TECHNOLOGY: A HISTORICAL PERSPECTIVE

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Don't stop thinking about tomorrow. Don't stop, it'll soon be here.
— Fleetwood Mac

Technology is among one of the essential determinants for the study of military history along with other factors such as political, social and cultural foundations, military doctrine, logistics, leadership, strategy and tactics. Technology has often had a pervasive effect on the battlefield, with victory often the result of possession of superior weapons, with other factors remaining the same. The role of military technology as a force multiplier has been well established in lessons learnt from the past wars of the 20th century. It is more likely that military technology will play a dominant role in future wars.

Nations have endeavoured to develop new and more advanced technologies with the goal of achieving military advantage throughout history. New technologies resulted in new weapons and brought dramatic change in military strategy and tactics. The increase in the destructive power of soldiers in the US Civil War and the resulting horror and futility of the frontal assault ushered in a change to trench warfare. The military aircraft, tanks, and the newly developed radio and radar made a new kind of dynamic warfare possible during World War II.

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World War II ended with a remarkable technological achievement—the development of the atomic bomb. In response, the Soviet Union detonated its first atomic bomb in 1949, followed by the successful test of a hydrogen bomb. By the early 1950s, missile programmes were underway in two leading countries – the USA and USSR. In the absence of knowledge and accurate threat assessments of each other, their responses were based on the worst-case scenario approach. Recognising the dangers of this uncertainty, the USA took up the development of a new generation of sensors and reconnaissance satellites. In response to the Soviet quantitative advantage in military forces, the US conceived a new "system of systems" of intelligence sensors, smart weapons and stealth aircraft. These new systems were developed during the late 1970s, produced in the early 1980s, and they entered into force in the late 1980s—just in time for Desert Storm. Thus, two leading nations of the world, apart from others, continued with their enhancement of military technology and subsequent weaponry. The technological advances of the last 50 years have surpassed the developments of the past 300 years, resulting in drastic changes in all spheres of human thinking and actions.

Today, the threats of terrorism and proliferation are the greatest threats to the world. This can lead to a nightmare scenario where a terror group may attack any nation with Weapons of Mass Destruction (WMD). Advanced information is critical to counter this threat. There are technological opportunities, necessities and challenges in all the components of security: intelligence, prevention, protection of infrastructure, detection of attacks, surveillance, reconnaissance, counter-attack and consequence management. But these improvements will not evolve automatically. It will demand single-minded dedication and will power to acquire the technological competencies to effectively deal with the future demands. As a nation, India must mobilise all the resources and support to develop cutting edge technologies and respond to the challenges even before it is needed.

This paper aims to deal with the historical perspective of technology in general and military technology in particular in order to generally highlight the evolution of military technology as part of military history. It also aims to bring out the relevance and importance of military technology in the past major conflicts of the 20th century. The historical process and the mechanism behind the spread of military technology are of significance for broadly identifying the order at which India is today in the world. It also intends to advocate and create awareness for the necessity to attain technological leadership and be a strong and powerful nation—militarily, economically and politically.

Technology includes the entire infrastructure necessary for the design, manufacture, operation, and repair of technological artefacts, from corporate headquarters and engineering schools to manufacturing plants and maintenance facilities.

TECHNOLOGY AND DIMENSIONS

What is Technology?[1]

Technology is the process by which humans modify nature to meet their needs and wants. Most people, however, think of technology in terms of its artefacts: computers and software, aircraft, pesticides, water-treatment plants, tanks, and ships, to name a few. But technology is more than these tangible products.

Technology includes the entire infrastructure necessary for the design, manufacture, operation, and repair of technological artefacts, from corporate headquarters and engineering schools to manufacturing plants and maintenance facilities. The knowledge and processes used to create and operate technological artefacts – engineering knowhow, manufacturing expertise, and various technical skills – are an equally important part of technology.

1. http://www.nae.edu/nae/techlithome.nsf/weblinks/KGRG-55A3ER

Technology is a product of engineering and science, the study of the natural world. Science has two parts: (1) a body of knowledge that has been accumulated over time; and (2) a process—scientific inquiry—that generates knowledge about the natural world. Engineering, too, consists of a body of knowledge—in this case, knowledge of the design and creation of human-made products-and a process for solving problems. Science aims to understand the "why" and "how" of nature, and engineering seeks to shape the natural world to meet human needs and wants. Engineering, therefore, could be called "design under constraint," with science—the laws of nature—being one of a number of limiting factors that engineers must take into account. Other constraints include cost, reliability, safety, environmental impact, ease of use, available human and material resources, manufacturability, government regulations, laws, and even politics. In short, technology necessarily involves science and engineering.

The Nature of Technology

The nature of technology has changed dramatically in the past hundred years. Indeed, the very idea of technology as we now conceive it is relatively new.

For most of human history, technology was mainly the province of craftsmen who passed their knowhow down from generation to generation, gradually improving designs, and adding new techniques and materials. By the beginning of the 20th century, technology had become a large-scale enterprise that depended on large stores of knowledge and knowhow, too much for any one person to master. Large organisations were now required for the development, manufacture, and operation of new technologies. Complex networks of interdependent technologies were developed, such as the suite of technologies for the automobile. These include gas and oil refineries, filling stations and repair shops, tyre manufacturers, automobile assembly plants, the highway system, and many more. The government began to play a larger role in shaping technology through technological policies and regulations.

