE PROBLEMS

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PREFACE

This RAND Memorandum presents the general features of a scheme for using directed, high-intensity light flashes to thwart enemy night operations by causing substantial periods of flash blindness or damage to the retina. Such a scheme could have application to the defense of hamlets, military outposts, and military bases against enemy ground operations in Southeast Asia. An air-delivered variation of this scheme could help reduce the effectiveness of visually controlled anti-aircraft fire.

This Memorandum examines briefly the characteristics of such a "flash bulb" technique. The flash intensity required is estimated, and the physical components of the system are described. Precise design and performance specifications are not attempted here because of physiological and operational uncertainties connected with use of the technique. The objective is rather to establish the practicality of flash blinding, and to gain a rough idea of applications.

SUMMARY

The use of devices similar to flash bulbs in their operation could produce a substantial degradation in the efficiency of night attacks conducted by insurgent forces, such as those of the Viet Cong in Vietnam. This degradation would be accomplished by focusing and directing the light from such flashes toward the attacker. The light source would be in the defended area, and the enemy forces, in pressing their attack, would be likely to look in the direction of the defending forces; therefore, a significant probability of flash blindness would exist.

By this technique, periods of temporary flash blindness, lasting perhaps five to ten minutes, can be produced. If a very high-intensity source is used, considerable retinal damage may result, including the distinct possibility of extensive permanent impairment of vision. If binoculars are used by the insurgents, even a low-source intensity would be amplified to produce retinal burns.

To accomplish these ends, the ignition of amounts of flash powder on the order of 1 gram (for temporary blindness) and 100 grams (for permanent damage) is required. Binoculars, which are often used by the Viet Cong in the field to assist night vision, can readily increase the retinal intensity from the smaller flash charge to an injurious level; the intensity from the larger charge would be catastrophic to the observer.

Such a system of high-intensity light flashes would be basically simple in nature and probably could be operated by indigenous personnel. Its cost would be low since the components consist essentially of a primitive reflecting system, a stockpile of cheap flash charges, and a mechanism to ignite the charges.

CONTENTS

I. INTRODUCTION

A singular feature of the Vietnam war is the comparatively high rate of night activities by the enemy. For many of these activities the vision of the Viet Cong must be directed toward specific areas or positions if they are to accomplish their objective. For example, if the objective is to overrun a hamlet, the direct fire weapons used against the hamlet defenses must be preceded and accompanied by visual observation of these positions. The same would hold true for the attack of an outpost, a Special Forces camp, or a U.S. base.

The very nature of these attacks suggests that a weapon based upon an intense light source, interposed between the defender and the attacker, might cause significant degradations in the attacker's efficiency. In essence this technique would be the adaptation of an operational problem in nuclear bombing (where momentary flash blindness can affect the proficiency of the pilot) to a guerrilla warfare situation. Whereas procedures readily can be worked out to prevent serious effects during nuclear operations, there would be no counterpart for the guerrilla role. Any attempt to take protective measures would also interfere with one's vision and thus with combat effectiveness.

Since the Viet Cong must spend an appreciable fraction of their time observing the target they are attacking, it would appear that intense flashes of light, directed toward their general location and burst frequently, but at a random rate, could have a highly adverse effect. From a physiological standpoint the magnitude of this effect could range from temporary flash blindness to permanent retinal damage, including the possibility of immediate blindness. However, if the latter effect is to be avoided, the flash intensity can be kept to levels that insure that no permanent damage can occur.

The light-gathering ability of binoculars makes them highly useful for night operations. Apparently the Viet Cong make substantial use of them in their night attacks. Such use would produce an extremely large amplification of the effectiveness of this scheme. Image sizes

on the retina would increase in proportion to the power of the binoculars, and image intensities would increase in proportion to the increase in light gathering -- that is, the area of the objective lens compared with that of the pupillary opening. This would not only increase the degree of temporary flash blindness by magnifying the after-image, but it could have catastrophic effects on the retina if intensities sufficient to cause permanent damage existed.

Although it is hardly possible to predict, quantitatively, how effective such a system might be, there are some important aspects of the problem that can be discussed.

