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ATOMIC ENERGY ACT OF 1954

U.S. AIR FORCE

Project RAND

LOW-YIELD FUSION WEAPONS FOR LIMITED WARS [redacted]

June 1, 1959

R-347

President briefed on this 10 Nov 59 VSDE

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ATOMIC ENERGY ACT OF 1954

PROJECT RAND

Contract No. AF 18(600)-1600

LOW-YIELD FUSION WEAPONS FOR LIMITED WARS [redacted]

S. T. COHEN

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SUMMARY

In many tactical situations—and in limited wars in particular—troops may be the most important target of nuclear attack. Because of the high vulnerability of humans to the effects of nuclear radiation, the development of low-yield fusion weapons that maximize radiation effects appears to be of utmost importance.

Development of such weapons will only be possible if weapon testing is continued. These weapons are particularly well suited to testing under ground, in line with present U.S. test limitation proposals.

Two classes of low-yield fusion weapons, currently being investigated by the AEC, have been examined in the light of their antipersonnel effectiveness:

[redacted]

These devices, used as antipersonnel weapons, will have the following advantages over the types of tactical fission warheads currently in stockpile:

- They will be as effective against personnel as a fission weapon having [redacted] and at a smaller nuclear cost.
- If desired, they can be used with much less physical destructiveness than fission weapons of equal or greater yield. In fact, it appears that troops occupying built-up areas can be attacked without significantly damaging the structures.
- [redacted]

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LOW-YIELD FUSION WEAPONS FOR LIMITED WARS

Weapon developments now on the horizon promise to lend a new dimension to the complex discussions concerning the feasibility and potential effects of using nuclear weapons in limited wars. It now appears likely that during the next decade we may have low-yield [redacted] fusion weapons available whose nuclear-radiation effects will dominate their blast and thermal effects. This report examines arguments for and against use of nuclear weapons in limited wars and, by describing expected characteristics and effects of possible future fusion weapons, indicates how they may be used to advantage in limited wars.

Development of such weapons will only be possible if weapon testing is continued. These weapons are particularly well suited to testing under ground, in line with present U.S. test limitation proposals.

NUCLEAR WEAPONS AND LIMITED WARS

It is frequently argued by those who oppose the use of nuclear weapons in limited wars that their use will induce a degree of instability that may easily lead to general war. There is the danger that even if small-yield weapons are used initially, the tendency will be to seek military advantage by using larger and larger yields. As this competition proceeds, the danger of all-out war will increase.

A second objection to the use of nuclear weapons in small wars is based on the danger of killing innocent civilians—through fallout or by detonating weapons near or in cities. Few wars have spared civilians, but such casualties should be minimized.

Finally, there is the question of whether nuclear weapons provide any advantage when both sides may use them. A real military advantage *may* be gained if we have certain future weapons and the enemy does not.

LOW-YIELD FUSION WEAPONS

The low-yield fusion weapons of the future are likely to have several characteristics especially fitting them for use in limited wars:

- They will be much more effective against the most important targets in limited wars—troops and support forces—than either current or future fission weapons of equal yield.
- By being relatively or completely clean, fallout will not be an important by-product of their use. (Low-yield fission weapons burst at low altitudes may produce significant surface contamination because of scavenging by rainfall.)
- By producing radiation deaths considerably beyond the range of blast and thermal effects, they will permit destruction of the enemy without significant damage to physical property.
- If we are able to use these weapons, and the enemy does not have them, their military effect can only be matched by his use of larger-yield dirty weapons—with the political and propaganda penalties their use implies. Of course the converse will also be true.

