CENTRE FOR JOINT WARFARE STUDIES

DISRUPTIVE DEFENCE TECHNOLOGY KALEIDOSCOPE & A WAY AHEAD FOR ATMANIRBHAR BHARAT

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By

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TECHNOLOGIES ASSOCIATED WITH DISRUPTION

Key words - Artificial Intelligence, Quantum Computing, Quantum Key Distribution, Additive Manufacturing, Gene Editing - Biotechnology, Drone Warfare - Counter drone systems & Swarms, Smart Munitions, 6G, Blockchain, Extended Reality (XR), Big data analytics, Battlefield IoT, Space Technology, Edge & Cloud Computing

INTRODUCTION

This brief draws its motivation from the 'Disruptive Technology for Defence Transformation' online conference which was conducted from 15-18 September 2020, organised by Defence IQ.[i]

Disruptive technology is a term popularized by a Harvard business professor and may be defined as an innovation that forces the advancement in security or degrades current security as related to changes in geopolitical, military, economic or social cohesion factors.[1] The Cambridge online dictionary offers another definition - "A disruptive technology overturns a traditional business model, which makes it much

i https://www.defenceiq.com/events-disruptivetechonline/ - An event bringing together senior figures from Armed Forces, Government, Industry and Academia to explore the integration of Digital Age technologies to retain strategic overmatch in future hybrid warfare.

harder for an established firm to embrace".[2] Stemming from this, simply put, it may be out-of-the -box thinking with respect to any aspect that allows asymmetric advantage or a magnified gain allowing the odds to turn favourable. The aspect of technology is more profound & hence discussed in greater detail in this brief.

IMPLICATIONS OF THE FOURTH INDUSTRIAL REVOLUTION (4IR)

Science & technology trends have been greatly influenced by the 4IR. Implications of the 4IR towards international security can be seen across a variety of factors.[3] As international security is deeply influenced by 4IR, the role play of disruptive technology becomes more evident, both 4IR driven technology & disruptive technology being intertwined.

Technology – Dual Edged Weapon. Resulting asymmetry due to disruptive technology is clearly visible, however, a weaker adversary might utilise this easily available at times technology, to pose greater threat for the opposing state.

Feel Good Factor. This feeling of superiority (at times) may be ill-founded due to a miscalculation assuming an upper hand in technology.

Deterrence & Pre-emption. Greater deliberation by Commanders/ users of disruptive technology will be needed to decide whether technology is to act merely as a deterrent or cause irreparable damage.

New Arms Race. Resources are now being pooled by various agencies working in tandem to develop new technologies. Dual use technologies such as encryption, nano-satellites, genomics, AI & drone technology is now developed by students in universities, in labs or basements further multiplying the problem.

"A conventional conflict in the near future will be extremely lethal and fast, and we will not own the stopwatch."

- Maj Gen Willian Hix, US Army (Annual meeting, Association of the U.S Army, October 2016)

New Frontiers & Blurred Boundaries. Technology disruption has led to blurring of boundaries between deterrence & destruction as also new means to effect damage. Case in point of cyberwarfare where the aggressor has plausible deniability leaving no trace, obfuscating the situation & acting as a trigger to escalate into a full-scale war.

Fig.1 - Disruptive Technologies Categorised Under Four Heads

Perception, Processing, Cognition	Performance and Materials	Communication, Navigation and Targeting	Manufacturing, Logistics and Supply Chain
• Cloud Computing	• Quantum Computing	• Precision Position, Navigation and Timing	• Robotics
• Big Data Analytics	• Autonomy	• Directed Energy	• Additive Manufacturing
• Artificial Intelligence	• Novel / Smart / BioMaterials	• Electro-Magnetic Weapons	• 4D Printing / Smart Materials
• Cyber capabilities	• Meta-technologies	• Cyber Capabilities	• Synthetic biology manufacturing
• Virtual and Augmented Reality	• Composites for Aerospace	• Unmanned Systems	• Virtual and Augmented Reality Manufacturing / Simulation and Training / Computer Aided Design
• Robotics / Unmanned Systems	• Internet of things	• Hypersonics	
• Advanced Sensors	• Energy capture and storage	• Optical satellite links	
• Internet of things		• Visible light communication	

(Image Source: https://ndupress.ndu.edu/Portals/68/Documents/prism/prism_8-3/prism_8-3_Raska_64-81.pdf)

Convergence in 4IR & Dual Use Technologies & the Defence innovation trajectories of USA, Russia & China has been amply elucidated & studied in detail by Michael Raska.[4] The convergence in these technologies (See Fig.1 above) causes an imbalance as far as the technological advances are concerned in various parts of the globe. One can recollect as an example, how during the Gulf War – I, asymmetry in Information & Communication Technology (ICT) led to a Revolution in Military Affairs (RMA). Similarly, since the Cold War, strategic imbalances have been created leading to breaching new technological frontiers. The forecast disruptive technologies will also lead to altering the theories of warfighting as we know them.

A concise gist of the forecasted technologies, a total of 29 of them considered to be the causative agents for RMA has been brought out

