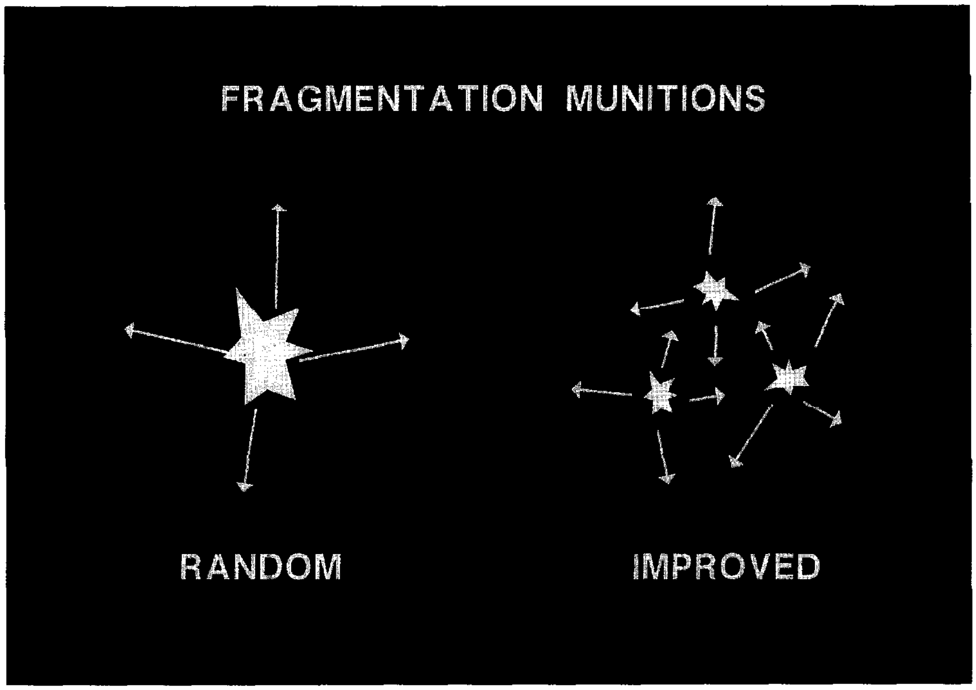

Fig, 1-31, The random-fragmentation munition on the left produces a powerful blast effect and a limited number of relatively large fragments. The cluster munition on the right produces many small fragments, which—although less lethal individually—may generate more casualties because they hit more individual targets many times.

modern improved-fragmentation munitions rely on preformed spheres (still called shrapnel) to do their damage. With the exception of their fuses—the old shrapnel ball used a primitive, often unreliable fuse to ignite its explosive powder—the principle of these weapons has remained unchanged.

Cluster* (or *Cargo-Carrying) Munitions. Another way to increase the effectiveness of a fragmenting munition is to load a number of smaller explosive munitions into a larger cargo-carrying munition. When a cluster munition is detonated (either before or upon the carrier's impact), its submunitions or bomblets are disseminated over the surrounding terrain. When they explode in turn, fragments are dispersed over a much wider area than would have been affected if the same mass of potential fragments had been derived from a single thick-walled shell casing (Figure 1-31).

These two modern developments—improved-fragmentation munitions and cluster munitions—are not incompatible; indeed, cluster munitions depend upon the improved-fragmentation submunitions for their source of wounding agents (Figures 1-32 and 1-33).

The concept of the cluster munition is not new. In two among many examples, cluster bombs were used extensively by the Germans in the battle of the Kursk Salient on the eastern front in 1943[12] and were implicated in a 1944 accident at an English air station.”

Almost every weapon system in modern conventional warfare uses improved-fragmentation or cluster munitions. The absolute radii of these munitions from point may not be its great as that of random-fragmentation munitions, simply because their fragments may not the fewer but heavier random fragments might. But the nature of combat is such that most casualties are generated at relatively close distances. Thus, the effectiveness of improved-fragmentation and cluster munitions will be greater, because their smaller, more uniform fragments—albeit perhaps lacking the mass and velocity to kill distant personnel outright—will be much more numerous in the vicinity of most of the combatants (Figure 1-34). Consequently, many more soldiers are likely to be hit and at least incapacitated (Figure 1-35). The surgical resources required to treat *so* many injured personnel would be severely strained.

Secondary Missiles. **A** primary projectile may strike or blast apart rocks, trees, buildings, sand, or other materials with a force sufficient to create *secondary missiles* out of them, and they, in turn, may have the velocity necessary to wound personnel in their paths. Such wounds (like a face peppered with sand, for

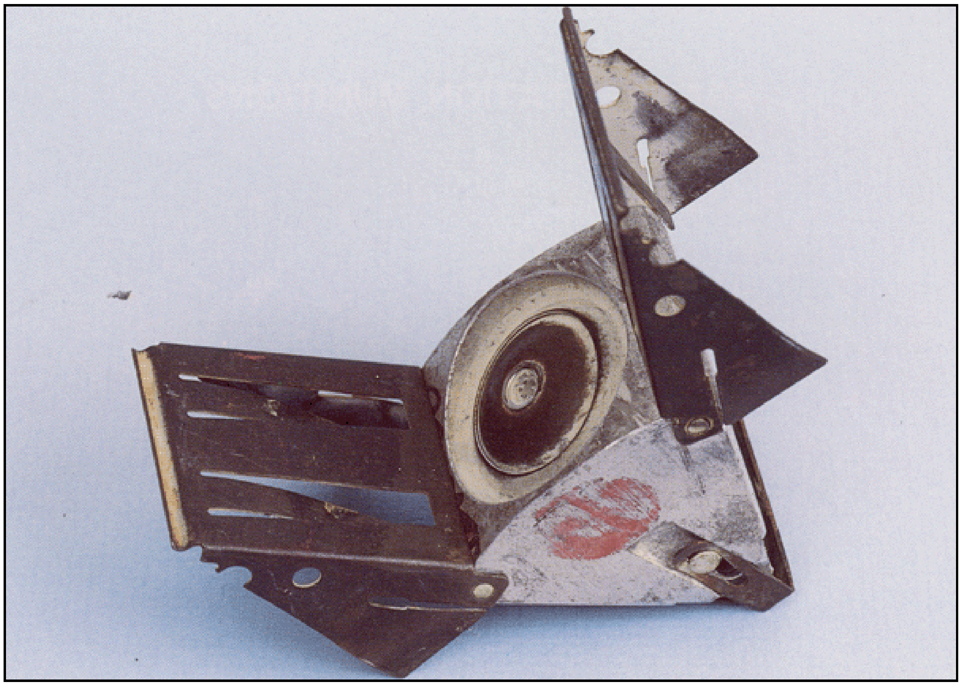

Fig. 1-32. Cluster munitions carry smaller submunitions, such as this aptly named *Dragon Tooth,* an early design that was used during World War II. It was designed to explode on impact.
Source: Explosive Ordnance Disposal Group, Quantico Marine Corps Base

