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The Centre for Joint Warfare Studies (CENJOWS) is an independent, professional research institute established in 2007, in pursuit of strengthening the concept of 'jointness' within the defence forces, as well as with other agencies that jointly contribute towards a nation's war fighting capability. SYNERGY is the CENJOWS Journal that strives to expand and deepen the understanding of issues concerning defence, national security and civil-military interface which are so very essential for joint war fighting.

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FROM THE DESK OF CDS

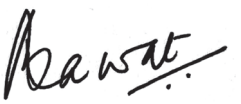
Technology is fundamental agent of change, particularly in the military realm. Major shifts in military history have often followed Ground-breaking Developments in the history of science and technology. A rapidly evolving technological landscape in the past decade is fast changing the very definition and character of war fighting. Military conflict zones of Crimea, Syria, Afghanistan, Iraq and Nogorna-Karabakh have amply demonstrated the prowess of emerging technologies in shaping the outcomes, not only in conventional, but also in Grey Zone situations.

Current innovations, in Artificial Intelligence, Robotics, Autonomous Systems, Internet of Things, 3D printing, Nano technology, Biotechnology, Material Science and Quantum Computing are likely to bring unprecedented transformation in war fighting. The capabilities they could provide may directly or indirectly affect the preconditions for peace, the nature of conflicts and how insecurity is perceived and managed, by people and states.

Given India's strategic environment, the development and incorporation of such avant-grade innovations will not only ensure better preparedness of our Armed Forces against our adversaries but also boost capabilities in countering non conventional threats. Indigenous production of such technologies remains a crucial factor in their realistic military incorporation. Majority of these technologies grow out of commercial pursuits and then due to its dual-use nature

can be applied to the evolving military needs. Consequently, civil-military synergy is critical for indigenous innovation and realistic technological enhancement. Recent initiatives by the Indian Government to focus on incorporating these disruptive technologies, is a welcome move towards careful nurturing of a sustainable commercial domestic ecosystem.

The Feb 2021 issue of the Synergy Journal addresses a wide range of issues on new age technologies through well researched articles, which will help incubate new ideas towards capability enhancement of our Armed Forces.



(Bipin Rawat)
General
Chief of Defence Staff

FOREWORD BY CISC

Emerging and potentially disruptive technologies are fundamentally challenging the manner in which security strategies are being formulated and enforced at national and multilateral levels. New Age technologies are empowering and enabling smaller powers to compete and successfully challenge great powers. Disruptive technologies are emerging as a new frontier for conduct of future warfare.

Autonomous fighting platforms, Cyber Warfare, Artificial Intelligence, Quantum Computing and Unmanned Aerial Vehicles are some new area technologies that have already begun to impact war fighting. Russian cyber-attacks on Estonia way back in 2007, Houthi directed drone attacks on Saudi ARAMCO in Sep 2019, attacks on Iranian General Qasem Soleimani in Jan 2020 and the recent Nagorno-Karabakh conflict are testimony to the range, power and sensational impact of these new age technologies on war fighting.

Focus by many countries on civil-military fusion has facilitated efforts towards rapid development of hypersonic weapons, space based assets, directed energy weapons and Artificial Intelligence equipped systems. With the changing character of warfare, it is imperative for our Armed Forces to acquire desired capabilities for fighting future conflicts including in non-conventional domain. The recent initiatives taken by the Government to develop new age technologies and

provide requisite budgetary support are steps in the right direction to develop desired products to modernize our Armed Forces.

Compliment the team of CENJOWS to have chosen this contemporary topic for the Feb 2021 edition of the Synergy Journal and covering very relevant issues that will make good reading for all researchers and practitioners of modern warfare.

(R Hari Kumar)
Vice Adm
CISC & Chairman CENJOWS

DIRECTOR'S REMARKS

Science and Technology developments are so much interdependent that while technology evolves from sciences, it in turn inspires sciences to pursue a more meaningful direction of research and the cycle is virtuous. As the nature of wars gets diversified and takes the shape of the Grey Zone Warfare, the role of technology and especially new age technologies attains critical significance.

As if the reach, lethality and precision of the already prevalent technologies manifested in stealth aircraft, armoured fighting vehicles, intercontinental missiles silent submarines and aircraft carriers was not enough, new age technologies are beginning to take shape and offer more and more applications for Defence Forces as well. The recent Azerbaijan - Armenian conflict offers several lessons for exploitation of new age technologies especially drone warfare.

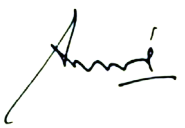
The field of new age technologies is complex, multifaceted, multidisciplinary and ever evolving. Compilation of essential elements of most of these technologies in one volume was a challenge which has been addressed in this Feb 2021 issue of the Synergy Journal.

Besides giving a historical perspective, the global application of the new age technologies by the military has been outlined. Major new age technologies such as Quantum Computing, Bio-Technology and Hypersonic Weapons have been summarised. Modern Bio-technology offers enormous potential military applications and is likely to have a major impact on the soldiers and the techniques of war fighting.

The volume also outlines a roadmap for Anti Space Asset Weapons Development and Employment. Unmanned Systems alongwith Manned-Unmanned Teaming and its Imperatives for India have been explained. Detailed measures for employment of 5G IC Technologies for enhancing Combat Effectiveness of the Defence Forces have been fleshed out.

An analysis of India's status in various interlinked technologies especially aero engines has also been carried out and the readiness for development of Sixth Generation Combat Aircraft Technologies assessed. The linkage between emerging warfare concepts and evolving new generation technologies has also been explained.

Many other niche and disruptive technologies such as Artificial Intelligence, Robotics, Big Data Analytics, DEW, etc have been deliberately left-out for want of space and are likely to be addressed in future publications. Happy Reading.



(Sunil Srivastava)
Lt Gen (Retd)
Director

EMPLOYMENT OF TECHNOLOGIES BY THE MILITARY: HISTORICAL PERSPECTIVE

Brig Rajat Upreti*

Abstract

Evolution of military technologies over the years has been dictated by the needs of the people, technological advancements of the times, resources available and the communication of knowledge between various parts of the World. Starting from the early period of human inhabitation on the Earth, the growth of Military technologies has contributed very significantly in the shaping the past and will dictate how the future pans out. The evolution of these technologies has been in spurts with very slow initial development and speedy growth when humans gained expertise over metals and other materiel as also developed skills in machining and other related fields. The explosion of technology in the twentieth century has truly transformed this field and it has rightfully been termed as a revolution in military affairs (RMA). The development and growth of military technologies in the last hundred years far outstrips the earlier pace of development, however the past technologies have shown the way in developing new ones and this contribution will only continue with new arenas opening up with greater technological prowess of the mankind. This article aims to cover the history of military technologies over the years and their impact on war fighting and progress of Human Civilisation.

The evolution of mankind has been intrinsically linked to development of new technologies and innovation. The discovery of basic tools and weapons by the early man changed the nature of his existence and from a weak species focussing only on survival against much stronger and agile animals, man became a hunter and rose to the top of the food chain. The rise of mankind was largely attributable to the cognitive skills which allowed the germination of new ideas and creation of potent tools of survival and growth. The discovery of fire, creation of weapons from stones and wood, the invention of wheel, domestication of animals, farming and shift to hunter-gatherer etc, are all watershed moments in the evolution of mankind.

The early man devoted considerable time and energy on hunting and expansion of territories for the same, which led to conflicts. Any new discovery or invention with the capacity to influence outcomes in early battles with animals, fellow humans and nature affecting aspects of survival were the start of innovation and use of technologies. The tools developed for hunting of animals were equally effective in conflicts against fellow men. There was hardly any distinction between hunting and military weapons, thus the earliest military weapons were the tools commonly used for hunting like sticks, stones and spears. Leveraging mechanics to increase reach and accuracy of weapons were perhaps the very first innovative technologies developed by mankind. The use of spears, bow & arrow gave great advantages which overcame the human limitations of strength and speed in killing much stronger and faster animals or other enemies. The early man employed spears and arrows of fire-hardened wood, chipped and sharpened stone followed by bronze and Iron, the earliest of which, the stone arrowhead, is believed to have been used 60,000 years back.

As time progressed, it was clear that with the use of the weapons mankind could easily protect and subjugate the rest of the animal kingdom. However the danger from fellow human beings was another matter entirely as they possessed the same cognitive skills. Human ambition is

perhaps the most important reason for the continuation of technological evolution of weapons giving impetuous to the race to produce better and more potent arms in order to gain supremacy and overcome opposition. The use of metals for making swords, shields and armour gave great advantage to its user against lesser enemies, similarly the use of horse mounted cavalry, elephant mounted spearman gave the mobility and firepower which tilted scales in battles. The use of gunpowder, artillery weapons capable of destroying enemy at long ranges, development of large ships with firepower, etc were the technologies developed in the early period for use by militaries. The person who first effectively utilised these technologies became the most powerful and gained great importance. The Greeks under Alexander the Great, the Romans under Ceasar, The Mongols under Genghis khan, Hannibal crossing alps with elephants, The use of Gunpowder by Chinese, The Shipping Armada of the Cholas, Chinese, Portugese, Spanish and the Britishers, are all examples of these.

The modern era saw extensive technological growth in all fields and a paradigm shift was also witnessed in the military technologies. From the late eighteenth century and upto the Cold War period, the needs of the militaries were the driving force for innovations, subsequently the needs of the society became the harbinger of change and technologies were developed more for civil use with applicability in the military domain also. The two great wars, especially the second war saw great innovations and mil technologies especially in the fields of artillery guns, rockets, development of tanks, aircrafts, battleships, communication and IT, the development of radars, mines etc which changed the dimensions of war. The scope and use of technologies have evolved from the initial use over land to all dimensions including under the oceans and the space. Post the great wars the growth of technologies has been nothing short of miraculous and a generational shift in war-fighting has taken place since the gulf wars which showed for the first time the network centric use of combat power in multiple domains. As the nations compete to gain supremacy in the world geopolitical stage the necessity to create

and discover new frontiers of military technologies will continue as is visible in the ongoing battle for technology between USA and China. The areas of Space, AI, IOT, Cyber, Hypersonic vehicles, DEW, Drones, Quantum radars, Satellite and anti-satellite warfare, big data analytics, etc are some of the new areas where the future wars will be fought and the growth of technologies seen.

The development and use of technology by militaries over the centuries has been driven by various reasons, primarily dictated by the threats, the scientific progress of the times, availability of resources and societal needs. Based on the chronological timelines, the evolution of military technologies can be divided into the three main periods which are summarised in the following paragraphs.

The Ancient World: Early Man-500 AD

The early part of this era covers the period where the development of technology by man was driven by necessity of survival against more powerful species. The first stone tipped arrowhead used for hunting date back to 60,000 years ago. Bows and arrows were invented by the late Paleolithic period, around 9,000-11,000 BC. The opposable thumb, cognitive skills and communication ability of human beings were a great asset in the development of newer tools. These skills were passed down through the generations and thus ensured higher degree of evolution. The militaries were not highly evolved and tools used for both survival and conflicts were primarily sticks, stones, wooden spear, mace from bones, bows & arrows and spears with stone heads which were followed by the use bronze, Iron and other metals.

The most important areas of development of technologies corresponded to the growth of human civilisation in the River basins of Tigris-Euphrates, Nile, Indus, Yellow River and Aegean and Mediterranean basin. The need of survival from animals changed to survival from other competitors, desire to grow more powerful, protect

and expand ones civilisations. The discovery of Bronze around 4500 BC transformed the nature of weapons. Earliest bronze mace and spears were made by the Sumerians in the period 2500 BC and it was also used for making Sword, Shields and Lances by the Mesopotamian, Egyptian, Indus and Chinese civilisations in the period 3000-1500 BC.

When people started horse riding at around 2500 BC, composite bows were created. In 1200 BC, the Hittites, originating from Anatolia, shot arrows using their bows on light chariots. In 1000 BC some of these horse-riding archers from Central Asia invented the recurve bow, which was in the shape of a “W” and had an improved elasticity. It was in the period around 2200 BC that trade by sea between the Egyptians with the Phoenicians commenced. This was the start of innovations in Sea warfare which started with fixing bows on a boat for safety to eventually using bigger ships of seventy to eighty tons suited for long voyages by the Egyptians. In order to have smooth trading relations, they built a large fleet and took control of the sea and recorded these in important places like the temple of Medinet Habu which has reliefs depicting the fleet of Ramses III fighting a naval battle against the Phoenicians, also called the Sea People.

The battle for supremacy between the Assyrian, Egyptian, Greek, Macedonian and Roman empires in the period from 2000 BC - 500 AD saw the emergence of innovative war fighting techniques and new technologies being used to create weapons like the Khopesh Sword (main Egyptian weapon), Trident (main Greek weapon), Gladius (main Roman weapon), Spears, Catapults, Helmets, Sheilds and body Armour for protection. The use of Cavalry, battering rams to overcome siege, mobile watch towers, fortifications etc were important innovations which came about in this period.

The Shang dynasty, the first of the great empires in China, rose to power through their control of the new technology of bronze working. From 1300 BC, they moved from being foot knights to chariot archers,

using composite recurved bow, a double-edged sword known as the jian and armour. Use of Chariots and Crossbows was very pronounced in the Chinese Military and the Zhou conquest of the Shang at the turn of the millennium may have been attributable to these innovative technologies. During the Qin dynasty and thereafter, the Han, the Chinese armies were faced with military threat from the nomadic tribes from the North. These nomads were fast horse archers who had a significant mobility advantage over the Chinese. In order to counter this threat, the Chinese built the Great Wall as a barrier to these nomadic incursions around 220 BC. This was probably amongst the first great fortifications created in the ancient world.

This later part of this era was characterised by human ambition and conquest driving technologies. The important aspect during this period was the pre-eminence given to the militaries as the ruler was beholden to the Military for his power. The survival of nations and their power came from the might of militaries and the ability to invent and innovate newer technologies of war fighting which would give them the advantage. Thus the growth of military technologies was of paramount importance but these new technologies were few and far between as there were limitations of material, tools and scientific thought. The militaries were predominantly focussed on muscle power and innovations were aligned towards maximising these aspects of warfare. Lack of communication and transportation means further isolated the various civilisations around the world and the growth of technologies were restricted with both technology and tactics being shaped by geography, climate and topography.

The Medieval Period : 500 AD - 1500 AD

During this period the Roman Empire declined and the new powers arose. The barbarian tribes in Europe, the Byzantine Empire carved from the Eastern Roman Empire, the Tang and Song Empire of China, the Golden Hordes of Ghenges and Kublai and the Islamic empires were the main

contributors to evolution in warfare and weapons. The use of Axe by the Franks during the period 400-700AD saw them overcoming the other Barbarian tribes, The Byzantine engineers were using powered arrows and excellent fortifications, the Chinese discovered the gunpowder which revolutionised warfare. The use of cavalry by Ghenges and the Islamic empires along with devices like the Trebuchet, long range Artillery guns and use of Longbows by the Normans and the Islamic armies were some of the important innovations of the times.

It was during this period that the horse mounted cavalry displayed its ability to manoeuvre and win battles with shock action complemented by high mobility. The use of cavalry by Gothic tribes in 400 AD resulted in the defeat and final destruction of the Roman Empire. The Knights of Europe, the Armies of the Seljuk turks, The Islamic warriors, the golden hordes of the Mongols all experimented with this form of warfare in their battles for supremacy. These were further improved during the Crusades in the eleventh century and the 100 year war between England and France from 1337-1453. The advantage gained by the cavalry were soon neutralised by development of Longbows and Crossbows which gave a much longer reach to the Infantry. This was assisted by the use of gunpowder which was invented in China in the ninth century AD but probably used first by Mongols. From the Mongols, the use of gunpowder progressed to the European nations in the 13 Century AD and it was these nations who started the first modern scientific revolution in military affairs by developing gunpowder for multiple use. The initial use of gunpowder was in Artillery and these were limited by the metallurgy of the times so the development of gunpowder for warfare progressed slowly. The use of wrought Iron canons propelling iron balls weighing 200 kgs to large distances by the power of gunpowder in the early 14 Century AD can be taken as the start of this new form of warfare. The use of long range canons by Sultan Mehmet resulted in the capitulation of Constantinople to the Islamic world in the 1453. From muzzle loaders to breech loaders, canons developed into mobile pieces. With improvements in metal processing and foundry, bronze based cannons were developed and

the use of canons progressed into sea warfare too. The French and the British were the leaders in developing these technologies in the fifteenth century and these were instrumental in helping these nations conquering large territories in the coming times and establishing their empires.

The Modern Period : 1500 AD- Present times

The use of cast Iron canon by England in 1543 transformed the nature of warfare and canons soon became the centre piece of battles. The armies with the maximum numbers and range of canons normally emerged victorious. In the 15th century exploding shot was developed by filling hollow cast-iron balls with gunpowder and fitting a fuze that had to be lit just before firing. Seeing the usefulness of firing balls over large distances by canons, it was only a matter of time that use of this technology for development of individual firearms came about. The earliest small arm was probably the Matchlock which was invented by German engineers in the late fifteenth century; this was followed by the Flintlock in the middle of sixteenth century. The muzzle loading Flintlock rifles were replaced by the bolt action rifles which were used by Prussians in 1866 to defeat the Austrian Army. The French and other European powers transited to the breech loading rifles in the late nineteenth century.

Rockets in a very crude form were first used by the Chinese in the thirteenth century but the modern rockets are attributable to Hyder Ali in the Indian Peninsula when he waged a war against the Britishers and used Rockets propelled from tubular structure to ranges greater than 1km. Hyder Ali's son, Tipu Sultan, continued to develop and expand the use of rocket weapons and these rockets were used with considerable effect against the British in the battles at Seringapatam in 1792 and 1799. Thereafter the Britishers started work on these and Sir William Congreve can said to be the first scientist who used scientific techniques fo making rockets with either an explosive (ball charge) or incendiary warhead allowing air bursts of the warheads at different ranges. The first use of these modern rockets was in a successful naval bombardment

of the French coastal city of Boulogne in 1806. The Second World War saw great developments in this field with both US and Germany developing a variety of rockets which could be used from Land, Sea and Air. Subsequent developments in this field led to the evolution of missiles and the arms race between the USA and USSR during the Cold War contributed to stupendous growth of missile technology. By 1970s both the superpowers had replaced rockets with missiles especially for longer ranges and accurate targeting. Most modern armies today rely on extremely accurate guidance with a variety of delivery and flight means and use missiles for various purposes from the tac level to the strategic and nuclear deterrence. Tac missiles, SAMs, SSMs, Cruise missiles, Ballistic missiles (of various ranges), MIRVs, hypersonic missiles etc are the modern day weapons which will play a decisive role in todays wars.

The use of cavalry in the Middle Ages led to the understanding that a mobile weapon platform which also provides protection could be a formidable adversary. This led to the development of the armoured fighting vehicle which were designed using the steam engine initially and later the internal combustion engine which truly revolutionised this concept. The first Armoured and armed self propelled vehicle was made by Vickers, Maxims and sons of England in 1902, however the development of tanks truly accelerated during the WW I when it was realised that this technology could overcome the stalemate created by trench warfare. The British were the first to use a tank, named little Willie, in 1915. The interwar period saw a number of countries developing lighter, faster and better armed tanks with the British, French, Russians and Americans leading the charge. WW II revolutionised the concept of massed use of tanks with the Germans using the Panzers in Division strength with telling effect in the advance through Europe and North Africa in 1939-1941. The German tank, Tiger II, at 68 tonnes was the heaviest tank used in the war. The Russian army too had a formidable arsenal of tanks with T34 playing a vital role along with the US Sherman tank in the war. After the war, developments in all aspects of tank technology improved tremendously with USA, Russia, Germany Britain and France

spearheading the developments. Gulf war showed the great role that tanks could play. The technological advances in M1A2 Abrahams, T 90, Leopard 2A7+, Merkava Mk 4, Challenger II and various other modern tanks makes them a lethal asset for any armies, however the use of anti tank weapons especially the drones as seen in the Nagorno-Karabakh arena will challenge the existing concepts and result in more scientific innovations in this field.

Use of hot air balloons in 1786 is considered the start point of military aviation. This was followed by the use of aerostats for Reece but the first aircraft used for military was the Aircraft No 1 which the Wright brothers made for the US army in 1909. Airships, Zeppelins and a few monoplanes were used in WWI but by the time WWII started there were improvements made in many areas, especially power plants, aerodynamics, structures, and weapons which resulted in better performance growth in military aviation leading to the introduction of aircraft into new roles, including Airborne Early Warning, electronic warfare, weather reconnaissance, and flying lifeboats. Post the WW II the growth in aviation has been astounding with the use of extremely fast and lethal platforms being used for multiple roles. The use of stealth technology, Advanced avionics, lethal armaments including PGMs, accurate navigation, failsafe communications, networked environment with AWACs etc have transformed military aviation. The aviation arena is now expanding into space and the use of satellites, spaceships and weapons in space coupled with quantum computing, AI, and hypersonic vehicles are the new frontiers being explored.

The modern times have witnessed great innovations and discoveries due to advances made in all spheres of sciences especially computing, metallurgy, power production, lethality of weapons, communications means etc. The evolution of Aircraft carriers, submarines and modern communications have transformed the Naval arena. The use of modern aircrafts, radars, missiles and lethal PGMs has made the skies a deadly battle ground. The networked and multi domain warfare

has introduced the use of big data, IOT, AI, cyberwar, IW, Drone warfare, swarm technology and non traditional wars on the already existing environment. The use of Info warfare in subduing or influencing the opponents mind and winning wars without fighting as quoted by Sun Tzu is becoming easier in todays environment where communication has no limits and cyber world enables this reach. The use of nuclear energy as a devastating war fighting tool was first witnessed in 1945 and has evolved the intervening years. It can only be hoped that this technology is used only for peaceful means else humankind may well be destroyed by the technologies it has created. The power of this Military technological growth is like a game of chess with each new discovery tilting the scales till its counter is discovered. The use of technology will open new frontiers and give exponential gains to the users, thus it would be fair to say that though the times have changed much from the early periods, however the basic needs of mankind and its drive for supremacy remains the same and the use of technology for military will continue to play a leading role in ensuring victory in this battle for supremacy.

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GLOBAL APPLICATIONS OF NEW AGE TECHNOLOGIES BY THE MILITARY

Air Mshl PP Khandekar, AVSM (Retd)*

"Technology has advanced at such a pace that this aggression may destroy us all by nuclear or biological war."

– Stephen Hawking

Abstract

Starting with the genesis of the word Technology, the author has covered a wide array of technologies that are going to impact in the coming 20 years as brought out by Michael O' Hanlon. Unhackable internet, AI, Quantum computing, LAWS are a few of the prominent technologies. The author has compared the USA, China and Russia in a few technologies. Russia seems to be lagging behind in general in major technologies of tomorrow. The jury remains out.

When I came to know the theme of this issue of Synergy, what struck me was the motto of Military Institute of Technology (MILIT) when it was under HQ DRDO as one of the Laboratories. Then the motto was "Technology Always Wins". As the institute was brought under HQ IDS, the motto changed to "Victory Through Technology". Well…jugglery of words but with AI making inroads in a big way, the fear expressed in the

earlier motto may well be true if the human element is made to go out of the decision-making loop in future.

Historical Perspective

Let your plan be dark and impregnable at night and when you move, fall like a thunderbolt." – Sun Tsu

Ancient China's military strategist Sun Tzu had famously said that the supreme art of war is to subdue the enemy without fighting. India's own ancient philosopher Chanakya has said that if the end could be achieved by non-military methods – including intrigue, duplicity and fraud – he would not advocate an armed conflict. And this is precisely what Army chief General M.M. Naravane stated when he recently spoke about the need to incorporate 'Chanakya neeti' in India's strategic and military thought process. India needs to prepare for the war of the future rather than just for tomorrow. The war of the future will not be fought just militarily. It would involve a combination of modern weapons, artificial intelligence, diplomatic muscles, cyber, and space capabilities that can give a deadly blow to the enemy even before it could initiate a strike. India's armed forces need to radically change the way long-term perspective plans are chalked out. Instead of focusing on adding more equipment for a conventional war scenario, there should be a single-minded focus on the use of modern warfare capabilities that countries like the US, China, Russia amongst others are already testing.

In the book on "History of Technology", the author Robert Angus Buchanan has dwelt over the term technology, a combination of the Greek technē, "art, craft," with logos, "word, speech," meant in Greece a discourse on the arts, both fine and applied. When it first appeared in English in the 17th century, it was used to mean a discussion of the applied arts only, and gradually these "arts" themselves came to be the object of the designation. By the early 20th century the term embraced a growing range of means, processes, and ideas in addition to tools

and machines. By mid-century technology was defined by such phrases as “the means or activity by which man seeks to change or manipulate his environment.” Even such broad definitions have been criticized by observers who point out the increasing difficulty of distinguishing between scientific inquiry and technological activity. John F. Guilmartin defined Military technology as range of weapons, equipment, structures, and vehicles used specifically for the purpose of warfare. It includes the knowledge required to construct such technology, to employ it in combat, and to repair and replenish it. Barry Commoner has rightly observed “WW II had a very important impact on the development of technology as a whole.”

Military Technologies

“This war, like the next war, is a war to end war.”- David Lloyd Lange

When I searched open-source literature, I noticed that there were no new articles of breakthrough technologies for the militaries. It confirms the theory that the technology breakthroughs take place as per S and pearl curves and it seems to be a flattened portion at present. Maybe we are in the wait for the technology breakthrough any moment. In 2019, a few experts identified and expected breakthroughs in Military Technology. They were Augmented reality headsets, Robots joining human squads, U.S. hypersonic missiles get faster, more operable, The SB-1 Defiant and V-280 Valor, Light tank prototypes, more autonomous aircraft, especially Army helicopters to name a few. On 26 February 2020, MIT identified a few technologies that will affect how we live and work. These are Unhackable internet, Hyper-personalized medicine, Digital money, Anti-aging drugs, AI-discovered molecules, Satellite mega-constellations, Quantum supremacy, Tiny AI, Differential privacy and Climate change attribution.

Smriti Srivastava highlighted cyber security, cloud computing, RPA, Big Data Analytics, Robotics, Drones, IOT, AR/ VR and AI. Harish

Pant and AS Mann have discussed AI/ ISR, LOCUST, HSTDV and DEW getting affected by Disruptive technologies. JR Wilson has elucidated top Enabling technologies for warfighting in diversified fields such as Cyber, space, Medical technologies including exoskeletons, Advanced materials, EMP amongst others. Sea domain has UUVs while air domain would have hypersonic weapons. He has touched upon DARPA-ATLAS CONOPS. The fifth wave a sci-fi movie is also indicative of how technologies will permeate all levels.

