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REVIEW PAPER

Conventional Armaments for Coming Decades

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ABSTRACT

Conventional armaments have continued to play a decisive role even in the present scenario of nuclear weapons and electronic warfare. As a war-fighting technology, they are low cost, reliable, highly effective and proven in several battlefield situations. With the application of advancements in electronics, materials and manufacturing technologies, computers and propulsion technologies to conventional weapon systems, they are capable of having greater flexibility, lethality, accuracy and effectiveness. This communication gives an overview on advancements in conventional armament systems, emerging trends in weapon technologies and modern enabling technologies for advanced weapon systems.

1. INTRODUCTION

The array of nuclear weapons along with chemical and biological weapons may be the most destructive and potent means available to war strategists. However the 'balance of terror' achieved in all these fields of 'ultimate destructive powers' has produced a stalemate in the first use of these options. Chemical weapons convention (CWC) and other international conventions coupled with public sentiments act as powerful deterrents against the use of these weapons of mass destruction. Mere possession of an advanced war-fighting technology does not necessarily empower a nation to employ it indiscriminately. This scenario has ensured that conventional armaments will continue to play a decisive role. 'Strategic defence initiative', 'cyber war', 'star wars' and other technologies of the future will also need the powerful arm of conventional armaments.

As a war-fighting technology, conventional armaments are of relatively low cost, reliable, highly effective and proven in several battlefield situations. The systems can be mass-produced easily and their availability is not subject to the vagaries of imports.

The development of conventional armaments has a long history of incremental progress and would have slowly reached a plateau, but for revolutionary developments in electronics and computers (Fig. 1). These new technologies have added a new dimension to armament technology. The attack on Iraqi nuclear reactor sites in 1980 followed by the Bekka valley operations against Syrian SAM sites in 1982 gave the foretaste of hi-tech warfare with Israelis achieving phenomenal success through integrated use of a spectrum of these advanced technologies. The Gulf war was the first major land operation with extensive use of force multiplier technologies including airborne warning and control system (AWACS), joint surveillance and target attack radar system (JSTARS), F-117 'stealth' fighters, air- and surface-launched cruise missiles, electronic warfare (EW) and electronic intelligence (ELINT).