The meaning of the word "technology" evolved to reflect these changes. In the 19th century, technology referred simply to the practical arts used to create physical products, everything from wagon wheels and cotton cloth to telephones and steam engines. In the 20th century, the meaning of the word was expanded to include everything involved in satisfying human material needs and wants, from factories and the organisations that operate them to scientific knowledge, engineering knowhow, and technological products themselves.

Technology and Science

Science and technology are tightly coupled. A scientific understanding of the natural world is the basis for much of technological development today. The design of computer chips, for instance, depends on a detailed understanding of the electrical properties of silicon and other materials. The design of a drug to fight a specific disease is made possible by knowledge of how proteins and other biological molecules are structured and how they interact.

Conversely, technology is the basis for a good part of scientific research. The climate models that meteorologists use to study global warming require supercomputers to run the simulations. And like most of us, scientists in all fields depend on the telephone, the Internet, and jet travel.

It is difficult, if not impossible, to separate the achievements of technology from those of science. When the Apollo 11 spacecraft put Neil Armstrong and Buzz Aldrin on the moon, many people called it a victory of science. When a new type of material such as lightweight, super strong composites, emerges in the market, newspapers often report it as a scientific advance. Genetic engineering of crops to resist insects is also usually attributed wholly to science. And although science is integral to all of these advances, they are also examples of technology, the application of unique skills, knowledge, and techniques, which is quite different from science.

Technology and Innovation

Technology is also closely associated with innovation, the transformation of ideas into new and useful products or processes. Innovation requires not only creative people and organisations, but also the availability of technology

Technology and culture refer to the cyclical co-dependence, co-influence, co-production of technology and society upon each other.

and science and engineering talent. Technology and innovation are synergistic. The development of gene-sequencing machines, for example, has made the decoding of the human genome possible, and that knowledge is fuelling a revolution in diagnostic, therapeutic, and other biomedical innovations

Technology and Culture

Technology and culture refer to the cyclical co-dependence, co-influence, co-production of technology and society upon each other. This synergistic relationship occurred from the dawn of humankind, with the invention of the simple tools; and continued into modern technologies such as the printing press, computers and the Internet.

ECONOMICS AND TECHNOLOGICAL DEVELOPMENT

Looking back into ancient history, economics can be said to have arrived on the scene when the occasional, spontaneous exchange of goods and services began to occur on a less occasional, less spontaneous basis. It probably did not take long for the maker of arrowheads to realise that he could probably do a lot better by concentrating on the making of arrowheads and barter for his other needs. Clearly, regardless of the goods and services bartered, some amount of technology was involved—if no more than in the making of shell and bead jewellery. So, from the very beginnings, technology has spurred the development of more elaborate economies.

In the modern world, superior technologies, resources, geography, and history give rise to robust economies. In a well-functioning, robust economy, economic excess naturally flows into greater use of technology. Moreover, because technology is such an inseparable part of human society, especially in its economic aspects, funding sources for new technological endeavours are virtually illimitable. However, while in the beginning, technological investment involved little more than the time, efforts, and skills of one or a few men, today, such investment may involve the collective labour and skills of many.

TECHNOLOGY AND FUNDING

Consequently, the sources of funding for large technological efforts have dramatically narrowed, since few have ready access to the collective labour of a whole society, or even a large part of it. It is conventional to divide up funding sources into governmental and private business or individual enterprises.

Government Funding: The government is a major contributor to the development of new technology in many ways. In the United States alone, many government agencies specifically invest billions of dollars in new technology. Many other government agencies dedicate a major portion of their budget to Research and Development (R&D). Technology has frequently been driven by the military, with many modern applications being developed for the military before being adapted for civilian use. However, this has always been a two-way flow, with industry often taking the lead in developing and adopting a technology which is only later adopted by the military.

Private Funding: R&D is one of the biggest areas of investments made in the developed countries by corporations towards new and innovative technology. Many foundations and other non-profit organisations contribute to the development of technology. In the Organisation of Economic Cooperation and Development (OECD), about two-thirds of R&D in the scientific and technical fields is carried out by industry, and 20 percent and 10 percent respectively by universities and government. But in poor countries, the industry's contribution is significantly less. The US government spends more than other countries on military Research and Development (R&D).

SOCIOLOGICAL FACTORS AND EFFECTS OF TECHNOLOGY

The use of technology has a great many effects; these may be separated into intended effects and unintended effects. Unintended effects are usually also unanticipated, and often unknown before the arrival of a new technology. Nevertheless, they are often as important as the intended effects.

Values and Ethics*:* The implementation of technology influences the values and ethics of a society by changing expectations and realities. The implementation of technology is also influenced by values and ethics.

Lifestyle: In many ways, technology simplifies life with better communication, specialisation, global networking and multi-tasking capabilities, etc. However, technology also complicates life by increasing pollution, traffic congestion, and obesity.

Institutions and Groups: Technology often enables organisational and bureaucratic group structures that otherwise were simply not possible: the rise of very large organisations such as governments, the military, health and social welfare institutions and corporations would not have been possible. The commercialisation of leisure and almost instantaneous dispersal of information, especially news and entertainment, around the world has become a reality.