AI remains single most dominant technology in the available readings to have evolutionary impact if not revolutionary in years to come. Digressing though and in a lighter vein, in 1987 while undergoing PG at NITIE Mumbai, we were in search of an elective and being service sponsored wanted such elective which may not have an expertise in the institute! And we found AI and Expert systems as an elective! We gladly selected. First lecture, the professor came and told that he will learn along with us the subject. LISP and Turbo-prolog were the two languages then. It is nice to see now that field has come into real focus- after three decades or so. AI research is underway in the fields of intelligence collection and analysis, logistics, cyber operations, information operations, command and control, and in a variety of semiautonomous and autonomous vehicles. Already, AI has been incorporated into military operations in Iraq and Syria. Although AI has the potential to impart a number of advantages in the military context, it may also introduce distinct challenges. AI technology could, for example, facilitate autonomous operations, lead to more informed military decision making, and increase the speed and scale of military action. However, it may also be unpredictable or vulnerable to unique forms of manipulation. As a result of these factors, analysts hold a broad range of opinions on how influential AI will be in future combat operations. While a small number of analysts believe that the technology will have minimal impact, most believe that AI will have at least an evolutionary—if not revolutionary—effect. Military AI development presents a number of potential issues having long term ramifications.

I am tempted to produce extracts of my articles published in Feb 2020 issue of Synergy here as I found Michael O'Hanlon, a Technology forecaster to be one of the reputed individual to have the domain knowledge. In his book on Forecasting changes in Military Technology 2020-2040 he has studied 29 technologies that interact to bring changes in 38 systems and associated infrastructure and facilities. There are seven systems under Sensors, eight under Computers and Communications, twelve under Projectiles, Propulsion and Platforms and 11 under Other Weapons and Key Technologies. They are as follows:-

Technologies	Levels of Changes		
	Moderate	High	Revolutionary
Sensors			
Chemical sensors		x	
Biological sensors		x	
Optical, infrared, and UV sensors	x		
Radar and radio sensors	x		
Sound, sonar, and motion sensors	x		
Magnetic detection	x		
Particle beams (as sensors)	x		
Computers and communications			
Computer hardware			x
Computer software			x
Offensive cyber operations			x
System of systems/Internet of things			x
Radio communications	x		
Laser communications		x	
Artificial intelligence/Big data			x
Quantum computing		x	

Projectiles, propulsion, and platforms			
Robotics and autonomous systems			x
Missiles	x		
Explosives		x	
Fuels	x		
Jet engines	x		
Internal-combustion engines	x		
Battery-powered engines		x	
Rockets		x	
Ships	x		
Armor		x	
Stealth		x	
Satellites		x	
Other weapons and key technologies			
Radio-frequency weapons	x		
Nonlethal weapons		x	
Biological weapons		x	
Chemical weapons		x	
Other weapons of mass destruction	x		
Particle beams (as weapons)	x		
Electric guns, rail guns		x	
Lasers		x	
Nanomaterials		x	
3D printing/Additive manufacturing		x	
Human enhancement devices and substances		x	

The terms moderate, high and revolutionary are subjective and somewhat imprecise. In general terms, technologies showing moderate advances might improve their performance by a few percent or at most a couple of tens of percent—in terms of speed, range, lethality,

or other defining characteristics—between 2020 and 2040. Those experiencing high advances will be able to accomplish tasks on the battlefield far better than before—perhaps by 50 to 100 percent, to the extent improved performance can be so quantified. Finally, technology areas in which revolutionary advances occur will be able to accomplish important battlefield tasks that they cannot now even attempt. The above assessment gives some idea of applications in these 29 technologies interlaced intricately as the innovators galore. He expects revolutionary changes to take place in six technologies as can be seen from above, mainly in cyber domain. There is enough evidence to suggest that unless there is a breakthrough in technology following pearl curve or S curve, his assessment by and large is correct.

On 10 November 2020, a paper was presented to the US congress on Emerging Military Technologies: Background and Issues. This report provides an overview of selected emerging military technologies in the United States, China, and Russia. They are artificial intelligence, lethal autonomous weapons, hypersonic weapons, directed energy weapons, biotechnology and quantum technology. It also discusses relevant initiatives within international institutions to monitor or regulate these technologies, considers the potential implications of emerging military technologies for warfighting, and outlines associated issues. These issues include the level and stability of funding for emerging technologies, the management structure for emerging technologies, the challenges associated with recruiting and retaining technology workers, the acquisitions process for rapidly evolving and dual-use technologies, the protection of emerging technologies from theft and expropriation, and the governance and regulation of emerging technologies. Such issues could hold implications for authorization, appropriation, oversight, and treaty-making. Interested reader may go through the paper available in the open source. I have summarised salient points in a table form below:-

S.N.	Technology	Terms	USA	China	Russia
1.	AI	Narrow AI General AI	identifies five key lines of effort for driving U.S. AI competitiveness: (1) investing in research and development, (2) applying AI to national security missions, (3) training and recruiting AI talent, (4) protecting and building upon U.S. technology advantages, and (5) marshalling global AI cooperation.	China's 2017 "Next Generation AI Development Plan" describes AI as a "strategic technology" that has become a "focus of international competition. few boundaries exist between Chinese commercial companies, university research laboratories, the military, and the central government. China's National Intelligence Law, for example, requires companies and individuals to "support, assist, and cooperate with national intelligence work.	Russian AI development lags significantly behind that of the United States and China.

2.	LAWS	Human out of loop Human in Loop	not known to be developing LAWS currently, nor does it currently have LAWS in its inventory; however, there is no prohibition on the development, fielding, or employment of LAWS. DODD 3000.09 e	five attributes: lethality, sufficient pay load (charge) and means autonomy, absence of human intervention and control during the entire process of executing a task. impossibility for termination, meaning that once started there is no way to terminate the device. indiscriminate effect, meaning that the device will execute the task of killing and maiming regardless of conditions, scenarios and targets. Evolution, meaning that through interaction with the environment the device can learn autonomously, expand its functions and capabilities in a way exceeding human expectations.	"unmanned technical means other than ordnance that are intended for carrying out combat and support missions without any involvement of the operator" beyond the decision of whether and how to deploy the system. Russia has not publicly stated that it is developing LAWS.

3.	Hypersonics > 5 Mach	Glide Vehicles Cruise missiles	in contrast to Russia and China, the United States is not developing hypersonic weapons for potential use with a nuclear warhead. As a result, the United States is seeking to develop hypersonic weapons that can attack targets with greater accuracy, which could be more technically challenging to develop than nuclear-armed—and less accurate—Russian and Chinese systems	China is testing a [nuclear-armed] intercontinental-range hypersonic glide vehicle … which is designed to fly at high speeds and low altitudes, complicating our ability to provide precise warning. China has tested the DF-ZF hypersonic glide vehicle at least nine times since 2014. In 2018, China successfully tested Starry Sky-2, a nuclear-capable hypersonic vehicle prototype.	Russia is pursuing two nuclear-capable hypersonic weapons: the Avangard and the 3M22 Tsirkon (or Zircon). Avangard is a hypersonic glide vehicle launched from an ICBM, giving it "effectively 'unlimited' range." 74 Russian news sources claim that Avangard entered into service in December 2019.75 Tsirkon, a ship-launched hypersonic cruise missile, may become operational as early as 2023

4.	DEW		Directed-energy weapons programs continue, however, to face questions about their technological maturity, including questions about the ability to improve beam quality and control to militarily useful levels and the ability to meet power, cooling, and size requirements for integration into current platforms. These programs are intended to scale up power levels from around 150 kW, as is currently feasible, to around 300 kW, a level at which cruise missiles could potentially be intercepted, by FY2022 and to around 500 kW by FY2024.	China has reportedly developed a 30-kilowatt road-mobile DE system, LW-30, designed to engage unmanned aerial vehicles and precision-guided weapons. China likely will field a ground-based laser weapon that can counter low-orbit space-based sensors by 2020, and by the mid-to-late 2020s, it may field higher power systems that extend the threat to the structures of non-optical satellites.	Russia claims to have fielded the Peresvet ground-based DE weapon system in December 2018 to disrupt Global Positioning System (GPS) and communications signals and may be able to perform C-UAS and antisatellite missions.

5.	Biotechnology	biological weapons, genome editing, or more invasive forms of human performance modification.	DARPA, for example, has a number of biotechnology programs devoted to battlefield medicine, diagnostics, and prognostics. It is also exploring options for mitigating the effects of traumatic brain injury, treating neuropsychiatric illnesses such as depression and post-traumatic stress, and protecting against infectious diseases and bio-engineered threats to the U.S. food supply. United States is researching or has previously researched biotechnology and neuroscience applications to increase soldier lethality, including applications to make soldiers "stronger, smarter, [and] more capable, and … give them more endurance than other humans."	. In 2016, Chinese scientists became the first to use the CRISPR gene-editing tool on humans, and in 2018, a Chinese scientist produced the first "gene-edited babies." China's Central Military Commission "has funded projects on military brain science, advanced biomimetic systems, biological and biomimetic materials, human performance enhancement, and 'new concept' biotechnology," while the Chinese military's medical institutions have conducted extensive research on CRISPR gene editing.1	, the Soviet Union is known to have maintained an extensive, long-standing biological weapons program, Biopreparat, in violation of the 1972 Biological Weapons Convention. BIO2020 identifies Russia's priority areas for biotechnology research as biopharmaceutics and biomedicine, industrial biotechnology and bioenergetics, agricultural and food biotechnology, forest biotechnology, environmental protection biotechnology, and marine biotechnology.

6.	Quantum technology	Quantum technology translates the principles of quantum physics into technological applications.	"quantum sensing applications are currently poised for mission use whereas quantum computing and communications are in earlier stages of development…	President Xi has cited quantum communications and quantum computing as key research initiatives "prioritized for major breakthroughs by 2030,"	Russian development of quantum technology, as with artificial intelligence, lags significantly behind that of the United States and China, with some analysts noting that Russia is likely "5 to 10 years behind" in quantum computing.

Jaron Lanier's experience in this field is interesting. He says "I have been around military technology people a lot because of my role in virtual reality. I have seen weapons from conception to implementation. And there is an extra ordinary gadget lust that drives military technology. So, it is possible that war is just the ultimate expression of creativity." Similarly Don De Lillo has expressed similar feeling by saying, "War is the ultimate realisation of modern technology." So where does it lead to? Technologies are bound to explode, disrupt and radicalise way of governance and world politics. Each technology whether dual use or otherwise brings out with it, its own sets of challenges and ethical issues for the human race. Creativity and use of technologies for betterment of human beings will remain the philosophical goal of all the countries racing in the technologies domains to become dominant.

Timothy Garton Ash is optimistic when he says, "Developments in Information technology and globalised media mean that the most

powerful military in the history of the world can lose a war, not on the battlefield of dust and blood, but on the battlefield of world opinion." With the present modernisation programmes of ambitious China to be No. 1 Super power, notwithstanding the inherent contradictions she is grappled with, we can only hope that his optimism will stand the test of time. I sign off with the following statement.

"Technology is a useful servant but a dangerous monster." – Christian Louis Lange.

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TECHNOLOGY DEVELOPMENT ROADMAP FOR DEFENCE FORCES - HIGHER STRUCTURES AND LINKAGES

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"Artificial intelligence, machine learning, internet of things, blockchain and big data hold the potential to take India to new heights"

- Prime Minister Shri Narendra Modi

Abstract

The Indian Military is in the process of major reforms, the need is to 'Transform from a Military Force to a Military Power' in concert with a risen, resurgent India, a global leader. For the transformation to be optimal and effective it is imperative that the armed forces absorb and exploit new age technologies, to enhance our combat and cost-effectiveness. The author attempts to define a 15-year vision, a seven-year strategy and an action plan for technology development, induction, absorption and exploitation in the Indian context.

Indian Armed forces are by far the most battle hardened and combat rich military force in the world. Despite being committed, disciplined, secular, apolitical and effective, Indian armed forces continue to be a 'MILITARY FORCE'. In concert with a new India, a risen, responsible, resurgent India, a global leader in the emerging Post COVID-19 World order, Indian Armed Forces need to transform from a 'MILITARY FORCE to a

MILITARY POWER'. At long last, a number of transformational changes and Defence reforms have been initiated like the integration of the military in the national decision-making apparatus by the appointment of CDS, a push to self-reliance, Atmanirbhar in defence manufacturing, integration and jointness. However, for the transformation to be optimal and effective it is imperative that we absorb and exploit new age technologies, to enhance our combat and cost-effectiveness. The old world order was driven by Geopolitics, Geostrategy and Geoeconomy, however, the emerging world order will be dictated by another additional factor GEOTECHNOLOGIES. The nations with Geotechnology leverages will be the lead players in the new world order. National security is all about protecting and projecting our national interests and assets. To ensure National security and contribute to our National Aim of 'Transforming India to a Modern, Prosperous and Secure Nation' it is imperative that the military contribute its might to comprehensive national power to ensure long term peace stability and development, as also the well being of the 137 Cr people. India faces security challenges across the full conflict spectrum from low-intensity conflict to nuclear. New age warfare will be multi-domain, multi-dimensional waged in many battle spaces simultaneously. Linear wars as we have known and fought in the past though will continue to be a subset of MDW. Therefore technology will be the new battle winning factor. Indian Armed forces need to identify and systematically induct and absorb technologies to be future-ready.

China and COVID-19 have been the biggest disruptors of the century, impacting the behaviour of individuals, society, people, nations, regions and the world. China's aggressiveness along the LAC has changed India's threat perception and security challenges, with a high probability of a two-front collaborative threat from China and Pakistan manifesting in the near to mid-term. The Armed forces will be tasked and asked to do 'More and More in Less and Less' on account of the China threat and the economic challenges posed by the Pandemic. The only option for the nation and the armed forces is to identify, induct, absorb and exploit technologies both as a force multiplier and a force substitutor.

The Armed forces need to define a 15-year vision, a seven-year strategy and a three-year action plan to chart out a pragmatic, implementable cost-effective technology development plan.

Vision

Indian Armed Forces to exploit technologies to dominate Time, Space and Complexities in all domains to protect and project National Interests

Mission

Enable and empower services and soldiers to integrate New age technologies to deter war and defeat present and future security challenges ensuring Combat and Cost-Effectiveness.

Technology Development Objectives

- Develop and Deliver Transformational Technologies to enhance the effectiveness of Strategic Capabilities as deterrence.

- Reform the Way Science and Technology are Led and Managed especially in the Armed Forces.

- Synergise Scientific and Technological developments as a national initiative.

Each of these objectives is an integral element necessary to make the vision a reality. These will also directly contribute to a more combat and cost-effective military capable of achieving military objectives by building a more lethal force.

Strategy

A suggested strategy to support reforms that will help drive the vision could be:-

- Develop and Deliver Transformational Strategic and Operational Capabilities in 2025.

- Reform the way Science and Technology Is led and managed to incentivise and encourage induction of New age Technologies in the armed forces - a dedicated organisation with adequate funding is a must.

- Deepen and Expand the Scientific and Technical Enterprise by competing R&D, Integrating academia, scientific community, industry and Users.

- Reform the MoD for better performance and optimal resource utilisation, need to align authority and accountability.

- Ensure convergence and congruence between military and civil by encouraging the development of Dual-use technologies.

A Suggested Roadmap

The aim should be to identify and develop the roadmap for new-age niche technologies at the national level to be future-ready. The way forward is to have a responsive and streamlined system in keeping with the vision and mission with a policy framework backed by robust processes institutionalised by the government. The Department of Science and Technology (DST) should be the nodal ministry. It should, along with the office of NSA, be responsible for inter-ministerial coordination. All ministries should have a department of technology and innovation and carry out a detailed study to identify futuristic technologies and their

development agencies and targets. DST with NSA office or NSCS should prioritise the needs and ensure that technologies are fully exploited with a military - civil fusion.

Interaction with institutes, academia and other stakeholders as also friendly foreign countries be carried out and a detailed paper on the technologies which are required in the short, medium and long term along with their use and impact be listed. The requirement of funds, the nodal agency for each identified and the timelines worked out. Apart from this, a number of other issues pertaining to multiple use technologies, reverse engineering procurements and intergovernmental agreements will be required to boost indigenous efforts. Cutting edge technologies like AI, Big Data, Quantum Computing, Hypersonic, Blockchain, ML, Augmented Reality, 5G, IOT, robotics, advanced metallurgy, space technologies, biotechnology, genetic mutation and nuclear arena are some which require to be inducted and exploited earliest. Their applicability could be in multiple domains but one ministry should be the nodal point with the representation of other stakeholders. In critical and urgent areas, mission mode models would be instituted. The mission mode projects could be monitored by the PMO.

Indian Armed Forces will have to evolve new structures to fight the new generation wars. Creation of Theatre Commands and joint structures for operation, logistics and training is the way ahead. A leaner, agile and technological adaptable organisation would be required to fight the high-tech war. Doctrine and strategies will have to be reviewed and defined accordingly. The same will also entail having a relook at our training methodology, leadership and manning policies. The technology-enabled military will be the key battle-winning factor.

India needs to chart out a technology roadmap for the defence forces including pragmatic, implementable structures and linkages with existing and envisaged technology capabilities and capacities at the national level. The road map should aim to IDENTIFY - DEVELOP-

INDUCT- ABSORB - INTEGRATE - EXPLOIT the technologies. The initial focus should be on exploiting available technologies, at the same time develop and import niche technologies to exploit a late mover advantage. Essentials of the Road Map are:-

- Needs to be derived from and be in consonance with the latest National Technology Development Vision of India

- At the national level Department of Science and Technology (DST) is responsible for the overall technological development of India

- Technology Information, Forecasting and Assessment Council (TIFAC), an autonomous organization under the Department of Science and Technology (DST) a think tank within government has come up with a “Technology Vision 2035” for India with a Foreword from the PM; military use technologies should be an integral part of the National Technology Vision 2035, at present this is not so. However, talking about the technology and comprehensive national power, the document states that “Technology is a fundamental element in comprehensive national power; accessing, producing and leveraging technology will remain a core national interest with strong external linkages”.

- Only revolutionary changes in our country’s education system will make our country technologically competitive and NEP seeks to bring about these changes.

- MoD, DRDO and Defence Forces need to link and synchronise their vision and roadmap to the national technology vision 2035 for meaningful indigenous development and harnessing of the technologies for enhancement of comprehensive national power of India.

- Technology Perspective and Capability Roadmap – 2018 (TPCR- 2018) provides to the industry an overview of the equipment that is envisaged to be inducted into the Indian Armed Forces up to the late 2020s, this needs to be reviewed in consultation with DRDO, academia and industry.

- This roadmap may guide the industry in planning or initiating technology development, partnerships and production arrangements.

- A dedicated roll on budget is an imperative.

Successful Models - US and China

A brief look at some of the prevalent models and structures is a must before evolving our own which are best in the Indian context.

DARPA - US model states “Our goal is nothing less than to create fundamentally new concepts, technologies, and capabilities for warfare in the ground, maritime, air, space, cyber, and human domains.” DARPA comprises approximately 220 government employees in six technical offices, including nearly 100 program managers, who together oversee about 250 research and development programs. A lean and agile organisation, it is an ideal model to replicate. Briefly, DARPA is a projects agency that thrives on risk and rewards and aims at:-

- To make pivotal investments in breakthrough technologies for national security.

- Explicitly reaches for transformational change instead of incremental advances.

- Identify, recruit and support excellent program managers—

extraordinary individuals who are at the top of their fields and are hungry for the opportunity to push the limits of their disciplines.

CHINA 2025 The ten-year plan calls for promoting breakthroughs in 10 key sectors. The key sectors have a direct correlation contributing to their broader strategic goals.

- New generation of information technology and biotechnology standard system.

- There is a focus on developing standards for the so-called Internet of Things, cloud computing, big data, 5G and Artificial Intelligence (AI). These are all seen as crucial future technologies that could underpin critical infrastructure in the world.

However, given our procedures and processes, this is unlikely to be accepted.

Higher Defence Structures for Technology Development in the Armed Forces

At present several verticals in the Ministry of Defence (MoD) are engaged in technological developments in different fields and at different levels. DRDO, the R&D wing of MoD, with 51 laboratories is doing its bit to achieve self-reliance in critical defence technologies. Various DPSUs' design and development wings undertake technology development in their respective fields. OFB and its Factories undertake technology development in various fields, Dhanush gun being a rare success story. DRDO's pursuit of self-reliance and successful indigenous development and production of strategic systems and platforms such as Agni and Prithvi series of missiles; light combat aircraft, Tejas; multi-barrel rocket launcher, Pinaka; air defence system, Akash; a wide range of radars

and electronic warfare systems; etc., have given quantum jump to India's military might, generating effective deterrence and providing crucial leverage. However, the focus has been on high visibility military hardware and not really on technology development. Various public and private organisations funded by the MoD undertake technology development in various fields. In addition, Defence Forces are involved in the technology development in a big way, Army; a late starter has set up Army Design Bureau (ADB) with very broad-based technology development goals with Directorate General Perspective Plans (DGPP) responsible for harnessing technologies for the future requirements of the Army.

Department/Service specific structures and linkages seem to have resulted in a compartmental and sub-optimal technology development so far. Several research and development activities are underway through DPSUs and OFB Factories under the MoD itself, DRDO, DPSUs and OFB Factories do not always work in unison with a long term vision and a focussed approach. Despite these multiple capabilities, there is little or no synergy among various stakeholders, often competing with each other for the limited financial resource and limelight. Thus there is a need for formal structures with requisite budget and targets to ensure a technology-enabled and empowered military.

- A Defence AI Council like institution at the Apex level functioning directly under the RM free from bureaucratic control and fuelled with a national zeal of making India not only self-sufficient but meeting the defence items export goal of the nation within a stipulated time frame is needed to be created.

- The DAIC like apex organisation should be constituted with the following members to provide necessary guidance to enable and effect development or tailoring of operating framework, policy-level

changes and structural support.

- Raksha Mantri - Chairman
- Chief of Defence Staff - Vice Chairman
- Chiefs of three Services - Members
- Defence Secretary - Member
- Secretary (DP) - Member Secretary
- Secretary DRDO - Member
- FA(DS) - Member
- National Cyber Security Coordinator - Member
- CISC - Member
- Eminent representatives from industries and academia as members

The recent Azerbaijani- Armenian conflict is an indicator of the course of future warfare. The advent and exploitation of new age technologies especially drone warfare as demonstrated, will now force militaries to invest in and acquire high technology weaponry and tools. This is actually the first war in the history of modern warfare that has been won almost entirely on the strength of drone warfare and new technologies. There is a technology wave which will now dictate to militaries to reorganise and re-structure to be prepared to prevent and wage future wars. USA, China, Russia, France, Japan, Germany, and other nations are all investing mainly in niche technologies as they prepare for multi-domain warfare of tomorrow. India too must exploit this opportunity and ensure a technology ready military.

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QUANTUM COMPUTING APPLICATIONS FOR THE DEFENCE FORCES[1]

Air Cmde T Chand (Retd)*

Abstract

Quantum Physics is more than a century old science and had contributed to the design of transistors which form building blocks of even the most advanced microprocessors of today. Notably, two of its characteristics, namely superposition and entanglement have begun to figure prominently in the design of the quantum computers and quantum communication devices. Several countries have earmarked huge budgets for employment of these technologies as they offer promising results in ultra high speed computing, hack proof communication, simulations, software validation and aviation. All these areas are of significant interest to the Defence and Security organisations and they have started using them in a limited way. Indian Government has earmarked sizeable budget for further research in this field. Defence and Security Organisations will do well in ensuring that their long term interests are looked after by the Department of Science and Technology entrusted with the task of the research in this promising field.

Quantum Theory

"Quantum theory is the unique approach of modern physics for explaining the nature and behavior of matter and energy on the atomic and subatomic level and is known as quantum physics and also quantum

1 An earlier version of this paper was published by the CENJOWS, as a Synodos Paper

mechanics. Quantum mechanics (QM) is the body of scientific laws that describes the unusual behavior of photons, electrons and other particles that make up the universe. QM is defined as a theory of matter that is based on the concept of the possession of wave properties by elementary particles, that enables a mathematical interpretation of the structure and interactions of matter on the basis of these properties, and also incorporates within it quantum theory and the uncertainty principle, called wave mechanics".[2]

Quantum mechanics is very important for understanding how individual atoms combine covalently to form molecules. QM also explains the working of the electromagnetic waves and is also called quantum physics or quantum theory. Max Planck, in 1901, described the electromagnetic radiation accurately by assuming that radiation was emitted in discrete packets or quanta. Planck's quantum hypothesis is a pioneering work, of quantum theory. In the words of Scott Aaronson[3], "Quantum mechanics is a generalisation of the laws of probability based on the two-norms, and on complex numbers rather than nonnegative real numbers. It can be studied completely independently from its applications to conventional physics. This generalised probability theory leads to a new model of computation – the quantum computing model – that challenges ideas about computation once considered a priori. While quantum mechanics was invented a century ago to solve technical problems in physics, it can now be explained from an extremely different perspective: as part of the collection of ideas, in computation, and philosophy, about the limits of the knowable."

The world is currently witnessing a second quantum revolution. In the first quantum revolution, the fundamental laws of the microscopic realm were discovered and quantum science was formulated. In the

2 Merriam Webster, "Definition of quantum mechanics". https://www.merriam-webster.com/dictionary/quantum%20mechanics. 25 December 2020.

3. Scott Aaronson, Quantum Computing since Democritus, (Cambridge University Press, ISBN 978-0-521-19956-8).

years that followed, new technologies such as the transistor and the laser were developed. These inventions can best be understood and developed with the help of quantum mechanics. In the second quantum revolution, technologies are being developed which explicitly address individual quantum states and make use of the unusual quantum properties, such as superposition and entanglement, commonly referred to as quantum technologies (QT). A number of start-up companies were founded over the last decades which offer QT to highly selective markets. Quantum cryptography is among the most advanced QT with highly specialised enterprises offering their products to governments, banks and other customers with high security applications. Big global companies such as Google, IBM, Microsoft and Toshiba have already started to invest in QT in a big way. Governments are also starting large funding programmes in the field. Besides quantum computation, quantum communication holds promise for many countries, especially in China, with plans to invest on large scale and have already launched a satellite with quantum communication equipment.

Quantum Computing

"Quantum computing employs theoretical computation systems (quantum computers) for making direct use of quantum technologies, such as superposition and entanglement, to perform operations on data".[4] The development of actual commercial quantum computers is still in early stages, but experiments have been carried out in which quantum computational operations were executed on small number of quantum bits. Ongoing research by many countries is continuing for development of a quantum computer for commercial and military applications and funds in large amount are being earmarked for this purpose. Large-scale quantum computers would theoretically be able to solve problems much more quickly than classical computers using even

4 Gershenfeld, Neil; Chuang, Isaac L. (June 1998). "Quantum Computing with Molecules", Scientific American. 18 December 2020

the best algorithms. A classical computer could in principle simulate a quantum algorithm, as quantum computation does not violate the basic computing principles. Quantum computers may also be able to efficiently solve problems which are difficult to be solved on classical computers.

Digital computers use either a one or a zero to describe discrete states whereas quantum computers use qubits for undertaking operations. Each qubit can represent a one, a zero, or any quantum superposition of those two qubit states. Quantum algorithms are generally probabilistic in design as they provide solution with a certain known probability only. Thus a quantum computer employing qubits is totally different from a classical computer employing the same number of classical bits. Qubits can hold exponentially more information than their classical counterparts, but are only in a probabilistic superposition of all of their states. More details on the sequences of operations used for various quantum algorithms such as study of Shor's algorithm, Grover's algorithm, Deutsch–Jozsa algorithm, amplitude amplification, quantum Fourier transform, quantum gate, and quantum error correction is useful for understanding quantum computing. Quantum simulation is emerging as an important means for deep studies in sciences such as chemistry and technology such as nanotechnology and could be employed for simulation of the behavior of atoms and particles under difficult conditions such as the reactions inside a reactor.