Fig.2- Predicted Advances in Technology

	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	

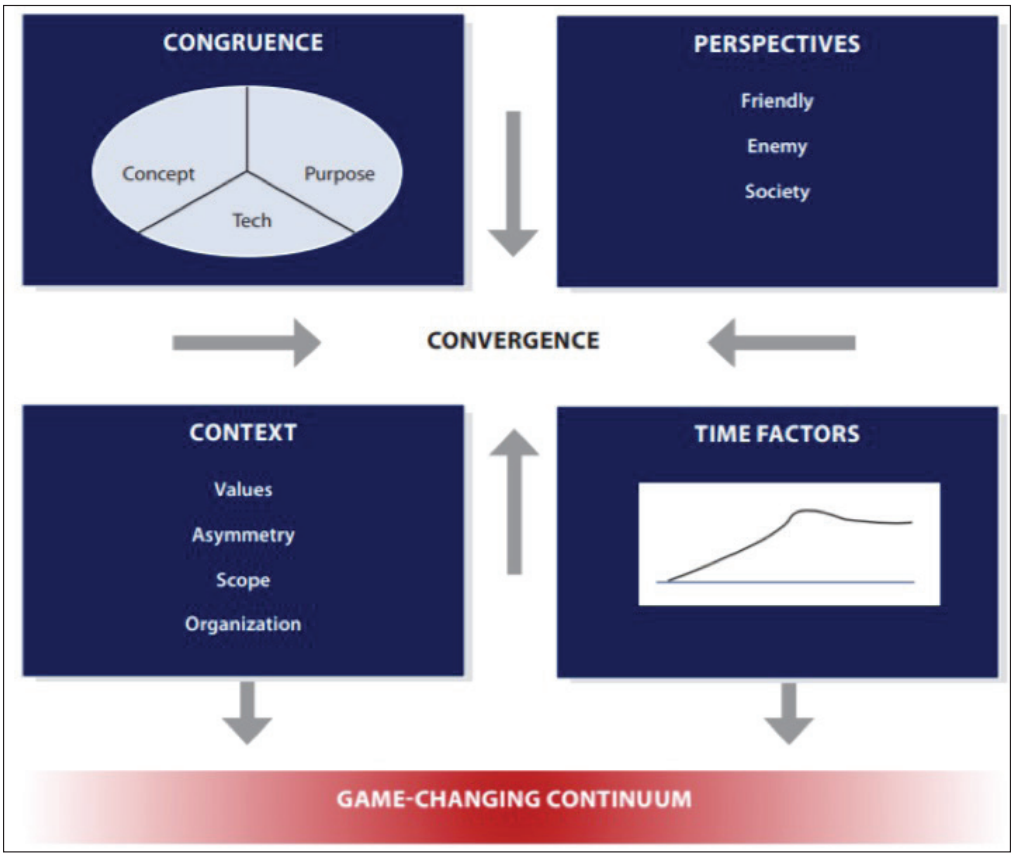
(Image Source: https://www.brookings.edu/research/forecasting-change-in-military-technology-2020-2040, pp 5)

in a book "Technological Change and the Future of Warfare"[5] & later these have been analysed in a paper[6] by the same author. Then, in another paper, the latest by the author, change in military technology in the two decades 2020-2040 has been covered[7]. Projected advances in key deployable technologies has been clearly spelt out & forecasted in this latest paper. Four relevant categories have been considered while retaining the key 29 technologies specified in the book to begin with. The categories are that of Sensors. Computer & Communication Systems, Weapon platforms & fourthly, Weapon Systems with their associated technologies. Stand alone, these technologies may not cause any sizeable change. It will be the synergistic gameplay of these technologies that will lead to actual revolution.

THE WORLD DISRUPTIVE TECHNOLOGY CONTINUUM

What will the technology continuum look like? This has been elucidated very well in the paper by the Centre for a New American Security.[8] The paper mentions that although prima facie, all technologies look game changing, congruence among various factors (concept, purpose & time) will lead to technologies having a game changing impact. Time is an important factor because the effect of game changing technology is time sensitive. Too late, and technology might lose its edge (See Fig.3 below). Congruence among the concept, the tools used to effect the change & the purpose for the technology being used is essential to a game changing technology. Similarly, the perspective matters. To paraphrase from the paper, an aircraft carrier was game changing in the previous century, say 60s or 70s. Presently, a small nation state getting an aircraft carrier capability may cause concern, however, will not have a game changing effect. How the technologies are to be put into use & adopted is governed to some extent by the societal view. Values enable or constrain the development & use cases of these technologies influenced by society at large.

Fig.3 - The Technology Continuum – What Truly Comprises Game Changing

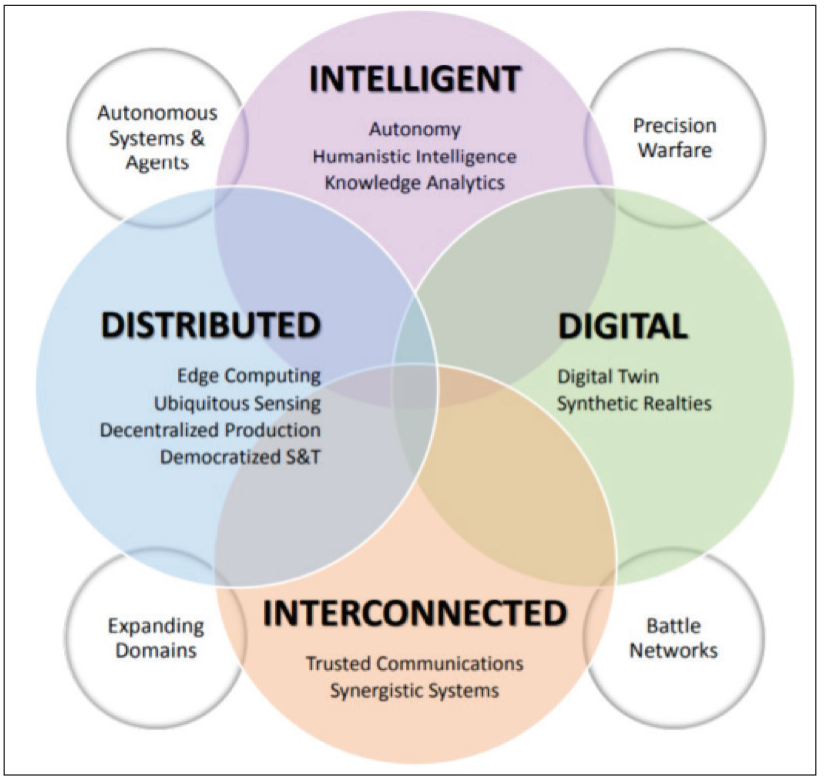


(Image Source:https://www.files.ethz.ch/isn/170630/CNAS_Gamechangers_BrimleyFitzGeraldSayler_0.pdf.)

The NATO Science & Technology Organisation has also proposed the I2D2 (Intelligent, Interconnected. Digital, Distributed) model anticipated for the next two decades where an interplay[ii] of various predicted technologies will lead to development of new technological frontiers/ advances (See Fig.4 below). I2D2 interplay explained in the report as in Intelligent + Distributed = Autonomous systems, Interconnected + Digital = Resilient communication networks, Intelligent + Digital = Precision.