PHYSICS OF FISSION AND FUSION WEAPONS

Figure 1 depicts the fission process. A neutron is captured by some fissile nucleus (U^{235} in the figure), and a number of reaction products

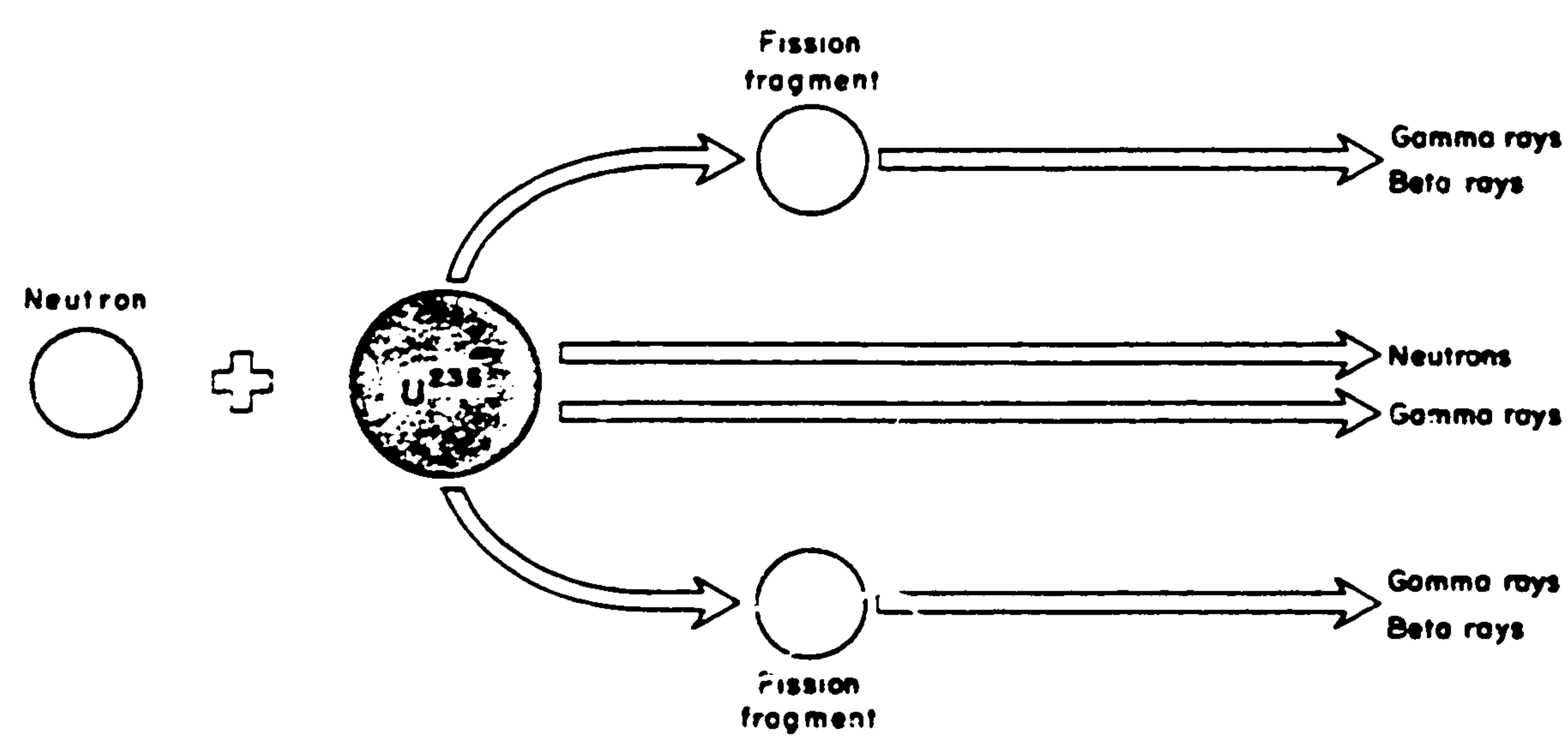
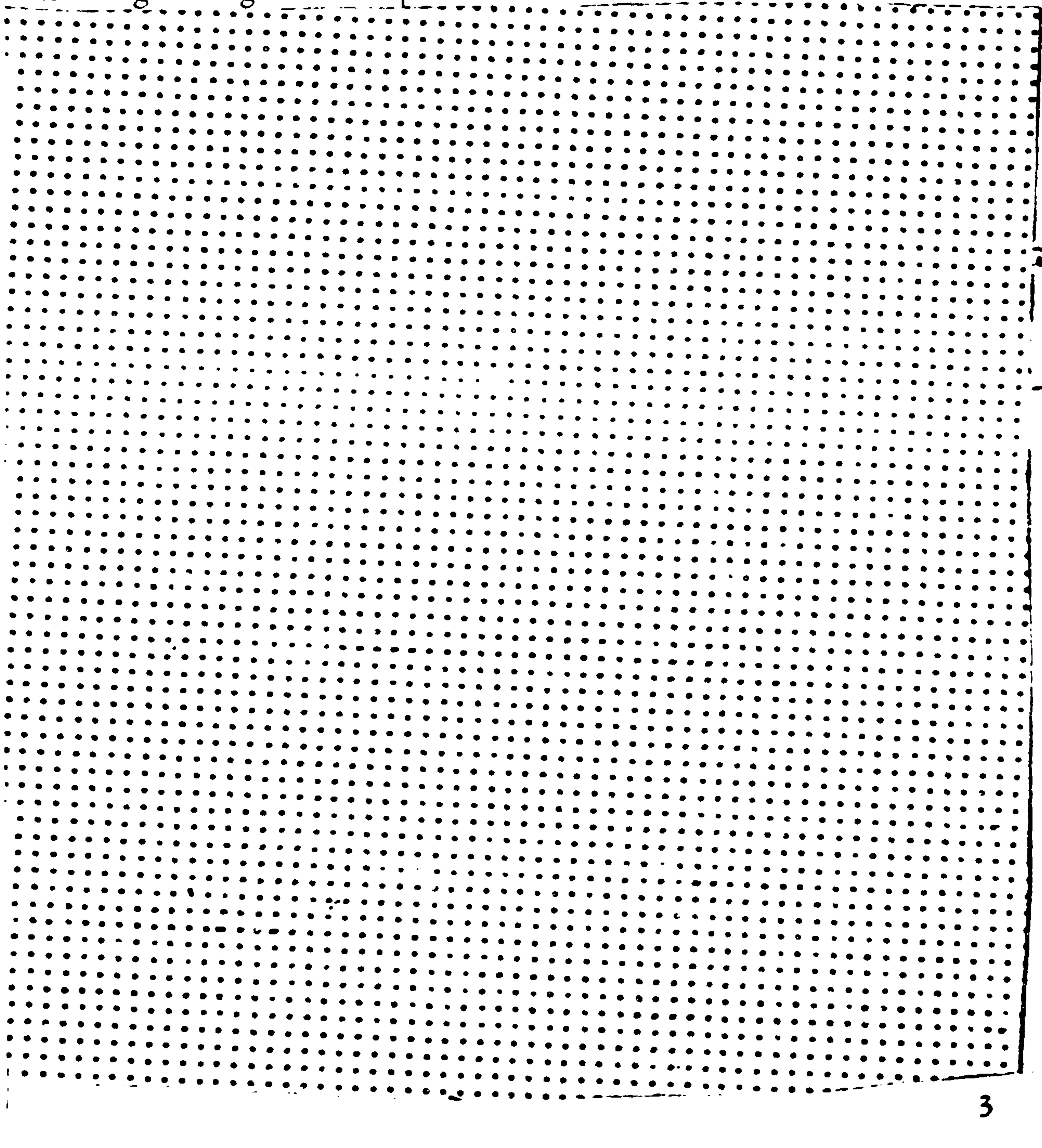