The ideal expected number for a universal quantum computer is 50 qubits. At this level scientists will surpass the functionality of the fastest supercomputers today. New supercomputers are extremely powerful and will continue to be employed for applications requiring very large processing applications such as in life sciences. Beyond the processing power of these computers the quantum computers will find their place without competition. Therefore, International Conference on Quantum Science and Applications (ICQSA-2016 conference) also focused on modern theoretical and experimental developments of quantum science in multi-disciplinary aspects of areas of mathematics, physics, statistics,

chemistry, biology, computer science, electronics, informatics, medicine and education.

Employment of Nuclear Magnetic Resonance (NMR) in Quantum Computing. Nuclear Magnetic Resonance quantum technique has potential for formulation of a qubit using the spin states of nuclei within molecules. After discarding the experimentations with the liquid state NMR, solid state NMR is being tried for quantum computation.

Global Developments

IBM earlier announced that the company is set to build the first universal quantum computer for science and business and a new division has been set up to make such computers and sell them commercially.[5] The IBM Company has prepared an Application Program Interface that enables developers and programmers to build required interfaces between the existing five qubit cloud-based quantum computer and classical computers, without needing a deep background in quantum physics. For the end user, initial quantum computers will be accessed via the cloud. Recently, IBM announced the successful testing of most powerful universal quantum computing processors for future more powerful quantum computers. More countries, including Russia, China, the US, and Europe are striving to develop their own Quantum Computers, with the US and China leading the research in this field.

Russia. Russia's Quantum Center, for creating quantum computers has engaged Russian quantum computing research institutes, the Russian Quantum Center and the MISiS National University of Science & Technology. The Russian state atomic energy corporation and the Foundation for Advanced Studies and the Ministry of Education and

5 Sputnik News, "IBM's Quantum Computers to Open 'New Realm of Computational Power", 08 March 2017. https://sputniknews.com/science/201703071051354761-ibm-quantum-computer/. 10 November 2020

Science have also joined together for development of a quantum computer. Rosatom's nuclear weapons research institute at the All-Russia Research Institutes of Automatics (VNIIA) has been designated to take the lead in organising the project.[6]

USA. Though the technology is still considered to be at a nascent stage, technology services provider IBM, at its 'Think 2019 Summit' held at Taipei, indicated that commercial quantum computers will be available in the next three to five years.[7] It is believed that investments for the development of quantum computers by companies such as Microsoft, Intel, IBM, D-Wave and Google make the US the leader in this field. In December 2015 NASA publicly displayed the world's first fully operational 15-million USD quantum computer made by the Canadian company D-Wave at the Quantum Artificial Intelligence Laboratory at its Ames Research Center in California's Moffett Field. The presence and use of quantum effects in the D-Wave quantum processing unit was more widely accepted. National security issues are at the top of the agenda. For instance, the U.S National Quantum Initiative Act, passed in December 2018, describes itself as "An Act to provide for a coordinated Federal programme to accelerate quantum research and development for the economic and national security of the United States." The Act infused 1.2 billion USD into the U.S. federal government's existing quantum programmes to accelerate research in quantum technology. In October 2019, Google claimed quantum supremacy by unveiling its quantum computer, 'Sycamore', which optimises the processing time of computer programmes.

Google has also partnered with the National Aeronautics and Space Administration (NASA) to create a joint public-private initiative, called 'Quantum AI Lab' (QuAIL), with a focus on machine learning and

6 Sputnik News, "Quantum Computing Arms Race Takes Shape as China, US, Russia Vie for Supremacy". 12 may 2017https://sputniknews.com/military/201705111053523495-quantum-computing-military-applications-analysis/. 17 October 2020.

7 Sagnik Chakraborty, "India's billion-dollar quantum push", Gateway House, 13 February 2020. https://www.gatewayhouse.in/indias-push-quantum/. 25 November 2020.

Artificial Intelligence (AI) for advancing NASA's aeronautics. Microsoft's research station, Q, and Intel Labs, are other major U.S. players.

Europe. Europe is focusing on the creation of its own quantum computer over the next ten years, investing the equivalent of about a billion dollars into its Quantum Technologies Flagship Program. The flagship will be structured along four mission-driven application domains.[8] The first domain will deal with the communication, by using quantum resources for communication protocols. The second domain of computation will use programmable quantum machines to solve problems beyond the reach of classical processors. The third domain will be simulation, for resolving important problems by analyzing them through quantum systems. Quantum systems are planned to be used for resolution in measurement and diagnostics as a fourth domain. European Quantum Communication Research Agenda[9] flagship will centre mainly on quantum cryptography and quantum networking. In flagship terms, this domain is simply called quantum communication. Its main applications are in probably secure communication, long-term secure storage, cloud computing and other cryptography-related tasks, as well as, in the future, secure quantum communication networks.

China. China is already launching unhackable experimental satellites with quantum-based communication systems, building quantum radars, hundreds of kilometers worth of quantum communication lines, and creating the world's fastest supercomputers. China's quantum satellite - Micius was launched in August 2016 and now China has plans to invest in a big way especially to enable the PLA to break cipher codes.[10] China is believed to be working on quantum processors and quantum algorithms,

8 Max F Riede, Daniele Binosi, Rob Thew and Tommaso Calarco, "The European quantum technologies flagship programme", Quantum Science and Technology, Volume 2, Number 3, 23 June 2017.

9. Ibid.

10 Sagnik Chakraborty, "India's billion-dollar quantum push", Gateway House, 13 February 2020. https://www.gatewayhouse.in/indias-push-quantum/. 29 November 2020.

to build a quantum computer. 'Baidu Research', the research arm of Baidu Inc., a search engine company, is also involved in the research work of Quantum computers.

Japan, South Korea, Canada, Netherlands, France, UK and Germany are other countries having major quantum technologies research initiatives.[11]

Developments in India

The Defence Research and Development Organisation (DRDO) of India is deeply involved in the development of quantum technological applications. One focus area, the secure communication system using quantum technologies was recently revealed successfully. Two DRDO laboratories; 'Research and Development Laboratory (DRDL)' and the 'Research Centre Imarat (RCI)' participated in a demonstration of their achievements in use of communication between them, using, Quantum Key Distribution (QKD) technology.[12]

At a national level, the Indian government has taken a lead for nurturing the emerging quantum technologies. It has announced a 'National Mission on Quantum Technologies and Applications' and provided for an amount of Rs 8000 Cr for a period of five years; this mission will be managed by the Department of Science and Technology of India.[13] Focus area of research by the DST under this mission is likely to centre around quantum computing, communications, cryptography,

11 Smriti Srivastava, "Top ten Countries Leading In Quantum Computing Technology", Analytics Insight, 14 December 2019. https://www.analyticsinsight.net/top-10-countries-leading-quantum-computing-technology/. 02 December 2020.

12 The Hindu, 09 December 2020. "DRDO successfully demonstrates quantum communication between two labs". https://www.thehindu.com/sci-tech/technology/drdo-successfully-demonstrates-quantum-communication-between-two-labs/article33292632.ece. 11 December 2020.

13 GOI, DST, "Budget 2020 announces Rs 8000 cr National Mission on Quantum Technologies & Applications". https://dst.gov.in/budget-2020-announces-rs-8000-cr-national-mission-quantum-technologies-applications. 08 December 2020.

encryption, key distribution, sensors and materials etc. Outcomes from these research areas is likely to find applications in aviation and space systems; simulators of various kind, more accurate weather predictions, financial sector security, innovative new ventures leading to technology lead economic growth.[14] Through this approach India would expect to be at the forefront of developments and applications of these critical and hard to develop technologies.

The existing digital infrastructure of India faces many cyber security challenges. Employment of quantum technologies by adversaries is likely to jeopardise India's security because quantum cryptography can break existing encryption algorithms. The RSA encryption, a popular algorithm to convert data into cipher codes, used by modern computers and the internet for secure communications, is considered unbreakable with existing technology. However, quantum technology will be able to crack such encryptions.[15]

Indian Institute of Science was deeply involved in the Quantum Computing research activities. The areas covered by the Institute were: Nuclear Magnetic Resonance quantum algorithms; superconducting qubits; quantum dots and nanostructures; ion trap qubits; Quantum algorithms; Quantum entanglement; computation with integer, polynomial and power series and many other aspects of quantum computation.

The Indian Institute of Science, Bangalore, and the Harish Chandra Research Institute, Allahabad, have interest and involvement in theoretical aspects of quantum computing, Department of Science and Technology of the Indian Government is planning to fund the quantum computing project in a big way.[16]

14 ibid

15 Sagnik Chakraborty, "India's billion-dollar quantum push", Gateway House, 13 February 2020. https://www.gatewayhouse.in/indias-push-quantum/. 30 November 2020.

16 Jacob Koshy, "India joins quantum computing race", The Hindu, 21 September 2017. https://www.thehindu.com/news/national/india-joins-quantum-computing-race/article19723359.ece. 11 November 2020.

Likely Defence Applications

The first applications for a universal quantum computer are likely to be for drug and materials discovery, financial services and supply chain. Purely theoretical computation capabilities aside, the development of Quantum Computers is of great importance for the defence forces as well. Most major countries have already commenced projects for this purpose.

An important military application for a quantum computer would be capability to intrude into encrypted military servers and national infrastructure systems of the probable adversaries.[17] The former NSA contractor Edward Snowden had revealed that the US National Security Agency was running a big research programme for developing a quantum computer capable of overcoming adversary's encryption.

Quantum communication is already used today for niche applications, but as the technology develops, its use will spread and it has the potential to become an integrated, standard component of global communication networks. To reach this goal, a significant amount of software and hardware development would be needed.[18]

Quantum Computing Aerospace Applications.[19] In July 2017, Quantum Computing Center (QCC) of Southern California University researchers upgraded their existing 512-qubit D-Wave, two systems (D-Wave 2X processor) to 1,098 qubits. This new processor is likely to facilitate the study of quantum technologies further and also improve

17 Sputnik News, "Quantum Computing Arms Race Takes Shape as China, US, Russia Vie for Supremacy", 12 May 2017. https://sputniknews.com/military/201705111053523495-quantum-computing-military-applications-analysis/#comments. 17 December 2020.

18 Max F Riede, Daniele Binosi, Rob Thew and Tommaso Calarco, "The European quantum technologies flagship programme", Quantum Science and Technology, Volume 2, Number 3, 23 June 2017

19 Woodrow Bellamy III, "Quantum Computing for Aerospace, What are the Possibilities?"15 August 2016. http://www.aviationtoday.com/2016/08/15/quantum-computing-for-aerospace-what-are-the-possibilities/. 23 December 23020.

computer modeling and simulation which will further facilitate the difficult task of Verification and Validation process of the software written for this purpose. The verification and validation of software is a complex, costly and time consuming process and quantum computing has the potential to expedite this process.

Avionics and other software system of the aircraft is safety critical, requiring strict regulated and certified software eco system. Designers and developers of these machines have to ensure that the written software is absolutely correct. The F-35 combat aircraft employs nearly eighty lakh lines of correctly written code. Quantum-computing technology has the potential to achieve such difficult tasks swiftly and facilitating cost effective measures for optimum route flying.

As a result, alongwith others, Airbus Industries is engaged in development and employment of quantum computing technology in its research work and had established a quantum computing unit at its Newport, UK plant; mainly for exploring the use of quantum computing for is digital modeling and simulation. The facility is also to facilitate the design of new aircraft armaments.

Quantum Computing is likely to usher in a new era of cyber security and ultrafast computations with a number of applications especially for the defence and security agencies. According to market reports, the global Quantum Computing market accounted for 88.1 billion USD in 2019 and is likely to grow at a CAGR of 29.1 percent during the forecast period of 2019 to 2026. India has already earmarked necessary funds for research in this important field. Defence and security organisations will do well to ensure that there long term interests are taken care of by the research work pursued by the Department of Science and Technology.

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UNTAPPED POTENTIAL OF BIOTECHNOLOGY FOR THE DEFENCE OF INDIA

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Abstract

Biotechnology is emerging as a "new domain of warfare" since modern biotechnology development is increasingly being foreseen for both offensive and defensive uses. The advent and advancement of Biotechnology has made Biological Warfare more complex. Biotechnology can enable military goals to be achieved with no need of massive killing, thus avoiding injury to nonmilitary objects (civilians) or destruction of ecological environments and human civilization. The significance of military application of biotechnology lies in promoting a healthy development of modern biotechnology, abide by the Biological and Toxin Weapons Convention more effectively, and thereby avoid use of traditional biological weapons. The various fields, which offer opportunities for application of Biotechnology in the armed forces and where the work is going on, are: Force Protection, Biosensor Technologies, Nanotechnology, Genomics and Proteomics.

Biotechnology falls in an increasingly accessible technological realm and the country investing properly in it will have the 'first mover advantage' in dominating this field. Visualizing the potential of biotechnology in warfare, increasing number of countries are incorporating biotechnology in to their national defense programs. China and the United States both are not

only investing heavily in biotechnology capabilities but have dedicated strategies for harnessing their use in military as well as commercial settings. Thus, there is huge untapped potential in Biotechnology that India needs to exploit with a view to strengthen its armed forces to fight effectively in this new domain of warfare. One can easily consider biotechnology as the most versatile and innovative technologies of the 21st Century, whose exploits for defense are yet to be fully realized.

Introduction

Though the 'discoveries' or 'developments' in Biotechnology date back to 1800s but the path for modern biotechnology was carved out after the end of the second world war when some, very crucial discoveries were reported. However, Karl Erkey, a Hungarian Engineer, used the term biotechnology for the first time in 1919.1 Later on different scientists defined biotechnology. The office of Technology Assessment of the U.S. Congress defines biotechnology as "any technique that uses living organisms or their products to make or modify a product, to improve plants or animals, or to develop microorganisms for specific uses."2Biotechnology is employed not only to improve human health and human environment but its principles have the potential for destruction too.

The term biotechnology was originally framed to explain the commercial use of living organisms. However, with increased availability of information on deoxyribonucleic acid (DNA) and advent of recombinant DNA technology, all activities associated with gene manipulation (genetic engineering) have also been included in the domains of biotechnology. Today, biotechnology is a multidisciplinary science, having vast potential in different walks of life, e.g., agriculture, sericulture, biopolymers, industry, medicine and warfare etc3 visualizing the potential of biotechnology in warfare, increasing number of countries are incorporating biotechnology in to their national defense programs. For example, People's Republic of China (PRC) is not only investing heavily in biotechnology capabilities

but has dedicated strategies for harnessing their use in both military and commercial settings.[4]

China's national strategy of military-civil fusion has highlighted biology as a priority, and the People's Liberation Army could be at the forefront of expanding and exploiting this knowledge. In 2015, Major General He Fuchu, the then president of China's Academy of Military Medical Sciences had opined that biotechnology would become the new "strategic commanding heights" of national defense, from biomaterials to "brain control" weapons.[5] In fact, Biotechnology is emerging as a "new domain of warfare" since modern biotechnology development is increasingly being foreseen for both offensive and defensive uses. Biotechnology falls in an increasingly accessible technological realm and the country investing properly in it will have the 'first mover advantage' in dominating this field.

Thus, there is huge untapped potential in Biotechnology that India needs to exploit with a view to strengthen its armed forces to fight effectively in this new domain of warfare. It is proposed to study and analyze the employment of Biotechnology in the Indian Armed Forces under the following heads:-

- Brief History of Biotechnology.
- Biotechnology and Biological Warfare.
- Applications of Biotechnology for Defense Forces.

Brief History of Biotechnology

Although the term Biotechnology was not used until 1919, ancient civilizations used biological processes to leaven bread, brew beer, and ferment wine. The form in which biotechnology is now being used by scientists and academics became widespread since last 50 years when enzymes were recognized and isolated from naturally occurring bacteria (also referred to as wild-type organisms). Once enzymes were isolated, scientists could begin to direct the recombination of deoxyribonucleic

acid (DNA) and perform genetic engineering, which is the basis of the biotechnology industry.[6]

Typically, only a very small sample of DNA molecules is available naturally. The amplification of DNA in a test tube using DNA derived from wild-type organisms was first performed in 1985 by a method called the polymerase chain reaction (PCR). Kary Mullis invented the PCR technique in 1985 while working as a Chemist at the Cetus Corporation, a Biotechnology firm in Emeryville, California. In 1993, Nobel Prize in chemistry was awarded to Kary Mullis for his invention of the PCR. In PCR technique, a small amount of DNA can be copied or “amplified” to generate over a short period of time a large number of DNA molecules that are exact replicates of the originating material.[7] With large amounts of DNA (measured in milligrams), scientists were able to carry out many studies that would not have been possible otherwise.

The first DNA polymerase isolated and identified was a protein from the thermophilic bacterium Thermus aquaticus (abbreviated Taq). The interval between the discovery of Taq and its use in PCR to identify the Hantavirus in 1993 was less than seven years. PCR, which can now be carried out in almost any laboratory using an instrument about the size of a shoebox, is no longer the exclusive purview of a few large research centers. In fact, these days, experiments with DNA are often projects at high school science fairs. Because PCR has enabled a broad range of investigators to work at the level of DNA, it has democratized accessibility of DNA.[8]

Prior to 1970, gene-directed recombination of DNA was limited to plants and animals and carried out through selective breeding. Today, many plants, animals, and microorganisms have been genetically engineered, and genetic information from one species can even be introduced into a different species. New and beneficial properties can be introduced in a directed and predetermined way, starting with test-tube manipulations of DNA. For example, DNA derived from a human

being has been introduced into E. coli to create a modified bacterium from which human insulin can be derived.[9]

The process has multiple applications in medicine, genetics, and forensic medicine. PCR, because of its ability to extract DNA from fossils, has become the basis of a scientific discipline paleo-biology. Forensic scientists use it to identify crime suspects or victims from traces of blood, and other biological material left at a crime scene via DNA comparison. In Medicine PCR makes it possible to identify the causative agent of a bacterial or viral infection directly from a very small sample of material. PCR is also used to screen for genetic disorders. It is an important tool in gene sequencing.[10]

Many improvements have been made to the basic technique and many adaptations have evolved, such as real-time PCR and reverse transcription PCR (RT-PCR)[11] that is considered as gold standard for detection of Novel Coronavirus (SARS-CoV-2), the cause of COVID-19 pandemic.

Biotechnology and Biological Warfare

Biological warfare is the employment of disease-producing agents to cause death or injury to humans, animals or plants. This includes any living microorganisms (bacteria, viruses) and toxic biological products that can be delivered by conventional warhead or using civilian means. Basically, there are two types of biological weapons: Pathogens, which are disease-causing microorganisms, some of which can reproduce in a host over time and keep spreading long after the attack and taking the form of an epidemic. Examples are bacteria such as Anthrax, Plague, Q fever and so on and virus such as Smallpox; and Toxins that are poisonous substances produced by living things. Many toxins are extremely lethal and small quantities can kill very large numbers of people, such as Ricin, a plant toxin that is 30 times more potent than the nerve agent VX by weight or Botulinum Toxin, occurring naturally in the

soil and is effective in small-scale poisonings.[12] Biological agents and herbicides can be released as part of anti-crop warfare to destroy crops and even the buffer stocks of food, thereby causing famine, malnutrition and food insecurity amongst the targeted population. For example, defoliants were widely used during the Vietnam War to target sweat potatoes, soybeans, sugar beets, cotton, wheat and rice.[13]

The advent and advancement of Biotechnology has made Biological Warfare more complex. Because most of the biotechnology equipment employed by modern pharmaceutical companies or laboratories can be gainfully employed to enhance biological weapons program, identification of offensive Biological Warfare agents becomes extremely difficult. These equipment have legitimate applications, providing potential users the ability to conceal biological weapons development within the framework of legitimate research and development and industrial programs. For example, development of vaccines for human or veterinary use can camouflage the production of large quantities of Biological Warfare agents.[14]

Biological weapon is considered as a 'poor man's atomic bomb' because of its ability to cause mass casualties equivalent to a nuclear weapon but at a much lesser cost. However, like a nuclear weapon traditional biological weapon cannot distinguish between military and civilian targets whereas biotechnology can be used specifically with a singular purpose of attacking military targets or localized targets. Thus biotechnology can enable military goals to be achieved with no need of massive killing, thus avoiding injury to nonmilitary objects (civilians) or destruction of ecological environments and human civilization. The significance of military application of biotechnology lies in promoting a healthy development of modern biotechnology, abide by the Biological and Toxin Weapons Convention more effectively, and thereby avoid use of traditional biological weapons.[15]

Applications of Biotechnology for Defence Forces

The developments in Biotechnology have been taking place at an enormous pace and it is having a profound effect on the progress of science and technology, as also on the global economy. The demand for new drugs and vaccines and genetically engineered products is a major incentive for the exponential growth in the Biotechnology industry. Biotechnology has enormous applications for the betterment of mankind, such as, it will provide: a means of feeding growing populations, especially when the resources are getting limited like the arable land; Therapeutics for treating chronic diseases using biotechnology-derived methods and products; Diagnostics and treatments for cancer, heart disease, and some types of genetic disorders; and Vaccines against most infectious diseases. These civilian applications can equally be used to meet the requirements of defense forces both for protective measures as well as for aggression. The various fields, which offer opportunities for application of Biotechnology and where the work is going on, are: Force Protection, Biosensor Technologies, Nanotechnology, Genomics and Proteomics.

Force Protection

Biotechnologies can be used in providing health protection to the forces in the battlefield and thereby improve the warfighter performance. Some of the examples are discussed as under:

Microbiome Engineering. The human microbiome consists of thousands of different bacterial species that reside in the mouth, gut and on the skin. The specific kinds of microorganisms complement each other and their host, fulfilling functions that are essential to life - some gut bacteria synthesize vitamins and neurochemicals; others aid digestion and strengthen the immune system; some may even guide how the brain develops. Though everyone's microbiome is similar, it varies from one individual to the next.[16] For the soldiers operating in

different types of terrain and climate, digestive distress is a real problem, which can keep them out of the fight. Microbiome engineering holds great promise because of advances in the field of synthetic biology as it will be able to colonize the gut with genetically modified "smart" bacteria that detect and stamp out disease at the earliest possible moment. Work is also going on to design bacteria that secrete anti-inflammatory molecules when inflammation is detected, providing site-specific drug delivery within the intestine that automatically shuts off when the inflammation is eliminated. In addition to recording memories and treating inflammation, these smart bacteria may ultimately help combat invading pathogens, correct diarrhea or constipation, and regulate mood or behavior.[17] Conversely, the human microbiome could be co-opted to harm humans — for instance, through the development of agents that can target the natural microbiome or cancel the effects of therapeutic microbiomes.[18]

Identification of Biological Samples. Unambiguous identification of biological samples is essential to protect the soldiers from pathogens. This is also referred to as "Bio-forensics" because of its use in legal proceedings. An example is the successful identification in 1993 of a mysterious pathogen that destroyed human lung tissues. The lethal pathogen, discovered in New Mexico, was traced to a Hantavirus using PCR technology.[19] Another example is the 2001 anthrax letter attacks in the United States, wherein anthrax contained in letters were sent through the U.S. mail to its various officials. Investigators used techniques similar to PCR along with other biotechnology tools to detect the "biological signature" of anthrax spores.[20]

Biomaterials. Research in biological hybrid materials and biologically inspired materials holds great promise in producing biomaterials which will be of tremendous use in enhancing the fighting capability and endurance of soldiers in the battlefield. Some of the examples are: Biomaterials compatible with human body can stimulate the wound-healing processes on the battlefield and accelerate the repair

of bones through self-replication; Innovative tissue engineering along with the stem cells may be able to repair cartilage and replace dead or damaged tissues.[21] Further, many innovative biological materials can be dual-purposed for civil as well as military use, such as spider silk. Kraig Biocraft Laboratories, a biotech company has delivered to the US Army a prototype fabric that could change tactical garments forever. It has been named “Dragon Silk”, and is made by genetically engineering silkworms to produce spider silk. The fibers used in the material are similar to natural spider silk, which is stronger than steel by weight. Spider silk is the strongest naturally occurring fiber known, which give it serious potential for bulletproof armor. Tactical spider silk garments are both lightweight and incredibly strong. The fibers are biocompatible, which means are less likely to create irritation and could be worn directly against the skin. The garments fashioned from Dragon Silk are believed to be more comfortable than traditional body armor.[22]

Biomimetic. An infantry soldier carries over 40 Kg (or around 90 lbs.) of load in to the combat. World over, the endeavor is to reduce this load and the biotechnologists draw their lessons from nature suggesting that soldier load-carrying capacity and efficiency can be increased. For example, an ant can lift 50 times its weight and pull 30 times its own weight. Perhaps mimicking the ant may lead to solutions that will help soldiers carry even heavier loads. Biological systems may also serve as models for improving materials for uniforms, particularly by reducing their weight and increasing their functionality. For example, an ordinary horse can withstand winter cold and desert heat protected only by hair and its leathery skin. Understanding how horses and other animals overcome drastic changes in their environment would be extremely useful in developing a soldier’s clothing that must provide protection against extremes of weather, chemical and biological agents, heat and humidity, and other factors. Biomimesis is considered as so important that the US Army has declared Biomimetic as one of its Strategic Research Objectives.[23]

Biosensor Technologies

In the modern hi-tech, multi-domain battlefield environment, the space between operational headquarters and personnel on the field having been increased tremendously, commanders are concerned about two critical aspects: one, tracking the health and performance of soldiers in real-time; and two, to detect the hazards or dangers, which the soldiers are likely to encounter and warn them in advance, such as threat from biological or chemical agents or even from food and water contamination. Biosensors have emerged as powerful and innovative analytical devices to achieve these objectives. Biosensors decompress the space between operational headquarters and personnel on the field by providing real-time physiological status monitoring (RT-PSM)[24]. There are wearable and implantable biosensors in which the sensed biological, chemical and physiological process is converted in to electronic data to provide real-time feedback of a soldier's individual health and performance. For example, smart helmets have been developed for measuring electroencephalogram signals - regarded as one of the most important types of physiological signal – in real-time to detect fatigue in soldiers.[25]

There are various types of biosensors - enzyme-based, tissue-based, immunosensors, DNA biosensors, and thermal and piezoelectric biosensors – that are capable of detecting threats in the air and water. Biosensors are also used to sensitively and selectively identify biological warfare agents (BWAs) namely, bacteria (vegetative and spores), toxins and viruses posing threat in virtually real time.[26] This will allow commanders to make necessary tactical adjustments if ground units are confronted by chemical or biological hazards that could impact their physical readiness en masse.[27]

In the United States, San Francisco-based Company Profusa has been developing tissue-integrated biosensors. These biosensors are flexible and are only 2 millimeters to 5 millimeters in length and 200 microns to 500 microns in diameter. The biosensors comprised of

a bioengineered “smart hydrogel” that is similar to the material used for contact lenses and are embedded just under the skin through the use of a special injector. The biosensors connect to optical readers that send real-time information to a smartphone app.[28] Further, there are biochips as small as postage stamps that can now perform sophisticated chemical and biological analyses of food products.[29]

Convergence of Nanotechnology and Biotechnology

Many of the top-down advances in nanotechnology have occurred because of bottom-up revelations in molecular and cellular biology. Thus Nano scale devices and materials make a perfect partner for biology. In fact, there is a ‘natural synergy between nanotechnology and biotechnology because nanomaterials such as dendrimers and quantum dots can be made at the same diameter as proteins and ribosomes. Thus, their small size allows them to pass through cell membranes and interact with biomolecules.’[30] Nano scale structures that mimic biological functions can be used to assess physiological status, such as alertness or responses of soldiers to battlefield contaminants or biological threats.[31] Nano tubes or ceramics produced from bioengineered cells, have the ability to operate in electronics, organic batteries or other instrumentation.[32]

Genomics and Proteomics

Genomics is the analysis of data derived from DNA sequencing. It requires high-quality genomic material from the cell. It involves extracting data from DNA by looking at the up and down-regulation of genes, assessing which steps in the body’s metabolic pathways are affected, and correlating this information with human characteristics. The vast amount of information coded by genes is available for exploitation for the benefit of mankind. In terms of force health protection, genomics can be extremely useful. Genomics research will allow drugs, dosages, and therapies to be “tailored” to individual soldiers and may lead to scientific ways to predict

behavior.[33] Even service members with genetic predispositions can be identified for diseases caused by various environmental exposures. Also, DNA sequence analyses in exposed personnel might identify induced mutations related to mutagenic agent exposures.[34]

Proteomics is the study or knowledge about the proteins in the host and is leading to a multitude of important applications. For example, specific proteins that can enable growth of synthetic materials on biological surfaces may resolve biocompatibility issues and facilitate the implantation of sensors, monitors, and other micro scale devices. Public health and force health protection could potentially use proteomics to identify specific biomarkers associated with specific disease states or health anomalies and to detect metabolic changes associated with those diseases. Full proteomic analysis includes serum as well as cellular proteins from the host.[35] Various benefits to the Army include:-

- Protein-based electronic components, lightweight armor produced from structural protein polymers, and catalytic enzymes for the degradation of toxic materials.

