Critical Defence Technologies and National Security - The DRDO Perspective

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DRDO has been the torchbearer of the defence research and development in the country. It has been responsible for identifying critical technologies, working out modalities for technology development and identifying partners for technology acquisition. The author argues that the government along with several other stakeholders such as the Services and the industry need to play an important role in the technology development and production. It is emphasised on successful research and development which requires steady funding and incentives for scientific talent. Sustained development of DRDO projects is, therefore, important.

Self-reliance is not just a function of numbers or of percentages. At its heart is our ability to clearly define those strategic and critical areas in which development of national capability is a must. We must pursue this goal with determination and a long-term perspective.
Prime Minister Dr. Manmohan Singh, May 2008

DRDO - the R&D arm of the Ministry of Defence is widely regarded as the custodian of Defence R&D in the country. Over the years with the changing geo-political scenario and a globalised world order, DRDO has adapted itself to these developments without losing focus of its primary aim of establishing self-reliance in critical defence technologies, guided principally by compulsions of national security.

Why do we need to develop critical defence technologies in India? There are three overriding compulsions which answer this question. Firstly, it provides immunity against technology denials and DRDO has been a victim of this game through its major programmes. Secondly, it enables the pursuit of an independent foreign policy without having to kowtow to global powers and finally perhaps most importantly an indigenous technology base provides an impetus for a country's economic development. Worldwide literature provides enough evidence to substantiate the fact that money ploughed into defence R&D returns considerable benefits to the economy—a fact corroborated by a recent study initiated by DRDO with the National Council of Applied Economic

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Research, which has come up with an important finding—that regardless of time and cost overruns, the investment in DRDO has generated positive return to the economy.

A quick overview of DRDO and its operations is necessary to provide the requisite background for this paper, as DRDO has long been considered as the torchbearers of defence R&D in the country. DRDO's mission is to design and develop state-of-art defence systems and technologies and to provide technological solutions to the Services while developing infrastructure and committed quality manpower. Started in 1958, DRDO grew from a modest beginning of 10 units to its present umbrella of 50 labs engaged in a wide variety of technology disciplines. It operates with a financial outlay of about 6 per cent of the Indian Defence budget, which compares very modestly to the R&D expenditure of world leaders with USA at 15 per cent, China at 20 per cent and Israel at about 9 per cent. About one-third of this budget is utilised for development projects and technology development, another third is earmarked for strategic systems development and the remaining third utilised for manpower, training and infrastructure build-up. DRDO's technology spectrum encompasses the entire gamut of defence requirements ranging from aeronautics and naval systems to materials and life sciences as also from soldier selection and protection to sophisticated ballistic missile defence and strategic systems.

In the field of Aeronautics, is the flagship project LCA Tejas, the unmanned aerial vehicle Nishant and Lakshya, state-of-art avionics and lighter than air systems. Developments in this important arena have led to establishment of much needed technologies including—fly by wire digital flight control systems, control laws for unstable configuration, open architecture mission computers and composite structures. These technologies have played an important part in giving India much needed clout with technically advanced countries of the world.

The Indian Missile showcase is DRDo's pride. It has developed a family ranging from the strategic Prithvi and Agni to the tactical family of Trishul, a low level quick reaction SAM, Akash, a medium range air defence SAM and the top attack anti-tank missile - Nag.

The Indian Missile showcase is DRDO's pride. Conceived as part of the prestigious Integrated Guided Missile development programme, DRDO has developed a family of missiles ranging from the strategic Prithvi and Agni to the tactical family of Trishul—a low level quick reaction SAM, Akash—a medium range air defence SAM and the top attack anti-tank missile—Nag. This cluster has given to the country a range of technologies driven by the sheer breadth of platform requirement—from ship and underwater launch to ground and air launched –

which has resulted in a multitude of technologies viz. re-entry vehicle structure, twin engine liquid propulsion, stabilisation and launch from moving platform, Autonomous navigation, pre-fragmented and submunition warhead, to name a few.

Electronics systems are another key area of expertise and accomplishment. Due to the nature of threat, DRDO has had to develop a family of Electronic Warfare(EW) systems including land based and naval EW systems, Command, Control and Communication systems, a family of radars ranging from the man portable Battlefield Surveillance Radar to the sophisticated target acquisition and fire control radar for our missile systems. This has resulted in an indigenous technology base encompassing high accuracy direction finding systems, jamming technologies, electronics support and countermeasures, travelling wave tubes and TR modules—each technology a very vital tool which cover applications for the three wings of the Armed Forces.