[ii] I2D2 explained as –**Intelligent**: Exploit integrated AI, knowledge-focused analytic capabilities, and symbiotic AIhuman intelligence;**Interconnected**: Exploit network of virtual and physical domains, including networks of sensors, organisations, individuals and autonomous agents, linked via new encryption methods and distributed ledger technologies;**Distributed**: Employ decentralised and ubiquitous large-scale sensing, storage, and computation;Digital: Digitally blend human, physical and information domain.

Fig.4 - I2D2 Model of Technology 2020-2040



(Image Source: D. Reding and J. Eaton, "Science & Technology Trends 2020-2040", NATO Science & Technology Organization, Brussels, 2020.)

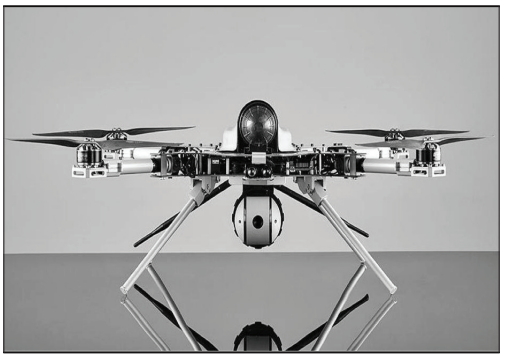
While elaboration of all the technologies classified as disruptive as well the anticipated use cases will not be possible in this brief, a pertinent few will be discussed alongside the developments taking place in major nations of the world.

Artificial Intelligence (AI)

AI as a technology cannot be studied in isolation or as a stand-alone topic or concept. It refers to the entire gamut of technologies that uses algorithms to learn from data, environment & experience. Autonomy & enhanced processing power make it a technology to reckon with. Many

countries such as China are employing state-owned enterprises to exploit this niche technology for use in multiple disciplines including defence.

Fig. 5 - Left: The Boeing Airpower Teaming System is a new unmanned aircraft using artificial intelligence to be that force multiplier. It's designed to work as a smart team with existing military aircraft to complement and extend airborne missions. Right: KARGU -2 Autonomous Attack Drone



(Image Source: White paper titled "The current state of AI in Defence and Security", Defence IQ, September 2020)

To paraphrase form a strategy paper[9] (mainly pointed against China by the USA) on the topic of AI brings out a five-pronged approach to tackle the present situation viz.,

Direct - Selection of prioritised areas where AI is to be exploited as a technology.

Engage - Incentivize participation among the various stakeholders. Sharing & collaboration of data among various organisations.

Govern - Stronger partnerships & collaborations to understand & develop standards for the use of data conjointly & collaboratively.

Compete - Exploit the alliances to gain maximum advantage against all adversaries.

Protect - Protect own technology from falling into or a takeover by the adversary.

Both, China (2017) as well as Russia (2019) have already formulated their AI roadmap & strategy aimed at utilising this technology aggressively. China especially has made it evident to the world of its desire to become the AI leader by 2030. The current use cases of AI (See Fig. 5 above) which have been trial evaluated include the autonomous aircraft as well as drones.[10] US Airforce is already conducting wargames with AI piloted aircraft against usual human-piloted aircrafts. Various use cases of AI can be summarised as given below (See Fig.6 below).

Fig. 6 - AI: Use Cases

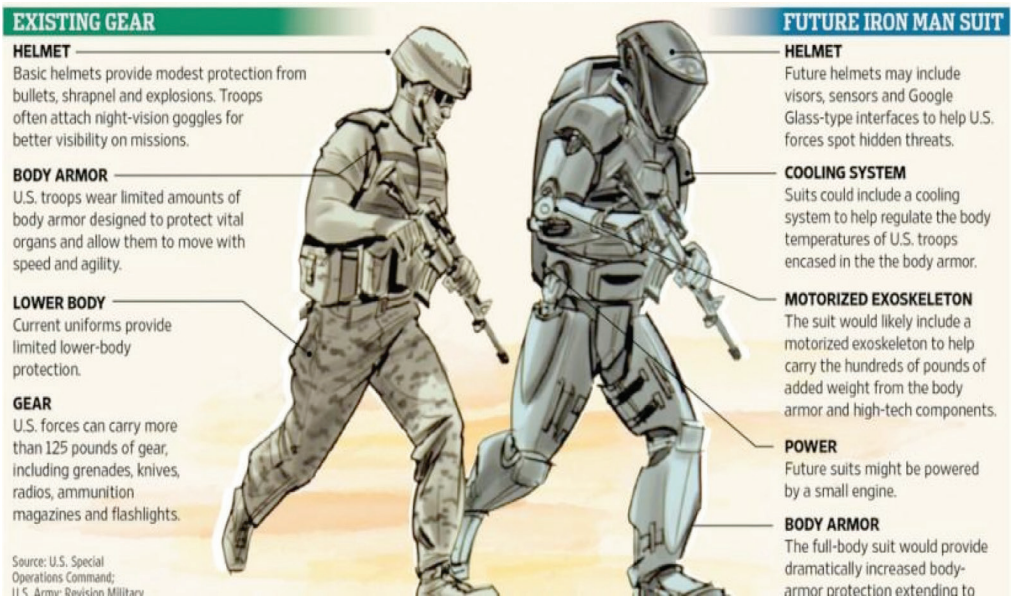
(Image Source: https://www.atlanticcouncil.org/wp-content/uploads/2019/12/AC_CandleinDark120419_FINAL.pdf)

Exoskeletons

A study[11] predicts that by 2050, exoskeletons[iii] will enable soldiers to carry weapons of all calibres, a situation which is unimaginable today. The study predicts the same based on a mathematical formula derived over seven centuries of weapon development & predicts the soldier load carrying capacity to increase by 50 percent by 2050.

[iii] An **exoskeleton** is an external frame that can be worn to support the body, either to help a person overcome an injury or to enhance their biological capacities. Powered by a system of electric motors, the frame gives limbs extra movement, strength and endurance.