- Protein-based computer memories provide secure and practically limitless data storage in harsh field environments.

- Additionally, there is strong evidence that genetically engineered proteins can be used to make electronics components immune to radiation weapons.

- Biological photovoltaic cells, mimicking natural photosynthetic processes, may provide soldiers with alternatives to batteries for radios, displays, and other field equipment.

- Advances in agricultural biotechnology that are enabling production of multifunctional foods and edible vaccines, can potentially simplify logistics support for small units.[36]

Genome and proteome technologies can accurately modify living tissues according to precise procedures and conditions. Through the interaction of proteins, we can modify cell functions as needed.

Ultramicrodamage. When attacking an enemy with biotechnological military weapons, we can choose targets from a nucleotide sequence or protein structure. We can cause physiological dysfunction by producing an ultramicro damaging effect to a gene's or a protein's structure and functioning. Precision injury and ultramicro damage are two important methods based on genomics and proteomics. Because they target the primary structure of the gene or protein, they are completely different from traditional weapons of war that directly damage tissues and organs.[37]

Toxicogenomics, an area closely related to genomics, involves studying correlations between gene and protein expression (e.g., immune response characteristics) and reactions to toxic agents. Genes often respond to toxic insult weeks or even months before the onset of observable pathology and at exposure levels that do not produce overt symptoms. Toxicogenomics research can provide insight on how to detect and defend against chemical and biological warfare agents as well as toxic industrial chemicals or pathogens.[38]

Conclusion

The history of biological warfare is nearly as old as the history of warfare itself. But the revolution in biotechnology, namely the new tools for analyzing and specifically changing an organism's genetic material, has given a new direction to the employment of biological warfare agents. Today, nearly all countries have the technological potential to produce large amounts of pathogenic microorganisms safely. Classical biological warfare agents can be made much more efficiently than their natural counterparts, with even the simplest genetic techniques. Further, with modern biotechnology it has become possible to create completely new biological weapons. And for technical and/or moral reasons, they

are more likely to be used than classical biological warfare agents. These possibilities have generated new military desires around the world, including within those countries that have publicly renounced biological weapons in the past.

China and the United States both are not only investing heavily in biotechnology capabilities but have dedicated strategies for harnessing their use in military as well as commercial settings. Modern biotechnology offers enormous potential military advantage. Hence, India must give due attention to incorporate biotechnology in its military arsenal, given the expertise its scientists and technologists have in the civil or commercial use of biotechnology. Though, military biotechnology has not yet become an instrument of military power but in the near future, when military biotechnology is highly developed, it will have a revolutionary impact on the soldiers as also on the techniques of war fighting. One can easily consider biotechnology as the most versatile and innovative technologies of the 21st Century, whose exploits for defense have yet to be fully realized.

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DEVELOPMENT OF HYPERSONIC WEAPONS FOR FUTURE INDIAN DEFENCE NEEDS

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Whoever said that pen is mightier than sword obviously never encountered automatic weapons.

- Douglas MacArthur

Abstract

Hypersonic weapon system going to play a huge role in future conflicts, as core pillars of geopolitics such as geography and technological power can be undermined by hypersonic missiles. India has now joined the select club of four countries, which have developed hypersonic missile technology. Defence Research and Development Organisation (DRDO) has successfully test-fired the Hypersonic Technology Demonstrator Vehicle (HSTDV) from the Abdul Kalam Island off the coast of Odisha. Only three other countries — the United States, China and Russia — have mastered this technology.

The successful test will pave the way for missiles that can travel at five times the speed of sound. The successful demonstration, many critical technologies such as aerodynamic configuration for hypersonic manoeuvers, use of scramjet propulsion for ignition and sustained combustion at hypersonic flow, thermo-structural characterisation of high temperature materials and separation mechanism at hypersonic velocities

have been successfully tested. They can deliver conventional or nuclear payloads within minutes. China, Russia and the United States are spending billions to develop hypersonic weapons in a bid to outpace ever-improving missile defences. The US Army has showcased a new video of Hypersonic weapon at the annual Space and Missile Defense (SMD) Symposium, which is being held online in 2020 due to the COVID-19 pandemic.

Introduction

Every country dreams of a weapon in the hands of its soldier which is better than the potential enemy. Military commanders will never contemplate arming their soldier with a weapon inferior to those held by the enemy soldier. Those nations, which have overlooked or relegated such imperatives for fighting a war, have ended up paying a hefty price in the battlefield. The latest talked weapon, which is under production by the most advance countries are Hypersonic Weapons. The name "Hypersonic" implies that weapon's speed is the distinguishing factor and the most important characteristics that provide advantage. Hypersonic weapons are missiles and aircraft capable of reaching speeds of Mach 5 and more i.e. five times faster than the speed of sound (approximately 3836 mph), which is around one mile per second. They are extremely difficult to intercept due to their high speed and maneuvering capabilities. India has joined the club of nations having the power to develop hypersonic weapons, which may travel several times faster than the speed of sound. Presently, only US, Russia and China had this capability.

India is involved in developing hypersonic weapons in cooperation with Russia. This system is known as the BrahMos II, which is based on a supersonic cruise missile. The system already tested which is designed and built indigenously and will serve as the basis for a nuclear-capable cruise missile.[1] This test, which took place in Sep 2020 was a success

1 https://www.armscontrol.org/act/2020-10/news/india-tests-hypersonic-missile

and termed as a "landmark achievement" that contributes to vision of India becoming self-sufficient. With this, India has now joined the elite club of countries having the ability to develop hypersonic missiles. India displayed its first BrahMos missile, developed jointly with Russia, in 2018. Presently, BrahMos is the only supersonic cruise missile with Indian Armed Forces.

Hypersonic Weapons

The name "Hypersonic" means that weapon's speed is the distinguishing factor and the most important characteristics that provide advantage. A hypersonic missile exceeds Mach-5 (3,800 mph). Currently, there's no operational defence system which will deny the utilization of those strategic weapons. Many world powers including the US, Russia, India, and China are working on hypersonic weapons presently. But, there are many technological hurdles to overcome, particularly with regards to sustaining combustion inside the missile system, while sustaining the extreme temperatures of hypersonic speed. Compared with today's cruise missiles, hypersonic vehicles do offer significant speed advantages. While compare with long-range ballistic missile systems, ballistic missiles already travel at hypersonic speeds during a large portion of their flight. As hypersonic systems do not follow ballistic trajectory, their ability to fly at low altitude to avoid detection by earth-based sensors and the ability to manoeuvre during flight providing unpredictability of trajectory to avoid interception are the major military achievements apart from their hypersonic speeds to evade missile-defence systems. If we take an example, the terrestrial-based radar cannot detect hypersonic missile until late in the weapon's flight, leaving no time to activate defences to counter it.

Types of Hypersonic Weapons

Hypersonic weapons systems[2] can be categorised into two types:-

Hypersonic Glide Vehicles (HGV). These are typically boosted to

2 https://www.jstor.org/stable/resrep19984.8?seq=1#metadata_info_tab_contents

hypersonic speed in the upper atmosphere by a missile and then released from the boost vehicle to glide unpowered at high speeds at the edge of the atmosphere before descending through the atmosphere to a target. This type of hypersonic missile utilises re-entry vehicles. The missile is launched into space on an arching trajectory initially, where the warheads are released and fall towards the atmosphere at hypersonic speeds. After that warheads are attached to a glide vehicle which re-enters the atmosphere, and through its aerodynamic shape it can ride the shockwaves generated by its own lift as it breaches the speed of sound. The glide vehicle surfs on the atmosphere between 40-100km in altitude and reaches its final destination by leveraging aerodynamic forces.

Hypersonic Cruise Missiles (HCM). Hypersonic Cruise Missiles are the weapons that would use high speed, air-breathing engines known as scramjets and travel to hypersonic speeds. This type of cruise missile reaches its target with in a high-speed jet engine that allows it to travel at extreme speeds, in excess of Mach-5. It is non-ballistic and it is opposite of traditional Intercontinental Ballistic Missiles (ICBM), which utilises gravitational forces to reach its target.

Hypersonic Glide Vehicles (HGVs)[3], like all weapons payload of medium- and longer-range ballistic missiles, can travel at the speeds greater than Mach 5. The key difference between missiles armed with HGVs and missiles armed with ballistic re-entry vehicles is not their speed, but their ability to manoeuvre and change course after they are released from their rocket boosters. Their shape determines most of the performance characteristics such as glide distance, speed, and manoeuvrability.

Overview of Hypersonic Weapons

After a long interval, hypersonic missile research and development[4] is back in full swing. Countries, like Russia, China and the US have been racing

3 https://www.claws.in/static/IB136_Hypersonic-Weapons-and-Strategic-Stability.pdf

to develop hypersonic weapon so fast that it cannot be intercepted by any current missile defence system. Hypersonic weapons will play a huge role in foreign policy in the years to come. It will be a core pillar of geopolitics such as geography and technological power which can be undermined by hypersonic missiles. In a recent uptick in "successful" tests from the likes of China and Russia, hypersonic missiles are much closer than we think, forcing a global re-assessment of traditional notions of deterrence.

Present Position of Hypersonic Weapons

Few countries already have the Hypersonic Weapons Capabilities like Russia's upcoming Kh-47M2 Kinzhal air-launched ballistic missile. It is capable of reaching Mach 10 speeds (7672 mph) and distances up to 1200 miles. When we compare the US Tomahawk missile – the United States Navy and Royal Navy's go-to long range missile-system, which is subsonic, travelling around 550 mph and travelling a maximum distance around 1500 miles. When hypersonic weapons become operational, the gap between missile defence systems and missile offence are going to be huge. Presently, there is no operational missile defence system that is capable of intercepting a hypersonic missile, which is why the race to develop hypersonic weapons is such an crucial one. Hypersonic weapons remain a top guarded secret, but in recent months, many governments have announced successful tests and future projects.

Hypersonic Weapons and Strategic Stability

Hypersonic weapons, which combine the speed of the fastest ballistic missiles with the maneuverability of cruise missiles, will enter the arsenals of China, Russia and the US over the next five years.[5] Arrival of these weapons starts an action–reaction cycle in military spending or further weakens crisis stability. As per Russia's defence ministry announcement,

4 https://partyardmilitary.com/hypersonic-missiles-what-are-they-and-can-they-be-stopped/
5 https://www.iiss.org/publications/strategic-comments/2020/hypersonic-weapons-and-strategic-stability

they had deployed a missile regiment armed for the first time with a hypersonic glide vehicle (HGV). Many countries including Australia, China, France, Germany, India and the United States are also developing hypersonic weapons. They want their potential to penetrate advanced missile-defence systems and threaten mobile missile launchers.

Russia and the US are the oldest research programmes focused on hypersonic technology. Currently, China appears to possess the largest and best funded research programme. China spends phenomenal every year on research and development and which has not been publicly disclosed. Their first HGV, the DF-17, is likely to become operational soon and has the potential to function as a highly effective anti-access/ area-denial weapon in entire region. Russia's new weapon – Avangard replaces the typical ballistic re-entry vehicle at the tip of an SS-19 intercontinental ballistic missile (ICBM) with a glide vehicle carrying either a conventional or nuclear warhead. The term 'hypersonic weapon' is also used as a shorthand to refer to both HGVs and hypersonic cruise missiles, which are under development.

Impact of Hypersonic Weapons in World

There are a number of advantages of hypersonic weapons over the subsonic and supersonic weapons, particularly with regard to the prosecution of time-critical targets, where the additional speed of a hypersonic weapon is very valuable. It can overcome the defences of heavily-defended targets like an aircraft carrier. The deployment of hypersonic weapon systems will significantly enhance the strike capabilities. But these weapons system may be problematic in terms of escalation control in the context of a US-China and NATO-Russia confrontation.

Development of Hypersonic Weapons by India

India has developed a hypersonic cruise missile in cooperation with Russia. This is based on a supersonic cruise missile and this system is

known as the BrahMos II. The system is designed and built indigenously and tested in September 2020. India with this test has joined the elite club of countries having the ability to develop hypersonic missiles, which can travel several times faster than the speed of sound. So far, only US, Russia and China had this ability so far. BrahMos is also moving ahead with its hypersonic version BRAHMOS-II, which will have a scramjet engine in place of ramjet.

The Hypersonic Technology Demonstrator Vehicle (HSTDV), which was test fired by the DRDO on 07 September 2020 flies at a lower altitude. There are going to be varieties called subsonic cruise missile, Supersonic cruise missile and then hypersonic cruise missiles in that cruise missile. The scramjet engine, which is developed by Indian scientists, helped the flight achieve a speed six times the speed of sound! Very few countries have such capability today.[6] Also, Cabinet Committee on Security (CCS) approved the request of raising a new regiment of an advanced version of BrahMos missiles to be deployed in Arunachal Pradesh. The regiment would include 100 BrahMos missiles and will be equipped with five autonomous missile launchers with command post.

The DRDO tested Hypersonic Missile equipped with scramjet engine, which works at the hypersonic speed breathing the air in the atmosphere, taking the oxygen from the atmosphere and then burns it, this all happens at hypersonic speed. The scramjet engine developed by the DRDO has been tested for a specific time to ensure its working. This missile will have scramjet vehicle, which has the hypersonic cruise speed. India and Russia is testing the scramjet air breathing engine on its new BrahMos-II hypersonic cruise missile as a prelude to this weapon's first test flight. Recently, Russia successfully carried out the first test firing of a hypersonic version of BrahMos missile in Russia and their sources already indicated that the test was successful and the missile flew at the speed of more than Mach 5 up to Mach 6. The test carried out from a

6 https://www.sundayguardianlive.com/news/india-among-nations-hypersonic- missile-tech

land-based testing range, which could be followed by multiple launches in coming days. When in comparison, this speed is double that of the current operational version of BrahMos. Presently, the BrahMos-I is already in service with the Indians armed forces and this missile is considered to be the world's fastest cruise missile at the moment with speeds of around 2.8 Machs. The range of extended version of the BrahMos Missile can be launched at targets beyond 400 kms. This missile can strike its targets at longer ranges than before. Earlier it was used for striking targets slightly less than 300 kms. In October 2020, China paraded launchers for land-attack DF-17 and anti-ship DF-100 hypersonic missiles. However, the BrahMos-II deployment has caused a lot of anxiety and nervousness in our northern neighboring countries. After few days of the news of BrahMos deployment in Arunachal Pradesh came out, PLA China declared it as a threat to China and to ongoing boundary dispute.

China is making hue and cry over this small step of India going for hypersonic system. After all, the range of the BrahMos missile is just 290 KM and it can carry a warhead of just 200/300 KG. This supersonic cruise missile of short range ramjet was developed under a joint project of Russia and India that started in the late 1990s. The main purpose of the BrahMos project was to develop an Indian version of P-800 Oniks anti-ship missile. In comparison with other cruise missiles like Tomahawk (of the USA) and Babar (of Pakistan) that fly at a sub-sonic speed of 500-600 KMPH, BrahMos can touch an astonishing maximum speed of Mach 2.8 (roughly 3400 KMPH). The range of this missile is limited i.e. just 290 KM and it can carry a light warhead of just 200-300KG, however. Its ability to maintain supersonic speeds while skimming at low altitude makes it very difficult to detect and intercept.

India is always ensuring that its armed forces have the necessary equipment and infrastructure available to thwart any Chinese aggression. During short and swift war, such deadly, accurate and stealth weapons will be of immense value to destroy Chinese command and control centers, firepower centres, Radar and Air Defence sites etc. This would change

the course of the conflict. This missile will be 500KG lighter than its Army and Naval versions. It weighs 2.5 ton and will carry a warhead of 300 KG. After a structural modification and strengthening SU 30MKI, the first demonstration flight carrying BrahMos-A was conducted. Indian Air Force will be acquiring 40 Su-30MKIs with BrahMos and has already deployed Su-30 MKI Squadrons near China border in north-eastern part of India.

Indian Navy has already equipped with one or two 8-cell UVLM for BrahMos block I and II missiles. Navy has already been doing long patrols and with the signing of Logistics Exchange Memorandum of Agreement (LEOMA) with the USA, which is going to give both Indian Air Force and Navy to US overseas naval bases. Though the LEOMA is for few specific reasons like joint military exercises, training, port calls, humanitarian missions and other military activities that both sides mutually agree to undertake. China will not rule out the possibility where these bases could give necessary logistic support to Indian vessels or fighters to carry out an operation against Chinese mainland as desperate times call for desperate measures. Indian government has demonstrated its clear objectives in every field. To counter the Chinese threat, the processes of the development of missiles are on the fast track. Now India is turning the table on Chinese, whereas earlier India just looking at the Chinese `String of Pearls` encircling.. China has been supporting and equipping Pakistani armed forces with various weapon platforms in last 50 years. It helped Pakistan with Strategic weapons, missile development and facilitated missile designs from North Korea. Therefore, it helped Pakistan get both the weapon and the delivery system. China has been closely associated and working with other countries like Sri Lanka, Myanmar, Maldives etc. to gain port access there and that is how the term `String of Pearls` came into existence.

Presently, the string is getting reversed with India ready to sell BrahMos missile to Vietnam and Philippines, with whom China has a long dispute over the South China Sea. The likely sale of BrahMos to these countries has already created ripples in China. The People’s Liberation

Army Navy (PLAN) has no defense against BrahMos supersonic cruise missile -- the fastest anti-ship missile in the world -- and India is intent on selling these world-beating best missiles to both Vietnam and the Philippines. The new missiles PLAN ship-borne SAMs can only effectively engage anti-ship missiles travelling at half the speed of BrahMos.

Taiwan and Japan are future customer of both Naval and Air Force version of the missile. This hypersonic version of BrahMos (flying at 6000KMPH) is already being developed and should be ready in coming 5-7 years and this deadline is on realistic basis. China has reasons to worry about[7] as BrahMos-II is going to provide India a major strategic advantage in mountain warfare. Also, it is designed to select targets hidden behind a mountain range. This hypersonic weapon's immense destructive power will result from kinetic energy. Object striking a target at 6 Mach will generate 36 times the force of an object of the same mass striking the target at 1 Mach speed. This has made hypersonic weapons well suited to attacking hardened or deeply buried targets like bunkers or nuclear and biological-weapon storage facilities.

India with collaboration of Russia has taken the lead in developing a hypersonic missile. It is developing a second generation BrahMos-II missile. This missile is going to use the same scramjet technology that Zircon has been using. The BrahMos-II is expected to have a range of 600 km. The missile has successfully tested in Sep 2020.

Brahmos II Characteristics

Speed	:	Mach 7
Range	:	290 kilometer
Warhead	:	300 kg, conventional, shrapnel, or armor piercing
Launch platform	:	Ship, as the first phase[8]

7 https://www.sify.com/news/brahmos-missile-why-china-is-nervous-news-columns-qjxi93bbajhbj.html

8 https://defenceupdate.in/brahmos-ii-indias-future-hypersonic-cruise-missile/

DRDO have successfully proven the hypersonic air-breathing scramjet technology with the flight test of Hypersonic Technology Demonstration Vehicle (HSTDV) from the Dr APJ Abdul Kalam Launch Complex at Wheeler Island, off the coast of Odisha. With this, the country has entered into the hypersonic regime paving way for advanced hypersonic vehicles like US, Russia and China.

Conclusion

Hypersonic weapons are definitely the cutting edge of the generation next weapon system and going to boost Indian Defence potential. The potency and accuracy of this weapon system have determined that there is currently no operational or reliable method of intercepting them. However, as defence technology advances in future, the countermeasures may emerge. New technologies such as directed energy weapons, particle beams and other non-kinetic weapons may be an effective defence against hypersonic missiles. These weapons would greatly reduce the time required to demolish a target. The warning time available to an adversary, and the time available for defensive systems to engage the incoming threat will be short. Hypersonic weapons threat would pose a significant challenge in current surface-to-air and air-to-air missile systems and such systems would, particularly in the conventional precision strike role. It will also require a robust intelligence, surveillance, target acquisition and reconnaissance (ISTAR) network. Indian Defence forces have to ensure all these capabilities.

Hypersonic weapon systems are all set to play a significant role in foreign policy of India in the years to come. As we enter new era, China, Russia and the United States are spending billions to develop hypersonic weapons in a bid to outpace ever-improving missile defenses. As strategic-range cruise or ballistic missile strikes may be detected between 15 minutes to an hour before impact, hypersonic missiles are capable of exceeding five times the speed of sound threaten to decrease that margin to just a few minutes. The quick response missile

is going to be a fast tempo of destruction which would destabilize the current balance of power by making first strikes more effective and unpredictable. The second generation hypersonic BrahMos-II missile of India would be game changer in entire region.

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UNMANNED SYSTEMS AND MANNED-UNMANNED TEAMING: CAPABILITY DEVELOPMENT IMPERATIVES FOR INDIA

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Abstract

Use of unmanned systems has seen accelerated expansion in recent times. Their innovative use in hostile environment – including manned-unmanned teaming (MUM-T) – can enhance operational effectiveness of such platforms manifold. Sheer range and variety of Chinese unmanned systems, enables its military to innovate upon their mission profiles, as also provides great employment flexibility. When the PLA Navy starts getting deployed in the Indian Ocean Region on near permanent basis, synergistic use of manned and unmanned systems would tend to give it asymmetric operational advantage in India's primary areas of maritime interest. It is thus, imperative that the Indian techno-scientific establishment indigenously produce sufficient quantities of multi-domain unmanned systems, to enable the Indian maritime security forces to exploit them in innovative ways, both, in standalone as well as MUM-T modes.

Introduction

Unmanned systems – aerial, underwater, surface, or ground vehicles – by definition operate without an integral pilot/crew. They can be categorised as follows on the basis of their modes of operation:-

- Automated or remotely piloted vehicles, which refer to systems that are firmly controlled by the operator and do not allow for self-deviations during operational deployment. Most of the contemporary UAVs, USVs and UUVs would fall in this category.

- Autonomous systems, meaning they have the ability to independently assess the situation from pre-programmed circumstances during deployment and choose between different courses of action. Artificial intelligence (AI) which refers to the ability of computer systems to perform tasks normally requiring human intelligence, including learning and self-correction, is the basic foundational ingredient for effective functioning of autonomous systems. These would generally include cruise missiles, though UAVs and UCAVs are increasingly being developed with AI algorithms to make them more and more autonomous.

The use of unmanned systems – which includes all UAVs/UCAVs, USVs and UUVs/submersibles – has seen accelerated expansion since the start of new Millennium, both, in civil and military domains. In fact, unmanned systems have become the preferred option for many missions which may either be highly repetitive, requiring longer sustenance or dangerous. Their use in hostile environment – besides being cost effective – is also seen as less escalatory as compared to usage of other conventional military hardware or platforms.

As the diversity of tasks has increased, so have the types of unmanned systems. They come in all shapes, sizes and configurations, and are generally made as per role and mission specifications. Some such roles and missions of unmanned systems in the military domain may either be one or a combination of the following:-

- ISTAR (Intelligence, Surveillance, Target acquisition and Reconnaissance)

- Armed missions
- Swarming
- Electronic warfare
- Logistics
- Security

This Paper seeks to discuss latest development in the realm of unmanned systems in all three domains in brief. These mainly include contemporary developments by China, as also current progress by the Indian defence and scientific community. It is followed by specific and innovative usage of unmanned systems in collaboration with manned systems, so as to create vast asymmetries vis-a-vis the adversary. Finally, the implications arising out of employment of unmanned systems – including manned-unmanned-teaming applications – employed by Chinese maritime assets in the Indian Ocean region are investigated; along with certain recommendations for Indian maritime establishment to address the challenges emanating therefrom.

Latest development in Unmanned Systems

There has been significant progress world-wide, in developing and deploying automated unmanned systems. The US, Russia, China and Israel in particular, have displayed strong interest and capabilities in developing autonomous programmes. Though the scale and scope of development in USVs is far lower than that of UAS, a growing ambition to develop more capabilities in USV and UUV platforms has been seen, of late. This section discusses the latest developments in the realm of UAS, USVs and UUVs and incorporation of high-technologies therein, which make their innovative employment in combat scenarios possible.

Unmanned Aerial Systems

The contemporary UAS – inter-changeably referred to as UAVs too – are of fixed wing, rotary wing and hybrid types. These can either be

close-in or personal types requiring little or no launch infrastructure; or small tactical ones for short/medium range missions. They can also be Medium-Altitude Long Endurance (MALE) types capable of flying between 25,000 to 50,000 feet; or high Altitude Long Endurance (HALE) types which are able to operate up to 65,000 feet height.

The US is an acknowledged global leader in production of unmanned aerial systems and their very effective combat exploitation, both, for battlefield surveillance, as also pin-point targeting anywhere in the World. RQ-4 Global Hawk surveillance UAVs, and MQ-9 Reaper and Predator attack drones are the best unmanned systems in the World. Innovative concepts like loitering munitions, search and attack anti-radiation UCAVs and manned-unmanned teaming (MUM-T) between aircraft and AI-enabled smart UAVs were all pioneered ab-initio in the US.