DRDO also has a number of laboratories working exclusively for Naval applications in the field of underwater sensors and weapons, special materials and fleet support systems and critical oceanographic studies in the Indian Ocean Region. The major technologies developed by DRDO include transducer arrays and state-of-art signal processing techniques for sonars and propulsion batteries, homing systems and on board computers for torpedoes, to give an indicative idea.

In the field of armaments and combat vehicles, DRDO has achieved considerable success with the development of the MBT Arjun-one of the few countries in the world to have developed its own MBT, Multi-barrel Rocket Launching system Pinaka, engineering and bridging systems which spurred a number of variants and gave rise to key technologies viz. composite armour, hydrogas suspension, flow formed rocket motors, mobile launchers and composite propellant technology.

DRDO also has a number of laboratories working in the Life Science cluster in support of the man behind the machine. The areas of interface cover the entire gamut of soldier requirements right from selection and training to performance evaluation, protection, clothing and nutrition in hazardous environments.

System and product development can only be achieved by development in the key area of material sciences. DRDO has mandated specific labs to carry out basic and applied research work which have produced considerable success in the field of conventional metallic alloys, metal ceramic, polymer matrix, composites intermetallics etc. Work is ongoing in the area of smart materials, fullerenes and stealth materials. All of which will be essential feeder to future development projects.

A summary of the systems and technologies produced by DRDO is given in the table below:

Discipline	System/Product	Technologies
Aeronautics	Combat Aircraft: LCA Tejas, UAVs: Lakshya, Nishant Aerostats Avionics	Control Laws for Unstable Aircraft, FBW DFCS, Open Architecture Avionics, Composite Structure, Mobile Launch/Recovery Mechanism, Jam Resistant Data Links, Image Processing.
Missiles	Strategic: Agni, Prithvi, Dhanush Tactical: Akash, Nag, Trishul Cruise : Brahmos	Re-Entry Vehicle Structure, Liquid Propulsion, Autonomous Navigation, Stabilisation/launch from Moving Platform, Multi-target Tracking, Command Guidance, Folding Fin Mechanism.
Naval	Sonars: Humsa, Nagan, Ushus, Mihir; Torpedoes; Processor based Mines; Naval paints	Transducer Arrays, Signal Processing Techniques, Homing Technology, On-Board Computers Fire Control, Propulsion Systems, Platform Interface, Non-skid and Corrosion Protection Paints.
Electronics	EW systems: Samyukta, Sangraha Radars: BFSR, 3D CAR, Rajendra C4I systems, Communication, Lasers	Direction Finding, Jamming Techniques, Voice Recognition, Secrecy Systems, Network Centric Information Fusion, High Accuracy Trx/Rx Modules.
Armaments and Combat Engineering	Combat Vehicles: MBT Arjun, Bhim, Tank Ex MBRL Pinaka, Sarvatra Bridging Systems, BLTs, AERVs, ICVs	Hydro-Gas Suspension, Composite Armour, Flow Formed Rocket Motor, Launcher Mechanisms, Propellants and Warheads.
Materials	Composites, Rare Earth magnets, Special steels, Carbon Nanotubes and Nanocomposites	Titanium Sponge Extraction Technique, Aerofoil and Super Alloy Castings, Multi Walled Carbon Nanotubes, Thermal Protection For Structures, Conducting Polymers.
Life Sciences	Selection, Protection, Nutrition packages for Soldier, Bio-waste Management, High Altitude Agro-tech and NBC systems	Psychometric Tests, Hapo Management, NBC Sense/Detect Technologies, Integrated Life Support Systems, Diagnostic Kits, Food Pre-Processing for Extreme Conditions Use.

Infrastructure

Project development in DRDO went hand in hand with the development of infrastructure for testing evaluation and special manufacturing technologies. Some of the major test infrastructure established by DRDO include the integrated test range at Balasore for missiles, structural dynamic vibration test facilities for aircraft structures, electronic warfare test ranges, propulsion test facilities, test tracks for land based combat systems, underwater weapon test ranges and EMI/EMC test rigs to name a few. These infrastructure–state-of-the-art and customised to meet Indian defence needs are today a National asset which can continue to be used for future requirements.