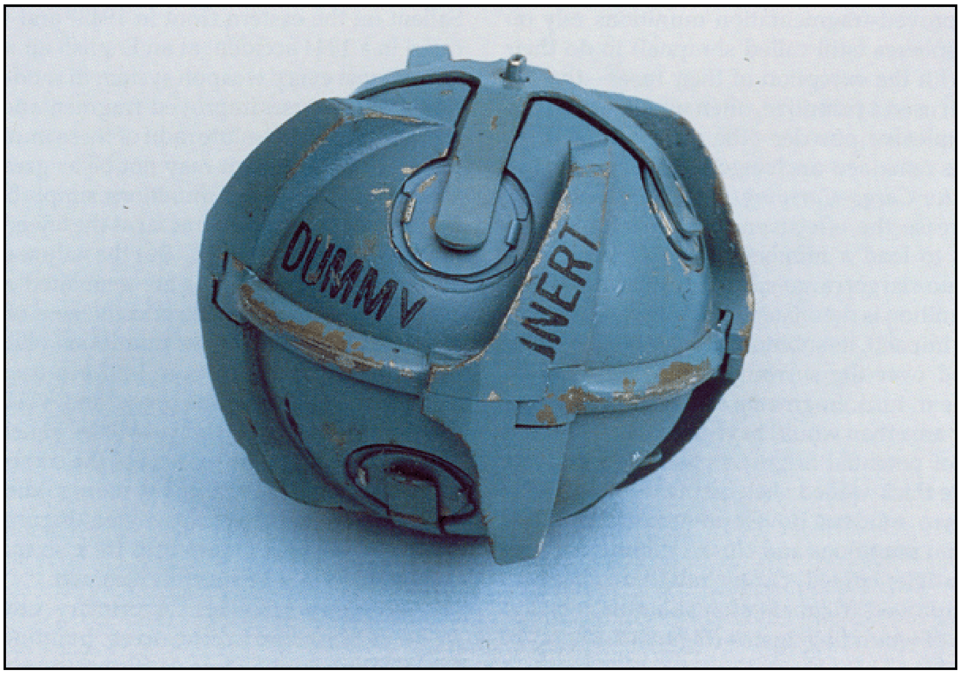

Fig. 1-33. A cluster bomb may contain dozens of these grenadelike *bomb-launched units* (BLUs). **A** preset BLU may explode after delays of **up** to several days and, once set, cannot be deactivated.
Source: Explosive Ordnance Disposal Group, Quantico Marine Corps Base

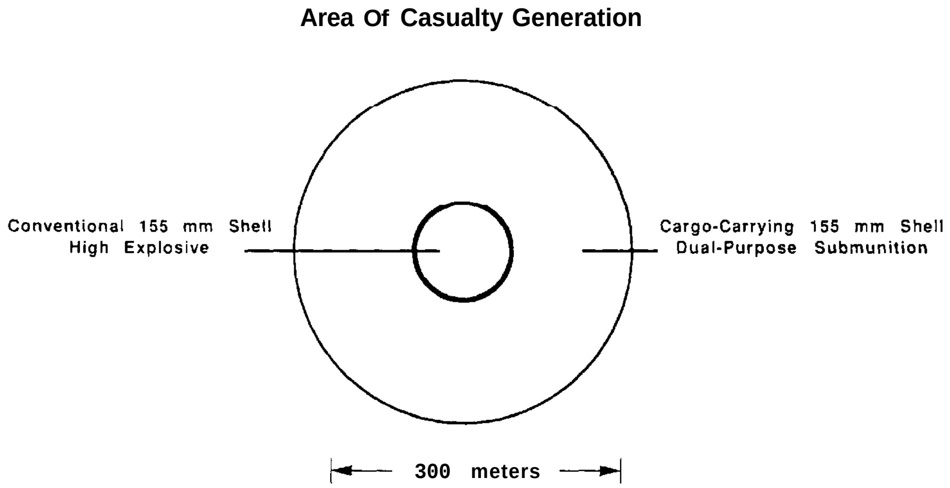

Fig. **1-34.** The effective radii for conventional and cluster munitions

Fig. 1-35. Modern exploding munitions have changed the nature of injuries in warfare. This casualty has received many small penetrating wounds from one cluster munitions in World Wars I and II who would have presented with one (or a few) relatively large penetrating wounds, such as those in Figures 1-23 and 1-24.
Source: Wound Data and Munitions Effectiveness Team

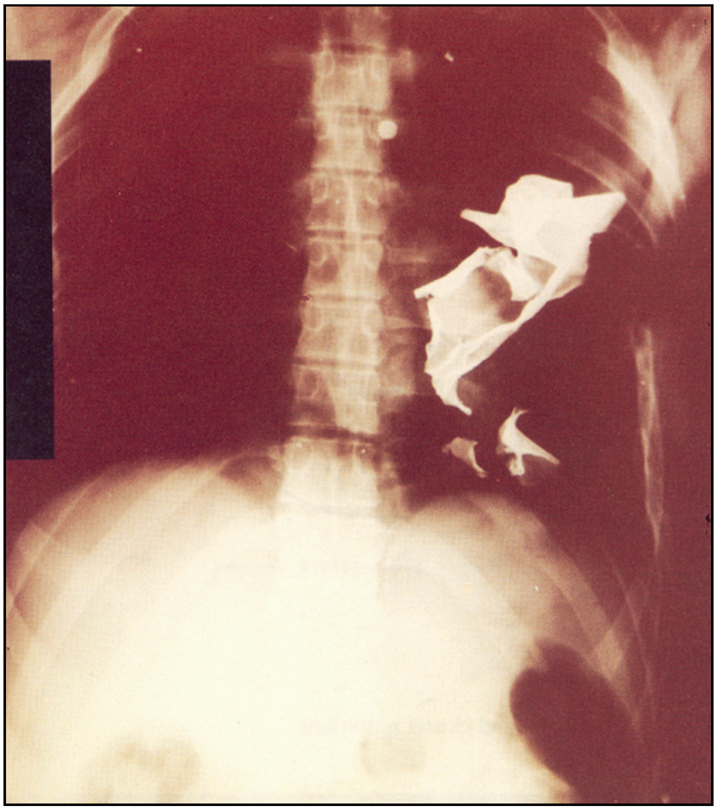

Fig. **1-36.** The soldier shown in this roentgenogram was killed by a secondary missile (a piece of metal roofing that was blown off by a rocket).
Source: Wound Data **and** Munitions Effectiveness Team

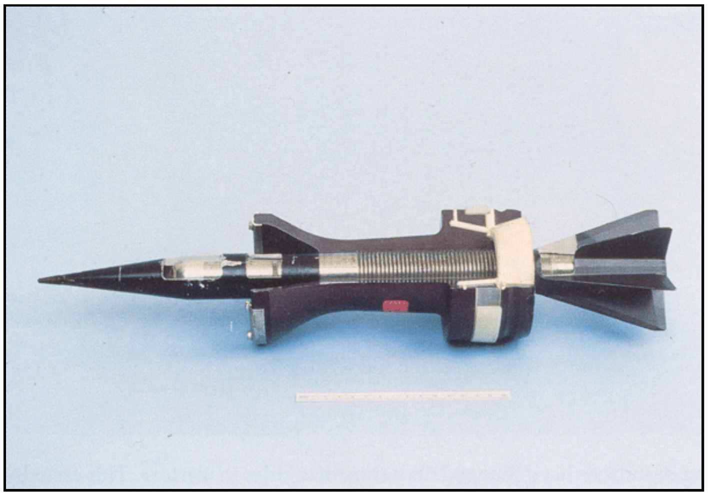

Fig. **1-37.** This 105-mm APDSFS antitank projectile has a sabot (the cylinder around the middle of the arrow-like penetrator).
Source: Explosive Ordnance Disposal Group, Quantico Marine Corps Base

example) may be relatively trivial but debilitating enough to keep a soldier out of combat for some time; others that involve heavier secondary missiles, such as bricks, may be much more serious (Figure **1-36).**

In the aerial bombing of cities, secondary missiles probably produce more casualties than all other causes of injury combined. Flying glass is particularly dangerous, even at a considerable distance from the source of the blast; its thin, sharp shards can easily penetrate flesh, and the more glass breaks into small pieces, the more wounds it can cause.