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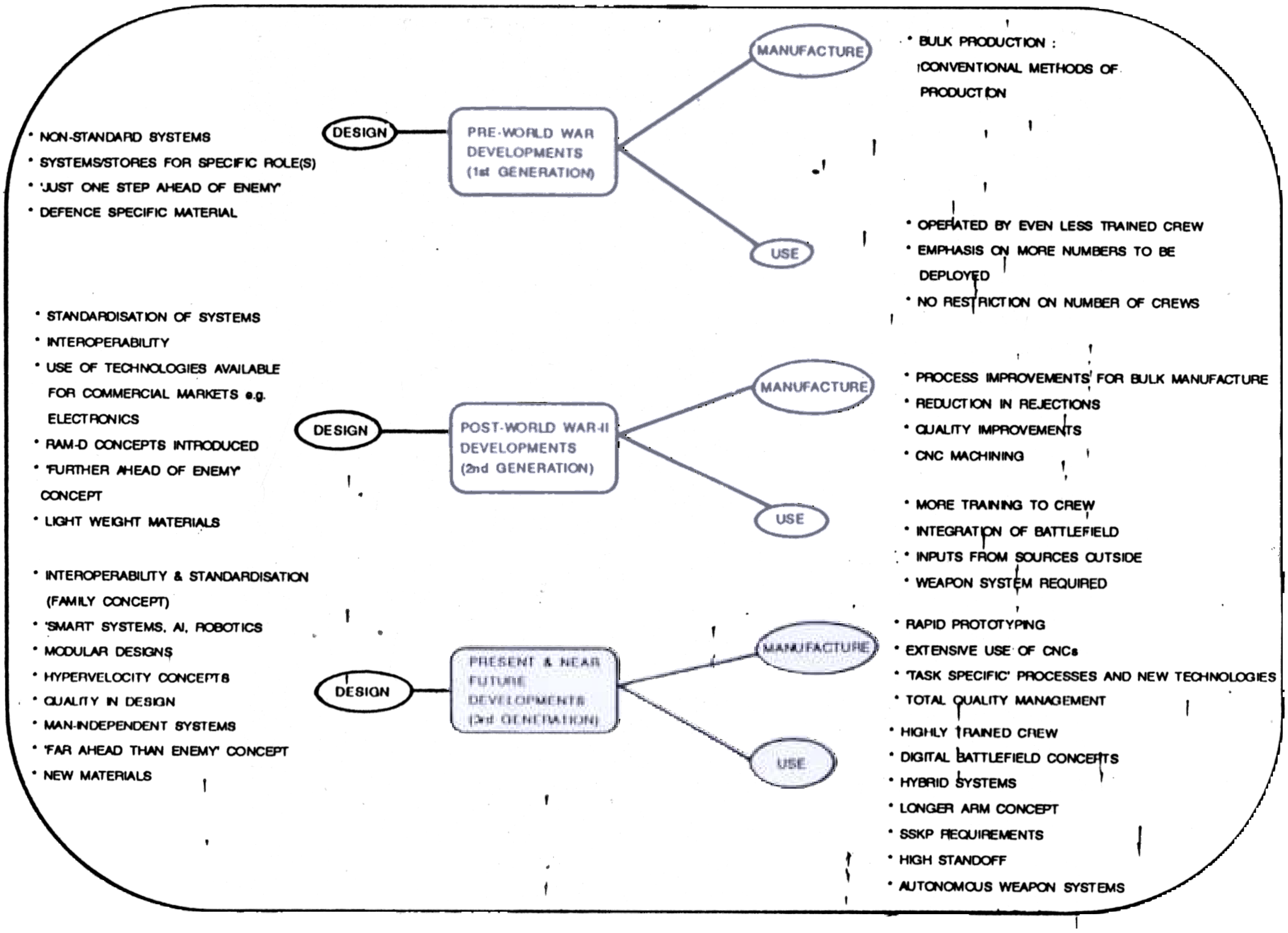

Figure Trends in conventional armaments

Devices like the forward looking infrared (FLIR) night vision, global positioning system (GPS)-based navigation aids, multiple launch rocket system (MLRS) rocket launchers, Army tactical missiles (ATACM) from MLRS, depleted uranium (DU) kinetic energy penetrators and fuel air explosives (FAEs) were all field tested and their worth proved in real world scenarios. This war also yet again proved that a technological edge can affect the final outcome of the war and offset the disadvantage of quantity with quality.

This paper summarises the various driving forces that will dominate conventional armaments in the coming decades. It also makes a mention of the new capabilities that have to be developed in emerging technologies, viz., materials, electronics, propulsion and other allied fields.

2. ARMAMENT SYSTEMS & RECENT ADVANCEMENTS

Conventional armament systems have been deployed by all the three wings of the Defence Services. Different weapon systems have been developed catering to the diverse needs of today's changing battlefield scenarios. Some of the major systems making a substantial contribution to the war machinery are discussed here:

2.1 Infantry Weapons

These weapons include rifle, light machine gun (LMG), carbine & small arms ammunition along with mortars, light anti-armour weapon (LAW), recoilless (RCL) guns and grenades. Developments in the field of small arms have been incremental, reduction in weight of weapon and cartridge being a recurrent theme along with an attempt to achieve maximum commonality in ammunition between the family of small arms weapons. 5.56 mm rifles which fire high velocity projectiles at a cyclic rate of 850 rounds/min may be considered as a representative system. Russia and NATO countries have also shifted to similar small arms systems. Shoulder-fired antitank guided weapons (ATGW) is a potent antitank weapon possessed by today's infantry. Mortars in calibres 51-81 mm and RCL guns with calibres 84-106 mm are used by most of the infantries of the world.

