Self Reliance in Emerging Defence Technologies

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Introduction

To provide national security, the Indian military must be able to dominate the complete range of military operations. Key to achieving this full spectrum dominance will be the ability of defence forces to acquire technologies that enable it. Technological superiority being the decisive factor in future battles, it is imperative to build indigenous capabilities, relevant to specific requirements. It is becoming increasingly important for a country like India to be able to exercise its own independent foreign policy in the interest of its national security. This can be achieved only through a sustained effort to technological self reliance that would not only enable the country to have an independent techno-military strategy for defence but also provide the nation with the vital techno- economic strength.1

In the complex matrix of achieving self reliance, the role of Defence R&D is clearly to provide the 'Critical Technologies' for defence needs and to build the 'Core Competence' for enriching the technology base in the country. An effective long term 'Self Reliance', implementation plan therefore must advocate selective investments in 'Critical Technologies' that would help realise the 'Self Reliance' objectives specific to national needs.2

The development of technologies in line with a comprehensive and realistic security doctrine could radically alter our entire strategic and tactical vision, not only on the conventional and sub-conventional battlefield, but in every aspect of the national enterprise.

Technology Forecasting

Technology forecasting enables to identify the likely opportunities and threats, and to develop a technological road map for the future. Technology forecasting has now assumed importance in India due to the structural reforms introduced in our economic system with a view to creating a market driven economy. Technology forecasting is used for the purpose of scanning the technological environment, anticipating emerging technological changes and identifying suitable technologies by evaluating various alternatives.3

To enable the military to meet the challenges of the future battlefield, we need to initiate research and development in some of the emerging technologies like Nanotechnology, Directed Energy Weapons, Smart Munitions, Biomimetics, Micro electro mechanical system / Micro opto-electro mechanical system, Artificial Intelligence and Armour Materials.

Nanotechnology

Nanotechnology is the miniaturisation of technology to one billionth of a meter (10-9m), to design and manufacture intelligent miniature machines, programmed to perform specific tasks. The reduction of size into the nanometer area often results in characteristic properties of substances and materials undergoing change which can be exploited for new applications. Nanotechnology, the science of designing microscopic structures in which materials are machined and controlled atom by atom, has the potential to produce further miniaturisation of weapons. The use of Nanotechnology in defence equipment opens up ways to improved weapons, innovative materials and new application areas.

In vehicles and aircrafts, conventional structural materials could be replaced by more rigid and lighter materials. Improvements could also be achieved in direct (armour) and indirect protection for military vehicles (camouflage through colour changes with 'intelligent' surface coatings). Important impact of nanotechnology can also be expected in the conversion and storage of energy ie suitable membranes and catalysts for operating fuel cells, and enhanced battery performance. There are many possible applications in military reconnaissance based on the use of nanotechnology components in sensors, sensor systems and sensor networks. Weapons and munitions are also being directly affected by the improved sensory capabilities, enhanced computing power and storage capacity due to nanotechnology. Another option is the development of nano scale powders for use in propellants and explosives, enhancing the energy yield and speed of explosion.

The impact of nanotechnology is expected to be greater than the combined influences that the silicon integrated circuit, medical imaging, computer aided engineering and man made polymers have led in this century.

Biomimetics

Biomimetics (imitate life) is an inter disciplinary effort aimed at understanding biological principles and then applying them to improve existing technology. This process can mean changing a design to match a biological pattern or actually using biological materials such as proteins, to improve performance. The scope of biomimetics appear to vary widely depending upon the specialised discipline of the investigator. Electronic companies are supporting biomimetic research with a view to learning the way biological systems process information. Material scientists view biomimetics as a tool for learning to synthesise materials under ambient conditions and with least pollution to the environment. Engineers attempt to explore the relationship between structure and function in natural systems with a view to achieve analogous synthetic design and manufacture.

Another interesting case of learning to design from nature pertains to characteristic feature of fish. It has the ability to accelerate very fast, has low turning radius of only about 10-30 per cent of its body length, high velocity and the conservation of energy during a dive to lower levels. The tail of the fish pushes the water backwards and creates a column of moving fluid called a ‘jet’. The jet includes the vortices and derives its propulsive efficiency which is about 86 per cent. In contrast, the propeller driven underwater ships reach an efficiency of only 40 per cent. It is the body of the fish, rather than the tail, that creates the strongest vortices. Based on these observations a swimming machine with a flapping tail has been constructed and submarines and boats with a flapping tail are likely to be seen soon.

