ANTI-PERSONNEL WEAPONS

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Stockholm International Peace Research Institute

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Preface

This book describes the development, uses and effects of conventional anti-personnel weapons such as rifles and machine-guns, grenades, bombs, shells and mines. It is intended as a contribution to the ongoing efforts to prohibit or restrict the use of some of the more inhumane and indiscriminate of these weapons.

The most urgent requirement for the modernization of international humanitarian law is a rule prohibiting the use of nuclear weapons and other means of mass destruction, including chemical weapons. There is also a need to prohibit or restrict the use of certain so-called 'conventional' weapons. The most immediate requirements are as follows:

(*a*) a rule prohibiting the use of napalm and other incendiary weapons (including white phosphorus) against personnel, the human habitat and natural resources;

(*b*) a rule prohibiting high-velocity small arms projectiles designed to yaw significantly, break up or deform within 150 mm of soft tissue or tissue simulant;

(*c*) a rule prohibiting the use of cluster bombs and shells and other area fragmentation munitions within a specified range of inhabited areas; and

(*d*) a rule requiring that all remotely delivered delayed-action weapons, including mines, should be fitted with a reliable neutralizing device, and prohibiting their use in inhabited areas.

In addition the implications of the development of fuel–air explosives, uranium projectiles, laser weapons and other wave-propagation devices must be carefully considered.

This book was written by Dr Malvern Lumsden, a SIPRI Research Fellow.

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March 1978

Frank Barnaby
Director

Abbreviations, Acronyms and Conventions

Abbreviations and acronyms

AC	Aircraft Cannon
AR	Assault Rifle
CDDH	Diplomatic Conference on the Reaffirmation and Development of International Humanitarian Law Applicable in Armed Conflicts
CEP	Circular Error Probable
ECM	Electronic Countermeasures
FAC	Forward Air Controller
FAE	Fuel–Air Explosive (also FAX)
FAESHED	Fuel–Air Explosive Helicopter Delivered
FAX	Fuel–Air Explosive (also FAE)
FVG	Fixed Vehicle Gun
GP	General Purpose
HAR	Heavy Assault Rifle
HE	High Explosive
HEAT	High-Explosive Anti-Tank
HEI	High-Explosive Incendiary
ICRC	International Committee of the Red Cross
LASER	Light Amplification by Stimulated Emission of Radiation
LMG	Light Machine-Gun
LNG	Liquid Natural Gas
LORAN	Long Range Navigation
MAD	Mass Air Delivery *or* Massive Assured Destruction
MMG	Medium Machine-Gun
PE	Probable Error
PGM	Precision-Guided Munition
RII	Relative Incapacitation Index
RPV	Remotely Piloted Vehicle
SAR	Search and Rescue *or* Short Assault Rifle
SAWS	Squad Automatic Weapon System
SLUFAE	Surface Launched Fuel–Air Explosive
SPIW	Special Purpose Individual Weapon

SSB	Salvo Squeezebore
SSZ	Special Strike Zone
TEA	Triethyl Aluminium
WP	White Phosphorus

Conventions

. .	Data not available
–	Negligible; not applicable

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Introduction and summary

Combatants have a legal obligation to care for the victims of war, and under the auspices of the International Committee of the Red Cross (ICRC), these obligations have been successively extended. From an early stage the Red Cross was concerned that unnecessary injuries to soldiers and civilians should be stopped. This would best be achieved by preventing war itself, but the Red Cross has not entered the field of war prevention; rather it has concentrated its efforts on the alleviation of suffering if war occurs. There can be little doubt that the greatest contribution to this would come from prohibiting or restricting the more inhumane and indiscriminate methods of warfare.

Modern conventional weapons have devastating effects and attention has been drawn to these during recent negotiations to modernize the 1949 Geneva Conventions. Proposals to prohibit or restrict the use of some of these weapons have been put forward, but all too often military considerations come before humanitarian concerns.

Several attempts have been made through the centuries to restrain legally the development of new weaponry. A few of these attempts have succeeded, only to be made obsolete by new technology. As will be seen in this book, an effort has been made in recent years to prohibit some of the more inhumane and indiscriminate weapons, and an examination of the legal, military and humanitarian issues raised by them is made.

Anti-personnel weapons may be defined as those weapons primarily intended to incapacitate *persons*. They may be distinguished from anti-matériel weapons, which are primarily intended to destroy or damage inanimate objects, although some munitions are referred to as 'general purpose' and may be used both against personnel and against matériel. Reference is made to general purpose munitions in so far as they are used against personnel.

Although nuclear, chemical, biological and incendiary weapons may be used as anti-personnel weapons, they are omitted from the present book since they are covered in other SIPRI publications (e.g., SIPRI, 1971, 1973, 1975*a*).

This book provides the background to the present international legal discussions of specific anti-personnel weapons.

Chapters 1 and 2 describe the rise of anti-personnel weapons from the earliest times until the present, showing the part they have played in history. At a time when there is a concerted effort to make the world a better place, we must not forget that the industrial powers produced devastating anti-personnel weapons in order to further colonialism. Modern anti-personnel weapons are more sophisticated than the sticks and clubs of the Stone Age, but they are still a very primitive way of tackling urgent social problems. They are unlikely to stop the trend towards a new order in the long run and they may greatly increase the human cost of progress.