Closer home, rapid progress in the field of design, development and production of UAS by Chinese technologists, both, in State-owned and private sectors, has brought about a revolution in the quantum, scale and innovativeness of these systems. In fact, this revolution – primarily led by private enterprises – has made China the World's leading supplier of drones for multifarious civil applications. According to informed estimates, Da-Jiang Innovations (DJI) – a private Shenzhen-based Chinese drone manufacturing firm – accounted for about 70 percent share in the global commercial personal drones market. In fact, seven of the top 10 drones for personal use, as ranked by PC Magazine were built by DJI, while the eighth ranked model was also Chinese, manufactured by Yuneec's Typhoon Company.

A natural spin-off of this technological expertise has been that a large number of UAVs for broad-spectrum of military applications have also been produced; and exported to countries looking for comparative cost competitiveness. Some of these models include Wing-Loong (1,2) and Caihong (CH-3, CH-4, CH-5) series of UAVs/ UCAVs. Other latest

Chinese UAS development projects include the following types:-

- 'Rainbow' High Altitude Solar Powered UAV
- 'Divine Eagle' (Shen Diao) twin-fuselage surveillance UAV
- 'WJ-600A/D' high speed Stealth UAV
- 'Xianglong' (Soar Dragon) HALE UAV
- Cloud Shadow HALE UAV
- Gongji-11 (GJ-11) stealth UCAV
- 'Sky Hawk' (Tian Ying) high-speed HALE UAV (MUM-T capable)

As for India, most of the UAVs currently operated by the Indian Defence Forces are imported, though the DRDO has been running a robust indigenous UAV programme from quite a while now. The imported systems mainly include Heron, Harop and Searcher UAVs from Israel. The Predator and Guardian UAVs are also slated to join the Forces in near future after renewed technological collaborative understanding with the US in recent times. In fact, two predator drones were taken on lease from the US in November 2020, for operation from Indian Navy's aircraft carrier 'Vikramaditya.' The Indigenously developed systems – most still under trials/development with mixed results – include 'Nishant' and Rustom UAVs; 'Rustom-II' and 'Ghatak' UCAVs; 'Nethra' quadcopter and 'Lakshya' Pilotless Target Aircraft. The Indian private sector is also trying to indigenously develop UAVs under collaborative ventures. However most of their components continue to be imported.

Unmanned Surface Vessels

As mentioned in the case of UAS, the US, as also some European countries, are at the forefront of development, production and operational trials of unmanned surface vessels (USVs). The US Navy built a 132 Feet long, twin-engine USV named 'Sea Hunter'; and conducted autonomous sailing experiment from San Diego on mainland till Hawaii, and back in October 2018. Enamoured with the success of this trial, the US Chief of Naval Operations (CNO) Admiral Greenert envisioned that future USVs

would be able to support US Navy operations by acting as radar or Sonar scouts for the Fleet ships; and supplying ammunition, missiles and other modular payloads to warships at sea. Such USVs could also be tasked to carry out the proverbial 3D – dull, dirty and dangerous – work. The US Navy apparently wants to induct at least 10 large USVs in near future, and has asked the industry to present ideas to this effect.

China – following in the US footsteps – is progressing its own USV programme, mainly for use by the PLA Navy. It is developing a number of USVs – and UUVs too – for envisioned military roles like 'near sea' protection, power projection and capacity-building for future warfare. Some USVs either produced or under development include the following models:-

- Sea Fly USV
- M-80 series USVs for hydrographic survey/ intelligence collection
- 'Huster 68' USV
- A-1150, B-850, C-1500 and D-3000 series of USVs built by China Aerospace Science and Technology Corporation

To conduct end-to-end testing and trial of these USVs and pursue many more ambitious projects like World's first unmanned cargo ship; a large unmanned vessels test range has been built off Zhuhai coast in southern China. The test range – first of its kind in Asia – covers a sea area of 771.6 sq km; and has separate designated areas for simulated, model and actual vessels. In fact, design, development and construction of World's first unmanned cargo ship, 'Jindouyun Yi hao' (magical cloud No. 1) was done in this test range commencing 2017; finally culminating in its first autonomous sea sailing trial in December 2019.

Though the Indian Navy has been using imported Radio Controlled Target Boat (RCTB) since 1990s for practice firing by ships' guns, the Indian indigenous USV effort – as compared to China – is virtually non-existent. The Indian Navy has sought to develop an indigenous RCTB through private industry participation, as mentioned in its Indian Naval

Indigenisation Plan (2015-2030) document. Another indication that a USV may be produced in India came, when a model of Seagull USV was presented by Elbit Systems of Israel to the Garden Reach Shipbuilders & Engineers (GRSE) during Def-Expo 2018. The attendant insinuation was that the two companies would jointly build this USV. However, further progress about both these projects on ground, if any, is not known.

Unmanned Underwater Vehicles/submersibles

The US, as in case of other unmanned systems, continues to be a technology leader in the domain of underwater vehicles and submersibles. However, the Indian maritime security establishment has to be more cognisant of the challenges posed by rapidly developing Chinese expertise in this field; as the Chinese maritime bandwagon inexorably marches towards permanent presence in the Indian Ocean – the very area of utmost importance to India's security and economic well being. In this context, the latest development of UUVs/ submersibles and their employment patterns by China requires to be monitored carefully.

China has progressed quite comprehensively in designing and manufacturing a broad range of UUVs. In fact, it is envisioned that China's autonomous UUV programme could lead to a new generation of PLA Navy's underwater patrol vessels in future. Chinese UUVs/ submersibles are currently of two major types, namely, 'Qianlong' series (1,2,3) of submersibles and 'haiyi-7000/Haiyan' underwater gliders. 'Qianlong' autonomous underwater vehicles (AUVs) which are capable of operating up to 4,500 meters depth, are being regularly carried onboard Chinese research vessels cum mother ships for undertaking deep-water deployment in the Indian Ocean. For instance, 'Xiangyanghong-10' mother ship, along with Qianlong-2 AUV, was deployed in the South-West Indian Ocean for eight months commencing December 2017.

'Haiyi' (meaning 'sea wings') underwater glider – and its suffix denoting maximum depth to which it can dive – looks like a torpedo with

a pair of wings. It can glide beneath the sea without human intervention for days, months, or even one year – all the while collecting data for scientific research and environment monitoring. Haiyi-7000 underwater gliders have also been deployed in the Indian Ocean by their mother ships in similar manner as AUVs. The latest mission of Haiyi gliders in the Indian Ocean was reported between mid-December 2019 and mid-February 2020, wherein 12 sea-gliders were deployed from their mother ship 'Xiangyanghong-6' for conducting 3,400 plus observations.

China's latest achievement relates to the building of an unmanned submarine – also referred to as Extra-large UUV (XLUUV). China unveiled this XLUUV during its National Day military parade on 01 October 2019, referring to it as autonomous underwater vehicle (AUV) HSU-001. While details are not known as yet, maritime analysts believe that such XLUUVs can be carried to deployment locations onboard warships, landing ships or even large helicopters. These XLUUVs in turn, can carry smaller UUVs, mines or torpedoes, which can be autonomously deployed by the XLUUV.

Research and development scenario in India, in respect of UUVs is decidedly better than that of USVs. DRDO is currently designing and building multiple types of AUVs to meet naval requirements. These range from small slow-speed vehicles, flat-fish types, to military-class, free-flooding ones weighing up to 1.7 tons. These AUVs can perform various roles like surveillance, mine counter measures etc, in harbours, coastal waters, as well as in deep seas.

Another UUV named as AUV-150, is built and patented by the Central Mechanical Engineering Research Institute (CMERI) with active collaboration of DRDO. This AUV measuring 4.9 meter long with half meter diameter, is capable of seabed mapping, coastal surveillance, mine counter-measures, oceanographic measurements, surveying, underwater photography and inspections. Indian private sector is also developing AUVs for the Indian Navy. M/S Larsen and Toubro Defence have designed

and are producing 'Adamya', 'Amogh' and 'Maya' series of AUVs for the Indian Navy. These can be carried onboard a submarine, and can be launched through its torpedo tubes for various underwater tasks.

Employment of unmanned systems in collaboration with manned platforms

Unmanned systems in their initial phase of development were more like tethered extensions of manned platforms, and were fully controlled by operators from such manned platforms. The advent of wireless communication, digitisation and miniaturisation of components made it possible for unmanned systems to get rid of limitations related to umbilical dependency. Subsequently, large increase in processing speeds, global connectivity through satellites, and integration with GPS has enhanced the ability of unmanned systems to perform increasingly complex tasks. Rapid strides in the field of Artificial Intelligence (AI) – coupled with infusion of AI algorithms in operating software – has also enabled unmanned systems to progressively become more autonomous. These developments have opened up innovative and exciting possibilities for unmanned systems to operate alongside manned platforms, and enhance their mission capabilities like never before.

US and European Manned-Unmanned Teaming (MUM-T) initiatives

The US – as has been the precedence in initial roll out of every high technology – has been experimenting with joint and synergised operation of manned and unmanned systems – particularly between aircraft and UAS – for over a decade, under the Manned-Unmanned Teaming (MUM-T) concept. The US Army Aviation Centre (USAACE) defined MUM-T in 2013 as "synchronised employment of soldiers, manned and unmanned air and ground vehicles, robotics, and sensors to achieve enhanced situational understanding, greater lethality, and improved survivability."

The Airbus Industries of Europe carried out live demonstration of

MUM-T concept over Baltic Sea in October 2018, wherein five Airbus-built Do-DT25 drones were controlled from an airborne manned command and control (C2) aircraft. Airbus claimed that MUM-T trial flights served multiple purposes, including validating aspects such as connectivity and human-machine interface; and the concept of teaming intelligence through mission group management on the manned aircraft. American Boeing Company followed suit soon after. The US and Australian Air Forces are already conducting trials between their fighter aircraft and pilot-controlled UAVs acting as their 'loyal wingmen.'

Integration Efforts of Chinese Fighter Aircraft and UAVs

China's UAV technologists – in a bid to acquire similar capabilities as western countries in MUM-T domain – are also seeking to develop UAS which would be able to communicate and collaborate with manned aircraft during surveillance and combat operations. A Chinese stealth drone which would be equipped with such a capability has been provisionally designated as the 'Sky Hawk' (Tian Ying). This high-speed HALE UAV with flying-wing design, would be capable of conducting patrol and reconnaissance missions. It was showcased in a static display during Zhuhai Air show in China's Guangdong province in November 2018 (Figure-1).

Figure 1 – Sky Hawk (Tian Ying) MUM-T Capable HALE UAV
(Source: South China Morning Post)

Some over-ambitious Chinese narratives claim that in the next five years, PLA Air Force fighter aircraft like the J-20 and J-31 could have the capability to control several UAVs while in flight; and alter the mission profiles of UAVs under their active control, in real time if required. Trials of the technology are expected to commence with twin-seat fighters such as the J-16. Possible utilisation of advanced AI algorithms to control 'UAV Wingmen' will certainly enable the PLA Air Force in gaining advantage in high risk missions; though mastering of the technology involved for effective MUM-T, is easier said than done.

India's Development of Combat Air Teaming System (CATS)

Some Indian media reports suggest that a Bengaluru based start-up, M/S New Space Research and Technologies, is collaborating with HAL to develop futuristic systems like the air-launched swarm drone systems, smart glide bombs and robot-wingman drones, as part of Combat Air Teaming System (CATS) programme initiated in 2017. The ALFA-S (Air Launched Flexible Asset-Swarm) drones are about 1m long, can carry explosive payload and are designed to be air-launched from panniers – types of dedicated canisters – carried aboard fighter jets. When deployed, these drones would fly in formation at speeds of 100 km per hour, search for targets of opportunity using their infra-red/ electro-optical sensors, and carry out autonomous attack on designated targets. A Sukhoi-30 fighter aircraft can apparently carry 30 to 40 such drones, because of their compact size. The drones are supposedly inter-connected through electronic data-links, which enables them to relay possible target details back to control aircraft/station and receive target allocation for attack.

The new robot wingman, on the other hand, is an unmanned aircraft half the size of a regular fighter, generally endowed with stealth features. Such AI-enabled drones are designed to fly 50-100 km away from the controlling manned fighter aircraft, either to forewarn/engage the threats ahead, or to protect it from rear sectors. The efficacy of CATS

concept was apparently tested by the Indian Air Force in 2019, though further details are not known. The fact that these futuristic UAS find no mention in official website of HAL, points to their classified nature of development.

Manned-Unmanned Teaming in Surface and sub-surface Realm

Currently, major portion of ongoing global MUM-T narrative is dominated by activities in the aerial domain – probably on account of highly visible nature of the medium, relatively lesser technological challenges, and possibility of spectacular results. However, the potential of this concept and its applications to transform the nature of future warfare in surface and sub-surface domains, is no less exciting. The USVs and UUVs, in concert with manned platforms like ships – or submarines in some cases – can provide relatively inexpensive alternatives for countering the adversary's maritime superiority in off-shore areas by deterring, dissuading or delaying their offensive missions.

The USVs, operating synergistically with other networks of manned and unmanned systems in sea, under-sea and air domains can also act as force multipliers for coastal surveillance, protection of off-shore installations, and limited engagement of opposing forces. USVs, when carried by blue water naval assets and employed in distant waters, can also support in power projection and out-of-area missions. They can also provide additional capabilities to the naval ships in maintaining situational awareness at high seas, by engaging in ISR and serving as remote sensors. USVs can also play a vital role as particularly important element of future warfare. For instance, networked swarms of inter-connected AI-enabled USVs, operating in tandem with each other and controlled from a manned platform far from the scene of action, can render an enemy warship greatly vulnerable by inundating its defensive systems.

The UUVs/AUVs can be carried onboard bigger submarines or dedicated naval or research ships to the intended mission areas; and

employed – either autonomously or under control of manned platforms – for various benign-looking survey tasks, but of great value for anti-submarine warfare. They can also carry out covert military tasks like mine laying; acting as mobile mines themselves; underwater cable laying, repair or shifting; or even planting underwater sensors for monitoring movement of enemy warships and submarines. There are, of course, great challenges in undertaking MUM-T below the sea because of connectivity, communication and sustainability issues. However, technologists worldwide are striving hard to overcome them, and hoping for early technological breakthroughs.

Chinese Unmanned Systems and MUM-T Spplications: Implications for Indian Maritime Security

The sheer range and variety of task-specific UAS available with China enables it to innovate upon their mission profiles in ingenious ways. This provides a large number of deployment options to the PLA Navy also, against the adversary in IOR. Larger scale usage of UAS in combat situations in collaborative regime with manned assets, will obviously reduce the attrition of both, manpower and platforms. This in turn, will extend their combat utility and ensure more effective operational results. While VTOL type UAVs launched from PLA Navy ships and mobile landing platforms (MLPs) would provide tactical surveillance, MALE UAVs and UCAVs operating from Chinese aircraft carriers or Landing Helicopter Dock ships (LHD) could assist the Force in building long range MDA, detect and track targets over prolonged duration, and also prosecute certain opportunity targets. Exploitation of such UCAVs from control stations far away in China using satellite communication and data relay, or AWACS/fighter aircraft under MUM-T regime in future – like the US does so effectively – is very much feasible.

While the scope of using unmanned surface vessels by PLA Navy for the kind of proactive posture it is likely to adopt in IOR could be quite limited; there can be immense utility of UUVs in restricting the

availability of operational maritime space to the adversary. Extra-large UUVs (XLUUV) – of the type showcased during October 2019 Parade – carried by the Chinese MLPs 'in ready to deploy' state to a location of its choice, would provide it the mobility and flexibility to disrupt the entire operational plans of the adversary. Incorporation of AI would further increase their lethality by improving stealth, navigational ability, sustenance, survivability, and reliability during classification, tracking and prosecution missions.

Further, submersibles carried by Chinese non-military research vessels could be used for developing underwater domain awareness (UDA) at selected locations in IOR. They would, at the very least, also provide daily updated underwater hydrological conditions data and sea water temperature, density and salinity profile around operationally vital locations to the entire Force. These vital inputs would enable the PLA Navy ships and SSNs to plan their undersea operations against the adversary, more effectively. These UUVs/AUVs operated and controlled by their respective mother ships could also lay underwater buoys with hydrophones at critically assessed locations to detect the adversary's submarine movements.

Similarly, small chains of underwater sonar sensors could also be laid on the seabed – akin to US SOSUS chains – at selected narrow straits, navigable gaps between islands in Andamans and Lakshadweep, or due south of Sri Lanka by these submersibles, to monitor the movement of India's maritime and naval traffic in near-real time. This will ultimately enable the PLA Navy platforms to plan undersea warfare against its adversary, much more effectively.

Way forward

Shri Narendra Modi, India's Prime Minister, while addressing the delegates during Def Expo-2018, stated thus:

"New and emerging technologies like Artificial Intelligence and Robotics will perhaps be the most important determinants of defensive and offensive capabilities for any Defence Force in future. India with its leadership in information technology domain would strive to use this technology tilt to its advantage."

While the vision of the Indian Prime Minister is articulated quite well, the challenge lies in its implementation. The future outlook and requirement of unmanned systems for the Indian Defence Forces has been clearly laid out in the 'Technology Perspective and Capability Roadmap (TPCR)-2018' published by the Headquarters, Integrated Defence Staff (HQIDS). This document has quantified future requirement of various types of UAVs for next 10 years. These include 100-150 MALE, more than 20 HALE, 25-30 VTOL, 10 submarine launched, 50 short range and 30 hybrid remotely-operated pilotless aircraft (RPAs). In addition, 50 ship-borne systems for Navy – each comprising 3 RPAs – are projected for induction. It also details the planned induction of at least 10 multi-mission high-endurance AUVs/ROVs with expected life cycle of 15 years. These AUVs are expected to undertake MCM operations including mine neutralisation. In addition, they would have to be capable of conducting ISR missions, carry different payloads and act as communication relays/links for submarines.

The Indian Naval Indigenisation Plan (2015-2030) has, in addition, included the development of micro and mini UAVs – launched either from shore or ship – for specialised operational support requirement in its list of future technologies. This document also flags inescapable requirement of UUVs as part of future technologies, for conducting wide range of sub-surface warfare missions.

While the above projections are indicative requirements for the Global industry, Indian designers and developers – in public or private sector – need to move rapidly for providing indigenous solutions; lest some foreign vendors bag the contract on account of original technology,

and criticality of the equipment for the Navy. It is quite apparent from the ongoing efforts of DRDO – and private sector to some extent – towards indigenous UAV and UUV programmes; that domestic technological capacity and infrastructure to meet bulk requirement of Indian Armed Forces does exist. All it requires is more concerted effort in mission mode, rather than the current practice of 'process-based' approach with attendant inefficiencies leading to large time and cost overruns.

Thus, the first imperative is to make sufficient quantities of preferably domestically designed and produced multi-domain unmanned systems available to the Indian maritime security establishment. Thereafter, the Indian Navy and Coast Guard can go about formulating operating doctrines and standard operating procedures (SOPs) for their employment and optimum exploitation in both, standalone mode as well as under MUM-T regime.

The utmost need of the hour therefore is to radically speed up the assimilation of high technologies involved in indigenous design, development and production of unmanned systems – specifically Artificial Intelligence and Robotics as reiterated by the Indian Prime Minister – in 'national mission' mode.

Only then can the Indian maritime security establishment hope to proactively address similar Chinese capabilities which would tend to give asymmetric operational advantage to their maritime forces in India's primary areas of maritime interest.

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ANTI-SATELLITE WEAPONS DEVELOPMENT ROAD MAP FOR INDIA

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Abstract

Many countries have space lunch capability today but, all do not have the Anti-Satellite capability. United States, Russia, China have already demonstrated their Anti-Satellite capability using kinetic kill technique on the satellites at the LEO. They are however, capable of targeting satellites in all space regions from LEO to GEO using other ASAT techniques such as Co-Orbital and employing non contact modes viz: Directed Energy Weapons (DEW), Jamming and Cyber attacks. India joined this group after its anti-satellite Direct Ascent -kinetic test (Mission Shakti) in March 2019.

Initially, the lead nations United States and erstwhile Soviet Union considered using nuclear tipped missile as an Anti-Satellite weapon since the missile guidance then was of poor quality which precluded the direct hit. The nuclear pulse however, besides damaging the targeted satellite will also incapacitate other satellites in the line of sight. The Co-Orbital ASAT was developed in 1960-1970. The Direct Ascent Kinetic Anti-Satellite technique was tested in 1970-80. The non contact ASAT measures such as the Directed Energy Weapons, jamming, cyber have now emerged as the preferred ASAT modes because of their ability to attack target satellites at all heights secondly, these modes have built in flexibility and can be switched on/off at will. Thirdly, these ASAT measures

allow deniability as it is extremely difficult to attach responsibility of attack on a nation.

The areas needing attention in India are; first, enunciate Defence Space Policy. Second, acquire space Situational Awareness Capability (SSA) as satellite characterisation is important for ASAT action. Third, harden own satellites and use Defensive Counter Measures to ward off / disorient adversary's ASAT attacks and finally, develop and enhance capacity in other ASAT non contact measures based on DEW, Jamming and Cyber.

Satellites have increasingly become vital to the modern society. These have opened up the new possibilities of doing business in civil and military. In security domain, space assets provide new means for securing the national interest and projecting power. Hence, increasing number of countries are looking forward to enhance their military capabilities and national security with satellites. Growing all round reliance on space has also encouraged space powers to develop Defensive Counterspace to protect one's own space assets from attack, and Offensive Counterspace to prevent the adversary from using its space assets.[1] Anti-Satellite (ASAT) weapons aim to destroy or incapacitate space assets for any reason civil or military thereby, denying their usefulness to the targeted nation. Anti-Satellites action thus is an Offensive Counterspace capability.[2]

It is generally understood that nation having Anti-Ballistic Missile (ABM) capability can suitably tweak it for the ASAT role. Four nations namely US, Russia, China and India have demonstrated their Anti-Satellite Capabilities. India the last entrant joined the group with its anti-satellite test of March 2019 code named, "Mission Shakti". Apart from these, United Kingdom, France and Israel may also have the undeclared anti- satellite capability. Except for some criticism, India's ASAT test was

1 https://swfound.org/media/206970/swf_counterspace2020_electronic_final.pdf
2 https://www.unidir.org/files/publications/pdfs/-en-703.pdf

largely well received by the friendly nations and the strategic community. The critics however, rued that test would add to the existing space debris which poses threat to the safety of the in-orbit satellites. The skepticism about the test was suitably explained and negated by the DRDO, the testing agency. The addition and consequent threat from the debris was exaggerated since India's anti-Satellite test was carried out at very low orbital level (300km) and its debris would eventually decay in a short span. The country's leadership also allayed the fear of Anti-Satellite capability since it is not directed against any nation and has a limited role of defending and securing these valuable assets in the space. As per its declared policy, India will remain committed to the non-weaponization of the space.[3]

Undeniably, the act of destruction of the satellite will generate debris which orbits at the rate of average 8km/Sec. This potentially endangers the safety of other satellites at the same time, besides impairing the functioning of the targeted satellite the act itself, could escalate the conflict with far reaching consequences. As per the Outer Space Treaty 1967, all countries are free to use space for peaceful purposes as long as they respect the interests of other space users and operate in accordance with international law. It prohibits location of nuclear weapons/ weapons of mass destruction in the space or the heavenly bodies but, do not explicitly prohibit deliberate attacks on satellites or prevent ASAT Weapons tests. As such the development of ABM and ASAT has continued unhindered and countries justify their development and their offensive/ defensive use in furtherance of their national interests which has not been barred or prohibited by the UN

3 PM Statement after Mission Shakti," Today, I also want to assure the international community that the new capability we have developed is not directed against anyone. India has no intention to threaten anyone. This is an effort to secure a fast-growing India. India has always been opposed to the weaponisation of space and an arms race in outer space, and this test does not in any way change this position. Today's test does not violate any international law or Treaty obligation to which India is a party. "sourced at https://www.indiatoday.in/india/story/mission-shakti-narendra-modi-full-speech-1487838-2019-03-27.

Charter.[4] In the last decade (2010), European Union led initiative has attempted to formulate a draft a code of conduct for the space so that space assets are protected from aggression. The effort is still in limbo. In any case it cannot halt the development in this important area which has huge military implication. [5]

Development of ASAT Weapons. Anti-satellite weapons are as old as the space age itself. The advantage which is gained by use of satellites for communication, reconnaissance and in navigation effectively meant that major powers would eventually develop countermeasures to disrupt the capabilities of rivals.

USA began with its ASAT project by the end of the 1950's after experiencing the reality of first Soviet's satellite "Sputnik-1" in Oct 1957. On 19 June 1959, it conducted its first ASAT trial with an air-launched rocket from a B-47, to destroy the satellite Explorer 4, but it missed hit by six kilometers. The programme was called "Bold Orion". Subsequent trials too were not successful thereafter; further work on an air-launched ASAT was abandoned until the 1970's.[6]

In 1980's, President Ronald Reagan in a nationwide television address on March 23, 1983 proposed Strategic Defence Initiative (SDI). It was intended to defend the entire North American continent from attack emanating from space particularly from the Soviet Intercontinental Ballistic Missiles (ICBMs) by intercepting these at various phases of their flight. The programme covered the Anti-Satellite capability too in its ambit. The programme was eventually abandoned due the budget constrains and eventual break up of the Soviet Union after the end of the cold war.[7]

4 Article 51 of Cpt VII of UN Charter

5 https://www.ucsusa.org/resources/history-anti-satellite-programs#:~:text=In%20 2008%2C%20the%20U.S.%20demonstrated,%2Dto%2Dkill%20ASAT%20system.

6 https://www.webcitation.org/6753XcmjI?url=http://www.astronautix.com/craft/isa.htm

7 https://www.britannica.com/topic/Strategic-Defense-Initiative

In May 1987, President Ronald Reagan issued a specific directive to strengthen the security of the United States by developing Anti Satellite capability. He bemoaned that, Soviets had already achieved the capability to attack US space systems therefore, US must develop Anti-Satellite capability to challenge and to the deter the Soviets.[8] The directive essentially took forward the US Space Policy of 1982 which focused on two basic goals namely, strengthen the security of the United States and maintain United States space leadership.[9] The United States opted for an ASAT system that could intercept satellites by physically striking a target ("hit-to-kill") through either air launched or by a ground launched missile. US has credibly demonstrated capability to hit satellites in the low earth orbit using both techniques.[10] The air launched version using ASM 135 missile fired from F-15 Aircraft has been successfully tested in 1985. The ground launch version was tested n 2008, wherein U.S. used its sea-based Aegis missile for destroying a defunct U.S. satellite at an altitude of 240 km.[11]

Soviet Union had begun work on its anti-satellite system at the beginning of the 1960's. Starting from Jan 1963 till Dec 1982 Soviets carried out 15 Anti-Satellite launches and several of them were successful and displayed Soviet's ability to intercept satellites in the Lower Earth Orbits (LEO's),[12] Unlike the US strategy of relying on missiles, the Soviet Union adopted a 'Co-Orbital' technique. This involved launching a 'killer satellite', which would enter the same orbit as its target and approach it for destruction.[13] After carrying out series of such tests it declared the

8 https://fas.org/spp/military/program/asat/reag87.html
9 https://aerospace.csis.org/wp-content/uploads/2019/02/NSDD-42-Reagan-National-Space-Policy.pdf
10 https://www.theweek.in/news/sci-tech/2019/03/27/history-anti-satellite-weapon-us-asat-missile.html
11 https://www.ucsusa.org/resources/history-anti-satellite-programs#:~:text=In%202008%2C%20the%20U.S.%20demonstrated,%2Dto%2Dkill%20ASAT%20system.
12 https://www.webcitation.org/6753XcmjI?url=http://www.astronautix.com/craft/isa.htm
13 https://www.theweek.in/news/sci-tech/2019/03/27/history-anti-satellite-weapon-us-asat-missile.html

Co-Orbital Anti-Satellite capability operational in 1973.[14] Soviet Union also attempted ASAT using both air launched versions with MiG 31 and the ground missile.[15] Russian S 500 Anti Ballistic Missile (ABM) system besides the ballistic missiles can also target the satellites in LEO.

