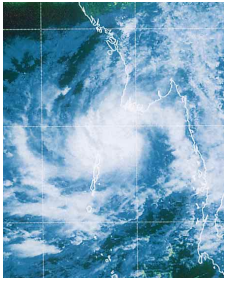

CHAPTER XXXI

DEFENCE RESEARCH AND DEVELOPMENT ORGANIZATION

The government of Independent India set up the Defence Science Organization in 1948 to advise and assist the Defence Services on scientific problems and to undertake research in areas related to defence. The Defence Research & Development Organization (DRDO) was set up in 1958, by merging the units of Defence Science Organization with the then existing Technical Development Establishments of the three Services. Subsequently, a separate Department of Defence R&D was formed in 1980, to improve administrative efficiency.

The mission of the Department is to attain technological self-reliance in defence systems and weapons. To accomplish this, the Department has the mandate to design, develop and lead on to production of the state-of-the-art weapon systems, platforms, sensors and allied equipment to meet the requirements of the Armed Forces and to provide support in areas of military sciences to improve combat effectiveness of the troops.

The Department of Defence R&D executes various R&D programmes and projects through a network of 49 laboratories/establishments of the DRDO located all over India and a Centre for Military Airworthiness and Certification (CEMILAC). It also administers the Aeronautical Development Agency (ADA), a society funded by the Department, which is engaged in design and development of the Light Combat Aircraft (LCA). These laboratories and establishments execute programmes and projects in diverse fields of aeronautics, armaments, missiles, combat vehicles, electronics and instrumentation, advanced computing and networking, engineering systems, agriculture and life sciences, advanced materials and composites and Naval R&D. They also conduct specialized training programmes in these areas. The programmes are carried out by a workforce of about 30,000 including more than 6,000 scientists and engineers, supported by a budget of the order of Rs. 30,000 million.

To fulfill its objectives DRDO has a strong partnership with about 40 academic institutions, 15 national S&T agencies, 50 PSUs and 250 private sector enterprises. This has enabled the organization to minimize the effects of sanctions and technology denials, imposed by technologically advanced countries from time to time.

During its first decade, between 1948 and 1957, DRDO was mainly engaged in activities related to clothing, ballistics, operations research, and general stores. During the next decade 1958-68, many products, including small and medium weapon systems, explosives, communication systems and cipher machines were developed. The important achievements of the next decade (1969-79), during which DRDO addressed major hardware systems included, field guns, sonar systems, radar and communication equipment and aeronautical systems. Between the years 1980-90, it embarked on programmes of a multi-disciplinary nature for the development of complex and sophisticated weapon

Top: Light Combat Aircraft (LCA) in flight.
Left: Kaveri engine for LCA.

systems having latest technology. The contribution of DRDO towards self-reliance in defence systems became evident with the development of flight simulators for *Ajeet* and *Kiran* aircraft, air launched missile target *Fluffy* and various other types of ammunition, low-level surveillance radar *Indra*, electronic warfare (EW) systems and sonars. During the decade of 1990-2000, certain major programmes undertaken during the previous decade culminated in weapons and systems, like the Ballistic Tank (MBT) *Arjun*, missiles *Prithvi* and *Agni*, pilotless target aircraft *Lakshya*; combat improved T-72 tank *Ajeya*, bridge layer tank on T-72; *Sarvatra* bridging system, artillery combat command and control system, 5.56 mm INSAS rifle; light machine gun and ammunition; the super computer PACE+, sonar systems and Naval mines.

Starting out as an agency which carried out science-based technical improvements to existing systems, DRDO has grown today to a high-technology agency capable of undertaking *ab-initio* design, development and integration, leading to production of world class weapon systems meeting Qualitative Requirements of the Services. DRDO has achieved technological self-reliance in ammunition, armoured systems, surface-to-surface missiles, sonar systems, Electronic Warfare (EW) systems and advanced computing.

Achievements and Programmes

Aeronautical Systems: DRDO has already delivered pilotless target aircraft *Lakshya*, aircraft arrester barrier, a variety of brake parachutes and balloon barrage system to the Armed Forces. The Light Combat Aircraft (LCA) programme, under execution at Aeronautical Development Agency (ADA), has led to the development of several state-of-the-art aeronautical technologies and the creation of a necessary infrastructure, despite the constraint of

sanctions imposed by the advanced countries and the country's industrial base unprepared for the requisite components and advanced materials. The first LCA Technology Demonstrator (TDI) has undergone a number of successful test flights. The remotely piloted vehicle *Nishant*, is at an advanced stage of evaluation. Certain crucial elements, of the modernized avionics of Su-30 MKI aircraft being acquired by the IAF, have been supplied and successfully integrated.