Chapter 3 makes a brief review of the subject known as 'wound ballistics' –

that is, the study of the effects of projectiles in the human body. These are responsible for well over 90 per cent of casualties in modern warfare. In order to make an evaluation of weapons in the light of international humanitarian law, it is essential to understand something of what happens when, say, a man is shot.

Chapter 4 traces the trend towards smaller calibre and higher velocity military small arms. It is concluded that the full-power 7.62 mm ammunition similar to that used by most of the world's armies since the 1890s is unnecessarily powerful for present conditions and that for both military and humanitarian considerations the power of ammunition should be reduced. The modern tendency to capitalize on inflicting severe wounds by using very high velocity projectiles should be restrained by international law, and the proliferation of these new weapons calls for urgent measures. A further cause for concern is the trend in some countries for police forces to adopt more injurious weapons.

Chapter 5 describes the development of fragmentation weapons, which category includes most conventional weapons. As with small arms, the 'high velocity' effect is used to reduce progressively the size of the fragments. The modern tendency is to replace larger fragmentation warheads with a host of small grenades or bomblets. This improves the 'combat economy'. Rules are required to restrain the use of area fragmentation weapons in places where the civilian population may be affected. The US Rules of Engagement in Viet Nam (see appendix 9D) show that it is quite feasible to determine a 'safety zone' for each category of weapon. Such an approach could profitably be examined in the context of international law.

Chapter 6 describes the effects of blast weapons on the human body and their development. Fuel–air explosives and other concussion bombs should not be permitted for use as anti-personnel weapons.

In Chapter 7 the question of delayed-action weapons is examined. These should be severely restricted so as to reduce their indiscriminate effects. The new remotely delivered mines – which can be spread in large numbers far from the front lines – are a source of particular concern for humanitarian and environmental reasons. The users of delayed-action weapons should be required by international law to make sure that their weapons can be disposed of when they no longer serve a military purpose.

A number of attempts to devise weapons on the basis of other physical principles, such as sound waves, electric shocks, flashing lights and lasers, are described in Chapter 8. At present the laser appears to be the most likely candidate for new weapons. A number of other devices have also been tried out in internal security operations.

Chapter 9 reviews the development of international humanitarian law with respect to conventional anti-personnel weapons. There is no doubt that, in a period of history when the use of force is prohibited (other than for self-defence or collective security), it would have been better to have removed the hazard of anti-personnel weapons simply by disarmament. But as no such measures are being taken, there must be other civilizing steps: the two Additional Protocols to the four Geneva Conventions of 1949 are one such step. They could be appropriately supplemented by rules, such as those reviewed in appendix 9D, prohibiting or restricting the use of a number of the weapons described in this book.

1. The rise of anti-personnel weapons, from antiquity to 1900

Superior numerals, thus [5], refer to notes on page 16.

I. Early anti-personnel weapons

It is a sad fact that man's use of tools to kill or injure his fellow man is one of his most abiding characteristics and distinguishes him from nearly all of the animal kingdom. Even today, enormous amounts of time and energy are devoted to improving means of slaughter.

Most modern weapons, like primitive weapons, are designed to transfer a quantity of energy to the enemy's body in order to crush, penetrate or burn it. It takes no more energy now to incapacitate a man than it did in the Stone Age.

Man is a peculiar mammal in that he is little adapted to meet the hazards that surround him; he is not equipped with effective camouflage or long limbs, or with teeth, claws or horns to serve as weapons. At an early stage, man turned to the use of simple hand-held weapons, and projectiles made of wood and stone. Perhaps he lacked the innate inhibitions about attacking members of his own species which are found in other predatory animals (Lorenz, 1966; Hinde, 1966; Eibl-Eibesfeldt, 1975). Simple tools and hunting weapons became potential instruments of war.

The first aggressive weapons were 'anti-personnel' in that they were made to injure or kill other men. Only later as people built protective walls around themselves were more powerful weapons needed to breach these defences. Sticks and clubs for use in hand-to-hand fighting evolved into maces and axes with stone, bronze or iron heads. Some of the Egyptian Pharaohs are depicted with a mace, which appears to have been preferred to the sword. Before discovering metal, some primitive peoples had war clubs with edges of shark's teeth, ray's tails, or other sharp objects, such as obsidian (Turney-High, 1971). Axes were designed for cutting, for use against an unprotected foe, for piercing, or for use against an enemy wearing armour. When the easily wielded iron sword came, the club and the axe became obsolete (Oakeshott, 1960).

Swords of copper or bronze were short because of the weakness of the metal, and it was not until the Iron Age that the gradual transition to the sword as a major weapon took place. The Greeks, for instance, did not make use of iron swords until the Doric invasions of about 1100 BC.

