

DRDO TESTS PINAKA ARTILLERY MISSILE SYSTEM IN SALVO MODE



INNOVATION >> p05

MOU >> p07

HRD ACTIVITIES >> p18

FOCUS >> p24

DRDO SERIES >> p27

VISITS >> p30

CONTENTS

JANUARY 2020
VOLUME 40 | ISSUE 1
ISSN: 0971-4391

COVER STORY 04

Pinaka Artillery Missile System Tested in Salvo Mode



INNOVATION 05

QRSAM Successfully Test-Fired off Odisha Coast
BrahMos Tested from Land and Air Platforms



MOU 07

EVENTS 07



HRD ACTIVITIES 18

OPINION 21

FOCUS 24

DRDO SERIES 27

PERSONNEL NEWS 29

VISITS 30



40th Year of Publication

Editor-in-Chief: Dr Alka Suri
 Associate Editor-in-Chief: B Nityanand
 Managing Editor: Manoj Kumar
 Editor: Dipti Arora
 Editorial Assistance: Biak Tangpua
 Multimedia: RK Bhatnagar
 Printing: SK Gupta
 Distribution: Tapes Sinha, RP Singh



Website: <https://www.drdo.gov.in/drdo/pub/newsletter/>

Please mail your feedback at:
director@desidoc.drdo.in

Contact: 011-23902403; 23902474
 Fax: 011-23819151

LOCAL CORRESPONDENTS

Ambernath: Dr Susan Titus, Naval Materials Research Laboratory (NMRL); **Chandipur:** Shri PN Panda, Integrated Test Range (ITR); **Bengaluru:** Shri Subbukutti S, Aeronautical Development Establishment (ADE); Smt MR Bhuvanewari, Centre for Airborne Systems (CABS); Smt Faheema AGJ, Centre for Artificial Intelligence & Robotics (CAIR); Ms Tripty Rani Bose, Centre for Military Airworthiness & Certification (CEMILAC); Smt Josephine Nirmala M, Defence Avionics Research Establishment (DARE); Smt Anuya Venkatesh, Defence Bioengineering & Electromedical Laboratory (DEBEL); Shri Venkatesh Prabhu, Electronics & Radar Development Establishment (LRDE); Dr Vishal Kesari, Microwave Tube Research & Development Centre (MTRDC); **Chandigarh:** Dr HS Gusain, Snow & Avalanche Study Establishment (SASE); Dr Prince Sharma, Terminal Ballistics Research Laboratory (TBRL); **Chennai:** Smt S Jayasudha, Combat Vehicles Research & Development Establishment (CVRDE); **Dehradun:** Shri Abhai Mishra, Defence Electronics Applications Laboratory (DEAL); Shri JP Singh, Instruments Research & Development Establishment (IRDE); **Delhi:** Shri Ashutosh Bhatnagar, Centre for Personnel Talent Management (CEPTAM); Dr Dipti Prasad, Defence Institute of Physiology & Allied Sciences (DIPAS); Dr Nidhi Maheshwari, Defence Institute of Psychological Research (DIPR); Shri Navin Soni, Institute of Nuclear Medicine and Allied Sciences (INMAS); Shri Anurag Pathak, Institute for Systems Studies & Analyses (ISSA); Dr Indu Gupta, Laser Science & Technology Centre (LASTEC); Ms Noopur Shrotriya, Scientific Analysis Group (SAG); Dr Rupesh Kumar Chaubey, Solid State Physics Laboratory (SSPL); **Gwalior:** Shri RK Srivastava, Defence R&D Establishment (DRDE); **Haldwani:** Dr Atul Grover, Defence Institute of Bio-Energy Research (DIBER); **Hyderabad:** Shri Hemant Kumar, Advanced Systems Laboratory (ASL); Shri Pramod K Jha, Centre for Advanced Systems (CAS); Dr JK Rai, Advanced Numerical Research & Analysis Group (ANURAG); Ms Bidisha Lahiri, Centre for High Energy Systems & Sciences (CHESS); Shri ARC Murthy, Defence Electronics Research Laboratory (DLRL); Dr Manoj Kumar Jain, Defence Metallurgical Research Laboratory (DMRL); Dr K Nageswara Rao, Defence Research & Development Laboratory (DRDL); Shri Lalith Shankar, Research Centre Imarat (RCI); **Jagdalpur:** Dr Gaurav Agnihotri, SF Complex (SFC); **Jodhpur:** Shri Ravindra Kumar, Defence Laboratory (DL); **Kanpur:** Shri AK Singh, Defence Materials & Stores Research & Development Establishment (DMSRDE); **Kochi:** Smt Letha MM, Naval Physical & Oceanographic Laboratory (NPOL); **Leh:** Dr Dorjey Anchok, Defence Institute of High Altitude Research (DIHAR); **Mussoorie:** Dr Gopa B Choudhury, Institute of Technology Management (ITM); **Mysuru:** Dr M Palmurugan, Defence Food Research Laboratory (DFRL); **Pune:** Dr (Mrs) JA Kanetkar, Armament Research and Development Establishment (ARDE); Dr Vijay Pattar, Defence Institute of Advanced Technology (DIAT); Shri AM Devale, High Energy Materials Research Laboratory (HEMRL); Shri SS Arole, Research & Development Establishment (Engrs) [R&DE (E)]; **Tezpur:** Dr Jayshree Das, Defence Research Laboratory (DRL)

PINAKA ARTILLERY MISSILE SYSTEM TESTED IN SALVO MODE

Pinaka, an Artillery Missile System, developed by DRDO was flight-tested from the Integrated Test Range (ITR), Chandipur off the Odisha coast on 19 and 20 December 2019. In the trial conducted on 19 December missile was fired at 75 kilometre range.

In the second trial on 20 December, the mission objective was to test low range, functioning of live warhead along with its proximity initiation, and salvo launch. Two Pinaka missiles

were launched in salvo mode with 60 seconds interval between two firings. Both the missiles were fired with high accuracy to engage a target located at 20 km. The missile was integrated with live warhead with proximity fuse and was tracked by multiple range systems viz. telemetry, radars, Electro-Optical Tracking System, which confirmed the textbook flight performance.

The system has been jointly developed by DRDO's Armament

Research and Development Establishment (ARDE), Research Centre Imarat (RCI), Defence Research and Development Laboratory (DRDL), Proof and Experimental Establishment (PXE), and High Energy Materials Research Laboratory (HEMRL).

Secretary Department of Defence R&D and Chairman DRDO Dr G Satheesh Reddy congratulated the teams involved in the flight trials.



QRSAM SUCCESSFULLY TEST-FIRED OFF ODISHA COAST

Quick Reaction Surface-to-Air Missile (QRSAM) system developed by DRDO was successfully flight-tested from ITR, Chandipur on 23 December 2019. The missile was flight-tested with full configuration in deployment mode and intercepted the target in mid-air meeting the mission objectives. The entire event was monitored by Ground Telemetry Systems, Range Radar Systems, Electro-Optical Tracking System, etc.

The QRSAM weapon system, which

operates on the move, comprises a fully automated Command and Control System, Active Array Battery Surveillance Radar, Active Array Battery Multifunction Radar and a Launcher. Both radars are four-walled having 360° coverage with search on move and track on move capability.

The system is compact with minimum number of vehicles for a firing unit. Single stage solid propelled missile has mid-course inertial navigation system with two-way data link and terminal active

seeker developed indigenously by DRDO. The missile successfully engaged the aerial target establishing its capability. With this successful testing, the developmental trials of the weapon system are complete and the system is expected to be ready for induction by 2021.

Raksha Mantri Shri Rajnath Singh and Secretary, Department of Defence R&D and Chairman DRDO Dr G Satheesh Reddy congratulated the teams involved in the flight trials and development of QRSAM.



BRAHMOS TESTED FROM LAND AND AIR PLATFORMS

DRDO, Indian Air Force (IAF) and BrahMos jointly conducted two tests, one each from land and air platforms, of BrahMos supersonic cruise missiles on 17 December 2019.

The first launch was from a land-based mobile launcher. Most of the components of the tested BrahMos were indigenous including its airframe, fuel management system and the seeker designed by DRDO.

The second launch of the missile was carried out by the IAF from Su-30 Mk I against a sea target. The test conducted in user configuration, revalidated the ship attack capability of the advanced Air Launched Cruise Missile (ALCM). During the test, the missile was gravity dropped from the combat aircraft's fuselage. The two-stage missile propelled towards the intended target at the sea and hit it with pinpoint accuracy.

IAF had successfully tested the missile against a land-based target in the Car Nicobar Islands region earlier also on 22 May 2019. The BrahMos ALCM promises to bolster the air combat capability of IAF from stand-off ranges.



INDIAN NAVY & INMAS SIGNS MOU

A Memorandum of Understanding (MoU) was signed between Director General Medical Services (Navy) and Director, Institute of Nuclear Medicine & Allied Sciences (INMAS) at Sena Bhawan, New Delhi.

Dr Tarun Sekhri, OS and Director INMAS and Surg. Vice Admiral MV Singh, AVSM, PHS, DGMS (N) signed the MoU.

The MoU envisages the active collaboration between both the agencies for research, provisioning of

domain drugs and devices, training and consultancy in the areas of mutual interest.