Wounds may also be badly contaminated by secondary missiles. A landmine, for example, creates high-velocity secondary missiles from the ground in which it is buried, making it likely that the severe wounds it causes will be filled with dirt, pebbles, and even chunks of plants.

Antimatériel Munitions That **Have** Antipersonnel **Effects**

Antimateriel munitions are designed to penetrate targets, such as buildings or fortifications, and to destroy (or render inoperative) armored fighting vehicles. Their warheads work on either of two principles: *(a)* they punch a hole through armor, because they travel at **very** high **speeds** and therefore have great kinetic energy, or *(b)* they depend upon explosive effects, such as fragmentation or blast. To be effective, fragmentation warheads must produce fragments that are much larger than those resulting from antipersonnel exploding munitions. Personnel who are caught in the path of an antimateriel exploding munition's effects will almost always be injured or killed.

When these penetrating warheads hit armored vehicles and similar enclosures, the crews are exposed to reflected (and thus greatly enhanced) blast waves known as *complex blast waves.* Antitank munitions that can produce significant blast effects behind armor include *(a)* kinetic-energy warheads, and *(b)* explosive antimatériel warheads.

Kinetic-Energy Antimatériel Warheads. Usually these munitions are fired from heavy guns, which have barrels that are long enough to give these warheads the velocities they need to be effective. The names of these munitions—such as *long-rod penetrators, APFSDS (armor-piercing, fin-stabilized, discarding-sabot) rounds,* and *composite rigid* shots—reflect essential aspects of their design. The mechanisms of armor penetration in these kinetic-energy weapons, however, are the same.

The long-rod penetrator operates on the same principle as the armor-piercing round used by small arms, but on a much larger scale. Its muzzle velocity may exceed 5,000 fps (much faster than the velocity of a bullet from an M16, for example, which is 3,200 fps).

The APFSDS round has several unusual characteristics (Figure 1-37). First, its arrow like penetrating warhead is *subcaliber* (that is, it is much smaller than the bore caliber of the weapon that fires it). Second, the warhead is encircled by a cylindrical *sabot* (literally, shoe) that has the same diameter as the bore of the barrel. The sabot not only positions the penetrating warhead steadily in the barrel, but also is exactly wide enough to receive the full thrust of the separately loaded propellant when the weapon is fired. This ensures that the projectile will be traveling at a maximum velocity when it leaves the barrel. Third, when the projectile and its sabot are propelled free of the barrel, the sabot falls away from the projectile, greatly reducing the aerodynamic drag on the penetrator. Fourth, the penetrator has fins so that it does not lose any of its kinetic energy by becoming unstable during its flight. Finally, the density of the tungsten or depleted-uranium rod inside its streamlined nose cone facilitates the penetration of the target.

The composite rigid shot resembles the APFSDS round, but its outer layer is not discarded. Instead, the area between the penetrator and the barrel is filled with a lightweight as aluminum) **and** the whole munition stays together in flight.

When the rod from one of these munitions reaches armor, its enormous kinetic energy is applied to a small target area. It penetrates the armor, blowing out a cloud of fragmentation debris (called *spall*) from the inside wall of the hull or turret, along with a plug of armor, followed by the residual portion of the rod. Because these objects are traveling at supersonic speeds, the shock waves produce a blast overpressure that is enhanced when the waves are reflected from the vehicle's inner walls.

The principal injuring mechanisms of the kinetic-energy warhead are fragments and secondary fires. This warhead will kill any people in its path, whether they are inside or outside an armored vehicle.

Explosive Antimatériel Warheads. The best-known explosive antitank warhead is the *shaped-* or *hollow-charge warhead.* Unlike the kinetic-energy warhead, a shaped-charge warhead can cause several distinctive kinds of injuries. An explanation of its operating principles may clarify the etiology of these unusual wounds.

Shaped-charge warheads contain a high explosive that has been cast or pressed into a cylinder. Late in the nineteenth century, munitions designers found that the energy released by a warhead's detonation could be focused by hollowing out the front of the explosive into a cone-shaped cavity with an apex that faced the middle of the cylinder. During World War I, they learned that lining the face of the cavity with a nonferrous, low-melting-point metal (called a *melt sheet*) focused the energy even more.

The charge is detonated at the base of the explosive cylinder. As the detonation wave travels through the explosive, it causes the cavity's metal liner to collapse on its axis of symmetry, beginning with the cone's apex. About 20% of the liner—together with the gas from the explosive's combustion—is forced into a high-velocity jet, which takes the shape of a long, thin rod. The front of the jet may reach a velocity of 20,000 fps, while the rear of the jet travels at about 6,000 fps. The jet's velocity allows the warhead to perforate monolithic steel plate that is about 5.5 times the diameter of the explosive cylinder. Thus, a weapon like the American-made TOW2 that has a 6-inch warhead can penetrate steel armor that is more than 33 inches thick (Figure 1-38).[14]

Among the first shaped-charge weapons to appear in World War 11—which are now known as *light antitank weapons* (LAWS)—included the American-made bazooka (which fired a shaped-charge warhead propelled by a rocket) and the German-made Panzerfaust (a shaped-charge warhead fired from a recoilless gun). Since then, a variety of *high-explosive antitank (HEAT) weapons* utilizing shaped-charge warheads have appeared, many of which are used directly against personnel (Figure 1-39).

Because armor penetration by a shaped-charge warhead does not depend upon the warhead's impact velocity, the munition need not be fired from a large, heavy gun to be effective. In fact, these warheads are fielded in a great variety of sizes, and can be fired from small arms or even thrown by hand. Because of their versatility, shaped-charge warheads can be used very effectively as antipersonnel weapons.

Unlike the effects of any other weapon used in conventional war, the effects of a shaped-charge warhead on body tissues are a complicated mix of ballistic, blast, and thermal traumas.