DRDO's challenges for the future include development of advanced surveillance platforms, extended reach next generation combat aircraft, expanded air defence and ballistic missile defence capability and autonomous unmanned systems for land and water. Some of the breakthrough technologies which will be required to be developed include Hypersonic Vehicle Technology, Network Centric Warfare Components, Directed Energy Weapons, Nanotechnology and advanced materials.

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DRDO and its Linkages

DRDO operates with a number of external linkages at various levels with different agencies. At the centre of its operations are the users – the three wings of the armed forces – who are the main customers. Their vision and operational requirements give shape to the choice of development projects.

The major production partners are the Ordnance factories and Defence PSUs, who have traditionally been DRDO's manufacturing partners. However, during the course of its developments projects DRDO has built up a good network of private industries both medium and small scale, who have played an important role in the development programmes of IGMDP and LCA, so much so that DRDO can today take credit for upgrading to a large extent, the technology capabilities of the Defence Industrial Base (DIB).

DRDO also interacts with Indian academia for basic research and technology seeding which serve as feeder to development projects. The directorate of extra mural research at DRDO Headquarters initiates research activities in academic institutions to meet the long term technology needs of the organisation. DRDO has also created five centres of excellence in key areas of interest, in an effort to fill up the technology gaps in the country. They include computational fluid dynamics centre at IISc, composite manufacturing at NAL and IIT Kanpur, aerospace design at IIT Mumbai, life sciences at Bharathiyar University, millimetric devices at University of Calcutta and high energy materials at University of Hyderabad. In addition to these CoEs, DRDO has also instituted the concept of research board in the areas of aeronautics, armaments, naval sciences and life sciences. These independently run Boards chaired by eminent experts in the relevant field, invite research proposals with some relevance to defence needs—from independent and academic researchers. At present, about 100 academic institutions across the country are part of the DRDO-academia network.

DRDO has developed extensive linkages with other national S&T agencies viz. DOS, DAE and CSIR for carrying out basic and applied research for a number of common applications and experts from these organisations also act as experts for technical reviews and performance audits of DRDO projects.

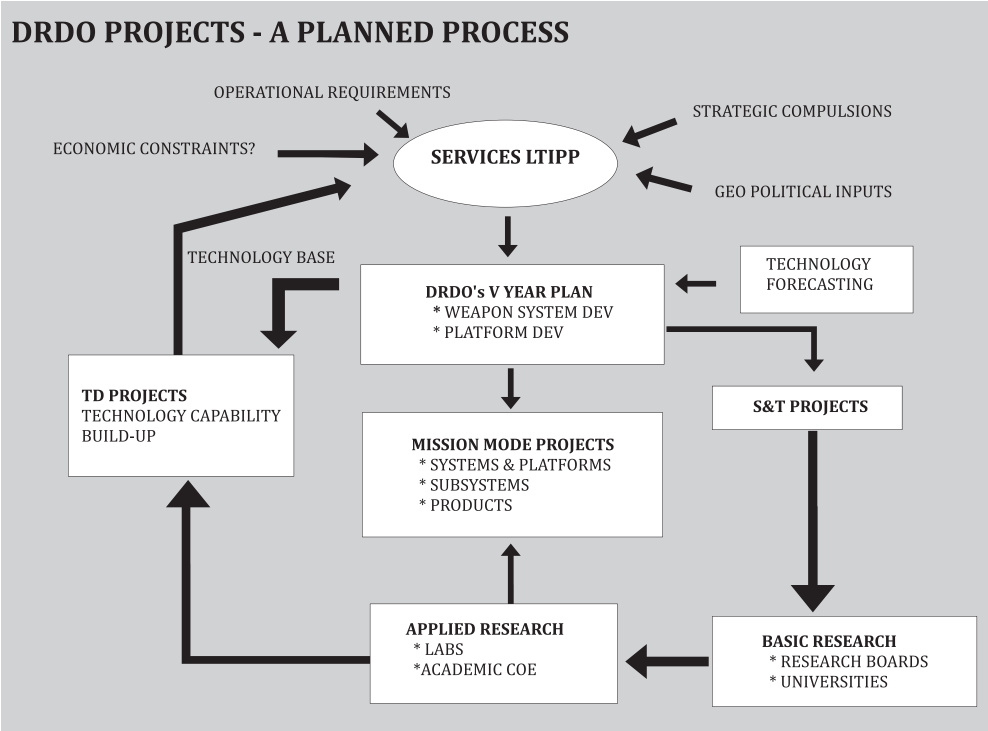
Over the recent years, DRDO has developed a special bond with various think tanks and has sponsored studies in policy doctrines and military strategies both for India and for countries of interest. These have provided valuable inputs to help shape the choice of development projects.