2.2 Artillery Weapons

2.2.1 Guns: Medium, Heavy & Light

Calibres of 105 mm, 155 mm and heavy 203 mm are now standard. The 155 mm is now the workhorse of field artillery and available both in towed and self-propelled (SP) versions. In addition, more and more specialisation is being done with trends towards tracked chassis and armour protection that increases its survivability and mobility. Minimising response time after fire requests, with capabilities to reach new positions before enemy can put counter-battery fire, is a crucial feature. Ammunition for towed artillery presents conflicting demands of range and lightness. They retain their relevance in rapid reaction and air mobile roles. The 105 mm is popular because of its reliability, light weight and range (around 17 km), which outguns standard heavy mortars.

Technologies introduced in the form of extended range full bore (ERFB), rocket-assisted projectiles, and base bleed (BB) techniques that lower the drag have helped to increase the range of conventional tube-launched artillery. Ranges of the 155 mm gun extend up to 30 km with rocket-assisted projectiles and up to 41 km with ERFB/BB projectiles.

Multi-Barrel Rocket Launchers

Multi-barrel rocket launchers (MBRLs) have the capability of area saturation and denying enemy battlefield mobility as well as capability of attacking armour formations with antiarmour shaped charge munitions. The MBRLs can also, to a large extent, obviate the necessity of tactical bombers flying short-range missions. Calibres extend to 233 mm and ranges are around 30 km with typical systems firing at a cyclic rate of 12 rds/m.

Munition technologies for warheads are wide and varied and the selection is done on the basis of target and desired end effects. Different types of warheads being developed include conventional blast, fragmentation, incendiary and shaped charge. Self-forging explosively formed projectiles (EFP) and tandem warheads are being developed mainly for top attack of tanks. FAE warheads that first create a dispersed aerosol and then ignite it to create a blast are new warheads that have already been used to deadly effect in the Gulf war. They can also be used for mine clearance operations. Submunitions in warheads are also being empowered with smart technologies.

2.2.3 Artillery Mortars

Mortars have been useful in indirect fire role, especially in mountainous terrains. Their most attractive feature is their simplicity and ruggedness. Calibres of 120 mm are being used with ranges of over 10 km. The trends include rocket assisted projectiles which can push ranges to over 17 km at the expense of reduced target effects.

2.2.4 Air Defence Artillery

Air Defence Artillery has gained importance right from the inception of aircraft utilised for offensive purposes. Very high rate of fire combined with accuracy and consistency is the prime requirement of air defence guns that have to defend vulnerable points/areas against fighter ground aircraft (FGA). The 35 mm Oerlikon and 40 mm L70 air defence gun systems are in the forefront of weapon systems all over the world. The advent of air defence guns based on Gatling gun has enhanced the rate of fire to very high values. As such, air defence guns can be deployed even against missiles, sea skimmers and low flying aircraft.

2.3 Armament Systems for Armoured Fighting Vehicles & Infantry Combat Vehicles

Armament systems for armoured vehicles have been punctuated by a see-saw battle between armour and kill mechanisms.

2.3.1 Armoured Fighting Vehicles

The primary weapon of the main battle tank (MBT) is a long rod kinetic energy projectile. High density penetrators with *l/D* ratio of 20 are commonly used with recent designs shifting to *l/D* ratio of up to 30. Materials used for the penetrators include depleted uranium (DU) and high density tungsten. The DU, which is easily the best material with its large density and additional pyropherric effects, has problems in terms of radiation hazards and environmental considerations. High explosive squash head (HESH), which can be defeated by spaced armour, is on the way out, but retains its relevance against light armoured vehicles. High explosive antitank (HEAT) projectiles have capability of defeating over 1000 mm of rolled homogeneous armour (RHA). However, new protection mechanisms like explosive reactive armour (ERA), spaced armour, have necessitated the development of new warheads like the tandem warhead, and the explosively formed projectile (EFP) warhead.

