DRDO NEWSLETTER
डीआरडीओ न्यूज़लैटर

A monthly house bulletin of Defence Research & Development Organisation ■ Vol. 31 No. 7 ■ July 2011

Prithvi (P-II) Missile Launched Successfully

The surface-to-surface Prithvi (P-II) Missile was successfully flight-tested at 9.00 hr on 09 June 2011 from Launch Complex-III, Integrated Test Range (ITR), Chandipur, Balasore, Orissa. The launch was carried out as part of the regular training exercise of the Armed Forces.

Prithvi-II, the first indigenous surface-to-surface strategic missile, capable of attacking targets at a range of 350 km, reached the pre-defined target in the Bay of Bengal with a high accuracy of more than 10 m. All radars and electro-optical systems located along the coast monitored the flight path of the missile, and an Indian Naval ship located near the target witnessed the final event.

The entire launch operation of the missile was carried out by the Armed Forces and monitored by DRDO scientists. Shri VLN Rao, Programme Director AD, Shri SK Ray, Director, RCI, top officials of Strategic Force Command, and DRDO were present during the mission. The flight test met all the mission objectives and was like a text book launch. Dr VK Saraswat, SA to RM, DG DRDO, and Secretary Defence R&D, witnessed the perfect launch of the missile and congratulated the Armed Forces and the DRDO scientists for the success.

Prithvi (P-II) Missile successfully launched

In this issue...

Raksha Mantri inaugurates Advanced Centre for Energetic Materials

Hon'ble *Raksha Mantri* Shri AK Antony, inaugurated DRDO's state-of-the-art composite propellant processing facility – Advanced Centre for Energetic Materials (ACEM) at Nasik on 29 June 2011. The facility has been setup by High Energy Materials Research Laboratory (HEMRL), a Pune based DRDO laboratory engaged in R&D of high energy materials including solid rocket propellants.

Raksha Mantri delivering the inaugural speech.

In his inaugural speech, *Raksha Mantri* stated that he was happy to dedicate this facility to the nation and congratulated the scientists for achieving this milestone. He hoped that the team of young scientists, guided by their experienced colleagues, will deliver world-class rocket motors and fulfill requirements for various strategic projects. 'The responsibility of making this facility as one of the best facilities in the field of energetic materials in the world, and making it advanced in every sense of the word lies collectively upon all of you', he stated.

Speaking on the occasion, *Raksha Mantri* stated that today, missiles have become one of the most important and effective means of delivering warheads. He stated, 'our strategic capability to boost our defence preparedness is judged by the weapon delivery systems developed by us. Despite doing well in many fields, we continue to be on the wrong side of the information divide. 'Nations the world over are today judged by which side of the information divide they are on. I am sure that with the inauguration of this facility, we will take a small but significant step towards bridging this gap'. Expressing satisfaction that most of the plants and machinery under embargo have been constructed indigenously; he stressed that to be more meaningful and sustain for a longer term, the indigenisation process must be total and irreversible. Highlighting the critical issue of safety, he emphasised to ensure that all hazardous operations are automated and carried out with minimum human exposure at all times.

Dr VK Saraswat, SA to RM, in his address highlighted the contributions of various personnel in the creation of this facility. He stated that this was not the end but the beginning of a longer journey as new and more efficient propellants will keep emerging, for which facilities need to be created. Shri S Sundaresh, DS and CC R&D (ACE) stressed upon the need to identify additional land for the residential complex in the vicinity of the facility and sought the help of district administration in this regard.

SA to RM addressing the gathering on ACEM facility.

ACEM has been set up as a dedicated facility to meet the requirements of composite propellants for solid rocket motors during their development phase as well as during the limited series production (LSP). The facility is equipped with state-of-the-art equipment and machinery operated remotely through Programmable Logic Controller (PLC) and Supervisory Control and Data Acquisition (SCADA), thus, avoiding human exposure to hazardous processes.

It incorporates a large number of critical technologies and machinery, designed, developed, and realised indigenously with the support of over 40 private firms participating in the endeavour. Many of these technologies and machinery, such as special-purpose mixers, were inaccessible to India due to 'denial regimes'. The mixers were designed and developed jointly by DRDO and Central Manufacturing Technology Institute, Bengaluru. Thus, the Centre is equipped with advanced facilities for processing, non-destructive testing, quality control, as well as static testing of various rocket motors. Installations are compliant to the applicable explosive safety norms and are equipped with integrated fire-fighting system to ensure adequate safety.

Dr A Subhananda Rao, DS and CC R&D (Aero) and Director, HEMRL, while welcoming the Hon'ble guests informed the gathering about the history and importance of the facility. Shri Harishchandra Chavan, Hon'ble Member of Parliament welcomed *Raksha Mantri* and all others, and expressed hope that more such facilities will come up in the region. Shri Anil Sahebrao Kadam, Hon'ble Member of Legislative Assembly stated that the ACEM with the state-of-the-art facilities was a pride possession of Nasik.

The occasion was also graced by Shri Avinash Chander, DS and CC R&D (MSS); Dr Hardiwar Singh, former Director HEMRL; Dr SN Asthana, Director, Dte of Armaments; Shri Ajay Singh, Chief Executive (Works & Estates); Shri B Bhattacharya, General Manager, ACEM; and senior DRDO officials and officials from the District Administration.

Raksha Mantri asks DRDO to focus on 5000 km Range Missile

Hon'ble *Raksha Mantri*, Shri AK Antony, addressed the gathering after presenting the DRDO Awards on 03 June 2011. He called upon Defence scientists to deliver the Agni-V missile at the earliest. He said, 'DRDO must demonstrate its capability to deliver missiles, which can reach the range of 5000 km at the earliest. The Interceptor Missile Development Programme has taken India to an elite club of nations that possess the capability to demonstrate missile defence capability. DRDO should now work towards developing a credible ballistic missile defence for our country'. Speaking to reporters later Dr VK Saraswat, SA to RM, said that the Agni-V test launch will take place before this year end.