Armaments: DRDO has achieved a high degree of developmental self-reliance in the area of armament and ammunition. More than 300 ammunition items based upon DRDO technology worth Rs. 50,000 million have been manufactured by ordnance factories. These include 5.56 mm calibre rifle and machine gun, anti-tank ammunition, illuminating ammunition, mines and a variety of bombs for the Air Force. The project for the development of a multi-barrel rocket system is at an advanced stage of evaluation.

Missile Systems: DRDO has established core competence in the area of surface-to-surface missiles, which has been demonstrated through development of *Prithvi* missile and its variants, demonstration of re-entry and related technologies for *Agni-I* and development of the longer range version, *Agni-II*. The surface-to-air missiles *Trishul* and *Akash* and anti-tank missile *Nag* are at an advanced stage of flight evaluation. For the first time in the world, the indigenously developed capability to hit a target at 4.18 km in top attack and the fire-and-forget mode has been demonstrated through a flight test of *Nag* missile.

Radar and Communication Systems: In spite of the non-availability of indigenous microelectronic devices and components, DRDO laboratories have successfully developed and delivered a variety of systems falling under this group including INDRA PC radar, equipment for Army Radio Engineered Network (AREN), very low frequency receivers, satellite communication terminals and secure telephones. A number of projects, for development of other radar and communication systems, are being carried forward.

Agni missile.

Electronic Warfare (EW) Systems: DRDO developed a number of EW systems with considerable success. These include *Ajanta*, *Coin*, *Vikram* and Radar Warning Receiver (RWR) for MiG-23 and MiG-27 aircraft, which have been delivered to the Services. In addition, the self protection jammer for MiG-27, is ready for delivery. Development of an advanced RWR for MiG-21 aircraft has been completed. The current EW projects, *Samyukta* and *Sangraha* for the Army and the Navy are at an advanced stage and should reach the Services in the next few years. India is now capable of developing any type of state-of-the-art EW system for the Services.

Combat Engineering Systems: DRDO's efforts have led to successful development of a variety of complex multi-disciplinary systems including bridge layer tanks, mat fording vehicles, mine field marking equipment, mortar carrier vehicles, armoured engineering recce vehicle, armoured amphibious dozer, operation theatre complex on wheels, ward container and mobile water purification systems. The R&D expertise in DRDO and the production infrastructure in the country can now be brought together for world class engineering systems for Defence Services.

Main Battle Tank: *Arjun*, and its derivative systems have met stringent requirements of the Army successfully. This tank is contemporary to world class tanks like M1A2 of the USA and Leopard 2 of Germany. The bulk production of MBT *Arjun* is now at an advanced stage. Based on the experience gained during the development of MBT *Arjun*, DRDO has successfully integrated a 155 mm SP turret on *Arjun* derivative chassis for development of a 155 mm self-propelled weapon system. It has also modernized the T-72 M1 tank to improve its fire power, mobility and protection.

Underwater Warfare Systems: This has been another area in which a solid foundation for self-reliance has been established by successful development and delivery of a number of sonar systems, including *Simhika, Humsa, Humvad* and *Panchendriya* and a number of Naval systems including triple tube torpedo launcher and Processor Based Ground Mine and Processor Based Moored Mine. The systems in advanced stages of development include *Mihir* and *Nagan* sonars, advanced experimental torpedo *Shyena* and also wire guided torpedo.

Other Major Achievements

Advanced Computing and Software Products: DRDO has successfully developed Supercomputer PACE+, consequent to the denial of such a computer by the advanced countries. DRDO's expertise in software has been demonstrated through the development and commissioning of war games *Shatranj* and *Sangram* for the Army; *Sagar* for the Navy and air war game software for the Air Force. A landmark toward self-reliance in microprocessor technology has been achieved through development of ANUCO, a floating-point coprocessor and a 32-bit RISC processor ANUPAMA. Its processing speed is being further enhanced from 33 MHz to 350 MHz. In addition, a three-dimensional medical imaging system 'ANAMICA' has been developed. Softwares called GITA (Graphical Interactive Three Dimensional

Main battle tank Arjun.