Guns that are being used include the 105 mm, 120 mm and 125 mm calibre. Most of the state-of-the-art guns are variations of the German Rheinmetall 120 mm smooth bore gun.

2.3.2 Infantry Combat Vehicles

The primary function of the infantry combat vehicles (ICVs) is to carry personnel. As a consequence of this, the space available for armament is limited. The global scenario indicates calibre in the range 25-60 mm for high velocity guns and 73-100 mm for low pressure guns. Muzzle velocities range from 900 to 1400 m/s with ammunition including the high explosive (HE), HEAT and armour piercing incendiary (API). Machine guns and autocannons have the advantage of favouring crew capacity over firepower with the latter having the capability of engaging thin-skin targets as well as enemy infantry. Other ICV weapons include automatic grenade launchers (AGLs).

2.4 Air Armaments

Conventional air armaments which include guns and bombs continue to play a major role which may be outlined as follows:

2.4.1 Guns in Air-to-Air & Air-to-Ground Roles

For aircraft guns calibre selection is a compromise between ground attack roles which generally require a higher calibre gun, while the air-to-air role requires a smaller calibre, high rate of fire guns. Calibres range from 20 mm M-61 multibarrel guns of the F-16 to the 27 mm and 30 mm guns of ground attack aircraft with some aircraft deploying both types of guns. Firing rate can be as high as 6000 rpm.

2.4.2 Dumb Bombs

These include ballistic as well as retarded bombs used mainly for runway denial purpose or as cluster weapons. Cluster weapons having tactical munition dispensers can dispense a number of bomblets/minelets for runway cratering or air field denial roles.

2.4.3 Standoff Smart Bombs

The modern trend is a shift away from dumb free-fall bombs to powered or gliding standoff ammunition, which will form a growing proportion of air arsenal. Such munitions do not need to penetrate point defences surrounding the target and substantially erode the effectiveness of enemy air defences. Bombs in this range include the US GBU series, which is initially released in the glide mode and at a later stage motor takes over and provides standoff distances in the range 20-30 km. Other versions with snap-out wings have range enhanced to 100 km. The current emphasis is on defeat of hardened/deep-buried targets like command bunkers, hardened A/C shelters (HAS) and runways.

2.5 Naval Armaments

Naval armaments have to tackle myriad threats from air, underwater as well as surface craft. As in the case of air armaments,conventional armament continues to play a crucial role.

Naval Guns

Guns are staging a comeback in littoral warfare role for bombardment of shore targets at extended ranges in addition to their conventional role in ship and shore defence.

2.5.2 Torpedo Warheads

Anti-submarine torpedo is the main kill mechanism against submarines as well as surface ships. The torpedo is a compromise between endurance, size of the warhead and weapon control equipment. The over-riding aim is to remain undetected so as to give the opponent no chance to counterattack. Torpedo warheads may be launched from submarines, surface craft or from helicopters.

2.5.3 Naval Mines

Naval mines impede movement of naval and civilian craft and consequently wield tactical influence disproportionate to their cost. These devices are extremely sophisticated and can be triggered by a variety of methods, including increase in pressure due to a passing vehicle, magnetic effect of a ship's hull, or acoustically. The activating mechanism may be set to ignore certain signatures or to respond only after passage of several potential targets.

2.5.4 Decoys

These systems are developed to provide protection to ships against missiles and to confuse launch platforms. They are basically chaff dispensing electronic countermeasure systems and may be deployed from a rocket, gun or grenade launcher.

2.6 Fuzes & Armament Electronics

Fuze systems capable of operating in a variety of modes, including graze, impact, proximity, delay and variable time, capable of sustaining severe launch environments have been deployed for the whole range of munitions for Army, Airforce and Navy. Increasingly miniaturised, ruggedised electronic and microprocessor-based intelligent fuzing systems are replacing the conventional mechanical fuzes.

