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Technology, Warrior and the Changing Face of Warfare

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Introduction

Key Points

- Technology offers the soldier, superiority in certain key abilities that they desire.
- The growth cycle of technology shows that neither the development of new technology nor its availability is about big investments – but rather about increasing convergence with the existing technologies.
- Exponential technologies' growth cycle helps judge the timeline of a technology's availability for the battlefield.
- Certain technologies are already available/soon to be available, which can boost the soldiers' abilities.

The Biblical Book of Samuel describes the story of David versus Goliath. Challenged for a single combat to settle the outcome, the Israelites nominate David to face Goliath, the champion of Philistines. Armed only with his staff, sling and five stones, David confronts Goliath, a giant of a man fully attired in his armor and armed with a javelin. David hurls a stone from his sling and hits Goliath in the center of his forehead, Goliath falls on his face, and David cuts off his head – thus, victory is of the underdogs. While the story is often used to teach children how underdogs can overcome odds; to a warrior, it would signify a standoff attack in which a projectile is delivered while the launcher remains out of harm's way. David thus, possessed a technological superiority that negated the advantages of his opponent.

Military history has many such examples where technology has helped underdogs to overcome the odds. The legendary exploits of the Korean Turtle Ships (many consider the world's first armored battleships) are indicative of how technology can be leveraged.[1] On the other hand, the exploits of the Indian Gnat Fighters (nicknamed Sabre Slayers), which held their own against the technologically superior Pak Sabres[2] – are indicative of how better training and tactics have enabled the Indian Pilots to overcome technological disadvantages.

This enduring debate between tactics and technology brings into perspective the need to understand how technology is likely to affect modern war and what technologies maybe visible on the battlefield in the years and decades to come.

Technology and the Warrior

The influence of technology can be either positive or negative. The ancient Greek hoplite infantrymen is an example of positive influence. Their arms and armor were most effective for fighting in close formation, which led in turn to marching in step, augmented cohesion and made the phalanx a tactically formidable formation. The late medieval knights offer an example of the negative influence. To wield his sword and lance effectively, he and his charger needed considerable space, yet his closed helmet made communication with his fellows extremely difficult. It is not surprising, then, that knights of the late Middle Ages tended to fight as individuals and were often defeated by cohesive units of less well-equipped opponents.[3]

However, a study of the military commanders shows that they insisted on proper equipment and supply, trained their men in use of weapons and military evolutions, and that they sought to inspire them with courage; but one finds no evidence that commanders believed in science or mathematics, or expected any other skill in their troops than that of managing their pieces dexterously and carrying out orders on the field[4]. Yet, most commanders or their predecessors introduced the latest technological innovations. Alexander the Great's Army benefitted with innovations like longer spears, lighter helmets, Phrygian Helmet, molded cuirass body armor and siege weaponry.[5] Similar examples can be quoted from the lives and campaign organisation of most successful military commanders.

The dichotomy can best be explained by the fact that technology shapes warfare, not war[6] —the former being the conduct of war. The most vaunted thought leaders of war – Sun Tzu, Kautilya, Machiavelli, Clausewitz, Napoleon etc – may not succeed in today's war, as the warfare is different. Warfare affects soldiers and Commanders and they need to adapt to the latest technologies that affect their trade. However, soldiers can only look out towards science when they have a concept of what science is, what it does,[7] and how they can benefit from it or how not adapting to it will lead them to defeat.

Abilities Desired by a Soldier: Perusal of historical military campaigns showcases certain abilities, superiority in which have helped the warrior not only in survival but also in achieving decisive victory. Some of these are in the realm of technology while the balance in the realm of the human mind. These include the following

- **Realm of the Mind.** Where, how, when and in what strength to deploy are decision issues and are in the realm of the mind.

- **Technological Realm.** The soldier must be able to detect and hit the enemy before he is seen, while remaining out of harm's way, for this he needs the following abilities: (a) to know where he and his friends are; (b) to know where the enemy is, while hiding himself; (c) to communicate securely while listening to the enemy; (d) to move faster than the enemy; (e) to hit and damage the enemy at ranges larger than what he can hit; and (f) to protect himself if the enemy hits.

Technological Abilities Desired by a Soldier

I. *Ability to know where He and His Friends Are*

The significance of locating own and enemies' position cannot be over emphasized for a soldier. It can be the difference between life and death, defeat and victory. Importance of the information gets accentuated when troops are moving in unknown enemy territory.