Applications, a general purpose CAD software and AUTOLAY, a design for software manufacture is being marketed internationally. DRDO has also set up a Very Large Scale Integrated Circuits (VLSI) design facility, which has been used for developing a number of Application Specific Integrated Circuits (ASICs) like the digital signal processing chip.

Critical Electronic Components: Initiatives to achieve self-reliance in the field of electronic components has been taken by setting up facilities for production of Gallium Arsenide and Silicon devices. Under the programme, CODE, several types of components have been indigenized, like integration components, microwave components, millimeter wave components and other special types

of components required for various ongoing DRDO programmes. A facility has been created to lead to fabrication of Gallium Arsenide wafers and Monolithic Microwave Integrated Circuits (MMICs) in 1-18 GHz range. Under a co-operative venture with other S&T Departments and Industry, DRDO has contributed in setting up a silicon foundry which has the potential of making the country independent of foreign sources in respect of most of the VLSI requirements.

Electronic and Strategic Materials: DRDO has developed several types of strategic materials like 'Jackal M-1' steel for bullet-proof jackets and bullet-proof vehicles; aluminium alloy for structural applications in the Light Combat Aircraft; single crystal super alloy and directionally solidified super alloy for use in high performance aero-engines; fibre reinforced plastic (FRP) composites for immunity against small arms ammunition and missile fragments on board ships; kevlar/aramid composite material for light weight combat helmet and rare earth based high energy magnets for application in India's space programme. DRDO has undertaken certain initiatives for making the country self-sufficient in a number of strategic materials, like setting up a facility for carbon fibre and prepegs for application in aerospace structures; launching of a national programme for development of smart materials and technology development for high purity alumina substrate and PTFE soft substrate for use in microwave integrated circuits. Technology for Fullerenes and carbon nano tubes which have potential applications in stealth, smart materials and micro-electronics have been indigenized and facilities for nano tubes at 5 gm/day level has been established.

Metal/Material Processing Technologies: The technology to convert titanium tetrachloride into titanium sponge, which is a closely guarded secret of the few titanium sponge producers in the world, has been developed which will enable India to utilize the world's largest reserves of titanium which the country has. This can be gainfully utilized in defence, aerospace, oil and power sector industries. In addition, innovative processes comprising air induction melting and electro-slag refining have been developed to produce iron aluminide based advanced inter-metallics. Aluminium based particulate metal matrix structural composites for aerospace applications have also also been developed. Technologies and processes such as ion plasma deposition of protective layers and laser processing have been established. Two grades of ultra clean structural and armour steels of High Strength Low Alloy (HSLA) steel variety, copper-boron (CuBux) and armour (ARx), have been designed and developed for structural and armour applications in marine vessels.

Radar and Communication Technologies: To meet the requirements of modern radars, namely longer detection ranges, faster data rates (short reaction times) and ability to accommodate increased target densities, DRDO has indigenously developed the technology area of array design and developed expertise in the development of radiating elements, taking into account the mutual coupling, collimation and beam steering, feeds etc. A planar, phased array system has been successfully implemented in *Rajendra* radar. Another achievement is the speech secrecy systems based on state-of-art encryption techniques for telephone secrecy (speech), secrecy over radio and multi-channel (bulk) secrecy over voice and data. The satellite communication terminals, based on state-of-art techniques like spread spectrum multiple access, high grade secrecy and low bit-rate voice digitization, have been developed. One such terminal in S-band was used during the Orissa cyclone in 2000, for communication with remote villages.

Missile Technologies: During the execution of IGMDP programme, DRDO developed several technologies that have gone into various missile systems. These include: strapdown inertial guidance system, high strength low weight magnesium alloy

wings; manoeuvrable trajectory; accurately deliverable high lethality field interchangeable warheads; multiple target tracking; composite airframe; nitramine based smokeless propellant; ram rocket technology; three beam command guidance system; carbon-carbon technology; and manoeuvrable re-entry guidance and control for long range missions.