As the metallic jet passes into an armored vehicle, it produces fragments, a bright flash, heat, smoke, and blast overpressure. The blast levels and expanding gases are usually sufficient to blow the vehicle hatches open, and personnel who are sitting in openings may be propelled out of the vehicle. Anyone in the path of the high-temperature jet will suffer catastrophic burns. As American medical officers in War and their Israeli counterparts in the Yom Kippur War noted, these injuries often looked as though they had been

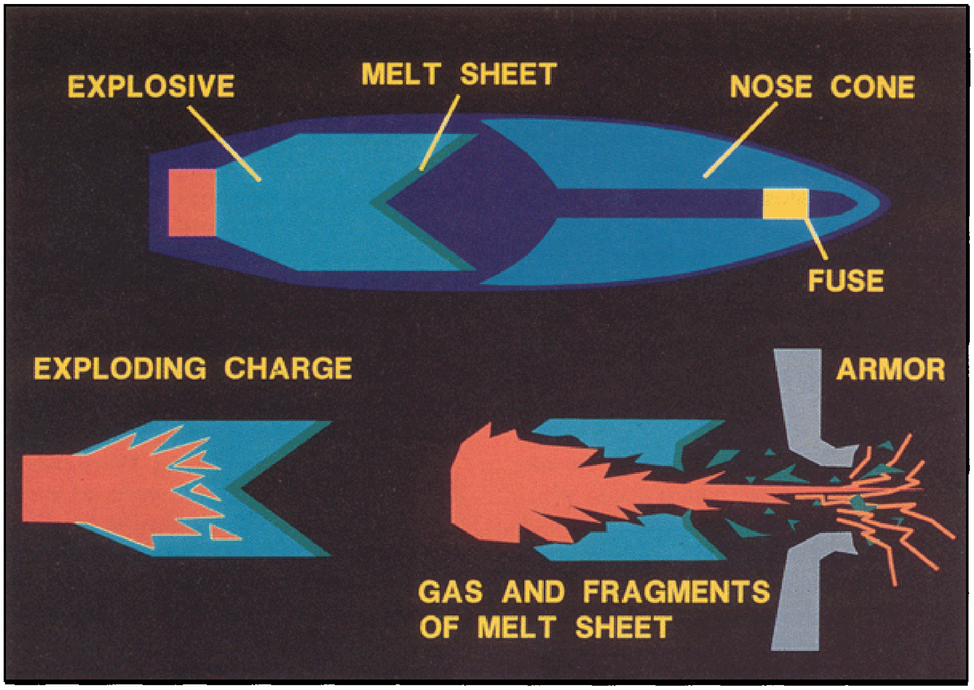

Fig. 1-38. In a shaped-charge warhead, the thermal and kinetic energies of the explosive detonation are focused by both the shape of the charge and the melt sheet that lines it. Although the resulting jet of gas and molten metal has a temperature that may exceed 5,000” C, it is the jet's tremendous kinetic energy, rather than its temperature, that allows it to penetrate armor that is more than 1 foot thick.

Fig. **1-39.** The marine holds a cutaway version of a Dragon medium antitank missile, in which the characteristic hollow shape can be clearly seen.
Source: Explosive Ordnance Disposal Group, Quantico Marine Corps Base

created by a blowtorch (Figures 1-40 and 1-41).

While perhaps not as predominant as the catastrophic injuries caused by the jet, fragmentation wounds are common with shaped-charge warheads. The fragments come from three different sources: *(a)* the nonferrous metal melt sheet of the warhead, *(b)* the nose cone and casing of the warhead, and *(c)* the target itself.

Fragments from the melt sheet exist transiently as globules of hot metal, which may cause deep burns (Figure 1-42).

Fragments from the nose cone and casing are usually small; like the melt sheet, they are made of nonferrous metal and are difficult to detect in a casualty by standard imaging techniques (Figure 1-43). They are most likely to hit those personnel who are off to the sides of the projectile's path. These casualties will tend to be injured by the fragments rather than by burns from the hot metal.

Most of the fragments come from the target itself. When an antitank warhead perforates an armored wall, the wall produces a shower of spall fragments that range in size from small, dustlike particles to large chunks. These fragments scab off in a cone-shaped pattern on the interior side of the armored wall, resulting in multiple fragmentation injuries to anyone within that cone-shaped area (Figure 1-44). In addition, the dustlike particles may burn rapidly in air, a phenomenon known as the *vaporific effect.* Anyone who is exposed to these particles may incur small but deep localized burns (Figure 1-45).

In World War 11, injuries were caused primarily by fragmentation. The kinetic-energy penetrator of the shaped-charge warhead tended to break up into many fragments. American forces in Vietnam were more likely to be injured by spall.

Some warheads can do great damage even without penetrating the armor. Unlike the shaped-charge warhead (in which spalling was just one of the damaging effects), a *high-explosive squash-head antiarmor warhead* relies completely on spall as its damaging mechanism. This warhead forms a large blob of plastic explosive when it is squashed against the target at the moment of impact. The ensuing detonation creates a

Fig. 1-40. This casualty, who was killed inside an armored personnel carrier, suffered the characteristic mutilation that a shaped-charge antitank warhead (in this case, a Soviet-designed RPG-2) may inflict.
Source: Wound Data and Munitions Effectiveness Team

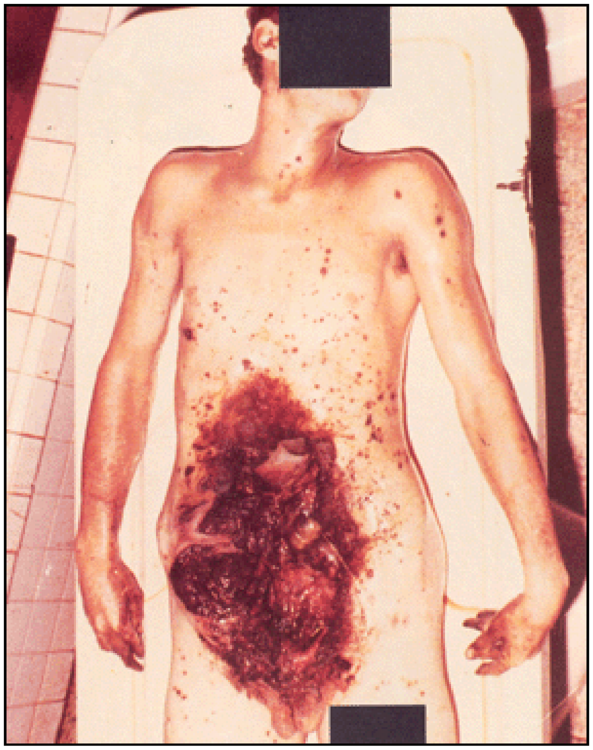

Fig. 1-41. This casualty was killed by a small shaped-charge warhead that was fired from a grenade launcher.
Source: Wound Data and Munitions Effectiveness Team

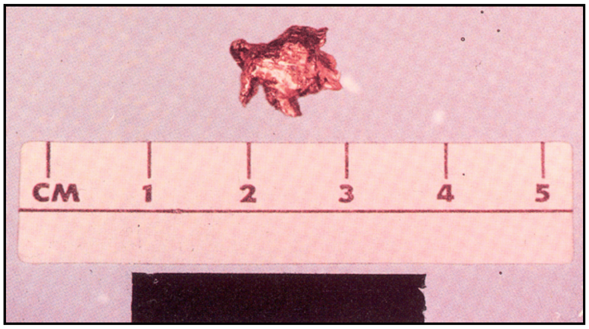

Fig. 1-42. This copper globule came from the melt sheet of an RPG-2 and was found embedded in the casualty's brain.
Source: Wound Data and Munitions Effectiveness Team