The MoU is the result of continuous efforts by bilateral authorities and executors over a period of last six years.



EVENTS

DRDO PARTICIPATES IN DUBAI AIR SHOW 2019

DRDO along with Hindustan Aeronautics Limited and Bharat Dynamics Limited participated in Dubai Air Show 2019 held at Al Maktoum International Airport, Dubai from 17 to 21 November 2019. DRDO showcased its static models of key export ready products, which included Light Combat Aircraft Tejas, Airborne Early Warning & Control System, HELINA Missile System, ASTRA Missile System, Onboard Oxygen Generating System (OBOGS), Low Level Transportable Radar (LLTR), Brake Parachutes for Fighter Jets, Athermal Laser Designator



and Low Frequency Dunking Sonar.

Air Marshal Harjeet Singh Arora, Vice Chief of Air Staff, inaugurated the Indian Pavilion. VIPs who visited DRDO pavilion included Crown Prince of Dubai; Shri Pavan Kapoor, Ambassador of India at UAE;

Shri Viney Gupta, Trade Commissioner, Govt of Canada; Captain Mouhamad Loubani, National Defence HQ, Canada; Vice chief of Morocco Air Force; and officials from UAE and Saudi Arabia Defence Services. DRDO's products

and technologies received lots of attention of the visitors. The presence in Dubai Air Show is a major step towards exploring export potential of technologies developed by DRDO and realization of Government of India's Make in India initiative.

WORLD QUALITY DAY CELEBRATIONS

World Quality Day is being celebrated worldwide since 2008 on the second Thursday of November every year to increase awareness of the important contribution that quality makes towards both organizational as well as national growth and prosperity. Various organizations across the world take part in a number of activities such as seminars, presentations, quizzes, competitions at their work place. The following DRDO labs/estts also celebrated World Quality Day at their respective places:

ARDE, PUNE

A lecture by Shri S Saratchandran, GD (QFRG), VSSC, Thiruvananthapuram, on "Quality Practices at VSSC" was organised. Besides, lectures on "Advanced Tools & Techniques in Quality" by Mr Hemant Urdhwarshhe, Director, Institute of Quality & Reliability, India, and "Industry Perspective on Quality" by Shri Yogesh Pitkar, GM (Six Sigma & Lean Mfg), John Deere Technology Centre, India were also organised. A demo on Minitab Software by Digilogic was also held. ARDE employees actively participated in quality slogan and quiz competitions. In recent years, a number of ARDE scientists have become Certified Quality Engineer (CQE) and Certified Reliability Engineer (CRE) from ASQ. The successful participants were felicitated by Director, ARDE. Quality practices observed by project groups and contributions by individuals for the same were acknowledged.



Shri S Saratchandran delivering talk on Quality Practices at VSSC

DEBEL, BENGALURU

Mrs Manimozhi Theodore, OS and Director, Defence Biomedical and Electromedical Laboratory (DEBEL) inaugurated the function and addressed the audience. Invited talks were delivered by Dr TL Dhanabalan, former Deputy Director, ISRO, on "Rendezvous with Quality" and Shri S Padmanaban, Consultant, SAAI TQM Solutions on "Implementation of AS 9100



Dr TL Dhanabalan delivering his talk on Rendezvous with Quality

Revision in R&D Environment and its Effectiveness." The speakers shared their experiences on the importance of quality in all areas of work. More than 150 participants attended the programme.

DMRL, HYDERABAD

Shri JS Yadav, Sc 'G', in his welcome address highlighted the implementation of Quality Assurance in R&D from project inception to the final product realisation. Dr Vikas Kumar, DS & Director, DMRL, delivered the Quality Day address and emphasized the importance of Quality Assurance as an integral part of the projects. Cmde S Nandula, former Director, DQRS, DRDO HQ, delivered a lecture encompassing the theme of World Quality Day 2019—"100 Years of Quality". He outlined the importance of observing World Quality Day and the significant contribution of quality in advancements of various technologies.

Shri CVS Sai Prasad, Sc 'G' & Director (Q&R), DG (MSS), Hyderabad, delivered a talk on "Mission Assurance in Aerospace Systems." He spoke about failures of various space systems and their major causes.



Dr Vikas Kumar felicitating the speakers

HEMRL, PUNE

As a part of World Quality Day celebrations, article writing competition on “Innovative Techniques to Enhance the Quality in Processing of High Energy Materials and Allied Products” and slogan writing competition in Hindi, English & Marathi on “Quality” were organised. Dr TK Varadrajan, Joint Controller CQA (ME), Pune, the Chief Guest delivered keynote address on “Quality Assurance Practices: Global Perspective.” Shri C Gururaja Rao, AD (QARD), briefed about the steps taken by HEMRL to improve the quality of the products and services delivered by the laboratory.



Dr Manoj Gupta presenting memento to Dr TK Varadrajan

INMAS, DELHI

Institute of Nuclear Medicine & Allied Sciences (INMAS) organized a lecture on “Quality Management in Research & Development by Shri Rohan Sharma, Sc ‘D’, Centre for Fire, Explosives and Environment Safety (CFEES), Delhi.



Dr Tarun Sikari, Director, INMAS delivering his World Quality Day address

ITR, CHANDIPUR

Shri HK Ratha, Sc ‘G’, Offg. Director, Integrated Test Range (ITR),



Inauguration session of World Quality Day Celebration at ITR

in his inaugural address highlighted the importance of quality in test firing of missiles. Shri PK Mohanty, Sc ‘G’ delivered a lecture on “QMS Procedures and the QR, HR & Audit Effectiveness” being adopted in ITR making it a world-class test range. More than 100 officers and staff attended the programme.

MTRDC, BENGALURU

Microwave Tube Research and Development Centre (MTRDC), organised a lecture on “Significance of Robust Reliability & Quality Assurance Structure” by Shri Jagadeesh Kumar R., AGM and Head of Nalanda, Bharat Electronics Limited Academy of Excellence. Shri Kumar brought out the difference between quality control and quality assurance. He emphasized on the need for quality from the requirement specification and design stage itself, and the importance of quality through explanation of corrective and preventive actions and root cause analysis. He also talked about risk categorization based on the impact and frequency of



Shri Jagadeesh Kumar R delivering talk on Significance of Robust Reliability & Quality Assurance Structure

occurrence and the risk management techniques. Linking this to projects, he explained about management of scope, schedule and cost of project with acceptable risk.

NPOL, KOCHI

Shri T Gopalakrishnan, Sc ‘H’ & GD (Q&R), Mission & Software Group, VSSC, Thiruvananthapuram, delivered a technical talk on “Software QA Processes: An ISRO Perspective.” He covered the quality aspects to be taken care for any mission and elaborated the quality and reliability aspects of software processes in ISRO. He added that simulation before actual launch is the strength of VSSC, since failure in any software element can be catastrophic. Smt KH Kochaleema, Sc ‘G’ & GD (QRS) in her welcome speech briefed the importance of quality, reliability and safety in projects. Shri S Vijayan Pillai, OS & Director NPOL in his inaugural speech stressed the need for quality and reliability procedures to be followed in sonar R&D.

A new portal ‘System Engineering & Technology Management’ was launched by Shri S Vijayan Pillai. The portal would facilitate NPOL scientists with templates and documentation for project approvals, project documentation and closure. Dr K Ajith Kumar, Sc ‘G’ & Associate Director (SE&TM) delivered a talk in which he introduced a new framework for sonar project development using the systems engineering principles.



DIBER PARTICIPATES IN RAIBAAR AT TEHRI & ICAR-VIVEKANAND PARVATIYA KRISHI ANUSANDHAN SANSTHAN KISAN MELA AT ALMORA

Defence Institute of Bio-Energy Research (DIBER), Haldwani, participated in Uttarakhand State Foundation Day Celebration—RAIBAAR 2 at Tehri Garwal on 3 November 2019. Hon'ble CM of Uttarakhand Shri Trivendra Singh Rawat, Hon'ble CM of Uttar Pradesh Yogi Adityanath, and Chief of Army Staff General Bipin Rawat were present on the occasion. Dr Madhu Bala, Director, DIBER, briefed the dignitaries about the technological solutions developed by DIBER for improving the livelihood in Uttarakhand in general and that of border villages in particular. She elaborated on doubling the income

of farmers by scientific cultivation of European vegetables, medicinal plants, and by utilizing hydroponics and hydro fodder technologies developed by DIBER. She also emphasized on state-wide replication of pilot project of DIBER in collaboration with Border Road Organization for soil stabilization of hills by planting specific grasses to address the issue of landslides at highways and generating employment opportunities.

Hydroponics, hydro fodder, soil less cultivation, nursery production, herbal and medicinal mushroom products, hybrids/varieties of high-altitude vegetables were some of the leading

technologies of DIBER displayed at the exhibition.

DIBER also participated in Kisan Mela organized by ICAR-Vivekanand Parvatiya Krishi Anusandhan Sansthan (VPKAS), Almora, on 15 November 2019.

The mela was inaugurated by Prof. Arup Pattanaik, Director, ICAR-VPKAS and Smt Priyanka Singh, Chief Agriculture Officer, Almora. Various products and technologies developed by DIBER were displayed in the Mela. DIBER stall was highly appreciated by dignitaries and masses alike.