Naval Technologies: During the course of the development of indigenous surface, ship and submarine sonars and other sonar systems by DRDO, a number of technologies have been developed. These include multi-channel sonar signal conditioning and data acquisition; sonar signal processing hardware; sonar display systems; sonar simulation and sonar power amplifiers. In the development of underwater acoustic transducers of various types, special acoustic materials like polymers, polymer matrix composites, elastomers and adhesives have been developed along with expertise in engineering aspects like packaging underwater sealings and encapsulations. DRDO is a world leader in development of Impressed Current Cathodic Protection (ICCP) technology to supplement the protection provided by paints to underwater structures against sea water corrosion. Work is in progress on 'Dual Zone' ICCP system. Fire retardant intumescent paint; non skid and high performance exterior paints and polymer based materials like vibration damping material; ion exchange-cum-indicator resin and polyurethane sealant have been developed. Work is also in progress on fuel cells as an alternative source of power. In the area of underwater weapon propulsion, magnesium-silver battery technology and contra rotating motor with indigenous design and technology have also been developed. Machinery Control Room (MCR) simulators for training engine room crew have been developed. The DRDO-developed hydrophone system was used to detect Gujarat earthquake victims buried under the debris, based on which it was possible to rescue five persons.

THE DRDO-DEVELOPED HYDROPHONE SYSTEM WAS USED TO DETECT GUJARAT EARTHQUAKE VICTIMS BURIED UNDER THE DEBRIS, BASED ON WHICH IT WAS POSSIBLE TO RESCUE FIVE PERSONS.

Agriculture and Life Science Technologies: Cold desert agro-animal technologies have helped to sustain the population of Leh (Ladakh) and to meet the requirements of military and para-military forces deployed in these regions. These technologies have helped to grow off-season vegetables for soldiers and the local people. Growing of fresh vegetables locally and greenhouse cultivation during frigid winters are saving considerable transportation costs for the Army. DRDO has helped in establishing a self-sustaining village, Nang, at a height of about 4,000 m. It has developed technology for soil-less agriculture or 'hydroponics' which is very effective in areas not having suitable soil and where economy in water use is mandatory. An internationally acclaimed concept of 'radio iodine split dose therapy' for management of hyperthyroidism has been developed. In addition, several man-machine and man-medicine interface technologies and food preservation and food processing technologies have been developed.

National Infrastructure Assets

DRDO has been instrumental in creation of sophisticated and high cost R&D facilities for test, evaluation and other purposes. These may be termed assets, as these fulfill the requirements not only of DRDO but also of other scientific organizations and of the industry. A brief account of such facilities created, is presented.

Range Test Facilities: To meet the requirements of various missiles and other weapon system development programmes, a total of four launch complexes have been established: three at Interim Test Range, Balasore, and one on an island. These launch complexes suit specific requirements without affecting the natural environment in the test range. The range of instrumentation includes sophisticated radars, electro-optic tracking system, telemetry system, range computer and wide band data acquisition and processing system. With the help of these sophisticated instrumentation, the post-flight data are available within thirty minutes of the flight. In the recent past, the range facility was utilized by Ministry of Defence, Singapore, on a paid basis.

Flight Simulation Facilities: DRDO has created several flight simulation facilities to support design investigations of fighter aircraft performance, handling qualities and capabilities in close combat and mission system performance. Some of the facilities include: research flight simulation facility, pilot-in-loop flight simulation facility, air combat simulator, mission avionics systems simulator, cockpit environment facility and aircraft system maintenance simulator. A virtual reality centre has been set up to address the requirements of virtual prototyping of LCA. The Aeronautical Material Testing Laboratory (AMTL), a national facility, is one of its kind for testing aeronautical material and components. In addition, under Aeronautics Research & Development Board (AR&DB), DRDO helped in setting up of sophisticated test facilities at IISc, Bangalore, IITs, some universities and at other technological institutions like NAL, to support R&D in aeronautics and applied science. Some of these major facilities are: modified trisonic wind tunnel (NAL), 200 mm hypersonic wind tunnel (IISc), high temperature low cycle fatigue test facility (IIT-B) and full-scale fatigue test facility (NAL).

National Centre for Automative Testing: DRDO has set up a National Centre for Automative Testing (NCAT), at Ahmednagar, for testing and evaluation of automotive vehicles, their systems and components for certification for compliance of various national/international standards. Spread over an area of 450 acres, this facility consists of track testing and testing for emission, photometry, EMI and safety and has necessary supporting infrastructure to provide a one-stop solution to the requirements of Indian automative industry. A variety of test tracks and facilities are spread over an area of 450 acres. The test tracks simulate a variety of ground/road surface conditions which a vehicle normally encounters during its span of use.