Fig. 7 - US Army Tactical Assault Light Operator Suit (TALOS) Project (Exoskeleton)



(Image Source: https://www.slashgear.com/u-s-militarys-talos-project-tapped-hollywood-designer-06336534/)

An overview of the exoskeleton programs in different countries is covered ahead[12]. There can be full body exoskeletons such as Human Universal Load Carrier (HULC) or lower body exoskeletons only as shown below.

Fig. 8 - Left: HULC – Human Universal Load Carrier, Ekso Bionics & Lockheed Martin Below: DARPA Warrior Web Exosuit

(Image Source: https://exoskeletonreport.com/2016/07/military-exoskeletons)

Three more exoskeleton varieties are elucidated, namely, stationary, passive & energy scavenging exoskeletons. Similarly, Russia too is not far behind in this race. Life- saving elements are seen in the Russian Ratnik-3 exoskeleton from Russian weapons maker TsNiiTochMash. The suit is comprised of five subsystems: life support, command and communication, engaging, protecting, and energy saving. (Fig. 9)

Fig. 9 - Ratnik-3 Russian Exoskeleton

(Image Source: https://www.defenseone.com/technology/2018/08/russia-us-are-military-exoskeleton-race/150939/)

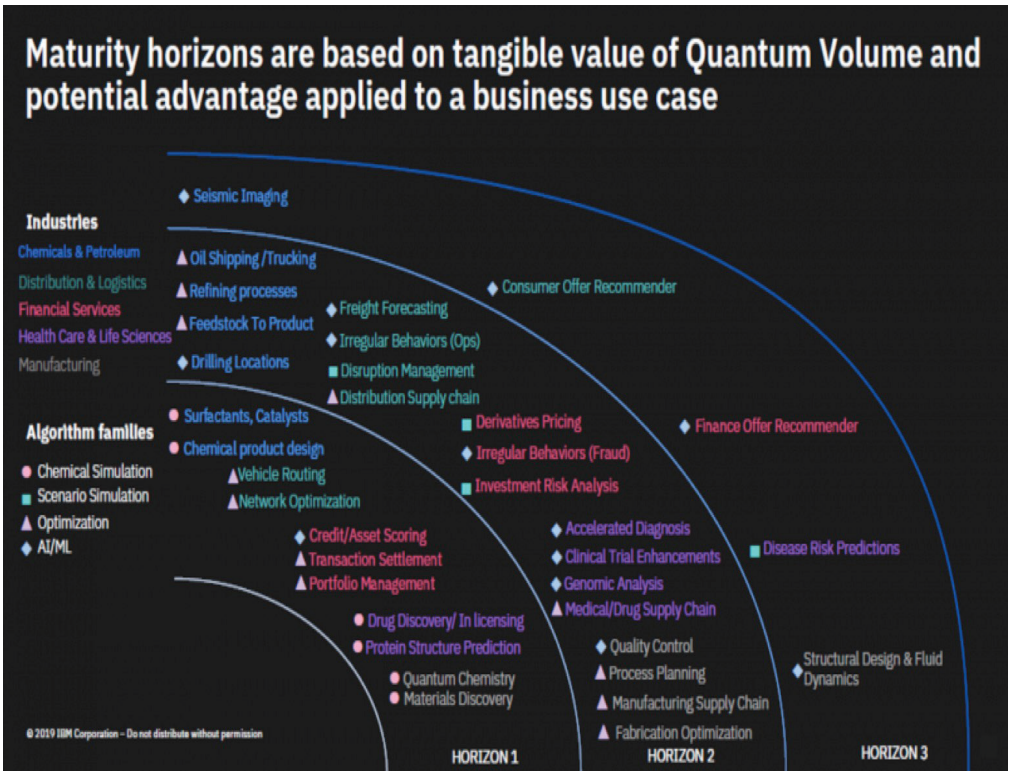
The challenges faced, while designing exoskeletons are varied ranging from load carrying capacity to the range of weapons to be carried. Associated equipment is another factor which is further compounded by the terrain of employment. Degree of movement (freedom) as well as being able to incorporate the technical maturity & intended use all add on to the complexity array while designing such a system.[13] However, the day is not far when 'iron man' turns into a reality & is not restricted to a sci-fi thriller.

Quantum Computing

The most talked about technology after AI is probably the field of Quantum Computing which has far reaching effect on communication & cryptography. Use cases as predicted by IBM have been divided into three horizons viz.,

- Horizon 1: Applications in the next few years
- Horizon 2: After stable but not optimally working quantum computers
- Horizon 3: Beyond 15 years

Fig. 10 – Quantum Technologies - Horizons



(Image Source: IBM, available at https://research.aimultiple.com/quantum-computing-applications/)

Robotics

The scepticism involving having to work with AI/ Robots as part of the fighting squad can no longer be considered as a dream or work of fiction. A study has been carried out which lists out only the requirements for such units, but also scrutinises the after-action reports to serve as an inspiration fuelling further development.[14] Several R&D projects are also in the pipeline for establishing superior ISTAR capabilities.[15] Taking into account that future battlefield will shift to the urban environment, study carried out reveals the tactical & technical requirements for such unmanned ground vehicles.[16] (Fig. 11)

Fig. 11 - Tactical & Technical Requirements of Unmanned Ground Vehicles

Example System	Capability Class	Other Possible Applications
Small robotic building and tunnel searcher ("Searcher")	Teleoperated ground vehicle	Mine detection, mine clearing, engineer construction, EOD/UXO, materials handling, soldier-portable reconnaissance/surveillance
Small-unit logistics mover ("Donkey")	Semiautonomous preceder/follower	Supply convoy, medical evacuation, smoke laying, indirect fire, reconnaissance/surveillance, physical security
Unmanned wingman ground vehicle ("Wingman")	Platform-centric autonomous ground vehicle	Remote sensor, counter-sniper, counter-reconnaissance/infiltration, indirect fire, single outpost/scout, chemical/biological agent detection, battle damage assessment
Autonomous hunter-killer team ("Hunter-Killer")	Network-centric autonomous ground vehicle	Deep RSTA, combined arms (lethal direct fire/reconnaissance/indirect fire for small unit defense or offense), static area defense, MOUT reconnaissance

EOD/UXO = explosive ordnance disposal/unexploded ordnance; RSTA = reconnaissance, surveillance, and target acquisition; MOUT = military operations in urban terrain.

