The Impact of the Industrial Revolution on Warfare
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The Industrial Revolution in the nineteenth century had an incredible impact on the conduct of war. Historians often call the American Civil War the first truly modern war. It showed the effects of the technological advances in industry and agriculture, which were to revolutionize warfare. To fully understand the significance of the Industrial Revolution, one must look at it in the context of a century of rapid and drastic change, one in which new advances in industry, science, and technology would be readily applied to the conduct of war. New technology made it possible to mass-produce weapons with enhanced accuracy, power, and range. Many of the new weapons and corresponding tactics went against the fundamental conceptions of what constituted proper conduct of war, making change difficult and unsettling. Military conditions were in constant flux during the industrial age as new weapons were developed and transportation and communication improved. The American Civil War saw the death of many traditional modes of warfare, the adoption of new weapons, and the birth of new inventions.

The early part of the nineteenth century, from 1815 to 1848, saw a long period of peace in Europe with extraordinary industrial expansion. America too, except for the war with England in 1812-15 and the Mexican War in 1846-48, saw political tranquility and phenomenal national growth up to the outbreak of the Civil war. Armaments were generally neglected, for many imagined peace would be permanent. By mid-century tensions were increasing, and an intense rivalry developed again between England and France, partly because of the change from sail to steam in their navies. On land, the development of the railroad brought another revolutionary change. Its consequences for war could only be guessed at, at first.

The latter half of the century, torn with strife, saw the following struggles: the Crimean War, the American Civil War, the Austro-Prussian War, the Franco-Prussian War, the Russo-Turkish war, the Boer War, and the Spanish-American War. During these wars, there was an abundant opportunity for experimentation with and testing of new weapons, and for the realization of the impact of science and the Industrial Revolution upon tactics and strategy. Communications and logistics were completely transformed by the steamship, the railroad, and the telegraph. Armies were much bigger than before and more mobile. Firepower was vastly more effective, thanks to the adoption of rifles and breech loading weapons of all kinds. War became more destructive than ever in the past.

Thanks to the Industrial Revolution, the civilian was now responsible for providing the industrial means of war, and the workshop became as vital a part of the struggle as the battlefield. The soldier and the civilian were now fundamentally dependent upon one another. The importance of the role of the scientist-inventor became increasingly recognized. Scientific improvements of the new century sprang up independent of any special war-stimulated research. Chemistry made tremendous strides during the century, though there was a lag before most of the new discoveries affected military technology in any way. Most of the common modern explosives were discovered in the nineteenth century. There was even the use of the rocket though not used very successfully. Throughout the nineteenth century, improvements in iron and steel manufacturing were steady and cumulative. Thermodynamics, which deals with the relations between heat and mechanical energy, grew into a respected science with an impressive body of theory and experimentation. The fields of physics and electricity as well as chemistry advanced with the development of cables being laid under the Atlantic Ocean, the mariner's compass and tidal gauges, to name a few. The effects of many talented men on the science of the time were significant. Many of the new discoveries were put to use by the military. The new

discoveries lead to the creation of a new philosophy of warfare, less mental and physical and more dependent on technical capability. Technologies become the foundation of military thought while tensions between rapid change and military conservatism developed.

By the mid-nineteenth century, military logistics had become a blend of new and old technologies. The railroad could move troops and supplies fifteen times as fast as their marching speed. On the other hand, beyond the railhead, soldiers still marched and draft animals still drew supply wagons. Thus, the layout of the rail system began to assume the role of the framework of strategy. Only the Prussian army really mastered the technique of combining an offensive strategy with defensive tactics. Military men of the mid-nineteenth century tended to cling to Napoleonic tactical methods long after they were out-of-date by developments in rifled arms. This lag was due in part to the rapidity with which wars of the mid-century came in succession. Even thoughtful soldiers had little time to assess their lessons. No other army of the time had the equivalent of the Prussian War College and General Staff, organizations well suited for the study and rapid application of lessons learned from experience. In the American Civil War, the Americans had to learn the lessons of the new warfare the hard way through a four-year ordeal. In many ways, the effects of the Industrial Revolution on the military were slow in coming.

