IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

Revolution in Armed Forces Strategies Post Nanotechnology Era

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Abstract:

Nanotechnology is the technology dealing with the nanoscale. It is not about just scaling down macro and micro levels of matter but also changing them to materials having significantly uncommon properties leading to applications in almost every field we can think of. The materials developed using this technology have brought transformations in Science and Technology and have a great potential to lead a breakthrough in real life. With the advancement in technology, the Armed forces around the world have become technical and technology has replaced manpower to a great extent. Nanotechnology has played a vital role on various fronts of the Armed Forces; therefore, their strategies have changed during the post-nanotechnology era. Nanotechnology provides many advanced tools, technologies, and resources to overcome current global problems like extreme weather conditions and reduced dense green areas, increased number of ports on seat belts, increased residential area, etc. Nano properties have a tremendous impact on many military platforms, equipment, weapons, suits, jackets, sensors, mines, bullets, and missiles where materials are of prime importance. Due to these advancements in these fields, it has been revealed that the mode of war has also changed. The quantity of man and muscle power has been superseded by the technical quality of the Armed Forces. The Army, Navy, Air Force, and other paramilitary forces across the globe have undergone a revolution due to advancements in nanotechnology which forced them to apply new strategies during this Nanotechnology era.

Keywords: Nanotechnology, nanomaterials, Armed Forces, Nanoscale, Nano-sensors, nanocomposites.

1. Introduction:

Nanotechnology has emerged as the technology of the 21st Century. A decrease in particle size of the material increases its surface-to-volume ratio thereby enhancing its reactivity and change in its inherent properties. This technology has impacted almost all walks of life of human beings. The Armed forces have undergone drastic change in recent years with the involvement of more and more technology. These forces are deeply benefited by the advancements in technology. Nanotechnology being the most advanced technology, almost all the segments of armed forces are benefited by this technology forcing the armed forces to come out of the traditional ways of protection, attack, and wars. Thus, their strategies have changed drastically after the popularisation of nanotechnology. The army soldiers are exposed to drastic extreme weather conditions and must carry a lot of weight along with them. The suits/uniforms and Jackets developed from nanomaterial fabrics are lightweight, strong, heat resistant, bulletproof, durable, long-lasting, doorless, and do not require frequent washing. Newly developed nanotechnology-based, fuels have better efficiency and improved economics. The tanks: infantry body wear also contains health monitors and communication equipment in which Energy for communication can also be generated by normal body movements. The use of strong and sturdy but light vehicles is needed by all armed forces. Nanotechnology has improved the performance of all kinds of vehicles due to the use of carbon fiber nanocomposite materials which are 40% stronger than aluminum, and 75% lighter, exhibiting extremely good fuel consumption. Many nanomaterials are used for absorbing a good range of electromagnetic spectrum. Using thin film nanotechnology, the aircraft and tanks are coated with microwave absorber nanomaterials to make them non-detectable by the RADARs. The technology also provides medicines and bandages for wound healing which stops bleeding much rapidly as compared with traditional medicines. Nano silver, nano magnesium, and nano Zinc nanoparticles being anti-microbial, antioxidants and anti-browning activities are used in packing to prevent oxygen transfer, product destabilizing, and thermal stability. It makes the food carried by the battalions during wartime more durable and hygienic. It has immensely benefited the soldiers by increasing their strength and immunity during wartime. Nanosensors are of great importance in the armed forces activities. They can be integrated with the threat surveillance reconnaissance technology drones and LIDARs so that objects and enemies are detected from very far distances. Nanotechnology has led to the advancement of RADAR, SONAR, Satellite, and Drones technologies. The coating of nanomaterials has resolved the problem of corrosion largely for Naval Ships. The effectiveness of explosives used in Missiles, Mines, Bullets, etc. is enhanced using Nanotechnology. Due to this advancement, it has been revealed that the mode of war has also changed. The quantity of man and muscle power has been superseded by the technical quality of the defence forces. The chapter will elaborate and justify how the Army, Navy, Air Force, and other paramilitary forces across the globe have undergone revolution due to advancements in nanotechnology which forced them to apply new strategies during this Nanotechnology era.

2. What is Nanotechnology?

It is the technology dealing with the nanoscale of matter ranging from 1nm to 100 nm. The materials having this scale in at least one dimension are said to be nanomaterials. These materials exhibit unique properties. They are developed by either of the Top-Down or Bottom-Up approach employing various Physical, Chemical, Mechanical, and biological techniques. The materials developed using this technology popularly known as nanomaterials have many fruitful usages in Chemistry, Biology, Biotechnology, Medicine, Electronics, geology, Space technology, Information technology, Bioinformatics, etc. with great potential to lead a breakthrough in real life. It has been observed that at macroscale and microscale the properties of the materials change. When one starts reducing the size of the material to nano-level, its appearance completely changes, especially where metals are concerned. The Gold which appears lustrous yellow at the macroscale turns to red or blue depending on the size (Sharon et al, 2019).

3. What are the Armed Forces?

The Cambridge Dictionary's meaning of defence is “the act of protecting someone or something against attack or criticism” and “using or carrying weapons” (Cambridge Dictionary). Therefore, we can broadly say that its the workforce carrying weapons engaged in protecting the Countries/States from any external attack. In other words, the workforce associated with the safety, security, and expanding the boundaries of the states has been part of the forceful human resource took control of with the arms and thus called armed Forces. In other words, the workforce associated with the safety, security, and expanding the boundaries of the states has been part of the forceful human resource with the arms known as armed Forces.