Airborne Landings during the allied invasion of Sicily, were beset with the issue. American pathfinders landed incorrectly and then strong winds scattered the balance airborne forces.[8] Meanwhile close to 50 per cent of the British forces landed in the sea and over 200 drowned.[9] More than the loss of lives, the Axis forces managed to evacuate nearly one lakh men to fight and defend Italian mainland.[10] Franco Prussian War of 1870 was a similar tale of lack of locational knowledge. Troops unwittingly bumped into each other,[11] and were caught in battle and skirmishes, without any plans or directions from the leaders.

Apart from own location, knowledge of location of your friends is important for: (a) identification of friend or foe and therefore avoidance of fratricide, and (b) seeking and applying timely reinforcements at critical junctures of battle, which often play a decisive factor in defeat or victory. This never-ending quest has spurred research ranging from the use of celestial bodies, magnetic compasses and now the Global Positioning system with many intermediate milestones.

II. Ability to Know Where the Enemy, is while Hiding Himself

In 217 BC, Hannibal defeated the Romans during the second Punic War at Lake Trasimene. While some claim this to be the earliest example of a strategic turning movement others claim it to be the largest ambush in military history, in terms of the men involved.[12] The Romans contributed a great deal in their loss by entering a defile without reconnaissance, intelligence or appreciating it to be a likely spot for a stand, by the enemy. The pattern was repeated in 1915 at Gallipoli where lack of intelligence, knowledge of terrain or reconnaissance led to the allies losing over 44,000 men with nothing to show for gains.[13] Operation Market Garden[14] was an ambitious plan to encircle the heart of German Industry. Albeit, it failed due to lack of intelligence about the 9th SS and 10th SS Panzer divisions.[15]

Efforts towards this ability, have spurred research in camouflage and concealment as also various detection technologies. The latter ranging from night vision devices to heat detecting radars etc. Some scientists are even now working towards the holy grail of the invisibility cloak.

III. Ability to Communicate Securely while Listening to the Enemy

Lord Alfred Tennyson had romanticised[16] the action of 25 October 1854 in the Battle of Balaclava as part of the Crimean War. While, the charge is often remembered as a battle steeped in valor, defiance and endurance,[17] it also stands a classic case of failure of communication.[18] The failure ensured that first the complete order of battle never assembled, then the charge by the light brigade was on a wrong target and finally the troops in a position to help and extricate the Light Brigade never came into action and instead retreated.

The importance of secure communication was again highlighted in the second World War when Alan Turing managed to break the Enigma code. His work contributed immensely to the success of the Allied War Effort.[19] A similar effort by the US to break the Japanese Purple Cipher helped the allies in their campaign against Japan[20]. On the other side the axis

powers had limited success in this effort. The Germans code breakers were spread over a number of agencies which achieved little collaboration till 1943 and nothing after that,[21] while the Japanese efforts floundered after Pearl Harbor.[22]

Starting with the messengers and network of messenger posts, to homing pigeons[23] and pre-designated signals based on flags,[24] this pursuit of secure communication has today advanced to software defined radios and Link-22.

IV. *Ability to Move Faster than the Enemy*

Amongst many other tactical innovations, one crucial advantage leveraged by the forces of Genghis Khan was the innovative use of the horse. Possibly amongst the first to use the stirrup and to develop a harness,[25] it allowed the Mongol armies to travel longer distances, faster, as also fight while standing hands free in the saddle.[26] It also gave them the ability to twist in the saddle and continuously advance and then retreat. These, hit and run tactics permitted them to attack while remaining out of harm's way.

Speed has always been essential for domination of space and time since times immemorial. Apart from the Mongols certain other military commanders who were famous for this included Hannibal in the Battle of Cannae in 216 BC,[27] Khalid ibn al-Walid, against the Persian Empire at the Battle of Walaja in 633 AD;[28] Napoleon, Fredrick the Great, Von Clausewitz and Bismarck.

In modern times the advent of mechanization increased the ability to strike faster and deeper. The German Blitzkrieg remains the most memorable example of the same. Maneuver warfare is relational movement, to pit one's strength against the enemy's weakness. For it, the ability to move faster than the enemy expects and faster than he can react, is a prerequisite ability for a soldier.