Sensors capable of detecting electro magnetic radiation across the spectrum from the infrared through the visible and into the ultraviolet regions have become integral part of military weapon system. There are biological systems possessing sensing capabilities unmatched by current technologies. The infrared sensitive beetle (Melanophila acuminate) is attracted to fires and smoke 50 km away. The forest fires emit infrared radiation that the beetle detects via a specialised infrared sensor known as the infrared pit organ or infrared sensilla. By understanding the mechanism and the biological process involved in this infrared sensor, one could develop new and improved materials and sensors for various applications.4

Artificial Intelligence

Artificial intelligence is the capability of a machine to imitate intelligent human behavior. The conventional Artificial Intelligence includes methods such as expert systems, case based reasoning and Bayesian networks. Expert systems process large amount of information and provide conclusions. Case based reasoning is the process of solving new problems based on the solutions of similar past problems. It has been argued that case base reasoning is not only a powerful method for computer reasoning, but also a pervasive behaviour in everyday human problem solving.

Bayesian networks are used for modelling knowledge in medicine, engineering, image processing, data fusion and decision support systems. The military application of Artificial intelligence includes target extraction in images (pattern recognition), identification friend & foe, Multilayer Neural Networks, testing of intelligent systems and autonomous Robotic systems.5

Use for Decision Making. Increasing amount of information available from surveillance, reconnaissance and target acquisition systems makes it a near impossible task to collect and analyse. This job has to be done by a computer. Computers are becoming more and more capable of making decisions – of which weapons to select and when to fire them. The concept of using computers for making important decisions has been on the anvil for a long time. Neural cells are being utilised to make smart decisions whether they are for force structuring, adopting the most suitable doctrine or form of warfare.

Directed Energy Weapons

Directed Energy Weapons have very useful capabilities in the battlefield. Charged or neutral particles can travel close to the speed of light in vacuum, but traveling through air slows them down to about 1000 km/sec. A highly directional beam should be able to pick up and destroy a single enemy target without damaging friendly forces nearby.

The function of a directed energy class of weapon is to place on target, sufficient energy to inflict lethal damage or at

least disable some critical component of the target. LASER Directed Energy Weapons thus have two levels of applications, one for Electro Optic Counter Measures (EOCM) where relatively low energy LASER is used to disable hostile sensors or front-end optics. The other is the use of high power LASER for direct structural damage to attacking enemy platforms or weapon systems. A high-energy LASER sweeping across the battlefield could be a potent psychological weapon, particularly when inflammable materials catch fire. It may be militarily useful against soldiers with little protective clothing. Attack on battlefield sensors with modest-power LASER beam, cause them to lose track of what they were observing.

A high-energy LASER takes somewhere from a second to several seconds to do enough damage to “kill” a target, though actual times are classified and will depend on the type of target. An intense charged particle beam could do the job in a single short pulse. There are many types of physical or mechanical damage that could be lethal to a military target. Missiles and aircraft could be destroyed by rupturing fuel tanks and causing explosions, and enabling some critical components to malfunction. As the intensities needed to cause mechanical damage are much higher, the requirement of making such high power LASERs battlefield worthy is of importance.

The Tactical High Energy Weapon is a high-energy LASER weapon system that uses proven LASER beam generation technologies, proven beam-pointing technologies, existing sensors and communication networks to provide a new active defence capability in counter air missions. It can provide an innovative solution not offered by other systems or technologies for the acquisition and close-in engagement problems associated with short-to medium-range threats, thereby significantly enhancing coverage of combat forces and theatre-levels assets.

Micro Electro Mechanical System (MEMS)/Micro-Opto-Electro Mechanical System (MOMS)

MEMS includes mechanical and electrical elements that convert one form of energy into another, operating by transduction. The transducer is a device that is actuated by energy of one form and supplies energy of another form. Transducers encompass both sensors and actuators. Micro Electro Mechanical devices are made of extremely small parts or microchips. This miniature device comprises mechanical elements, activators and electronics on a common silicon substrate, which is fabricated using micro systems technology. Micro sensor converts a non electrical quantity, for example, pressure, temperature, gas concentration or magnetic phenomenon, into an electrical signal. Actuator converts electrical signal back into non electrical quantity.

MOMS overcomes challenges posed by Micro Electro Mechanical System. It offers higher bandwidth, lower cost, smaller size and an easier integration. Micro Electro Mechanical System pressure sensors and accelerometers are being used for missile applications, rate gyro’s and measuring exhaust emissions.

Bots and Nanobots (robots in combat)

Talking about robots in combat, such a robot, the Pack Bot was actually deployed in Iraq and Afghanistan. It entered caves, scouting around and reporting to human operators using wearable computers. In the future, its role could accommodate combat duties – such robots could be loaded with explosives to blow up locations not accessible to soldiers. Thanks to its 802.1 lb connection, the PackBot can also be operated over the Internet, allowing for remote operations. Another Defence Advanced Research Projects Agency (DARPA) funded project, dubbed the High Mobility Tactical Microrobot (HMTM), is in the works. Weighing just 5 lbs, it is being designed for surveillance and reconnaissance. The HMTM has a camera on top of a periscope to look around corners, in addition to an inbuilt homing device that will work even if its 802.1 lb connection breaks.