Speaking on Light Combat Aircraft (LCA) Tejas, *Raksha Mantri* stated, 'After getting the Initial Operational Clearance given for LCA Tejas, it is moving towards Final Operational Clearance. I am sure DRDO and our Indian Air Force (IAF) will work together for the production of Tejas on schedule.' He called for minimising procedural delays and asked DRDO and the Services to be more accommodative of each other's needs and potential. He also said that our single objective is to achieve self-sufficiency through indigenisation in the defence sector to the maximum extent. This will be possible only if all the participants – DRDO, DPSUs, the Armed Forces, and the private sector come together to contribute to the defence sector in equal measure. Our Armed Forces, DRDO and the defence industry should hold frequent consultations with each other at every stage of designing, manufacturing, and production of equipment.

Pointing out the delay in the development of Main Battle Tank 'Arjun' Mark-II and 'Kaveri' engine for LCA Tejas, *Raksha Mantri* said that DRDO must re-orient itself to survive in a fiercely competitive world. He said, 'a strong competitive spirit is crucial for achieving excellence in any field - including the defence sector. Modern day customers are highly demanding and will be satisfied with the best, cost-effective product and good service. DRDO must strive to meet the high standards of quality and technology for its end users - our Armed Forces. You ought to make the satisfaction of the end user the litmus test of your endeavours. This objective can be achieved only through a judicious blend of creativity and innovation for developing high quality products and implementing projects on time.' At the same time, he called upon the Armed Forces 'to show more confidence in indigenous capabilities and be more reasonable with indigenous systems having shortcomings since the Services with imported weapons also have, at times, major shortcomings or rejects'.

In his address, SA to RM said that the DRDO is focused on futuristic technology development and a roadmap 'Defence Technology Vision 2050' is being framed. He also stated, 'the DRDO is now working on designing a 1500 horsepower engine and artillery guns of 155 mm calibre'.

Dr Saraswat dedicates Integrated Shelters to the Army

Dr VK Saraswat, SA to RM, DG, DRDO, and Secretary, Defence R&D dedicated the integrated thermally regulated shelter, to the HQ 14 Corps in Leh, Ladakh, on 15 June 2011. These shelters provide protection to the soldiers against extreme climatic condition of the Himalayan regions.

Dr Saraswat handed over these shelters to Lt Gen Ravi Dastane, VSM, GOC, HQ 14 Corps. Speaking on the occasion, Dr Saraswat thanked the GOC 14 Corps for the whole-hearted support to DRDO, particularly to the Defence Institute of High Altitude Research (DIHAR). He also assured DRDO's continued support and cooperation to the Armed Forces present in the region. Dr Saraswat also thanked the local authorities and farmers in the region for their support to DIHAR. He emphasised on the large-scale utilisation of solar and other non-conventional energy resources to meet the energy requirements at high altitude regions. He also appreciated the dedicated efforts made by the personnel of Dte of Civil Works & Estates (DCW&E), DRDO HQrs, in restoring the infrastructure and facilities after the devastation caused by flash floods last year. The Dte. which has made outstanding contribution in highly specialised nature of civil works, required to be carried out at DRDO facilities, many of them located in difficult and hazardous areas, has been instrumental in design and development of these shelters.

SA to RM handing over the integrated thermally-regulated shelters.

Integrated thermally-regulated shelters.

The thermally-regulated shelters designed and developed by DRDO, are equipped with integrated temperature regulators, biodigesters, and air-monitoring systems. The shelter design is modular and all the services like HVAC, electrical, plumbing and water supply, sewage disposal, kerosene gensets, and solar power, are well integrated within the shelter. The shelters have been designed to withstand seismic activities up to a level of zone 5, wind velocities up to 55 m/s and sub-zero temperature up to -35° C. The CO_2 level inside the shelter is closely monitored and maintained within the safe limits.

Dr W Selvamurthy, DS and CC R&D (LS & IC) apprised the soldiers and officers present during the occasion on the life-support systems developed by various DRDO labs. He particularly appreciated DIHAR's contributions in the development of agro-animal technologies, which have led to an annual production of 5,000 metric tonne of fresh vegetables, and availability of fresh meat/eggs in abundance. In addition, about 25 per cent of milk requirement and 10 per cent of the meat requirement is being met locally.

Later, Dr Saraswat visited DIHAR, where he launched a Herbal Adaptogenic Appetiser developed by DIHAR, which has high anti-oxidant and adaptogenic properties. The formulation is effective in ameliorating hypoxia-induced decrease in appetite. Since the extreme climatic conditions and low 'oxygen partial pressure' at high altitude adversely affects several physiological processes and leads to loss of appetite, the herbal appetiser improves the endurance to high altitude and augments the performance of our troops in high altitude regions. Dr Saraswat appreciated the research initiatives and efforts taken by the scientists of DIHAR and released the 50 Years Logo of DIHAR during the occasion.

Dr RB Srivastava, Director, DIHAR, Leh; Dr G Ilavazhagan, Director, DLS, DRDO HQrs; Dr (Mrs) Shashi Bala Singh, Director, DIPAS, Delhi; and Shri DP Makkar, Addl Dir (Works), DCW&E, DRDO HQrs were also present on the occasion.

DRDO AWARDS

Hon'ble *Raksha Mantri* Shri AK Antony presented the DRDO Awards for 2010 to the scientists/ technologists for their outstanding contributions in various areas of science and technology on 03 June 2011, at Kothari Auditorium, DRDO Bhawan, New Delhi. Eleven categories of DRDO Awards are presented each year to DRDO scientists/teams for their outstanding contributions. The transformation of technologies developed by DRDO into products/ systems/processes for the Armed Forces requires absorption of technologies by the production agencies. Defence Technology Absorption Awards are given to production agencies associated with productionisation of DRDO-developed technologies for their excellent support.

Silicon Trophy for 2010 for the Best Systems Laboratory of DRDO has been awarded to Research Centre Imarat (Programme AD), Hyderabad in recognition of the outstanding achievements of the Laboratory in developing a Ballistic Missile Defence System.

Titanium Trophy for 2010 for the Best Science Laboratory of DRDO has been awarded to Defence Laboratory, Jodhpur, in recognition of its contributions in the areas of camouflage and low observable technologies for the Armed Forces and development of critical defence equipment.