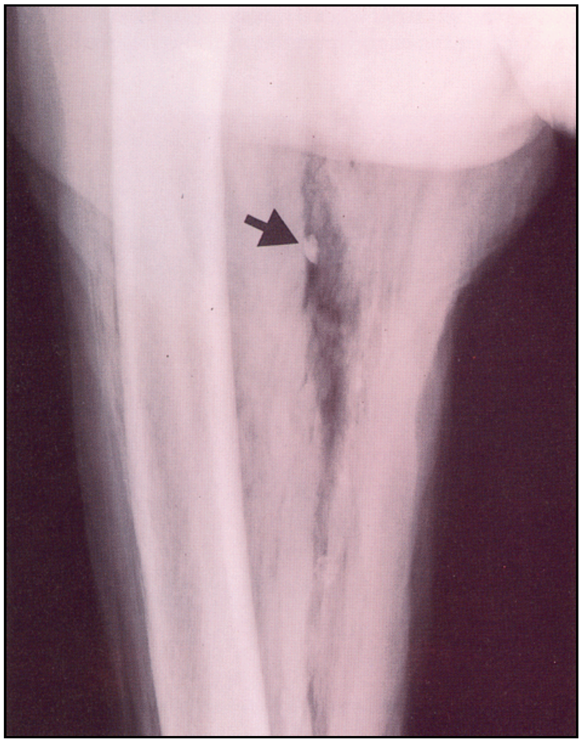

Fig. 1-43. Only the largest of six aluminum casing fragments from a shaped-charge warhead, ranging in size from 2 mm to 6 mm, can be seen in this roentgenogram of soft tissue.
Source: Explosive Ordnance Disposal Group, Quantico Marine Corps Base

shock wave that passes through the armored wall and throws off large scabs of metal spall when the shock wave reaches the wall's far side. Even though the armor is not penetrated, the effects of the shock wave not only damage or destroy the materiel, but also cause secondary explosions and fires involving any munitions that are contained within.

Ordnance Utilizing Explosive Munitions

The three categories of weapons that fire explosive or larger-projectile munitions are cannons, mortars, and guns.

Other munitions (such as bombs, rockets, grenades, and mines) use explosive devices as well, but these are dropped, launched, thrown, or planted rather than fired by artillery ordnance.

Cannons. A cannon is like a large machine gun that uses a recoil automatic-firing mechanism. Its firing trajectory is relatively flat, and its range may reach 1–2 km. Unlike a machine gun, a cannon fires 20–40-mm explosive rounds instead of inert bullets (Figure 1-46). Because it is also much larger than a machine gun, the cannon is mounted on an armored fighting vehicle, which takes the brunt of the weapon's punishing recoil.

Cannons are not big enough to be used against tanks but are usually too big to be used against personnel, and so they have a relatively small role on the battlefield. They are intended to be used primarily against aircraft and lightly protected armored vehicles. In Vietnam, however, the opposing forces had few of these materiel targets, and therefore the American forces found that twin-mounted 40-mm cannons were effective as ad hoc antipersonnel weapons.

Some cannons use the *Gatling gun* principle. Unlike most cannons, which have one barrel, the Gatling gun has six barrels arranged in a circle, and operates like six small arms put together in one weapon. Each barrel is at a different stage of the firing sequence at any given instant, and thus the loading, firing, and extracting processes can be continuous and extremely rapid—6,000 rounds/minute is not an unusual rate of fire. The original model of the Gatling gun used a gas-operated firing mechanism, but modern versions use electric motors. They fire cannon shells or antiarmor projectiles containing tungsten rods.

Mortars. Unlike cannons, mortars are ubiquitous on the battlefield. This muzzle-loading weapon has a relatively short, stubby barrel (called a *tube),* the bore of which varies from 60–240 mm (bore calibers of 81 or 82 mm and 120 mm are the most common). Its light weight and small size allow it to be carried by a small crew of two or three soldiers, yet the World War II

[redacted]

Fig. 1-44. This casualty was killed by spall from the hull of an armored personnel carrier when it was struck by a shaped-charge warhead. Other munitions, including the squash-head warhead and the kinetic-energy penetrator, also create spall.
Source: Wound Data and Munitions Effectiveness Team

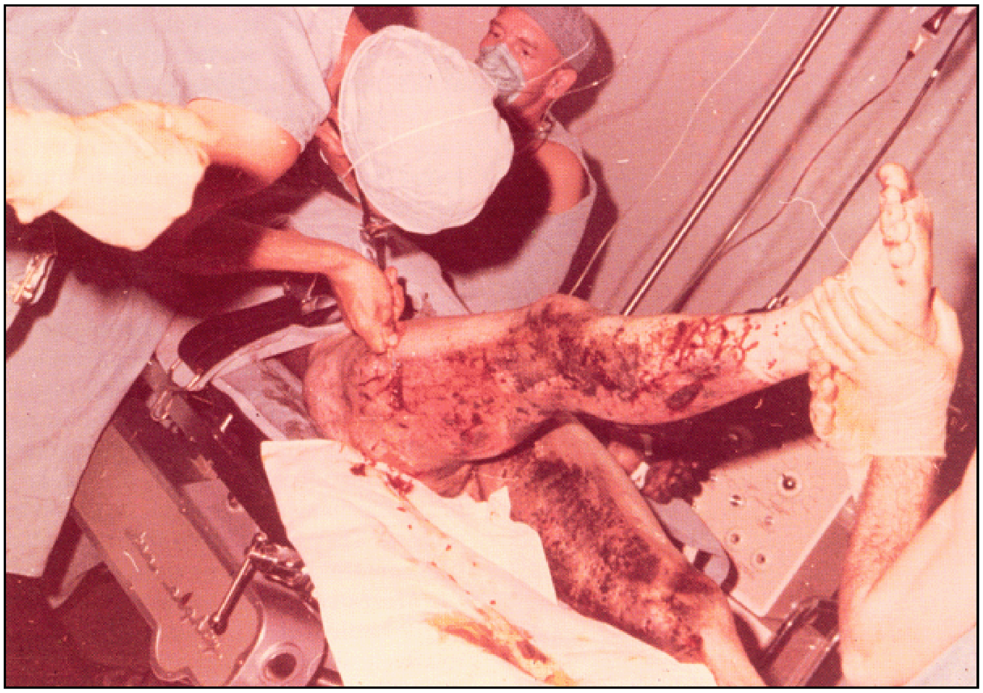

Fig. 1-45. This casualty's many tiny, deep burns were caused by small particles of burning aluminum that were created when a shaped-charge warhead struck the hull of an armored vehicle.
Source: Wound Data and Munitions Effectiveness Team

experience showed that one 81-mm mortar had the casualty-generating potential of three general-purpose machine guns, which would be served by a total of six to eight soldiers. Because its recoil is directed into the ground rather than controlled by a mechanism in the weapon itself, the mortar is one of the simplest of weapons to operate.

The primary mission of a mortar is to cover those units that are not covered by artillery fire. Mortars are designed to fire an explosive projectile at an angle between 45" and 80". Once the crew has identified the target, they consult a table to determine at what angle the mortar should be set and the size of the explosive charge that should be loaded with the projectile. By varying the height of the parabolic trajectory, the mortar crew can select ranges between several hundred meters and several kilometers.