ENVIRONMENT AND TECHNOLOGY

Technology provides an understanding, and an appreciation for the world around us. Most modern technological processes produce unwanted by-products in addition to the desired products, which are known as industrial waste and pollution. While most material waste is reused in the industrial process, many forms are released into the environment, with negative environmental side effects, such as pollution and lack of sustainability. Different social and political systems establish different balances between the value they place on additional goods versus the disvalues of waste products and pollution. Some technologies are designed specifically with the environment in mind, but most are designed first for economic or ergonomic effects. Historically, the value of a clean environment and more efficient productive processes has been the result of an increase in the wealth of society, because once people are able to provide for their basic needs, they are able to focus on less tangible goods such as clean air and water.

The effects of technology on the environment are both obvious and subtle. The more obvious effects include the depletion of non-renewable natural resources (such as petroleum, coal, ores), and the added pollution of air, water, and land. The more subtle effects include debates over long-term effects (e.g. global warming, deforestation, natural habitat destruction, coastal wetland loss). Each wave of technology creates a set of waste previously unknown to humans: toxic waste, radioactive waste, electronic waste. One of the main problems is the lack of an effective way to remove these pollutants on a large scale expediently. In nature, organisms "recycle" the wastes of other organisms, for example, plants produce oxygen as a by-product of photosynthesis, and oxygen-breathing organisms use oxygen to metabolise food, producing carbon dioxide as a by-product, which plants use in a process to make sugar, with oxygen as a waste in the first place. No such mechanism exists for the removal of technological wastes.

HISTORY OF TECHNOLOGY[2]

The history of technology is the history of the invention of tools and techniques, and is similar in many ways to the history of humanity. Background knowledge has enabled people to create new things, and conversely, many scientific endeavours have become possible through technologies which assist humans to travel to places we could not otherwise go to, and probe the nature of the universe in more detail than our natural senses allow.

Technological artefacts are products of an economy, a force for economic growth, and a large part of everyday life. Technological innovations affect, and are affected by, a society's cultural traditions. They also are a means to develop and project military power.

EARLY TECHNOLOGY

Stone Age

During the Stone Age, all humans had a lifestyle which involved limited use of tools. The first major technologies, then, were tied to survival, hunting, and food preparation in this environment. Fire, stone tools and weapons, and clothing were technological developments of major importance during this period. Stone Age cultures developed music, and engaged in organised warfare. A subset of Stone Age humans developed ocean-worthy outrigger

2. http://en.wikipedia.org/wiki/History_of_technology

ship technology, leading to an eastward migration, across the Indian Ocean to Madagascar and also across the Pacific Ocean, which required knowledge of the ocean currents, weather patterns, sailing, celestial navigation, and star maps. The early Stone Age is described as Mesolithic.

The later Stone Age, during which the rudiments of agricultural technology were developed, is called the Neolithic period. During this period, polished stone tools were made from a variety of hard rocks largely by working exposures as quarries. The polished axes were used for forest clearance and the establishment of crop farming. They were very effective and remained in use when bronze and iron appeared.

Copper and Bronze Age

The Stone Age developed into the Bronze Age after the Neolithic Revolution. The Neolithic Revolution involved radical changes in agricultural technology which included development of agriculture, animal domestication, and the adoption of permanent settlements. These combined factors made possible the development of metal smelting, with copper and later bronze, an alloy of tin and copper. The polished stone tools continued to be used for a considerable time due to their abundance compared to the less common metals, especially tin.

Iron Age

The Iron Age involved the adoption of iron smelting technology. It generally replaced bronze, and made it possible to produce tools which were stronger and cheaper to make than bronze equivalents. In many Eurasian cultures, the Iron Age was the last major step before the development of written language. It was not possible to mass manufacture steel because high furnace temperatures were needed, but steel could be produced by forging iron to reduce the carbon content in a controllable way. Iron ores were much more widespread than either copper or tin. In Europe, large hill forts were built either for refuge in time of war, or sometimes as permanent settlements. The pace of land clearance using the more effective iron axes increased, providing more farmland to support the growing population.

TECHNOLOGY IN ANCIENT CIVILISATIONS

It was the growth of the ancient civilisations which produced the greatest advances in technology and engineering, advances which stimulated other societies to adopt new ways of living and governance.

The Egyptians invented and used many simple machines such as the ramp to aid construction processes. The Indus Valley Civilisation, situated in a resource-rich area, is notable for its early application of city planning and sanitation technologies. Ancient India was also at the forefront of seafaring technology. Indian construction and architecture, called *Vaastu Shastra*, suggests a thorough understanding of materials engineering, hydrology, and sanitation.

The Chinese made many first-known discoveries and developments. Major technological contributions from China include early seismological detectors, matches, paper, cast iron, the iron plough, multi-tube seed drill, suspension bridge, parachute, natural gas as fuel, magnetic compass, raised-relief map, propeller, crossbow, south pointing chariot, and gunpowder.

Greek engineers invented many technologies and improved upon pre-existing technologies. Ancient Greek innovations were particularly pronounced in mechanical technology, including the ground-breaking invention of the watermill which constituted the first human-devised motive force not to rely on muscle labour. Apart from their pioneering use of water power, Greek inventors were also the first to experiment with wind power and even created the earliest steam engine, opening up entirely new possibilities in harnessing natural forces whose full potential came to be exploited only in the industrial revolution. Of particular importance for the operation of mechanical devices became the newly devised right-angled gear and the screw.