The fear of blindness, either temporary or permanent, runs deep in most human beings. In spite of an abundance of assurances on the safety and stringent control over flash blindness experiments, there has been a prevailing anxiety and uncooperativeness shown by the subjects of such experiments. The Viet Cong, who would be subjects in an uncontrolled experiment, might be expected to show considerably greater anxieties -- being technically unsophisticated and essentially unaware of what was happening to them. Thus a psychological amplification of the physiological effects could provide a major deterrent against subsequent attacks. Of course, if flash intensities sufficient to cause permanent damage were employed, or resulted through the use of binoculars by the Viet Cong, the psychological aspects would be in a much different framework, and the deterrent value might go up substantially.

If the Viet Cong desired to employ countermeasures, they would have to be of a highly sophisticated type. Since the attackers must be able to see their target, measures that will reduce the light intensity will be unsatisfactory, since they also reduce the ability to see the target. This rules out something as simple as dark glasses, which would probably produce an intolerable reduction in night vision. Therefore, unless very advanced equipment was available, which is extremely unlikely, simple countermeasures would be a self-defeating process.

II. THE SYSTEM

Basically, a system to produce the effects just discussed is extremely simple. It consists of a metallic reflector, a supply of flash charges, a mechanism to ignite the flash charges, and an operator. Inasmuch as the system, if effective, would undoubtedly become an important target it would be desirable to harden it against the effects of enemy weapons.

Since the most vulnerable elements of the system probably would be the operator and the supply of flash charges, the hardening could be accomplished by digging a trench. Whereas the flash charges might be additionally protected in the trench, the trench probably ought to remain open to allow any smoke to clear out.

Above the trench (see Fig. 1) would be a reflector, roughly the shape of an elliptical paraboloid. The flash charges would be ignited at the focal point. The reflector would then serve to fan out and direct the impinging beam toward the general location of the attackers. The reflecting properties of the reflector are determined by a geometry that is essentially two dimensional. The third dimensional increment relates to the height of the beam at the point where it is intercepted by the eyes of the attacker. Thus the distribution of light, from the reflector, would be in the form of a pie-shaped wedge having a thickness of, say, 6 feet. This would cover enemy positions ranging from prone to fully erect. If desired, the reflector could be swivelled for greater flexibility of application. However, as will be discussed below, a fixed reflector can cover so extensive a section using such a modest amount of flash powder, that this feature may not be too worthwhile.

The reflector would be constructed of some metal having a good reflection coefficient. It should be sufficiently thick to be tough enough to withstand any stresses produced by the light bursts, and also to withstand the effects from enemy fire -- except, of course, a direct hit by an explosive charge such as a mortar shell. Aluminum would be a satisfactory choice.