In his book *War and the Rise of the State*, Bruce Porter writes that in the beginning, industrialization was a secondary phenomenon, a “bubbly froth” on the surface of deeply rooted traditional societies. However, as industrial technology advanced, it set in motion powerful social and economic forces. These forces included population dislocations, growing concentrations of private capital, unionization, and labor unrest, all of which seriously strained the established order in every industrializing country. Despite its many effects on societies and economies, initially industrialization had only a limited impact on change. The bureaucracy bent little under the pressure of industrialization. As it related to warfare, many had trouble accepting the new weapons, which went against traditional codes of military conduct and honor. This was especially true of the submarine, which was unpredictable and relied on skulking and deception to succeed. Society clung to traditional concepts of warfare based on hand-to-hand combat and individual heroism long after new weapons made them obsolete. New weapons of destruction, such as the machine gun and dumdum bullet, while were received coolly by European nations at home, were used to great effect in their colonies where they allowed small numbers of Europeans to defeat and control much larger native populations.

At the onset of the American Civil war, both North and South scrambled to establish powerful armies to support their causes. The military leaders on both sides, however, all shared the same basic military training as well as the basic concept of how an army should be built and how a war should be fought. The military training as well as tactics of the civil war was geared towards emulating the grand armies created by Napoleon. The campaigns of Napoleon formed the bases of formal military education through out the western world. At the onset of the civil war, the existing doctrine of military warfare was about to become obsolete. The old lessons of warfare had to be re-written by the American Generals serving in the American Civil War. War began to take a new turn. Old world tactics and training were inefficient due to modern weaponry. The American Civil War was an event that was unparalleled in the annals of military history. It was a revolution of warfare in itself. U.S. military minds re-wrote military strategy to encompass all aspects of modern technology developed in the private sector. The conflict hosted the first ever use of rail and waterways and armored ships over a larges area of military operations and redefined previous lessons of battlefield deployment.

Previously learned infantry tactics quickly proved to be disastrous. American Generals were forced to adapt and even abandon the lessons of military thought that existed before the war. The railway made armies mobile to a degree that was previously unimaginable. Their development completely altered the entire concept and strategy of managing army's. The civil war laid down lessons to be copied and learned for the up coming wars in Europe. Along with lessons and tactics came the new emphasis on newer and modern units and an increased importance assigned to battlefield preparation and geography. Through observation of the federal military development, European observers witnessed the importance of a solid industrialized infra structure supporting the warfront. The North showed the world how strong industry and support can offset valor and other military qualities. European leaders learned from the civil war the proper employment of mass armies, railroads, telegraphs, armored ships, railway, artillery, refilling, and trenches. Leaders such as General Sherman place the industrial concept of efficiency above traditional conceptions of military conduct, believing that the ends justified the means.

Another maker of history, Ulysses S. Grant, was affected by the Industrial Revolution. He insisted that in the end, technology cannot be denied. Grant discovered that in a war of people against people, dispersed in a vast, rich, but almost empty land, an army need have no permanent base. All that it required to operate was the ability to draw military supplies behind it by river and railroad, while it fed itself on the produce of the districts through which it marched. Rivers and railroads were the means by which Grant brought his armies to the battlefield. Spies, scouts, and the telegraph were the media through which he informed himself of the enemy's own movements. The new weapons made available by the Industrial Revolution were the instruments of Grant's war.

It was not until the last half of the 19th century that revolutions in communication, transportation, and weapon technologies would fundamentally alter the conduct of war. Improvements in long-range, rapid-firing rifles and cannon afforded a defending enemy decisive advantages in firepower, and threatened to make the successful execution of an infantry attack, especially a frontal one, impossible. As Moltke wrote in 1858, "the universal and fundamental improvements in infantry weapons alone necessitated a change in the tactics of all branches. The firepower of an infantry platoon surpasses the range and destructive effect of the case-shot of a six-pounder cannon." His response to this general need for change was his promotion of combining the advantages of flank attacks and the tactical defensive, enticing the enemy to attack, waiting for the right moment to smash his assault with overwhelming firepower, and then finishing him off with an annihilating counterattack. This solution had obvious limitations in that it required either an available flank for the assaulting force, or an enemy willing to attack first. Nineteenth-century warfare lacked neither. In sum, Moltke's 70-year military career permanently enhanced and legitimized a long aggressive tradition and shaped an entire way of military thinking. He conducted near-perfect battles at a time when military technology severely challenged traditional procedures and preferred notions. He remained committed to decentralized execution, a creative approach to tactics, logical methods of strategy, meticulous and continuous war planning, and the ideal of personal and total dedication to duty, perhaps to a fault.