Electronic Warfare Test and Evaluation Facilities: DRDO has created Electronic Systems Evaluation Centre (ELSEC) for ground integration of EW systems and testing of systems under real life conditions. A Range on Wheels (ROW), comprising six mobile ground stations has been made operational. It is a unique facility for evaluation of airborne EW systems during development, user acceptance and system enhancement phases. The setting up of EW Simulation Testing and Evaluation Station (SITES) and Microwave Components Qualification and Testing Centre (MQTC) is in progress.

Underwater Research Facilities: A premier research facility called High Speed Towing Tank (HSTT) for carrying out studies on experimental hydrodynamics related to model testing of ships, propellers and submerged bodies has been set up. An Underwater Acoustic Research Facility (AURF), a lake facility established by DRDO at Kulamavu in Idukki district of Kerala, carries out calibration and full-scale testing of underwater acoustic transducers, array and other sub-sea equipment like fish finding sonars, echo sounders and underwater communication systems. A dedicated research ship *Sagardhwani* equipped with state-of-the-art laboratories has been developed and is being used for collection of oceanographic data. Materials and

Transducers Simulated Test facility (MATS), the only one of its kind in the Asia Pacific region and one of the very few in the world, has been established recently which provides static and dynamic measurements on materials and transducers under different conditions of temperature and pressure, simulating ocean depths. The setting up of an underwater range and a cavitation tunnel facility is in progress.

R&D for Societal Benefits

Floor Reaction Orthosis (FRO): As a medical spin-off of advanced composite technology used in making missile nose cones, Floor Reaction Orthosis, a walking aid for polio patients with quadriceps muscle weakness, has been developed. This weighs only 300 gm, as against 3 to 3.2 kg for the commonly used variety, is inexpensive and can be worn easily with and without shoes. More than 2,500 such walking aids have been fitted to polio handicapped persons in camps organized for this purpose.

Coronary Stents: Using special grade austenitic stainless steel, developed for LCA and missile programmes, two types of stents have been developed for dilating constricted arteries. Over 115 stents have been fitted in patients so far. The cost of the indigenous stent is Rs. 15,000 as against Rs. 40,000 or more for the imported one.

Cardiac Pacemaker: An external pacemaker has been designed and developed for intensive care of patients suffering from degenerative heart diseases. The system has been clinically validated at Nizam Institute of Medical Sciences, Hyderabad. Efforts are being made to convert it into a portable system.

Cardiovascular Catheters: These have been developed to offer a heart patient the option of non-surgical treatment of defect within the heart and the rest of the circulatory system. The cost of the indigenous catheter would be Rs. 1,500 against Rs. 4,500 for the imported one.

Cardiac Stress Test System: A PC-based, low cost indigenous system has been developed to acquire and analyse the ECG of a person doing exercise. The system comprises a standard protocol of graded exercise programme, acquisition, analysis and documentation of ECG and trends in BP, heart rate and ECG, indicating heart abnormalities. The system hardware consists of a 12-channel ECG data acquisition system and is priced at Rs. 350,000 to 400,000 as against Rs. 1.2 to 1.5 million for the imported one. The system is in operation at Air Force Hospital, Delhi, and its technology has been transferred to trade.

Cytoscan: Using the latest pattern recognition and image processing technologies, a computer aided cancer detection device has been developed by DRDO. The system is used for diagnosis and prognosis of several cancers, including cervical and breast cancer. The system has been used for detection of cervical cancer amongst tribal women in Andhra Pradesh under Project *Tulsi*, funded by the Ministry of Social Welfare. The programme will be extended to rural areas of Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh. More than 20,000 rural women have been scanned so far.

Slit Lamp Microscope and Drishti: India's first Nd-YAG ophthalmic laser system *Drishti-1064* has been developed by DRDO. The system is used for ophthalmic applications in the treatment of glaucoma.

Dental Implants: Using commercially pure titanium, a technology has been developed to design and fabricate titanium endosteel implants and bone plates. It has tremendous application in oral and skeletal rehabilitation. The Drug Controller of India, Ministry of Health & Family Welfare, has accorded approval for multi-centric clinical trials.