Dr Madhubala, Director, DIBER, explaining DIBER products to the Chief Minister of UP Yogi Adityanath

CELEBRATION OF CONSTITUTION DAY

DESIDOC, DELHI

Constitution Day, also known as Samvidhan Divas, is celebrated in India on 26 November every year to commemorate the adoption of the Constitution of India and raise awareness about the Indian Constitution among common people. On 26 November 1949,

the Constituent Assembly adopted the Constitution, which came into effect on 26 January 1950 marking the dawn of a new era. The year 2019, is the 70th anniversary of the adoption of the Constitution.

To acknowledge the contribution of the framers of the Constitution and to

apprise the people their rights and the prominent values of the Constitution, Defence Scientific Information and Documentation Centre (DESIDOC), Delhi celebrated the Constitution Day by mass reading of the Preamble by the officers and staff.



ITR, CHANDIPUR

Constitution Day was celebrated in Integrated Test Range (ITR), Chandipur on 26 November 2019. The programme was inaugurated by Dr BK Das, OS and Director, ITR. In his inaugural address

Director ITR highlighted the values of Indian Constitution and administered the preamble of Indian Constitution to ITR fraternity. In order to educate and aware the employees, a lecture on Constitution of India was delivered by

Prof. (Dr) Geetanjali Dash, Dean of Social Science and Humanities, FM University Balasore. More than 150 officers and staff attended the programme. Shri PN Panda, Sc 'F', and his team organised the programme.



RAISING DAY CELEBRATIONS

DIPR, DELHI

Defence Institute of Psychological Research (DIPR), Delhi celebrated its 71st Raising Day. Dr G Satheesh Reddy, Secretary, Department of Defence R&D and Chairman, DRDO, was the Chief Guest. He congratulated DIPR for providing a long innings of dedicated service to our brave hearts. Positing his faith in the institution, he opined that DIPR can also contribute in the organizational development of DRDO. Dr AK Singh, DS & DG (LS), DRDO, Directors of sister DRDO labs, former Directors of DIPR and representative from the Services were present on the occasion.

DG (LS), in his address said, as the tussles in this contemporary world are becoming more strategic and psychological rather than physical, the role of an institute like DIPR gets more and more pivotal.

An application, named ComBAT ACTIVE, developed by DIPR was released by the Chief Guest. It is the first stress management application for troops of Indian Army in Hindi and Roman Hindi. Other major events of the day were release of a souvenir encompassing DIPR's journey for last 70 years and a compendium of major research works of DIPR. DIPR Platinum Exhibition organized on the occasion showcased major achievements of the institute.

DMRL, HYDERABAD

Defence Metallurgical Research Laboratory (DMRL) celebrated its 56th Annual Day with great fervour. Dr Avinash Chander, former SA to RM and Secretary, DDR&D graced the occasion as the Chief Guest. Dr DK Likhi, CMD, Midhani and Dr SV Kamat, DS & DG (NS&M) were the Guests of Honour. Dr G Jagan Reddy, Chairman, Steering Committee, delivered the welcome



Chairman DRDO releasing Stress Management App developed by DIPR

address. Dr Vikas Kumar, Director, DMRL, presented the progress and achievements made by the laboratory during the past year. He mentioned that keeping in view the armed forces and system labs requirements, DMRL is rapidly changing its role; graduating from providing advanced materials to ready-to-fit and certified components. In line with latest worldwide research

trends, DMRL is also going to employ latest tools like ICME, Materials Data Informatics, and AI/ML for accelerated materials development cycle. Dr DK Likhi in his address commended the achievements of DMRL in materials science & technology, translation of technology into functional components and also its future vision for development of materials for defence.



Dr Avinash Chander, former SA to RM and Secy, DD R&D releasing DMRL's corporate video film



Dr SV Kamat, also appreciated DMRL's achievements. Chief Guest Dr Avinash Chander, in his address recalled his memories when he was the Chief Guest for DMRL Golden Jubilee Celebrations – 2013. He appreciated that a lot of new facilities like 3D printing, new materials data analytics, etc., have come up after his previous visit to DMRL. He congratulated DMRL team, its leadership over the years, hard work of its employees, and labs contributions in supply of critical materials for space, aeronautical, atomic energy and defence sectors, without which lot of missile and other programmes would not have been possible.

GTRE, BENGALURU

Gas Turbine Research Establishment (GTRE) celebrated its 58th Raising Day on 6 November 2019. Dr Mysamy Annadurai, Vice Chairman, Tamil Nadu State Council for Science & Technology, was the Chief Guest of the occasion. Dr Tessy Thomas, DS & DG (Aero), DRDO, was the Guest of Honour. To commemorate the day, a Coffee Table Book was released and lab awards in different categories were distributed to the meritorious employees.

Shri MZ Siddique, OS & Director, GTRE in his address highlighted the untiring efforts put in by all the employees in the steady progress of the lab. There is an inescapable need to push beyond our capabilities to evolve as technology leaders rather than being followers, said Director, GTRE. Dr Tessy Thomas expressed her happiness on the progress made by the lab and said that everyone is destined to do great things. One cannot be declared winner unless he surmounts the challenges and GTRE is in the right path. She also emphasized on augmenting the manufacturing and test facilities.

Dr Mysamy Annadurai, in his presentation on 'Engineering for Change' brought out how the country has made exponential progress in the field of Aerospace. He conveyed that



Release of Coffee Table Book on the occasion of GTRE Raising Day

one cannot assume anything with fifty percent knowledge. We should be prepared for surprises in our endeavour and gear up for change management.

MTRDC, BENGALURU

Microwave Tube Research & Development Centre (MTRDC) celebrated its Raising Day on 5 November 2019 at BEL Kalakshetra, Bengaluru. Dr Sudhir Kamath, DG (MED & CoS), DRDO, New Delhi was the Guest of Honour. Shri SS Nagaraj, OS and Director, LRDE, was the Chief Guest. Dr SUM Reddy, Director, MTRDC, enunciated the achievements

of the last year and proposed targets for the upcoming year. In his address, Dr Sudhir Kamath highlighted the confidence of tri-services on indigenous world class platforms and systems developed by DRDO and spoke about the capability of HPM-based DEW for destroying the enemy's assets. He emphasised on the need of development of high power, high frequency devices. Shree SS Nagaraj highlighted the benefits of attitude change, focused approach and team work and urged MTRDCians to develop advanced devices/modules to make country proud of indigenous developments.



Inaugural function of MTRDC Raising Day

VIGILANCE AWARENESS WEEK

ASL, HYDERABAD

Advanced Systems Laboratory (ASL), observed Vigilance Awareness Week with the theme 'Integrity—A Way of Life.' Integrity pledge were taken by employees. A pamphlet on Dos and Don'ts in preventive vigilance was distributed to the employees. Posters and banners were displayed at prominent places in the campus to create awareness among the employees.

DVS, DRDO HQ

The week commenced with taking of integrity pledge by all employees of DRDO HQ. Vigilance awareness posters with messages, both in Hindi and English, were displayed at prime locations of DRDO Bhawan and on digital notice board at Main Entrance of the building. A one-day workshop was also organised in DRDO HQ. Maj Gen MK Handa, Director, Vigilance and Security, in his welcome address brought out the significance of vigilance awareness week and highlighted activities carried out by the DVC during the entire year. Dr (Ms) Chitra Rajagopal, DG (RM), the Chief Guest, defined and discussed the meaning of integrity as the "quality of being honest". She described vigilance administration as preventive and punitive anti corruption measures. Shri TP Sharma, OSD of CVC, also delivered a lecture on "Integrity—A Way of Life". Various other topics related to vigilance were discussed during the workshop.

NSTL, VISAKHAPATNAM

Naval Science and Technological Laboratory (NSTL) observed the week by giving wide publicity through messages and by displaying banners at various places. Shri PVS Ganesh Kumar, OS & Officiating Director, NSTL, administered the integrity pledge. Shri P Vimaladitya, IPS, Superintendent of Police (CBI), Visakhapatnam, gave a lecture on "Integrity—A Way of Life."



Administration of Integrity Pledge at ASL



Maj Gen MK Handa, Director, Vigilance and Security, speaking at Vigilance Workshop



Celebration of Vigilance Awareness Week at NSTL

INTERNATIONAL CONFERENCE ON OPTICS & ELECTRO-OPTICS

Optical Society of India organised an International Conference on Optics and Electro-Optics (ICOL-2019) at Instruments Research and Development Establishment (IRDE), Dehradun. The focal theme of the conference was “Trends in Electro-Optics Instrumentation for Strategic Applications”. The Opto-electronics community in India including optics manufacturers, system integrators and end-users participated in the conference.

Dr Satish Kumar, former DG (MSS), DRDO & Director NIT Kurukshetra, was the Chief Guest and delivered the theme address. Dr SS Negi, former OS & Director, IRDE, was the Guest of Honour and delivered the keynote

address. The event provided a platform for interaction to all stake holders including scientists, researchers, manufacturers, academicians and students across the globe. The technical conference included keynote addresses, panel discussions, lectures, oral and poster presentations. Around 90 invited talks and 400 contributed papers comprising of 100 oral and 300 poster presentations were presented during the conference. The latest advances in optics were discussed and an exhibition of over 50 manufacturers and users provided insight into the new developments in the country and on a global scale.