Smart Dust

Smart Dust can help reduce casualties, which was a primary goal during the Iraq war. The central idea is to replace people with machines that could gather intelligence. In Iraq, the US military used smart robots and small UAVs to reduce danger to personnel. Another DARPA-supported technology, called Smart Dust, could possibly reduce casualties and gather information even more effectively.

Smart Dust is an “autonomous sensing and communications device in a cubic millimeter” package. A millimeter device has not yet been created, but the goal is to package a light sensor, power supply and circuitry, a communication device, and a programmable processor into a small space. On achieving the desired apparatus, aircraft can “spray” Smart Dust over a conflict area. The specks would be light enough to stay afloat and monitor the movement of enemy troops, or perhaps the presence of biological or chemical weapons. In a recent test, a Smart Dust researcher controlled

a drone about 8 inches long which flew at 100 kmph for 18 minutes, carrying a camera that sent live feed back to headquarters!

Smart Munitions

Smart ammunition is the one, which after being fired can be controlled to a certain extent, towards the terminal part of its trajectory, incorporating homing device, guidance system and target seekers. The sensor fuzed ammunition has fixed intelligent sensor which identifies a target and fires a projectile towards it.

The sensor used in this ammunition is a Millimetric wave Radar in which Millimetric wave frequencies of 35-94 GHz are able to penetrate poor weather conditions and battlefield smoke to give high target signature resolution. The infrared detector sensor identifies targets through their hot spots and creates an image. Targets can be perceived through adverse weather and smog. The dual mode seeker sensor is potentially more cost effective due to its lower false alarm rate and increased tolerance to counter measures.

The brilliant munitions employ multi sensors and have many steerable surfaces. Owing to their bulk, these are delivered as sub munitions by large calibre guns (203mm) or by rockets. These sub munitions autonomously seek targets with freedom of flight direction, enabling it to locate targets within a large radius of the dispensing point. Also, these munitions provide first round hit against a universal target set, including hot and cold, stationery, moving and hard or soft targets.

Armour Materials

The Armour materials presently in use and under development are steel armour, aluminium armour, titanium armour, composities and ceramics. The synergistic combination of aluminium armour with outer layers of hard steel has been adopted to provide greater protection than that afforded by a single type of armour. Where space allows, the effectiveness of aluminium steel combination can be further increased by separating the two armour layers by an air gap. As an alternative to steel, there is also possibility of combining aluminium armour with plates of titanium. The ballistic performance of titanium and the prospects of its cost coming down have encouraged its greater use particularly, as hard outer layer over softer Aluminium armour structures.

Ceramics are ballistically effective because of their hardness, which is considerably greater than any other material, and also they are lighter than steel. Titanium diboride will serve as protection against projectiles of the future having cores of tungsten-cobalt composites. Flexible ceramic armour, consists of small ceramic spheres embedded in an electrometric matrix. The damage in this kind of armour would be confined to a relatively small area instead of spreading across, which enables the armour based on them to withstand multiple closely spaced hits.

Way Ahead

Research organisations must take initiative in developing the above emerging technologies required by the Army. Memorandum of understanding and agreements in the field of defence technologies must be undertaken with major foreign partners. The technologies developed by research agencies should be transferred to industry for production.

Where ever it is technologically feasible and economically viable, effort should be made to locate and develop broad based indigenous supply sources both in public sector as well as the civil trade for sophisticated and complex equipment. A significant change should be brought about in the role of private sector/ civil trade in the field of indigenisation i.e. from the role of supplier of raw materials, components, sub systems, they should become partners in manufacture of complete defence equipment/ systems. The defence industry sector, which was so far reserved for the public sector, has now been opened up for participation by the Indian private sector. The Indian companies are now eligible to apply for licence to set up defence industry for manufacture of all types of defence equipment. There is also a need for a major overhaul to convert the defence PSU’s into unprotected competitive entities to succeed in the new environment of economic reforms and open market competition. The self reliance in critical technologies should be a ‘national mission’ for a country like India, with co-ordinated efforts at National level and commitment from R&D organisations in the country.

Emerging technologies will revolutionise warfare in this Century and India cannot remain a mute spectator to this change. The fact remains that countries that can exploit emerging technologies and synergise the same with the

innovative operational doctrines and organisational changes could achieve far higher levels of relative military effectiveness.

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