How are Programmes Selected in DRDO

DRDO projects are dictated basically by two major considerations- the Services Long Term Integrated Perspective Plan (LTIPP) and its own technology forecasting based on global developments. These two combine to give rise to DRDO's Five Year Plans, which fall into three major categories:

- Mission Mode Projects: involving user initiative, time bound and normally involves more than one lab with users having a major say in steering the project. This kind of project normally depends on technologies that are already available, proven and readily accessible either within DRDO/India or from abroad at short notice. As time is at a premium in this case, there is normally an alternate/parallel path, which is earmarked.

- Technology Demonstration Projects: normally initiated by DRDO as feeder technologies for future or imminent projects. These are funded and controlled by DRDO with little or limited user inputs. The purpose is to develop, test and demonstrate a particular technology. Modules of this may be developed by industry and design/analysis packages by academia.



- Science and Technology Projects: low level funding solely at lab level with loose alignment to future technology needs. This kind of project is normally taken up with academia involvement and includes a quantum of analysis and simulation modules.

Steps in Technology Development

Long range defence technology capability is a long drawn and time consuming process, each step of which must be meticulously gone through, to achieve desired results. DRDO operates with a three step formula in the development process:

- Identify Critical Technologies: This is done keeping in mind two basic tenets - the global technology developments and users' long term plans and missions. Ideally, the two should be co-ordinated and aligned in order to determine what really are the critical technologies required for tomorrow.

- Assess the Technology Readiness Level in the Country: The TRL[1] table made famous by NASA, which is widely followed in USA and Europe is modified and adapted by DRDO. This serves as a Decision Aid for Technology Evaluation during the project proposal stage and will decide the development path to be taken.

Work Out Basic Modalities for Technology Development and Identify Partners for Technology Acquisition:

There are basically three different kinds of research[2] in DRDO:

- Basic Research: carried out mainly in academia concentrating on basic sciences i.e. physics, chemistry, electronics and materials. The Indian Academia is the right choice of partner in this endeavour. Technology readiness levels will be extremely low in such cases—mostly at baseline of 1-2. These are mostly carried out in our science labs and work here is focused on basic sciences.

- Applied Research: Again in labs perhaps with collaboration with academia TRL is slightly higher at 2-4. This involves certain knowledge base at start and will involve development of certain level of products—technology labs of DRDO work in this area, interacting with foreign Universities and with Centres of Excellence set up by DRDO.

- Product development with critical technology carried out by labs with industry support for manufacturing - TRL is at an improved level of 3-6. System labs of DRDO work mostly in the area of mission mode projects interacting with Indian Industry for process manufacturing and production interface.

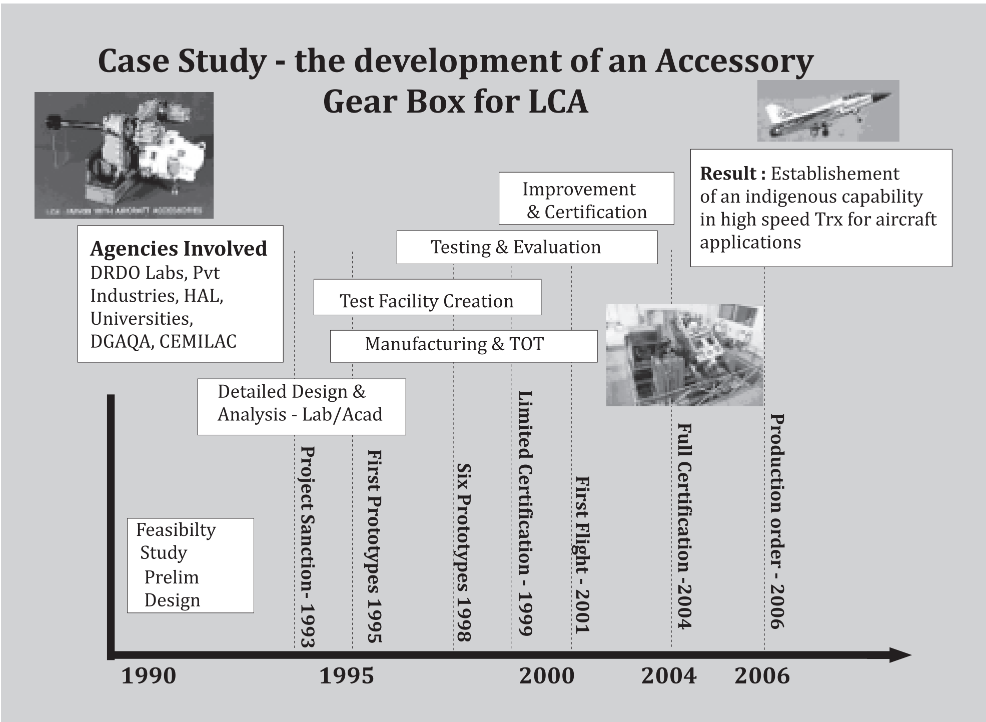
- International Collaboration: Taken up in special cases, as countries do not normally collaborate on critical technologies, which they would like to retain for themselves. There is also the chance of collaboration being withdrawn at crucial juncture because of restrictions on control by foreign policy makers. DRDO looks ideally at International Collaboration as "equal partners with complementary skills" model – so as to obtain access to technologies faster, which otherwise would take much longer and necessitated due to the pressures of Mission MODE projects.