The production of steel from iron, which was achieved during the first millennium BC, resulted in blades that could be honed to a fine edge (Derry & Williams, 1960). Sabres (swords primarily designed for slashing) remained a feature of warfare until the first decades of the twentieth century. They were used mainly in cavalry charges.

The spear also developed from the dagger of the Bronze Age, and later the pike gave the wielder a longer outreach. Javelins were spears designed to be thrown; a quiver of javelins was a common fixture on Greek and Roman chariots. Some Roman javelins were designed to break in two or bend at the tip to prevent their reuse by the enemy. A later development was the lance, designed to utilize the force exerted by a charging horse and rider.

The earliest projectiles were stones thrown by hand and later by sling (cf. Krause, 1905). Since the sling required considerable skill, some armies relied on mercenary slingers such as those from the Balearic Islands. In their hands, shot of stones or lead slugs had considerable accuracy and a range of about 200 m (Korfmann, 1973).

The bow marked the earliest use of mechanical energy to project a missile. It also is of prehistoric origin and was apparently used originally for hunting. Its development as a weapon of war is attributed to the Akkadians in their conquest of the Sumerians. It became the main weapon of war by about 1500 BC. The Greeks and the Romans did not favour the bow and for a time it went out of fashion. The most powerful bows had an effective range of 300–400 m, and a maximum range of twice that, which is similar to the ranges for which modern military rifles are designed. A trained man with a longbow could shoot about five arrows a minute. These arrows were often tipped with about 2 cm of steel and could penetrate chain-mail. In one recorded instance in 1182, such an arrow penetrated oak doors 10 cm thick (Oakeshott, 1960). In 1346, the Battle of Crécy demonstrated the effectiveness of the bow against soldiers wearing armour. The bow remained in service in European armies until about the end of the sixteenth century.

The crossbow, which uses a hand-crank to set the bow, probably entered Europe from China, and was inherited by the Romans from the Greeks and Carthaginians. The steel military crossbow of the fifteenth century had a range of some 380 m and a point-blank range of about 65 m (Hogg, 1970). Crossbows may have greater range and accuracy than conventional bows, but they are more complex and cumbersome and have a slower rate of fire. In the same way the heavier weapons which gave rise to early forms of artillery were slow. Examples of these are the catapult and the ballista. Some of these were designed to project small or large stones while others released arrows or iron-tipped darts weighing about 3 kg.

II. Early firearms

It was only many years after their appearance in the fourteenth century that the significance of firearms and explosives was appreciated. Firearms as we know them have their origins in the development of metallurgy and chemistry about AD 1200–1300 (Derry & Williams, 1960). The techniques of bell-founding appeared about AD 800, and by 1250 the Moors used cast-iron buckets to project stones using a powder charge. Gunpowder came into more general use about 1300 (Partington, 1960) and cannon by 1350 (Hogg, 1970).

The first firearms were developed while the crossbow and the ballista were still in use, and used similar projectiles, such as bolts or darts, usually made of iron. They had iron fins or feathers for stabilization and weighed about 200 g (about three times the weight of the normal crossbow bolt). The bolts were wrapped in leather so that they fitted tightly in the barrel of the gun. Later they gave way to small balls of about the same weight cast in lead. Stone, iron and bronze shot were used in heavier guns.

Early firearms were laboriously loaded at the muzzle and this restricted their rate of fire. Hand-guns were mainly used for sport, where time was not so vital. Rifled gun barrels were known as early as 1525 but they were not used in combat until the Thirty Years' War (1618–48); they permitted more accurate fire at longer ranges than smooth-bore guns.

The usefulness of the hand-held firearms improved considerably with the step-by-step evolution of the firing mechanism from match to matchlock to wheel-lock (originating in Italy between 1494 and 1559) and then to flintlock (originating in France about 1630). The flintlock was adopted by the French Army in 1660 and by the British in 1688 and it remained in use until the Battle of Waterloo in 1815. The addition of the bayonet in the 1600s led eventually to the obsolescence of the pike. The curved stock mitigated recoil and thereby improved the accuracy of fire.

Until the Napoleonic period, tactics were largely dictated by the effective range of the flintlock musket – about 200 m. The infantryman could carry about 60 rounds of ammunition and fire them at a rate of two per minute. The cavalry could cover 200 m in about 30 seconds. Once the musketeer had shot at the cavalryman, he had a good chance of being cut down by the cavalryman's sabre before being able to fire a second shot.

For many years artillery was used primarily to breach fortifications. Specialist gunners, sometimes hired for the occasion, operated the heavy pieces. Sometimes artillery was used for defence against besieging forces. About 1630 the Swedish king, Gustavus Adolphus, effectively introduced the use of concentrated fire from light artillery on to the battlefield to break up the 'Spanish square' of opposing infantry. By the time of Napoleon, the French Inspector General of Artillery, de Gribeauval, introduced new tactics and matériel which enabled the artillery to charge up close to the enemy and decimate the front lines (Manucy, 1949).

A great many kinds of shell and shot were developed to be fired by artillery. A shell[1] is a projectile containing an explosive or other chemical substance and is designed to detonate or disperse the active material on or over the target. Shot refers to solid projectiles designed to penetrate the target by means of kinetic energy; the 'cannon-ball', or round shot, was for many years the most common type.