Fig. 1—The fission process

result. First, fission fragments are formed, which together add up to approximately the weight of the parent nucleus. Second, prompt neutrons and prompt gamma rays are produced as a direct result of the fission. Third, delayed gamma and beta rays appear, emanating from the radioactive fission fragments. (The fission fragments will decay with half-lives ranging from fractions of a second to many years.) The figure does not show the neutrinos, tiny neutral particles of significant energy but contributing nothing to the weapon effects.



[redacted]

Neutrons

Most of the energy in the fission reaction goes into the fission fragments. These heavily charged particles travel only microscopic distances.

Their energy is transmitted to the bomb material itself, which becomes extremely hot. This energy concentration creates an enormous pressure, which results in a shock wave that races out of the bomb into the surrounding air and heats it to incandescence, creating the familiar fireball. The main effects, then, are blast and thermal radiation, representing about 85 per cent of the total energy release. The remaining energy goes into the neutrons, beta and gamma rays, and neutrinos.

In the fusion process most of the energy goes into the neutrons, which have no charge and can travel long distances in air. If the bomb designer can maximize the release of neutrons, this weapon effect can be made to dominate the blast and thermal effects.

The comparative nuclear-radiation effects of fusion and fission weapons can be illustrated simply. About one and one-half to two neutrons are available for release from the bomb with each fission, accompanied by a total energy release of 200 MEV. One neutron results from each fusion reaction, accompanied by a total energy release of 17 MEV. Dividing 17 into 200 and considering that there are more neutrons per fission than per fusion, we find that there are potentially between 5 and 7 times more neutrons available for release (per kiloton of energy released) from the fusion weapon than from the fission weapon.

More important, the average energy of the neutrons released by fission is of the order of 1 MEV compared with 14 MEV for the neutrons born of the fusion process. The fusion-bomb designer is interested in getting these more energetic and penetrating neutrons out of the warhead and into the air, where they may travel long distances.

Two advantages of a properly designed fusion weapon over a fission weapon have been described: Not only are there more neutrons available for release for a given bomb yield, but these more energetic neutrons travel farther through the attenuating air.

Gamma Rays

In the fission process, gamma rays emerge in two ways. Prompt gamma rays from fission do not entail a significant amount of energy and contribute little to the total radiation effect. Delayed radiations from the radioactive decay of the various fission fragments, extending over a period of time from a fraction of a second to many years, are mainly responsible for the gamma-ray effects. These delayed gamma rays have an average energy of about 1 MEV.

No gamma rays were shown in the diagram of the fusion process (Fig. 2). However, the very energetic (10- to 14-MEV) neutrons interact with nitrogen nuclei in the air to produce a very important secondary source of gamma rays. Neutrons in this high-energy range produce a gamma ray having about half the energy (5 to 7 MEV) of the neutron.

Again, in the production of gamma rays, the fusion weapon produces more, and more energetic, gamma rays than those arising from fission weapons.

TARGETS IN LIMITED WARS

Enemy troops will probably be primary targets in limited wars. The industrialized and urban areas of relevance in general war are not likely to be of concern. If materiel is stockpiled in sanctuary areas, and if some military operations are conducted from sanctuaries—e.g., air operations—the preponderance of targets will probably be the troops in the field, their supply lines, and their logistics support units.

RAND studies of limited wars in the Far East and Middle East areas provide support for these intuitive assertions. Studies of limited wars in the Far East indicate that between 50 and 75 per cent of the nuclear-weapon targets will be enemy troops. Middle and Near East war games show that nearly 100 per cent of the targets will be troop concentrations. Air Force studies also show that enemy troops may provide most of the targets in possible limited wars in the Far East.

Even when the targets chosen are of a physical nature, key personnel may still be more vulnerable to nuclear-radiation effects. For example, attacks on combat and supply vehicles may be more effective against the personnel than the machines, because the personnel are more vulnerable to radiation than the machines are to blast. A similar situation occurs in attacks on air bases: while we would like to destroy aircraft and support facilities, the aircrews and support personnel may be more vulnerable to nuclear-radiation effects.