3. MISSION REQUIREMENTS & DESIGN CRITERIA

A large number of factors need to be considered in weapon design, depending on mission requirements. With time, these criteria have expanded and become complex, necessitating flexible weapon systems.

Target characteristics vary from the well protected AFVs and concrete bunkers, ICVs with relatively light armour protection to the practically unprotected infantry. The requirements of damage mechanism and warheads change with the type of target. The tendency to minimise the signatures of today's weapons has made the job of acquisition more crucial. Mobility and 'shoot and scoot' capabilities that today's armies advocate to protect them from counter-battery fire require usage of new light-weight materials and composites. The extended range of today's weapons has made improved fire control, laser range finders, and some methods of homing unavoidable, if desired accuracies are to be maintained. The necessity of avoiding colateral damage and civilian casualties coupled with the extra-large standoff ranges of todays weapons have resulted in technologists looking towards smart weapons to achieve the desired goals. Trends towards lowering the vulnerability of fielded systems have given rise to new propulsion concepts. Tomorrow's wars may be fought in all kinds of terrain both in day and night, in the presence of hostile electromagnetic interference with a premium on reliability and ruggedness. The change of philosophy in weapon system from 'quantity to quality' can be brought about only by making major infrastructural changes, particularly in manufacturing concepts. Tomorrow's electronic battlefield has changed requirements both in crew skill and comforts. Today's post-cold war scenarios have changed threat perceptions. The armament engineer has to reconcile to a multiplicity of divergent driving forces.

4. EMERGING TRENDS IN WEAPON TECHNOLOGIES

A growing shift towards lighter systems, towards the doctrine 'smaller is better', towards enhanced mobility, protection and firepower has become an encompassing motto for armament engineers.

Product improvement programmes and midlife updates are becoming common in weapon system development. Rapid prototyping, flexible manufacturing and virtual prototyping can give rise to systems that can be modified fast, keeping expenses low. New developments in virtual reality will simplify and accelerate the design process. Mechatronics, micromachining and micro electro-mechanical systems (MEMS) developments will be of vital importance in armament development.

Materials technology is central to improvements in conventional armament and include high temperature, high strength, light weight, erosion/ablation resistant materials, new alloys and composites along with the associated manufacturing technologies. Material technologies directed at signature reduction (infrared and electromagnetic signatures on land and acoustic signatures underwater) along with 'Stealth' technologies can improve the effectiveness and survivability of systems.

4.1 Electronic Battlefield

The most noticeable trend is the growing importance of the electronic and computer revolution. This revolution is fuelled by quantum jumps in semiconductors and microelectronics. Advanced fire control, avionics, night vision, radar along with other technologies have combined to give these weapons greater flexibility, lethality, accuracy and effectiveness.

The new family of improved conventional munitions and smart munitions are set to play a bigger role in future conflicts. The level of smartness varies from the GPS-guided competent weapon system as in barrel launched adaptive munitions (BLAM), the terminally-guided weapon incorporating imaging infrared (IIR) millimeter wave (MMW) smart sensors that identify target and attack it, to the brilliant ammunition, which have the capacity to identify targets, select targets, attack at the most vulnerable point, defeat counter-measures, and liaise with companion bomblets so that all do not attack the same target, conduct damage assessment and strike again, if necessary. Damage mechanisms are wide and varied and are discussed in the next section.

Hardening has to be done for very high *g* launch environments (10-20000 gs), against ECM and against electromagnetic pulse (EMP) generated by both nuclear and non-nuclear warheads and high power microwaves that can damage unprotected electronic circuits. Lasers for direct initiation of explosives will also play a role in this field of hardening conventional weapons.

4.2 Infantry Weapons

Small arms will focus on integrating the soldier and weapon system into an integrated fighting unit. Light mortars used in the infantry are being increasingly replaced by rifle grenade launchers. Shoulder-fired antitank guided missiles (ATGMs) are being further improved.