4. Revolutionary applications of Nanotechnology in Armed Forces:

These armed forces have undergone tremendous change from time to time. Their weapons made of wood and leather are replaced by the ones made from the most advanced smart materials falling into the category of nanomaterials. It is not the 21st century when such armed forces are being deployed. It has been a practice since the existence of this system of division of the liveable land by mankind. The only difference between then and today is the kind and type of weapons being used, the resources being used, the mode of transportation being used, the mode and medium of communication being used, the techniques and strategies being used, etc. And if we understand the advancements in the field of nanotechnology, we can certainly say that nanotechnology has changed Armed Forces, or a Revolution has taken place in Armed Forces Strategies in the nanotechnology Era. In a nutshell, the armed forces comprising of Army, Navy, and Air Force have witnessed many significant applications of Nanotechnology and have largely impacted its strategies are discussed below.

4.1 Protection of Soldiers from Extreme Weather Conditions:

The soldiers of all the armed forces are exposed to extreme weather conditions. Under such extreme conditions, they perform various kinds of rigorous physical activities leading to hypothermia in extremely cold weather while being at high-altitude areas and hyperthermia while being in hot regions with excessive and warm clothing (Jayaswal et. al., 2001) It has been revealed that may soldiers die due to extreme climate borne diseases. To overcome this, nanotechnologists have developed nano combat suits that can warm or cool the body and have greater tolerance to temperature change. Battery-operated arctic gloves are used by aircrews operating at high altitudes. They heat automatically if the temperature goes below -20ºC and help the soldiers maintain their body temperature (Oinam Roselyn Devi, 2021). Non-woven polyester materials are used in the gloves as an insulator and wind stopper against the cold wind. Nanotechnology is crucial for such development because without miniaturization such functionalities cannot be adapted to lightweight, wearable systems. Certain fabrics are also used to develop nano jackets which can open or tighten the weaving pattern as their properties change with temperature. These fabrics can also be coated with antimicrobial nanoparticles to protect soldiers’ bodies from microbial infection during extreme weather conditions (Madhuri Sharon et al, 2019).

4.2 Camouflage:

Camouflage is a French word meaning disguise and is used to mislead the enemy by misrepresenting the true identity of an installation, an activity, or an item of equipment. It allows an individual to see without being seen, thereby enabling him to strike first, conclusively, and at minimum cost. (FM 5-20, Department of the Army Field Manual, Ch-1, 1959). The camouflage techniques are used for concealment, disguise, and dummies. These techniques are applied to troops, vehicles, and positions. As a part of the strategy, the armed forces hide their identity during war or otherwise also to remain unnoticed by the enemy. Therefore, all three armed forces wear camouflage uniforms while being on the field which can be Land, Sea, or Sky. The colours of their camouflage uniforms are such that their uniforms match the environment and their existence can be hidden. Nanotechnology provides several possibilities in principle to change the (apparent) colour of a surface (Jurgen Altmann, 2006). With nanoparticle-coated fabrics, the colour of the combat can be instantly changed with the surroundings. These fall under the category of adaptive camouflage. The change in colour of the fabric is based on a reflective electrochromic device. Adaptive camouflage changes colour in response to the environment. These kinds of coating are applied over tanks, vehicles, and other items used on fields. It is called electrochromic camouflage. On the other hand, with the help of nanocomposites, seven-layered ultrathin fibers absorb all 7 wavelengths of the Visible spectrum and hence soldiers wearing it cannot be seen or disappear. An "ultrathin invisibility skin cloak for visible light" is an outcome of this idea (Ni et. al., 2015). It's called metamaterial cloaking as it uses metamaterials.

4.3 Stealth and Cloak: Stealth is a technology that enables militaries to hide their arms, equipment, and vehicles from the electromagnetic waves transmitted by radar. Thereby disallowing them to be detected. The shapes of many fighter Aircraft are designed so that they are not easily detectable to enemy radar systems. Some of the Stealth technology aircraft are B-2 Spirit - (United States), F-22 Raptor - (United States), F-35 Lightning II - (United States), Chengdu J-20 – (China), and Sukhoi Su-57 – (Russia). Also, using the concept of cloaks using which the soldiers can become invisible/non-detectable leading to more complications in dealing with enemies. It has been revealed that if the objects are smaller than the wavelength of visible light (300–700 nm), they pass straight through and cannot be seen. Therefore, the fabrics coated with nanomaterials of 300 nm or less size become invisible even with high magnification. The cloaks are the materials, fully covered with gold nanoparticles. Though it seems beyond reach today, it will become a reality; especially with the recent report of a dielectric "surface wave cloak" from Hao's group (La Spada et. al. 2016), this fantasy seems to be a possibility soon.

4.4 Uniform/Jackets: Uniforms are an integrated part of the armed forces. The basic objective of the uniforms in the armed forces is to make the soldiers feel equal and united. Their uniform must shield them from unpredictable weather, remain durable in varying terrains, and, most importantly, protect them against numerous forms of lethal weaponry (Michelle Revels, 2021). Also depending upon the type of Armed forces Viz. Army, Navy, or Air Force, the colours and types of uniforms are different. But the safety of the soldiers is of prime importance to any armed forces. Therefore, along with the regular uniforms worn by the soldiers during peacetime, various other uniforms with aided safety features are used in the armed forces. Nanotechnology has provided value addition in protecting the soldiers on various fronts. As discussed above in all the above sections from 4.1 to 4.3, nanomaterials are useful in protecting soldiers from extreme weather conditions, hiding their existence in the war fields, and making them invisible to some extent. Along with these features, the various other properties like the hardness of nanomaterials have helped the armed forces develop flexible and lightweight bulletproof jackets. It has also helped develop jackets that can protect soldiers from biological and chemical attacks. Nowadays, suits as thin as spandex containing health monitors and communications equipment reduce fatal injuries. The fabrics used in the combat uniforms have changed to such an extent that it. The fabrics are also coated with encapsulated insecticides to eliminate mosquitoes. Multi-Functional Textiles are also available with advancements in nanotechnology which can be used for sensing, energy harvesting, and energy storage. Which can further be used for various purposes. Many advancements have taken place in the area of Signature Reduction, ballistic Protection, fire-retardant fabrics, chemical/biological protective nanocomposites, etc. (V. Singh et al., 2020). Similar Nanofibers are made from electrospinning techniques and have several other attractive features in developing Combat suits for soldiers in the various armed forces across the world (Pooja Sharma et. al., 2020)