(Image Source: Operational and Technical Requirements." National Research Council. 2002. Technology Development for Army Unmanned Ground Vehicles. Washington, DC: The National Academies Press. doi: 10.17226/10592)

Having seen some of the more pervasive disruptive technologies, let us take a scan of the developments made by leading nations such as USA, Russia, China & the EU.

Comparative Reports on USA, Russia, China & European Defence Agency

A Congressional Research Service report[17] brings out the following pertinent aspects about emerging disruptive military technologies in the USA, Russia & China: -

Artificial intelligence - To be further divided into two categories **- General AI & Narrow AI.** General AI will perform a broad range of tasks while narrow AI will focus on specific tasks for which it has been trained & developed. Narrow AI has been introduced in the military domain with specific use cases like logistics, Intelligence Surveillance & Reconnaissance (ISR) capabilities, cyber operations, Command & control etc. AI algorithms, however, have a major drawback & that is in terms of training the algorithm. A wrongly/ poorly trained algorithm can yield catastrophic results.

China's 2017 Next Generation AI Development Plan describes AI as a strategic technology & China plans to have no holds barred approach by the commercial companies, research laboratories, military & the Government. China too has forayed into the field of swarm technologies & is developing a suite of AI weapons for cyber operations.

Despite Putin emphasising the role of AI, Russia lags significantly with respect to USA & China.

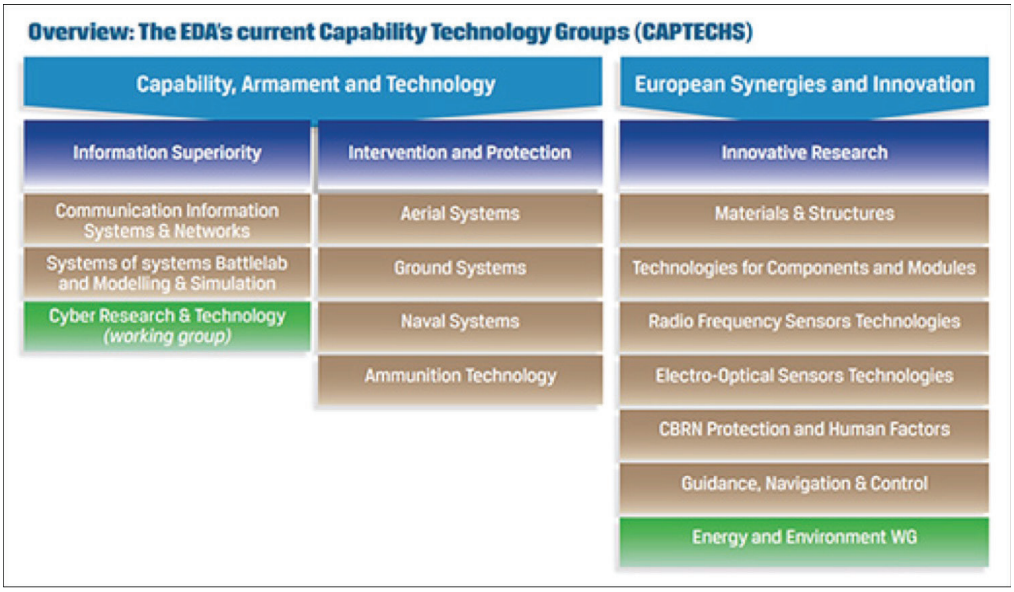
Disruptive technologies listed by the European Defence Agency (EDA) can be divided (based on Capability Development Plan[iv] which was initiated in 2008) as Short term: maturity to be reached within the next 5 years, Short to medium term: maturity to be reached between 5-10 years, Medium term: maturity to be reached between 10-15 years, Medium to long term: maturity to be reached between 15-20 years &

[iv] The European Defence Agency's work in the Research & Technology domain is in line with the Agency's mission to support Member States in their efforts to improve defence capabilities. EDA organises its R&T priorities in different Capability Technology Areas (CapTechs), which are networking fora for experts from government, industry, small and medium enterprises (SME) and academia, moderated by EDA.

Long term: maturity anticipated after 20 years. The various capability based groups where focus has been emphasised is elucidated below. (Fig.12)

EDU Plan - Aim at joint investment programmes for development. Deep learning programme has been launched by the Radar Capability Technical Group. Also, Communication & Information systems group with Modelling & Simulation Group have also launched there AI based programmes.

Fig. 12 - EDA Capability Groups



(Image Source: https://www.eda.europa.eu/webzine/issue14/cover-story/disruptive-defence-innovations-ahead)

Lethal Autonomous Weapons Systems (LAWS) - An unconventional name given to weapons, **Lethal autonomous weapon** systems (LAWS) are a special class of weapon systems that use sensor suites and computer algorithms to independently identify a target and employ an on board weapon system to engage and destroy the target without manual human control of the system. It is disruptive in the sense that it will be employed at various places where traditional systems cannot

operate in degraded or denied environments. As we will see below, the differing definitions adopted by various nations have the ethical angle also to consider.

USA - Department of Defence defines LAWS or 'Man- Out- Of - the- Loop' systems as "class of weapon systems capable of both independently identifying a target and employing an onboard weapon to engage and destroy the target without manual human control".[v]

Russia - For Russia, LAWS could "ensure the increased accuracy of weapon guidance on military targets, while contributing to lower rate of unintentional strikes against civilians and civilian targets."[vi]

China - China has no prohibition on the development of LAWS, which it has characterized as weapons that exhibit—at a minimum—five attributes: lethality, autonomy, impossibility for termination, indiscriminate effect & lastly, evolution on the fly (continuous adaptation).[vii]

Hypersonic Weapons - Namely two varieties, **Hypersonic glide vehicles[viii] & Hypersonic cruise missiles.[ix]** US Navy's Conventional Prompt Strike Program is spearheading the development with a budget allocation of nearly $3.2 billion for hypersonic research.