Life Time Achievement Award for 2010 has been conferred on Air Cmde (Retd) R Gopalaswami, Defence Research and Development Laboratory (DRDL), Hyderabad, for his exceptional contributions of the highest order in the development of liquid rocket engines for missiles and multi-fold array of technology and management initiatives.

Technology Leadership Award for 2010 have been awarded to following scientists:

Dr V Bhujanga Rao, Distinguished Scientist and Chief Controller R&D, DRDO HQrs and Director, Naval Science and Technological Laboratory (NSTL), Vishakhapatnam, for outstanding contributions in the design, development, and induction of indigenous underwater weapons, naval stealth products, underwater mines, fire control systems, and autonomous underwater vehicles.

Shri S Sundaresh, Distinguished Scientist and Chief Controller R&D, DRDO HQrs for his pioneering the development of complex, multi-disciplinary, technology-intensive Integrated Fire Control System (IFCS) for MBT Arjun through successful system integration, weapon system trials, and user acceptance.

Dr G Malakondaiah, Distinguished Scientist and Director, Defence Metallurgical Research Laboratory (DMRL), Hyderabad, for his valuable contributions in the development of speciality low-alloy steel DMR-1700 as a cost-effective replacement of maraging steels. AB class naval steels were indigenised under the leadership of Dr G Malakondaiah and are being used in the construction of first indigenously built aircraft carrier at the Cochin Shipyard.

Agni Award for Excellence in Self-Reliance for 2010 have been conferred to the following scientists along with their team members for their excellent contributions towards building self-reliance in defence technologies.

1. Dr Jagannath Nayak, Sc 'F', Research Centre Imarat (RCI), Hyderabad.
2. Shri G Raghavaiah, Sc 'G', Defence Electronics Research Laboratory (DLRL), Hyderabad.
3. Shri RC Agarwal, Outstanding Scientist and Director, Defence Electronics Applications Laboratory (DEAL), Dehradun.
4. Dr AK Singh, Sc 'G', Electronics and Radar Development Establishment (LRDE), Bengaluru;
5. Shri MZ Siddique, Sc 'G', Gas Turbine Research Establishment (GTRE), Bengaluru.

DRDO Award for Performance Excellence for 2010 for excellent performance and contributions, has been awarded to the following scientists:

Shri PS Krishnan, Distinguished Scientist and Director, Aeronautical Development Establishment (ADE), Bengaluru and his team.

The other award is shared equally among Dr Satish Kumar, Outstanding Scientist and Director, Terminal Ballistics Research Laboratory (TBRL), Chandigarh and team members from TBRL, NPOL, Armament Research and

Agni Award for Excellence in Self-Reliance for 2010

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Development (ARDE), Pune; Research Center Imarat (RCI); Hyderabad, SPIC, and ADE, Bengaluru.

Shri SK Shenoy, Sc 'G', and his team members from NavalPhysicaland Oceanographic Laboratory (NPOL), Kochi.

DRDO Scientist of the Year Award for 2010 have been conferred to the following 20 scientists:

1. Dr Ramprasad R Panyam, Outstanding Scientist, Defence Research and Development Laboratory (DRDL), Hyderabad.
2. Shri J Chattopadhyay, Sc 'G', Advanced Systems Laboratory (ASL), Hyderabad.
3. Dr Chitra Rajagopal, Sc 'G', Centre for Fire, Explosive and Environment Safety (CFEES), Delhi.
4. Dr Manoj Gupta, Sc 'G', High Energy Materials Research Laboratory (HEMRL), Pune.
5. Dr Dipti Deodhare, Sc 'F', Centre for Artificial Intelligence and Robotics (CAIR), Bengaluru.
6. Dr AK Singh, Sc 'E', Defence Institute of Advance Technology (DIAT), Pune.
7. Dr K Maheswara Reddy, Sc 'G', Defence Avionics Research Establishment (DARE), Bengaluru.
8. Smt Padmavathi, Sc 'F', Aeronautical Development Agency (ADA), Bengaluru.
9. Dr Kadiyam Venkateswara Rao, Sc 'G', Naval Science and Technological Laboratory (NSTL), Visakhapatnam.
10. Shri P Sivakumar, Sc 'G' and Director, Combat Vehicles Research and Development Establishment (CVRDE), Chennai.

DRDO Scientist of the Year Awards for 2010


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11. Dr DK Dubey, Sc 'F', Defence R & D Establishment (DRDE), Gwalior.
12. Shri Gopal Bhushan, Sc 'G' and Director, Dte of International Cooperation, DRDO HQrs.
13. Shri Shyam Govind Vaijapurkar, Sc 'F', Defence Laboratory (DL), Jodhpur.
14. Dr Dev Raj Saroha, Sc 'G', Terminal Ballistics Research Laboratory (TBRL), Chandigarh.
15. Dr Bikash Chandra Chakraborty, Sc 'G', Naval Materials Research Laboratory (NMRL), Ambarnath.
16. Dr (Mrs) KS Premavalli, Sc 'F', Defence Food Research Laboratory (DFRL), Mysore.
17. Shri Gokula Ranjan Panda, Sc 'F', Integrated Test Range (ITR), Chandipur.
18. Dr S Guruprasad, Sc 'G' and Director, Research and Development Establishment (Engrs), Pune.

DRDO Scientist of the Year Awards for 2010


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19. Shri G Satheesh Reddy, Sc 'G', Research Centre Imarat (RCI), Hyderabad.
20. Shri MS Easwaran, Sc 'G', Centre for Airborne Systems (CABS), Bengaluru.

Defence Technology Spin-Off Award for 2010 has been awarded to Defence Food Research Laboratory (DFRL), Mysore, for developing physiologically active foods, Aloe vera juice, Aloe vera based fruit spread, seabuckthorn based herbal tea and baked foods, Rhodiola-based coffee for combating diabetes, hypercholesterolemia, colon cancer, and other stress related disorders and diseases.

Special Award For Strategic Contribution for 2010 is conferred on Shri Ajay Singh, Chief Executive, Dte of Civil Works & Estates, DRDO HQrs and his team for outstanding contributions in the completion of civil works of highly specialised nature at some of the most difficult and hazardous areas within the stipulated time frame.