4.5 Armors:

Armors are the most essential requirement for the protection of the soldiers. In ancient times, armoured materials were made up of raw materials of natural origin such as wood and stones. Then skins of animals and metals were used. These materials that we now know as ceramics, metals, biomaterials, polymers and others have undergone man-made transformations; these changes have usually been made at the macro and micrometric scale (Ashcroft et. al, 2001). With the advancements in nanotechnology there has been a drastic development in these types of materials too. Fabricating the stronger and smarter materials to be used for armours have become possible by use of polymer and carbon nanomaterials. Tungsten being 5 times harder than Steel, is used in nanoform for body Armor to give ballistic protection. It is also useful for vehicle Armor, shields, helmets, and protective enclosures. A concept of weaving artificial muscles into Armor is being developed with the help of nanotechnology which can enable soldiers to leap tall walls. Improved body Armor using SiO or TiO_2 nanoparticles embedded in epoxy matrix is being explored which are strong, lightweighted. Carbon nanomaterials, especially those having onion like layering or are multiwalled, i.e., multiwall carbon nanotubes, have also shown strong and durable properties when embedded in polymers. Investigations are underway to make nanosized umbrellas that open to seal the pores, making it impervious to airborne chemicals and pathogens. That would be much easier and lighter than the current equipment required for protecting against biochemical warfare. With the development in nanotechnology, nanoelectronics-based light textiles are developed to protect against various threats like bullets, grenade fragments, bioagents, and chemical agents embedded with physiological sensors on textiles i.e., ECG (electrocardiography) to monitor heart rate, respiration, temperature, dehydration. These suits have a power grid and energy generating system using ZnO nanowires on textile fibres which will act as piezoelectric nanogenerators. To face extreme temperature conditions, thermal management technologies for textiles use carbon nanofibers and CNTs for heat conductance, ventilation, insulation, and local cooling. They will have external sensors for communication and identification. Adaptive camouflage has already been discussed above **(**Madhuri Sharon et al, 2019**).** To protect the lives of the soldiers, it is not only necessary that the armored materials have resistance to being penetrated by projectiles or bullets, but also by sound waves (which can be life-threatening), radiation, viruses or dangerous substances, commonly gases. It is important to highlight that there are properties of intelligent materials such as self-repair, camouflage, memory, and the delivery of medicines by fibers or materials that are being incorporated into military technology (Pio Sifuentes Gallardo, Sharon et. al. 2019)

4.6 Weapons:

After having fulfilled the basic needs of food, clothing, and shelter, the most intelligent creatures of the universe, i.e., Humans started expanding their boundaries of existence while protecting their own boundaries. Hence, started exploiting his intelligence to make weapons from stone, wood, and metal until reaching the use of explosive chemicals and nuclear energy of today. The most recent and advanced field of science i. e. Nanotechnology is now attracting them. Scientists have realized the perfection of nano-sized particles manifested in their mega impact and immense application. (Sharon, 2019). Armed Forces around the world are trying to develop cheaper, lightweight, efficient but most lethal weapons. Weapons focus on precision targeting optimal impact damage and onboard intelligence. Developing non-lethal weapons is also required, so as not to destroy the enemy but rather temporarily neutralize or disable them. Such weapons can be fabricated by using nanotechnology-enabled high-strength and lightweight polymer nanocomposites. Stealth and smart skin materials with built-in condition and firing monitoring sensors will also be of great use (Wisniewski, 2022). Scientists are also trying to develop (i) Nano-sized cone materials that sharpen upon impact and can cause additional damage. (ii) Quantum structures for use as small and efficient directed energy weapons such as directed microwave and laser systems. Nano-dispersed alumina is being used as high energetic propellant. Nanotechnology is also being used to equip weapon systems with sensors for μ-radar, μ-bolometer (infrared) and acoustic arrays for better targeting. (iii) Nanoparticles of aluminium are used to create compact and powerful bombs. These bombs will create ultra-high burn rate chemical explosives much more powerful than conventional bombs. (iv) Mini-nukes that are very small, and light (less than a few kg) are on the agenda of many countries. These mini nukes use super lasers to trigger comparatively small thermonuclear fusion explosions in a mixture of tritium and deuterium, which will be equivalent to less than a ton to hundreds of tons of high explosives. They are known as future weapons of mass destruction. Since these devices will use very little fissionable material, there will be "virtually no radioactive fallout." (v) Just like nano-flotillas for targeted drug delivery, targeted delivery of highly toxic substances to vulnerable areas can be done using nanotechnology. Now it is believed that nanotechnology has the potential to eventually replace conventional nuclear weapons with nano weapons because they are easy to build, easy to deliver but hard to monitor and become obsolete almost immediately. The advantages that defence personnel is seeing in the use of nanotechnology for making weapons of mass destruction will reduce the amount of payload on the stealth fighter planes carrying them and delivery will be more accurate (Madhuri Sharon et al, 2019). High-Energy Laser Weapons High-energy laser weapons carried by trucks are expected to be on the battlefield very soon (Perram et. al., 2004). A laser is being employed by Nanotechnology and Weapons for building the optics needed to track and focus lethal laser energy on to rockets, artillery shells, and mortar rounds. Bonadies (Christopher et. al., 1997) has defined nano weapons as such: "Nano weapons may be constructed applying a combination of techniques and materials to produce very small mechanical devices or inorganic nano-materials or biomaterials that could interact with, and potentially damage or otherwise alter several different biological or non-biological systems" (Christopher et. al., 1997). Nano weapons can also be developed by assembling molecules designed to be used as a Trojan horse to deliver or inject lethal toxin doses of hyper-destructive chemicals that are lethal at the nanogram level. A single small package of such a device can carry billions of such weapons to destroy a population of billions of human beings and other living things, including crops, etc., in one go (Chetna Sharon, 2019). Mini-nukes and mosquito-like robot weapons are being considered for future warfare by several countries. Such nano weapons could be used for firing mini-nuclear bombs and insect-like lethal robots. These insect-like nanobots could be weapons of mass destruction as they can be used or programmed to perform many tasks like injecting toxins into people or contaminating the water supply; they can act like a nano drone and fly into a room to drop poison onto food for targeting a particular group or individual. Since nano weapon research is mostly carried out in an army or defence laboratory, most of the information on their developments are highly secret projects. However, there have been reports that an advanced drone the size of a fly with a set of tiny robotic legs has been fabricated, which can enter any building undetected to perform their function (Sheftick, 2014). Another horrific form of nano weapon that is in the offing is micro-explosives delivered with nanobots, which may be bioweapons with inhalable crippling chemicals or toxins. Eventually, these autonomous bots may become self-replicating. Invisible bullets or needle bullets are other devices that are now at the fantasy level but may soon become a reality. This future weapon of mass destruction can be fired from a great distance to disable victims. Similarly, molecularly manufactured nano dust can be used as infiltrators to affect brain functions, i.e., through neurons to control the mind of the victim, or even may function as "nano mind erasers" that will modify or erase a person's memory by targeting specific brain areas (Bennett-Woods, 2008).