4.3 Artillery Weapons

Guns and MBRLs are complimentary and will continue to coexist. Armies employing both will have a wider range of options. Trends are towards larger calibre guns, which facilitate introduction of greater number of submunitions. The MBRL will be increasingly used for the deployment of antitank mines and the newer smart ammunition, including brilliant ammunition, particularly against tank formations.

Trends in mortar include possible use of liquid propellants and automatic loading, which is particularly useful as calibres become larger. In addition, there are schemes under which the mortar's high angle of fire is used to achieve top attack with smart and brilliant submunitions. Other improvements include introduction of GPS, ballistic computer, breech loading, turret mounting on ICVs, all aimed at improving the response time of mortars.

The concept of cargo ammunition, improved conventional ammunition (ICM) and dual purpose improved conventional ammunition (DPICM) gives a decisive edge to armament technology. These ammunition can be either tube launched or fired from conventional tube artillery.

The ERFB, BB and rocket-assisted projectiles will continue to be refined in artillery and naval gun systems. Newer schemes like the South African velocity enhanced long range artillery (VLAP) combining base bleed and rocket assistance are pushing ranges to 50 km. Multiple round simultaneous impact (MRSI) concepts will be of great value in confusing enemy fire. Ultra-light weight 155 mm projectiles made mainly from titanium alloy are also being developed. Improvements in fire control radars and digitised battlefield intelligence systems are expected to have a force multiplier effect in artillery guns.

4.4 Mines

Anti-personnel mines have been controversial and there is a wide consensus fuelled by growing public opinion that these should be banned. However, this technology in more acceptable forms, including remotely delivered mines (RDMs) and wide area mines (WAMs), against armour and helicopter and intelligent mine fields are being developed as future cost-effective deterrents to enemy advance. New mines with smart sensors attached are proposed for changing the mine to an active combat arm from the passive area denial weapons of the past. These intelligent mines can assume a major role in antitank defence with lower manpower and added advantage of air transportability. These new mines will have features for neutralisation making it possible to redeploy the mines, if necessary. An entire array of proposed mines include conventional and fibre optic-guided antitank mines with remote fuzing, dynamic mines, such as pop up mines, wide area denial mines with multi-mode sensors optimised for top or side attack of armoured vehicles and anti-helicopter mines. Also envisaged are semi-autonomous or remotely controlled battlefield robots employing antitank rockets or mines with self-forging fragment warheads.

4.5 Armoured Fighting Vehicle

Future trends in armoured fighting vehicle armament in calibre may involve a shift to 140 mm with an integrated autoloader. Muzzle velocities are expected to shift upwards towards the 1800 + m/s and muzzle energies to the 15-18 MJ range. However, new protection mechanisms like explosive reactive armour (ERA), spaced armour have necessitated the development of new warheads like the tandem warhead, and the explosively formed projectile (EFP) warhead. The preferred mode of delivery for these warheads is missile launched, making attack on the vulnerable top of the tank possible. Missiles fired from tank main armament are emerging as a complimentary kill mechanism with Russia as the world leader. These missiles have a greater lethal range compared to guns. More use of ceramic armour may give rise to the requirement of hypervelocity projectiles, which may become the only defeat mechanism for frontal attack. Hypervelocities may be achieved either by electrothermal chemical (ETC) or electromagnetic (EM) railgun. New projectile concepts like segmented projectiles will have to be explored to take full advantage of hypervelocity. EM-based gun may lead to a future 'all electric tank'.

4.6 Propulsion Technologies

Research in advanced solid propellants with several schemes of propellant modification include deterred or inhibited propellants, programmable energy release concepts, consolidated charges, very high burning rate (VHBR) monolithic propellant concepts and temperature compensation techniques.

Ramjet and travelling charge concepts continue to be explored with solid fuel ramjets (SFRJ) being a promising configuration for future extended range artillery guns.