ICOL-2019 covered diversified areas in the Optical Engineering,

Optics and Electro-Optics for Strategic Applications, Optical Thin Films, Optical Materials, IR Sensors, Image Processing and Systems, Photonic Band Gap Materials, Adaptive Optics, Optical Image Processing and Holography, Lasers, Fiber Lasers and its Applications, Diffractive Optics, Innovative packaging of Optical Systems, Nanophotonics Devices and Applications, Optical Interferometry and Metrology, Terahertz, Millimeter Wave & Microwave Photonics, Fiber, Integrated & Nonlinear Optics.

Shri Benjamin Lionel, OS & Director, IRDE, was the Chairman, Organizing Committee and Shri Sudhir Khare, Sc ‘G’, IRDE, was the convener of the Conference.



ICOL-2019 Inaugural Session

ADE GETS CMMI CERTIFICATION

Aeronautical Development Establishment (ADE), Bengaluru has been certified CMMI Development V2.0 at Maturity Level 3. Shri Chandrashekar, Senior Consultant and Lead Appraiser from Cunix Infotech Pvt. Ltd, a partner of CMMI institute, USA, presented the CMMI certificate to Dr S Venugopal, OS and Director, ADE. ADE started the journey of CMMI in the year 2018 with implementation of CMMI practices. The final appraisal took place during last week of August 2019 and ADE was listed in CMMI institute, USA website, on 7 October 2019.



ITR GETS KALINGA SAFETY EXCELLENCE AWARD

Integrated Test Range, Chandipur was awarded the prestigious Gold Prize in Kalinga Safety Excellence Award-2018 as a special appreciation for being role model in Odisha for implementing best safety practices in the range and maintaining zero accident record. ITR was selected for the gold prize from among 44 Public, Private and Govt industries in Odisha. The award is instituted by the Institute of Quality & Environment Management Services, Bhubaneswar, IPE, Hyderabad and Odisha State Productivity Council.



BOOK EXHIBITION IN INMAS TIRC

Dr Tarun Sekhri, OS & Director INMAS inaugurated a book exhibition organised by Technical Information & Resource Centre (TIRC), INMAS. Latest edition of around 5000 science & technology books were displayed covering subjects like Biomedical Sciences, Life Science, Medical Science, Pharmacology, Computer Science and other related subjects. The exhibition got overwhelming response and around 275 new books were suggested by the users.



SWACHH BHARAT ABHIYAN

In commemoration of 150th Birth Anniversary celebration of Mahatma Gandhi, Naval Science & Technological Laboratory (NSTL), Vishakapatnam, organised “Swachh Bharat Abhiyan” on 2 November 2019 in NSTL campus with large participation of employees. Dr OR Nandagopan, OS & Director NSTL, and employees from the O/o DG (NS&M), AO (R&D), MES, Ramanath Secondary School and the MKM along with their family members participated with great enthusiasm to make the campaign a grand success. Dr Nandagopan thanked all for taking interest for the noble cause and hoped that the practice would continue to achieve clean and green NSTL.



PLASTIC SE RAKSHA CAMPAIGN AT METCALFE HOUSE

DRDO observed ‘Swachhta Pakhwada’ for preservation of environment from 1-15 December 2019 as part of Swachhta hi Sewa initiative of the Govt of India. Metcalfe House-based DRDO labs organized a special plogging rally to commemorate the occasion. More than 260 employees, including Directors, enthusiastically participated in the campaign and collected sizeable plastic waste for further waste management.

The campaign was conducted to spread awareness against the ill-effect of plastic on the environment and bring behavioural change with respect to sanitation. The drive sent a message to give up the use of plastic including carry bags, plastic cutlery, plastic water bottles, etc.



Community awareness programmes such as debates, quizzes, nukkad natak, painting competitions will be held in

future. Dr Rajeev Vij, Sc ‘G’, DESIDOC, coordinated the event.

MTRDC CELEBRATES KARNATAKA RAJYOTSAVA

Karnataka Rajyotsava was celebrated in Microwave Tube Research and Development Centre (MTRDC), Bengaluru on 5 November 2019 at BEL Kalakshetra. Shri Mallikarjunaswamy Mahamane was the Chief Guest and Dr Sudhir Kamath, OS and DG (MED & CoS), DRDO, was the Guest of Honour. The

Chief Guest congratulated the officers and staff of MTRDC on the occasion and conveyed the role and importance of Kannada language. He suggested that the technical articles should also be published in the local languages in simple form so that they reach the common people and they get educated.

Dr SUM Reddy, OS and Director,

MTRDC, congratulated MTRDCians on the occasion and said that nurturing the mother language is of utmost importance and proposed to bring one technical book containing technical articles written in Kannada. A cultural programme was organised on the occasion.



Karnataka Rajyotsava celebration at MTRDC

HRD ACTIVITIES

COURSE ON FUTURE TRENDS IN STRATEGIC SYSTEM

Centre for Advanced Systems (CAS), Hyderabad, organised a three-day course on "Future Trends in Strategic System" during 20-22 November 2019 under the Continuing Education Programme (CEP) of DRDO. Dr MRM Babu, DS and Director ASL, graced the inaugural function as Chief Guest and delivered a keynote address on Future Trends in Strategic Systems. Shri Praveen Tandon, Sc 'G' & Course Director, welcomed the delegates and participants. Shri G Ramaguru, OS & Director, CAS gave an overview of the present and future sub-systems of strategic missiles.





Various topics like communication system, propulsion system, hypersonic systems and hypersonic wind tunnel tests, future mission, etc., were covered

in detail during the course. Forty-three participants from various DRDO Labs, SSQAG and BDL participated in the Course. Dr RK Gupta, DS & Dr M

Manickavasagam, OS, ASL were the Guest of Honour for the valedictory function. Shri Pramod Kumar Jha, Sc 'F' & DOMS, proposed the vote of thanks.

TRAINING COURSE ON OFFICE PROCEDURE

Centre for Personnel Talent Management (CEPTAM), Delhi, organised a training course on "Office Procedure" at Himachal Pradesh Institute of Public Administration (HIPA), Shimla. Nineteen participants

from different DRDO laboratories and establishments attended the course. Interactive and informative lectures were delivered during the course by the experts including from HIPA, Shimla.

Topics like office management,

record management, security of official information and documents, dak, receipt, file number system, file management, office automation, etc., were covered during the course.



TRAINING ON TOMATO PROCESSING

Defence Research Laboratory (DRL), Tezpur, conducted Skill Development Training on "Tomato Processing" in collaboration with Tezpur University (TU) at DRL R&D Centre, Salari, Arunachal Pradesh on 2 November 2019. The expert team of Dr Poonam Mishra, Associate Professor, TU, Shri Ranjeet Patel, TO 'B', Mrs Barnali Bailung, TO 'A', Dr Duyi Samyor, RA and Dr Juri Das, RA, from DRL gave hands-on training on preparation of tomato ketchup and tomato paste. A total of 26 participants from Salari, Rahung, Jirigaon, Dikhiyang villages of Arunachal Pradesh attended the training.





COURSE ON EXTREME SITUATIONS: ISSUES & EXIGENCIES

Institute of Nuclear Medicine and Allied Sciences (INMAS), Delhi, organized, a three-day CEP course on “Extreme Situations: Issues and Exigencies” for scientists and technical staff of DRDO Life Sciences laboratories. The purpose of the course was to familiarize researchers to learn and assess extreme situations and find best possible solutions and eventually create a pool of researchers of different disciplines who can come together for providing better solutions and services to the users.

The inaugural lecture was delivered by Surg. Cdr Naryayan S, Cdr (MS) Submarine and Nuclear Cell, O/o DGMS (Navy). He emphasized on the need of enhancing preparedness



among defence forces during extreme situations including CBRN scenario. He also discussed underwater exigencies

with special reference to submariners. Eighteen lectures were organized along with hands-on training.

COURSE ON CBRN EMERGENCY MANAGEMENT

A three-day training programme for Railway Protection Force (RPF) officers was conducted by Division of CBRN Medical Management, Medicine and Extreme Medicine and Drug Development, INMAS. Thirty RPF officers of sub-inspector and above rank from Delhi Division including RPF posts New Delhi, Delhi Main, Nizamuddin, Anand Vihar, DRM Gate, Delhi Lahori Gate, Cash Guard, NW Line and PK

Road participated in the course.

Director INMAS, Dr Tarun Sekhri, inaugurated the course. Faculty from INMAS discussed in detail basics and general awareness of CBRN agents, threats and mitigation approaches. Hands-on exercises and practical demonstrations were conducted to familiarize the participants with realistic scenarios and management strategies to be undertaken. This training course

was considered as pilot training batch and on the basis of feedback received from participant railway board would be extending the scope of this initiative to other major cities.

Dr Aseem Bhatnagar, Sc ‘G’ was the Course Director. Dr Dhruv Kumar Nishad, Sc ‘D’ and Shri Anubhav Jain, Senior DSC (RPF), were the Course Coordinators.