4.7 Cameras/ Drones and Sensors:

For an effective armed force, it is not only important to be well equipped with weapons and safety measures for their soldiers but also with the latest technology to deal with the modern techniques and threats thereof. The use of Nano cameras, and Drones has become a regular feature of the armed forces to identify the existence of enemies and their Equipment hiding their own identity. Researchers from Princeton and the University of Washington have created ultra-compact cameras as small as a coarse grain of salt. The nano camera system employs 1.6 million cylindrical posts that process light. The camera chip can be produced like a regular computer chip. Such micro-sized cameras already exist, and they have uses in medicine and robotics. They can also be used as a detective tool during war or peacetime to keep track on enemy activities (Chris Smith, 2021). Drones are useful in taking video shoots and photos from the aerial view to get a better idea of the battlefield. The Black Hornet Nano is one such military micro unmanned aerial vehicle (UAV) developed by Prox Dynamics AS of Norway and in use by the armed forces of Norway, the United States, France, the United

Kingdom, Germany, Ireland, Australia, the Netherlands, Poland, New Zealand, India, Turkey, South Africa and Algeria (Desk, 2022). The drones measure around 16 × 2.5 cm (6 × 1 in) and provide troops on the ground with local situational awareness. They are small enough to fit in one hand and weigh 18 g (0.7 oz), with batteries (Den, 2016). Sensors of various kinds have become part and parcel of all strategies of armed forces. They use sensors of various kinds, viz. sensing light by photocells, sound by microphones, ground vibrations by seismometers, and force using accelerometers. On the other hand, sensors for sensing magnetic fields, electric fields, radiation, strain, and acidity, are other kinds of sensors used by the different organizations associated with armed forces. Different types of ultrasensitive nano-sized sensors are now being developed for various applications. The use of nanotechnology for developing sensors is focused on (a) Smaller and ultra-compact sensors with the help of micro-electromechanical systems; these nanosensors have an electronic nose and cantilever molecular sensors. (b) Smarter devices are another new mantra of nanotechnology. The nanosensors have Nanotechnology's Entry into the Defence Arena 29 built-in "intelligence" which can store and process data on the spot, selecting only the most relevant and critical items to report. (c) Faster mobility with the help of today's wireless networking technologies; such sensors can send back data from remote locations or even while they are in traveling mode (Madhuri Sharon et al, Chapter-1, 2019).

4.8 Biological Warfare:

There was a time when wars used to be fought with Visible weapons and that too during the day hours with sufficient visibility. There used to be certain ethics of the war. On the other hand, now the wars have no defined timings, no restrictions on the types of weapons to be used (except nuclear weapons) and that is the reason, now most of the armed forces have NBCD (Nuclear Biological, and Chemical Damage Control) branch along with the other branches. Biological warfare is an integral part of war tactics now. The Office of Disarmament Affairs, United Nations defines biological weapons as "Biological weapons disseminate disease-causing organisms or toxins to harm or kill humans, animals, or plants. Almost any disease-causing organism (such as bacteria, viruses, fungi, prions, or rickettsiae) or toxin (poisons derived from animals, plants microorganisms, or similar substances produced synthetically) can be used in biological weapons. The agents can be enhanced from their natural state to make them more suitable for mass production, storage, and dissemination as weapons" (www.un.org/disarmament/biological). Biological weapons (bioweapons) can also be defined as biological organisms, and substances derived directly from living organisms, that can be used to cause death or injury to humans, animals, or plants. Diseases and biological toxins have been used as weapons of war (Joseph et. al 2002) These Biological weapons can be disseminated in various ways, viz. through the air by aerosol sprays, using in explosives (artillery, missiles, detonated bombs), putting/mixing into food or water, by injected into the skin, etc (Edmond Hooker, 2022). People suspect that the COVID-19 virus is also a biological weapon used against developed and developing countries to destroy the world economy, although it has spread all over the world. Nanotechnology helps on both sides i.e., spreading and controlling such biological weapons. However, looking at the hazards causing damage to mankind due to such biological weapons, the International Committee of the Red Cross (ICRC), banned the use of chemical and biological weapons after World War 1 and reinforced the ban in 1972 and 1993 by prohibiting their development, stockpiling and transfer.