China has tested the **DF-ZF** hypersonic glide vehicle at least nine times since 2014. Reports have identified the range of the DF-ZF as approximately 1,200 miles and have stated that it may be capable of performing evasive manoeuvres during flight.[x]

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[v] Report of Group of Governmental Experts of the High Contracting Parties to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May Be Deemed to Be Excessively Injurious or to Have Indiscriminate Effects. 23 October 2018.

[vi] ibid (CCW/GGE.1/2018/WP.6 R)

[vii] ibid (CCW/GGE.1/2018/WP.7 P)

[viii] Hypersonic glide vehicles (HGV) are launched from a rocket before gliding to a target

[ix] Hypersonic cruise missiles are powered by high-speed, air-breathing engines, or "scramjets," after acquiring their target

[x] "Gliding missiles that fly faster than Mach 5 are coming," The Economist, April 6, 2019, https://www.economist.com/science-and-technology/2019/04/06/gliding-missiles-that-fly-faster-than-mach-5-arecoming

Russia's programmes include the **Avangard and the 3M22 Tsirkon** (or Zircon). Avangard is a hypersonic glide vehicle launched from an ICBM, giving it extended ranges.[xi]

EDA is planning to acquire a hypersonic missile by 2025.

Directed Energy Weapons - Weapons using concentrated electromagnetic (EM) energy rather than kinetic projectiles can be safely said to be directed energy. The Navy plans to deploy its 60-kW laser, **HELIOS**[xii], aboard the USS Preble in 2021, while the Army plans to field its first "combat relevant" laser—the 50-kW Directed Energy Mobile Short-Range Air Defense System[xiii]—on Stryker fighting vehicles in FY2022.

China has reportedly developed a 30-kilowatt road-mobile DE system, **LW-30**[xiv], designed to engage unmanned aerial vehicles and precision-guided weapons. Based on the inputs of the US Defence Intelligence Agency, China plans to develop direct energy weapons against low earth orbit sensors to tilt the balance in its favour in the Indo-Pacific.

Russia has fielded the **Persevet ground based weapon system**[xv] on the similar lines as that of China.

The EDA selected in August 2019 the winning industry team consisting of European missile specialist, Italian companies CETENA and Leonardo, French companies CILAS and Naval group and TNO, the Netherlands Organisation for applied scientific research. MBDA UK alongside its partners (including Leonardo) is working on the **DRAGONFIRE**[xvi]. Also known as the Laser Directed Energy Weapon (LDEW). MBDA France

[xi] "First regiment of Avangard hypersonic missile systems goes on combat duty in Russia," TASS, December 27, 2019, https://tass.com/defense/1104297.

[xii] https://www.lockheedmartin.com/content/dam/lockheed-martin/rms/documents/directed-energy/HELIOS_Infographic_FINAL.pdf?_ga=2.39690019.1834033795.1607746307-1313878.1607746307

[xiii] https://www.defensenews.com/land/2019/08/01/northrop-and-raytheon-to-compete-to-build-laser-weapon-for-short-range-air-defense/

[xiv] https://www.globalsecurity.org/military/world/china/laser.htm

[xv] https://militaryleak.com/2018/12/18/russia-deploys-new-peresvet-ground-based-laser-weapon/ & https://www.thespacereview.com/article/3967/1

[xvi] https://www.mbda-systems.com/press-releases/dragonfire-laser-turret-unveiled-dsei-2017/

has also opened a new laser testing facility in to test the effects of lasers on materials and to specify future laser weapons for military customers. Developments are also in progress for laser weapons atop naval vessels such as K130 corvette.

Biotechnology - Plans to leverage life sciences for technological applications encompasses the efforts to use (arm/ weaponize) bio-agents as a disruptive technology. Trump administration has released the National **Biodefence Strategy**[xvii] which outlines how the DoD can effectively harness the power of bio-tech weapons to respond to biological threats. DARPA is already running a few programs on leveraging this technology.

China has been one of the first countries to use CRISPR[xviii] on humans for gene editing.

Russia released its BIO2020 document[xix] to highlight its policy towards use of bio-tech, although it lags behind both USA & China in this territory.

As for the EDA, **Next Generation Sequencing -** High-throughput DNA sequencing against bio-agents & EBLN (European Biodefence Laboratory Network) are programmes under development.

Quantum Technology - Quantum physics & Quantum technology are poised to be one of the most state of the art ground breaking technologies. Military applications include communications, cryptography, radar systems etc. US has taken the lead in quantum sensing technologies, however, encryption & communications are in the development phases. “In September 2018, the United States published its National Strategic Overview for Quantum Information Science, which defined quantum science as ‘leveraging quantum mechanics to enhance the fundamental

[xvii] https://www.kff.org/news-summary/trump-administration-releases-new-national-biodefense-strategy-signals-continuation-of-global-health-security-agenda/

[xviii] https://www.livescience.com/58790-crispr-explained.html

[xix] http://bio-economy.ru/upload/BIO2020%20(eng)%20-%20short.pdf

accuracy of measurements and/or enabling new regimes or modalities for sensors and measurement'."[18]

China has been an early leader in quantum research and development. "In 2016, Beijing launched the world's first quantum satellite, which teleported a photon to Earth in 2017. The *Micius* satellite has now successfully completed QKD from orbit to ground stations in Xinglong, China, and Graz, Austria. In 2017, China also established the first long-distance, terrestrial quantum-communication link between Beijing and Shanghai."[19] The planned National Laboratory for Quantum Information Sciences in Hefei, Anhui province, will lead the nation's drive for quantum computing and sensing. China's National Science & Technology Innovation Program highlights the development of this novel technology as a key research area & has given it top most priority.

Despite the Quantum technology Roadmap of Russia, it is still behind USA & China in this sphere.

European nations are also investing substantially and making significant advances. The European Commission's quantum-technologies flagship programme will be a large-scale research initiative over a ten-year period. It is intended to focus on four main areas of quantum technology: communication, computation, simulation and sensing.