LIFE SCIENCES RESEARCH BOARD WORKSHOP

The Life Support and Biomedical Devices (LSBD) Specialist Panel under the aegis of the Life Sciences Research Board (LSRB) conducted a one-day workshop on “Interaction between Academia and DEBEL on LSRB-LSBD Activities to Evolve Roadmap” on 7 November 2019 at Defence Bioengineering and Electromedical Laboratory (DEBEL) and BEL, Bengaluru. The workshop was presided over by LSBD Chairperson Mrs Manimozhi Theodore, OS and Director, DEBEL along with Dr NR Jagannathan, Professor & HoD, AIIMS, New Delhi as the Co-chairman. Dr RP Bhatt, Member Secretary, LSRB, DRDO HQ; Prof. M Ramasubba Reddy, IIT Madras, Chennai; Dr G Ravindran, former Director, Centre for Medical Electronics, Anna University, Chennai; Dr JD Roy Santosham, Professor of Radiology, Sri Ramachandra Medical College, Chennai; Dr DT Selvam, Sc ‘F’, DRDE, Gwalior; and senior scientists from DEBEL participated actively as expert members. There was an overwhelming participation



of 60 academicians representing 21 Universities and Institutions across India. In his welcome address, Shri M Anandan, Sc ‘G’, Member Secretary LSBD, presented an overview of LSBD and its ongoing activities. Member Secretary, LSRB gave an overview of LSRB, its structure and achievements in the past two decades and appreciated LSBD for organising a workshop that would enable and accelerate academia interaction with DRDO. Scientists from all departments of DEBEL presented

their project activities and technology gaps in the area of life support system, protective equipment and biomedical devices. They also demonstrated the products and technologies of DEBEL and had a detailed interaction with the academicians in their research areas. The workshop was concluded with a brain storming session that included areas of improvement and various implementation strategies for future projects.

OPINION

EMERGING TECHNOLOGIES TOWARDS RESHAPING LAWS ON LETHAL AUTONOMOUS WEAPON SYSTEMS

Meetul Kumar, Chanchal De & Atul D Rane, DIC, DRDO HQ

The means of modern warfare has changed over the last decade. The evolution of technology has potential to change the outcome of the armed conflict. Fully autonomous weapon systems embedded with Artificial Intelligence (AI) can engage target(s) of interest without meaningful human control/intervention. The United Nations General Assembly in December 1977, held a conference

on prohibition or restriction on the use of specific conventional weapons that may result in excessive injury and have indiscriminate effects. The objective of the conference was to establish Convention on Certain Conventional Weapons (CCW). The State Parties (member states in the forum) to the Convention on CCW are engaged in deliberations on various legal aspects due to advances in

emerging technologies related to the lethal weapon systems. Considering these technological advances, the state parties to the convention on certain conventional weapons had established a Government Group of Experts (GGE) to address the challenges emerging from the development of lethal autonomous weapon systems with embedded autonomy in its critical functions. Most new generation weapon systems possess



advanced autonomy in respect of time and space with increased adaptability to the environment. Currently, the level of autonomy is related to the degree of human intervention and the stage at which intervention is made to accomplish an assigned task. With the advancement of technology, the enhanced mobility as well as adaptability of autonomous weapon systems will have lesser predictability due to the self-learning capabilities to modify its goal in response to the surrounding environment. The self-adaptation by the autonomous weapon system allows it to incorporate advanced learning algorithms through interaction with surrounding environment as well as other weapon systems which in turn will result in self-organized swarms or group of autonomous systems. The objective of this article is to provide status of the Lethal Autonomous Weapon Systems (LAWS) and a probable stand of India in the light of varied geopolitical factors.

The objectives of GGE are: (i) to explore potential challenges posed by the emerging technologies in the area of lethal autonomous weapon system and to characterize systems with autonomous functions, (ii) to consider the involvement of human element in the use of lethal force, (iii) to review probable scenarios of potential military applications of lethal autonomous weapon systems, and (iv) to explore various options for addressing humanitarian and security challenges posed by the emerging technologies in LAWS.

The GGE conclusions in respect of characterization of systems with autonomous functions were that purely technical characteristics such as physical performance, endurance or sophistication in target acquisition and engagement alone may not be sufficient to characterize lethal autonomous weapon systems. Technical characteristics related to self-learning and self-evolving aspects needed further deliberations. Attempts to define general threshold level of autonomy based on technical criteria alone is difficult as autonomy involves a wide spectrum of technical aspects, and

the understanding the effect of working environment on different functions of weapon systems to demonstrate different degree of autonomy. Autonomy exists throughout the complete process of engagement of a threat i.e., during identification, orientation, observation, decision, and action phases. In response to involvement of human element in the use of lethal force, the Group concluded that accountability threads together with human-machine in CCW and human beings must at all times remain accountable in compliance with the International Human Law (IHL) for decisions on the use of lethal force. It is also agreed that inter-disciplinary perspectives must be integrated in research and development wherever feasible and appropriate, including independent ethics reviews, keeping the national security considerations and restrictions on commercial proprietary information.

The GGE also viewed that verification and certification procedures covering all the likely intended use scenarios must be developed, the experience of applying such procedures must be shared bearing the national security considerations. Accountability of lethal autonomous weapon system for the use of force in armed conflict must be ensured in accordance with applicable international laws including operation of weapon system within a responsible chain of command and control. Human responsibility must be retained throughout the development and deployment cycle of the emerging technologies pertaining to such autonomous systems. The human responsibility for the lethal autonomous weapon system can be excised in various ways across the life-cycle of these weapons and through human-machine interactions. The degree of human-machine interaction including elements of control and judgment are needed at different stages of application of weapons to ensure compliance with IHL. The emerging technologies in autonomous weapon system are expected to impact

all domains of warfare.

The Group's conclusions on review of military applications are that contributions from technical community, cross-disciplinary experts, industry, academia, and civil society to build awareness and understanding of the potential military applications of the emerging technologies of lethal autonomous weapon system are necessary. During the design, development, testing, and deployment of lethal autonomous weapon systems under LAWS, the risks inter alia of civilian casualties as well as precautions to minimize risks of incidental losses, injury to civilian population including damage to civilian objects, risks of unintended engagements, risks of loss of control of the system, risks of proliferation, and risks of acquisition by non-state actors needs to be considered. The Group agreed to continue discussions on the inclusion of advanced emerging technologies related to lethal autonomous weapon systems through dialogue within the State Parties.

In reference to addressing humanitarian and security challenges posed by the emerging technologies in the area of lethal autonomous weapon system, the Group opined that legal bindings are essential to ensure human control on the critical functions of lethal autonomous weapon system, political declaration to outline principles of human control in the use of force, human accountability and clarity on the implementation of existing obligations under the international humanitarian laws.

In the conclusion of the GGE meeting in August 2018, the following ten guiding principles were adopted by the State Parties to the CCW¹.

- * International Humanitarian law continues to apply fully to all autonomous weapon systems;
- * Human responsibility for decisions on the use of weapon systems must be retained since accountability cannot be transferred to machines.

1. Report of the 2018 session of the Group of Governmental Experts on Emerging Technologies in the Area of Lethal Autonomous Weapons Systems. Geneva, 9-13 April 2018 and 27-31 August 2018.



This should be considered across the entire life cycle of a system;

- * Accountability for developing, deploying, and using any lethal autonomous weapon system must be ensured in accordance with the applicable international law, including the operation of such systems within reasonable chain of human command and control;

- * In accordance with the States obligation under international law, in the study, development, acquisition or adoption of a new weapon, means or method of warfare, determination must be made whether its employment would in some or all circumstances be prohibited by international law;

- * Risk assessments and mitigation measures should be part of the design, development, testing and deployment cycle of emerging technologies in any weapon system;

- * Consideration should be given to possible emerging technologies in the area of lethal autonomous weapon systems and uphold compliance with IHL principles and other applicable international legal obligations;

- * Experience-sharing in national policies and practices that guide the development, testing and deployment of emerging weapon system should be fostered to bearing in mind the national security considerations or commercial restrictions on proprietary information;

- * In crafting potential policy measures, emerging technologies in the area of lethal autonomous weapons should not be anthropomorphized or seen as stand-alone physical objects;

- * Discussions and any potential policy measures taken within the context of the CCW should not hamper progress or access to peaceful use of intelligent autonomous technologies;

- * CCW offers an appropriate framework for dealing with the issues of emerging technologies in the area of lethal autonomous weapon systems within the context of the objective and purposes of the Convention.

In August 2019, based on the deliberations on the objectives of the GGE, the Group agreed to introduce the following additional guiding principle to the objective of the convention²:

“Human-machine interaction, which may take various forms and be implemented at various stages of the life cycle of a weapon, should ensure that the potential use of weapon systems based on the emerging technologies in the area of lethal autonomous weapon systems is in compliance with applicable international law, in particular IHL. In determining the quality and extent of human-machine interaction, a range of factors should be considered including the operational context and characteristics and capabilities of the weapon system as a whole.”