Best Innovation/ Futuristic Development Award for 2010 was conferred on Dr V Ramanujachari, Sc 'G', Defence Research and Development Laboratory (DRDL), Hyderabad and his team for having successfully designed, developed, and static-tested the scramjet combustor for HSTDV Project.

Best Popular Science Communication Award for 2010 is conferred on Shri R Raveendran, Combat Vehicles Research and Development Establishment (CVRDE), Avadi, and his team members in recognition of their valuable contributions, for coordinating with 24 laboratories all over India in the 98th Indian Science Congress and successfully organising the DRDO exhibits where more than 122 models from various laboratories were exibited in the DRDO pavilion. Also, the DRDO pavilion was given the Best Exhibitor Award. The award has been equally shared with Dr JP Singh, Sc 'F', Directorate of Planning and Coordination, DRDO HQrs for disseminating information pertaining to DRDO's contributions to the Parliament and its committees.

Defence Technology Absorption Award for 2010 is conferred on M/s Tratec Engineers Pvt Ltd, Gurgaon, and M/s VEM Technologies, Hyderabad, for their excellent support associated with the design and development of critical DRDO technologies.

DRDO: RECENT ACHIEVEMENTS AT A GLANCE

Defence Research and Development Organisation (DRDO), a premier research establishment of India, is engaged in developing defence technologies covering various disciplines like aeronautics, armaments, electronics, combat vehicles, engineering systems, instrumentation, missiles, advanced computing and simulation, special materials, naval systems, and life sciences. Many important systems were accepted/inducted by the Services. The production value of systems based on technologies developed by DRDO (inducted/accepted/orders) placed during the past one decade is well over 1,10,000 crore.) Some of these technologies have been highlighted here.

Agni II

Agni, the 3500 km range ballistic missile was successfully launched with users' participation. Flight tests were held by the Services for various missiles that have been already inducted. These included two flight tests each of Agni–I, Agni–II, and Dhanush (from naval ships) and five flights of Prithvi II (P–II). Orders worth over Rs 25000 crore for surface-to-air missile – Akash have been placed by the Services. These include 8 squadron for the Indian Air Force (IAF) and 2 regiments for the Army. Successful flight tests of Endo Atmospheric Interceptor for 2000 km class target were carried out. Each flight led to a direct

Dhanush missile

Akash surface to air missile

target hit and disintegration of the target. Capabilities of Nag, the third-generation antitank missile, which is a vehicle-mounted system, were demonstrated in a series of user trials. Advanced versions of BrahMos

Nag-anti-tank missile

supersonic cruise missile, the only one of its kind in the world, were developed and flight-tested. Thus, BrahMos Block II with target discrimination and

BrahMos supersonic cruise missle

precision strike capabilities, was test-fired. Similarly, BrahMos Block III with capability for steep diving from high altitudes and high manoeuvers at multiple points during supersonic flight, was also tested. Development of advanced missile systems is a continuous effort and requires systematic development of more and more advanced technologies. Ring Laser Gyro (RLG) based Inertial Navigation System was developed, qualified, and tested. An Active Radar Seeker for advanced missions was successfully developed. A Fibre Optics Gyro was successfully developed and tested onboard.

In the area of Aeronautics, Tejas, the Light Combat Aircraft (LCA) successfully completed its extensive flight tests including weapon trials, dropping of bombs, jettisoning drop tanks and night flights; leading to its Initial Operational Clearance (IOC) on 10 January 2011. Over 1640 flights covering a period of more than 969 h have been completed by Tejas

LCA-Tejas

Mark 01. The first prototype of LCA (Naval version) was rolled out and its induction tests were completed. In tune with changing war scenario, major thrust has been given to develop Unmanned Aerial Vehicles (UAVs). Successful flight trials of Rustom-1, a UAV with endurance of 14 h and altitude ceiling of 8,000 m demonstrated the capabilities for automated/remotely-piloted landing/ take-off and associated technologies.

Rustom UAV

Nishant UAV

Nishant, another UAV developed by DRDO was ready for induction by the Army. A medium-sized aerostat-based platform was developed for surveillance applications. A novel method was developed and flight-tested for an in-flight structural monitoring of the manned as well as unmanned aircraft structures. The scheme was flight-tested on a Nishant UAV. Besides, over 100 test flights of a 3,000 gm Micro Aerial Vehicle (MAV) designed and developed by DRDO were carried out. A laser seeker kit – 'Sudarshan', for 1,000 lb bombs was developed and initial demand for significant number of seeker kits has been received from the Services. Major milestones in the indigenous development of fighter aircraft engine were achieved with the completion of Official Altitude Testing (OAT) of Kaveri Gas Turbine Engine for simulated operating conditions. Subsequently, test flights of Kaveri engine were successfully carried out on a Flying Test Bed (FTB) proving the technological capability and

Kaveri Engine gas turbine

maturity of the indigenous efforts. This is for the first time that an indigenously developed gas turbine engine for fighter aircraft has been flown on a FTB. DRDO has developed expertise in the field of testing and certification for various components, sub-systems, and systems as well as complete airborne platforms. Thus, Initial Operational Clearance of both LCA and Advanced Light Helicopter (ALH) MK–III were the major activities in this area.

Advanced active-cum-passive integrated sonar system Humsa NG was designed, developed, and installed on various ships of the Indian Navy. Autonomous Underwater Vehicle (AUV) capable of navigation was demonstrated at sea. A CO_2 curtailment system for submarines has been designed and developed, which has also been accepted by the users. Sanjeevani MK-II, a device designed and developed to locate victims trapped under the debris was handed over to the National Disaster Management Authority (NDMA) and Kerala Govt Fire Services.