4.9 Logistics:

Logistics is an essential element of future warfare. It is concerned with how perfectly and safely the goods are transported and how the speed and efficiency of this chain are improved. In the armed forces, supply chain management forms an important component of logistics. This needs automated, unmanned operations for tracking, tracing, and identification of security mishaps. Nanotechnology and advanced robotics operations deliver critical payloads and materials to designated sites that may be miles across the control system. There will be a need for unmanned ground and aerial vehicles linked to high-precision, multi-platform, and strike capabilities for protecting supplies in transit. Nanotechnology can offer logistics lightweight containers made of nanocomposite polymers that will also be able to absorb shock, reducing the impact of G-forces (Sharon et al, Chapter-1, 2019). Military aircraft also provide logistic supply to forward bases, conduct airlifts (cargo and troops), and participate in rescue operations during national disasters.

4.10 Transportation through Efficient Vehicles:

The performance of the armed forces is dependent on the vehicles used by them to a great extent. Vehicles to be used in defence are expected to be lightweight, multipurpose, intelligent guided, energy efficient, safe and protective for passengers. Armor protection and specific monitoring systems for weapons detection and surveillance also must be taken into account while selecting a vehicle for the armed forces (Sharon et al, Chapter 1, 2019). Nanotechnology has directly impacted all classes of vehicles used by armed forces. It has reduced the overall weight and improved its fuel efficiency and ergonomics. Many nanomaterials exhibit ultrahigh strength or mechanical properties. This is possible due to the use of Carbon nanotubes (CNTs) which have very high intrinsic strength. Whether used alone or in conjugation with other materials, such as polymers, CNTs offer not only stronger materials but also a substantial weight reduction. These kinds of materials would apply to tanks, infantry combat vehicles, gun towers, engineer vehicles, and load carriers. Nanotechnology makes the vehicle stronger in the event of a crash (P K Chakravorty, 2019) (Sanjiv Tomar, 2019). Recently, nanotechnology has been extensively applied in the vehicle industry to bring novel functionalities and improve vehicle performance (Mathew et. al. 2018, Isenstadt et. al, 2016). The application of nanomaterials in vehicles can provide better strength and durability performance over conventional materials. Nanotechnologies may offer new methods or tools for controlling or modifying the structures and properties of the materials used for making vehicles to achieve better performance (Tahmassebi et. al, 2010, Seubert et. al., 2012, Jarosz et. al. 2012). For the specific safety and durability of vehicles (automobile, aerospace, and marines), nanomaterials have the potential to enhance vehicle safety due to their specific properties (Qian et. al, 2015, Lazaro Garcia et. al. 2013, Malani et. al. 2016). Moreover, to manufacture cost-effective and efficient vehicles, various nanomaterials, such as nanopowders and nanocoating, are increasingly being used (Mathew et. al. 2018, Malani et. al. 2016). Within the transportation industry, coatings represent the largest portion of nanotechnology applications in which the optimal selection of nanomaterials can significantly enhance the sustainability of the coatings (Mathew et. al. 2018). The primary objective of the application of nanotechnology is to create safe and sustainable vehicles around the world (Muhammad Shafique et. al., 2019). The outer surface of the vehicles must be very smooth and scratch resistance of coatings is free to enable it to be more efficient and resistance free. This is done on the automotive body and windows (which are mostly made in preferably by incorporating polycarbonates in modern vehicles) to protect nanoparticles in the automotive paint systems (Sharon et. al. 2010). It protects the surface and the underlying layers from mechanical damage, and chemical and UV degradation; preferably by incorporating it in automotive paint systems. Moreover, to increase fuel efficiency, lighter bodies are made using mold-in-color (MIC) color plastics to replace painted interior and exterior components. To improve the scratch resistance of automotive coats, Barna et al. (Barna et. al., 2005) have worked on developing a scratch-proof nanocomposite for clear coatings, through the introduction of nanoparticles, because certain nanoparticles can increase the surface hardness and resistance to indentation. The nanoparticles can be uniformly distributed throughout the coatings, or they can be designed to preferentially segregate to the top surface. Another attempt is to make abrasion-resistant thin film nanocomposites composed of co-sputtered chrome zirconium (CrZrx) alloys on polymeric substrates. This is due to small grain sizes and complex grain boundaries of crystalline materials and a lower atomic packing density of an amorphous phase (Evans et. al, 2012). However, many concerns about using nanoparticles are currently being discussed (Shi et al., 2010) such as the long-term resistance to scratching of the coatings containing nanoparticles primarily at the surface not being known, as the morphological changes during weathering may reduce the effectiveness of this approach. Another approach to combat scratching is developing it based on self-healing technology. (Sharon, 2019).

4.11 Microwave/Radar Absorbing Materials:

The first and most common RAM is composed of tiny spheres coated with ferrites. This is painted on the aircraft. Radar waves induce molecular oscillations from the alternating magnetic field in this paint, which converts radar energy into heat. The heat is then absorbed by the aircraft and then dissipated. Another modified RAM that is now used consists of neoprene polymer sheets in which ferrite grains or carbon nanotubes are embedded.