V. Ability to Hit and Damage the Enemy at Ranges Larger than his Ability to do so

Stones, bows & arrows, crossbows, javelin and lances all have been used in various forms since pre-historic times. The aim of these, was always to strike the enemy from a distance, a range beyond the latter's striking capability. One such unique weapon was the **Halberd,** designed to keep the foot soldier out of danger while facing an armored man on horseback.[29]

This quest for longer ranges, even in ancient times, led to development of the earliest artillery. Roman Onagers, Trebuchets and the Catapult thus emerged. Advent of the gunpowder, brought a revolution to ranges. No longer were the weapons limited by muscular strength. Flintlock and cannons emerged and proved decisive against any force lacking the same – the first Battle of Panipat stands testimony to that.[30]

The desire of being able to out-range the opponent has manifested into Beyond Visual Range Weapons and Inter Continental Ballistic Missiles and today possibilities of loiter weapons.

VI. Ability to Protect Himself if the Enemy Hits

In ancient times, the design and production of individual defensive equipment was restricted by the shape of the human form. Helmets, shields and body armor were common warrior attire, who had to balance the defensive requirements with the weight they could carry. Simultaneously, the era saw the emergence of walls and forts. The stone walls of Jericho, which date from about 8000 BC, represent the first known use of walls and were intended to protect the settlement and its water supply from human intruders.[31]

The medieval times saw improvements in fortifications; walls became fortresses and then castles to challenge the attacker who in turn needed special siege equipment to attempt breaching them. On personnel front, high-quality iron armor emerged and was then replaced with a Knight's Mail Armor.[32]

In modern times, the emergence of gun powder led to the advent of earthen ramparts, sunken profile and digging in. As parity of technology was achieved, firepower became the queen of the battlefield. Massed Cavalry charges or soldiers marching on the double against a firing line had little chance of success, unless they also presented a wall of fire. This was the origin of Frederick's "moving wall of fire".[33] Albeit when the defenses were combined with innovative defensive obstacles to stop the moving wall, the defender again gained an upper hand. This caused a comparative stalemate in the first world war, which required emergence of new technology once more to restore mobility.

Development of Technological Abilities

The pace of development of technological abilities of a soldier has not been uniform. Most, Commanders till the mid-20th century were able to innovate and develop one or two isolated abilities in their time. Short spears being replaced by longer, sturdier and lighter spears or short bows by long bows to increase the range of hitting the enemy. Adding stirrups allowed firing arrows on the move and ride longer distances. But, in no era could all the desired abilities be addressed simultaneously.

This changed in the second half of the 20th century. The advent of the computer age provided an unparalleled impetus to innovation. Resultantly, all the technological abilities desired by the soldier were now addressed and improved simultaneously. This got popular in the end 90s as the 'Revolution in Military Affairs'. The revolution – if anything – is just accelerating as new innovations keep adding to the abilities of the soldier.

Militaries which fail to keep pace with this, often lose the warfare aspect of war. Al Qaeda and Taliban versus the US is a typical example. Irrespective of the outcome's perception – the technological laggard former, loses soldiers many more times than the US. Having no answer to drones, the Al Qaeda issued its own guidance for avoiding drone attacks,[34] but the success of these are limited. Even armies much more advanced compared than Al Qaeda and Taliban are not immune to losses attributed to technological asymmetry – this was highlighted when Iran lost Maj Gen Qassim Suleimani to a drone strike.[35]

Technology and Future Warfare

Exponential Technologies

- ***Kurzweil's Law of Accelerating Returns.*** Moore's often quoted Law states that the number of transistors on a microchip doubles about every two years, though the cost of computers is halved.[36] But computers are essentially an enabling technology affecting all fields of life; latter's convergence in turn, results in an exponential scale of improvement. Ray Kurzweil defined this as the 'Law of Accelerating Returns' – which has increasingly found evidentiary support. An analysis of the history of technology shows that technological change is exponential, contrary to the common-sense "intuitive linear" view. So, we won't experience 100 years of progress in the 21st century — it will be more like 20,000 years of progress.[37] To view it in context, agriculture is estimated to have begun between 13,000 and 9,500 years ago.[38] How technology of today, will be viewed as, by a time traveling hunter gather of 20,000 years ago, will be how much technology is likely to change in the next 100 years.