An advanced facility was created to undertake full-scale processing of large rocket motors. The facility was commissioned and the casting of various motors commenced. Pinaka–Multi-barrel Rocket Launcher System was developed and technology transferred to production agencies. Two regiments of Pinaka (worth Rs 1300 crore) have been raised by Army, which is also likely to place orders for another two regiments. The Transfer of Technology (ToT) for multi-mode grenade was completed, for which the Army has placed an order for 10 lakh grenades. Under-barrel Grenade Launcher (UBGL) for INSAS and AK-47 rifles was introduced into the Services with order for 10,000 launchers. The state-of-the-art microcontroller-based system Instant Fire Detection and Suppression System (IFDSS) BMP-2/2K has been developed for providing protection against fire to the troops and engine compartment was accepted by the Army. Production order worth Rs 168 crore has been received.

MBT Arjun Mark-I was successfully inducted in the Army and two regiments of Arjun Main Battle Tank have been raised. A Carrier Command Post Tracked (CCPT) vehicle was accepted by the Army for induction. A modified Armoured Amphibious

MBT Arjun

Dozer (AAD) completed its User Trials. User Trials of remotely operated vehicle (ROV Daksh) were successfully carried out and Limited Series Production (LSP) order for 20 number is being executed. Design of Snow Gallery for protection of personnel and equipment from avalanches and design of Instrumented Composite Tower for studies on avalanches have been completed.

In the field of electronics and electro-optics, many systems were inducted/accepted by the services. 3-D medium-range surveillance radar – Rohini and its naval variant, Revathi were inducted. 3-D low-level lightweight radar – Aslesha (for IAF) as well as Bharani (for Army) have been accepted by the Services. The engineered version of upgraded Weapon Locating Radar (WLR – Swathi) developed by DRDO was realised by the production agency. Electronic Warfare Systems Samyukta (Naval variant) and Sujav were inducted. Orders have been received for the Combat Net Radio (CNR) with anti-jamming features. A holographic sight for rifles/carbines was developed for aiming in closed-quarter battle role and has been accepted by the Services.

Even with the most advanced weapon systems, the man behind the machine is the most crucial factor in winning the war. The Life Sciences laboratories of DRDO continue to develop technologies to maximise the operational efficiency of our soldiers and provide them with adequate support and protection. Some of the major achievements are highlighted. Three mobile laboratories for nuclear, biological, and chemical defence were handed over to the users and rigorous training imparted to them. An upgraded first-aid kit for protection against chemical and biological agents as well as nuclear radiation was accepted by the Services. Technology for producing DRDO-developed kits for the detection of Swine Flu was transferred to the production agency. The Combat Free Fall (CFF) Protection System to meet the requirements of high

CFF Suit

altitude paratroopers' mission was designed and developed and is under LSP. A Submarine Escape Suit (SES) for escape from an abandoned submarine from depths of 100 m was designed and developed. Navy has projected a requirement of over 400 Submarine Escape Suits. Greenhouses were established at powerplant locations such as Siachen Base Camp, Chushul, Battalik, etc., and an average of 1400 kg vegetables of high nutritive value produced in each greenhouse by standardising the practices and procedures. About 5000 MT of vegetables are locally grown for meeting Army's requirements. A Computersed Pilot Selection System (CPSS) was designed, developed, and accepted by the Air Force. Series production of systems for deployment at all the Air Force Selection Boards of the IAF is underway. Yoga Training Modules have been developed for toning up cardio-respiratory, respiratory, endocrine, and nervous systems to maintain optimum physical fitness and mental health of troops deployed at high altitude extreme climates. Yoga training was provided to over 2000 army personnel who were to be deployed at Siachen Glacier. Bio-toilets have been installed in Lakshadweep Islands and North-East region of India for safe disposal of human waste and MoUs signed with the Indian Railways and the Ministry of Urban Development for their installations in rail coaches and homes. MoU with Ministry of Urban Development is under process for joint development of bio-toilets and their installation under Mass Civilian Programme.

Advanced materials have been always at the core of weapon systems and military hardware. Significant milestones have been achieved in this critical area. A low-alloy steel DMR-1700 with ultrahigh strength and high fracture toughness has been developed as a cost-effective replacement of 250 grade maraging steel. The alloy was proven by successful demonstration in the intended application. A 500 tonne per annum capacity Titanium Sponge Plant based on DRDO technology was set up at Kerala Minerals and Metals Limited (KMML) on 27 February 2011. Lightweight composite armour for Mi-17-IV helicopter of IAF has successfully undergone integration and flight-trials. Technology developed for vacuum investment casting of gas turbine blades for Kaveri engine was extended for making high pressure turbinea blades for land-based gas turbine for power generation. The runways at strategic locations often require rapid repairs. Many of these locations are in extreme cold regions where the normal concrete does not set in easily. Technology for rapid repair of runways in cold regions has been developed and successfully demonstrated at sub-zero temperatures.

A dedicated team of DRDO engineers executed highly specialised nature of Civil Works at some of the most difficult and hazardous areas within the stipulated time frame. Agreements for cooperation/ co-development in frontline areas of science, technology, and engineering were signed with several countries.

With '*Balasya Mulam Vigyanam*' as the *Mool Mantra*, DRDO continues its march towards achieving self-reliance in critical defence technologies.

POPULAR SCIENCE

GRAPHENE

Introduction

A sheet of crystalline carbon one atom thick is called Graphene . Such a two-dimensional structure was long believed to be a physical impossibility in terms of stability. This status was transformed by a group led by Andre Geim at the University of Manchester in 2004 when they successfully realised small fragments of graphene monolayers. What is truly amazing is that the group could achieve this seemingly impossible task with a childishly simple technique, called 'Scotch tape method'. The technique uses adhesive tape to rip-off sheets of carbon from graphite. More sophisticated methods like epitaxial growth have since followed but the scotch tape method still remains immensely popular. Graphene has a single layered honeycomb structure and can be justifiably called the mother of all carbon-based systems. This is because all other forms like graphite, carbon nanotubes , buckminsterfullerene, etc. can be derived from graphene as seen in Fig 1.