The military has evolved its electronics engineering development is marked by an endless series of measures and countermeasures. Nowadays, the armed forces have undergone a huge expansion of frequency ranges for their communication system for soldier-to-soldier, soldier-to-satellite, aircraft-to-ground, missile-to-target, and more. Whereas military electronics used to operate in a narrow band of frequencies, today, military design engineers must protect equipment from damaging signal interference and enemy detection at a wider range of frequencies than ever before including radar at frequencies as low as 100 MHz and as high as 95 GHz falling to the category of microwaves. If these microwaves are absorbed, it can eliminate electromagnetic wave pollution and reduce radar signatures; hence, they are used in civil as well as military applications. As reported by Emerson (Emerson et al. 1973) the first electromagnetic wave absorber came into light in the mid-1930s to improve the front-to-back ratio of a 4 GHz antenna. With the development of radar, there has been a growing and widespread interest in radar-absorbing material (RAM) technology. The first and most common RAM is composed of tiny spheres coated with ferrites. This is painted on the aircraft. Radar waves induce molecular oscillations from the alternating magnetic field in this paint, which converts radar energy into heat. The heat is then absorbed by the aircraft and then dissipated. Another modified RAM that is now used consists of neoprene polymer sheets in which ferrite grains or carbon nanotubes are embedded. Stealth technology for defense is an area where these microwave absorbers are employed for effective countermeasures against radar surveillance (John et. al., 1998 & Stonier et. al. 1991). The application of microwave-absorbing coatings on the exterior surfaces of military aircraft and vehicles also helps in avoiding detection by radar. This technology is also applied to unmanned combat aerial vehicles (UCAV) such as the Boeing Phantom Ray (Madhuri Sharon et al, Chapter-1, 2019). Microwave absorbers are employed for effective countermeasures against radar surveillance in stealth technology for defence (John et. al., 1998). The application of microwave-absorbing coatings on the exterior surfaces of military aircraft and vehicles also helps in avoiding detection by radar (Stonier, 1991). Nanotechnology-based next-generation warships of the United States are in the offing. These warships are all electric. It has been claimed that warships based on this new technology will be more effective, will have longer survivability, and will be comparatively cheaper. Various kinds of nanomaterials are the potential stealth materials to be used to reduce radar reflectivity. These include specific paint coatings such as (i) Conductive carbon, metals, and glass fibers; conductive inks or paints with small cell foams; (ii) fine-grained ferromagnetic or ferrite particles suspended in a variety of rubber, paint, or plastic resin binders; (iii) ceramic coatings heavily loaded with electrically conductive fillers or ferromagnetic particles; (iv) radar absorbing honeycomb material that is very lightweight composite with open cells; (v) transparent radar absorbing material; (vi) alteration in the design to avoid detection by radar and (vii) infrared treatments by paints and coatings (Madhuri Sharon et al, Chapter-1, 2019). Ships, Planes, and Vehicles Nanotechnologists have developed invisible left-handed metamaterials that show negative refractive index and therefore could be virtually invisible to the human eye, roaming radars, and heat-seeking missiles. Although this sounds like a fantasy, it may soon become a reality (Sharon et al, 2019).

4.12 Aircraft:

Any country's armed forces cannot be complete without aircraft. Military uses aircraft in both offensive and defensive roles. Aircraft are majorly used by the Air Force. However, almost all forces use aircraft like Choppers, Fighter jets, Fighter planes, etc in one or another way. All the armed forces have a special branch to deal with these aircraft called as aviation branch and the science or practice of building and flying aircraft is called aeronautics. The efficiency of these aeronauts depends upon their Fuel Efficiency, Speed, and armament carrying capacity. Nanotechnology is being envisaged for developing lightweight, intelligence-guided, low visual signature, high speed, and maneuverable fighter jets and missiles, having specific detection and surveillance sensors and weapon systems. Many nanomaterials exhibit ultrahigh strength or mechanical properties. This is especially true for CNTs, which have very high intrinsic strength. Whether used alone or in conjugation with other materials, such as polymers, CNTs offer not only stronger materials but also a substantial weight reduction. In aircraft as well as land vehicles a lighter material will also be a big support for soldiers. It is expected that nanotechnology will offer an overall weight reduction by a factor of 2–3. For making lighter and stronger vehicles or aircraft, composites of polymers blended with other nano-inorganic chemicals, nanoplatelets or nanotubes in a particular ratio have been developed (Madhuri Sharon et al, Chapter-1, 2019). Like the soldiers, it is also important be keep these aircraft less visible to the enemy. Camouflaging was the first and simplest attempt to make a plane less visible to the enemy. Many camouflage schemes such as countershading the aircraft are done to counter visibility, i.e., coating the upper surface with a disruptive pattern of ground colours (green and brown), lower surface with sky colour, and aircraft that fly by night with black colour. Active or adaptive camouflage is another technology that allows colours, patterns and brightness to rapidly change to match the background or the surroundings (Madhuri Sharon et al, Chapter-1, 2019). The strength and weight of the aircraft are the key factors in deciding the milage of the craft. That is the reason Aluminium is used for building the aircraft. Other suitable materials being considered for lighter and faster aircraft is nanocrystalline metals (< 100 nm) and ceramics. Helicopters are another kind of aircraft used by the armed forces. To improve the performance of helicopter rotors, a modification in its shape is done so that it will last longer, and a reduction in rotor vibration is achieved, etc., are also being researched by nanotechnologists (Sharon, 2019). In addition to the large aircraft, for intelligent Surveillance and better protection, the Security Scientists in various defence laboratories are working on a revolutionary idea of manufacturing nano-sized fighter jets that will weigh no more than 10 g. These remote-controlled nano air jets will be as small as a seed and can go anywhere. They can collect military information from both indoors and outdoors and can carry a payload of up to 2 grams. These nano jets will be useful in protecting the lives of soldiers and enhancing operational effectiveness (Madhuri Sharon et al, Chapter-1, 2019).