In other fields, ancient Greek inventions include the catapult and the crossbow in warfare, hollow bronze-casting in metallurgy, and in infrastructure, the lighthouse, central heating, the tunnel excavated from both ends by scientific calculations, the ship track way, the dry dock and plumbing. In transport, great progress resulted from the invention of the crane, the winch, the wheel barrow and the odometer. Further, newly created techniques and items were spiral staircases, the chain drive, sliding calipers and showers.

The Romans developed intensive and sophisticated agriculture, expanded upon existing iron working technology, created laws providing for individual ownership, advanced stone masonry technology, advanced road-building, military engineering, civil engineering, spinning and weaving and several different machines like the Gallic reaper that helped to increase productivity in many sectors of the Roman economy. Roman engineers were the first to build monumental arches, amphitheatres, aqueducts, public baths, true arch bridges, harbours, reservoirs and dams, vaults and domes on a very large scale across their empire. Because Rome was located on a volcanic peninsula, with sand which contained suitable crystalline grains, the concrete which the Romans formulated was especially durable.

TECHNOLOGY IN MEDIEVAL AND MODERN CIVILISATIONS

Medieval Europe

Genuine medieval contributions include, for example, mechanical clocks, spectacles and vertical windmills. Medieval ingenuity was also displayed in the invention of items like the watermark or the functional button. In navigation, the foundation to the subsequent age of exploration was laid by the introduction of lateen sails, the dry compass, the horseshoe and the astrolabe.

Significant advances were also made in military technology with the development of plate armour, steel crossbows, counterweight trebuchets and cannon. Perhaps best known are the Middle Ages for their architectural heritage: while the invention of the rib vault and pointed arch gave rise to the high rising Gothic style, the ubiquitous medieval fortifications gave the era the almost proverbial title of the "age of castles".

Arab Agricultural Revolution

From the 8th century, the medieval Islamic world witnessed a fundamental transformation in agriculture known as the "Arab Agricultural Revolution", or "Islamic Green Revolution". Islamic traders' movements across the Old

World during the "Afro-Asiatic Age of discovery" enabled the diffusion of many crops, plants and farming techniques, as well as the adaptation of crops, plants and techniques from beyond the Islamic world. The diffusion of numerous crops during this period, along with an increased mechanisation of agriculture, led to major changes in the economy, population distribution, vegetation cover, agricultural production and income, population levels, urban growth, distribution of the labour force, linked industries, cooking and diet, clothing, and numerous other aspects of life in the Islamic world.

Muslim engineers in the Islamic world were responsible for numerous innovative uses of hydropower, and early industrial uses of wind power, and petroleum. Watermills were in widespread use from the 8^{th} century onwards. A variety of industrial mills were developed in the Islamic world, including fulling mills, gristmills, hullers, sawmills, shipmills, stamp mills, steel mills, sugar mills, and windmills. By the 11^{th} century, these industrial mills were in operation throughout the Islamic world, from North Africa to the Middle East and Central Asia. Muslim engineers also developed crankshafts and water turbines. A number of inventions were produced during this time.

A particularly important contribution from the Islamic world was the "water management technological complex" which was central to the "Islamic Green Revolution" and, by extension, a precondition for the emergence of modern technology.

Age of Exploration

The sailing ship enabled the age of exploration. Pioneers like Vasco de Gama, Cabral, Magellan and Christopher Columbus explored the world in search of new trade routes for their goods and contacts with Africa, India and China which shortened the journey compared with traditional routes overland. They also rediscovered the Americas while doing so. They produced new maps and charts which enabled following mariners to explore further with greater confidence. Navigation was generally difficult, however, owing to the problem of longitude and the absence of accurate chronometers. European powers rediscovered the idea of the civil code, lost since the time of the Ancient Greeks.

Industrial Revolution

The British Industrial Revolution is characterised by developments in the areas of textile manufacturing, mining, metallurgy and transport driven by the development of the steam engine. Above all else, the revolution was driven by cheap energy in the form of coal, produced in ever-increasing amounts from the abundant resources of Britain. Coal converted to coke gave the blast furnace and cast iron in much larger amounts than before, and a range of structures could be created, such as the Iron Bridge. Cheap coal meant that industry was no longer constrained by water resources driving the mills, although it continued as a valuable source of power. The steam engine helped drain the mines, so more coal reserves could be accessed, and the output of coal increased. The development of the high-pressure steam engine made locomotives possible, and a transport revolution followed.

19th Century

The 19th century saw astonishing developments in transportation, construction, and communication technologies originating in Europe, especially in Britain. The steam engine which had existed since the early 18th century, was practically applied to both steamboat and railway transportation. The first purpose built railway line opened between Manchester and Liverpool in 1830, the Rocket locomotive of Robert Stephenson being one of the first working locomotives used on the line. Telegraphy also developed into a practical technology in the 19th century to help run the railways safely.

Other technologies were explored for the first time, including the incandescent light bulb. The Portsmouth Block Mills was where manufacture of ships' pulley blocks by all-metal machines first took place and instigated the age of mass production. Machine tools used by engineers to manufacture other machines began in the first decade of the century, notably by Richard Roberts and Joseph Whitworth. Steamships were eventually completely iron-clad, and played a role in the opening of Japan and China to trade with the West. Mechanical computing was envisioned by Charles Babbage but did not come to fruition. The Second

Industrial Revolution at the end of the 19th century saw rapid development of chemical, electrical, petroleum, and steel technologies connected with highly structured technology research.