Additional kinds of shot included:

(*a*) *bar shot*, shaped like a dumb-bell and intended to tumble in flight, so creating more injuries amongst a concentration of troops;

(*b*) *chain shot*, consisting of two balls linked by a chain and intended to destroy the masts and rigging of sailing-ships. It carried incendiary candles to set fire to the sails;

(*c*) *knife-blade shot*, which had hinged blades designed to open as the projectile left the muzzle; and

(*d*) *incandescent or hot shot*, which was simply iron shot heated until it was red-hot shortly before being loaded into the gun.

These projectiles were in the main intended for use against matériel targets, such as ships. Other kinds of ammunition were developed which were primarily anti-personnel. They included a quantity of small projectiles, such as pieces of iron, nails, stones or flints, which were loaded directly into the gun. Later, such missiles were enclosed in a container and became *case* or *canister* shot. Case shot is said to have been first used at the Siege of Constantinople in 1453 (Hogg, 1970), and a later version, filled with small iron balls, was known as *hail shot*. In 1573 a German gunner, Zimmerman, invented a shell with a powder charge which burst the lead jacket and dispersed the enclosed hail shot.

In 1784, following the siege of Gibraltar, a British lieutenant, Henry Shrapnel, proposed his *spherical case shot*. On 11 June 1852, ten years after Shrapnel's death, the British Government, which had by then adopted the shell into service, ordained that shells of this kind should be called *shrapnel shell*. In case shot, the shell opened at the muzzle, but the shrapnel shell could be fired to any distance up to about 1 200 m, before it opened to release the lead shot.

Another weapon which depended on the effects of gunpowder – though not as a propellant – was the hand-grenade. This consisted of a hollow iron sphere, about 5 cm in diameter, filled with powder. Although it was introduced during the seventeenth century, it was not widely used until the Russo–Japanese War of 1904, which foreshadowed the trench warfare of World War I.

III. The rifle

During the nineteenth century, percussion cartridges were invented which simplified the loading and firing of rifles. Conical bullets, such as the French Minié bullet (designed to fit the grooves in the barrel), improved the efficiency of the rifle. These innovations permitted the development of the breech-loading gun and the repeating rifle. The Minié bullet was widely used, not only by the French but also by the British, who paid the inventor the sum of £20 000 and modified it for use in the Crimean War (1853–56).

An account of wounds inflicted by the weapons of the time is given in the British official medical history of the Crimean War (Matthew, 1858). While sword and lance wounds were 'generally not of a grave nature', patients were categorized according to their most severe wound, which was 'almost invariably found to be that inflicted by the bullet' (ibid., p. 262).

> The conical bullets used so extensively in this campaign inflict a much more severe and dangerous wound than the old round. ... The worst and most dangerous wounds appeared to be inflicted by the British old-

fashioned Minié bullet with the iron cup. This sometimes had the effect of splaying out the ball on encountering an obstacle. (Matthew, 1858, p. 263)

The heaviest Russian conical ball (54 g) and the British Enfield bullet (37.5 g) caused more severe wounds, such as compound fractures of bones, than the older round balls, though these resulted in a more regular wound channel.

The Enfield version of the Minié bullet[2] was introduced into the British armies[3] in India by 1857. The paper cartridges were heavily lubricated with animal fat, and the ends were supposed to be bitten off by the user before loading the gun. However, since the cow is sacred to Hindus and the pig unclean to Muslims, the Indian troops refused to do this and were imprisoned by their British officers. This helped to precipitate a mutiny which developed into a major uprising against British rule.

According to Smith (1969), the Minié bullet also played a role in the history of the United States:

> It was the ball generally used in all the muzzle loaders used by both the North and the South during our Civil War; it was responsible in very large measure for the catastrophic loss of life in that terrible conflict. (Smith, 1969, p. 33)

Diffenbaugh (1965), summarizing the surgical history of the US Civil War, records that the Minié bullet 'produced marked destruction, shattering bone rather than piercing it, frequently emerging from the body in a transverse axis, producing horrible wounds' (p. 490).

Inspired by several earlier designs, a British Major Fosbery (1869) described how his own invention, an exploding bullet for use in the standard British rifle of the time, was first introduced in the summer of 1863 as an aid to judging the range of fire. The British were at the time engaged in 'pacification' operations in the North-West Frontier district of India. The steep mountains made it difficult to judge the distance to the enemy, and firing trial artillery rounds would remove any chance of surprise. The explosive bullets (the impact of which could be seen and heard) provided an effective alternative, enabling the artillery to be accordingly targeted.

It was not long before Fosbery's bullets were used 'on the enemy generally' when it became desirable to have a 'strong moral effect'. In this respect the exploding bullet seemed to be successful, for Fosbery records that the tribesmen 'were at pains of sending us a deputation, under a flag of truce, praying that their use might be discontinued' (Fosbery, 1869, p. 23).