Importance of Graphene

What makes graphene such an important material that a large number of groups are putting their best brains in it? The reasons are many but let us list out a few significant ones:

1. The honeycomb–lattice structure allows physicists to observe relativistic effects at speeds that are much below the speed of light. This behaviour is due to the strong interaction between the electrons in the Graphene layer. These strong interactions ensure that the energy and momentum of electrons in Graphene are related through the equation, $E=\nu P$ where ν is called the 'Fermi-Dirac velocity' and P is the momentum. In special theory of relativity energy, E and momentum P are related by the equation, $E=\sqrt{(Mc^2 + P2c^2)}$ which yields E = c P as M turns to zero. Thus the electrons in Graphene behave as if their mass is zero. Two things have to be remembered to fully appreciate this effect in Graphene. Firstly, the Fermi-Dirac

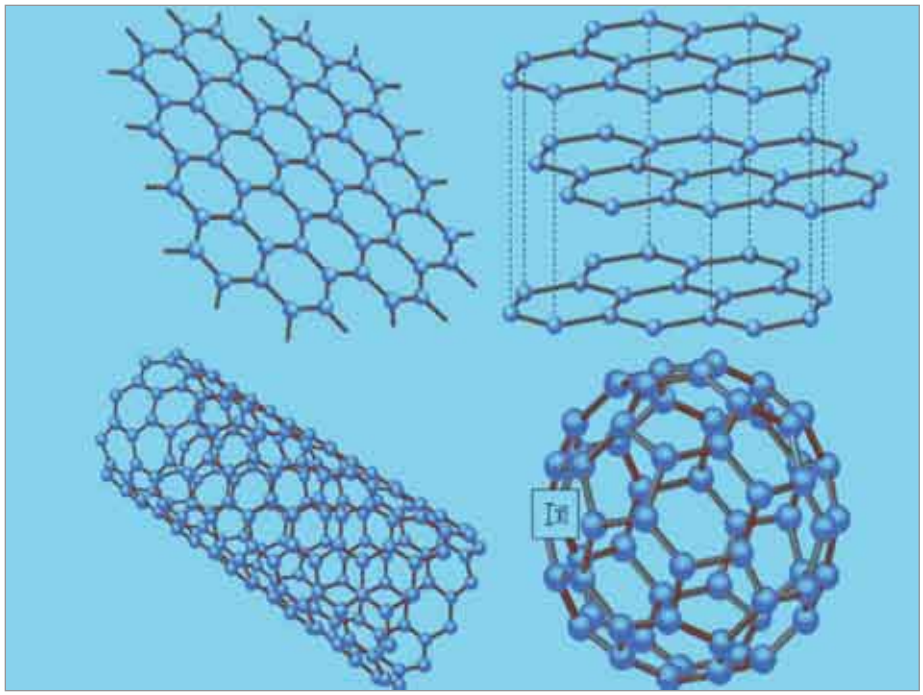

Figure 1: 2-D hexagonal lattice of carbon atoms and its transformation into graphite, carbon nanotube, and buckminsterfullerene.

velocity in graphene is about 300 times less than the speed of light, and secondly, that electrons moving in honeycomb-lattice only produce this energy-momentum relationship whereas other lattices like square or triangular always end up having electrons with finite band mass. The mass-less electrons are however quite different from their particle–physics cousins neutrinos. This is because unlike electrons neutrinos carry no charge and therefore cannot interact strongly with any matter. The electrons in Graphene can however interact with matter and can also be manipulated through externally applied electromagnetic fields. This manipulation is what makes graphene a very interesting candidate trying to beyond the technology limits set by silicon-based systems and devices.

2. Hall Effect is a phenomenon in which a material with a current flowing through it in the presence of a transverse magnetic field has a potential drop in a direction that is at right angles to both the current and the magnetic field. Moreover, the ratio of the potential drop to the current flowing, called the Hall resistivity, is found to be directly proportional to the applied magnetic field. Around a century after the discovery of Hall Effect, studies carried out by Klaus von Klitzing revealed that for 2-D electron gas at temperatures that are close to absolute zero, the Hall resistivity is quantised and can take only discreet values of the ratio (h/ne^2) where h is the Planck's constant , n is a positive integer, and e is the electronic charge. In graphene, the Hall resistivity gets quantised in terms of odd integers only. In fact this 'anamalous' integer QHE; as it is called, is a signature of presence of graphene. The QHE effect in graphene has been observed at room temperature unlike at temperatures near absolute zero in other materials. The cause lies in the fact that the cyclotron energy in graphene is around 100 times greater than other materials. The anomalous QHE is also found to be thickness dependent. Thus, the QHE can be used to distinguish between single, double or multilayer graphene structures.

3. In ordinary metals, electrons suffer scattering due to impurities in the crystal. This in turn leads to energy loss due to resulting electrical resistance. In graphene, the electrical resistance is not dependent upon the number of impurities and the electrons can travel large distances without suffering collisions with impurities. This property of electrons in graphene makes it a promising material for developing a high-speed electronic switching device called a 'ballistic transistor'. Resistance offered by graphene is in fact lower than even silver, which is the least resistive metallic material. Graphene also conducts heat ballistically since phonons also encounter very little resistance as these travel through graphene. This results in amazing thermal properties for Graphene layers.

4. In the absence of an applied field, graphene has no band gap since the electrons in graphene are already in the conduction band. A bi-layer graphene however has a tuneable band gap under the influence of an applied electric field. Studies have shown that the band gap of graphene can be modified or tuned in the range 0–250 milli electron volts. This tuneable band gap would enable device engineers to design extremely small chips with millions of graphene electronic devices and connections.

Applications

The important properties and characteristics of graphene mentioned would makes graphene a good choice for several applications. Some of these applications include:

1. Graphene layers possess very high carrier mobility and low noise and therefore can lead to use in the channel region of field effect transistors. Thus, graphene has the potential to replace silicon in the future generation integrated circuits. In fact, the smallest working transistor ever created uses graphene of one atom thickness and a ten-atom thick width. Due to the high area-to-mass ratio of graphene, it can be used for making the conducting plates in ultra capacitors. These ultra capacitors could result in extremely high storage densities.

2. Graphene layers have very high electrical conductivity and optical transparency. This makes graphene a good candidate for applications requiring transparent electrodes. The devices

that could benefit include touch-screen phones, hand-held computers, organic photovoltaic cells, and organic light-emitting devices. Before these ideas become practically realisable, issues like reproducible growth and stability would have to be suitably looked into.