4.13 Medical Assistance:

It is said that the life in the armed forces is very uncertain. Every day is the last day while serving in the armed forces. All the armed forces have their medical care or wing to deal with their medical emergencies during war and peacetime. The combatants must survive, recover faster and more completely, and return to duty sooner. However, due to growth in science and technology, almost all the fields have progressed to a great extent and so is the field of Medicine. With the advancements in nanotechnology, this field has immensely benefitted starting from the healing of small wounds, blood check-ups, diagnosis and imaging, pharmaceuticals, drug delivery, and treatment of other accidents and diseases that occurred due to odd duty hours. We have already seen in section 4.1 how lightweight, strong, and multifunctional materials used in clothing developed by nanotechnology help soldiers keep their body temperature moderate during extreme weather conditions. That keeps the soldiers fit at high altitudes also. Medical help for a soldier on the field needs a multidirectional approach. Improved medical and casualty care for soldiers is one of the main aims of military research. Most combat injuries in military operations occur due to the penetration of bullets in the body parts caused by explosive munition fragments (Champion et. al., 2003). These types of wounds offer unique challenges to medical providers both on the battlefield and during long-term care. However, recent advances in silver nanoparticles and copper used in the field of dressing have been proven to be better injury materials (Gregory, 2016). Nanotechnology helps monitor vital signs, such as heart rate or brain signals of soldiers. Sensors and antennas for communicating information can be woven into the fabric of shirts or even pillows to use for a wounded soldier. These sensors would also provide the soldier's location to medics via radio. An adhesive chest patch fitted with sensors and a tiny radio can also be used if they are not embedded in the textiles. Another futuristic approach will be to develop medical nanobots and nano-enhanced reconnaissance and communication devices, such as micro-radar, for faster intensive medical help. To help a soldier with an injured arm or leg, scientists have developed nanofibers (that are woven into the fabric of the uniform). This fabric will constrict into a tourniquet and thus save blood loss till wounded soldiers can be treated. Antitoxin guard is made of thin packaging films using nanotechnology that can detect pathogenic microorganisms, which can cause illness or disease. The concept of lab-on-a-chip is being worked out with the advancement in medical technologies. It is expected that shortly, a portable diagnostic kit may be provided; so that the injury can be detected at the point of need. A lab-on-a-chip integrates many laboratory functions on a single chip of only a few mm to a few square cm in size and can handle multiparameter analysis using extremely small fluid volumes of less than Pico liters. A lab-on-a-chip is made using silicon, glass, or plastic with tiny pumps and valves, along with sophisticated readout lasers and advanced charge-coupled device (CCD) cameras, etc. A lab-in-a-phone is a concept that can convert a standard cell phone into a portable blood diagnosis machine that can detect HIV, malaria, etc. Smart flexible phones and GPS for navigation are already on the market to support immediate health care. Nanotechnology-supported targeted drug delivery systems are expected to be of great help in providing timely medical help to injured soldiers. It offers several advantages over traditional drug administration routes including- Increased treatment efficacy, increased specific localization, Decreased toxic side effects, Improved patient compliance, Reduced dose, Controlled biodistribution, and Modulated pharmacokinetics (Kumar et al., 2012. Nanomaterials can be used for selective filtering and purification of the blood. Scientists have imagined developing a wearable, extracorporeal artificial kidney of nano-dialysis system in combination with a micro-pump and nano/micro-sensors, along with a wearable device for the purification of blood. Smart flexible phones and GPS for navigation are already on the market to support immediate health care. The concept of weaving artificial muscles into Armor that could enable soldiers to leap tall walls is being considered. This material uses nanotechnology and electricity and flexes when jolted by electricity and then relaxes when the electricity is turned off. In-situ tissue repair is a part of regenerative medicine in which nanotechnology is applied to stimulate the body to generate new cells in situ via bioactive DNA-carrying nanoparticles that induce specific cell growth. Some nanoparticle-based biomimetic scaffolds are developed for optimal uptake and growth of new cells on them. This is further supported by molecular nanomotors to synthesize drugs, repair damaged DNA, and release drugs in a cell (Madhuri Sharon et al, Chapter 1, 2019).\

4.14 Satellites:

Information and communications technologies are now integral to the conduct of military operations. Forces around the world are committing to constant technological innovation in this field. Satellites are the most important segment of the communication process. Military satellites are mostly used for observation, inspection, remote sensing, telecommunications, and direct television, broadcasting. communication, navigation, intelligence gathering, communication, etc (Ricky, 2014). Many leading countries have dedicated satellites for armed forces from the security and privacy point of view. Global positioning systems, designed initially for military applications, have also successfully transitioned to civilian use. The satellite system has impacted privacy worldwide. With the output of the strong satellite systems, nothing in the world has remained secret. Because of the GPS and allied imaging software like Google Earth, now any corner of the world can be seen on screen thereby exposing all kinds of structures developed and the arms placed at the borders. Now although, it is said that the Armed Forces area is restricted to Civilians for security reasons, many things can be seen on computer screens with the help of Satellite-based systems. Therefore, it has become easier to monitor the activities of the enemy across the border. A reconnaissance satellite or intelligence satellite is one such observation satellite or communications satellite deployed for military or intelligence applications. Nanotechnology helps develop small-sized, lightweight satellite systems with smaller launch vehicles making it cost-effective. These nanosatellites could be used for radar, communication, and intelligence in swarms. Such satellites could also facilitate high-resolution dedicated images of enemy territories. This is expected to not only make them cheaper to manufacture but also to launch them into orbit in space. Trials are ongoing for a distributed network of small satellites instead of one large one. Based on their weight these will be minisatellites (50–500 kg), microsatellites (10–50 kg), nanosatellites (1–10 kg), and even beyond nano, picosatellites (< 1 kg). Each micro-satellite will have its solar panels as a power source. The goal is to develop a complete satellite-on-a-chip, the so-called picosatellites. One Delfi-C3 microsatellite was already launched in 2008 for a 3 kg CubeSat measuring 10×10×30 cm. It flies thin film solar cells, two autonomous wireless sun sensors, and a miniaturized UHF-VHF transponder Sharon et al, Chapter-1, 2019).