- ***Growth Cycle of Exponential Technology.*** The cycle of growth of technology in the modern world consists of the following stages:[39]
    - ***Digitalisation:*** This is the stage when technology becomes digital. At this stage, it jumps on the back of Moore's Law and begins accelerating exponentially.
    - ***Deception*****:** In this stage the technology generates a lot of hype but early progress is slow. Hence, initially the technologies fail to live up to the hype.
    - ***Disruption:*** The stage when the technologies start impacting the world and disrupting existing products, services, markets and industries.
    - ***Demonetisation:*** In this stage the technology no longer has a cost – either money totally vanishes from the equation or becomes cheap enough not to be of consequence.
    - ***Dematerialisation:*** This is the stage when products disappear as the technology converges with other products.
    - ***Democratisation:*** In this stage, the technology is so widely available that not having it is an exception while enforcing its denial is an issue.

- ***What the growth cycle shows.*** It shows that neither the development of new technology, nor its availability is about big investments – but rather about increasing convergence with the other existing technologies. When 1.8 gigapixel[40] camera Argus – 1S had to be designed – instead of spending money designing and manufacturing a new imaging chip – the designers made do with imaging chips found in the common cell phone. A mosaic of 368 of these chips was used to design and construct the Argus – 1S – having the capability to recognize a bird from 17,500 feet. In addition, it has a much wider field of view compared to a routine UAV camera.[41] Similarly, the technology packed in a smart phone would have cost a million USD in 2012, today it costs less than 50 USD.[42]
- ***Forecasting the Future.*** To study the effects of technology on any aspect of the future, focusing on technologies which have crossed the digitalisation stage is helpful. These are proven technologies, and it's a matter of time before they are widely available. A similar approach to understand future warfare is astounding in the changes that may occur.

Technologies which may Affect Warfare within a Decade

I. Block Chain

Essentially an enabling technology, it has the potential to be a bedrock of the worldwide record-keeping systems.[43] Post its appearance in 2008[44] the technology has evolved and has become the foundational core of systems where data integrity is key. Many large companies have already adopted the technology,[45] while national governments and/or their departments have been experimenting with it.[46] Estonia has implemented the technology across the board in governance.[47] Recent advances in (what is claimed as virtually unbreakable) encryption technology further boosts digital data storage.[48] Within India, *Niti Aayog* has also released a paper recommending a strategy for its' adoption[49]. As per pages 19 and 23 of the document – in a pilot project – *Niti Aayog* managed to optimize the fertilizer subsidy supply chain by using it. The paper also recommends its use for other sectors where data integrity of immutable records are essential.[50]

In the armed forces, immutable data integrity is essential for its functioning and, a prerequisite for trust in digitization. Considering that digitized data is but the first step for exploiting exponential technologies, block chain offers the ideal (and possibly the sole) bridge between trust and the future.

II. Artificial Intelligence (AI)

According to John McCarthy, "AI is the science and engineering of making intelligent machines, especially intelligent computer programs".[51] An intelligent machine is a machine that mimics the way humans think, feel, move and make decisions. It could also act in conjunction with a human to compliment and improve their ability. It's a technology which had been on charts since early 1950s[52] many believe that's it not even out of the laboratory as yet. Albeit, it's virtually already available on our mobile phones. A decision enabling technology, which enables people to rethink how we integrate information, analyze data and use the resulting insights to improve decision making.[53] Consequently, it is transforming every walk of life.[54] Its applications are limited only by imagination.

- ***AI in Defence***

  - ***Data Analysis.*** AI can play a substantial role in national defense. Through its Project Maven, the American military has deployed AI "to sift through the massive troves of data and video captured by surveillance and then alert human analysts of patterns or when there is abnormal or suspicious activity.[55]"

  - ***Near Real Time Analysis of Data.*** The big data analytics associated with AI, will profoundly affect intelligence analysis, as massive amounts of data are sifted in near (if not) real time. This would provide commanders and staff a level of intelligence analysis heretofore unseen. While command and control will similarly be affected as human commanders delegate routine, and sometimes certain key decisions to AI platforms.

  - ***Reduction of OODA Loop.*** This would dramatically reduce the time associated with the decision and subsequent action.[56] So fast will be this process, especially when coupled with automatic decisions to launch artificially intelligent autonomous weapons systems, that a new term has been coined specifically to embrace the speed at which war will be waged: hyperwar.[57]

III. Information War

Information war is the manipulation of information trusted by a target without the latter's awareness so that the target's decisions are against their own interest and in favor of the one conducting it. Strictly it is in the realm of war, albeit, in its' application it has implications for warfare also.