3. Graphene would also find applications in the field of composite materials. Of course questions like mass production and cost would have to be suitably answered. Applications could include gasoline tanks, food containers, sports equipment, aircraft and automobile parts, wind turbines and medical implants, to name a few. Mechanical strength coupled with light weight would be the plus factors in favour of graphene for many of these applications. Other important properties that would find use would include high electrical conductivity and higher operating temperatures. The biggest competitor for graphene in this area would be carbon nano tubes. Graphene is however cheaper and does not suffer from toxicity issues that affect carbon nanotubes which can penetrate lungs and cause complications that can lead to cancer.

4. Graphene has the ability to store large amount of hydrogen and produce corresponding changes in the local electrical resistance. These properties make graphene a good choice for solid-state gas detection applications. Long distance transportation of gases through pipes could gain immensely from Graphene's properties. The inside surface of the pipes carrying gas could be coated with Graphene layer and leaks, if any could be detected by monitoring the electrical resistance across the entire length. Thus, the graphene layer would not only strengthen the transporting pipe but would also serve as a sensor element that is distributed throughout the length of the pipe.

5. Electron beam lithography techniques can be used to pattern graphene to realise electron waveguides. The properties of these waveguides can be controlled using externally applied voltages. Such waveguides can be put to novel applications in communication and other similar systems.

6. Graphene-based field-effect transistors (FET) fabricated on diamond–like carbon substrates have shown cut-off frequencies in the region of 155 GHz with typical gate lengths of just 40 nm. The fabricated FETs have been shown to work down to temperatures as low as 4.3 K. The diamond-like carbon is a non-polar di-electric material, and therefore, does not trap charges or scatter charges the way the more conventially used silicon dioxide does. The key to pushing the cut-off frequency up lies in improving the quality of graphene layer that is obtained using CVD process.

7. Graphene can be ripped to shreds to obtain graphene nanoribbons (GNR). The structure at the edge of the ribbon can either be zig-zag or armchair. Interestingly, zig–zag ribbons behave as conductors whereas armchair ribbons behave as semiconductors. The band gap of armchair ribbons can be modulated by modulating the width of the ribbon, and experiments have shown that the band gap is inversely proportional to the width. Thus, thinner ribbons result in higher band gap. Such graphene ribbons can be realised in practice by cutting open carbon nanotubes.

Conclusion

It has been concluded that some amazingly simple techniques can result in graphene layers that have properties required by many applications and devices. The full realisation of the potential of this material would however require a large number of studies on its growth and characterisation. There is no doubt that better graphene layers would soon be realisable using sophisticated growth techniques like chemical vapour deposition, and the developed material would find use in electronics, composite materials, and semiconductor devices. Along with this, graphene layers would also help Physicists study some interesting effects that require much more sophisticated set-ups and structures than made possible by the special properties of this wonder material.

Dr DK Bhattacharya, Sc 'G', SSPL, Delhi

New Biogas Plant for NPOL

Shri S Anantha Narayanan, OS and Director, Naval Physical and Oceanographic Laboratory (NPOL), Kochi, inaugurated the new biogas plant named, 'AMAL' on 24 May 2011. Shri MG Thimmaya, Sc 'E', Estate Manager, EMU, Bengaluru, graced the ocassion. The waste management plant is aimed at generating biogas for cooking at DROMI. The plant can process waste of 20 kg/day with a production rate of 10-cubic metre biogas. The plant was set up with the technical support of Biotech India, Thiruvananthapuram. The technology involved in the conversion of waste into biogas is with the help of microbes. The use of biogas as cooking fuel has a combined advantage of tapping non-conventional source of energy as well as effective waste management. A similar type of biogas plant titled, 'VIMAL' is also functional in the Technical Complex.

Inauguration of the biogas plant – 'AMAL' at NPOL.

Inauguration of PGM -Electronics Centre and HILS-facility at ARDE

The Precision Guided Munition (PGM)-Electronics Centre and HILS-Facility at Armament Research and Development Establishment (ARDE), Pune, was inaugurated on 06 June 2011 by Shri Anil M Datar, OS and Director, ARDE, Pune. This Centre has three parts, viz., control electronics, guided sensors and hardware-in-the-loop simulation (HILS). The facilities available at this Centre are inertial test setup, precision acceleration test setup, three-axes flight motor simulator, two-axes linear trial motion simulator, GPS simulator, and electronic integration facility for PGM. This Centre will be specialised in electronics for PGMs.

Shri Anil M Datar, OS and Director, ARDE inaugurating the Facility.

R&DE (Engrs) Golden Jubilee Celebrations

A symposium on 'Robotics and Autonomous Vehicles – Views and Perspectives' was organised at R&DE (Engrs) as part of its Golden Jubilee Celebrations. The Symposium was inaugurated by Dr W Selvamurthy, DS and CC R&D (LS and IC), DRDO.

The keynote address was delivered by Lt Gen (Retd) VJ Sundaram, Advisor, National Design and Research Forum. Speakers included eminent personalities from Indian Air Force, ISRO, BARC, DRDO, C-DAC, NIO, IISc, IIT, Hyderabad; BITS, Pilani; M/s IdeaForge Technology Pvt Ltd, Mumbai; M/s Hitech Robotic Systemz, Gurgaon; M/s Systemantics and M/s Serial Innovation from Bengaluru; and M/s Wavelet Group and M/s KPIT from Pune.

The Symposium provided a forum for interaction between users, industry, academia, researchers, and scientists for exchanging views and sharing their experiences in the development of unmanned vehicles in space, air, ground, and underwater. The event was attended by over 250 delegates. An exhibition of robotics and autonomous vehicles was also arranged with live demos of various unmanned systems.

Lighting the lamp ceremony. L to R: Shri Alok Mukerjee, Sc 'F'; Dr S Guruprasad, Director, R&DE(E); Dr W Selvamurthy, DS & CC R&D (LS & IC); and Lt Gen (Retd) VJ Sundaram, Advisor, National Design and Research Forum.