20th Century

20th century technology developed rapidly. Communication technology, transportation technology, broad teaching and implementation of scientific methods, and increased research spending all contributed to the advancement of modern science and technology. Due to the scientific gains directly tied to military research and development, technologies including electronic computing might have developed as rapidly as they did in part due to war. Radio, radar, and early sound recording were key technologies which paved the way for the telephone, fax machine, and magnetic storage of data. Energy and engine technology improvements were also vast, including nuclear power.

The National Academy of Engineering, by expert vote, established the following ranking in descending order of the most important technological developments of the 20th century: electrification, automobile, airplane, water supply and distribution, electronics, radio and television, mechanised agriculture, computers, telephone, air conditioning and refrigeration, highways, spacecraft, Internet, imaging, household appliances, health technologies, petroleum and petrochemical technologies, laser and fibre optics, nuclear technologies, materials science.

21st Century

In the 21st century, technology is being developed even more rapidly, especially in electronics and biotechnology. Broadband Internet access became commonplace in the developed countries, as did connecting home computers with music libraries and mobile phones.

Research is going on into quantum computers, nanotechnology, bioengineering, nuclear fusion, advanced materials (e.g., enhanced armour), the scramjet, superconductivity, genetics and green technologies such as alternative fuels and more efficient LEDs and solar cells.

The newly-invented airplane contributed its share to the defence, for aerial reconnaissance made it difficult for surprise in attack.

The understanding of particle physics is also expected to expand through particle accelerator projects. Theoretical physics currently investigates quantum gravity proposals such as the M-theory, superstring theory, and loop quantum gravity. Despite challenges and criticism, the National Aeronautics Space Agency (NASA) and European Space Agency (ESA) have planned a manned mission to Mars in the 2030s.

TECHNOLOGY AND 20TH CENTURY WARS

Technology has often had a pervasive effect on the battlefield, with victory often the result of the possession of a superior weapon. Although the importance of technology has been proven from time to time, it becomes a more relevant determinant of victory if used in the right mix with other important determinants such as political, social and intellectual forces. While the terms 'political forces' and 'social forces' are self-explanatory, the term 'intellectual forces' would include factors like theory, strategy, tactics, doctrine, organisation, leadership and morale, etc. War is a complex affair, hence, no single determinant can be visualised to ensure victory in all circumstances. However, all things being equal, an army with better weapons must surely overwhelm an army with inferior weapons.

The importance of military technology as a determinant in the modern battlefield can be experienced from the lessons of some of the major wars that have taken place in the 20th century.

World War I on the Western Front

Technology was mainly responsible for shaping the battlefields of World War I. Decisive battles which were possible in previous wars were now out of the question because of the use of a range of weapons which gave immense power to the forces. Rifles and artillery were now of longer range and greater accuracy. For protection against their deadly barrage of iron and explosives, the armies had to dig in. The humble spade became an indispensable tool for the individual soldier. And to protect themselves against infantry assaults, obstacles were created and covered by machine guns which spewed death at the hapless troops caught crossing. The newly-invented airplane contributed its share to the defence, for aerial reconnaissance made it difficult for surprise in attack. Under such circumstances, infantry troops could no longer mount an attack without suffering frightful casualties. The impact of technology was, therefore, huge. The intellectuals of the time were unable to rise to the challenges of modern technology. Indeed, the war was fought with 20th century weapons by leaders drilled in 19th century tactics. Neither commanders nor thinkers were able to devise new strategies and doctrines to overcome the new technology, to bring victory. In short, technology outran strategy, tactics and doctrine.

Tanks, artillery and motorised infantry were combined in cohesive Panzer divisions with dive bombers providing tactical support.

Western Europe in World War II

World War II was, in contrast to World War I, a war in which the opening moves by the German forces brought spectacular victories. In the conquest of Western Europe, extensive use was made of the tank, airplane and artillery. Tanks, artillery and motorised infantry were combined in cohesive Panzer divisions with dive bombers providing tactical support. In the attack, tanks supported by artillery and dive bombers would break through enemy lines, and then penetrate deeply to his rear areas to destroy his headquarters and lines of communications. Using this tactic, swift and devastating victories were won in Western Europe. There was no reliance on a single technology. It was not only the use of weapons that was the determinant of the victories but the way in which they were used by the Germans that also made the difference.

War on the Korean Peninsula

Technological developments during World War II ushered in the age of nuclear weapons. Two concepts emerged: one, that the atom bomb had made land warfare relatively obsolete; the other that possession of the bomb conferred on its owner exceptional power or immunity against attack. When a 135,000-strong North Korean Army invaded South Korea in June 1950, these concepts were shattered. The US, a victor of World War II, could not use the bomb to stem the North Korean offensive. The use of the bomb in pursuit of a foreign policy objective which had nothing to do with US security would have established a dangerous precedent for other nuclear powers in the future. Besides this, the US would have lost its moral standing with the rest of the world. The new technology was a war-winning weapon, but only if it could be used.

From June to August 1950, North Korean forces surged down the peninsula, forcing South Korean forces and American reinforcements from the Eighth Army to retreat. The first victory went to the North Koreans. This outcome was partly due to the poor state of readiness amongst the American troops, as well as to North Korean superiority in equipment, for their Soviet-built T-34 tanks were invulnerable to the 2.35 inch bazookas of the Americans.