US and Russia both have developed multiple Anti-Satellite technologies which includes co-orbitals, kinetic kills with air delivered or ground launched missiles, Directed Energy Weapons (DEW's) comprising primarily lasers and Electronic Warfare (Jamming of navigation, SAR and communication) against the Satellites.

In Jan 2007, China tested its first Anti-Satellite weapon using a converted ballistic missile to hit at a non-operational Chinese weather satellite, the Fengyun-1C (FY-1C), at an altitude of 863 km, completely destroying the satellite. The test was widely criticized as it left behind in its wake a cloud of space debris of 3000 fragments. China has proven Direct Ascent Anti- Satellite (DA-ASAT) capability at LEO. It has also carried out such test against deep space targets (at MEO and GEO), but this is still assessed to be in the developmental stage. China has also tested several other ASAT technologies namely, Co-Orbital ASAT at LEO to GEO where it manoeuvred satellites close to each other. The object stated was development of technology for debris removal or refueling etc but, Co- Orbital technique has military implication too as it could be used for ASAT role. Chinese are known to have developed proficiency in Jamming navigation, communication and Synthetic Aperture Radar (SAR) satellites, Electronic warfare provides an excellent ASAT option because of the flexibility it offers and that it can be switched off after achieving the objective. In the past, Americans have reported the instances of dazzling of their satellites by the Chinese. This is a proof

14 https://www.ucsusa.org/resources/history-anti-satellite-programs#:~:text=In%202008%2C%20the%20U.S.%20demonstrated,%2Dto%2Dkill%20ASAT%20system.

15 https://www.theweek.in/news/sci-tech/2019/03/27/history-anti-satellite-weapon-us-asat-missile.html

that they are also working on the Directed Energy weapons (Lasers)[16]

France too has some non contact offensive and defensive counterspace capabilities. It has an elaborate space situational awareness infrastructure around France space assets which enables it to provide active defence of its satellites. France is expected to use ground-based lasers to dazzle or incapacitate the adversary's satellites.[17]

India has nearly six decades of experience in space (Aryabhata was launched 1962) but, it remained committed to the peaceful use of space. India realised the need for the military use of the space after the Chinese ASAT test of Jan 2007. It eventually demonstrated its ASAT capability in LEO in Mar 2019 with a Kinetic ASAT test code named, (Mission Shakti). The technology for the test was admittedly developed from the existing Ballistic Missile Defence (BMD) which is already awaiting approval from Government of India for operational deployment. The prime motive for the timing of the test was to display India's ability to assure safety of our space assets. Secondly, the ongoing international consultation could ban ASAT tests and India wanted to avoid this bind.

India has not issued any national Space policy but in year 2007 a Defence Space Vision was issued which listed intelligence, surveillance, reconnaissance, navigation and communication as the primary thrust areas.18 With the anti-satellite test, India has entered in the realm of offensive counterspace and calls for fresh look at the Defence Space Vision. In Apr 2019, a tri-service organisation Defence Space Agency (DSA) has been established to command, control and coordinate all military space operations encompassing all roles. It replaced the Integrated Space cell which was essentially set up in 2010 to coordinate space needs of the Armed Forces with ISRO.

16 https://swfound.org/media/206970/swf_counterspace2020_electronic_final.pdf
17 ibid
18 ibid

Development of Anti-Satellite Technology. The development of the satellite technologies presents a very interesting time line. Initially, US and erstwhile Soviet Union being in the leadership position, led the effort till China joined them with its Anti Satellite test in 2007.

Between years 1950-60, the lead nations, US and Soviets mainly considered launching nuclear tipped missiles as ASAT weapons to compensate for the poor guidance systems but, an indiscriminate nuclear explosion could destroy many satellites including their own which are in the line of the sight.

Between the years 1960-70, the soviets focussed on "Co-Orbital" technology in which the ASAT satellite could be guided and then exploded near the targeted satellite. As a result of the explosion, the target satellite would face extensive damage from the emanating shrapnel. After carrying out several tests Soviet Union declared Co-Orbital ASAT operational in 1973.

Between 1970-80, the focus shifted to both air and ground launched Kinetic Anti-satellite weapons (hit to kill weapons). This type of ASAT gave flexibility in launch. The Air launched interceptor missile was particularly advantageous due to its short reaction time.

Between the years 1980-90, the research in ASAT weapons shifted to the Directed Energy Weapons (DEW's) which provided a potential to attack satellites with a different level of intensity ranging from dazzling / blinding the satellites to permanently damaging / destroying them. Both US and Soviets focussed on the development of Laser ASAT weapons. US navy in particular worked on the ground based chemical lasers.

By year 2000, subtle ASAT techniques like satellite Jamming emerged. The communication, earth observation satellites with Synthetic Aperture Radar (SAR) and navigation satellites of the adversary were targeted and jammed. Jamming has far greater advantage over the

kinetic kill technique as it provided deniability to the attacker and also did not result in space debris.

Presently, there appears to be all round effort to develop the ASAT capability in all realm. While, the subtle ASAT technique would be preferred mode in real time when needed than the kinetic Kill technique because of obvious disadvantages. But still for first-time demonstration which is aimed to draw attention of the likely adversaries, the Kinetic kill ASAT is preferred mode to evoke deterrence. Other subtle ASAT mode may be ignored by the adversaries.[19]

Cyber Capabilities. Many countries possess Cyber capabilities against the space assets. In 2011, Iran captured a US Drone RQ170 (Sentinel Unmanned Aerial Vehicle) allegedly using Cyber means. This possibly happened after Iran took over the UAV guidance from US GPS satellite. The Cyber attacks on satellites would grow in time to come and control of the satellites would be attempted by the rogue individual/group or the adversarial nation.[20]

Space Situational Awareness (SSA). SSA is the ability to accurately understand the space environment. It needed to monitor the space objects, their characteristic and the potential threats. For Counterspace Offensive and Defensive action, the possession of space surveillance is vital. Apart from the characteristics of the satellites and their trajectory, it is vital to know about the weather as well to take any anti-satellite action. SSA comprises a network of radars and high-power telescopes.

Presently, United States and Russia have an elaborate space surveillance infrastructure. Europe too has some radars and telescopes for space observation but, it primarily depends on USA for early warning

19 https://www.ucsusa.org/resources/history-anti-satellite-programs#:~:text=In%202008%2C%20the%20U.S.%20demonstrated,%2Dto%2Dkill%20ASAT%20system.

20 https://swfound.org/media/206970/swf_counterspace2020_electronic_final.pdf

of space debris.[21] France also possesses some SSA capabilities around their satellites whose details are not in open domain.

As regards to China, it tracks satellites from its purple mountain observatory in all orbital regimes with multiple telescopes located at seven separate locations. In addition, it is also planning to integrate the three telescopes of Pakistan, Peru and Iran in the network. PLA also uses four radars located at Hunan (46.53N,130.76E), Yunnan (36.02N, 118.09E), Hangzhau 30. 29N, 119.13E), and Korla (41.64N, 86.24E) for space surveillance. China has launched a Space Debris Monitoring and Coordinating Centre to monitor the debris and through its Asia – Pacific Space Cooperation organisation essentially established to assist the Asia Pacific countries. It is assessed that China has adequate space surveillance capabilities to track satellites in LEO, MEO and GEO regimes.

India has lone tracking radar at Bangalore which is capable of monitoring the space objects in the LEO. It can presently track ten objects of size of 0.25 m up to the height of 1000 km. Indian main land has six civil observatories with telescopes which would be integrated with the SSA network. In 2019, ISRO began with a project called “Network for Space Object Tracking and Analysis” (Netra)which is intended to give India its own SSA network by bringing together, the space surveillance radars, telescopes data processing and a control centre. Initially it will start identing and tracking at LEO and slowly it would be extended to GEO once capability builds up.[22] A Directorate of Space Situational Awareness and Management (DSSAM) has also been established at ISRO to enhance Space Situational Awareness.[23] However, India SSA capability is still at nascent stage and would still need lot to grow.

21 http://www.esa.int/esapub/bulletin/bulletin133/bul133f_klinkrad.pdf
22 https://swfound.org/media/206344/india-ssa-perspective-mrunalini-d.pdf
23 https://zeenews.india.com/india/explained-all-about-isro-s-new-center-dedicated-to-space-situational-awareness-2331190.html

Way Forward for India

India has spent huge sum in building and placing satellites in the space both for the civil and military use. We are heavily depended on them in virtually in all spheres of life and their loss can create a huge void. Therefore, it is necessary to protect these space assets. India is fourth largest space power hence, we may be possessing ability of executing other ASAT options but, we opted for DA Kinetic kill option in ASAT test of March 2019 since, it alone could credibly signal our adversaries that in case of ASAT attack, their satellites too would face similar reprisal from India. But, should we ever become victim of adversarial action on our satellites, we should not merely respond by targeting any random satellite but, choose the satellite which impairs adversary's vital services and war fighting ability. This requires that we should have the ability to identify, track and then credibly target the chosen satellite from among the various ASAT options to which is most appropriate and less intrusive and environment friendly. Presently, we have good relations with all space powers and do not expect any Anti-Satellite strike from them except China which also has the ability to target Indian satellites. So, while the India's Kinetic ASAT test was not directed against any country but, it would have credibly signalled our adversaries.[24]

The test however does not mitigate the Chinese ASAT threat as China's ASAT threat is wide ranging covers all space regimes. It has proven kinetic ASAT capability to target satellites in LEO, Cyber and Jamming attacks against our telemetry tracking and command and control stations, jamming our communication, Synthetic Apertures Radars (SAR) of Earth observation Satellite satellites and navigation satellites. It could also use DEW (laser) and carry out co orbital attacks in all space regimes from LEO to GEO. It is ever increasing its ASAT capability since it is competing with United States but, nonetheless these

24 https://carnegieendowment.org/2019/04/15/india-s-asat-test-incomplete-success-pub-78884

can be used against India.[25] India therefore should develop the ability to target adversary's satellites at all levels to truly deter adversary's anti-satellite capability.

Roadmap to Boost India's ASAT Capability

Space Policy: India currently does not have National Space Policy. The Defence Space Vision has identified only intelligence, reconnaissance, surveillance, communication and navigation as the thrust areas. The defence ministry in 2010, in 15-year "Technology Perspective and Roadmap", had envisioned development of ASAT weapons "for electronic or physical destruction of satellites (2,000km altitude above earth's surface) and GEO-synchronous orbits" as a thrust area.[26] Now after the March 2019 ASAT test, the Defensive and Offensive space counter measures naturally should find place in the space policy. The newly established Defence Space Agency (DSA) has the task cut out to draft a defence space policy so that future growth of defence space capabilities can be institutionally progressed.

Space Situational Awareness (SSA). The defensive or offensive counter measure can possibly be taken only if we can characterise the space objects. This area therefore, is of prime importance and takes precedent over all other space functions. India need no longer be dependent on North American Aerospace Defence command (NORAD) for early warning of the space objects/debris. It is now itself engaged in developing an independent capability in this area. ISRO has launched a Network for Space Object Tracking and Analysis (NETRA) to track space debris and other potential threats to Indian satellites in space. It has planned to integrate the telescopes of the existing civil space observatories spread all over India and establish radar network to

25 Ibid

26 https://timesofindia.indiatimes.com/india/After-Agni-V-launch-DRDOs-new-target-is-anti-satellite-weapons/articleshow/12763074.cms

characterise the space objects as threatening or benign. The system is already live and would need to build towards a robust status.[27]

Hardening of own Satellite. The Defence Space Agency has to be able to defend Indian Satellites from jammers, lasers, electro magnetic pulse and other ASAT weapons of our adversaries which they already possess or are developing. Defensive Counter Measure besides, improving the effectiveness of the satellites call for adopting Passive counter measures (like miniaturisation and orbit selection deception, hardening with shielding etc.) and Electronic Counter measures, Electro-optical Counter measures (i.e. use shorter wave length and more directional aerial) and proliferation of the capacity for much needed protection to our satellites. Distribution of some tasks, on the civil satellite as a back up will also make it difficult for the adversary to act against our satellites.[28]

Weaponize Kinetic ASAT Weapon. After March 2019 ASAT test, India has demonstrated the ASAT capability against its own satellite. This capability can truly be weaponised against the adversary only after attaining SSA capability for which the work is already in progress with setting of NETRA system. Finally, the kinetic Kill option should be a less preferred option firstly, no country including India has confirmed ability to hit satellites above the LEO secondly, it generates huge debris which potentially threatens the safety of all satellites including own. It also precludes deniability which is feasible in non kinetic techniques such as laser, jamming and cyber ASAT attacks.

Expansion of the ASAT Capability. Due to the obvious draw backs brought out above, other modalities of ASAT must be exploited/ developed. These will allow the ASAT coverage from LEO to GEO. The co-orbital or non contact ASAT techniques such as DEW, Jamming and

27 https://www.businessinsider.in/isro-project-netra-will-track-space-debris-and-hostile-missiles/articleshow/71286808.cms

28 https://aerospace.csis.org/wp-content/uploads/2018/09/OTA-Report-on-ASAT-Weapons-and-Countermeasures-1985.pdf

use of cyber in ASAT will enhance the capability. Dr. Satheesh Reddy in April 2019 had confirmed that all these modalities of ASAT are under consideration. [29]

Conclusion

Satellites services bring capacity building or the force multiplier effect in civil and military domains. The Anti-Satellite measures are employed to destroy or incapacitate this vital component. Possession of ASAT capability plays vital role for the nation. On one hand, it enhances own military capability while on the other hand, it deters the adversary from carrying out an Anti-Satellite attack for fear of reprisal on its own space asset. Many countries have space launch capability today but, all do not have the Anti-Satellite capability. United States, Russia, China have already demonstrated their Anti-Satellite capability with kinetic kill of the satellites at the LEO. They are however; capable of targeting satellites in all space regions from LEO to GEO using other ASAT techniques such as Co-Orbital and employing non-contact Directed Energy Weapons (DEW), Jamming and Cyber attacks. India joined this group after its anti-satellite kinetic test (Mission Shakti) in March 2019.

The interesting feature of development of Anti-Satellite technology is that initially, the lead nations United States and erstwhile Soviet Union considered using nuclear tipped missile as an anti-satellite weapon since the missile guidance then was of poor quality which precluded the direct hit. The nuclear pulse however, besides damaging the targeted satellite will also incapacitate other satellites in the line of sight. The Co-Orbital ASAT was developed in 1960-1970. The direct ascent Kinetic anti-satellite technique was tested in 1970-80. The non contact ASAT measures such as the Directed Energy Weapons (Laser) jamming, cyber have now emerged as the preferred ASAT modes because of their ability to attack target satellites at all heights secondly, these modes have

29 https://swfound.org/media/206344/india-ssa-perspective-mrunalini-d.pdf

built in flexibility and can be switched on/off at will. Thirdly, these ASAT measures allow deniability as it extremely difficult to attach responsibility of attack on a nation.

India's ASAT test at LEO assures deterrence from direct kinetic attacks but, will it deter other forms of non contact ASAT attacks remains a question? The answer to this lies in possessing ASAT capability in other noncontact modes too. We are fourth space power and may already have the non contact ASAT capability if not, with available intellectual capital, we should be able to acquire non contact ASAT capability soon.

The areas needing attention are; first, enunciate Defence Space Policy. The Defensive Counter Measures and Offensive Counter Measures must find place in it. Second, acquire space Situational Awareness Capability (SSA) as satellite characterisation is important for ASAT action. Third, harden own satellites and use Defensive Counter Measures to ward off/disorient adversary's ASAT attacks and finally, develop and enhance capacity in other ASAT non contact measures based on DEW, Jamming and Cyber.

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EMPLOYMENT OF 5G IC TECHNOLOGIES FOR ENHANCING COMBAT EFFECTIVENESS

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Abstract

5G is the luminance we are all heading for in the technology space with its promising capabilities such as low latency and high data rates. The movement of our society and much of the world from the industrial age to the information age has been hastened to a large extent by the liberalised availability of frequency spectrum. The capability of 5G technologies to connect sensors with autonomous vehicles and machines with in-built sophisticated artificial intelligence algorithms will mean faster, deadlier, less human warfare. Technological superiority has always been the main battle winning factor all through the history of warfare and the same is bound to be an impact on the Armed Forces.

Introduction

5G is being rolled out in three phases and will give very high bandwidths; from the 1Gbps of 4G, upto 30 Gbps. 5G will also provide Massive Machine Type communication (mMTC) which will cater for IoT. In the third phase of 5G Ultra Reliability Low latency Communication (URLLC) will be provided. 5G has immense applications like connectivity when travelling at speeds of 300 Kmph in bullet train, for Augmented Reality/

Virtual Reality (AR/VR) and for driverless autonomous vehicles. 5G is going to transform the telecom industry across sectors and will also have major applications in defence. Consequently 5G Information Communication Technologies will have a major role to play in enhancing the combat effectiveness of the Armed Forces, providing both opportunities and challenges to both friend and foe alike. This paper talks about understanding 5G, how 5G IC technologies can enhance combat effectiveness and security related aspects of 5G.

Government Position Towards 5G

Pilot Projects. India wants to lead in the upcoming 5G technology and wants to have its own IPR becoming a part of 5G in global standards. Department of Telecommunications (DoT) has invited incumbent telcos- Vodafone Idea, Bharti Airtel, Reliance Jio and Bharat Sanchar Nigam Limited (BSNL) in addition to network vendors such as Cisco, Ericsson, Samsung and Nokia to undertake 5G-based pilots on spectrum allocated for trial purposes for a certain period of time and showcase India-centric use cases. On 04 Jan 21, the government announced that it will commence bidding for the next round of spectrum auction from 01 March 2021, for which spectrum worth Rs 3.92 lakh cr is put on the block. A total of 2,251 MHz spectrum in seven bands ranging from 700 MHz to 2500 MHz will be auctioned. The spectrum for 5G however won't be auctioned this time. The objectives of the government for the auction include obtaining a market-determined price for spectrum, ensuring efficient use spectrum and avoid hoarding, stimulate competition in the sector and maximizing revenue proceeds.

Funding National Security. Technology in general and telecom business in particular has three components- National Growth (which is talked about by everybody), National Security and the Money. Out of these three, a nation can at best optimize only two aspects; either a nation can grow with money or we can have money with national security (and forget about growth) or else a nation can choose to grow

with money (and forget about national security). If however money is the driving factor for a nation then the other two attributes at times tend to get compromised/ neglected. It was however advisable that while doing so we should not throw caution to the winds as regards National Security. Hence the requisite funds must be made available for induction of 5G IC technologies to enhance combat effectiveness.

Understanding 5G

There are three issues regarding 5G ie - the technology, the architecture and understanding of 5G. There is a need to first understand what 5G is all about and how it is going to be rolled out in India before one can talk of its usage in general and then one can think about its utilization in the Armed Forces.

Phased Rollout. 5G is being rolled out in three phases. In 2021, in the first phase of 5G, eMBB is expected to roll out, which will give very high bandwidths; from the 1Gbps of 4G, upto 30 Gbps. In 2022, the second phase of 5G should come, which will include mMTC; this will cater for Internet of Things (IoT). In the third phase of 5G URLLC will be rolled out. Low Latency implies that the difference between the source and the destination, or between action and reaction, will be minimal; in 4G while it is 10 msec, in 5G it will be less than 1msec. 5G will give very high density of connections. Present density in 4G is that in one square km there are about one lakh connections; in 5G it's going to be one million. It will cater for situations where people are in very close proximity and there will be a need for a large numbers of IP addresses.

Flavours of 5G. 5G is customer driven and is primarily due to the emergence of IoT and Machine to Machine (M2M) communication. While 4G provides 100 Thousand connections per square km, peak data rates of 1Gbps, supports data traffic of upto 7.2Exabytes /month and a latency of 10 msec; 5G will provides One Million connections per square km, peak data rates of 20Gbps, will support data traffic of upto

50 Exabytes /month and a latency of less than 1 msec. 5G Network is envisaged to accommodate Apps & Services with different Latency, Reliability & Bandwidth. 5G is not only about broadband speeds, it is but one of the basket of services. There are three main 5G Use Cases; eMBB – Enhanced Mobile Broadband, mMTC – Massive Machine Type Communications and uRLLC – Ultra-reliable and Low Latency Communications, which had been explained earlier. The range of services offered is actually a tradeoff between the three sides of the triangle depicted below in Fig 1.1. At the low end of the services, there is an application of an embedded/ underwater/ underground sensor whose battery has to last for a long period (10 years or so) and it has to be really cheap. At the other end we have uRLLC which is used for critical applications like autonomous cars. The range of services offered is as depicted below:-

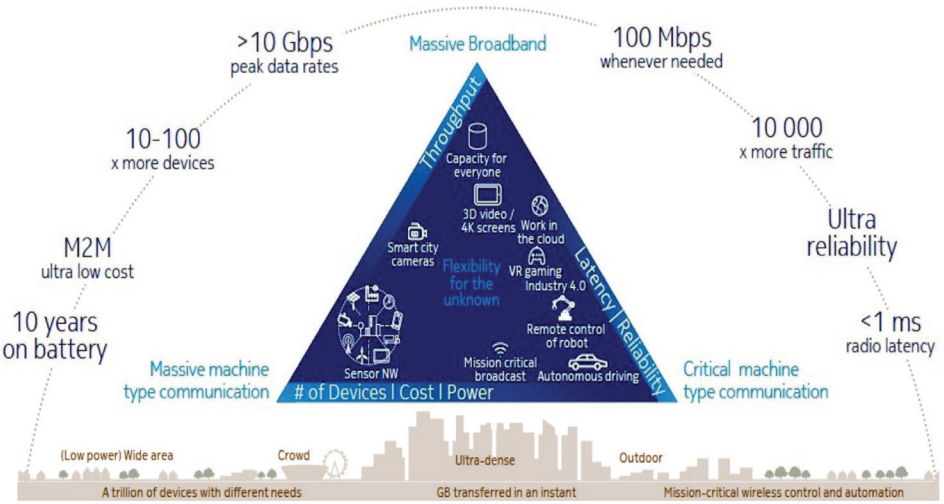

Fig 1.1 : Range of Services Offered by 5G

5G & Massive MIMO. Higher capacity is there in 5G due to MIMO technology ie there are a large No of antenna elements implying more simultaneous users. Thus leading to better spatial resolution. The coverage also increases due to beamforming and transmission diversity. Elevation Beam Forming (EBF) is carried out and is a fundamental requirement of massive MIMO and mm (Millimetric) waves

5G Technology & Combat Effectiveness

Telecom Transition. The telecom transition during the last two decades, has been phenomenal, moving from the era of 1G, 2G, 3G and 4G. There is a pressing requirement of 5G IC technologies for the Armed Forces because 5G is bigger than just mobile phones; it's about Communications, Storage, Processing, Smart Vehicles, Smart Grids, Connected Establishments, e-Health, remote diagnostics/surgery and of various applications which were beyond imagination and in the realm of science fiction. For all of these the soldier needs 5G speeds and data transfer capability. The futuristic soldier will wear at least six IP addresses; one each for monitoring the ration state, the ammo state, health, for AI, to get inputs from all sensors and one sensor to relay to the ops room so that that the commander sitting there sees and hears what all he does. The Armed Forces have already catered for this for the future and as of now a number of satellites based equipment applications have been approved for procurement by the CCS.

Linkages: Technology, Strategy & Combat Effectiveness. It's extremely important for the Armed Forces to understand 5G Info Comn (IC) technologies because unless we properly understand a technology, we will be unable to either apply it or exploit it optimally for reaping military benefits. By not doing so, we would thus be doing great injustice to this technology which the whole world is talking about. Countries that control the Geo-technology domain will control all the other three domains of Geo Strategy, Geo Politics and Geo Economics. The nations which control these other three domains control the world. In the emerging

world order India has got a major role to play. In order to become a global leader, India and its Armed Forces need to harness these latest like 5G Info Comn (IC) technologies. There is however a need to ensure that their induction does not multiply forces. An optimal solution would be if these technologies could be deployed to become Force Substitutors, as that would give better payoffs as it would have more impact, more effect and at a lesser cost.

Spectrum Intensive Requirements. During the Balakot mission, to coordinate the massive air package, comprising of diverse platforms, a plethora of sensors/ communication equipment were used. All such missions and wars are a major national effort. It can be only be imagined that if so much activity took place over communication / sensor networks for only one mission, which was merely a preemptive non-military strike, then the requirement of communication / sensor networks during war, to carry out number of such strikes can only be imagined. Besides communications and sensors, modern day weapons and weapon platforms are highly dependent upon frequency spectrum. The precision ammunition used by us (SPICE 2000) uses GPS tracking to home on to its target. Military Warfare is spectrum intensive and there is a requirement of frequency by the Armed Forces, across the complete EM spectrum ranging from 3 KHz to 3000 GHz. Hence space in EM spectrum must be left for national security. 5G in India can happen alongside the requirements for the national security however in the absence national security, growth and making money will not be feasible and will at best be temporary.

5G: Motivation and Drivers. There is a wide basket of flavours that have pulled 5G, which are listed as under and these find close relationship with many operational requirements in the Armed Forces:-

(a) eMBB. This provides extreme capacity (upto 10 Tbps per square Km), Extreme data rates (peak rates of Multi-Gbps & user

experienced rates of 100 plus Mbps), Deep awareness (Discovery and optimization).

(b) Massive IoT. This facilitates Deep coverage (to reach challenging locations), Ultra-low energy (ie >10 years of battery life), Ultra-high density (1 million connections per square Km).

(c) Mission Critical Control. Due to Ultra-high reliability (<1 out of 100 million packets lost), Ultra-low latency (As low as 1 millisecond) and Extreme user mobility.

Modernisation of Ordnance Factory Boards (OFBs). An immediate benefit of employment of 5G IC Technologies that can be leveraged by the Armed Forces for enhancing Combat Effectiveness is by use of Industrial IoT (IIoT) in the various factories under OFB. On the issue of IIoT, while China has a rating of 7, India's score was only 3.5. Connected to this is that this factor will give 5 to 10% reduction in costs in operational optimisation, 10-40% savings in preventive maintenance and 20-50% cost reduction in inventory optimisation. So in overall, one can reduce the cost of the industry at the production stage by upto 40% and increase the quality of the product by 40%. The defence sector is possibly still functioning at sub optimal levels considering that our OFBs follow the oldest of procedures. All this needs to change if we have to find our rightful place under the sun in this new world order. Simply by doing this type of IIoT in our country, especially in the defence sector, one can reduce the production cost and increase the quality of the product. We can actually give a big boost to self-reliance, as envisioned by the Hon'ble PM in the vision of "Atmanirbhar Bharat".

