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ENGINEERING HISTORY PAPER #119

"ENGINEERING AND THE HISTORY OF WEAPONS OF WAR"

by Andrew H. Wilson

(previously produced as Cedargrove Series #76/2024 – Dec 2024)

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#76/2024

ENGINEERING AND THE HISTORY OF WEAPONS OF WAR

by Andrew H. Wilson

December 2024

Abstract

This paper attempts an historical overview of the development of weaponry for land, sea and air warfare. It makes no claim to be complete or comprehensive - simply illustrative - but attempts to capture the thrust of this development. Books have already been written on the subject, but another would likely lack a market!

About the Series

Principally, the Cedargrove Series is intended to preserve some of the research, writings and oral presentations that the author has completed over the past half-century or so, but has not yet published.

About the Author

Now in his nineties, he is a graduate in mechanical engineering (1949) and the liberal arts (1954). He has held technical and administrative positions in industry in the United Kingdom and technical, administrative, research and management positions in the Public Service of Canada, from which he retired in 1986. He became active in the history of engineering on his appointment in 1975 to chair the first History Committee of the Canadian Society for Mechanical Engineering (CSME). He was later president of the Society and of its 'parent,' the Engineering Institute of Canada (EIC) and chaired the History Committees of both, as well as the Canadian Association for the Club of Rome and the Canadian Engineering Manpower Council.

Background…

The weapons of war had to be engineered, so they are 'natural' for the Cedargrove Series!

The principal sources for this paper were Margaret MacMillan's book, *War: How Conflict Shaped Us,* Paul Kennedy's *Engineers of Victory* and, inevitably these days, *Internet/Wikipedia.* Their scope is worldwide.

Throughout history, attack and self-defence have been the two principal uses of weapons and of tools that could also be used as weapons, although they have also been used in the killing of animals for food and the avoidance of starvation.

How societies fought wars and the weapons they used affected, and were affected by, their values, beliefs and ideals, their institutions, their cultures in the broadest sense, plus their climates and geographies. They also spent time examining history for clues as to better ways to win wars, and to writing about them.

Three early dates to remember: the phrase 'Men using weapons and tools,' dates from around 300,000 years ago; 'Homo Sapiens' from around 200,000 years ago; and 'Modern Man' from around 50,000 years ago. Also, the last Ice Age ended around 12,000 years ago.

The reader will also notice that *engineering* has been *implied* throughout this paper, more than it has been mentioned or discussed. To do so, would have meant another book!

The Story of the Weapons…

The BC Years…

Although weapons may have been used by mankind to kill one another earlier than the Stone Age (30,000 to 3,000 BC), it was perhaps the ability of later Stone Age people (7,000 BC and after) to give sharp, cutting edges to stones that got the history of weapons underway. Much later, this process was undoubtedly helped along by advances in research and experience in science, engineering, military tactics and organization.

It is interesting to note, however, that the killing of animals for food may also reach back into pre-history, that the violence of one person against another may date back almost as far…and that it reaches down to the present day in countries such as the United States!

One should also note that fire, as 'fought' - and as an engineering phenomenon - may have been experienced as grassland fires in Africa several million years ago. Fire started by lightning strikes would have been discovered later, but might have been used as a weapon as long as 1 million years ago. And as combustible material was consumed by fire, the value of some of the residues left when it was extinguished (such as charcoal) would be discovered.

Bows and arrows arrived in Europe around 10,000 BC and the Americas by 6,000 BC. The bows were effective against 'distant' enemies. Longer bows gave greater accuracy. Different bow designs reflected the vegetation of the countries of their users. The first arrows had stone tips.

The metal, copper, was discovered in Anatolia around 6,000 BC, and bronze, an alloy of copper and tin and much harder than copper itself, around 4,500 BC. The discovery of these metals and of leather, influenced the development of spears, pole-axes, daggers and protective helmets. Bronze effectively replaced stone. Then iron appeared, to be succeeded in large measure by steel.