It seems evident that a weapon that is selectively more lethal as a radiation weapon against human beings than it is destructive of physical property may not only be more useful in limited wars but preferable. However, our antipersonnel goals are limited, too—we want to minimize the destruction of noncombatants and their cities. If we cause too much harm to the population and cities in the country we are trying to protect, it may well be the first and last limited war to be fought with nuclear weapons.

The RAND studies taught a valuable lesson regarding the use of large-yield fission weapons in limited wars. If fission weapons having yields of only tens of kilotons are surface burst in large numbers, the number of noncombatants killed may exceed troops killed in the ratio 5 or 10 to 1, largely as a result of fallout.

Even without surface bursts, bad weather may result in the scavenging of a fair fraction of the fission products brought down on the countryside by rain. However, this effect is most noticeable when lower-yield fission weapons (several kilotons or less) are used.

Finally, we may note that the use of fission weapons is also likely to result in blast- and thermal-radiation effects damaging to civilians and urban areas. In the past we have had no choice but to destroy towns and cities where troops have taken refuge. Certain fusion weapons of the future appear to promise a way to kill enemy troops in cities without leveling the city itself.

WEAPONS EFFECTS

The weapons effects of interest to us are thermal radiation; blast, as it affects both troops and structures; and nuclear radiation.

Thermal Radiation (Troops)

The effects of thermal radiation are varied and difficult to assess because they are affected by countermeasures and weather. Anything opaque will serve to cut off thermal effects completely, even if it is only a fraction of an inch thick. Fog, haze, dust, rain, etc., can drastically reduce the range of thermal effects. However, troops exposed in good weather can be affected at sizeable ranges. Severe burns can be caused by thermal intensities of 4 to 10 calories per square centimeter. How serious the effects will be will depend on which way the individual is facing, what he is wearing, and so on. However, 4 to 10 calories may be regarded as indicative of relevant thermal intensities.

Blast (Troops)

Unless a soldier is in a collapsible structure it will be difficult to injure or kill him with overpressure. For troops in shallow foxholes, overpressures of 25 to 75 pounds per square inch (psi) are required to produce disablement.

Blast (Structures)

In limited wars we may be anxious to minimize the destruction of urban dwellings, which may be significantly damaged at overpressures above psi. At about 5 psi, urban damage will be severe. (Thermal effects on structures are in general less important than blast effects.)

Nuclear Radiation (Troops)

Again, it is mainly people who are affected by nuclear radiation. We may select three levels of damage: First, injury, lasting for months. Second, death, even though not immediate. Third, immediate incapacitation leading to death in a very short time.

Troops who receive a radiation dose of 200 roentgens will suffer debilitation, sickness and nausea lasting several hours, and, after several days of apparent recovery, will become ill and unfit for combat duty for a few months.

Most individuals will die from a radiation dose of 600 roentgens—

not immediately, but in a week or two. The debilitating effect will be more drastic, followed by nausea, a recovery period of a few days, and then a decline leading to death.

A radiation dose of 1000 to 1500 roentgens will incapacitate the average soldier within minutes. There will be no recovery period of significance and death will usually ensue in a few days.

SOME WEAPONS AND THEIR EFFECTS

A 20-KT Fission Weapon

Assuming that limited wars should be fought primarily with nuclear weapons of limited yield, we will first consider the nominal-yield (20-KT) Hiroshima and Nagasaki fission weapon, representative of the low-yield fission weapons now in our stockpile.