4.15 Energy Storage:

Most of the time, the armed forces are required to travel and be stationed in remote places where it is not possible to get physical resources of any kind. On the other hand with the advancement in technology, the armed forces have also become technical to a great extent. Many electronic and electrical equipment must be used by these armed forces to create the basic setup of troops. It is also needed for all the combat systems in defense, such as for wearable invisible or camouflage suits or garments, helmets or head protection and hand weapons, integrated sensors, communication, etc. The energy supply systems have to be low-weight miniature power sources because there is a demand for lightweight batteries with a high energy density for wearable electronics, electric vehicles, and robotics Therefore, they need to have energy storage capacity with minimum space, lightweight, and cheaper systems. There are various energy storage devices like batteries and fuel cells of different kinds. Nanotechnology is used to develop better batteries, such as lithium-ion batteries, with improved energy density, charge and discharge efficiency, and cycle life. It is also useful to develop more durable and efficient fuel cells, which can convert hydrogen fuel into electricity. With the help of nanotechnology, the efficiency of these batteries is being increased substantially. A Li-ion battery stores electrical energy in a chemical form. Nanoparticles are being developed for metal oxide nanocomposite cathodes because they offer higher-density lithium intercalation, excellent electrical conductivity, and improved diffusion. For the anode, graphite and metal alloys are used. It offers higher tensile strength to cope with the increase in volume changes during the charging cycle and provides three times higher energy electrode material (Madhuri Sharon et al, Chapter-1, 2019).

4.16 Food Supply:

Many times, the armed forces are forced to stay back in the forest, Hills, Mountains, Oceans, and isolated areas where it is not possible to cook the food. In that case, they need to carry readymade food and energy drinks to maintain their body strength and stay fit. Nanotechnology offers tremendous benefits for improved food processing, packaging, and safety enhances flavour, and preserves the nutritional value of foods produced. Nanofood and supplements, also known as nanoceuticals, containing added nanoparticles are becoming available. Storing degradable vitamins and improving the bioavailability of nutraceuticals and flavour enhancers can be achieved by nano-encapsulating them. Smart packaging based on nanotechnology is another benefit of nanotechnology in food storage. Nonpackaging material works as a diffusion barrier via antimicrobial and UV-protecting additives that can identify and repel bacteria. In the future, there is the possibility of developing a packaging material that can display (based on polymer light-emitting diodes) information on the source, history since production, and nutritional status of products, such as signaling labels. The use of biodegradable nanosensors for temperature, moisture, time, etc., is also envisaged. Transparent UV-protective films based on TiO_2 nanoparticles along with antimicrobial, antifungal (e.g., silver or zinc nanoparticles) surface coatings are another possible use. A nanotechnological approach for purifying water by photocatalytic decontamination of water as well as air has been successful through many routes, such as by nanofiltration membranes, attapulgite clay, zeolite, active carbon, and polymer filters, using the photocatalytic activity of TiO2 nanosensor for the detection of contaminants. One of the great successes is a portable LifeSaver water bottle that a soldier can easily carry. This bottle has a membrane having 15 nm pores that prevent bacteria and viruses from passing through (Madhuri Sharon et al, Chapter-1, 2019). Nanoparticles avoid the degradation produced by the surrounding environment of the food or by the manufacturing process. Gökmen et al., 2011, have reported that omega 3 was successfully nonencapsulated and used in bread making. In addition to the positive effect of taste masking, thermos-oxidation during baking was reduced. Because of that, the production of other further degradation by-products (i.e. acrylamide) was strongly reduced. Nanoparticles containing essential oil have been used to improve antimicrobial activity in juices (Donsì et al., 2011). In this case, the addition of small amounts of nanoparticles containing terpenes to an orange and pear juice delayed or avoided the microbial growth (depending on the concentration), and thus the organoleptic properties were maintained. The contribution of particles to the stability of foams and emulsions is another aspect of interest in the use of nanotechnology in foods. Most of the foods are (or have been during processing) dispersions like emulsions or foams. Several examples could be derived from bakeries, confectionery, meat products, dressings, and spreads. Another example is the prepared foods. In general, foam and emulsion stability can be improved in the presence of nanoparticles and nanostructures (Paloma et. al. 2017)

5. Conclusion

It has been revealed through the chapter that Nanotechnology has impacted most of the fields related to the Armed Forces. Irrespective of the type of Armed Force, nanotechnology has brought significant improvement in the technology associated with the armed forces. Some technologies have been introduced just because of the advancement in the field of nanotechnology whereas few of them have been enhanced due to it. Combat suits, Armor, Weapons, Cameras and drones, Sensors, Satellites, RADARs, Food Supply chains, Medical assistance, aircraft, Logistics, Vehicles, and their efficiency, etc. have been impacted by nanotechnology. Therefore, all the armed forces across the world have to change their strategies to deal with their counterparts in the post-nanotechnology era.

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