PERSONNEL NEWS

Appointments

Director, NSTL

Shri SV Rangarajan, Outstanding Scientist, assumed charge as Director, Naval Science and Technological Laboratory (NSTL), Visakhapatnam on 06 June 2011.

Shri Rangarajan obtained BE (ECE) from Sri Venkateswara University, and ME (Advanced Electronics) from JNTU, Hyderabad. Thereafter, he obtained MS (Software Engineering) from BITS, Pilani, and is currently pursuing PhD in Wireless Sensor Networks. He is a recipient of many awards that include, *DRDO Technology Development Award* (1996), and *Scientist of the Year Award* (2002). His areas of specialisation include embedded system design, underwater weapon design and development, and project management. He is a Life Member of Institution of Electronics and Telecommunication Engineers and Condition Monitoring Society of India and Member of Society of EMC Engineers.

SA to CIDS

Shri Bhaskar Burman, Sc 'F' has been appointed as Officiating Scientific Adviser to the Chief of Integrated Defence Staff to the Chairman, Chiefs of Staff Committee (CISC) wef 31 May 2011 in addition to his duties in the Office of SA to CNS.

Shri Burman obtained BE (Electronics and Telecommunication Engineering) from Bengal Engineering College, Calcutta University, Kolkata, in 1984 and MTech in Computer Engineering from IIT, Kharagpur, in 1997. He joined DRDO in 1991 and has 20 years of R&D as well as techno-managerial experience. He has worked in Defence Electronics Applications Laboratory (DEAL), Dehradun, and Defence Terrain Research Laboratory (DTRL), Delhi. He was also privileged to work in G-FAST, a DRDO Think Tank, during 2004–2006. His research interest includes geospatial intelligence, satellite image processing, and imaging surveillance and reconnaissance. He has 10 research papers to his credit and was the recipient of *DRDO Technological Award* in 1996. He is a Life member of Institution of Electronics and Telecommunication Engineers (IETE), India, and Computer Society of India (CSI).

Awards

Best Contributor Award in Electronic Warfare

Shri TN Yadgiri Rao, Outstanding Scientist and Associate Director, Defence Electronics Research Laboratory (DLRL), Hyderabad received the 'Best Contributor Award in EW from DRDO' on the occasion of first Annual General Body Meeting of AOC India Chapter held at Hotel Lalit Ashok, in Bengaluru on 7 May 2011. Chief Guest, Dr Prahlada, DS and CC R&D (Ae&SI), DRDO HQrs, New Delhi, presented annual awards to eminent personalities from DRDO, PSUs, the Indian Armed Services, and the Indian EW Industry. The awards function was presided over by Dr UK Revankar, Director, DARE, Bengaluru, and Shri G Boopathy, OS and Director, DLRL, Hyderabad.

Shri TN Yadgiri Rao receiving the Best Contributor Award.

Inauguration of 'Health Motivation'-A Gym

Dr PS Goel, Chairman, Recruitment and Assessment Centre (RAC), Delhi, inaugurated 'Health Motivation', an INMAS-supported Gym, on 04 June 2011. Dr Arun Kumar, Director of Personnel; Dr RP Tripathi, Director, INMAS; and Dr Manas K Mandal, Director, DIPR were present on the occasion. The facility will cater to the additional needs of DRDO scientists/officials and service personnel. The facility consists of motorised treadmill, cross trainer, upright bike, recumbent bike, 4 station multi gym, seated chest press, seated rowing pully, leg extension/curl, arm curl/biceps, vibration plate machine, twister abdominal board, etc.

Dr PS Goel, Chairman, RAC inaugurating the Gym.

Visits to DRDO Labs/Estts

CAIR, Bengaluru

- Brig PC Ipe, VSM DDG, PMO, CIDSS, on 24 May 2011.
- Maj Gen VK Narang, ADGIS(B), on 31 May 2011.

Demonstration by the Information Security Division to Maj Gen VK Narang, ADGIS(B).

- Dr A Ravishankar DIG, NIA, Hyderabad, on 07 June 2011.

CVRDE, Chennai

Smt Sanhita Kar, IDAS, Controller of Defence Accounts, on 27 May 2011.

Smt. Sanhita Kar, IDAS, showing keen interest in CVRDE products and technologies.

DARE, Bengaluru

Vice Admiral Satish Soni, AVSM, NM, on 01 June 2011.

Vice Adm Satish Soni, AVSM, NM showing keen interest in the activities of DARE.

ISSA, Delhi

Maj Gen VK Narang, ADGIS(B), on 26 May 2011.

Maj Gen Narang taking keen interest in Land Wargaming Projects developed by ISSA.

LRDE, Bengaluru

Vice Admiral Satish Soni, AVSM, NM, OSD to CNS, on 02 June 2011.

Vice Adm Satish Soni evincing keen interest on MPR proto array.

NPOL, Kochi

Shri BD Basantia, Director of Audit (Navy), on 24 May 2011.

Shri BD Basantia showing keen interest in about the project activities of NPOL.

Shri IV Sharma, Director, (R&D) BE, Bengaluru, on 31 May 2011.

Shri IV Sharma, Director, (R&D) BE, Bengaluru, showing keen interest in the project activities of NPOL.

RCI, Hyderabad

His excellency Shri ESL Narasimhan, Governor of Andhra Pradesh, on 28 May 2011.

VRDE, Ahmednagar

Lt Gen MS Buttar, VSM, DG(W&E), along with Col Sirohi, Director, 13/14 (W&E), on 13 June 2011.

Lt Gen MS Buttar, along with Col Sirohi, witnessing demo of HMV 6x6 at steering pad of NCAT (VRDE).

The Editorial Team thanks all the DRDO Newsletter Correspondents for their contributions.

ISSN:0971-4391

निदेशक, डेसीडॉक, दिल्ली द्वारा डी आर डी ओ, की ओर से मुद्रित एवं प्रकाशित
दिल्ली-110 054
दूरभाष: 011-2390 2471
फैक्स: 011-2381 9151

Printed & published by
Director, DESIDOC,
on behalf of DRDO
Delhi - 110 054
Tel: 011-2390 2471
Fax: 011-2381 9151
Website: www.drdo.gov.in/drdo/publ/pubframeset.html
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