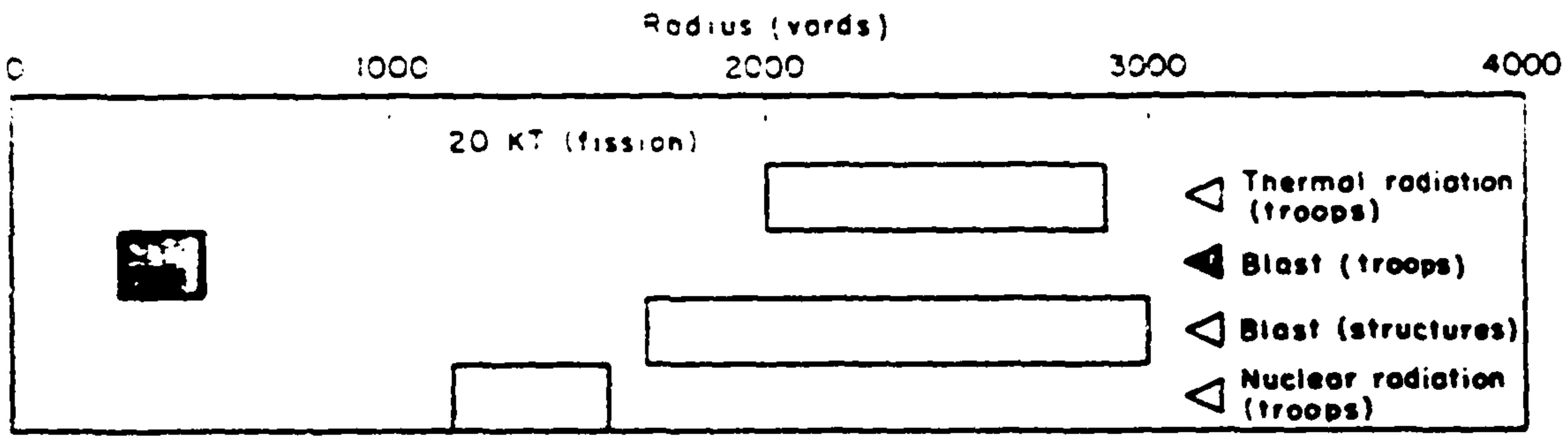


Fig. 5—Weapon effects: a 20-KT fission weapon

The radii of the various effects of this weapon, measured along the ground, are shown in Fig. 5 and are based on the assumption that the bomb is burst at fireball-radius altitude or higher to avoid fallout.

The first thing we notice is that the dominant effects of a 20-KT fission weapon are blast and thermal radiation. The range of thermal effects (4 to 10 calories per square centimeter) and blast effects (2 to 5 psi) extends far to the right of significant nuclear-radiation effects (200 to 1500 roentgens). The thermal effects shown assume a clear day and relatively unprotected enemy troops—an unlikely situation in general.

Of least consequence is the effect of blast on troops, since Fig. 5 assumes that an overpressure of 25 to 75 psi is needed to injure or incapacitate.

Even at the 20-KT level nuclear radiation is by far the most significant effect against troops because the other effects of greater range are fairly easily negated by simple countermeasures or by weather.

A 1-KT Fission Weapon

The second weapon we will consider, a 1-KT fission weapon, is in the yield range of weapons that might be unidentifiable under the terms of agreements now being considered at Geneva.