The Group agreed that legal reviews at national levels, development, acquisition or adoption of new weapons, means or methods of warfare can be useful tool to assess nationally whether potential weapon system based on the emerging technologies related to the LAWS would be prohibited by any rule of international law applicable to that State. It was agreed that the States are free to determine independently the means to conduct legal reviews of weapon systems. The final report of 2019 GGE, mentioned that the States need to assess the legality of new weapons developed/under development and their provisions in the international laws. As per the Additional Protocol-1 of CCW and the Article 36 of the Geneva Convention, all States in the development, acquisition of new weapons must remain compliant with the International Humanitarian Law. Legal reviews of weapon systems are important and must include (i) characteristics and capabilities of identified weapon system for review, and (ii) establish a review mechanism and body/committee for conducting such reviews.

Differentiation and selective targeting algorithms must be incorporated during the design and development phase with advanced cyber security features

in the lethal autonomous weapon systems. Considerable discussions and debates on the emerging technologies for autonomous weapon systems have underpinned the principles of proportionality; distinction and necessity to deploy these systems are in agreement with the clauses of IHL. Advancement in AI, machine learning and big data analytics during the initial design and development stages are expected to transform the functioning of autonomous weapon systems. Self-learning, self-evolving and self-adaptation by autonomous weapon systems is expected to bring paradigm shift in the ways and means of engagement. India is still in nascent development stages of such lethal autonomous weapon systems. It is expected that positioning of these systems will provide decisive edge to the armed forces and secure the territorial boundaries. It is prudent that India remains constructively engaged on the issues related to lethal autonomous weapon system and continuously map the technological advancements in this important area.

Disarmament rather than pre-empt ban on the autonomous weapon systems must form the framework of India's approach on Lethal Autonomous Weapon Systems. In the last three decades, country has evolved the policy that governs the arms control measures as a responsible state. Deployment of autonomous weapon system at the inhospitable territorial boundaries may result in tangible benefits to the Armed Forces of India. As India steps up its efforts towards the development of autonomous weapon systems, the national legal framework needs to be formulated and incorporated based on the rules of engagements in compliance with IHL. Indian national legal framework regime must encompass the condition of use, export, and its non-proliferation clauses.

The views expressed by the authors are of their own.

2. Report of the 2019 session of the Group of Governmental Experts on Emerging Technologies in the Area of Lethal Autonomous Weapons Systems. Geneva, 25-29 March 2019 and 20-21 August 2019.

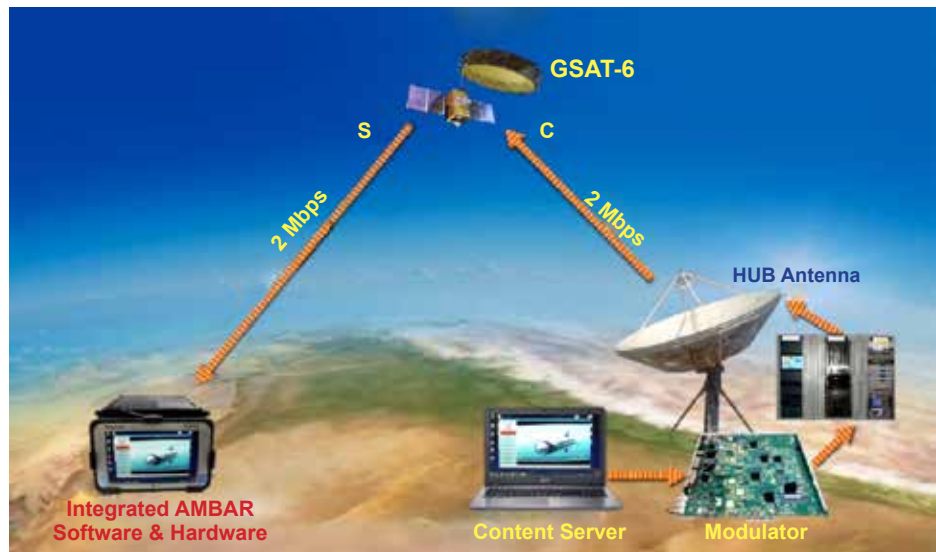
MULTIMEDIA BROADCAST RECEIVER – AMBAR

Advanced Numerical Research and Analysis Group (ANURAG), Hyderabad, has developed a handheld Multimedia Broadcast Receiver Terminal, AMBAR, for GSAT-6 Satellite. This terminal provides audio, video content like weather information, tactical EOB, maps, etc., to users in forward areas. AMBAR supports different data rates of content with maximum data rate of 2 Mbps. AMBAR's Content Server and Modulator are set-up at GSAT-6 Satellite Hub located at Defence Electronics Applications Laboratory (DEAL), Dehradun. AMBAR terminal is impressive in terms of sensitivity and data rate. RF IC and Integrated Baseband ASIC were designed as part of AMBAR project. The complete AMBAR receiver has been realized with in-house components. The terminal has been enhanced with content-on-demand feature by integrating the transmitter designed by DEAL. AMBAR Receiver terminal receives the multimedia content in S-band and works on any spot beam and supports beam-to-beam roaming.

System Overview

The C-band feeder link to the satellite from the hub is through the national beam. The corresponding down links are in S-band with five spot beams to cover the Indian land mass. Each beam has one transponder. The satellite has the C x S transponders and frequency reuse scheme.

Satellite Digital Multimedia Broadcasting (SDMB) service was to extend audio, video and data broadcast as a cost-effective streaming and data download service directly to the end user mobile handset. SDMB also offers live content streaming as well as emergency notifications, e.g., for disaster alert purposes, content-on-demand service, broadcast, multi-cast and uni-cast services. Multimedia contents are



Overall Satellite Communication System using SDMB Network

transmitted in C-band by the HUB and is broadcasted by the satellite in S-band.

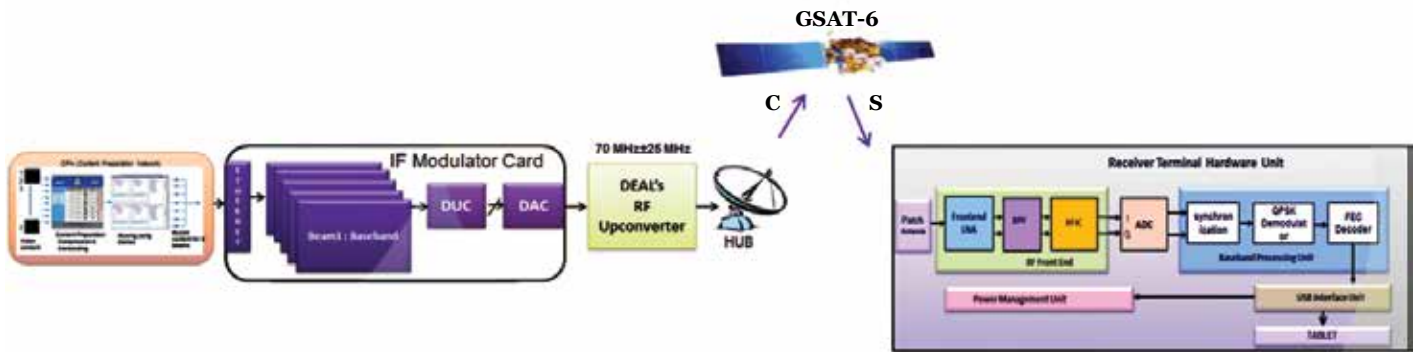
Project Evolution & Execution

The objective of the project was to develop technologies for ground segment for multimedia broadcast services compatible with Indian satellite GSAT-6. It included the development of a broadcast receiver terminal with interface to satellite MSS terminal and optional interface to smart phone, content server and terrestrial repeater. The concept of multimedia broadcast services was also demonstrated for mobile users utilizing above modules with GSAT-6. Indigenous chips were developed as part of the project to replace all the industry standard chips in AMBAR terminal.

The development of the satellite digital multimedia receiver was taken up in three phases: AMBAR Terminal-I: based on the off-the-shelf components; AMBAR Terminal-II: based on the in-house developed RFIC and baseband ASIC; and AMBAR Hybrid Terminal: to receive both satellite and terrestrial signals. AMBAR Terminal I was realized in one and half year and the prototype was tested in the laboratory.

AMBAR transmitter consists of content server and modulator, where the content server compresses the data, converts to MPEG2-TS format and multiplexes the data. Multiplexed data is later transmitted to the modulator using Ethernet interface. The data is processed in AMBAR modulator, which consists of the PHY layer adopted from the DVB-SHB Standard, along with FEC scheme based on TURBO encoder. The output is given to the HUB at IF. This IF output is connected to the DEAL's RF up-converter module. The SSPA output is connected to the DEAL's HUB Antenna to transmit the data in C-band frequency to the satellite. The signal in S-Band through the satellite is received by patch antenna of the receiver terminal and processed at the receiver and played back on tablet. The Receiver Terminal consists of Antenna, RF Front End, Analog Front End, Baseband Algorithms in FPGA, Power Management circuits and an USB interface for streaming out the multimedia content.

Receiver module is a customized receiver hardware platform having on-board, Maxim RFIC, ADC and FPGA supporting satellite line-of-sight



AMBAR communication with GSAT6 Satellite

(LoS) signal. Baseband demodulator algorithm with FEC has been implemented in FPGA. Demodulator with higher coding gain requires work with the receive signal with very low SNR. This satellite LoS signal will cover the rural environments where multipath fading is not dominant. This receiver was implemented for programmable data rates. The data rate can be chosen according to the bandwidth availability.