Developments in small arms ammunition opened the way to breech-loading rifles of the modern type. By the 1860s the Spencer and Henry repeating rifles, and breech-loaders of many other types were in service in the United States. The Prussians used the Dreyse needle-gun in the Schleswig-Holstein War of 1864 and in the Seven Weeks' War of 1866 with Austria. The Austrians, who still used muzzle-loaders, suffered many more casualties. This impressed upon other European powers the advantages of breech-loading weapons. The breech-loading needle-gun could be reloaded lying-down, the loader thereby presenting a much smaller target to the enemy. These guns had a range of about 500 m. By the early 1870s nearly all the major powers had equipped their forces with breech-loading rifles. The Franco–Prussian War of 1870–71 was the first major war in which both sides used breech-loading rifles, with bayonets hardly being used at all.

The US Peabody rifle was purchased by Austria, Bavaria, Denmark, France, Mexico, Romania and Switzerland. In Switzerland, modifications were introduced by Martini, and this design was matched in England to the Henry rifling system to produce the 'Martini-Henry' rifle, adopted in 1871 with a calibre .45 inch (11.43 mm) cartridge. The Imperial Russian Government bought a rifle designed by Berdan (known as Berdan I) and then redesigned it to produce the Berdan II. Another US breech-loading rifle design, patented by Rider and developed by Remington, was adopted by Denmark, Sweden and Norway in 1867, Spain in 1871, Egypt in 1870 and Argentina in 1879, and was widely used in China, Austria, Italy and several South American countries (Smith, 1969).

After the success of the Turks against the Russians at Pleven in 1877, the value of the repeating rifle was generally recognized by the European powers (Smith, 1969). During this battle the Turks were able to use 30 000 Winchester repeating rifles purchased from the United States. This led the military authorities to adopt the repeating rifles being patented by designers such as Mauser, Mannlicher and Lebel in the following decade.

The Federal Assembly of the Swiss Confederation approved the adoption of a repeating rifle in 1866 and the gun chosen, the Vetterli, went into production the following year. Later, in 1870, the Früwurth bolt-action repeater was issued to the Austro-Hungarian gendarmerie.

'Smokeless powder' – a much more powerful propellant than the old black powder – was introduced at the same time and led to a further increase in the power of rifles, with a corresponding reduction in the calibre from 10–14 mm to about 7–8 mm. A smokeless powder for shot-guns had been demonstrated in 1864, following Schönbein's demonstration of gun-cotton (cotton treated with nitric and sulphuric acids to produce nitro-cellulose) in 1846, but it was not until the 1880s that the French *poudre B* and Nobel's ballistite made the production of more powerful explosive cartridges possible. Edouard Rubin, a Swiss Army officer, designed the copper-jacketed bullet, which did not melt in the added frictional heat. The rifles adopted for the new ammunition – such as Mausers, the British Lee-Metford and the US Krag – had a range of 1 000 m or more.

At that time experiments showed that at ranges of under 500 m these bullets could create remarkable 'explosive' effects on the head and other organs (see chapter 3). Conversely, some soldiers complained that at longer ranges they had insufficient 'stopping power' (see pp. 59–60).

IV. The machine-gun

Developments in ammunition and firing mechanisms paved the way for the introduction of automatic weapons. James Puckle patented a flintlock gun with a revolver chamber in 1718. The Duke of Montagu purchased two of them but there are no further records of their use (Hogg & Batchelor, 1976). In 1851 a Belgian, Captain Fafchamps, designed a weapon which was manufactured by Montigny and known as the mitrailleuse. The French Army was equipped with 156 of an improved version of these guns in time for the war against Prussia in 1870. The original model had 37 barrels, and the bullets were fired successively by turning a crank; the French Army model had 25 barrels. Here the bullets were set in a plate matching the barrels so that all barrels could be loaded simultaneously. All the barrels were fired in about one second and about 12 plates a minute could be loaded. The bullets had a range of about 1 800 m. In the war of 1870–71 the French used these guns as field artillery pieces, but they could not match the Prussian artillery, which had a range of about 2 500 m.

The Austrians purchased a 37-barrel version of the Montigny mitrailleuse of 11 mm calibre and used it for the defence of fortifications.

Meanwhile, the American inventor Dr R. J. Gatling had designed a competing weapon with revolving barrels, and was offering it to armies in several parts of the world. This gun was invented in 1861, improved in 1865 and adopted by the US War Department in 1866. Tests by the British Government in 1870 demonstrated its superiority over the mitrailleuse, over shrapnel rounds from artillery, and over six infantrymen firing rifles. As a result, production facilities were set up in England. At about the same time similar guns were acquired by the Russian Government and named Gorloff; they were used in the war against the Turks in 1877 and were still in service during the siege of Port Arthur in 1904–05. The British first used the Gatling guns in the Zulu War of 1879 and they remained in service until 1905.

The Gatling gun revolves six or more barrels, loading and firing each one at a time; the entire process is operated mechanically by a hand-crank. In 1883 a drum-feed system was introduced which increased the rate of fire to 1 200 rounds per minute (rpm) and in 1893 Gatling added an electric motor, increasing the rate of fire to 3 000 rpm. But by this time mechanical operating systems had become obsolete.