China was an early, big-time, user of copper for spears, pole-axes, maces and composite bows, dagger-axes and bronze and leather helmets.

Armour was developed in the ancient world as a riposte to metal-tipped spears, swords and arrows. The Greeks and the Romans gradually developed foot soldiers and fortifications as a response to horse-borne warriors, but the pendulum was to swing back and forth between cavalry and infantry until the 19th century. One sword that should be mentioned is the short *gladius*, adopted by the Romans for close combat fighting. Roman infantry also carried spears, which could be thrown or thrusted.

About this time, also, native North Americans were familiar with bronze and flint weapons. They preferred bows and rows to spears, but they still had no horses. North Americans mostly used flint spears, and used bronze in decorative applications.

Elsewhere, around 2500 BC, people began riding horses and adapted the bow and arrow to this new platform. Over time, as new materials were discovered, the designs of these weapons changed and improved.

For centuries, the horse was also an important weapon in wars and for communications and transportation. The saddle (more a pad than the modern version) first appeared around 800 BC, the stirrup around 200 AD, and the horse collar around 400 AD - all of which improved the performance of horses (and their riders).

The early (Bronze Age, for example) naval battles were fought hand-to-hand, at deck level, with large stone, boiling oil and other projectiles, between the crews of opposing ships that were tied together for the crews to fight on deck. Fire was also used, plus catapults as artillery against both marine and shore-based targets.

Bows and arrows were preferred over spears because they were easier to handle. Bronze weapons could not hold their 'edge.', but they were preferred over spears because they were more mobile, easier to handle, and more accurate. They were also a boon for hunters.

Both the trebuchet and the catapult may have begun development, around the fifth century BC. The traction trebuchet was a Chinese product. The counterweight trebuchet was more versatile. Basically, both slung large stones or other missiles at fortifications or other solid targets. The very similar, but usually smaller catapult, invented by the Greeks, had similar uses. Eventually, both 'slings' had versions that could be operated by a single person.

As indicated above, the history of 'modern' weaponry most likely began in the late Stone Age, with the ability to give stones and pieces of them cutting edges. The weapons, however, may have been of much earlier origin. For example, it is believed that spears were in use earlier than 40,000 BC, that the use of boomerangs (for both warlike and hunting purposes) in countries like Australia, and continents like Africa and Europe, could date from around 23,000 BC. Arrowheads for bows and arrows could date from 20,000 BC,. but we should note that peaceful, formal farming began around 10,000 years ago. And spears, swords and tipped arrows could be fired from bows and crossbows. Battering rams were in use, by the Middle Ages, and the bow and arrow had been mechanized as the trebuchet, which could also fire stones, and some of the missiles they fired were incendiary.

Around 6,000 years ago, the building of fortifications against assault weapons began and continued in Europe at least, until the late Middle Ages. On the other side of the world, the building of the Great Wall of China began in the third century BC, and continued for more than a 1,000 years. From Roman times, western European countries also fought their wars using obstacles, like mountain ranges, walls, castles and fortresses, and waterways.

It would appear that the first wars were fought with chariots, sometime before the BC-AD changeover, and involved the Sumerians and the Hyksos in the Middle East, and their enemies. Four donkeys were used initially to pull four-wheeled vehicles that carried two men - a driver and a bowman. The superiority of the horse was quickly realized - as was the two-wheeled, two-man chariot, which became established practice. Two other contemporary weapons were the sickle sword (the khopesh), and the three-pronged trident - which was also used for catching fish! And the Greeks of Athens built a strong navy, but had no cavalry and relied on spears and bows and arrows.

Early AD Years to the Middle Ages…

The Middle Ages (450 to 1450 AD) were also called the Medieval Times. The Romans, at the height of their power in Europe - before, and after, BC became AD - spent time and effort building roads, along which their troops and supplies travelled, relatively easily, and to their advantage. These roads eventually became useless, through neglect, when the Roman Empire was busy splitting in two and its centre moving to Constantinople in the fifth century AD.