A mortar characteristically has a high rate of fire; in fact, short-time rates of 20–25 rounds/minute are not unusual. It fires explosive munitions that are conventionally called *bombs* (Figure 1-47). Although these are not true bombs because they are not dropped from aircraft, their tail fins resemble those of true bombs.

Guns. In the context of the artillery forces, a **gun** is a weapon that *(a)* is crew-served, *(b)* has a mechanism to control recoil, *(c)* has a bore caliber greater than 40 mm, and *(d)* has a barrel length greater than twenty times the bore caliber. The structure of a heavy gun resembles that of its small-arm counterpart, except that in a heavy gun the bolt is called a *breech block.* Depending on the gun's design, the sequence of loading the round and extracting the spent cartridge may be done either manually or mechanically, but—because the energy from the firing of one round is not used to chamber the next—not automatically. These heavy guns come in a variety of sizes and shapes, and can be either towed by tractors or trucks or propelled under their own power using their own tracks.

Most heavy guns are used primarily as indirect-fire weapons (that is, the crew cannot see the targets). When this is their mission, they may fire either antimateriel or antipersonnel munitions. However, guns may sometimes be used directly against specific, visible targets, such as armored fighting vehicles. In this situation, they usually fire antimateriel warheads, such as kinetic-energy penetrators.

Unlike small arms, in which the barrel length is relatively unimportant, the barrel length of heavy guns affects the muzzle velocity of the projectile. The longer the barrel, the greater the gun's range, but also

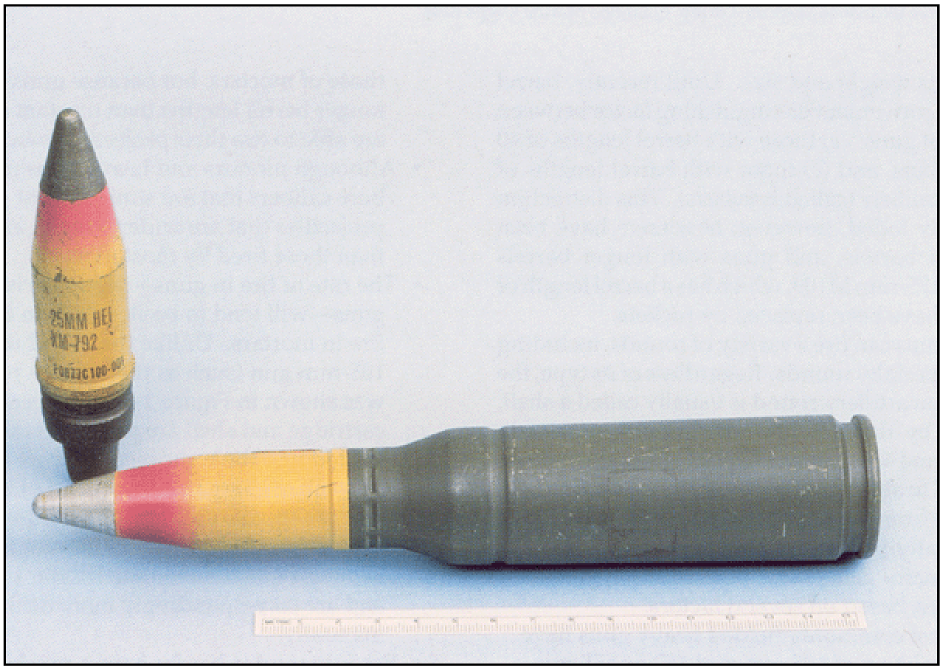

Fig. 1-46. This 25-mm round fired by the **M242** cannon of the Bradley Fighting Vehicle is a high-explosive incendiary round. **An** armor-piercing round is also available.
Source. Explosive Ordnance Disposal Group, Quantico Marine Corps Base

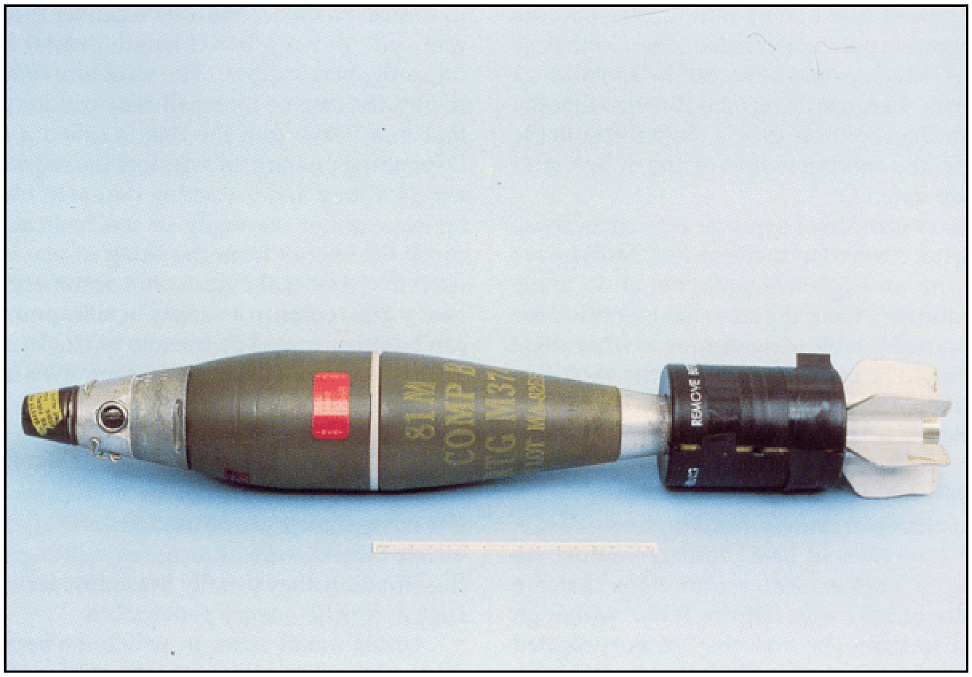

Fig. **1-47.** The propellant of this 81-mm mortar bomb consists **of** *(a)* a shotgunlike cartridge within the tail and *(b)* an auxiliary charge, which is the black incremental-propellant container wrapped around the tail. The weight of the mortar bomb totals about *3.5* kg, one-third of which is the weight of the explosive charge. The controlled breakup of a prenotched metal coil under the thin external case creates fragments.
Source: Explosive Ordnance Disposal Group, Quantico Marine Corps Base

the greater its weight and size. Until recently, barrel length was a convenient distinguishing factor between two classes of guns: (a) those with barrel lengths of 40 or more calibers, and *(b)* those with barrel lengths of less than 40 calibers (called *howitzers).* This distinction has gradually faded, however; howitzers have been given longer barrels, and guns with longer barrels (such as the 175-mm M109, which has a barrel length of 58 calibers) have been replaced by rockets.

Heavy guns can fire a variety of rounds, including all types of specialty rounds. Regardless of its type, the warhead of an artillery round is usually called a shell. Shells fired by the 105-mm and 155-mm howitzers weigh 15 kg and 43 kg, respectively. Although both are usually used to attack bunkers and other field fortifications, a shell from the larger weapon will clearly have greater casualty-producing potential.