Many other designs for mechanically operated machine-guns were put forward during this period and some of them entered into service. A gun designed by an American, William Gardner, and produced by the then newly formed engineering company Pratt & Whitney, was adopted by the British Royal Navy in 1884 and widely used in operations ashore. The Gardner gun fired two barrels alternately at about 365 rpm.

A gun designed by a Swede, Helge Palmcrantz, fed a row of barrels, and was known as the Nordenfelt after the financier who marketed it. This gun was made in various calibres, had 2–10 barrels, and was in service with the British Royal Navy between 1880 and 1903. Benjamin Hotchkiss, an American, patented a 'revolver cannon' in Paris in 1874 and the company he established there sold about 10 000 of these guns to Belgium, France, Holland, Italy, Russia and the United States.

Gatling guns and many other designs of the period required an input of mechanical energy to carry out the functions of loading, firing, extracting the empty cartridge and then repeating the cycle. An American inventor, Hiram S. Maxim, living in Europe, considered using the energy produced by the exploding cartridge to perform these functions. Between 1882 and 1885 he took out patents on many lines of development, and by 1885 he produced and improved a working system using the recoil of the gun to load and fire a single barrel. With this model he arranged demonstrations in many European countries and established the Maxim Gun Company which used manufacturing facilities of the Vickers Company in England. By 1890 the gun had been supplied to the Austrian, British, German, Italian, Russian and Swiss governments.

The first use of the Maxim gun in war was against a tribe in Gambia on 21 November 1888 (Hogg & Batchelor, 1976). It became one of the most used weapons of World War I and has since been widely used all over the world. It was used by Russian forces in both World Wars and by Chinese forces in Korea. The modified Maxim, known as the .303 (7.70 mm) Vickers, was introduced in 1912 and remained in British service until 1968.

The original Maxim gun had a rate of fire of about 600 rpm although it could also fire single shots. It was chambered to the .45 in (11.43 mm) Martini-Henry rifle cartridge but was later chambered to the .303 in (7.70 mm) and other calibres. Larger calibres were also produced, such as the pom-pom (37 mm), which was used in the South African War of 1900. Maxim guns were usually water-cooled, though some versions were air-cooled. They were mounted on many forms of carriage, and on pack-saddles on horses and camels. In 1909 the German Army requested a lighter model for use from aircraft, and a design by Heinemann – known as the Parabellum – was produced in 1911, the first of a long line of aircraft guns.

Another American, John Browning, designed a machine-gun which channelled off some of the gas near the muzzle of the gun into a cylinder. Here the gas propelled a piston which then extracted the empty cartridge, loaded a new one and fired it. He offered his invention to the Colt Company in 1890 and, after testing in 1892–93, it became in 1895 the first automatic machine-gun in US service. Many current assault rifles and machine-guns operate on this principle. An Austrian, Captain Adolf Odkolek, sold a design for a gas-operated gun to the Hotchkiss Company in Paris in 1893. The French Army adopted it in 1897 but later modified it. The gun was bought by several countries, including the USA, Britain and Japan. The Japanese used it against the Russians in 1904 and acquired a licence to produce it, subsequently introducing their own modifications.

A third operating principle, known as delayed blowback, was introduced in 1888 by two Austrians, the Archduke Karl Salvator and Count Dormus. It was produced by the Skoda Company, after which it was named. It was adopted by the Austro-Hungarian Army in 1893 and improved models were introduced in 1902, 1909 and 1913.

Although the Maxim is the best-known recoil-operated gun, the Danish cavalry adopted a light recoil-operated machine-gun, the Madsen, in about 1902. Although it was not adopted by any major military power, it was so successful that it was produced almost unchanged for over 50 years and was used by 34 countries. It fired 7.62 mm bullets at a rate of 500–600 per minute but weighed only about 10 kg – less than half the weight of other machine-guns of the period.

The four operating principles – mechanical, recoil, gas and delayed blowback – continue to be applied in the design of modern automatic weapons.

V. Artillery

The development of artillery roughly parallelled the evolution of small arms, but artillery was faced with special problems. There was a temptation to increase the size of the weapons to give them longer range and demolishing power; on the other hand there was a need for mobility.

Early attempts to design exploding artillery shells were rarely successful because of the difficulty of constructing a safe but effective fuze. It was not until about the end of the eighteenth century that shells were reliable enough to be taken into general service.

In the 1860s rifled barrels were introduced, and this brought about the need for cylindrical or conical shells. New varieties of case and shrapnel shell were in-introduced. The shrapnel shell forms an intermediate category between the shot, which is solid and inert, and the shell, which is designed to break up into fragments under the influence of an explosive charge contained in it. Improvements in fuze design meant that shrapnel shells could be adjusted to burst at zero range, giving them a similar effect to that of case shells. As a result, the terms are sometimes used interchangeably; indeed, 'shrapnel' is now used to refer to projectile fragments in general.