OTHER EMERGING TECHNOLOGY TRENDS

Certain other technology breakthroughs which are making waves have also been collated in this brief (Simultaneously, one has to remember the subtle difference between transformative & disruptive technology - **disruption** which refers to a radical change and even dissolution of traditional/ established processes and models, while **transformation** which is rather continuous process of change).[20]

Software as a Service (SaaS) along with egde computing are the driving forces for Battlefield IoT. This will pose a severe security challenge as all the devices & equipment will seem to be connected in a highly complex web.

Augmented analytics coupled with AI & machine learning (ML) will be the basis of decision support systems. Predictive analytics & Big data techniques will thus serve as elements revolutionising the way data is collated &interpreted.

Microwave Photonics - MWP technology, is suited for applications such as generation of very stable multi-band radiofrequency (RF) sources up to millimetre frequencies with low phase noise, precise wideband RF signal detection and digitisation, wideband beam steering of RF signals in phased array antennas, tunable RF filters and stable clock and signal distribution in networks.

Neuro-electronics - Interfacing the brain neurons with components which possibilities for new technological capabilities that could have significant impact on both civilian and military applications, i.e. it can offer novel treatments for neurological diseases & treatment for battlefield trauma, including paralysis, loss of limbs or brain injury.

Smart Textiles including textile antennae are being developed to seek improved camouflage & concealment features while at the same time deriving methods to improve communication.

Hyper enabled Operators along with bionic implants is also a widely being researched field to enhance the efficiency of the war-fighter on the battlefield.

The futuristic technologies that are catching the attention of leading groups in the United States are aimed at Space warfare, communication technology, missile defence system as well as alternative to GPS. While edge computing & cloud networks are paving the way for communication technology, Anti-satellite weapons as well as using Earth's magnetic field for guidance in case of GPS failure are also being simultaneously developed.[2122]

ETHICS OF TECHNOLOGY ACQUISITION & USAGE

Before we move onto the crystal gazing for India, there is a need to

address the concerns over the ethical use of such disruptive technology. With such rampant technological advances & futuristic scope, there also arises a question about the ethics to deal with & implement such disruptive technology. Disruption has & will alter the way man interacts with society at large & how soldiers fight.

Dolly, the ewe, was the first mammal to have been successfully cloned from an adult cell. She is regarded as a major breakthrough in clone technology. In 2004, a human embryo was also cloned. However, the ethics of playing around with 'God's creation' cannot be undermined. Concerns regarding the medical and social side effects of human enhancement technologies have been put out in public domain.

Despite artificial intelligence's (AI) potential for improved targeting to reduce collateral harm, the 2019 winner of the Nobel Peace Prize[xx], among many others, have called for a ban on research on machines that can decide to take a human life. The dual-use nature of cyber technologies raises concerns about the disruptive effect that an adversary's cyber operations can have on civilian life, something that could escalate into a very real war.

Measures have to be instituted to reach a trade-off between the benefits (read deterrence) accrued & the risks involved in the use of such face changing technology. Aggressor nations have to be isolated & convinced against the use of such technology & definitely have to be avoided in the hands of terror groups/ anti-national forces.

One has to always remember that there exists a very complex & fine balance between the society & military. Also, society is affected in a multitude of ways by the technology acquired & used by military. Ultimately one has to keep in mind the fact that a hostile act as perceived by a nation definitely merits a response, but, not 'any' response.

"Einstein was right: The development of the atomic bomb, and I would argue any disruptive technology, should be conditioned on whether it

[xx] https://apnews.com/article/0c99bd564d5f4cc585eb861adb20d28c

avoids a disadvantage for one's side that an adversary would likely be able to exploit."[23]

Prima facie, the development of technology, the one that gives an edge & is of utmost national security needs to be developed. However, the moral compass should guide the forces while using it. It is imperative that this concept is not lost sight of.

CRYSTAL GAZING THE INDIAN SCENARIO: RECOMMENDATIONS & WAY FORWARD

None of the technologies discussed above, in isolation, are ever going to tilt the balance in a particular fashion. However, in the backdrop of increased drone incursions on the Line of Control, the example of the ARAMCO attack by drone swarms & the way we want to project India as a regional power, give credence to the fact that the Indian Defence preparedness needs to participate in a big way to nurture these technologies.[24] The Prime Minister's focus towards Make-in-India (Atmanirbhar) has definitely provided the much need vigour to the MSMEs & Start-ups.

Being a strong nation when it comes to software development, areas of expertise such as AI can be used massively to our advantage. Similar is the case with hypersonic weapons (read Brahmos-II & HSTDV). However, in the field of Quantum physics, we are yet to take a substantial leap forward, although DRDO has demonstrated the communication between two laboratories[xxi]. Equipping the future infantry soldier has also not seen any significant gains.[25]

The competitive edge against China is widening. Hence a multi- pronged strategy is necessary to thwart any misadventures against us & maintain a credible deterrent posture.[26] The way operations are being conducted today & will be in times to come has been completely shaken by the

[xxi] https://timesofindia.indiatimes.com/india/drdo-successfully-demonstrates-quantum-communication-between-two-labs/articleshow/79644952.cms

plethora of development in the technology ecosystem world over. A broad-spectrum term Disruption in Military affairs (DMA) has also been discussed in various fora.[27] An important aspect brought to light is the fact of getting over the organisational inertia & steadily move towards achieving transformation in a graduated manner.

Nurturing such technologies & giving rise to knowledge & technology incubators is the need of the hour. The boundaries between MSMEs, industry & Defence technology institutes has to blur, mix & finally converge towards the final aim of acquiring the tech & thereafter implementing it. It is this deadly cocktail which will lead to India maintaining its global competitive edge. Some initiatives are already in place & available as open source data is covered subsequently.

AI for All - Niti Aayog

With a view to provide impetus to this ubiquitous field, Niti Aayog, India published its **National Strategy for AI in 2018**. Largely driven around the use of this technology for commercial purposes, this document highlights the importance of this technology & how the society can benefit at large.[28] The defence-oriented use cases are under development under the umbrella of IIsT, DPSUs such as DRDO, to name a few. However, we are still at as nascent stage when compared with big wigs such as China & USA. A positive development is to see the various AI based projects that have been fielded as Defence challenges in schemes such as Innovation for Defence Excellence (iDEX).