The casualty-generating potentials of guns and mortars differ, based on several factors:

- The most commonly fielded heavy guns have bore calibers of 105 mm and 152 or 155 mm, although the Soviets have supplied many clients with guns having calibers of 122 mm and 130 mm. These bore calibers resemble those of mortars, but because guns have much longer barrel lengths than mortars do, they are able to fire their projectiles much farther.
- Although mortars and heavy guns may have bore calibers that are similar, most guns fire projectiles that are wider, longer, and heavier than those fired by most mortars.
- The rate of fire in guns—particularly in large guns—will tend to be slower than the rate of fire in mortars. Unlike the round fired by the 105-mm gun (such as the beehive round that was shown in Figure 1-29), in which the cartridge and shell are joined together and loaded into the weapon as a single piece, the propellant charge and warhead of the 155-mm gun are separate and must be individually loaded into the breech. Gun rounds also tend to weigh much more than mortar bombs do, and are correspondingly more difficult to load manually.
- Because mortar bombs have a much higher trajectory than do shells from guns, they tend to strike the ground nearly vertically, whereas shells from guns usually strike more ob-

> liquely. Consequently, the area of fragmentation around the detonation point of a mortar bomb will be relatively circular, whereas the fragments from a gun-fired munition that lands obliquely will be expelled outwards in a projection that resembles a butterfly's wings around the detonation site (Figure 1-48). There will be few casualty-producing fragments disseminated either to the front or to the rear of the gun-fired shell; the fragments in front tend to go high into the air, and the fragments to the rear tend to go into the ground (Figure 1-49).

Bombs and Rockets. Although rockets and bombs differ in their modes of delivery, they both contain an explosive within a thin-walled case. The greater the ratio of the explosive mass of the munition to the mass of its wall, the greater will be the blast effects and the more numerous will be the small fragments.

Modern bombs are munitions that are dropped from aircraft. General-purpose aerial bombs may have cases that are so thin that more than 50% of the bombs weight can be devoted to the explosive. In comparison, conventional explosive projectile shells must have thick walls to withstand the enormous stress of being shot through a barrel. For example, an older random-fragmentation munition that had a thick, heavy case (and therefore a proportionately smaller explosive charge) would have produced relatively few, albeit large, fragments, and may have been able to devote only 5%–10% of its weight to the explosive.

The design of a bomb depends on its objective. An antimatériel bomb may weigh 5004,000 pounds, and if most of that weight is devoted to the explosive, then the detonating blast's effects on both materiel and personnel may be significant. Secondary missiles created by the blast, as well as large fragments of thin casing from the munition itself, may result in the additional danger of ballistic injury to personnel. Modern bombs that are used primarily against personnel, however, do not depend upon blast effects, but rather have warheads that are designed to injure by fragmentation. Because of their considerable size, these bombs are effective cluster munitions.

Rockets are munitions that are propelled to their targets by self-contained reaction motors. Examples of modern artillery rockets are the Soviet-made BM 21 launcher and the new American-made *Multiple-Launch Rocket* System (MLRS). The MLRS can fire a salvo of as many as twelve 230-mm rockets as far as 30 km. Its rocket is an especially sophisticated example of modern ordnance designed to be used against both personnel and light matériel. Each munition carries 644 warheads, any one of which could kill dozens of people. These dual-purpose warheads are actually shaped-charge warheads that have thick casings, thus combining an antimatériel penetrating function with the antipersonnel fragmentation function. Dual-purpose submunitions are becoming increasingly common in combat (Figure 1-50).

Blast effects were especially prominent with the German-made Nebelwerfer and the Soviet-made Katyusha, the first free-flight artillery rockets designed to be fired in salvo that were extensively used in war. The Nebelwerfer was originally designed to fire large, thin-walled, rocket-propelled projectiles that were supposed to be filled with toxic chemicals or obscurants but were actually fielded with high-explosive charges. The effects of the 15-cm Nebelwerfer 41 were noted in 1942:

> The shell fragments were large and thin and it was clear that the purpose of the projectiles was not to produce shrapnel but to create a blast effect. The presence of *so* many dead showing no external signs of injury seemed to support this theory. The rapid and successive detonations produced during a Nebelwerfer barrage produced such rapid variations in air pressure within the bombarded zone that many victims suffered extensive damage to their lungs which killed them.”

This description of a lung-contusion trauma that is now identified as *blast lung* may mark the first premeditated use of an enhanced-blast munition—in this instance, a *fuel-air explosive* (FAE).

To achieve the FAE effect, all rockets but one in a seven-rocket Nebelwerfer salvo were filled with propane; the remaining rocket was filled with a high explosive. The propane-filled rockets would break apart, releasing the fuel into the air above the target area; ideally, the detonation of the high-explosive rocket would cause the explosive combustion of the fuel-air mixture. Frequently, however, the fuel-air mixture was inexact, resulting in the propane's slow combustion rather than an explosion.

FAE munitions have become sophisticated and prevalent in recent years. **A** typical **FAE** device now consists of *(a)* a cylindrical container of a liquid fuel, such as ethylene oxide or propylene oxide, the walls of which are scored so that the container can break apart in a controlled manner, and *(b)* a burster charge, located at the center, which extends along the long axis of the fuel container.

First, the burster charge detonates, and the contents of the fuel container are dispersed as a mistlike, disk-shaped fuel-air cloud over the ground. The diameter of this cloud may range from 50 feet (from an 80-

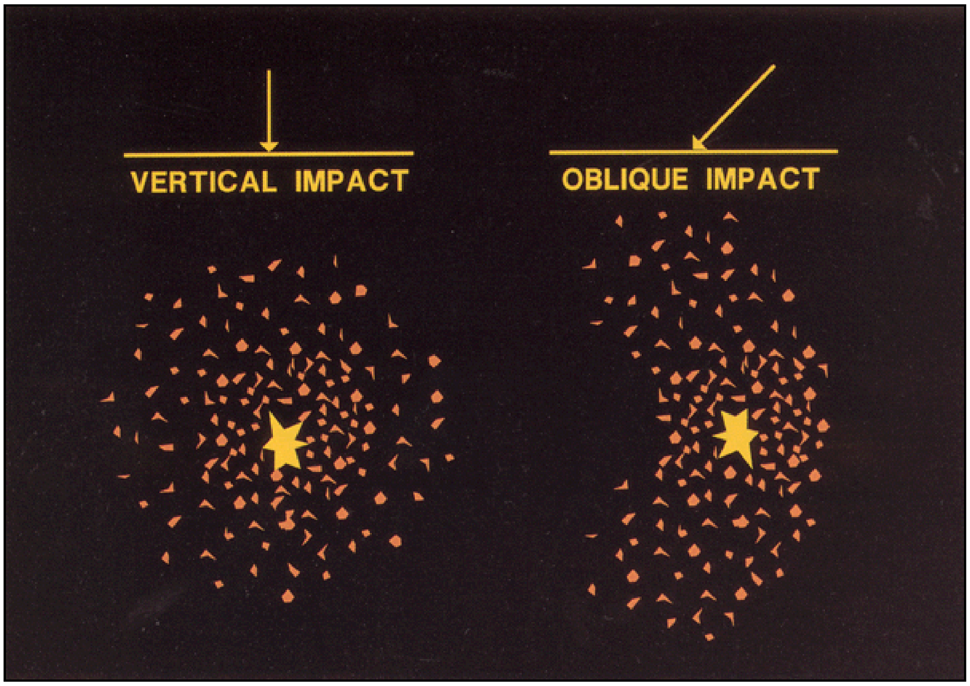

Fig. 1-48. The pattern of fragmentation produced by a random-fragmentation munition depends on the missile's trajectory at impact.