The effects of the projectiles in use in the mid-nineteenth century are quite well described in the British medical history of the Crimean War. In this war most of the injuries were inflicted by round and grape shot at close range:

> Wounds by direct contact of round shot usually exhibited the limb either carried away or hopelessly mashed into a mass in which the various tissues were almost indistinguishable. . .When a shell explodes the wound produced by its fragments is usually much less severe than those inflicted by round shot . . . Grape differs from round shot only in degree; and canister has much the same effect as round musket balls, but generally produces less injury than is inflicted by the latter. (Matthew, 1858, p. 263)

'The Charge of the Light Brigade' during the Crimean War (1853–56)[4] showed the plight of cavalry in the face of a concentration of field guns. These had a range of about 1 500 m with round shot and 500 m with case shot.

The impact of these weapons was seen again at the Battle of Solferino in 1859 when in one day 22 500 men of the Austrian Army were slaughtered and the French and the Piedmontese lost 17 200 men (Fuller, 1932). In the war of 1870–71, the Prussians used artillery extensively, often stopping attacks at 2 000 m.

Between 1880 and 1890 steel began to replace iron in the body of shells, and in the mid-1890s gunpowder began to give way to high explosive (HE) fillers. At the same time the first specialized armour-piercing (AP) shells were developed.

The blast of HE shells makes them effective against buildings and other matériel targets, and the mass of small high-velocity fragments makes them lethal weapons against troops. As a result of this combination of properties, they have largely replaced case and shrapnel shells since World War I except for certain specific tasks.

At the end of the nineteenth century the French introduced the quick-firing 75 mm gun, having a mechanism designed to cope with the recoil and keep the carriage steady. This avoided the necessity to re-lay the gun before each shot. Vickers Sons & Maxim manufactured a gun of this kind which was introduced to British forces in the Ashanti campaign of 1900. It was said to be 'of a type superior to any then in use in the British Army' (Myatt, 1974, p. 61). Subsequently, similar weapons were generally adopted. The powerful propellants introduced in about 1890 gave field artillery a range of approximately 2 000 m and heavier projectiles could be fired. Smokeless powder decreased the chance of detecting concealed guns. By 1914 field guns had a range of about 6 000 m with shrapnel shells (Myatt, 1974).

VI. Rockets

The rocket has competed with artillery for hundreds of years, particularly in Asia. In Europe the use of rockets declined between the fifteenth and the eighteenth centuries, but in 1804 Sir William Congreve introduced new designs which were used by the British for nearly a century. They were first used against Boulogne in October 1806, and in 1807 they caused considerable damage in Copenhagen. Congreve's rockets, stabilized by a protruding stick, were made in several standard sizes, from 6 lb (2.7 kg) to 42 lb (19 kg), the 32 lb (15 kg) size being the most popular. These rockets could be fitted with incendiary, shrapnel or case warheads and had maximum ranges of up to 3 000 m.

After 1870, breech-loading rifled artillery largely superseded rockets, though they remained in service until World War I. The theoretical advantages of the rocket (cheapness and simplicity) continued to interest some weapon designers. The success of German designers in the 1930s greatly stimulated the development of rocketry, and from then on, rockets and guided missiles came to play an important role in warfare.

VII. The influence of weaponry on warfare

The high-powered rifle, the machine-gun and the quick-firing artillery which were developed during the nineteenth century significantly altered the way war was waged.

The British military historian Fuller (1932) calls the US Civil War the 'first of the modern wars ... begotten by the industrial revolution' (p. 84). The period of the US Civil War saw the invention of the magazine-loading rifle and the machine-gun, the use of land-mines, booby traps, submarine mines, torpedoes, hand-grenades, rockets, explosive bullets, 'stink shells', and trench warfare, and the idea of bombarding a city (Richmond, Virginia) with incendiary shells (Fuller, 1932).

Writers, such as Havelock (1867), realized that the era of the cavalry charge and the lines of red- or blue-coated soldiers was drawing to a close. The cavalryman, let alone the infantryman, could no longer cross the danger zone separating the two lines of troops. The rifle and machine-gun, with their high-powered bullets, could easily hit the charging horse or its rider at 1 000 m and the cannon could do so at even longer range. On the other hand, the riflemen could pick off the artillerymen at longer ranges than they could reach with case shot.

But if neither side could get across no man's land and each was forced to dig trenches for protection, then 'the spade would be as indispensable to the soldier as his rifle' (Bloch, 1899).[5] Not only that, but the outcome of war would no longer be determined by the final cut and thrust of the sabre and bayonet but by the capacity of industrial society to pour out its resources:

> That is the future of war – not fighting, but famine, not the slaying of men but the bankruptcy of nations and the break-up of whole social organizations. (Bloch, 1899)

It was during the US Civil War that the prospect of replacing manpower with technology was stated by the Swedish inventor, John Ericsson, to President Lincoln:

> The time has come, Mr President, when our case will have to be sustained not by numbers, but by superior weapons ... such is the inferiority of the Southern States in a mechanical point of view, that it is susceptible of demonstration that, if you apply our mechanical resources to the fullest extent you can destroy the enemy without enlisting another man. (Cited in Derry & Williams, 1960, p. 706)