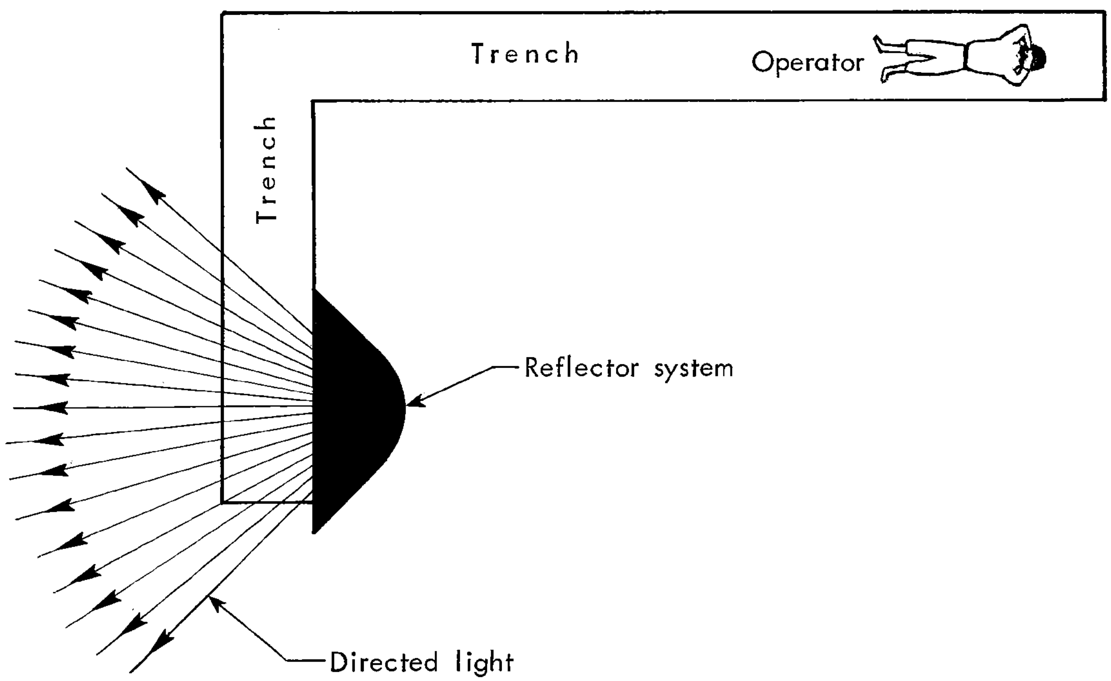

Fig. 1—"Flash Bulb" installation

To protect the operator from the effects of the bursts the trench might be L-shaped. After placing the charge and setting the fuse, the operator could move around the corner to a position in the rear of the reflector.

III. "FLASH BULB" REQUIREMENTS

The amount of light that should be released by individual flash charges is a function of three parameters:

1. The "weapon effects" criterion to be used -- namely, whether emphasis is placed on temporary flash blindness, or whether permanent retinal damage is selected;

2. The extent of the sector to be illuminated;

3. The extent of the image to be produced on the retina, which relates directly to the extent (at the target) to which vision is to be denied to the attacker.

Parameters 1 and 3 are difficult to assess because of the distinct possibility that binoculars may be employed by the enemy.

Suppose, to gain an order-of-magnitude feeling for the problem, the flash charge requirements are selected on the following basis:

An arc of a few hundred yards is to be illuminated (very briefly) at the periphery of the light wedge by a source that is a few hundred yards away. The apparent source size for this geometry will be a reflector 6 feet high. For this geometry, two "weapons effects" criteria will be selected: (1) An intensity, on the retina, that will prevent the unaided eye from adjusting to the ambient illumination condition for several minutes; and (2) An intensity that will produce a serious retinal burn, discounting the use of binoculars.

Experiments designed around the temporary flash blindness that stems from nuclear operations and manned space operations (where the astronaut inadvertently looks at the sun) have been under way for a number of years.[1,2,3] A principal finding of these experiments is the large variation in individual response. This factor involves differences in recovery times of as much as 5 to 10-fold, for the same flash exposure. Therefore it should be realized that numerical accuracy of prediction is not apt to be high. However, the uncertainty in average response of a group will be less. Since this uncertainty affects

only the amount of flash powder to be ignited and we are concerned with small amounts of cheap materials, this lack of precision is not a matter of real concern. In other words, to bank conservatively against the inaccuracy of the problem, a calculated estimate of, say, a gram of flash powder might be increased to several grams.

An examination of several sets of flash blindness data indicates that a retinal intensity of $\sim 0.01\ cal/cm^2$ will require about 3-4 minutes to recover vision, where the ambient illumination is approximately that of a full-moon. At a retinal intensity level one order of magnitude lower, the recovery time is 1-2 minutes.

These data, plus those from other experiments, suggest that for a lower background illumination level, say, quarter- to half-moon intensity (when the Viet Cong are more likely to attack), a retinal intensity of $0.01\ cal/cm^2$ will necessitate recovery times on the order of 5-10 minutes. For the (arbitrary) geometry assumed here this would entail a flash charge containing on the order of a gram of flash powder.

It is difficult to say how serious the effect on one's vision would be if an elliptical blind spot roughly 6 feet high at the target was the curtailing factor. Therefore, since the dimensions -- actually "dimension" is more appropriate as the target is viewed from a distance at the surface -- of a particular target in the area under attack undoubtedly will be significantly larger, a given installation might contain several reflectors, spaced perhaps 5-10 feet apart, which would be flashed simultaneously.

The threshold intensity for producing retinal burns is about $1\ cal/cm^2$, on the retina, for a light flash that delivers its energy to the eye within a blink time of approximately 0.1 second. At this level the temperature rise will be sufficient to cause destruction of retinal tissue.[4] If an intensity an order of magnitude higher exists, the effect will involve an area that may be considerably larger than the image size itself. At such a high intensity the tissue will be heated well above the boiling point and the resulting effect would injure tissue outside the heat absorbing volume. For an increase of

two orders of magnitude, which could readily result if binoculars were used, the effects would become explosive in nature and serious damage well beyond the image area would result.