The mediaeval Huns of the seventh century AD fought their battles on horseback, and used bows and arrows. Barbarian tribes developed their own weapons, such as the first iron-tipped arrows, two-edged swords and throwing axes.

The naval battles of this period were fought between ships with square- and lateen--driven sails, although some also used oarsmen. They still had wooden hulls. Combat could still be hand-to-hand, and projectiles could still be thrown from one ship to another.

Early fishing was from small boats which, in Egypt, were made of papyrus, and included the Welsh one-person coracles. As well, Canada was discovered in the 11th century by Leif Erikson.

Gunpowder was invented by the Chinese around the 10th century AD, using saltpeter, sulfur and carbon, and were the first to use it as a weapon. The Arabs followed, but used a different recipe, as did the Europeans, who preferred potassium nitrate. Gunpowder in these days could be carried in pots that were ignited by fuses and shot by artillery.

Although the wooden catapult originated with the Greeks, the Romans made theirs later from iron or bronze, were more powerful, and could launch a variety of spherical and dart-like projectiles, including jars of snakes and bees. They might also use springs and copper bearings.

The Normans who invaded England in 1066 wore chain mail, rode horses, shot arrows and swung swords. Their number also included those who used axes, and those who wore leather armour.

During the Crusades (1036-1300 AD), cavalry used lances for their early attacks, followed by double-edged swords, axes and war hammers. During the Hundred Years War (1337-1453 AD), infantry-dominated armies would engage opposing cavalry by digging ditches and flooding marshes, and using gunpowder and artillery weapons in open battlefields as well as for sieges. The Welsh longbow was introduced by the English to great effect at the Battle of Crecy in 1346.

Around this time, also, siege guns got larger and more destructive, swords became double-edged and smooth-bored arquebuses and muskets began to appear. The 15th century, however, introduced rifling, and the beginning of weapons called ‘rifles.’

As noted above, medieval times brought to cavalry warfare the development of the saddle, the stirrup and the horse collar, originating in the Asian Steppes and spreading from there into Europe. The 12th century brought improvements in the design of weapon such as crossbows, for better accuracy and effect. But better bows and arrows also triggered better defensive manoeuvres by defending armies, who invented mass movement drills to minimize their losses - for example, ‘the square.’

The power of feudal lords in Europe was broken as monarchs acquired sufficient force to destroy their private armies and level their castles.

During the Hundred Years War, infantry-dominated armies would engage opposing cavalry by digging ditches and flooding marshes, using gunpowder, and using artillery weapons in the open battlefield as well as for siege purposes.

This War also saw the beginning of the use of naval artillery, fired from bows and sterns. By the 15th century many navies throughout the world were using heavy ship-borne artillery, and some also had begun to develop broadside cannon. The latter advance also brought about changes in ship design, including the reinforcement of decks to accommodate the guns. The English ship, *Mary Rose,* was among the warships that, over the years, carried a variety of types of naval artillery.

In the Middle Ages, both the English and Scottish governments ordered their citizens to engage in regular archery practice. Also, the Tournaments of these Middle Ages were both a substitute for war and a training for it.

These were also the days of larger numbers of mercenary army soldiers and an increase in the rates of desertion from armies facing battle that required the development of measures to reduce/stop them.

Infantrymen carried mostly spears, swords, helmets, breastplates and shields and marched in formation into the early battles. MacMillan quoted Plutarch in regard to this: Men wear their helmets and breastplates for their own needs, but they carry their shields for the men of the entire line (page 169). So the shield helped to protect the man to the left of its carrier.

The Renaissance to the late 19th century…

… in other words, from the Renaissance (1450-1650), to the first Industrial Revolution (roughly 1750-1850) and the first part of the second one (roughly 1850-1900).