While, theoretically many types of information war can be described – two directly affect warfare and the soldier. These include: First, Psychological Warfare; wherein the aim is to sow doubts in the minds of the soldiers not only about the justness of their cause but also of their chances of victory-[58] it involves not only spreading misinformation but also protecting your own from it. The latter takes the form of rules to deny the services to own and/or firewalls to filter unwanted information. Second, Cyber War; while Stuxnet virus and its role in damaging the Iranian nuclear centrifuges in particular[59] and program in general is

comparatively well known, a lesser-known cyber-attack – though more widespread – involved the Russians in the 2008 Georgian war.[60] A Distributed Denial of Service attack it was aimed at the Georgian infrastructure. Similar attacks to impair opponents' infrastructure were again resorted to by the Russians – possibly four times – against Ukraine between 2015 and 2017.[61]These are likely to be affected by the following: -

- ***Network Availability.*** Today the network for data is dependent on availability of cell towers or fiber optic networks. Resultantly, areas devoid of these are still not connected. But certain projects – already in advanced stage of implementation – aim to bypass the requirement of towers and spread the web worldwide especially in rural areas where it is presently not available. These include: Alphabet's Project Loon;[62] Greg Wyler's OneWeb;[63] Amazon's project Kuiper;[64] Space X's Project Starlink;[65] and O3B Network.[66]
- ***Speech Synthetization.*** A large number of projects are today working to replicate an individual's voice with near complete accuracy. Bengaluru based Deepsynch[67] offers an Augmented Intelligence that learns the way you speak. It creates a digital model of the user's voice and learns hundreds of features including the accent to the way you subtly express oneself. It does this, by using advanced forms of deep learning.[68] Facebook claims it can clone an individual's voice in just 500 milliseconds.[69] Google's Wavenet claims that with 30 mins of data it can also adjust for emotion, pitch and speed.[70] The net result of these is that we may not be listening to the one we believe we are listening to but rather to some computer and will not be able to differentiate.
- ***Deeper Fakes.*** AI-generated fake videos are becoming more common and convincing. Reportedly first started in 2017, today it takes but a few steps to make a face swap video. All that is required is a high-end computer with powerful graphics cards or better still, computing power in the cloud. A Chinese mobile app – Zao – has brought the technology to a smartphone.[71] Combined with speech synthetization, it means we cannot be sure if any audio video message is real or fake.

The cumulative impact of these would be: -

(a) The receiver (presently mobile phone) would shrink drastically as

* Computation would move online.

* Need of a cell tower and in turn antenna in the receivers would be eliminated.

(b) Denying services through rules would be near impossible.

(c) National firewalls would lose effectiveness as there would be no fixed gateways.

(d) Psychological war will be based on hyper personalization as fake messages will seemingly be delivered by individuals we trust.

(e) Cyber-attacks on infrastructure would be easier and more frequent requiring not only hardening but also regular monitoring.

(f) Data will have little protection through rule-based regimes. The oil of the modern world - each individual will have to be conscious of and protect their data as they protect their currency savings.

IV. *Sensors*

In 2009 there were approximately 12.5 billion sensors of various kinds deployed in the world. By 2015 the number is estimated to have increased to 15 billion.[72] Compare this with the population of the world estimated to 7.8 billion.[73] The sensors are obviously not equally distributed but with the reduction in price and widespread availability of the web, it is but a matter of time before the gap is bridged. Many believe that the world has acquired an electronic skin.[74]

The accuracy levels of these has also been increasing – compared to the last generation accelerometer or GPS based devices like fitbit or apple watch – the likes of Oura Ring offers a 99 per cent accuracy compared to a medical grade heart rate tracker.[75] Moreover, the cost of these has already fallen to as low as 300 USD. This is likely to fall even further. These sensors are today being used from health monitoring to smart shelves for inventory control, from thermostats to pollution detectors the usage is limited only by imagination.

In the Armed Forces, these are already facilitating frontline casualty management, auto generation of demands, monitor usage of critical stores, and most importantly as eyes and ears of autonomous systems. Increased integration of these in the years to come will also facilitate decision making as well as advance warnings networked system with capabilities far in excess of the existing devices. On the flip side though, the fog of war is fast being replaced[76] with a data deluge, processing of which is no longer humanly possible without AI.

V. *Robots and Autonomous Weapons*

After the initial failure of robots at Fukushima, special plans were drawn worldwide to develop robots capable of operating in the most challenging environments. While the first successful foray inside Fukushima was accomplished not before 19 Jul 2017,[77] the endeavor ensured rapid development in the field.