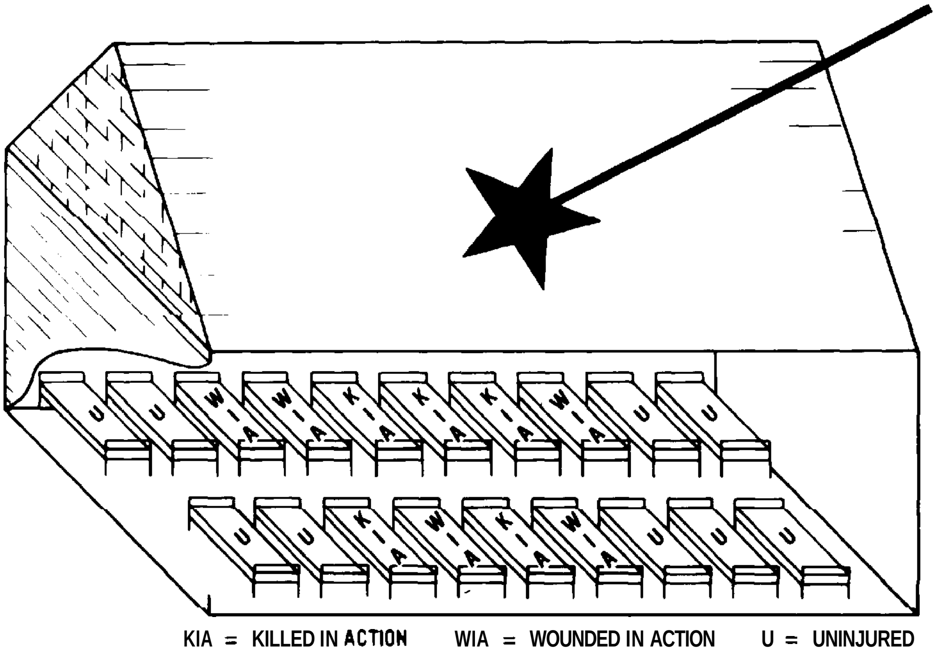

Fig. 1-49. This diagram illustrates the asymmetrical pattern of casualty generation that occurred when a 122-mm rocket struck the roof of a barracks in which soldiers were sleeping. The soldier who was immediately behind the detonation site sustained a nonlethal wound, as did the two soldiers directly in front of the rocket. However, several soldiers who were perpendicular to the rocket's impact trajectory on either side were killed.
Source: Wound Data and Munitions Effectiveness Team

pound FAE) to 150 feet (from a 2,000-pound FAE). The cloud flows around objects, such as trees and rocks, and into structures or field-fortification ventilation systems before it is detonated (Figures 1-51, 142, and 1-53).

Next, a second small charge ignites the fuel-air mixture (Figure 1-54). Given the appropriate complex conditions, the resulting detonation creates a lethal blast overpressure of 250–300 pounds/square inch (psi) throughout the cloud.

The vast dimensions of the FAE cloud ensure that the blast effects will occur over a much wider area than that affected by any conventional explosive munition. Since the Vietnam War, FAE weapons (such as the American-made BLU 96 guided glide bomb, which contains the tremendous load of 635 kg of propylene oxide fuel) have been improved so that their blast effects may now rival that of a small tactical nuclear warhead.'"

Unlike fragments, which move only on a linear trajectory, the FAE's blast wave can go around corners, penetrating the apertures in bunkers, the open hatches in armored fighting vehicles, and the hollows of trenches and foxholes. As this munition is used more frequently in conflict, blast lung and ruptured tympanic membranes will become more common; in Afghanistan, for example, FAE munitions (called volume bombs or vacuum bombs) made up a significant percentage of all the bombs that were dropped from Soviet aircraft."

Grenades. Grenades have been called the infantry's pocket artillery. These small explosive munitions are *(a)* thrown by hand, *(b)* fired from rifles, or *(c)* shot from specialized grenade launchers.

Hand grenades (the oldest of the three designs) have evolved in the way their fragments were generated. The earliest versions looked like small cast-iron or steel pineapples. The grooves cut into their casings were supposed to determine the size and shape of the casing fragments that would be produced upon detonation. In actual practice, however, fragmentation tended to be much more random. Most modern hand grenades have improved-fragmentation designs (Figure 1-55). The preformed fragments usually consist of several thousand small steel spheres held together in a plastic matrix. Like all explosive munitions, hand grenades have a fuse, but they also are designed with a delay of 4–5 seconds *so* that the thrower is not killed by the

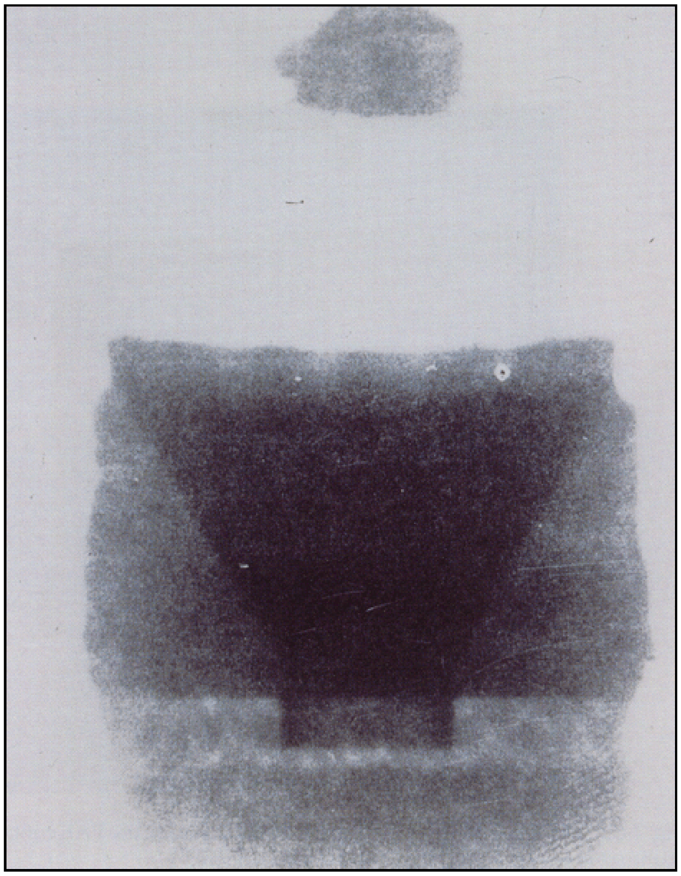

Fig. 1-50. The dual-purpose submunition shown in this roentgenogram measures about 4 cm in diameter and 8 cm in length. It contains about *30* g of explosive. The characteristic funnel shape of the shaped-charge warhead can be clearly seen. It not only can penetrate 80 mm of armor, but also can generate many antipersonnel fragments.
Source: **Explosive** Ordnance Disposal **Group,** Quantico Marine Corps Base