The Renaissance began in Italy, spread to Europe, and then to the rest of the world. It is, perhaps, best remembered for people like Leonardo da Vinci, who engineered many things, but left behind more written work than artifacts; Filippo Brunelleschi, who put the dome on the cathedral in Florence, which became the model for other domes elsewhere; Michelangelo who painted the ceiling of Rome's Sistine Chapel; and Johannes Gutenburg, who developed movable type and brought about a 'learning' revolution in Germany, Europe and, eventually, the rest of the world.

Then there were three major innovations that were applied to ships during the Renaissance years: the use of the lateen (triangular) sail, which allowed them to sail closer to the wind; the use of upright rear rudders and steering gear, which dispensed with the steering oarsman; and increased use of the compass as a navigational aid. As well, the planking of the hulls of some new ships were changed from overlapping clinker construction to the smoother and potentially faster, although leakier, carvel edge-joined construction. As well, several new sailing ship types emerged: the caravel, the carrack and the galleon, which could be used for cargo as well as combat duty.

The discoveries of the American and Indian continents included the voyages of Columbus, Cabot, da Gama and others, as well as the Spanish conquests in Central and South America in the late 15th and 16th centuries that came not just because of their horses and weapons, but because they violated a rule of Inca society that they should not seize the Emperor, which left his subjects leaderless. It was the Spanish, also, who introduced the horse to North America at this time.

Use of the bayonet began in the 17th century, enabling the musket to be used as a pike in close combat. Cartridges were also invented, making firearms easier to load.

At sea, towards the end of the 17th century, the 'line of battle' tactic was developed in naval warfare, to take advantage of the broadside, It lasted until after Nelson's victory at Trafalgar in 1805.

During the 18th century, two Revolutions took place, one in the British North American colonies and the other in France. The latter coincided with the rise of Napoleon and his aggressive attitude to expanding France and its influence. The so-called Napoleonic Wars followed, during the early years of the 19th century, and ending with the Battle of Waterloo.

In 1763, the first steamship patent - for a tugboat - was awarded. It used the Savary steam engine. And so began the slow switch from sail to steam. While the first patent for a side-paddler boat was awarded in the 15th century, it was not until the early 19th century that steam-powered paddlers were commonplace. For example, in 1802, engineer William Symington built the *Charlotte Dundas* for use on the Forth-and-Clyde Canal in Scotland. American engineer Robert Fulton launched his steamer *Clermont* at New York in 1807, and the *Accommodation,* owned by John Molson, began a steamboat service between Montreal and Quebec in 1809.

A change in the hull construction of ships from wood to iron, and later from iron to steel, was also under way This innovation also brought ironclad naval ships into being and a decline in the use of rows of cast naval cannon, which were replaced in battleships in the late 19th century by gun turrets. But the change from riveting to welding in the construction of ships' hulls had to wait until World War II.

With steam power in the 18th century came the development of railways in the 19th. Also, during this century, steel began to replace iron. The first Industrial Revolution, which began in the mid-18th century, and which brought major changes in the methods and means of production, and in science and engineering, made it possible for Western societies and some others to produce more and better weapons and to wage war on a greater scale, The idea that machine and engine parts should be interchangeable also caught on. The middle and working classes grew in size, while the upper classes lost some of their influence.

In the 18th century, the British Navy was the single biggest industry in the whole of the British Isles! It was also the fighting force that Napoleon never managed to defeat.

It should be noted that the establishment of engineering as a profession in the late 18th century (thanks, in part, to England's John Smeaton), served to attach their skills to weapons independently, and to advances in research. Some armies around the world, and in Europe especially, gave their officers and potential officers some engineering training.

The 19th century gave birth to the telegraph and the telephone, revolutionizing the means and operations of army and navy communications. The second Industrial Revolution began around 1850 and continued for the next hundred years. Whereas steam dominated the first one, it was steel that dominated the second.