The pace of technological innovation accelerated in the last part of the nineteenth century. The full impact of electricity upon war would not be felt until the twentieth century, though it was put to some use in mine and submarine warfare before 1900. The end of the century brought the invention of the wireless telegraph. By 1901, the wireless telegraph spanned 3,000 miles. Communications in wartime, already speeded by the telegraph and the submarine cable, were now made much more flexible, since sender and receiver were no longer tied to systems of cables and wires. Although throughout the latter part of the

nineteenth century wire systems were to be found on land wherever railroads ran, the wireless was especially important strategically to naval operations, since ships were otherwise devoid of any but visual communications while at sea. The internal combustion engine, destined to revolutionize first transport in war and then the implements of war themselves, like the tank and airplane, showed the same leisurely development through the nineteenth century as the electric generator, with tremendous acceleration in the final decade. The slowness in the development of the gasoline engine was partly due to the difficulty in finding and producing a satisfactory fuel. The development of rubber was also indispensable for the efficiency of motor transport. With the dawning of the twentieth century, science became so intertwined with the technology of war that the scientist in military work became so ever-present that he began to be anonymous.

The First World War demonstrated that by the twentieth century the Industrial Revolution had put into the hands of each nation a war machine of far greater power than any known before. This change was accompanied, however, by a near collapse of the forces previously serving to limit war, including that of common prudence. All rational concern with the proper political aims of war seems to have been suppressed. World War I was the pointless war which no one seemed to know how to prevent, and which, once begun, no one seemed to know how to stop. The technology of World War I was immeasurably more complicated than of any previous war. Much of it is a story of the improvement and perfection of previous weapons. Metallurgists and ballistics experts, for example, made machine guns and artillery weapons ever more accurate and powerful. Railroads were more efficient, communications were swifter, and logistics became ever more large and complicated, as transport was gradually motorized. Great innovations included the airplane, the tank, poison gas, and the submarine.

In striking contrast to the stories of technological innovation, where audacity in science and in strategic and tactical thinking became commonplace on both sides, the land fighting is largely a story of stupid rigidity and waste. The first blunder was the complete underestimation of the power of the machine gun by both sides. By late 1914, the armies were already stalemated. The firepower of the machine gun was so devastating that armies could no longer live upon the surface of the battlefield. The only answer to that either side could think of for a long period was artillery bombardment. The great artillery barrages of the war solved nothing. The time taken for massing the artillery gave warning of the coming attacks, and the preliminary bombardments warned the enemy of the point of attack. The Germans were the first to turn to science in earnest for a device to break the stalemate. Chemists very early in the war had pointed out to the German high command the possibilities inherent in chemical warfare, but the generals had been reluctant to adopt the proposals. The use of gas by all participants and the development of new chemicals were not successful in brining an end to the stalemate of the western front. The instrument that finally broke the sandbag and barbed wire blockade and restored the offensive to what it had been before the invention of the machine guns was the armored car.

The growth of national armies in the nineteenth century and of a competitive arms race, the Anglo-German naval rivalry and the development of techniques of mobilization, which, once started, were difficult to stop, all pointed to the likelihood of a major European war. It was at first expected that World War I would be short. Both sides hoped for a quick victory. The war soon evolved into a stalemate. This stalemate was caused by the fact that developments in technology had led to a predominance of the defensive and had not yet adapted to the offensive. This was most evident on the Western Front, where both sides could concentrate their biggest forces and where defeat would be decisive. The great railway network in this thickly populated industrial area, built with an eye to strategy as well as to commerce, had made it possible to rush huge armies to the frontier within a few hours

of a general mobilization. In the later years of the war, the gasoline engine was increasingly used to haul supplies of ammunition and food from the railheads to maintain the huge armies deployed from Switzerland to the North Sea.

Tactics on the Western Front were reduced to suicidal infantry assaults in shoulder-to-shoulder formations. The chief variations of these tactics attempted by the military leaders on both sides included preliminary artillery barrages to achieve surprise, creeping barrages behind which the infantry advanced, box barrages which isolated sections of enemy trenches, and saturation barrages which concentrated the fire of all available arms on a small area to obliterate it. Some attempts were made to achieve tactical surprise and the desired breakthrough by the introduction of new weapons. The Germans used poison gas shells in Poland in 1915, but with little success. On April 22, 1915, they tore a great hole in the allied front at Ypres by the use of chlorine gas, but failed to take advantage of the breach. Another example of the misuse of a new weapon that might have provided the tactical surprise necessary to breach the fortifications on the Western Front in the story of the tank. Armored cars existed before the war began; but they were restricted in use by the necessity of staying on hard roads.