Emphasis on Startups & Defence Innovation

We need to resuscitate the ailing R&D industry & provide a de novo look towards the Public -Private- Partnership (PPP) as well as fiscal policies especially in the case of disruptive technologies as highlighted. iDEX has come up in a big way under the Defence Innovation Organisation. There is a need to have the Defence forces understanding the concept of ‘Fail Fast, Recover Faster’ in the technology domain.

Israeli Defence Ecosystem is worth emulation. Unit 8200[29], which provides cybersecurity and intelligence services to the IDF and whose alumni have launched so many startups, that the unit is nicknamed "the start-up machine". Many defence startups, led by the veterans of these units have thrived and innovated in the Israeli defence ecosystem. Examples include Team8[30], Elbit Systems[31], mPrest[32] etc. Yozma & Lotem like programs need to be the mainstay to garner such technology breakthroughs.

Issues Plaguing the Present Set Up- We are gradually on our way to developing disruptive technology in defence sector. Although, it has been a late call, we are on our way to recovery. Certain issues which still need a revisit include the following: -

- **Getting rid of the One-upmanship syndrome -** One has to come to think of innovations as a collaborative effort rather than a show put up by a single individual or organisation. This has resulted in parallel developments in isolation leading to wastage of effort & resources. Need is to develop military establishments or training institutes as incubators of such technology in collaboration with industry. Facilities under the Atal Innovation Mission need to be established in military hubs like Hyderabad, Bengaluru, Manesar which afford access to electronics industry readily. This will automatically foster the growth required in the innovation sector. Competitions at University Level, for example the NASA Space apps challenge, DARPA organised competitions & the like need to be held with higher frequency to tap the talent at a nascent stage.

- **Development of a centralised forum for exchange of ideas** - brainstorm with a mix of academia, scientists, production agencies to reach a finished product. Far too many verticals exist who are duplicating the same project, violating the economy of effort. There is definitely a need for cross pollination & breaking of water tight compartments/ Silos.

- **Fast Tracking of Projects is a must**. It is well appreciated that harnessing technology & there after developing it for use is not easy & incurs time delay. However, far too long a gestation period leads to the technology getting outdated, further leading to a change in the requirements of the finished product which inturn leads to addition/ deletion of technology-oriented outcome. Hence, a lose-lose situation for both, the developer as well as end-user. There after it is no point passing the buck to either of the involved parties.

- **Revitalise DPSUs -** Instead of waiting for requirements from the users, why cannot the agencies develop a finished product & offer to the user? Further fine tuning of the product can take part as part of successive iterations. After all, these organisations too, are privy to what the world scene looks like. Just to cite an example, does Apple ask what it needs to include in its iphone range? Definitely NOT. It analyses the market sentiment, scans the environment for contemporary requirements & tries to offer it at a budget. Presently our system is too customer requirement driven.

- **Indian National Defence University (INDU) -** There is a need to encourage Think tank institutes. Also, transform ideas from drawing board to realisation on ground. The INDU should serve as the nerve centre for doctrines, research, sponsorship for candidates being trained abroad, be a congregation of academicians, engineers, scientists resulting in a rapid development - may serve as Military R&D foundation.

- **Funding Issues -** There is a requirement to fast track the paper work, release of funds so that the projects can start. A thorough understanding while the investments are high is required, however not at the cost of losing out on any time required for the technology to bloom.

- Issues of IPR & Technology Management, personnel/ Domain Expertise/ Knowledge Management & Harnessing technology while initiatives to stop brain-drain are also equally important.

CONCLUSION

Sustaining & disruptive innovations form an important part of the military innovation concepts. Sustaining innovations reinforce the existing technologies while the disruptive innovations cause the technologies to change & transform to such an extent that the original form lends itself to perish. The latter is caused by the radical use of many converged technologies resulting in an ultimate change in the very structure (core) of the organisation. It is also governed by the fact of how the technology is actually usd on ground.[33]

Disruptive technologies cannot be considered as a replacement for present day technologies. All the technologies discussed come with their own pros & cons. Most of these technologies being dual-use technologies will require a higher level of discretion while weaponizing them.[34] Technology is a game changer - a fundamental in the transformative change more so in the domain of defence industry where its impact is most profound. The nature of future conflicts will not be based upon the factor of asymmetry alone, but in the manner in which these disruptive technologies will be exploited to gain a decisive edge over the adversary. The technology trends discussed in this report will surely have impact on the future of warfare. Several of the discussed technologies will permit enhanced situational awareness of decision makers as also increased engagement range, precision, speed and faster decision cycles. The dynamics of the battlespace in times to come will dictate the rapid birth & death of technologies which will metamorphose the ways wars have been fought so far.

Throughout human history, we have been dependent on machines to survive. Fate, it seems, is not without a sense of irony.
- Dialogue by the character Morpheus, from the 1999 released Hollywood movie 'The Matrix'.

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ABSTRACT - In the next two decades the overarching characteristics of technology will be rooted in being intelligent (smart), interconnected & distributed. All technology coming in the future will ensure the war-fighter is stronger, more adaptable, lethal & versatile than ever before. The next two to three decades will bring forth a watershed moment in defence technology use cases. Sustaining & disruptive innovations form an important part of the military innovation concepts. Sustaining innovations reinforce existing technologies while disruptive innovations cause the technologies to change & transform to such an extent that the original form perishes. One has to remember that futuristic technologies may not map present-day capabilities as perceived. Speed & complexity of the technologies without a regulatory mechanism in place, may spiral into scenarios where morals & ethics will actually have to play a paramount role in decision making. However, these dual-use technologies are here to stay & transform not only our daily lives but also impact warfare indelibly. Further research is thus, the only way forward ensuring convergence in our actions & processes. One has to understand the current technological landscape & later suggest a coherent & rational framework which will help leverage these technologies to the maximum to benefit the war-fighter.

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