The late 19th century brought, for example, repeating rifles and smokeless powder, long-range artillery, high explosives, machine guns, mechanized transportation, and early radio. The first weapon to be guided to its target was of German origin: an anti-ship bomb. (Since then, electronics, inertial guidance and human assistance have also been used for this objective.) The rifling of gun barrels became *possible* around the year 1500, but could not be *used* until the 19th century. In 1803 the British began using shrapnel.

One might only look to the 19th century for the early experiments with balloons. These were used extensively in the research leading up to the phenomenon of human flight. Since then, as 'airships' they have provided the machinery for commercial and passenger transportation, as well the 'barrage balloons' that were developed for defence against attack from the air in World War II. There have been privately-owned balloons. There have also been the anti-aircraft guns, and cannons, missiles and machineguns designed to destroy enemy aircraft in war situations, which were prominent during both World Wars. And, most recently, there have been rockets, missiles, drones and spacecraft, built to explore inner and outer space, build satellites and fulfil roles in attack and defence.

Submarine engineering began in the 17th Century. The early subs were powered by hand cranks, and it was not until the mid-19th century that self-propelled torpedoes were first used. But subs had to wait for many more years before becoming effective as weapons.

In wars before the 19th century, soldiers died on battlefields, but more died of disease and wounds after the battles. From the 19th century on, more wounded survived, having received better medical care, thanks in part to Florence Nightingale and her nurses. There were also fewer instances of desertion.

Science and engineering in 19th century Europe helped give it and the larger 'West' an advantage over the rest of the world, which is only now just ebbing. The United States took over world leadership in engineering from Britain in the late 19th century, thanks in part to the World Exhibition at Philadelphia in 1876.

An interesting related social 'aside' originated in England, in the 19th century in Upper Class Boarding Schools, where the classical education the students received was designed to help them become better (and more heroic) officers in the wars fought by the British Army. The game of rugby (no protective equipment, unlike the American equivalent), and its coaches also had this objective, along with the unloved cold morning showers!

The 20th and 21st Centuries…

… beginning around 1900, ending around 2020, and including the balance of the second Industrial Revolution (roughly 1900-1950), and the larger part of the third one (roughly 1950 to 2020).

The Boer Wars were fought in South Africa at the turn of the 20th century. Perhaps the most important changes during them were a change in tactics, from formal battles to skirmishes, with an emphasis on small arms warfare, and a switch in the uniforms of British soldiers. At first, they wore the traditional coloured tunics and trousers. But the enemy found them easy targets, while remaining well camouflaged themselves, in their farming clothes. So, the British adopted khaki, and the remaining battles were more evenly fought.

In 1906, Britain launched the first of a new class of battleships: the *Dreadnoughts,* which were heavier and faster than any other contemporary battleship. Competing navies were forced to build their own versions of them. As well, the increasing range of naval guns meant that, by World War II, navies could fire on one another without being able to see the other sides' target vessels. Later advances in naval warfare brought aircraft carriers into being.

Until World War I, science, research and engineering had not been specially organized for military purposes, except on a small scale. Its trench and artillery warfare also influenced these activities. Tanks, poison gases, mortars, flame throwers and aircraft were among the transformative weapon innovations, as well as air raids on military and civilian targets, and the bulk production of materials such as steel and chemical weapons, which were first used on a large scale during World War I - in spite of an international agreement banning them.

It was not until 1915 that a plane could safely fire a machine gun through its propeller blades, and give rise to 'dogfights' during the War. Tanks were also used for the first time, but were often slow and vulnerable. The British research laboratory at Porton Down was established (among others) and it has continued to develop new weapons into the 21st century. Canada's National Research Council was established in 1916, originally to help the universities contribute to war-related research.

World War I was also noteworthy in that it was the first major war during which the people of the combatant nations, generally, could read and write! The support of ground troops was the main reason for Germany in World War II favouring short-range aircraft over long-range bombers - for example, the dive-bombing *Junkers Ju87* (the *Stuka)* and the *Dornier Do 217* bomber.