Liquid propellants and ETC electric guns hold out the promise of cheaper, less vulnerable and caseless propellants capable of achieving extended ranges. Electric guns (both ETC and EM) have the capability of accelerating projectiles to hypervelocities. Bulk-loaded liquid propellant gun (BLPG), mechanically the simplest to implement, suffers from limitations like lack of control over the internal ballistics process, catastrophic failures, variability in pressures and muzzle velocities, etc. The regenerative liquid propellant gun (RLPG), which involves the injection of liquid propellant into the combustion chamber, has been a subject of much research, particularly in the USA, and a 155 mm gun is in an advanced stage of development. However, the programme suffered setbacks primarily in the form of combustion instabilities and problems associated with compatibility of the liquid propellant, leading the US Army to revert back to solid propellant technology for the advanced field artillery system (AFAS) armament in March 1996. The work still continues and future breakthroughs may bring this technology back to centre stage. Electric gun research is being carried out in USA mostly in laboratory environments. Projectiles in the 8.5 MJ energy range as well as full scale tactical rounds have already been test fired at several laboratories woldwide. Electric gun technologies are at present constrained due to lack of compact power supplies. Power supply development is in progress to bridge the gap between the state of the art 3 kJ/kg and practical weapon technology requirements of 10 kJ/kg. Room temperature superconductors capable of sustaining high electric currents and fields can revolutionise the entire concept of electric guns.

4.7 Air Armament

Air defence artillery will work in conjunction with air defence missiles. Emphasis will be not only on defence against aircraft and helicopters but also against missiles, including Theatre ballistic missile warheads. Guns will also continue to play a role in air-to-air combat, especially in the context of developments in aircraft agility like thrust vectoring and integrated digital fly-by-wire controls. In air armament, dumb bombs are being converted to smart bombs using conversion kits. Development of rocket/air breathing propulsion kits to enhance the range of bombs to 80 km is also being attempted.

4.8 Naval Armament

Though missiles are the major protection mechanism against hostile anti-ship missiles, guns still have a major role to play as close-in weapon system (CIWS) after the outer screen of defensive missiles has been penetrated. Small calibre high firing rate guns have the capability to destroy the missile warhead as close as a kilometre from the ship. Air defence is a formidable task, especially when one considers key features like saturation and variety in the threats and the guns require to be fully automated and radar controlled to achieve the required response times. Increase in ranges in excess of 100 km may also become feasible with new propulsion concepts. New projectiles include 3P (prefragmented), armour piercing discarding sabot (APDS) and missile penetrating discarding sabot (MPDS).

4.9 Warheads

Self-forging EFPs and tandem warheads are being increasingly refined and fine-tuned. New developments include the fletchette warheads that release a large number of fin stabilised darts and special warheads for hard target penetration. These have a shaped charge to achieve initial penetration of concrete allowing the penetrators to follow and explode inside the structure. Also included in research is the development of multiple small EFPs, aimable warheads and warheads with controlled fragmentation either with constant mass or variable predetermined mass.

5. OFFBEAT CONCEPTS FOR FUTURE WARS

5.1 Non-Lethal/Less Lethal Weapons

This new class of munitions aimed at personnel/material immobilisation include several varieties, such as:

(a) Interference with lines of communication, say by introduction of computer virus,

(b) Disabling of power grids, as demonstrated in the Gulf war in the form of air deployed shorting carbon fibre,

(c) Damage of unprotected electronic systems by high power microwave or radio frequency generators or non-nuclear EMP generators using explosive flux compression,

(d) Directed energy weapons, including plasma bullets, neutral particle generators, high power lasers, high power microwave weaponry, which can be used against ballistic missiles and electronics,

(e) Portable lasers to be used against sensors and personnel that can disable optical and IR systems,

(f) Novel methods in antipersonnel/anti-material role include sticky foam, super-glues, deployable nets, entanglement weapons and high voltage stun guns,

(g) Liquid metal embrittlement,

(h) Combustion alteration technology, including chemical additives that change the fuel content, types of chaff with pyropherric particles that destroy engines, and

(i) Anti-traction technology in the form of super-lubricants that immobilise vehicles.