Suppose an intensity of 2 cal/cm^2 is selected as a permanent damage criterion. To deliver 2 cal/cm^2, for the geometry assumed here, would require an energy source of about 10^4 calories of light. This would entail the burning of about 100 grams of flash powder.

The image size for the case considered here will be about 0.1 mm. This size, however, is for the unaided eye; should binoculars be used, the image size would increase considerably. And, of course, the intensity on the retina would go up greatly. If, for example, 8-power binoculars were used by Viet Cong observers, the image diameter would become about 1 mm. This is approximately one-third the physical size of those parts of the retina necessary to central vision. If, say, the objective lens was 3 inches in diameter, the retinal intensity would increase about 100-fold. A burn of this extent, plus the amplification of effects resulting from such a high retinal intensity, would result in immediate and perhaps total loss of useful vision.

For situations where an observer might not be looking directly at a flash, the area of retinal damage probably will not interfere with his central vision; however, there may still be a significant period of temporary flash blindness. If a retinal burn criterion is used to determine the flash source intensity, this intensity may be some two or three orders of magnitude greater than that satisfying a temporary blindness criterion. Since there will be some scattering by the lens and vitreous humor as the light passes through the eye, a major fraction of the retinal area may receive a visual overload -- thus leading to significant temporary effects.

IV. OPERATION OF THE SYSTEM

The distribution of the flash installations would be determined essentially by the location of those targets that are adjudged most likely to be attacked. Since many Viet Cong attacks show that quite good target intelligence has been obtained to permit discriminate firing of weapons rather than an attack against the general area, this distribution criterion would be a sound one. However, since the installations are cheap, if additional personnel are available a more extensive coverage of the general area can be effected.

If the presence of the Viet Cong has been detected, or suddenly becomes known through the initiation of the assault, the flash installations would go into operation. Regarding the frequency of flashes from a given installation, this is more a matter of judgment rather than one stemming from quantitative evaluation.

If it is assumed that 5-10 minutes of flash blindness will affect a significant number of the attackers, then this might also become the flash frequency. Or a rough appraisal may be made of the reduction of the volume of enemy fire, and the operator can wait until the level goes up before he ignites his next charge. Or the operator may attempt to silence enemy fire by maintaining a maximum flash rate. Since a "flash damage" assessment is not readily available, the flash rate must remain somewhat of an imponderable.

The outcome of an engagement, where the defense uses this scheme, can only be a subject for speculation. Considering the psychological aspects of the problem, an attack thwarted in this manner might come to a sudden end as the Viet Cong (who have probably geared their operation to a fairly rigid schedule) retreat from the scene. However, if those who retreat cannot see too well to do so, the retreat might become a highly disorganized affair. Furthermore, an enemy situation of this nature would give the erstwhile defenders an opportunity to go on the attack to exploit the situation if the collective visual ability of the enemy has diminished appreciably.

If a significant reduction in visibility is caused by rain or fog, the combat abilities of all participants will be adversely affected. However, if the decrease in light intensity from the flashes is not large enough to bring it down below levels of flash blindness or retinal damage, weather can have an interesting bearing upon the problem. The scattering of light will, in effect, increase the apparent source size and thus the image size as well. In this sense, a reduction in visibility need not, up to some point, entail a corresponding reduction in effectiveness. Of course, significant scattering in the atmosphere might also have some effect upon the defenders if they are not alerted to the time of burst.

During daylight hours, the times required for adaptation to ambient illumination conditions are far less than at night. Even for extremely bright sources, recovery periods shrink to seconds and the application of flash effects becomes sharply limited. However, for certain roles there still may be effective uses for this concept.

In the Vietnam ground war it appears that most daylight engagements are distinctly different from those occurring at night. The fighting takes place where the combatants are usually in much closer quarters and where it is difficult to imagine a large-scale use of this scheme. But there are still situations where enemy snipers may be hidden in the trees, exchanging fire with a U.S. detachment a few hundred yards away. Under such conditions, perhaps a portable version (delivered by helicopter) of the installation described previously might provide a deterrent against sniper action, especially if the snipers use telescopic sights.