The science and engineering of World War II was perhaps dominated by the Manhattan Project and the atomic bombs, and by rockets in Germany, and radar in both Britain and Germany, and the work has continued in laboratories - particularly in the United States - into the 21st century in Germany, Russia, Britain and Canada and other countries. And universities, world-wide, have become associated with weapons research. The principal research subjects have included electronics, computing, astrophysics and oceanography, plus the biological and social sciences.

Radar (radio detection and ranging) was a weapon used by both sides during World War II. The Wikipedia source for radar is extensive and detailed, and only a short historical summary has been possible within the context of this paper.

The story began with experiments in Germany by Heinrich Hertz in the late 19th century and included later work by the three military services in the United Kingdom (by Robert Watson-Watt and others), Germany, the United States, the USSR, Japan, the Netherlands, France, Italy and Hungary. Britain also shared its developments with the Commonwealth and Australia, Canada, New Zealand and South Africa and work was also done in these countries.

At the beginning of World War II, both Britain and Germany knew of each other's work and the British work, as we all know, played its part in the Battle of Britain in 1940. The German effort, however, did not have Hitler's support, and faltered., something the Luftwaffe also failed to grasp. The RADAR acronym was actually coined by the U.S. Navy in 1940.

Britain's difficult financial situation in 1940 led to their more powerful magnetron being offered (and accepted) by the United States. Before the end of 1940, a radar lab was set up at MIT to develop later versions of radar. Meanwhile, work in Britain continued. At the end of the War, work on radar stopped in Germany and Japan, neither country having made the progress the Allies made during it.

During the 40-odd years of the Cold War, both sides used radar as an early warning tool, and many new versions were created, such as weather radar, and some that had nothing to do with the war in the air. Most recently, however, the arrival of space satellites has reduced the importance, and use, of radar, but not the development of new uses, which has continued. But the future of combat in the air is likely to rest with missiles and pilotless drones.

At the same time, one reason for Germany's defeat in World War II was its leader's underestimation of the value of science, although he took advantage of his engineers. Others were its lack of effective planning and rationing. And throughout World War II, all of the belligerents' GDPs increased significantly.

The first weapon to reach outer space was a German V-2 rocket, in 1944. The first weapons to attack targets in space were developed by the U.S. and the Russians during the Cold War. A recent advance has been the laser weapon system built by the United States Navy.

Many of the other recent advances in science and engineering - jet engines, transistors, computers - came about because they would be needed in wartime. Technology (engineering?) in war has been, and still is, a race between new devices or inventions and ways of dealing with them. At the same time, we should remember that wars on land and wars at sea and in the air are different. While the first can be 're-seen,' the latter two can not. And with regard to weather, winter is usually a foe, as it always has been.

The second Industrial Revolution ended around 1950, after World War II, when the third began. Its transformative technology has been electronics and, from the weapons point of view, has involved the further development of long-range missiles and drones, symbolizing the lengthening distances between the firing of the weapons and their targets, which could be on the other side of the world. Meanwhile, small, local wars continue to occur - for example, at the time of writing, the one between Israel and the Palestinians in the Middle East - a war that involves several other countries in peripheral roles. Another local war was triggered two years ago when Russia invaded the Ukraine.

Finally, the reader will have noticed that this paper has concentrated on the history of the *introduction* of the items of weaponry and have not followed up with descriptions of their later evolution or the model development of models or marks. This was simply because there are often so many of them that another book or books would be needed!

Brief Conclusions from the Text Above…

The four weapon innovations that set the scene for 'modern' (post-BC) warfare were the introduction of metals (initially bronze and iron, and later, steel), the domestication of the horse, bows and arrows and the introduction of gunpowder, invented by the Chinese, which led to the development of firearms, artillery and bombs.

The next weapon innovation 'package' came at the time of the Renaissance and the discovery of the American and Indian continents, and involved ships, their construction and navigation.

Centuries later, this process was undoubtedly helped along by contemporary or recent planned advances in research, engineering, military tactics and organization. But it should also be remembered that very early weapons made of wood or skins would not have survived, as those of stone (or metals) did.