6. ENABLING TECHNOLOGIES

A large number of new technologies will give a cutting edge to conventional armaments of the next decade. These technologies are now subject to substantial research and will have to be mature in concept and robust enough for practical military applications coupled with affordability, manufacturability and durability. These technologies include:

6.1 Sensors & Fuzing Technologies

These include new technologies like charge coupled devices—low level television (CCD-LLTV)/focal plane imaging IR/MMW/laser illuminated detection and ranging (LIDAR), etc. imaging infrared (focal-planar array) laser, acoustic, magnetic, seismic technologies. Integration of micro-electronics and mechatronic elements with sensor technologies makes it possible to have a new generation of sensor integrated fusing systems for both target sensing and initiation of kill mechanisms and sequencing functions for cargo/submunition warheads.

6.2 GPS/INS Position Fixing Technologies

The new generation of smart weapons depends on these to a large extent to provide them with positional data to achieve mission goals.

6.3 Piezoelectric Materials

Piezoelectric materials have potential applications in projectile course corrections after leaving the barrel. Poled piezoelectric materials can act like a compact power source or as high voltage generator, when depoled by explosives. It has applications as impact initiator for different types of warheads.

6.4 Software & Digital Technologies

This wide field envisages developments in new software systems, digital signal processing, image processing, neural networks and massively parallel processing (MPP), automatic target recognition systems, integrated optics, cryptography and C^3I systems in a munition environment.

6.5 Artificial Intelligence

Machine intelligence and artificial intelligence are expected to play a big role in battlefield intelligence management and to lead to flexible manufacturing techniques.

6.6 Remotely Piloted Vehicles & Robotics

Remotely piloted vehicles (RPVs) are being increasingly used to direct naval, artillery and aircraft attacks in addition to their role in jamming and deception. Pocket-sized pilotless flying vehicles can improve information gathering and scouting, while battlefield robots have the potential to replace human beings in high risk areas.

6.7 Simulators, Modelling & War Gaming

Simulators are of particular use for training personnel in real world situations. Infantry trainers, tank warfare and aircraft simulators help soldiers to hone skills and optimise weapon usage. Modelling and war gaming are being increasingly used in weapon evaluation and battlefield strategy development.

6.8 Fibre Optics

These technologies are useful in missile guidance and communication systems that are difficult to jam. Fibre optics-based weapon platform control can lead to remotely operated platforms that minimise risk to personnel.

6.9 Pulsed Power & Compact Electrical Energy Storage

This research is of vital importance in determining the future of hypervelocity electric guns, directed energy weapons, high energy lasers and high power microwaves.

6.10 Hypervelocity Projectiles

New projectile concepts like segmented projectiles need to be explored to exploit the potential of hypervelocity electric guns. Hypervelocities, besides achieving extended ranges, may become mandatory for defeating some of the new ceramic armour being developed. These may be virtually impenetrable to conventional projectiles.

6.11 Superconductivity

Room temperature super-conductivity is a technology that can change the entire face of weapon technology. It can have a major bearing on compact electric generators, electric energy storage, pulsed power systems, directed energy weapons and high power lasers.

7. CONCLUSION

The conventional armaments are necessary. However, development trends show that we are fast approaching saturation levels in design and performance. The process has been evolutionary so far. At the same time, the demands on performance criteria are increasing. New technologies are being researched into meaningful applications to armaments, but they have their own effects. Keeping the cost at affordable levels and making highly reliable, if possible, maintenance-free systems, is a real balancing act for the designer while using new technologies. There are two options: One philosophy is 'to do more with less' —modify existing systems on this line. In the era of shrinking budgets and demands on performance enhancements, improvements in conventional armaments will be the quickest way to earn an incredible leverage. The second philosophy would be to wait for something 'revolutionary'. We can neither wait long enough, nor can we afford to do without these 'revolutionary systems'. Clearly, both options have to be kept open.