Today, convergence with sensors and AI have ensured that robots are capable of performing a vast array of tasks. From delivery to load carriage to precision jobs and working in dangerous environments – customized robots are increasingly emerging as the solution. Some believe that they would singularly be responsible for the most profound change on the battlefield since the atomic bomb.[78] They are already capable of performing various combat roles like search and rescue, explosive disarmament, fire support, reconnaissance and logistics support to name but a few. Many believe we will see fully automated lethal autonomous systems in the near future, potentially making the role of human soldier obsolete.[79]

While fully automated weapon systems are believed to be in contravention of the Geneva conference,[80] the role of the man in the loop is increasingly becoming less. Today making a decision of an opponents' life is akin to playing a video game.

- First appearing in World War I[81] , the ambitious design was limited by the technology of the day. As the technology developed, military robots have slowly become essential tools in national arsenals.
- Even non state actors are already experimenting with these. The first such attack has already occurred on 04 Aug 2018[82] – a bid to assassinate President Nicolás Maduro of Venezuela. Though a failure for varied reasons, the attempt displays the lethal potential of the technology whose availability is rapidly increasing and cost reducing.

- Today a small quadcopter,[83] few inches in diameter (and costing less than a restaurant meal) can carry a small shaped charge - maybe just 1 to 2 gms – capable enough to punch a hole in few mm of steel. These can be carried, by the millions in one vehicle, programmed to operate in swarms to deliver and detonate the charges. With falling costs, success rates as low as 5 to 10 per cent can cause havoc in the enemy ranks. Additionally - unlike guns - millions of these can be controlled by just a couple of controllers.[84]
- The advent of robotic weapons will be further accelerated with further advances of technology e.g., University of Michigan reported on 20 Aug 2020 that they were able to increase the range of robots by as much as 72 times by using structural zinc and distributive batteries.[85]

VI. *Virtual and Augmented Reality*

Presence is the new development. For all of history our lives have been limited by the laws of physics, mitigated by the five senses. Virtual reality is rewriting these rules. It's letting us digitize our experience and teleport our senses, into a computer-generated world where the limit of imagination becomes the only brake on reality.[86] Holographic effects of virtual reality are already being used by politicians, to connect with voters en masse.[87] Costs have fallen dramatically[88]; consequently, they are today visible in the form of 3D advertisements of various products especially at shopping malls.

Advanced armies have integrated these for training purposes. It enables participants to get a real feel of the terrain much before they physically reach it. Additional, filters can be added to give them a presence in lifelike combat contingencies and permit practicing of drills in real time.

Augmented reality seeks to raise the bar to a whole new level. Its systems are targeting more senses than just vision[89] - 360^{O} audio, touch, scent, taste every kind of imaginable sensor is being integrated with it through convergence with haptic technology.[90] Even though standalone sets are not yet cheap, cloud computing brings the experience within reach of the common man. Pokemon Go is one such example, wherein Augmented Reality within a mobile phone allowed gamers to experience an alternative reality.

Resultantly the boundaries between the digital and physical world are starting to fade. The world, is gaining layers of information, invisible without the right apparatus. Rich, personalized and interactive data[91] can be made available with the right equipment. One such application already available is the Google Lens[92] which can help in decoding the landscape.[93] It will not only make maps redundant but also enable much larger information (which otherwise is limited to operations rooms) to be available in real time. Commanders leading platoons and companies can be told in real time when they are approaching possible ambush sites, minefields or when alternate routes are possibly available. Once such information is available digitally, information and experience gained by a unit or an individual will never be lost and subsequent units / individuals will benefit.

Another such application is called 'System for Telementoring with Augmented Reality' (STAR) which can bring advanced surgery to the frontline.[94]

The technology for this is already available.[95] It has the potential to teleport an individual from one location to another. Not yet a – "Beam me up Scotty" - moment from Star Trek, but close to it. With all our senses effective at the desired location, communications will be at a whole new level. Commanders for example may very soon be controlling operations by teleporting their senses.

VII. Space

With the growing dependence upon satellites for a variety of purposes,[96] space has once again emerged as the next frontier, this time for armed conflict. Currently, only four countries,[97] have anti-satellite (ASAT) capability. But earth bound ASAT weapons require immense power and can potentially create a cloud of debris[98] - which can threaten your own space assets as also those of friendly or neutral nations.