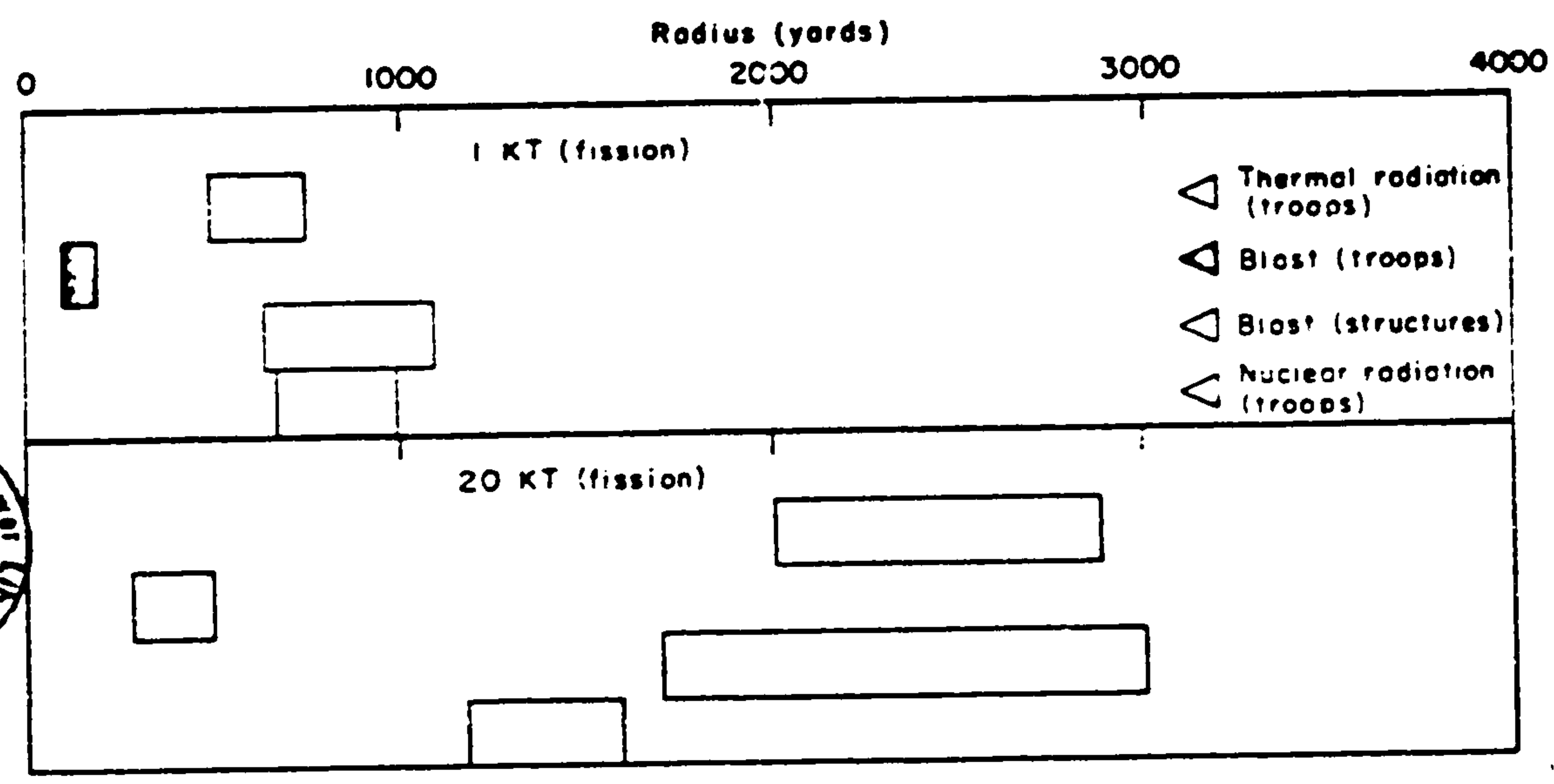


Fig. 6—Weapon effects: a 1-KT fission weapon (compared with a 20-KT weapon)

This weapon is assumed to be designed so that most of the neutrons can get out of the warhead, and we see from Fig. 6 that the nuclear-radiation effects are roughly comparable to the radii of blast effects against structures and that they are somewhat greater than the radii of thermal effects against troops. The range of blast effects on humans is quite small.

The reason for the change in the relative magnitude of these weapon effects lies in the scaling laws that apply to the effects.

[redacted] Most significant, about one-third of these neutrons will have energies in the 14-MEV range. This implies a very important secondary source of gamma rays (referred to earlier).