5G: A Maze of BTS's.

(a) One of the stated goals of the NDCP 2018 is to provide connectivity at 50 Mbps to every citizen. If the current network of

21 lakh BTS's is giving us an average of 7 Mbps then by simple maths it implies that to provide 7 x 7Mbps (ie 49 ~ 50 Mbps), we would need 21x 7 lakh BTS's or 147 lakh BTS's. These large No of BTS have to be physically installed somewhere. 5G antennas will use massive MIMO technology, implying a large number of antennas can be put. With higher frequencies, range becomes shorter and BTS antennas have to virtually become part of street furniture. While this may be implementable in cities and at best in static military stations, doing the same for field formations which are mobile, providing such a large number of antennas will be a challenge.

(b) Conventionally we will end up in a situation where a fleet of vehicles would be required only for this purpose, which is cost prohibitive. A possible alternative solution which will involve lot of ingenuity could be that the side panels or rooftops of the driver cabin of various military vehicles of field formations will have to be modified to also function as antennas for 5G and power supply provided to them from the vehicle itself.

Military Applications of 5G. In the Army, under the project being progressed by the DGIS, there were a number of different systems like BSS, BMS, AD CNRS etc and for each of these systems a dedicated system of intra communication had been planned for that particular battle field system application. Now with 5G in place, it should be able to take care of all the requirement of communications for various battle field systems/ applications. Due to the high speed and bandwidth offered by 5G, the need to have separate systems of intra communication for each of these military applications could be reconsidered. So the only aspect that merits consideration and deliberation here is that at the frequency bands in which 5G operates (presently sub 6 GHz bands , primarily 3 GHz onwards at present), the distances become very less . This implies that a very large number of base stations would be required in a particular area, as compared to the present day set up. How this

high density of BTS is to be set up in the battle field would be analysed by the domain experts from the Corps of Signals in the Army and other Subject Matter Experts (SMEs) in the other two services. The Tactical Communication System (TCS) of the Army is presently being reviewed and possibly a new Communication System for the Army, based on 5G would be considered to be evolved. The AFCELL of Air Force is based on CDMA technology is well established and may possibly merit an upgrade to 5G. For the Navy, while at sea, mobile communications is not a criticality or a priority and satellite communication actually meets the Navy's requirement. However for the Army, considering the large requirement of sensors, communications, systems and weapon platforms, 5G is the way ahead. 5G is the road for future and soon there would be 50 million devices connected over 5G. Few 5G use cases, which have been demonstrated live in India and could be of use to the Armed Forces are :-

(a) **Skyship & Facial Recognition.** 5G connected Skyship provides a real-time 4K HD quality 360 degree aerial view of a designated area. This will help in surveillance of the border areas prone to infiltration as well as provide another tier of surveillance of sensitive areas.

(b) **AR/VR Connected Vehicle.** Advanced sensors on unmanned vehicles can be put and it can be remotely driven from one location to another. This could be used as a scout vehicle by the recce patrol but again the challenge would be to provide it with connectivity.

(c) **Drone Flying on a 5G Network.** Drones could take surveillance pictures and also pick and drop a packet from point A to Point B. As was witnessed in the war between Armenia and Azerbaijan, drones can be effective weapon delivery platforms as well.

(d) **Smart Military Stations/ Bases.** 5G technology also has the potential of making the concept of smart bases a reality. With the maturing biometric technology, the same can be deployed at front gates for automated and robust access control. The government has given a push to develop 100 smart cities. On similar lines the armed Forces can bid for undertaking a project to develop Smart Military Stations/ Bases. Thus a datum level needs to be set for a smart city/ military station. The communication needs for a smart city or a smart military station also need to be quantified. In India, M2M/IOT is expected to reach 5 Bn connections by 2022. Some of these 5G applications which are tested commercially could be later adapted to meet the specific requirements of the Armed Forces.

(e) **Inherent Electronic Security Measures. As under:-**

(i) 5G will work on millimetre-wave band, with directional antenna and beam forming techniques (to counter for large-signal attenuations encountered due to smaller wavelength), shared spectrum access (enabled by directivity and low ranges) and provide super high-speed full-duplex communications [2].

(ii) The use of a directional antenna and low ranges with high bandwidth and low latency makes 5G an ideal technology for communication among various command posts of a formation, without the threat of detection, jamming, eavesdropping etc. The mm-wave signals are prone to attenuation by buildings, foliage, moving objects etc. Therefore, 5G technology will leverage directional antenna with beam forming which will inherently provide anti-jamming properties.

(iii) These properties of attenuation of 5G signals can be leveraged in designing multiple layers of spectrum for different networks with no additional hardware [3].

(iv) Further, since 5G communication will make the machine to machine communications possible, it will become a keystone of future military technology.

(f) **Enhanced Army Communications.** Army communication systems should be able to connect distant entities to attain higher operational flexibility and synergy amongst all components of the force in the tactical battle area. The communication network thus established should have continuity even across the borders with requisite redundancy and matching mobility to keep pace with the advancing forces even across the border. 5G technology entails establishment of 5G grid and cell sites & creating solutions for interoperability with the current equipment. There is thus a need to assess its operational viability in the Indian context. 5G provides all these attributes and one way to address the limiting factor of having a large number of antennas is by using the rooftop/ side panel of the driver compartment of all vehicles in the field formation, as an antenna. There is thus a fit case to establish a 5G test bed to ascertain its efficacy for the Armed Forces.

(g) **Application of 5G in Military Communications.** [4]. Reliable, secure, quick communications provided by 5G technology will enable remote and reliable connectivity, reduce latency, energy-efficient and will have wide bandwidths.

(i) All this will enable relaying of a life-threatening situation in the theatre of operation possibly reducing fatalities in the war zone.

(ii) 5G will also improve information sharing within the

various fighting groups, with secure and reliable video sharing using bodycams and location sharing [1].

(iii) Enhanced connectivity of sensors, robots, vehicles, troops in remote locations will reduce the response time in case of emergency and enable quick delivery of necessary supplies – ammunition, food, medicines etc - to precise locations through 5G connected Drones.

(iv) 5G technologies will enable better data collection on material usage and hence will positively impact the future supply chain and military budgeting. [1].

(v) With IoT, military communication devices will provide fast close-range communication using Device to Device (D2D) communication without requiring satellites relays and thus reducing the cost of military operations.

(vi) **Challenges.** The 5G components would however need to be suitably ruggedized and packaged as portable to be moved around. [5]. Also, suitable mechanisms in terms of enhanced processing or different cell architecture will be required to compensate for the higher losses of mm wave signals and a grid of antennas would need to be established.

(h) **Interception of Hypersonic Weapons.** [6,7] hypersonic weapons, being built by USA, Russia, China and others will be ready by 2022. With the super high speed (15-20 times the speed of sound), intercepting or guiding them is beyond the scope of current generation networks. 5G networks, as envisaged at present, will have both the required BW and minimal latency.

(j) **Perimeter Security.** 5G will leverage milli-metre waves spectrum where signal attenuates very fast thereby reducing the range significantly compared to the 4G spectrum of sub GHz. This property can be leveraged in two particular use cases for military installations A large number of sensors can be deployed across the perimeter due to available large bandwidth and Ultra-low latency to provide perimeter security without the threat of enemies detecting the sensor communications [3].

(k) **Real Time Exchange of Situational Awareness Data.** The real-time exchange of situational awareness data vis a vis available resources (manpower, weapons and ammunition, ration etc) at a base will definitely result in optimal deployment and distribution of weapons at the target, providing an edge in a theatre of operation.

(l) **Telemedicine & Robotic Surgery.** Another critical application of 5G will be robotic surgery in a remote battlefield providing the prompt and best healthcare to prevent lethality and disabilities

(m) **Misc Military Applications of 5G IC Technologies.** These are available in all fields of Command and Control like Security, Resilience/ Survivability, Mobility, Radio Determination, Asymmetric Operational (Op) Comn, Fire Control, Active/ Passive Surveillance and Time Critical/ Latency. Asymmetric Op Comn is of special relevance. Other applications are Edge Computing, Power Management , MIMO, Processing, Virtual Reality, Augmented Reality, Artificial Intelligence, Context Awareness, Peer to Peer, Small Cells , NFC and Face Recognition Radars. Using Virtual Reality, Augmented Reality, people sitting at Command HQs can actually feel to be part of the ops being carried out at a distant field location.

5G Recommended Use Cases to Enhance Combat Effectiveness. Listed in the table below are technologies developed as per different standards, used in different parts of the world. So if the Defence uses these standardized technologies for which equipment is available then our procurement process in the military will be much faster. Even DRDO could use these same standards to develop equipment for the Defence. 5G is a backbone technology for high speed, low latency telecom. It has extraordinarily low latency allows services such as AR/VR and an immersive and tactile internet. Each of the three use cases for 5G, offers avenues for the Armed Forces to utilize 5G, as tabulated and explained below:-

SNo	Use Case	Human To Human	Human To Machine	Machine To Machine
(a)	**eMBB**	VR/AR, Video Calling, Virtual Meetings	VR/AR, Fixed Wireless, UGH Video	Video Monitoring, Mobile Cloud Computing
(b)	**mMTC**	Wearables, Social Networking	Smart Homes, Smart Cities, Health care Monitoring	Smart Homes, Smart Cities, Vehicle to Infrastructure, Industrial Automation
(c)	**uRLLC**	Public safety	Remote Surgery, Vehicle to Pedestrian	Vehicle to Vehicle, Industrial Automation

Suggestions for Armed Forces to Enhance Combat Effectiveness. Few suggestions specific to the Armed Forces, to optimally use 5G IC Technologies to enhance combat effectiveness are as listed below:-

Specify Needs. Evaluate needs of Arms/Services; Combat/Support Arms, Logistics, and Static Establishments for their service needs. The specific requirements of the user needs to be identified.

Evaluate Potential. 5G services range from MTC to uRLLC and there is a requirement to evaluate how these technologies map the specific

needs of the Armed Forces. For example Use of HAPS and Drones as munition delivery platforms or for deployment of Network elements , especially for field formations could be a possibility, in light of there being a requirement of a mesh of antenna's to be established for 5G.

Exploit Digitisation. Use Network function Virtualisation (NFV) and SDN to customise network for specific needs of Armed Forces users and operational roles. This requires high level of digitization and is especially useful for doing remote surgery. This will be of immense use, especially useful for providing emergency medical support to combatants deployed in remote location and in inhospitable terrain.

Maximise Use of Available Data. Create a data repository with a common Armed Forces (AF) data exchange, to enable Big Data Analytics for enabling enhancing combat effectiveness, predictions, optimising response timings. This could especially be of use to the logistics or to EME/ Ordnance for inventory management.

Team Work. Nominate a Single Point of Contact (SPOC) /Special Team in HQ IDS to track and work/train/participate on future technologies events. Establish a working relationship with Indian industry to build a mutually supportive relationship.

Armed Forces (AF) App Ecosystem. Make an AF App ecosystem/ agency for developing services for the various users on the Armed Forces Networks, for use on wireless devices and on small but rugged form factors, viz: Ninja Tool.

Spectrum Utilisation. Rationalization of various spectrum bands for access and backhaul for enhancing MBB coverage in the short time frame to provide fibre like capacity connectivity.

Data Digitisation. Countries which have digitized their data across a common data format, which can be used to run an AI engine are in the

lead. While India has started off on a project called Digital Broadband Index of Readiness for various states, the Armed Forces could on similar lines consider steering a Digital Index of Readiness for various formations within their respective services. Only if the AF are digitized, will they be in a position to crunch numbers and provide services. This is a specialized area which requires continuity. The Armed Forces and HQ IDS would be well advised to nominate a Special Team in HQ IDS to track and work/train/participate on future technologies events pertaining to 5G and provide continuity to the said team.

Harmonization of Frequency Spectrum.

This is the biggest challenge for spectrum managers. This implies that if there is a place where the organization is using some kind of services in a particular set of spectrum band, the same band cannot be used by another user in the same locality. The range of EM spectrum varies from 300 KHz to 300 GHz. Spectrum has three distinct characteristics of Space, Time and Frequency. However when one is using a particular band of spectrum, there is a limitation that we can use only two of these three domains at any given point of time and place. Due to this reason and due to the fact that spectrum does not have boundaries, hence harmonization is a must. Harmonization needs to be carried out at a global scale and at the national level. Wireless planning commission (WPC) will face a major problem if defence is using a particular set of spectrum band and a Telecom Service Provider (TSP) also starts using the same band for commercial purposes, in the same general area. This leads to instances of interference, which need to be resolved between the Armed Forces and the commercial TSPs.

Defence IoT & Spectrum Requirements

The Indian Armed Forces (AF) have slightly different type of IoT requirements, on similar lines as is possibly applicable to the DoD of US and of other nations. The Defence Band existing with the Indian

Armed Forces lists out the frequency spectrum available for Armed Forces and it possibly needs to be given a holistic re-look to discard spectrum bands no longer required and include bands which would be required for 5G, as the same would be required for the Armed Forces. The standards available globally could also be looked at to meet the defence requirement. Different technologies of IMT-2020 like 3G, EVDO, LTE, LTE Advanced have been developed and defence is using some of these. There are few technologies which are already in use or have gone out of use like EVDO and CDMA.

Spectrum Specialists. Defence needs to identify the next best technology to which it should shift from the CDMA technology presently being used. The Armed Forces/ MoD of many other nations have a dedicated team of officers interacting with the vertical of the industry looking into these aspects. The Indian Armed Forces should also think on these lines and select a team of officers with requisite domain knowledge for preparing standards and to participate in discussions on future technologies events pertaining to 5G. In order to reap tangible results, Defence needs to provide continuity to the said team.

5G Security Aspects

Security Aspects. Security is an integral part of 5G and there are a lot of security focus areas in 5G to include Identity Management, Platform Security, Building Trustworthy clouds, data Integrity, Security Assurance, 5G Security and IoT security. The Armed Forces must ensure that they are part of all discussion forums where 5G security aspects are being discussed, because if one is not discussing their specific security needs then they will end up buying whatever security is being provided. Requisite expertise is available in the Armed Forces for leveraging various use cases for 5G and the same needs to be properly utilized. To the extent feasible, Armed Forces must ensure continuity of the person dealing with 5G and its security aspects, without linking it to the number of times he has been working in a particular appointment in the course of

his duty. In the civil street, people who have been dealing with telecom standards have been there since last 20 years or so.

Conclusion

Dedicated 5G Network for Armed Forces. 5G is all about use cases and it can be used to enhance op effectiveness. The feasibility of establishing a dedicated 5G cloud which can be made available only for the Armed Forces and it's security implications, merits deliberation. A dedicated 5G network, with 5G cloud and data centres could enable working on a paperless and automated environment, facilitating remote control. Such a system would need to be hack proof and there would be a need for separation of the commercial and military requirements. 5G will facilitate tracking and monitoring of the exact location of the person with a mobile device. So it is very important who has access to the data base and controls it. It is recommended that a special cell be created within the Armed Forces to understand and utilize the 5G technology to enhance the understanding of the subject and leverage op effectiveness. Also participation by defence reps in meetings of SA-3 and in 3GPP should be encouraged.

The vision of smart things, smart cities or smart military bases, requires realization of IoT, where every object will have inbuilt sensors and intelligence to sense and make decisions along with the ability to communicate to every other object, in vicinity that too in real-time resulting in a collaborative environment to meet certain objective, and all this will happen without human intervention. 5G networks are seen as the potential essential infrastructure necessary to make this a reality [8]. The capability of 5G technologies to connect sensors with autonomous vehicles and machines with in-built sophisticated artificial intelligence algorithms will mean faster, deadlier, less human warfare [2].

Great Game in Digital Realm. For 5G radios, the technology is either produced by ZTE or Huawei or Nokia or Ericson. Within the Armed

Forces, in order to have plurality of OEMs there would be requirement to source equipment from all the major OEMs. China has filed the maximum number of patents and IPRs in development of 5G. The current situation and standoff between USA and China is akin to the Great Game being played out in digital realm- The technological ascendancy of the West is being challenged by the Orient. India as a rising nation has to find it's own space in the overall scheme of things and the policy makers need to take a deliberate call on development and education at relatively lower costs versus security or a mid-course tradeoff between the two.

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SIXTH GENERATION COMBAT AIRCRAFT TECHNOLOGIES - IS INDIA PREPARED

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Abstract

Combat aviation has not only become the most preferred means of prosecution of war but has seen the fastest growth of technology. The special features of fighter aircraft are quick response, agility (speed, manoeuvrability), accurate weapon delivery, and long range engagement, capability to operate in all weathers and at night make it a potent weapon platform. Fifth Generation aircraft are already flying among major air forces, and sixth generation aircraft are under development. Sixth Generation aircraft will be characterized by multi-spectral stealth, Artificial Intelligence (AI), smart structures, hybrid systems, Adaptive Versatile Engine Technology, and uniquely designed composite wings. Weapons will be hypersonic or directed energy. Network of integrated systems will be disaggregated across multiple platforms. Aircraft must be able to operate in the anti-access/area-denial environment that will exist in the 2030–2050 timeframe. India would have to take proactive steps to catch up and join the leaders.

As two among the world's largest militaries, belonging to two nuclear powers, stand face-to-face in Ladakh, war clouds continue to hover on the horizon. The two air forces moved fighter jets to airbases near the place of action. As China flouts its upgraded H-6 bombers and J-20 fifth generation fighter aircraft, it has initiated discussions among strategists

and planners. Earlier, the Pakistan Air Force (PAF) riposte to Indian Air Force's (IAF) Balakot strikes and the air combat that followed on 27th March 2019, rekindled interest in fighter aircraft technologies and air combat capabilities. Combat aviation has not only become the most preferred means of prosecution of war but has seen the fastest growth of technology. The special features of fighter aircraft are quick response, agility (speed, manoeuvrability), accurate weapon delivery, and long range engagement, capability to operate in all weathers and at night make it a potent weapon platform.

After the advent of jet age, aviation community started classifying jet fighters by "generations". There are no official definitions, and they just represent stages in the development of fighter design, performance capabilities, and technological evolution. Most air forces currently operate fourth generation aircraft. There are a few fifth generation aircraft flying, and the sixth generation aircraft are on the drawing boards and technologies are evolving.

Air Superiority as a Concept

Air superiority fighter aircraft are meant for entering and seizing control of enemy airspace as a means of establishing complete dominance/ supremacy over the enemy's air force. They usually operate under the control/co-ordination of Airborne Early warning & Control (AEW&C) aircraft. Aircraft like USAF's F-15 and US Navy's F-14 were built to achieve air superiority from design & development stage. Both later had multi-role variants. Soviets/Russians developed MiG-29 and Su-27 around same time. Eurofighter Typhoon and Dassault Rafale though multi-role fighters but both have air-superiority missions. F-22 Raptor, Su-30 variants, Su-35, Chinese J-11 and J-15 were also air-superiority aircraft.

Fourth Generation Plus

Fourth-generation fighters strengthened the trend towards multirole

configurations. Concept of 'energy-manoeuvrability' and 'fast transients' called for small lightweight aircraft with higher thrust-weight ratio. The F-16, MiG-29 and Mirage-2000 evolved. Pulse-Doppler fire-control-radars added Look-down/shoot-down capability. Head-up displays (HUD), hands-on-throttle-and-stick (HOTAS) controls, and multi-function displays (MFD) allowed better situational awareness and quicker reactions. Composite materials helped reduce aircraft weight. Improved maintenance design and procedures reduced aircraft turnaround time between missions and generated more sorties. Low-observable (stealth) designs like Lockheed F-117 Nighthawk attack aircraft evolved.

Military budget cuts after Cold war, and high funding requirements of the fifth generation fighter, resulted in a term called the 4.5th generation fighters during 1990s to 2005.This sub-generation saw advanced digital avionics, newer aerospace materials, modest signature reduction, and highly integrated systems and weapons. These fighters operated in network-centric environment. Key technologies introduced included BVR AAMs; GPS-guided weapons, solid-state phased-array radars, helmet-mounted sights (HMDS), and improved secure, jamming-resistant data-links. Eurofighter Typhoon, Dassault Rafale and Saab JAS 39 Gripen were in this category. Many 4th generation aircraft were also upgraded with new technologies. Su-30MKI and Su-35 featured thrust vectoring engine nozzles to enhance maneuvering. 4.5th generation fighter aircraft were expected to have AESA radar, high capacity data-link, enhanced avionics, and ability to deploy advanced armaments.

Fifth Generation Fighters

The fifth generation was ushered in by the Lockheed Martin/Boeing F-22 Raptor in late 2005. These aircraft are designed from the start to operate in a network-centric combat environment, and to feature extremely low, all-aspect, multi-spectral signatures employing advanced materials and shaping techniques. They have multifunction AESA radars with high-bandwidth low-probability of intercept. IRST and other sensors are fused

in for Situational Awareness and to constantly track all targets of interest around the aircraft's 360 degree bubble. Avionics suites rely on high-speed data buses. Integration of all these elements is claimed to provide fifth-generation fighters with a "first-look, first-shot, first-kill capability". In addition to its high resistance to ECM, they can function as a "mini-AWACS". Maneuver performance is enhanced by thrust-vectoring, which also helps reduce takeoff and landing distances. Super-cruise is inbuilt. To maintain low signature primary weapons are carried in internal weapon bays. These aircraft are very expensive. F-22 costs around US$150 million. Lockheed Martin F-35 Lightening II fighters will cost on average US$ 85 million due to large scale production. Other fifth-generation fighter development projects include Russia's Sukhoi PAK FA, now SU-57. China's 5th generation fighter Chengdu J-20 has already inducted in service. Their second fifth generation aircraft, the Shenyang J-31 first flew in October 2012. India is developing the Advanced Medium Combat Aircraft (AMCA).

Light vs. Heavy Fighters

There is a continued decision conflict about light vs. heavy fighters. Light aircraft are relatively simple with only essential features, and lower cost. Light fighters generally feature a high thrust-to-weight ratio, high manoeuvrability, and high reliability. Intentional simplicity also allows buying larger numbers to out-number the enemy in the air under combat conditions. Modern single engine light fighters include F-16, JAS-39 Gripen, and Tejas LCA, all being significantly lower in cost. Larger fighters provide the opportunity for more technology, longer range radars, and heavier weapons, but are much more expensive and often unaffordable.

Unmanned Fighters

Unmanned Aircraft technologies are already proven, and it is clearly emerging that the future is unmanned. World is at a real time of transition.

There are some who see the JSF as the last dedicated manned fighter/ bomber. Dual use optionally manned aircraft are under development. Unmanned aircraft are already taking-off and landing by themselves including on the moving aircraft carrier (Northrop GrummanX-47B). Autonomous air refueling has been tested. Lockheed Martin's UCLASS drone 'Sea Ghost' looks rather like a stealth bomber and is expected to carry 1,000-pound class weapons. Russians had modified MiG 21 aircraft to fly remotely in 1990s and used them as targets for weapon trials. USAF has already modified F-4s and F-16s to fly unmanned. In France, Dassault leads a multi nation delta wing UCAV 'Neuron' of the size of Mirage 2000. UK has a Strategic Unmanned Air Vehicle (SUAVE) program 'Taranis'. This will be a supersonic autonomous stealth bomber with intercontinental range. USA is also working on Strike Bomber that is likely to be optionally manned.

Evolving Technologies

Artificial Intelligence (AI), smart structures, and hybrid systems will dictate the future. Demand for streaming high-quality data requires bandwidth, which involves innovating sensor/processing systems. Gallium Nitride (GaN) is a semiconductor material that is more efficient, easier to cool, and improves reliability for radars. The Passive Aero-elastic Tailored (PAT), a uniquely designed composite wing will be lighter, more structurally efficient and have flexibility compared to conventional wings. This wing will maximize structural efficiency, reduce weight and conserve fuel. Hypersonic cruise, fuel cell technologies, hybrid sensors, improved human-machine interface using data analytics and bio-mimicry, combination of materials, apertures and radio frequencies that ensure survival in enemy territory are under development. Additive 3D manufacture would create a world with spare parts on demand, faster maintenance and repairs. The development of a hypersonic aircraft would forever change ability to respond to conflict. Nano-materials will control sizes, shapes and compositions, and significantly reduce weight yet create stronger structures for air and spacecraft, yet drive down costs.

Future Weaponry

Hypersonic aerial missiles are already entering air force inventories. These will be difficult to defend against with conventional air defence technology. Continued experiments with DEW and lasers, used for defensive as well as offensive measures, delivering effects at the speed of light, are also likely to shape precisely what sixth generation fighters are equipped with. New aircraft will be as much about reusable weaponry (lasers) as it is about expendable weaponry. The solid-state laser systems defensively create a sanitized sphere of safety around the aircraft, shooting down or critically damaging incoming missiles and approaching aircraft with the laser turrets. They will attack targets on the ground with pinpoint precision, or even shoot down ballistic missiles. USAF is developing a new air-to-air missile, dubbed the Small Advanced Capabilities Missile (SACM) for 2030s. The missile with thrust vectoring will have improved 'high off bore sight' for rear hemisphere kills and 'lower cost per kill.' A sixth-generation missile could replace AMRAAM. A survivable, long-range missile with combined air-to-air and air-to-ground capabilities is being evolved. Longer range would be a big factor to counter potential adversaries with Chinese PL-15. DARPA's the triple target terminator (T3) program envisions combined capabilities of Raytheon's AIM-120 and AGM-88 High-speed Anti-Radiation Missile (HARM).

Heavy Stealth Revolution

Fighters like the F-35 and F-22 may be stealthy, but their support assets, like aerial tankers and AWACS are not. USAF is looking at 'heavy stealth' to evolve low observable tankers, transports, bombers and 'flying sensor and communications trucks', as these will be targeted. USAF could adapt the new stealth bomber design for the stealth tanker role. It will also give ability to insert special operations teams deep behind enemy lines via a stealthy high-altitude penetrating transport.

U.S. Sixth Generation Fighter Programs

In April 2013, DARPA started a study to try to bridge the USAF and USN concepts. Next-generation fighter efforts will initially be led by DARPA under the "Air Dominance Initiative" to develop prototype X-planes. The agency as well as industry are known to have started internal research on potential sixth generation technologies for several years. In 2016 the USAF announced to pursue "a network of integrated systems disaggregated across multiple platforms" rather than a "sixth generation fighter" in its Air Superiority 2030 plan. On September 14, 2020, the USAF announced that a prototype aircraft part of the Next-Generation Air Dominance program had flown for the first time at the Air Force Foundation's Air, Space, and Cyber Conference. The details remain highly classified. There is no available information on who the manufacturer of the aircraft is. The "Next Generation Tactical Aircraft"/"Next Gen TACAIR", will have enhanced capabilities in areas such as reach, persistence, survivability, net-centricity, situational awareness, human-system integration and weapons effects. It will counter adversaries equipped with next generation advanced electronic attack, sophisticated integrated air defense systems, passive detection, integrated self-protection, directed energy weapons, and cyber-attack capabilities. It must be able to operate in the anti-access/area-denial environment that will exist in the 2030–2050 timeframe."