As is to be expected of a developed country fighting a Third World enemy, the Americans had technological superiority over the Communists in armour, artillery and aircraft. Between 1951 and 1953, US aircraft downed 850 MiG-15s for the loss of only 58 of their own. However, the outcomes of offensives at each stage of the war were decided not only by the technological merit but by politics and skill in the operational art.

The Egyptian Front in the Yom Kippur War

On October 6, 1973, Egyptian and Syrian forces attempted to recapture territories lost in the Six-Day War when they attacked Israel simultaneously on two fronts at 1405 hrs.

To protect the bridgeheads, the Egyptians had earlier infiltrated some 8,000 troops armed with man-portable anti-tank weapons and anti-aircraft missiles 2 km into Israeli-held territory. Thus, when the Israelis attacked, their tanks ran into a deadly barrage of guided-missiles. The Israelis were aware that the

Egyptians possessed this weapon and knew of its capabilities but it was the scale and the coherent manner in which they were used that caught them by surprise. Israeli aircraft which attacked the Egyptians were also effectively countered by a dense air defence barrage consisting of SA-2, SA-3 and SA-6 missiles on the West Bank and the lighter, previously-infiltrated SA-7 missiles on the East Bank. At least half of the first attacking Israeli planes were shot down by the missiles' unexpectedly accurate and devastating fire.

The Egyptians' success in achieving strategic and tactical surprise and their clever use of technology up to October 8 inflicted upon the Israelis their worst defeat in history. The main component of the Egyptian plan was neutralisation of Israel's superiority in the air and in armoured warfare. This had been accomplished admirably but beyond the well-rehearsed crossing operations and use of anti-tank and anti-air weapons, the Egyptians were not able to exploit their success.

In the final phase of the war on the Suez front, an Israeli armoured force crossed to the West Bank to execute an operation. Superior initiative and daring skill at mobile warfare explained the Israeli success as much as the lack of them explained the Egyptians' inability to exploit the earlier opportunities granted by technology.

Arab-Israel War, 1982

In the summer of 1982, the Israelis fought the Syrians in the battle of the Bekaa Valley. The short operation was an enormous success for the Israelis who destroyed a complete air defence system, including 20 Surface-to-Air-Missile (SAM) batteries and 85 fighter aircraft in aerial combat for the loss of only two aircraft to ground fire.

Falklands War, April 1982

One modern British submarine kept the entire Argentine Navy at home while one Exocet missile destroyed a British ship. Thus, technology will forever be an essential element of combat power and an important determinant of victory on the modern battlefield along with intellectual, political and social forces that can influence operations to a great an extent.

HISTORICAL PROCESS OF THE SPREAD OF MILITARY TECHNOLOGY

The historical process and mechanism behind the spread of military technology has well been explained by Barry Buzan[3].

During the 19th century, only a handful of states managed to acquire the capability for sustained industrial development that was the key to manufacturing modern weapons. Britain was the leader in the early stages. Germany, France, the United States and some smaller European countries caught up quickly. Russia and Japan joined before the end of this first wave of industrialisation. Trade and investment provided a major mechanism for the transfer of technology among the members of this group. Technological leaders were generally more than willing to sell their products, and investments from Europe ushered the industrialisation of the United States and Russia. The later entrants to the group were able to use this transfer of finance and technology to bring their own process of industrialisation up to the point at which it became self-sustaining. All of these countries fairly quickly attained sufficient command of basic industry to develop and manufacture weapons up to the leading technological standard of the day. As they did so, their dependence on arms purchases declined, and some of them entered the market as sellers.

The leaders of the first wave, particularly Britain and Germany, did good business selling such military products as artillery, machine guns, and warships to countries unable to manufacture them. Late industrialised nations such as Japan, purchased major weapon systems like battleships until they developed the capacity to manufacture their own. Many countries, like Brazil and the Ottoman Empire, were not at this time serious entrants in the industrialisation process. Others, like Belgium and the Netherlands, were industrialising, but did not command the scale of industry or markets necessary to make domestic production of the whole range of modern arms an economic proposition. Both types of countries were forced to depend on the arms trade in order to keep pace with progress in military technology.

3. http://www.cia.gov/nic/pubs/research_supported_by_nic/conference_paper/chenghu.htm(1of12)[10/11/2002

The industrialised group contained most of the states that were already established as imperial powers—Britain, France and Russia. Germany, Belgium, Japan and the United States became imperial powers during the last rounds of empire-building. In their imperial roles, these powers spread elements of the revolution of frequent technological change all through the areas of the planet over which they exercised control, including most of Africa and large parts of Asia. But since the local peoples were not independent, there was no arms trade on a scale comparable to that between the industrialised powers and the other countries. Most of the industrial products that were transferred to colonial areas remained under the control of the colonising power, especially those associated with military capability.

The spread of military capability remained very much in this quite concentrated pattern until World War II, especially in terms of the capability for producing advanced weapons. Europe and America continued to be the focus of qualitative innovation in technology, and Japan and the Soviet Union caught up in terms of independent production capability. Technology was taken to the areas under colonial control, but seldom implanted there. Independent non-arms producers like the Latin American countries mostly made little progress towards industrialisation. After World War II, and as a result of it, the spread of military capability picked up speed across the planet. This acceleration was closely linked to decolonisation. In three decades, the number of states in the international system tripled. This added to the number of non-producing countries whose rulers needed to get their military equipment. Instead of being denied modern arms, the new rulers were treated as legitimate customers. Their need arose not only from the domestic order requirements of self-rule, but also from the complex pattern of relations with neighbours. India and Pakistan and the smaller states of South Asia that now worry about

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each other, fell in this category. Decolonisation, thus, facilitated the spread of military capability both by creating many new independent centres of political power, and by providing a new focus for a host of local disputes and rivalries.