Case Study

To better illustrate a typical development cycle, the specific case study of the development of an Aircraft Mounted Accessory Gear box (AMAGB) for the LCA is presented below, which captures product development in its entirety.

The AMAGB is a Single Input Multi Output Gear box which gets its input drive from the LCA engine and forms part of the secondary power system of the aircraft. It has an operational envelope of 15 kilometres altitude, temperature range of minus 54 degrees Celsius to 135 degrees Celsius and operates at speeds of up to 18000 RPM. This is a lightweight, high speed transmission unit which was a first time ab-initio effort for DRDO - specifically minicore oil galleries for inbuilt lubrication in a magnesium alloy casting was attempted for the first time in the country.

The project was initiated in 1990. The development cycle involved preliminary design and analysis even before formal project sanction. This was followed by detailed design, establishment of manufacturing techniques and identification of manufacturing partners, conceptualising testing requirements, creation of test facilities, followed by the long drawn process of testing and qualifying. The formal sanction for the project was accorded in 1993, first prototype released in 1995, six prototypes with limited testing



was ready by 1998. Certification to an altitude of 12 kilometres was accorded in 1999, just six years after sanction. AMAGB TD1 took part in the first flight of LCA in January 2001. Following which, feedback during flight trials and testing led to product improvement and final certification up to full altitude ceiling was awarded to AMAGB in February 2004. A number of agencies were involved in this project including HAL, DGAQA and CEMILAC. The whole exercise took about ten years and consumed about Rs. 16 crores, within which cost 12 prototypes were produced and test facilities to the tune of about 60 per cent project cost were established, which are today a national asset and continue to be used for testing the production units. Today this project team is working on the naval variant of LCA with hardly any additional cost. This cycle is typical of most development projects. Unfortunately, sufficient recognition of the intricacies of technology/product development cycle is not appreciated by many- who think that technology can be developed by a wave of the magic wand.

This technology/product was lucky to see the light of day, only because it resulted in a production order for LCA, however minuscule. What would have been the output if no production order had been placed on LCA - the entire exercise would have been rendered useless and the country deprived of a technological capability because a technology unutilised is a technology deprived.

International Experience

To put the issue into perspective, a couple of examples from International experience are presented. One such is the case of the Challenger 2 Main Battle tank of UK against the M1 Abrams of USA.[3] What perhaps is not well known is that this tank development was almost throttled at birth. But in December 1988, the Government of Margaret Thatcher chose to order a prototype British built tank over its proven American rival, against the recommendations of the British army, for a $2.3 billion battle force in a decision that was both politically sensitive and could determine the survival of a strategic British Industry. This bold decision was based on three major issues. Firstly, it saved over 10,000 British jobs. Secondly, an indigenous tank manufacturing industry gave the nation political kudos almost equal to nuclear power and finally it retained faith in UK's national engineering capability. Today, this Challenger is the mainstay of the British Army.