Piezodent--Ultrasonic Dental Scalar: Using piezo-electric transducer technology, a device has been developed for use by a dentist to remove tartar on

the teeth. This technology is more efficient as compared with the earlier magnetic strictive technology. The device is built around highly efficient piezo-ceramic transducer and is light and compact with ergonomically designed hand piece and is equipped with a unique swivel facility for multi-directional accessibility and parking of handpiece. The technology has been transferred to industry.

Water Desalination Technology: DRDO has developed water desalination, testing and purification technologies, based on which 30 desalination plants have been commissioned in 25 villages of Barmer district of Rajasthan under Phase-I of project *Sujalam*. A water testing field kit has been developed in accordance with the requirements of National Drinking Water Mission, for quick assessment of chemical and bacteriological quality of water for potability. The technology has been transferred to industry.

Tissue Bank Facility: A tissue bank facility has been created by DRDO for preparation of radiation processed chorio-amnion grafts. The grafts are extremely useful for treatment of burn injuries. The facility can provide 2,000 grafts per year.

Avalanche Forecasting: The organization has set up a number of observatories and automatic weather stations at various locations, based on which, avalanche forecast warnings with high accuracy are being issued to areas of Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh. An 'avalanche victim detector' has also been developed to locate avalanche victims and facilitate rescue operations.

HAPO Bag: DRDO has developed a High Altitude Pulmonary Oedema (HAPO) bag for HAPO patients by simulating a safe ambient pressure around the patient. A two-bedded hyperbaric chamber has been commissioned for civil application at Indraprastha Apolo Hospital, New Delhi, for carrying out hyperbaric oxygen therapy.

Jammer for RCIED: The Remote Control Improvised Explosive Devices (RCIEDs) are being used by criminal and anti-national elements by integrating devices, such as, cordless telephones, remote bell, remote control toys, garbage door openers and DTMF transceivers with explosive devices. DRDO has successfully developed a system as a counter-measure against RCIEDs. This system prevents the command signals entering the RCIED, which is initiated by a hand-held transmitter. The system can be installed on an Ambassador car for VVIP security, on Armada Jeep or a Tata Sumo vehicle, for paramilitary convoy protection.

DRDO HAS DEVELOPED A KIT FOR DETECTION AND IDENTIFICATION OF EXPLOSIVES BASED ON ANY COMBINATION OF NITROESTERS, NITRAMINES, TRINITROTOLUENE (TNT), DYNAMITE OR BLACK POWDER.

Bio-digesters: A consortium of bacteria and digesters for disposal of human waste through microbial degradation in an eco-friendly manner, for use in high altitude, low temperature areas has been developed. Some of these, installed at high altitudes and glacier regions, are functioning satisfactorily.

Explosive Detection Kit: DRDO has developed a kit for detection and identification of explosives. It can detect and identify explosives based on any combination of nitroesters, nitramines, trinitrotoluene (TNT), dynamite or black powder. The testing requires only 3 to 5 mg of suspected sample and only 3 or 4 drops of reagents.

Long-Term Storage of Tender Coconut Water: A

technology has been developed to preserve tender coconut water, a delicious natural and healthy drink rich in minerals, especially potassium. The drink is stored in aluminium cans and flexible polymeric pouches to preserve its natural characteristics up to six months. The technology has been transferred and the product is now being marketed.

Interaction with Academia

DRDO has constituted four research boards to nurture and harness talent in academic institutions, universities, R&D centres and industry. The organization provides necessary facilities for promoting basic research and to catalyse cross-fertilization of ideas with R&D agencies in other sectors for expanding and enriching the knowledge base in their respective areas. The boards provide grants-in-aid for collaborative defence-related futuristic frontline research having application in the new world-class systems to be developed by DRDO.

The catalytic role played by research boards has helped rapid growth in building capabilities in the area of aeronautical state-of-the-art systems like light helicopter, and in setting up a centre of excellence in Computational Fluid Dynamics (CFD) at the IISc, Bangalore, which is anticipated to give a boost to the designing of aeronautical systems within the country. Another centre of excellence in aerospace system design and engineering is being set up at IIT, Mumbai. A Centre for Composite Structure Technology is proposed to be set up at the National Aerospace Laboratory, Bangalore. Grants-in-aid by DRDO have led to setting up of a hypermedia digital library in IIT, Kharagpur, to the development of audio-visual training aids for aircrew, to indoctrination in air sickness and positive pressure breathing at the Institute of Aviation Medicine, Bangalore, and to the development of rarefied gas dynamic facility at IIT, Chennai.