In addition, for example, if a practical way could be found to place a very large flash bomb -- weighing, say, 100-200 lb -- in approximately the same position as an attacking aircraft, a degradation in visually controlled antiaircraft weapon effectiveness could result. Even a few seconds represents an important fraction of the time the aircraft may be exposed to defensive fire during its bomb run. Thus denial, or significant inhibition, of ability to maintain sighting on the aircraft during this period may produce beneficial results. If

binoculars are used by the defenses in spotting enemy aircraft and in fire control, the amplification of effects could lead to permanent visual damage to antiaircraft personnel. Calculations indicate that the M 120 flash bomb (weighing 165 lb) could produce this effect.

APPENDIX

The intensity upon the retina, from a distant isotropic burst of light, is given by the expression

$$q = \left(\frac{P}{f}\right)^2 \cdot \frac{T_e}{4\pi} \cdot e^{-\mu R} \cdot \frac{Q_e}{D^2}$$

where

q = intensity incident on the retina

P = pupillary opening (~3 mm in daytime and ~7 mm at night)

f = focal length of eye (17 mm)

T_e = transmissivity of eye (0.8)

$e^{-\mu R}$ = atmospheric transmissivity through a distance R from the source. (1.0 for distances of concern here, for normal visibility)

Q_e = light output of source

D = effective source diameter

The image size, I, on the retina is given by

$$I = \frac{D}{R} \cdot f$$

For estimating flash requirements to produce temporary flash blindness at night, suppose we take as an example the case referred to previously. This was a requirement for producing on the order of 5-10 minutes of flash blindness under ambient illumination conditions corresponding to a quarter- to full-moon. To accomplish this calls for, roughly, 0.01 cal/cm^2 on the retina. For this intensity, assuming (roughly) a source diameter of 6 feet, the required light output, Q_e, would be (for isotropic emission)

$$Q_e = \frac{0.01 \text{ cal/cm}^2 \times (6 \times 30.5)^2 \text{ cm}^2}{(7/17)^2 \times \frac{0.8}{4\pi} \times 1.0} = 3 \times 10^4 \text{ calories.}$$

This energy source, calculated on the basis of isotropicity, must next be modified in accordance with the constraints of the reflector system and the geometry of application. In this connection it is assumed that 50 percent of the light is utilized by the reflecting system and that the reflectivity of the system is 70 percent. (This reflectivity factor is approximately correct for aluminum reflectors.)

Using the specific geometry described in the text, suppose we assume that the reflecting system spreads the light to cover a 300 yard arc at a distance of 400 yards from the light source. For these conditions the reduction factor, for the isotropic case, is

$$0.5 \times 0.7 \times \frac{4\pi \times (1200)^2}{6 \times 900} \approx 10^3.$$

Therefore, on the order of $3 \times 10^4/10^3 = 30$ calories of light are required. Flash powder will yield about 5×10^4 cal/lb of visible radiation. On this basis it is estimated that $30/5 \times 10^4 = 6 \times 10^{-4}$ lb (0.3 gram) of flash powder will be needed to produce the temporary flash blindness called for in this example. Taking into account some system degradation (imperfect reflection, divergence of the beam, and so forth) perhaps on the order of 1 gram might be indicative of the magnitude of requirements.

For a retinal burn criterion (approximately 100 times the intensity for temporary effects) a charge of 100 grams of flash powder is indicated. For this application the M 112 flash cartridge (weighing 1 lb), which emits about 4×10^4 calories of light, might be a convenient "shelf item" to employ.

At a distance of 400 yards from a source diameter of 6 feet (roughly the reflector size) the image diameter, I, (on the retina), would be

$$I = \frac{6}{400 \times 3} \times 17 = 0.1 \text{ mm}.$$

Were binoculars or a telescope in use, the image size would increase proportionately to the magnifying power. Thus, if 8-power binoculars were used, the image size would increase to about 1 mm -- approximately one-third the diameter, on the retina, of central vision.

REFERENCES

1. Miller, Norma D., Visual Recovery, USAF School of Aviation Medicine, SAM-TR-65-12, AD 450-072, April 1965.

2. Hayes, Richard F., "Visual Capabilities in Manned Space Flight," Lecture at Stanford University, July 1966.

3. Parker, James F., Jr., Visual Impairment from Exposure to High Intensity Light Sources, Report No. 63-2, Biotechnology, Inc., May 1963.

4. Elswick, W. R., and H. H. Mitchell, An Evaluation of the Human Retinal Burn Problem Arising from Atomic Detonations, RM-2500, The RAND Corporation, December 1959.