Another example is the ongoing duel between US Boeing and the European Airbus.[4] A $40 billion USAF aerial refuelling tanker deal has today become a tug of war between Boeing and EADS-Airbus, in a politicised contest with domestic content and US jobs threatening to override performance and cost issues. The fight is being championed by “Buy America” advocates - concerned over the loss of US jobs if the project is awarded to Airbus and equally concerned about the point that the tankers would at least be partly designed and built in France—effectively passing control to Europe. In February 2008, the development contract was won by EADS-Northrop Grumman- which provoked Boeing to file a protest with the US GAO—the investigative arm of US Congress. GAO has upheld the protest and directed Pentagon to re-float the case. The matter has become so politically sensitive that the decision has been delayed until the next administration takes over in Washington.

It is thus amply evident that in the world's most technologically advanced countries, extra premium is placed on homegrown technology and platforms, even at the cost of price and performance. Indigenisation, therefore, is at the core of defence technology development. At the same time, it must be appreciated that technology development is embedded in system/platform development.

Self Reliance and Technology Development

Having established that an indigenous defence technology base is critical, let us consider the role of the stakeholders and their related responsibilities. The responsibility for self-reliance cannot be placed on DRDO's head alone, which neither has the freedom to choose its customer nor the power to impose its choices (NCAER Report). Hence for self-reliance to become a reality, requires a number of players working in synergy. While DRDO and academia can work towards creating critical technologies, the responsibility for sustaining it, will lie with Government policies and industry initiatives. A number of proactive measures will be required in this regard, some of which are detailed below.

> Self-reliance is not DRDO's responsibility alone, since it does not have the freedom to choose its customer nor the power to impose its choices.

Government Policies

The first and single most important factor is government policies. Considering the chain of events in a technology cycle—a process is developed, it leads to technology development, which in turn becomes part of a product. This product is made part of a system - this system needs to be accepted and inducted into service. Feedback on its operation leads to it being improved/upgraded with use. This is a concept known as spiral development, which is a common practice in leading nations like France and Israel. The whole cycle hinges therefore on acceptance/induction of the system/product, failing which the exercise is rendered infructous. The onus thus rests on the Government, which must:

- Necessarily mandate at least 70 per cent of defence acquisition as indigenous. Only then will the creation and sustenance of defence technology in the country become a reality,
- Provide tax relief to Industries for their R&D expenditure,
- Award special incentives to members of the Defence Industrial base, so as to draw in more members,
- Extend grants to academia involved in defence technology development,

- Liberalise procedures for high risk-high payoff projects of DRDO—crucial for critical technology development.

Services Efforts

The next important player in the exercise is the Armed Forces and they too have an important role to fulfil, as a part of the technology development cycle.

- They must stay abreast of global technology developments through structured training. The UK MoD has initiated a 30-year pre-planned programme for imparting technical engineering training to the three Services- outsourced through a Public Private Partnership model and Indian MoD can take a cue from this initiative.

- The Services must induct a greater percentage of technically qualified personnel into their ranks so that they can better understand the nuances of technology development.

- They must also provide stake-holding in development projects of DRDO, through manpower participation and funding.

In essence, the Services must transform themselves from being a customer to becoming a partner, because as long as they think of themselves as customers - they suffer from the "customer is king" syndrome which will negate the entire exercise of creation of a technology base.

Industry Initiatives are another important facet of technology development and sustenance. As India, moves towards a PPP model in defence projects there are certain initiatives that Indian industry should take.

- They must certify themselves as part of the defence industrial base and avail government incentives for strengthening their technical base.

- They must set aside a percentage of their turnover for R&D in their core competency area so as to better absorb technology when transferred.

- They must develop Tier II/Tier III industries on similar lines so that there can be improvement across the board for Indian Industry.

- They should partner with specific technology incubation centres in labs on a GOCO/Society model for a fixed tenure to get trained in various technology intensive areas.

- Finally, they must provide stake-holding partnership in DRDO development projects.

Only then, can Indian industry come of age and take on the mantle of defence manufacturing of world standards.

Academia Involvement: For science and technology to develop in any country, the starting point is academia, hence Indian academia should become an integral part of technology development in the country. Suggested measures in this regard include:

- Establishing centres of excellence in core competency technology areas,
- Initiating specialised courses to cater to defence requirements in PG and PhD level,
- Permitting exchange of HR between faculty and scientists on tenure basis so that there is better mixing of the practical and theoretical aspects of S&T,
- Identifying technology gaps for National Initiatives on the lines of the Nanotechnology Initiative.