In the second phase of the project, in-house designed baseband ASIC and S-band RFIC were developed. The baseband ASIC replaces the MAXIM 19713 ADC. The baseband algorithms have been implemented in Artix7 FPGA, whereas the S-Band RFIC replaces MAXIM 2837 RF Front End. The receiver has been miniaturized in terms of size and power using these ICs.

Software Development

AMBAR software system has been developed for targeting two ground segment modules, i.e., content server and receiver. Content server of the transmitter compresses the audio-video contents and converts data to TS format. This is given to multiplexer, which converts the contents into single stream. Multiplexed stream is finally fed to the modulator hardware for further transmission.

On the receiver side, receiver software has been hosted on the receiver tablet connected to receiver terminal. This software fetches content from the PSoC in hardware, processes the packets

and extracts the payload. It sends the video files to GUI and saves non video files (for content on demand terminal) on the tablet. GUI provides an interface to field user to select a channel from a list of channels to play the video. It also provides an interface view to show the content list and to place a content-on-demand request.



Content Operator Web Interface (top) & Receiver Software Tile display

Achievements

Satellite broadcasting network with GSAT-6 satellite has been successfully demonstrated with required set up at Hub and AMBAR Terminal at field. AMBAR Terminal-II, based on in-house components, was successfully tested with the GSAT-6 Satellite. Hybrid terminal, receiving both satellite signal and terrestrial repeater signal, has also

been tested. AMBAR broadcast set up with indigenous hardware and software can be easily reconfigured to wide range of user applications and technologies can be adopted to various military communication requirements. AMBAR project has achieved self-reliance in modem design based on advanced FEC scheme for wireless video transmission, RF Receiver and Baseband IC and software modules for multimedia streaming at Hub and Terminal.

AMBAR Terminal I

AMBAR Terminal I, realized in handheld form-factor and ruggedized terminal, has passed all the environmental tests required for field usage.



AMBAR Terminal I

AMBAR Terminal II

The S-Band RFIC was designed in 250 nm Bi-CMOS process having area of 15 sq.mm and packaged in QFN 64 package. Baseband ASIC integrates 11-bit pipelined ADC and baseband

algorithm. IC was designed in 65 nm CMOS process having area of 16 sq.mm and packaged in QFN 80 package. Chip consumes overall power of 150 mW at peak data rate. These ICs were successfully tested and characterized.

Technological Breakthroughs

The following technological breakthrough were made during project realisation:

- * Component level indigenization was done by developing the RFIC compliant to Maxim 2837 and developing Baseband ASIC replacing the Maxim ADC 19713 and the baseband algorithm implemented in FPGA.
- * Proof of Concept for the hybrid terminal was developed to receive both the Terrestrial (OFDM) and Satellite Signal (TDM).
- * By the implementation of the Turbo FEC an improvement of 3dB in sensitivity was observed with respect to other FEC schemes and a processing gain of 9 dB was achieved with respect to un-coded QPSK.
- * Technology spin-offs (high resolution video links from UAV, aircraft and missiles)
- * A comparative analysis of different implementation of the baseband algorithm in FPGA, DSP & ASIC platforms.

Salient Features

- ☑ Supports programmable data rates
- ☑ Auto Beam Switching
- ☑ High Sensitivity, Low Noise Figure
- ☑ Content on Demand

Partners in Development

AMBAR System was developed jointly with private industries and PSUs. SAC, ISRO Ahmedabad and DEAL Dehradun were involved in providing the necessary inputs to develop the system. DEAL was also involved in the development of the Content on Demand Terminal. CAIR was involved in the development of the security solution. CDOT, Bengaluru and BEL, Hyderabad and private industries, viz., Urumi Systems, Hyderabad; Alpha Design Technologies Ltd, Bengaluru; Lekha Wireless Solutions Ltd, Bangalore; ACD Communications, Hyderabad; Excel RF Technologies Pvt Ltd, Hyderabad; and Sankhya Labs Pvt Ltd, Bengaluru provided the various sub-systems.

Field Trials & Road Ahead

The corresponding Content Server along with modulator of AMBER I and II are operational at DEAL, Dehradun. As per the scope of the Project AMBAR, AMBAR Satellite Receiver Terminal supports only one way communication from the transmitter at the HUB to

the AMBAR receiver. Based on the requirement of DEAL, AMBAR was enhanced with the Content on Demand feature enabling the user to request for a content from the content list provided.



AMBAR COD Terminal

The field trials have already been successfully conducted at user site. Present form of AMBAR with Content on Demand feature has a potential applications for a remote field user to get the access to intelligence briefings, target designations, missile warnings, terrain data, messages, logistics, situation awareness, SIGINT, battlefield awareness. Technology developed under the AMBAR can be enhanced to many versatile applications like two-way video conferencing, remote guidance to troop movements through audio and/or video, a general purpose satellite modem, video link for UAVs, etc.

SOCIETAL ACTIVITY

DRL PROVIDES FLOOD RELIEF MATERIALS

A team of DRL family members especially the ladies stepped in to provide relief to the flood-affected areas of Assam. Essential commodities of over Rs 1.20 lakhs, donated by employees of DRL and their family members, AO (R&D) Tezpur, DRL DSC platoon, relatives, research fellows, friends circle and ex-employees of DRL were distributed among 500 people living in seven flood relief camps in Sirajuli and Gereki of Sonitpur districts of Assam. Furthermore, DRL employees also contributed around Rs 1 lakh in Assam Chief Minister Relief Fund.





DRDO HARNESSING SCIENCE FOR PEACE & SECURITY

CHAPTER 4: MARCHING FORWARD

The article is 46th in the Series of extracts of the monograph, "Defence Research & Development Organisation: 1958-1982", by Shri RP Shenoy, former Director of Electronics and Radar Development Establishment (LRDE).

AGRICULTURAL RESEARCH LABORATORIES

Research studies in the field of upgrading of local cows were initiated. FRL cross-bred Holstein Freisian cattle with the local Sahiwal variety to breed cows that gave a yield of 9 litres of milk per day. These cattle could be maintained during prolonged subzero temperatures without artificial heating. It was thus conclusively established that cross-bred cattle of Friesian and Jersey performed very well in milk yield in the high altitude region of Ladakh. Artificial insemination centres were opened to effect general improvements in cattle and also to improve their production potential.

Defence Agricultural Research Laboratory (DARL) situated in the hilly terrains of the Central Himalayas with an inhospitable climate and porous acidic soil. DARL has achieved breakthroughs in protected agriculture. Through the continuous process of selection and hybridisation, the Laboratory succeeded in developing varieties of high-yielding vegetables like brinjal, tomato, capsicum, cabbage and bittergourd. It developed greenhouse methodologies that had the advantages of early raising of nursery, quicker crop maturation, growth of off-season vegetables, low incidence of disease, 3-4 crops per year and vegetable produce at twice the normal yield. Non-availability of land mass due to steep slopes and snow in high altitudes, made the Laboratory to introduce hydroponic technology. Tomato and cucumber could now be grown throughout the year. Entomological investigations were carried out to identify 60 insect species that caused crop damage. Techniques for application of farm yard manure,

fertilizers and poultry manure were standardised for various seasons and for different agro-climatic areas of the region.

INSTRUMENTATION

There is only one laboratory in DRDO whose activities fall in the area of optical instruments and optical systems for the military. It is the Instrumentation Research & Development Laboratory, (IRDE) at Dehradun. The role of IRDE has been that of designing optical, infrared (night vision) and electrooptical systems in aid of the Artillery and of the Armour Corps to improve the fire of accuracy.

Instruments Research & Development Establishment

In 1960s, the only established technologies used by gunners and tank crew were that of optics in the day and of infrared in the night for sighting of their weapons before aiming and firing. Therefore, the main focus of IRDE was on the Army's requirements for enhancing combat potential in the night for tanks and for navigation of vehicles (Fig 4.27). A representative sample of the equipments successfully developed and which went into production were, Gunner's IR (Infra Red) scope sight and Commander's IR periscope for Vijayanta tank, IR Sniper scope for Infantry, IR Telescope for the Navy, and IR Search Light. In addition, binoculars for Vijayanta tank and Universal Mortar Sight for 120 mm Brandt Mortar were successfully developed and technology was transferred for production. Further, in anticipation of user's requirement, work in the area of general purpose laser range finders was initiated. The production orders by the Armed Forces

for the equipment exceeded Rs 25 crore.

In 1970s, there was a shift in the activities of IRDE towards lasers for ranging and passive night vision devices. Investigative R&D tasks were initiated and test and evaluation facilities were acquired as part of the process of building the competence in these technologies. In June 1969, the Laboratory was sanctioned a project on the development of general purpose laser range finder with the twin aim of containing its size and weight for shoulder mounting and providing it with a capability of ranging targets from 500 m to 10 km with an accuracy of ± 10 m. In the course of developing the laser range finder the scientists built up competence in the selection and use of laser material, the pumping source, design optimization of laser cavities, the Q-switching techniques, techniques and devices used for low level signal detection, heat exchangers, and mechanical housing. This laid a good foundation for the development of Nd glass and Nd-YAG lasers around which the Laboratory would develop future laser range finders. The first opportunity to utilise their expertise materialised in March 1979 with the sanction of a staff project to develop a laser range finder for T-55 tanks with capability to range targets from 400 m to 4 km.