Hence, nations have been experimenting with other ASAT proposals. France, for instance, is working on laser beams that could dazzle another country's satellite, preventing it from taking pictures of classified targets. North Korea is studying how to jam radio frequency signals sent to or from a satellite, and Iran is devising cyberattacks that could interfere with satellite systems.[99] China is testing lasers on satellites in the name of gravity satellite,[100] many believe that it can be used to dazzle hostile satellites too.

Russia has launched a commercial satellite specifically designed to rendezvous with other satellites.[101] Named Cosmos 2542; a week after launch, it released a sub-satellite, Cosmos 2543, capable of maneuvering in orbit to observe, inspect or spy on other satellites. This sub-satellite moved close to a US spy satellite, USA-245, and to another Russian satellite. On 15 Jul 2020, the system was tested and it released an object at a relative high speed, around 200 meters per second.[102] The Russian Defense Ministry called it a peaceful inspection,[103] but others believe that it is like a bullet in space. As satellites speed through the void at tens of thousands of miles per hour, the smallest contact with another object risks smashing a hole in its solar panels or damaging or even destroying it, depending on the size of whatever it may hit. US and UK hence called it a projectile "with the characteristics of a weapon".[104]

Other technologies being considered / experimented involve creating equivalent of armed satellites by mounting technologies capable of interfering with or destroying the opponents' satellites. These include: machine guns, lasers, directed energy weapons capable of firing a beam of microwave radiation, and radio jamming.

VIII. *3D Printing*

The technology has been around since 1981.[105] But the crucial difference is that earlier only plastic was being used but today many more materials are being utilized.[106] Hence, today increasingly complex objects are being printed.[107] Attempts are being made to print even replacement organs like capillaries and kidneys.[108]

Prices have already starting falling and it is today possible to add new products within hours. Apart from food,[109] and fuel almost everything can be printed with it. Experience of the technology utilization in disaster relief[110], especially when powered by solar power,[111] displayed its versatility. The technology has also proven itself proficient in improving the existing systems.[112]

It is believed that within a few years the technology will not only be the beginning of the end of supply chains but also of waste in terms of holding of inventories. The technology can potentially reduce the logistics chain for any combat force drastically.

IX. Material and Nano Technologies

This refers to fields of science which are solving everyday problems on a daily basis. From self-cleaning clothes and windows to lighter and more durable equipment, all fields of life are benefiting from these. Some of the current applications which can affect warfare include: -

- ***Renewable Energy.*** Considering that most of the operational deployments of armed forces are away from the available power grids, the costs of fuels to provide power for equipment and day to day activities is tremendous. In the medium to long terms these can be mitigated by adoption of renewable energy.
  - ***Solar Energy.*** The photovoltaic efficiency of solar cells has already doubled[113] from 8 per cent to more than 16 per cent, in lab conditions it is supposed to be touching 34.5 per cent[114] and more.[115] Simultaneously, the costs per watt of the system has fallen from 300USD per watt in mid-fifties,[116] to less than one USD presently.[117] Theoretically it is believed that a photovoltaic efficiency of 66 per cent may soon be achieved[118]. This would further reduce the costs.
  - ***Wind Power.*** Wind power has come a long way, but it still has a lot of room to grow. Apart from the efficiency that has been imbibed with lighter and more durable material,[119] costs have come down with its co-location with solar power plants.
  - ***Battery Technology.*** One of the primary problems with renewable energy, particularly wind and solar, is that power gets generated when the wind or sun is available, rather than when it's most needed. This problem would more or less disappear if the world could come up with a massive, cheap, long-lasting battery design that could be used to store power at grid-scale levels and feed it back out when required.[120] Molten salt batteries provide this answer.[121] Though not yet available for mobile equipment, these are ideal for static locations.

Other Nano Applications for Defense include: -

- ***Explosives and propellants.***[122] Explosives and propellants use chemical energy to produce a super/sub sonic wave. Nano-energy material has a faster decomposition reaction rate. It has been demonstrated that with equal mass these can produce double the energy. In addition, they deliver a better controlled burning rate and better safety.
- ***Management of CBRN threats.***[123] The small size of nano materials permits presence of greater number of constituting atoms/molecules at the surface of a material. This permits better bonding, higher reactivity and sensitivity which can be exploited in detection equipment.
- ***Camouflage and stealth.***[124] It is a big challenge for camouflage designers as well as material scientists to engineer materials that can meet the operational requirement of protecting the personnel and combat equipment from the detection over multiple wavelengths. Nanomaterials and metamaterials provide multispectral stealth solutions together with the scope of tailoring of such characteristics as per the requirement. They also provide for better radar and microwave absorption. Nanomaterial can also be used for adaptive camouflage.
- ***Lightweight military platforms.***[125] Lighter weight military platforms has been a constant requirement. Metals were replaced with alloys and now composites. Composites are materials made from a combination of two or more natural or synthetic materials differing in their physical or chemical properties. They are mechanically stronger than its individual components, have more life and lower cost. Nanocomposites include reinforcement material having at least one dimension in a nanosized range which makes them stronger and yet lighter.