The third 'package involved World Wars I and II, and includes tanks, aeroplanes, poison gas, the atomic and nuclear bombs, radar and the first rockets. It was during and after World War II that the strategic importance of Britain's Royal Navy gradually declined, except for its convoy work in the Atlantic in World War II.

The fourth 'package' has involved the Cold War and the years since 2000 AD, and has resulted in weaponry that can be fired on one side of the world at a remote target on the other side, and advances in electronics have affected weaponry. But many of the innovative weapons from the earlier periods are still in use.

Some Comments from the MacMillan Source…

Professor MacMillan's theme throughout her book is a plea for WAR to be taken more seriously, Its international effects are discussed in a broader context than had been happening in earlier analyses, and especially since World Wars I and II have not put an end to it. Even now, in 2024, small and local wars continue to be fought in several parts of the world, sometimes threatening more extensive and deadly warfare and use of weapons.

The MacMillan book is far too long to even consider using extracts or long quotations. But it makes several assertions, or summary words of wisdom, that bear repeating, by themselves, in this present paper. For example:

> …War is an indelible part of human society. (page xi)
>
> …Wars have repeatedly changed the course of human history (for example, the Battle of Britain in 1940), (xiii)
>
> …Over the centuries, war has become more deadly, (xv)
>
> …Tacitus said that money is the sinew of war (21); The British found it easier to collect taxes. (22)
>
> …Greed for what others have…has always motivated war. (35)
>
> …In a civil war, the small grudges and enmities of peacetime are magnified and become lethal. (43)
>
> …China was once divided among 150 small states, which were gradually consolidated in a painful and bloody process (mostly in the 5th-to-3rd centuries BC). (17)
>
> …The difference technology (and engineering) make depends on how it (they) are used in weaponry - indeed, on whether it (they) are used at all (62)
>
> …War deaths in the 20th century may amount to 75% of all war deaths in the last 5,000 years (7)
>
> …Will the 'long peace' since 1945 last? (it is implied!) (8)
>
> …Which technologies are adopted, and when, will…depend on a number of things: the need for the technology; the transmission of knowledge; and the openness of a particular society to change (78)

MacMillan's message, simply put, appears to be, "War is organized violence, which is attractive to some and repulsive to others!" It probably reached its peak in importance historically during the latter part of Napoleon's career and during World War II.

MacMillan has little to say directly about engineering and its influence on the development of weapons, but it underlies much of the story she tells.

MacMillan's main concern for the future appears to be over the probable devastation another World War might cause.

Some Comments from the Kennedy Source…

Kennedy's long book notes in the *Introduction* that it is not another general history of World War II, but is focused on problem-solving and problem solvers…and concentrates on the middle years of the War (1942-44). It also resists the conclusion that winning the war could be explained solely by brute force or by some wonder weapon or system…Winning the War was too complex for such simple explanations (page xv).

The five main chapters of the book tell the stories of the contributions of small groups of individuals and institutions who enabled their political masters to become victorious during these middle War years. These five titles are couched in "how to" language, how to: get convoys safely across the Atlantic; win command of the air; stop a blitzkrieg; seize an enemy-held shore; and defeat the "tyranny of distance."

One of the most important discussions in this book concerns the development of the American *Mustang (P-51).* It became the War's most successful long-range fighter aircraft after its original engine was changed for the British *Merlin.*

Kennedy also discusses the development and use of many specific types of aircraft (for example, the Flying- and Super-Fortresses, and the Lancaster, Wellington, Mitchell and Liberator bombers; the Spitfire,, Hurricane, Thunderbolt, Lightning, Focke-Wulf and Messerschmitt fighters; specific weapons (such as the *Hedgehog,* U-boats, types of tanks, plus the convoy system, specific battle-and-other ships and naval battles, the Russo-German land war, *as well as* the military leaders and leadership during the two Wars and earlier.)

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