The Armament Research Board (ARMREB) has approved projects in the fields of high energy materials, sensors, ballistics and other armament related fields. Under the Naval Research Board (NRB), projects are being pursued in five technology areas. Under Life Sciences Research Board (LSRB) projects have been supported in the areas of biological and bio-medical sciences, psychology, physiology, bio-engineering, specialized high altitude agriculture, food science and technology.

Collaboration with Industry

Eight DRDO laboratories working in the areas of advanced materials, robotics and artificial intelligence, communication systems, life-support systems, corrosion protection, advanced composites and desert technologies have been opened to the industry. Several technologies have been transferred to private industry such as the Scara robot, used for assembly jobs and the articulated robot used for material handling, welding, spray-painting etc. In the field of material science, the technologies transferred include: boropak, a chemical mixture to impart surface hardness and reduce wear and tear of ferrous and some non-ferrous metals; non-spark tools for copper titanium alloy; gigly saw for use by orthopaedic surgeons; rust converter for protection of ferrous metals against corrosion; moisture-resistant corrugated fibre board box as an alternative to timber for packing; and glacier tents for protection in sub-zero temperatures.

In a number of areas involving emerging technologies in which industries are not willing to invest setting up defence-specific manufacturing facilities, DRDO has also been collaborating with other departments as well as industry to help transform defence technologies for developing products for the civil sector. As these exercises involve long gestation periods, technological risk, lack of continuity of orders and lack of economy of scale, DRDO has assisted in setting-up dedicated facilities in such areas. Some of these initiatives are listed as follows.

Heavy Alloy Penetrator Project (HAPP): A fully automated factory for manufacturing highprecision components and assembly of Fin Stabilized Armour Piercing Discarding Sabot (FSAPDS) ammunition has

been established by DRDO at Trichy and handed over to Ordnance Factory Board. World class FSAPDS ammunition of different calibres are under regular production and have been supplied to the Army.

Bharat Dynamic Limited (BDL): A modern factory has been established for production of *Prithvi* and other missile systems being developed under Integrated Guided Missile Development Programme (IGMDP). Free flow production of *Prithvi* has been established.

Hindustan Aeronautics Limited (HAL): An Aerospace Division has been established to provide special thrust of *Prithvi* and other missile systems being developed under IGMDP.

Non-Ferrous Technology Development Centre (NFTDC): This society has been established as an advanced technology centre with participation of the Department of Mines, DST, DRDO and Industry (BALCO, NALCO, HCL and HZL). Some of the contributions of this centre include millform of copper alloys, silver-based brazing alloys, titanium implants and master alloys for grain refinement of aluminium.

Advanced Research Centre International (ARCI): This is a cooperative venture between India, Bylo-Russia, USA and Ukraine. India is represented by DRDO and DST. This Centre has been set up for advanced research in powder metallurgy and other special processes leading to uses by both defence and civil sectors. The contributions made by this Centre include development of coating for Adour engine turbine blade and exfoliated graphite for high temperature gasket.

Training Schemes

DRDO has introduced a number of schemes for training of defence-science personnel in universities and other leading academic institutions. It also has two training institutions namely, Institute of Armament Technology (IAT) at Pune and Institute of Technology Management (ITM) at Mussoorie. These institutes provide specialized training programmes in diverse fields. The ITM has recently started conducting MBA in Technology Management in collaboration with Bhartidasan University. The IAT has been accorded the status of a deemed-to-be university. In addition, a number of laboratories conduct training programmes in disciplines of their core competence like fire-fighting and fire-engineering, wargaming softwares, special clothing and so on. To cite an example, Defence Food Research Laboratory at Mysore conducts training programmes in food science and technology, modern methods of handling, hygiene, transportation, storage and packaging of food materials; comprehensive course in food microbiology and a ten-month postgraduate programme in food analysis exclusively for Service officers. In recent years, the PG Diploma Course (recognized by the University of Mysore) has trained many civilian candidates who have been absorbed by food industries. Other short-term orientation and specialized courses are conducted at the specific request of industries and laboratories, colleges and universities. A DRDO laboratory, the Defence Research & Development Establishment at Gwalior, has been recognized as a centre for training inspectors who are to be appointed by the UN Organization for Prohibition of Chemical Weapons.