[redacted]

Figure 7, above, shows how much farther the nuclear-radiation effects of a [redacted] warhead extend beyond the effects of blast and thermal radiation. It now becomes possible to use these effects selectively, if desired. Comparing the [redacted] weapon with the [redacted] fission weapon, we see that the radius of [redacted] nuclear-radiation effects is about [redacted] that of the fission bomb. In terms of area, the [redacted] has about [redacted] coverage as the [redacted] fission weapon.

From a military viewpoint, this means that a [redacted] weapon can accomplish as much radiological damage as four [redacted] fission weapons. Furthermore, if we are concerned about fission-product release, the amount can be reduced by about [redacted] Another important factor is that a fusion-type radiation weapon such as [redacted] delivers nuclear radiation almost instantaneously in contrast to the fallout-producing weapons. No significant residual surface contamination need result from the use of such weapons.

So much for the comparison of [redacted] and fission weapons. Figure 7 also shows that the radiation effects of the [redacted] are greater than those of the [redacted] fission weapon. In fact, to match the antipersonnel radiation effects of [redacted] a fission weapon having a yield of [redacted] must be used.

This observation bears on the question of instability in limited wars. If we are using low-yield fusion weapons, and the enemy does not have such weapons, he will have to increase the level of violence substantially to match the nuclear effects of our weapons. In terms of the other effects, blast and thermal radiation [redacted] fission weapons will extend beyond the scale of Fig. 7. In addition, the fission products released into the atmosphere will be vastly increased. This can have serious political implications.

Two things may be said concerning countermeasures against nuclear radiation. For troops in combat, digging to depths that will provide adequate shielding may be ruled out as impractical. In any case, earth being the primary shielding material, gamma rays are of prime concern and the more energetic gamma rays resulting from fission weapons are more important (or less attenuated) than those from fission weapons. [redacted]

To sum up this comparison of the effectiveness of [redacted] and fission bombs as antipersonnel weapons: first, fusion weapons are more effective per unit of yield; second, their radiation effectiveness can be matched only by a very substantial increase in yield of competing fission weapons; and third, physically destructive (blast) effects and radiological effects can be employed selectively, thus allowing a degree of flexibility not found in fission weapons of comparable yield.

VERY-LOW-YIELD NUCLEAR WEAPONS

It is now possible to envision all-fusion weapons [redacted]

[redacted]

[redacted]

Figure 8 shows the range of effects for the 1000-pound [redacted]

Radius (yards)

[redacted]

[redacted]

MILITARY APPLICATIONS OF LOW-YIELD WEAPONS

We have noted that in limited wars troops are likely to be primary targets. There may be many tactical situations in which enemy troops take refuge in built-up areas.

In the past, to dislodge troops or destroy such strong points, we have had to mount extensive raids with HE weapons—often we have had to destroy the city. Nuclear weapons can do this, too, and much more easily.

The low-yield fusion weapons of the future may make it possible, using radiation, to destroy or rout troops concentrated in built-up areas without necessarily destroying the city.

Even with the most judicious use of low-yield fusion weapons, overpressures of some significance will reach the ground. But it should be possible to blanket large areas with lethal radiation without inflicting severe blast damage. In all probability, overpressures of 1 psi or so will break windows, knock out doors, etc. But the point to be made is that serious levels of damage can be avoided and the city can remain reasonably intact after the attack.

CONCLUSION

Finally, the potential military capability promised by low-yield fusion weapons has an important bearing on current discussions of the use of nuclear weapons in limited wars. Such weapons represent more than a minor gain in offense capability. It can be argued that under some circumstances likely to occur in limited wars, such weapons may provide a realistic military capability where none can be provided by fission weapons or high explosives. The certainty of our having these fusion weapons may only be ensured by continued weapon development and testing along lines with which we are now familiar.

Development of low-yield fusion weapons for limited wars. Department Of Defense, 1 June 1959. U.S. Declassified Documents Online, https://link.gale.com/apps/doc/CK2349212965/USDD?u=camb55135&sid=USDD&xid=610fe4e1. Accessed 7 July 2020.