Because most of the new states had little or no industrial base, decolonisation initially just increased the number of arms non-producers in the system. Some of these countries had never had any industrial base. Others, such as Egypt and India had been major pre-modern centres of technology and production. They had been subordinated to, and in some ways deliberately deindustrialised by, the colonial powers in order to eliminate them as economic competitors and reduce them to the status of suppliers of raw materials and consumers of manufactured goods. The military imbalance between the producers and the newly independent non-producers was rectified to the extent that arms were now available rather than denied. But it was maintained in as much as the non-producers remained dependent on a small number of suppliers for their weapons. Non-producers of arms in both the newly independent areas of Africa and Asia, and the older ex-colonial area of Latin America, were not satisfied to remain economically and industrially dependent. Many of them actively set about acquiring industrial economies of their own. In several of the less industrialised countries—India, Egypt and China, and later Argentina, Brazil, Iran and South Africa—acquiring the capability for at least some military production was a priority. These industrialisation projects have been a mix of failure and partial success. This resulted in a broadening group of countries able to supply some of their own military needs. In a few of these, most notably India, Israel, South Africa and China, the quality and quantity of production were high enough to enable them to compete in some of the lower technology sectors of the arms trade

The mechanisms by which arms production capabilities have spread to these countries are similar to those that created the first group of producers. Straight transfers of arms do not assist development of production capability unless a sufficient industrial base already exists to enable local copies to be made. Civil industrial capability carries military potential, and so some of the new production capability simply reflects spin-ons from a broader process of economic development. But in many cases, the development of arms production has also been stimulated by the direct transfer of manufacturing capability from producer to non-producer countries, though even here the success of the transplant depends on the existence of a civil industrial base. The Soviet Union played this role in China during the 1950s and in Eastern Europe up to 1989. Several Western suppliers were doing the same in Iran up to 1979, and both East and West have done so in India.

Such transfers reflected economic and political competition among the supplier states. After World War II, the arms trade was dominated initially by the United States and Britain. The small number of suppliers created a seller's market. As other industrial states such as France, the Soviet Union, Germany, Czechoslovakia, Belgium and Italy recovered from the war, the number of arms suppliers increased. This trend has been reinforced by the development of arms industries in some Third World states, especially China, which has become a significant arms supplier. As the number of suppliers increased, competition among them for the export market became more intense, with the result that buyers have more leverage. In the buyer's market that the increase in the number of suppliers has now created, many states have used that leverage to get production facilities and knowledge as part of their major arms purchases. India, for example, negotiated many such deals with the Soviet Union, Britain and France. From being almost solely a purchaser during the 1950s, India has steadily built up an indigenous arms production capability of some sophistication.

Licensing production arrangements seldom transfer even production technology quickly, and do not represent a short path from dependence to independence. Despite the well-established view that licensing does not lead to independent production, India has demonstrated that over the years, such arrangements can promote the development of local component suppliers as well as capability for maintenance and design. India has built up some independent capability in the

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less technologically advanced areas of military production, and some foundations on which to wrest advantageous licensed production arrangements for more sophisticated weapons. Its partial success in this development would not have been possible without possession of a broadly based industrial economy, and even so has been expensive and not very efficient. Without devoting the much larger resources necessary to bring its own R&D up to the pace and standard of the leading edge of qualitative advance, even a country like India will not be able to achieve more than semi-independence in arms supply. Although it will be able to produce a variety of less sophisticated weapons independently, it will remain partly dependent on more advanced suppliers if it wishes to deploy weapons close to the highest standard of technology available.

Advanced military technology has spread throughout the international system in three ways: by the physical and political expansion of those states possessing it; by the transfer of weapons from those capable of manufacturing them to those not; and by the spread of manufacturing capability to ever more centres of control. In historical terms, these three mechanisms of spread have operated simultaneously, but not evenly. The mechanism of direct physical expansion was prominent during the colonial period, and has declined in importance since 1945. It is now relevant principally in the form of the overseas deployments and bases of a few great powers, and the end of the Cold War has brought about the closure and scaling down of many of these. Conversely, the spread of independent centres of manufacture has been increasing in importance, especially in the period since decolonisation. The mechanism of the arms trade has been steadier than either of the other two. It has been central to the spread of military technology throughout the period from the late 19th century to the present day, and it has been increasingly important as the number of states has increased.

The key to understanding the apparent permanence of the arms trade is the powerful constellation of vested interests that support it: 'supply push' from producers, and 'demand pull' from consumers. Supplier interests can be both political and economic. Possession of an arms industry serves the basic security value of self-reliance, and also supports the pursuit of power and influence. Traditionally, any state seeking to attain a leadership position in the international power hierarchy has needed its own arms industry. One important aspect of great power status is the independent ability to wage war: hence, a substantial measure of domestic arms production is an essential requirement. Once attained, an arms industry can add to the tools of influence at the government's disposal. Arms supply is one of the classical ways in which great powers compete for the allegiance of lesser powers.