The sixth-generation fighters are expected to use advanced engines such as Adaptive Versatile Engine Technology to allow longer ranges and higher performance. An engine is to be ready when fighters are introduced by the US Navy in 2028 and the Air Force in 2032. In November 2013, the Air Force Research Laboratory released a request for information (RFI) for a laser weapon that could be mounted on next-generation air dominance fighters by the 2030s. The laser and systems controls are to work at altitudes from sea level to 65,000 ft at speeds from Mach 0.6 to Mach 2.5. The Air Force wants a system to be fully technology ready by 2022.

There are significant differences between Navy and Air Force visions for their respective next-generation jet concepts, but both agree on some fundamental characteristic aspects they will share. American sixth-generation fighters are to feature artificial intelligence as a decision aid to the pilot, similar in concept to how advanced sensor fusion is used by the F-22 and F-35. They will also have Positioning, Navigation, and Timing (PNT), and communications that allow big data movement between both service's aircraft. The Navy aircraft is to have greatly increased speed and range compared to the Super Hornet.

In November 2016 the USAF Scientific Advisory Board announced studies for a Penetrating Counter Air (PCA) platform that would combine long range, supersonic speed, stealth and maneuverability and be fielded by 2030. PCA would have substantially longer range to fly long distances over the Pacific, especially in a situation where airbases in the vicinity of China are not available or if aerial tankers are destroyed. It would also escort bombers deep into Russia or China. It would include stealth against low or very high frequency radars like those of the S-400 missile system.

Lockheed Martin's Skunk Works division has revealed a conceptual next-generation fighter design that offers the first hints of an ambitious, long-term technology strategy for the new class of tactical aircraft that will emerge after 2030. Boeing and Northrop Grumman have teams dedicated to developing a sixth-generation fighter. Supersonic tailless jets may be optionally manned.

USAF intends to follow a path of risk reduction by prototyping, technology demonstration, and systems engineering work before creation of an aircraft actually starts. The sixth-generation strike capability not as just an aircraft, but a system of systems including communications, space capabilities, standoff, and stand-in options. USAF fighter maybe larger and more resembling a bomber than a small, maneuverable traditional fighter. Small size, high speed, and maneuverability may be less relevant and easier to intercept. Fighter significantly larger can rely on enhanced

sensors, signature control, networked situational awareness, and very-long-range weapons to complete engagements before being detected or tracked. Larger planes would have greater range that would enable them to be stationed further from a combat zone, have greater radar and IR detection capabilities, and carry bigger and longer-range missiles.

Other Sixth Generation Programs

France and Germany have awarded the first-ever contract – a Joint Concept Study (JCS) – to Dassault Aviation and Airbus for the Future Combat Air System (FCAS) program. The JCS is based on High Level Common Operational Requirements Document (HLCORD) signed in 2018. It identifies the preferred baseline concepts for its major pillars such as the manned Next Generation Fighter (NGF), Remote Carriers (RCs) and a System of Systems approach with associated next generation services. Both countries want to secure European sovereignty and technological leadership in the military aviation sector for the coming decades beyond 2040. The two-year study should complete by February 2021. FCAS is one of the most ambitious European defence programs of the century.

The BAE Systems Tempest is a proposed stealth fighter aircraft concept to be designed and manufactured in the United Kingdom for the Royal Air Force. It is being developed by a consortium consisting of the UK Ministry of Defence, BAE Systems, Rolls-Royce, Leonardo and MBDA, and is intended to enter service from 2035 replacing the Eurofighter Typhoon. Approximately $2.66 billion will be spent by the British government on the project by 2025. Tempest will be a sixth-generation fighter incorporating several new technologies. BAE Systems is planning to approach India for collaboration for the design and manufacture of the Tempest. Tempest could be optionally manned and have swarming technology to control drones. It will incorporate AI deep learning and possess DEWs. Tempest will feature an adaptive cycle engine and virtual cockpit shown on a pilot's helmet-mounted display.

China is still evolving its J-20 and F-31. Some are mentioning a Chinese sixth generation aircraft (J-XX) Huolong (Fire Dragon). Russian media has reported an aircraft designated J-28 as China's next generation fighter. But as on date China has serious limitations on radar, avionics, and engine technologies. China planned to field it in the 2025-2030 time frame. In Russia, the FGFA Sukhoi Su-57 is just being inducted, and work is on for its sixth generation aircraft Mikoyan MiG-41. Japan's Mitsubishi F-3 sixth-generation fighter would be based on concept of aircraft informed, intelligent and instantaneous, technologies for which are under testing on the Mitsubishi X-2 Shinshin test-bed aircraft.

Options and Challenges India

India is still at the basic Light Combat Aircraft (LCA) 'Tejas' stage with the second squadron still to get full numbers. The upgraded Tejas Mark 1A, which is as a stop-gap aircraft until the Mark 2, still awaits CCS (Cabinet Committee on Security) approval and funding. This aircraft will include digital radar warning receivers, an external ECM pod and a self-protection jammer, AESA radar, ease of maintenance and improvement in avionics, aerodynamics, and reduced radar signature. It is hoped that 83 Tejas Mark 1A will get approval very soon. It will take three years thereafter for the first aircraft to get into service. The Tejas two-seaters are already flying. More will be inducted soon. From the LCA two-seater, HAL has evolved the Supersonic Omni-Role Trainer aircraft (SPORT), a two-seater Lead-in Fighter Trainer (LIFT) aircraft. Medium Weight Fighter (MWF), also called "Tejas Mark 2", is to feature the more powerful General Electric F414-GE-INS6 engine with 98 kN of thrust. In November 2009, Ministry of Defence sanctioned ₹2,431.55 crore (US$690 million in 2019) for development of Tejas Mk 2. The Mk 2 will feature an AESA radar, an on-board oxygen generation system, and a built-in electronic warfare suite among other improvements to avionics. In Aero India 2019, a model of Tejas Mk 2 with close-coupled canards was displayed. Mk 2 will be slightly larger with a length of 14.6 m and a wingspan of 8.5 m. It will have an increase in payload capacity to

6,500 kg that will allow it to carry more weapons. It will include an infra-red search and track system and a missile approach warning system. The realistic timelines for this aircraft is around 2028. The Hindustan Aeronautics Limited (HAL) Advanced Medium Combat Aircraft (AMCA) is India's fifth-generation fighter aircraft. While individual technologies are being evolved by India's Defence Research Development Organisation (DRDO) and HAL, the aircraft is still on paper. Feasibility study on AMCA and the preliminary design stage have been completed, and the project entered the detailed design phase in February 2019. The earliest that metal may be cut could be 2022. AMCA will reportedly be unveiled in 2024. First flight around 2028, and the aircraft could enter service around 2035. DRDO has learnt a little in the initial work with the Russians on the, now closed Indo-Russian FGFA program. The IAF intends to have "full control" in "defining" technologies of the AMCA to avoid technology restrictions imposed when purchasing foreign-designed aircraft. AMCA will perform air superiority, ground attack, bombing, intercepting, strike and other types of roles. It will combine super-cruise, stealth, advanced AESA radar, super-maneuverability, data fusion and advanced avionics to overcome and suppress previous generation fighter aircraft along with many ground and maritime defences. The 20-ton aircraft would have a double delta wing configuration, and include horizontal and vertical stabilizers similar to the F-22, and would be eventually powered by two GTX Kaveri engines. Program is slated to be a public-private partnership as of 2020 for development as well as production. An AMCA Mark-2 variant is also planned which is expected to be produced in greater numbers.

Gas Turbine Research Establishment (GTRE) entered in a joint-venture with Klimov for the development of Three-Dimensional Thrust Vectoring (TDTVC), and Electronics and Radar Development Establishment (LRDE) with Tikhomirov Scientific Research Institute of Instrument Design (TSRIID) for the AESA Radar, and ADA with the Sukhoi for stealth technology and other various key technological fields. Boeing and Lockheed Martin offered to help HAL and DRDO in the field of stealth, thrust vectoring and other key technologies. Saab AB has

made an offer for participating in the program. One among General Electric, Rolls Royce, Snecma, Eurojet, and NPO Saturn could form a joint-venture to produce an engine of 110–125 kN thrust, using the Kabini Core-engine of GTRE. Till then the General Electric F414 may be used for initial few squadrons. AMCA uses a modular approach in its design, development and production. Most of the assembly and equipment are outsourced to both private firms and public sector undertakings. The AMCA will also feature a Diverterless Supersonic Intake, which will help improve its stealth capabilities.

The aircraft's avionics suite will have IRST and advance situational oriented electronic warfare system. Wide angle Head Up Displays (HUD) and large screen cockpit LCD displays are planned. The AMCA will feature an internal weapons bay, but a non-stealthy version with external pylons is also planned. The aircraft is planned to be equipped with beyond visual range missiles, close combat missiles, standoff weapons, precision weapons and laser guided bombs. Directed energy weapons are also planned to be equipped on the AMCA.

The engine, radar, EW suit, of the LCA are still of foreign origin. India has a long way to go. Joint venture route to master leading technologies may be the answer for time being. As planned modular approach and upgrades is the best strategy. Some of the fifth generation technologies will later be upgraded to sixth generation features. If the project gets inordinately delayed it could have more and more next generation features. India needs to think ahead, lest we get left behind again. The directions for its success must go from the highest level of the government and project monitored at that level.

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EMERGING WARFARE CONCEPTS AND NEW AGE TECHNOLOGIES PAIRING

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Abstract

One of the most important components of the Comprehensive National Power would be the Technological Power of the Nation. Since future Warfare is going to be based on technology; a country with high HDI (Human Development Index) and GII (Global Innovation Index) would be ahead of others in indigenous technology and R&D and therefore would have better chances of winning wars.

With the growth of technology, Warfare would shift more towards Non-Contact realm but with increased targeting capability - longer ranges, lethal warheads and high accuracy. With higher ISR (Intelligence Surveillance and Reconnaissance) using higher resolution satellite, nations would increasingly operate underground and undersea. Tunnel and undersea Warfare would become more prominent. Similarly, technology to detect and hit deep undersurface targets shall become need of the hour.

The Digital and Artificial Intelligence development is fast replacing the analog and the human deployment in the battlefield. Robotic soldiers and autonomous machines would dominate warfare, cutting short the OODA loop, increasing the speed and tempo of operations. Development in Power, Materials and electronics would dictate the innovation and spin new models of warfare. Nations would invest heavily into deception, Information Warfare and use of Nature as a force Multiplier. It would be necessary for the Armed Forces to take a lead in the current fourth Industrial revolution

and build the Military half a notch ahead of Industry 4.0. Such lead would guide the industry in innovating military needs for the next generation warfare called Military 4.5.

Warfare is a dynamic activity. While only constant factor would be fighting between adversaries; all other factors such as means, strength, resources, capacities, stamina, motivation, strategy, force ratios etc. would remain variable. The aim of any country in war would be to inflict maximum damage on the adversary and minimize damage on its own people and resources. The means adopted for this maximise-minimise postulation are optimized by the strength of the Nation - the Comprehensive national Power (CNP). One emerging factor that contributes to CNP is the Technological Power or Tech-Power. This is single most significant and incrementally important factor that would make nations grow economically and militarily and that too exponentially.

Combination of Human mind and technological prowess are most crucial in driving the Tech-power of a nation. India is blessed because it has potential to build tech-power but unfortunate that this potential is not fully exploited. There is a constant brain drain of human resources and lack of management. We are one of the lowest on Human Development Index (HDI) and dependent on import of technology. Though Indian diaspora contributes to high HDI of other countries. The Human Development Report introduced an Inequality-adjusted Human Development Index (IHDI) where India ranked at 129 last year (fallen to 131 this year) out of 189 countries, while neighbouring China is at 85 and United States at 15. At Global Innovation Index 2020 India ranked at 48 among 131 countries, China at 14 and US at No 3 after Switzerland and Sweden.

Future wars are going to be based on application of technology. Threats of War or vulnerability to being attacked are more pronounced in a country when its Defence preparations are inadequate. This happens when Defence budgets are considered as expenditure - a burden and not as an investment. This inadequacy results on poor R&D, low indigenous

manufacture of Military hardware, resulting in high dependency on Military imports, finally leading to country's low Military Tech-Power. A country poor in technology cannot hope to win battles against adversaries who have an access to better and evolving technology. The brute force, up to third generation warfare would remain relevant but with diminishing returns. The new warfare has to be understood beyond the conventional application of force. Till date, force ratios have been worked with number of traditional factors i.e. Manpower, Mechanical power and morale etc. The additional factor that is becoming the most important is technological superiority. Beyond conventional approach, technology has brought about a revolution in the non-kinetic and non-contact means hugely contributing to war wining ratios. The future of Warfare would bring in doctrinal changes as also application of technological means. Such possibilities are slowly becoming realities and are discussed in succeeding Paragraphs.

Stand-off engagements would be more pronounced, making eye-ball to eye-ball contact virtually redundant. Kinetic capabilities would increasingly be sharpened with higher lethality, high precision and longer strike ranges. The target engagement for a stand-off kinetic attack would need better ISR. Target acquisition would need accurate and real time geo-referencing, keep the target on lock with sensor-shooter synchronisation till delivery of attack. The sensors must have the ability to call off the strike before launch in case target is detected as dummy or irrelevant. This is possible only through spatial - digital and networked platforms. Similarly, counter to such stand-off attacks by the adversary is in having credible Missile Defence, that would need attacks to be intercepted and destroyed before they are delivered. It would be necessary to detect the launch sites of adversaries' ahead of time. Passive defensive means certainly include in hiding and hardening own assets.

Unmanned and Autonomous vehicles, aircraft and ships would see a larger role in the battlefield. The pilotless, driver less or crew less fighting machines would be all pervasive. The control stations of these machines could be located underground and far away from the War Zone. Such

machines would be remotely controlled through secure and stable radio waves and satellite communication which are uninterruptable, reliable and instant. The ranges or the radius of action and stamina of these machines would be enhanced through efficient power of hybrid engines requiring low maintenance or charging. The warheads could be kinetic, High Energy or radiological. Nuclear power would run engines in miniature plants that would empower these killing machines. These vehicles could be light in weight, smaller in size yet having ability to carry on themselves disproportionate loads. The rearming and refuelling, if and when required could be executed through autonomous logistic support system.

Underground Operations would be the norm in the era of complete battlefield transparency. This would also be the only way to achieve passive defence, even in depth areas. Tunnelling, borewell tubes and shelters that are not visible from the sky and ground would be a necessity. The logistic nodes, command and control centres and weapon platforms would need to be located under-surface and underwater. This would need huge amount of power to run breathing systems with filters, lights and generators. Nuclear power plants may be used for energy. The national Command and Control centres, may be located in remote areas and built deep underground, without any signs over ground. Even new multi-storied buildings could be based on 'Well designs' having minus floors concept underground.

Under-sea Operations would be an extension of the underground warfare. While some work has been done in the sub-surface technologies, but the use of robotics would enable better creation and maintenance of underground or sub-surface military infrastructure to be occupied by a soldier during war time. Under-sea warfare would be a new challenge to coastal Defence and surface assets.

Reverse Front would mean that attacker would turn defences by suddenly appearing in the rear. The third dimensional - vertical envelopment has been the age old concept, however, with autonomous multidomain fighting machines it would be possible to penetrate through

various means and attack more intensely in the rear areas with a combination of rockets, robot-soldiers, special forces and tunnelled approaches. The traditional concept of trench warfare would now be modified to make it possible to penetrate adversary's strongly held ground positions through tunnels. It would be possible for the adversary to be located underneath your positions and even in the rear. Detection of deep underground tunnels through deep penetration radars would be a necessity. High penetration shock waves may have to used to neutralise underground facilities.

Space Wars would be the most relevant because of the universal application of space technology to most digital platforms. PNT (Place Navigation and Time), Communication, Surveillance, planetary control and counterspace assets would dominate the security paradigm. Increasingly 5G and beyond - IOT would be all pervasive moving IoMT (Internet of Military Things) for strategic applications and IoBT (Internet of Battle Things) for the TBA (Tactical battle Area). Surveillance and Target Acquisition would be outsourced to Space providing better resolution to identify the target and engage with missiles with better accuracy.

Cyber Warfare is soon emerging as the mother of all Wars. The digitisation of Warfare with applications that connect the Human mind to war machines puts cyber ecosystem at the core of all functions. Cyber Warfare would mean hitting the electronic or digital nerve of the adversary while securing your own. It covers a very large canvas that includes from Information Systems to moving the digital platforms which are networked. Cyber domain can be compared with the human body that combines all the vital organs. A combination of Brain and heart. Brain being the nerve centre and heart being the power supply. Any of these get hit, the system shall paralyse. The Networks and Information would be the targets of the adversary. There is no Cyber front – it is all pervasive.

Network redundancies would be like contingency positions and contingency planning. A military which cannot bring in flexibility of

changing network domains at will, re-configure and create flexibility and adaptability would suffer heavily at the hands of adversary's frequently interfering in systems or destroying them, bringing the digital battle field to a grinding halt. Heavy network security and dynamic reconfiguration would be necessary, without creating any change in the warfighting plans. 'System of Systems' would replace the Net Work Centricity that would factor adequate redundancies.

Remote Controlled Warfare would be an extension of Systems of Network. The digital area and the industry 4.0 would make it possible for creating a network with C5 (command, Control, Communications, Computers and cyber) and connect the machines with the surveillance means connected with drones and Satellites, making ISR a real time possibility. The Sky and Space would provide a strategic vantage point for a decision maker at operational and strategic levels. There would be enough data and information available for the decision maker to decide, cutting short the OODA cycle. It makes it possible for the higher leadership not only decide but also control operations of strategic importance. With the advent of Artificial Intelligence and Sensors it would be now possible to robotise the battlefield. This would be a game changer as this would be making Remote Warfare possible. The battles can be fought on pre-programmed 'targeting on appearance'.

Information Warfare would target minds of different segment of people. Starting from young minds attending schools or playing computer games to higher age groups. It would be difficult to differentiate between truth and lies. This would exploit the vulnerability of people in different sections and throw thematic scares to alter the psychology. Increase in mass shooting in night clubs, educational institutions and religious places has been achieved by radicalization of vulnerable minds on the internet – a powerful tool of warfare. Recruitment drive for ISIS and other radical groups and use of dark web for supply and arms and ammunition has already been in vogue.

Electronic Warfare would remain a prime focus in the future battle field as cyber- electro-magnetic spectrum would make heavy electronic emissions on the battlefield. Hiding electronic signatures would be difficult yet important. Increasing shift of electronics emissions into tubes such as Optical fibre would become inescapable and shall conjoin the underground battlefield concept. Electronic emission suppressors and reflectors would be mandatory for survival.

High Energy Attacks would initialy complement and later supplement traditional kinetic energy attacks. These could be high laser, high electronic beams and use of EM pulse. EMP weapons have been tried by China. Such attacks are possible in counter space application as well, to neutralise the adversaries' military satellites through destruction or neutralising them.

Hybrid Wars would continue to shift in form, intensity, means and understanding. Targeting adversary with Artificial Intelligence platforms is fast becoming a reality. The border guarding forces would become Border Surveillance Forces manning smart borders with deep warning systems. This would give enough time for the Armed Forces to deploy forces armed with punitive response mechanism. There would be need to guard the interiors from vertical Kinetic and cyber-attacks of adversaries by hardening the critical infrastructure in all forms.

Protracted Engagements would be a norm, there would be few periods of peace as there would be fatigueless intervention by technology in military and public life. The security agencies and systems would need round the clock vigil round the year. Due to continuous state of security alerts, nations would need to remain either prepared for war if not already engaged that would mount expenses and make warfare unaffordable. Raising costs of wars would make warfare unstainable. Nations have no option but to save costs and prepare to fight economical wars. That is how sub-conventional and Hybrid Wars came into being as Low cost option. A defender cannot choose the means and the methods adopted by the attacker, therefore defence would be highest priority for National Security.

Low cost Expendable Military inventory would be mandatory for the industry to provide to cut costs of warfighting. The rapid change in concepts of warfighting and ever evolving technology makes it important that the war material becomes affordable as longer shelf lives will make the inventory redundant due to shift in concepts. Today, large conventional war machines are not useable due to deterrence of Weapons of Mass Destruction (WMD). Similarly, Hybrid Wars have made deterrence value of WMD less significant since the wars could not be completely prevented.

Space based Second Strike assets may be used to hold information, store high energy weapons as deterrent as also ensure that the ability to respond is not destroyed by the adversary. Nations are investing hugely in Space labs and large facilities. It would be possible for Space faring nations to build space arsenals for mass destruction meant for a second strike and to act as additional redundancy. However, such assets will need protection in the space that would happen through miniaturization and strong defensive and hardened assets.

Fighting through Alliances and collaborative technologies would bring a paradigm shift in war fighting. Data and technology compatibility and long-range vectors would make military alliances work differently. Space, Cyber and Missile Warfare would be elements to pools since they are global commons and know no boundaries. If the agreements are in place and technological compatibility is assured then military blocs could fight in Country groups and /or alliances. There would not be any need of physically flying or sailing to another country. In-situ location of resources can be brought to combat against an adversary in a collaborative manner with the click of a button.

Triggered Nature Attacks can be resorted by the adversary to degrade human ability to fight by use of Chemical, Biological, Radiological attacks and weather manipulations. Such indirect attacks can be used as deniable, to be covered under the acts of nature or 'Acts of God'. Conventional CBRN direct attacks would not be acceptable by international

community as all are banned under the UN conventions. However, these capabilities could be used with changed formulations to be covered under Nature attacks to escape accountability to such protocols by signatory or member states. Coronavirus attack should be seen under this category. This would complicate matters if imported vaccines mean to protect have hidden formulations such as impacting the reproduction of people of certain DNA, breed or a race. Even a news of this kind could create havoc.

Power, Materials and Electronics (PME) shifts will make new possibilities in technology. PME make three fields of R&D most relevant that change the game when any one of these fields or all of them are advanced. High voltage, sustainable and light weight power packs would be essentials. Materials would make a case for light weight, hard and malleable materials. Materials have to have various qualities for different uses. Electronics is the mother of technology but would remain dependent on development in Power and Materials and miniaturization. Electronics is the soul of technology.

Today our industry is at 4.0, making it possible for the Military to adapt to digital/ Net Work centric / System based warfare. The military must guide the industry by half a notch so that the industry caters for the R&D and technology needs of the Military for future warfare. 'Military 4.5' dictates that the industry and the military work collaboratively. Industry has not been aware of the needs of the military in the past as a result the industrial revolutions have been guiding the military to adapt to the available possibilities. In few countries certain innovations were made for the military only when military not only laid down their needs but also partnered with the R&D. DARPA has been successful in military innovations because the projects are led by the experienced military leaders supported by the scientists and the industry. Military however never laid the standards to dictate the revolutions. 'Military 4.5' is essential as the military itself would lead the industrial standards by taking the industry ahead by half a notch ahead of industry 4.0.

The digital Wars would be configured around C5I2-STAR2. C5 (Command, Control, Communication, Computers and Cyber) would ensure all platforms are connected to the Nerve Centre that would act as Communication, Data and a network hub. I 2 (Information and Intelligence) would empower decision making and STAR2 (Surveillance, Target Acquisition, Reconnaissance and Robotics) would ensure that the decisions are implemented, modified and delivered with complete impact and transparency. The system of systems approach would be needed to build security and redundancy. Artificial Intelligence and Robotics in warfare would make a paradigm shift in use of technology in warfare. The sensors and seekers would be more efficient and more versatile, giving a rise to a billion dollar industry where applications would be dual use IOT or IOA (Internet of Anything).

The future of warfare would be dictated by the whole of 'Nation' seen as one warfighting entity and not to be fought by a military or soldiers on the frontline. The definition of borders and frontlines would change, the targets would be less visible as such attacks by the adversary would be on the vital infrastructure that makes the nation strong. The centers of gravity would shift from borders to breaking core strength of the adversary in the hinterland with the combination of means. Technology would make it possible to make things convenient for human existence; unfortunately it is the same technology that would become responsible for human destruction. In the absence of regulators and Rule of Law for the new era of technology, there would be less recourse to justice. The attacks ranging from Corona to stand-off drone attacks on unsuspecting humanity or an individual makes it impossible to respond in equal measure, intensity and to the perpetrator. This is the complexity of a Hybrid war, where technology would make it possible to hit an adversary while hiding own identity; surviving through deniability or lack of detection.

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GUIDELINES FOR CONTRIBUTORS

The Synergy Journal is a theme based bi-annual research periodical published by the Centre for Joint Warfare Studies (CENJOWS), New Delhi. Themes of the journal usually centre around: Global, Regional and Neighbourhood Security Situation and likely Developments; Defence Diplomacy Enhancements; Security Challenges of India; National Security Strategy of India; Higher Defence Management and Organisational Reforms; Defence Acquisition and Defence Production Eco System; Defence Research and Development Reforms; Synergising and Strengthening Joint Warfare Policies and Structures; Enriching Multi Domain Warfare Concepts; Technological Developments and Likely Applications in Warfare; Defence Budget Optimisation; Theatre Level War gaming & Simulation and Evolving Nature of Warfare.

Articles should be written in MS WORD, 2007 and newer versions, in about 3000 to 4000 words, adhering to widely prevalent research norms. The electronic text should be preferably British spellings. The text should be in 1.5 spacing with standard margins. Articles should be submitted through e-mail to the ID; cenjows@cenjows.in with the subject: “Article submission for Synergy Journal”. A short introduction about the author (50 words), including Author’s full name, details of the author’s institutional affiliations, and contact information should be included in the mail. The copyright of the Journal rests with the CENJOWS.

A concise abstract (between 100–150 words) is required to be submitted along with the article.

All diagrams, charts and graphs should be referred to as figure and consecutively numbered. Tables should be kept to a minimum and contain only essential data. Each figure and table must be given an Arabic numeral, followed by a heading, and be referred to in the text. Citation/Notes should be placed at the end of each page.

The manuscripts should conform to the journal style. The 'Chicago Manual of Style for References', should be used.

References to books should give author's name: title of the book (italics); and the place, publisher and date of publication in brackets.

e.g. RK Narang, *India's quest for UAVs and challenges,* (New Delhi: KW Publishers, 2020), pp. 262-263.

References to articles in periodicals should give the author's initials and surname, the title of the article in quotation marks, title of the periodical (italics), the number of the volume/issue in Arabic numerals, the date of publication, and the page numbers:

e.g. T. Lazar Mathew, "Biotechnology in Defence", *Defence Science Journal,* Vol. 51, No. 4, October 2001, p. 393.

In case of Web references, the full URL should be given as well as the date on which the URL was last accessed.

e.g. Kyle Mizokami, "The U.S. Navy Wants To Build the World's Largest Robot Warship," *Popular Mechanics,* 16 August 2019. https://www.popularmechanics.com/military/navy-ships/a28712589/large-unmanned-surface-vehicle/.30 December 2020.

Articles should be original contributions and should not be under consideration for publication elsewhere. Serving Officers would be responsible for obtaining clearance from their respective HQs. All articles should carry the certificate that "This article is original in content, unpublished and has not been submitted for publication elsewhere. The facts and figures quoted are duly referenced, as needed, and are believed to be correct. The paper does not necessarily represent the organisation views of CENJOWS."