- ***Smart soldier technology.***[126] Nanomaterial based soldiers' equipment will be lighter weight than existing equipment. In addition, it can include Smart textiles, exoskeletons and energy harvesting systems. This will enable more multi-functionality with lesser load.
- ***Advanced weapon systems.***[127] Nanotechnology can enable development of precision-guided firearms at par to those designed for fighter jets. These will intrinsically include target acquisition, advanced fire control, and display technologies; enabling them to engage a target without any error in one shot. Such weapons can be made available for use by snipers, counter-defilade engagement, underwater amongst others. Apart from extended ranges these would reduce logistics. Similarly, the technology would be useful for hypersonic missiles, directed-energy, microwave, laser and particle beam weapons amongst others.

X. Miscellaneous Technologies

Many other technologies are under development and may appear on the battlefield – some sooner and some later. These have not been covered above because evidence has not yet appeared of their mass availability. These include:

- ***Quantum Systems.*** These include computers, communications, radars etc. The progress on these have been impressive in recent times and when these systems do appear, they will certainly be a disruptive force on the battlefield. One such example of progress is the achievement of the Chinese Quantum Satellite[128], others report feasibilities in Quantum internet[129], encryption[130] and communication[131]. Albeit most reports suggest that the systems are not yet out of the laboratory.
- ***Radio frequency, biological and chemical weapons.***
- ***Electric and rail guns.***
- ***Laser weapons.***
- ***Hypersonic Missiles and Vehicles.*** Weapons exceeding Mach 5 speeds, would be capable of targeting any point on Earth in less than an hour of decision and launch. Lots of reports do suggest that these may appear earlier as especially the Chinese have been testing weapons in excess of Mach 8 and 10,[132] Russia too has made similar claims.[133] Whether such systems truly wind up proving feasible, affordable, and effective in combat remains to be seen.[134]
- ***Neuro-Sciences or Brain Computer Interface.*** Originally developed to help patients, these are an innovative technology that uses brain signals to control an external device by bypassing normal neuromuscular pathways. Though still in experimental stage however, already the technology is being experimented with for direct brain to brain communication i.e. through thoughts only. In a research published in April 2019, researchers from University of Washington claim to have established a BrainNet system. With it, researchers claim to have developed a way

for three people to communicate and solve problems together using only their brains.[135]

Conclusion

Technology has always been decisive in warfare. These are critical in enhancing the soldiers' abilities, which in turn affect the outcome of a battle and the war. While military commanders themselves have not been men of science, they have benefitted by introducing the latest technologies. Till just a century back, national economies were highly reliant on militaristic achievements – which gave societies loot, colonies and captive markets. Hence, technologies were often developed for the military and later percolated to the civil field, where in turn they were a catalyst for further research.

But in recent times, these dynamics of technological advancement have changed. For one, the national economies have now become the driving force and militaristic achievements are secondary. Simultaneously, the advent of computers and digitization has boosted the pace of development to a rate never seen before. It is not surprising then that technology developed for non-military purposes is often, far advanced compared to the one being used by the armed forces. The challenge for military commanders therefore is to integrate and use the advancing technologies to meet their goals. Digitization is and will remain the bedrock on which exponentially advancing technologies can be integrated. It involves not only digitization of existing data but defining the problem statement in a manner which digitized systems can understand and innovate from.

The paper has attempted to cover some technologies which are known to have been developed beyond the laboratory and hence may appear on the battlefield within the decade. There would certainly be more, albeit digital platform would more likely than not, be the common denominator for their integration.

End Notes

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[127] Advanced weapon systems would include amongst others precision guided arms, extreme accuracy tasked ordnance, magneto hydrodynamic explosive munitions, unmanned combat vehicles, non-lethal personnel halting and stimulation response rifle, directed energy weapons, laser weapons, particle beam weapons and invisibility cloaks. Ibid., p. 303.

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