Political motives for states to acquire arms production capabilities are entangled with economic ones. In a trading environment, the market has some impact on setting standards of both quality and price that determine whether the pursuit of self-reliance by any state is a viable or desirable policy. The economic motives for states to spend money on domestic arms production are to save the cost of importing weapons and to improve the balance of payments by exporting them. Once an arms industry exists, it generates vested interests in profits, in jobs and in preserving high technology capabilities and these interests can lead to pressure to export in order to sustain the companies concerned. In the Cold War, spending on arms for economic motives was justified by reference to external military threats. Now state expenditure on technological innovation is being represented as a necessary part of industrial policy.

Another potent pressure to export is the fact that only states with large domestic requirements for arms have any hope of achieving economies of scale in their own production. Longer production runs lower the unit cost of the items produced. If the number of sophisticated items like tanks and aircraft required for domestic consumption is small, then home production

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will result in high unit costs unless exports can be found to lengthen the production run. Long production runs are especially necessary to amortise investment in advanced technology items where R&D accounts for a high proportion of total cost. Very few states have domestic requirements large enough to achieve economies of scale. Consequently, nearly all arms producers have strong incentives to export in order to achieve reasonable costs for that part of their production that they wish to buy for their own use. Second rank powers like Britain and France are the most vulnerable to this squeeze, as they are just big enough to be arms producers but have small requirements for arms. The need to export between one-third and almost half of their production is one reason why they have been aggressive in seeking export markets. Small arms and anti-personnel weapons such as land-mines, grenades and cluster bombs are easy to produce in economic quantities and so do not involve the same questions about economies of scale as do large weapons platforms. The need to guarantee economically attractive production runs for expensive modern weapon systems explains why the Western European arms producers are increasingly attempting multinational arms production projects like the Jaguar, the Tornado and the Euro fighter aircraft.

Even the United States has not been, and Soviet Union was not, immune from the need to achieve economies of scale, despite their starting advantage of large domestic arms purchases. The process of qualitative advance means that the unit cost of sophisticated modern weapons is usually higher than the cost of the previous generation. This cost, which tends to outrun the general rate of inflation, and the fact that the newer weapons are more capable than the older ones they replace, create pressure to acquire smaller numbers. This process is likely to accelerate now as the Cold War can no longer be used to justify large deployments. Shrinking domestic demand in terms of numbers of weapons in turn raises the incentives to lengthen production runs by finding export markets. The United States will increasingly find itself faced with difficult choices between maintaining its technological lead by keeping leading edge weapons to itself (e.g. stealth bombers, cruise missiles and BMD systems), or exporting them. Not exporting will mean bearing the extremely high unit costs of small production runs. Exporting them will mean loss of US leverage (whether with potential foes or dependent allies).

The right to buy arms is closely related to the maintenance of an international society based on sovereign equality of states. There is, thus, a potent shared interest between suppliers and recipients in maintaining the arms trade.

TECHNOLOGY AND INDIA

India, a one-time leader of international trade and commerce, became a victim of systematic deindustrialisation during more than 200 years of colonial rules and missed the wave of the industrial revolution. From a 'golden bird', it became a poor and developing nation.

Independent India seized the first available opportunity and gave due importance to development of technology by means of creating institutions *par excellence*, and showed preference for heavy industries within the politico-economic scenario prevailing in the world in general and in the country in particular. This raised great hopes for building India from scratch with the help of a leading role for technology and industry. In the past over 60 years, the country has progressed significantly and exceptionally on many fronts. Still, in order to increase the pace of the growth, attain self-sufficiency and a leadership role, a lot is yet to be done. India, with a large scientific community and many other advantages on her side, needs to accelerate the growth of, and strengthen, its technological and industrial base in both military and civil domains.

India has demonstrated technological acumen in many fields such as space, nuclear, information and communication, software and pharmaceutical, etc. However, India should strive to expand the area of influence in other areas by acquiring cutting edge emerging technologies which could take it into the league of technologically advanced nations with its strong political, economic and military strength.

CONCLUSION

History shows that nations have endeavoured to develop new and more advanced technologies with the goal of achieving military advantage. There are a number of different dimensions of technology. Before the 17^{th} century, inventions were diffused by imitation, while improvement was established by the survival of the fittest. Now, technology has become a complex but consciously directed group of social activities involving a wide range of skills, exemplified by scientific research and managerial expertise. The powers of technology appear to be unlimited. While some of the dangers may be great, the potential rewards are greater still. This is not simply a matter of material benefits for, as we have seen, major changes in thought have, in the past, occurred as consequences of technological advances.

It is likely that military technology will be even more visible in the way defence forces plan and fight in the future. Although the experiences of 20^{th} century conflicts show that superiority in technology is no guarantee for success, it is undeniable that technology is a great 'force multiplier'. The fact is that technology is an all time relevant, along with other factors that are equally important, and should, therefore, also be considered in peace-time planning, development and training. It will be appropriate to say that the superiority of armaments may increase the chances of success in war: it does not, of itself, gain battles. Therefore, to repeat a point made earlier, all things being equal, an army with better weapons must surely overwhelm an army with inferior arms. It pays to remember that during the Falklands War in April 1982, one modern British submarine kept the entire Argentine Navy at home, while one Exocet missile destroyed a British ship. Technology will forever be an essential element of combat power and an important determinant of victory on the modern battlefield along with intellectual, political and social forces.

Hence, India should strive for, and acquire, the emerging technologies to attain the leadership position in global order by exploiting its strength. An all-out effort must be made to achieve and maintain political, economic and military superiority.