On the Western Front in 1917, while the Americans desperately got themselves ready for the war they had entered, the French and British continued to hold the line. At the end of 1917, the British surprised the Germans with a raid by 380 tanks, which penetrated deep into the German lines, but were obligated to withdraw, since no reserves of fresh infantry was at hand to exploit their success. The Americans made good use of time given them. American farms and factories broke all records for production. Civilian industry was converted to war uses; radiator factories turned out guns, and piano factories manufactured airplane wings. Every possible means was employed to build up ocean shipping. Civilian consumption was drastically cut. Eight thousand tons of steel was saved in the manufacture of women's corsets and 75,000 tons of tin was spared in the making of children's wagons.

The First World War had a most serious effect on the society of the whole world. Its physical consequences alone were enough to slow the onward march of civilization and to destroy that general belief in the inevitability of human progress, which had marked much of the philosophy of the nineteenth century. The material cost of the war and the number of killed and permanently disabled were staggering. For the first time in human history, war came to be regarded by a large part of humankind as a primary evil. Many people became pacifists, declaring that war should be outlawed. Considerable debate within nation ensued about the size of their armies and navies and disarmament was discussed. Largely during the peace, which followed the First World War, development in arms ands in methods for using them, fell behind contemporary advances in science. This lag was especially true in democracies, where there were greater hopes for the creation of an effective system of collective security. However, while democracies were turning their backs on things military and were wrestling with the economic upheaval caused by the last war, Russia, Italy, and Germany in turn began to organize the whole structure of their state toward efficiency in war.

After the 1917 revolution in Russia, the communists had been faced with the necessity of defending themselves against counterrevolution and against both German and Allied intervention. Like the communist revolution in Russia, the First World War brought about the fascist revolutions in Italy and Germany. The military doctrine of the new German army was total war with all arms. This was in startling contrast to the pacifism of the Western democracies. Thus, the stage was set for another war and technology continued to improve the weapons of war.

In World War II, the scientist in the laboratory touched almost every aspect of the war operations and profoundly influenced tactics and strategy. The Germans believed that no new weapon needed to be introduced in a short war. Hitler was confident of winning with the weapons he had already developed and massed. Those weapons were largely those of World War I, though enormously improved technically. What he relied upon chiefly was a novel tactical use of these weapons, particularly the airplane and the tank. When the scientists were finally seriously mobilized by Germany, they made tremendous advances, particularly in ordnance, aerodynamics, and rocketry. After the fall of France, President Roosevelt acted quickly to put the resources of American science at the disposal of the desperately imperiled United Kingdom. These moves marked the beginning of what was to grow into a gigantic coordinated effort, in which hundreds of academic scientists, all the leading British, American, and Canadian universities, and in immense number of industries, as well as the research departments of all the armed services in all the Allied countries, worked at top speed to perfect old weapons, to invent new ones, and to invent countermeasures which could lessen the deadliness of enemy weapons. The dedication was universal and the results phenomenal. The most important of the new scientific developments of World War II, except for the Atomic Bomb, concerned radar, the proximity fuse, electronic fire control equipment, anti-submarine devices, incendiaries, and rockets. These new developments significantly affected the outcome of World War II and continue to affect warfare to this day.

The weapons revolution created by the Industrial Revolution and the revolution in military tactics and strategy directly affected the conduct of warfare. Black powder cannons gave rise to a full complement of modern warfare modes. From the time when conical bullets and rifles took to the battlefield as the forerunner of the age of technology, weapons immediately had an effect on warfare. First, it was the enormous steel-clad naval vessels that ruled the seas, launching the "age of battleships," then the "tank" ruled land warfare, after which the airplane dominated the skies, up until the atomic bomb was created, announcing the approach of the "nuclear age." Today, a multitude of new and advanced technology weapons continues to pour forth.

Modern warfare is a product of the Industrial Revolution. Gunpowder had been around for several centuries, but the introduction of the factory system, mass production, and new kinds of communications technology vastly improved the military potential of Europe, North America, and Japan. The use of interchangeable parts made possible uniformity in the quality of rifles and handguns. Rifles became more accurate at long range. Repeating weapons were improved, and the machine gun was invented in time for use in the American Civil War. The invention of the screw propeller, combined with the steam engine, brought about a new kind of naval ship and ended the age of sail. Mobile field artillery came into use, assuring the demise of cavalry units until motorized cavalry appeared in the 20th century. Communications and transportation systems were vastly changed. In the 20th century, there has been such a proliferation of inventions applied to war that no list could be complete. The Industrial Revolution is far from over. The world still may witness many tremendous changes in warfare as third world countries that are just now industrializing becoming great industrial powers. The impact of the Industrial Revolution on warfare will be felt for many years to come.

Historian Claude Fohlen once stated, “The industrial revolution is… a continuing phenomenon which is going on in front of our eyes… We must recognize that the process once launched knows no limits.

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