This principle of pitting technology against numbers was applied in the following decades, particularly in putting much of the world under colonial domination. Fuller says:

> As regards aggression the years 1870–98 are only equalled by the age of Genghis Khan. Between 1870 and 1900 Great Britain acquired 4 754 000 square miles [12 200 000 km^2] of territory, adding to her

> population 88 000 000 people; between 1884 and 1900 France acquired 3 583 580 square miles [9 300 000 km^2] and 36 553 000 people; and in the same years, Germany, a bad last, gained 1 026 220 square miles [2 700 000 km^2] and 16 687 100 people. There were many other nations besides who acquired land; but these three examples will suffice to prove the stupendous and rapid progress of this crusade. (Fuller, 1932, p. 134)

New weapons and a superior technology enabled small bodies of men to conquer large territories and populations. They gave the Western soldier a fire-power which could no longer be matched by the muskets made for generations by village gunsmiths in Asia and Africa.

The Minié bullet was used against Africans in 1852, and introduced into British service in the following year. Myatt (1974) says, 'the heavy bullet inflicted terrible wounds at close ranges and often had sufficient velocity to pierce through three or four men' (p. 28). It was soon superseded by the Enfield rifle which in turn was used to suppress the Indian Mutiny in 1857. The Snider gun (mainly produced from converted Enfields) was the first breech-loader and 'proved effective in the Abyssinian Expedition of 1867–68 and in the Ashanti war of 1873–74' (Myatt, 1974). It became the weapon of the Indian Army almost until the end of the century, when it was replaced by the Lee-Metford.

At the same time similar weapons were important in the pacification of the Indian peoples in North America: the high-powered rifle was used not only against the people themselves but also for killing the buffalo on which many Indian people depended. In the meantime, other European armies, equipped with the French Lebel or the German Mauser rifles, were gaining control over much of the rest of the world.

In India, explosive bullets were introduced in the 1860s and used against mountain tribesmen (see p. 7). In the 1890s, 'it was found in Indian hill warfare that the Lee-Metford bullet did not adequately protect the troops using it . . .' (*The Lancet*, 10 June 1899, p. 1573). The colonial authorities accordingly commissioned the arsenal at Dum-Dum, near Calcutta, to design the more destructive bullet which came to bear its name.

> It is not an explosive bullet, in the sense of containing any explosive substance, but having a soft metal nose which expands when the bullet has once penetrated it has been found to possess a 'stopping' power which the Lee-Metford bullet did not. That this property should be present is the essential point, and the Government of India are still making experiments with a view of obtaining a rifle projectile which will prove adequate for their requirements in the mountain warfare with the semi-civilized tribes in which it has so often and so reluctantly to take part. (ibid.)

About the same time the US War Department Board 'considered that cup-pointed bullets such as the "man-stopper" might be offered to troops fighting savage tribes and fanatics in bush and jungle. The bullet shows great execution on live animals' (LaGarde, 1914).[6]

The machine-gun and the field gun were also used extensively in colonial wars. Myatt, for example, writes that:

> Successive improvements in firearms in the second half of the century began to tilt the balance in favour of the British, for although the tribesmen [in India] usually contrived to arm themselves with good rifles, they had not access to artillery or machine-guns. (Myatt, 1974, p. 188)

At Omdurman (Sudan) in 1898, British troops, armed with 20 Maxim machine-guns and 44 artillery pieces, killed 11 000 Sudanese in four and a half hours, losing only 48 of their own men (Derry & Williams, 1960). Gatling machine-guns, which came into use in the 1870s, were still used at the end of the century when US forces invaded Cuba (1898) and the Philippines (1899–1904). They violently suppressed local resistance to the new occupying power replacing Spain.

Myatt (1974) reports that the British used rockets at the battle of Arogee in Abyssinia in 1867–68, in the Sudan in 1897–98 and at Kumasi in the Ashanti War of 1900, and in various other expeditions along the West African coast.

In Europe this same period is remembered as an age of development of international humanitarian law, and it was suggested that some of these weapons should be banned. On the urging of successive Russian Tsars, the Powers agreed not to use certain of the new inventions such as explosive and expanding bullets against each other (see chapter 9).

VIII. Summary and conclusions

From the earliest times until the end of the nineteenth century, weapons suitable for hand-to-hand fighting have given way to projectile-firing devices. Technological development and mass production techniques made it possible to inundate the battlefield with huge quantities of projectiles while the increased range of high-powered rifles, machine-guns and artillery kept battle lines about 1 000 m apart. Face-to-face combat became rare and most battle injuries were due to projectiles.

The greatly increased fire-power of the industrial nations contributed to the rise of colonialism by enabling small forces of Europeans to overcome opposition from local forces equipped with hand-made muskets.

The period from 1860 to 1890 was one of rapid change in military small arms and ammunition. The magazine breech-loading, high-powered rifle was adopted by all the major powers and it remained, with very little change, the standard infantry weapon until after World War II.

In Europe, efforts were made to prohibit the use of the more destructive bullets by means of international legal agreements signed at St Petersburg in 1868 and The Hague in 1899.