DRDO Initiatives: As the major player in technology creation, DRDO has a big role to play. Hence, a number of new initiatives need to be launched to enable DRDO to take a guiding role in this venture. The initiatives required can be broadly classified under two major heads – Human Resource and Project Management.

Under Human Resource initiatives, DRDO should adopt a more professional HR management style by:

- Evolving guidelines for putting the right man in the right job. DRDO is involved in basic research, design, manufacturing, test and evaluation, project management. Hence, there are enough avenues for each type of temperament and aptitude and due care must be taken to slot HR accordingly.
- It must provide compulsory and continuous technical training in relevant technology areas to its scientists.
- It must induct more PhD at entry level to strengthen its basic research capability and those involved in research must be kept free from the pressures of Mission Mode projects.

- Finally and very importantly, DRDO must provide incentives to its scientists for path-breaking R&D efforts.

In the area of project management, the efforts must focus on the following:

- Choice of the projects only after requisite expertise evaluation- with the mandate to offload as much as is technically feasible.

- DRDO must put aside a greater share of its funds – at least 5 per cent for Basic Research and 10 per cent for research into futuristic technologies i.e. high risk-high payoff Darpa type.[5] This must be both at overall DRDO level and lab level and the allocation of manpower must be done accordingly.

- DRDO must also start technology incubation centres for training industry in technology intensive analysis and manufacturing techniques.

- Finally, an important task is to get involved in military exercises of Services so that better understanding of the operational requirements of technology can be attained.

Conclusion

A recent study (by an independent group of top US Scientists including Nobel prize winners) authorised by Pentagon[6] which focuses on the technological innovation and research management of US DoD has come out with clear cut findings, which are detailed below:

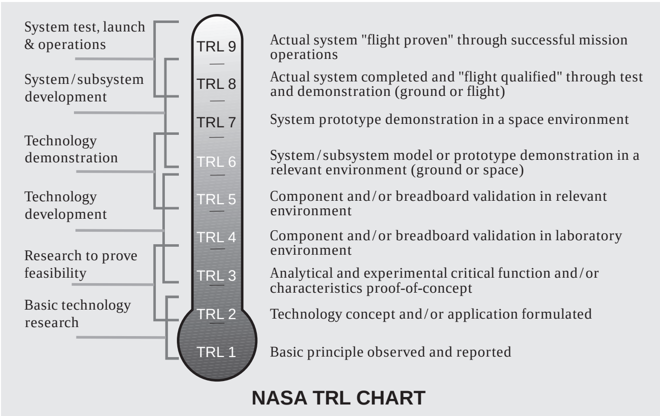
- Successful research requires steady commitment and funding and cannot have short term focus with on/off switching depending on the immediate requirements.

- Well-established links between acquisition and research and between the Defence Department and the research community are a must for establishing a sustainable research environment.
- Rewarding of scientific talent is essential to retain expertise.

India's MoD also needs to recognise the importance of this requirement and institutionalise arrangements for sustained development.

Notes

1. Technology Readiness Level Table



2. National Science Foundation (Science and Engineering Indicators, 1993) defined these terms as follows:
Basic Research: The objective of basic research is to gain knowledge that is more complete or understanding of the subject under study, without specific applications in mind. In industry, basic research is defined as research that advances scientific knowledge but does not have specific immediate commercial objectives, although it may be in fields of present or potential commercial interests.
Applied Research: Applied research is aimed at gaining knowledge or understanding to determine the means by which a specific, recognised need may be met. In industry, applied research includes investigations oriented to discovering new scientific knowledge that has specific commercial objectives with respect to products, processes, or services.
Development: Development is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.
3. Simon Dunstan, “Challenger 2 Main battle Tank”, Osprey Publishing, 1987-2006.
4. Competition Heats Up for Air Force Refuelling Tanker Deal, January 16, 2008.
5. USA- Darpa model: Created to achieve transformational results- operates differently with little or no control from mainstream defence R&D- their aim is to produce breakthrough technologies, high risk- high payoff efforts. Their success rate is reportedly only about 10 per cent- Internet and stealth were two major technologies produced. The important aspect of Darpa- which is perhaps not fully understood- is that they are basically a contracting agency which looks for avenues of funding breakthrough technology R&D- are staffed mainly by project managers who oversee the chosen projects. An important point is that they pursue breakthrough technologies independent of defined needs. It is also a developer of concept prototypes that they feel will address future needs.
6. Scholars Give Defence Department Failing Grade, November 2008.