R&D activity was also initiated in 1974 for development of passive night devices with the sanction of a project for the design and development of passive night sight for 106 mm recoil gun. The competence in night vision technology lay in the trade-off of the various relevant parameters such as range, magnification, field of view, size and weight and the selection from among the different options of Image Converter, Image Intensifier, Low Light Television and



Intensified Charge Coupled Devices for the design.

Expertise in innovative optical designs for effective filtering functions would also be necessary. In the course of development, IRDE was required to design high speed/aperture and catdiopic systems and also devise techniques for adjustment of the imaging mirror to an accuracy of 0.25'. In addition, a major facility with capability to test image intensifier tubes and measurement of its parameters such as resolving power, radiant sensitivity and so on was established. A long dark hall with target models and resolution patterns, and with facility to simulate night illumination conditions for evaluation and adjustment of night vision devices was under installation at the beginning of 1980s. The process of learning by doing was attempted to build the expertise in this vital area. The process required more iterations in design which resulted in the project activity continuing beyond the 1970s. The second activity in this area was the design and development of Commander's Passive Night Sight for Vijayanta Tank which was sanctioned as a staff project in 1976. It would also spill over into the 1980s.

Another R&D activity was the design and development of Optics module for Head Up Display system for use in military aircraft. The objective was to design the optics module which would have a field of vision of 15° in azimuth and 8° in elevation in such a way that the pilot could see in head up position the display of primary flight data and also navigation and weapon-aiming information. The requirement would be met with an optics module that would be a special type of bioptic system with a large aperture and low F number. The surface would be dichroic. The electronic circuitry for the flight data and for navigation and weapon aiming was being developed at ADE.

In addition to these activities, IRDE also undertook the development of a gyro-land navigation system for Vijayanta tank, recalibration of graticule marking on periscopic sight AFV30 Mk, muzzle bore sights for artillery guns, night-aiming devices for the mountain gun, gun rule for 75/24 Pack Howitzer, 25 Pounder and 5.5 inch gun for high angle

fire, direct sight and indirect sight for 105 mm IFG, collimeter type parallel scope and devices for identification of tanks and fire control plotter for field artillery. Most of these products developed at IRDE were accepted for introduction into the Services.

Besides development, modernisation of facilities for fabrication of precision optical components to high degree of surface angle and dimensional accuracies was also being carried out so that the project needs for a wide range of optical components, starting from simple lenses and prisms to more complex designs such as Q-switching prisms, laser rods etc., would be met.

LIFE SCIENCES & HEALTHCARE

DRDO undertakes extensive research on several aspects of human health encompassing physiology, biochemistry, nutrition, toxicology, psychology and nuclear medicine. The laboratories in the Life Sciences and Healthcare group are, the Institute of Nuclear Medicine and Allied Sciences (INMAS), Defence Institute of Physiology and Allied Sciences (DIPAS), Defence Institute of Psychological Research (DIPR) all situated in Delhi. INMAS, DIPAS and DIPR were transferred in 1973 to Director General, Armed Forces Medical Services (DGAFMS) and were reverted to DRDO in 1980.

Institute of Nuclear Medicine & Allied Sciences

The main charter of INMAS is to promote, develop and train in radioisotopic and related modern techniques in medical research, diagnosis and therapy and in allied sciences such as medical radiation biology and health physics. Nuclear medicine involves close integration of knowledge and expertise in several scientific and technical areas, like nuclear physics, radiobiology, radiopharmaceuticals, health physics, electronic instrumentation, clinical and experimental medicine, all oriented to the use of ionised radiation.

INMAS had its origins in the Radiation Cell set up at Defence Science Laboratory in Delhi in 1956 for the purpose of developing a programme of

applying radiation medicine for better healthcare of both Armed Forces and civilians. Because endemic goitre was prevalent along the entire Himalayan range, running approximately 2500 km from east to west, the sub-Himalayan belt as well as isolated pockets in almost every state of our country, due to deficiency of iodine in water and other foodstuffs, it was decided that the first application of radiation medicine would be to treat thyroid disorders. In 1958, a field unit was setup at Safdarjung Hospital in Delhi and radio iodine was used for treating thyroid disorders. This was the first ever application of nuclear medicine in our country and the good work carried out by the Radiation Cell led to the establishment of the Institute of Nuclear Medicine and Allied Sciences in Delhi in June 1961 under the Defence R&D Organisation. The clinical work continued at the Safdarjung Hospital until 1971, when the clinical outpatient department was set up at the Institute.

Investigations and Treatment of Goitre – In 1960s, the thyroid clinic of INMAS at Safdarjung Hospital witnessed remarkable growth and even today the INMAS clinical outpatient department draws annually about 50,000 to 60,000 patients from all over the country. The Institute has, over the years, developed a battery of radio isotopic, conventional biomedical and pathological tests to obtain a better understanding of the aetiopathology of the disease. The scientists studied the influence of familial and socioeconomic factors, age, sex, possible presence of goitrogen in the soil, water and foodstuffs. For example, the goitrogenic potency of some common vegetables with high thiocyanate content like okra (bhindi), radish (mooli), and yam (arbi) were demonstrated by chemical analysis and by animal studies. As early as 1962, INMAS recommended that an adequate dose of iodine should be ensured for the troops stationed in endemic areas as a prophylactic measure. Based on the findings of INMAS and other centres, the Government of India promoted the use of iodised salt throughout the country.

To be continued...



APPOINTMENT

Director, DMRL



Dr G Madhusudhan Reddy obtained his bachelor's degree in Mechanical Engineering with distinction from Kakatiya University in 1985. He completed his master's degree with Honours from IIT Roorkee in 1987. He started his carrier as a Scientist in 1987 at CVRDE, Chennai. He was transferred to DMRL, Hyderabad in 1989. In DMRL, he embarked on focused research in the welding of Aluminium-Lithium alloys for his Doctoral degree at IIT Madras. He was awarded Sudarshan Bhat Memorial Prize for the best thesis during the convocation in the year 1999.

Dr Reddy's career spanning nearly 32 years is marked by significant R&D contributions in the field of materials joining and surfacing and have been direct applications in defence and aerospace technologies. He is very well known internationally for his excellence in the field of friction-stir welding of very large components. He has made a significant breakthrough by establishing ballistic capabilities in welds, comparable to those of parent armour. Dr Reddy brought out the influence of electron beam oscillation and pulsed laser welding techniques in reducing the Laves phase during welding of super alloys, thereby improving the mechanical properties of aero-engine components. He has also developed the technology for welding of low alloy steel shaft to a cast super alloy blisk in solid state and brazing of aero-foil castings to the shroud rings for aerospace programs. Dr Reddy has contributed significantly to the structural integrity of joints in aerospace components and has setup one of the leading solid-state

welding laboratories in the country at DMRL, which he continues to lead. Dr Reddy's pioneering research on the refinement of weld zone microstructure, employing pulsed and arc oscillation technology, led to the development of joining technology for difficult-to-weld aluminium and titanium alloys employed in aerospace. Some of his other notable contributions include failure analysis of weldments related to armoured vehicles, premature failure of several motor casings made of ultrahigh strength steel, and bridge layered tanks.

Dr Reddy is the recipient of a number of awards for his outstanding contributions including Metallurgist of the Year Award (2007), Scientist of the Year Award (2013), National Technology Day Award (2017), Bharat Ratna Sir Mokshagundam Visvesvaraya Award (2018) by the Government of Telangana, GD Birla Gold Medal (2019), Binani Gold Medal (2010 and 1994), SAIL Gold Medal (2013), Technology Leadership Award (2018), Keith Hartley Memorial Award (2015), SK Mazumdar Memorial Award (2012), Engineer of the Year Award (2002) and Andhra Pradesh Scientist Award (2006). He has won 35 best paper awards for his scientific contributions from various professional Societies. He has been elected Fellow of American Society of Metals, Indian National Academy of Engineering and Telangana Academy of Sciences, Andhra Pradesh Academy of Sciences, Indian Institute of Metals, Indian Institute of Welding, and Indian Welding Society.

He has published more than 260 research papers in referred journals and equal number in conference proceedings apart from possessing several patents to his credit. He has the distinction of guiding several students for their doctoral degrees.

Dr Reddy has conducted several workshops. He is a Member, Governing

Council, International Advanced Research Centre for Powder Metallurgy and New Materials, Hyderabad. His expertise has been utilized as a Member: Board of studies for major Universities of Telangana and Andhra Pradesh.

HIGHER QUALIFICATION ACQUIRED



Shri Pradipta Roy, Sc 'F', Integrated Test Range (ITR), Chandipur has been awarded PhD from IIT Kharagpur for the thesis entitled "Video Object Segmentation on Parallel Cell Network."

Shri Praveen PC, Sc 'F', Naval Science & Technology Laboratory (NSTL), Visakhapatnam, has been awarded PhD by IIT, Madras, for the thesis entitled "Effect of Length and Size of Control Fins on the Manoeuvring Characteristics of Axi-symmetrically Shaped Underwater vehicle."



Shri Kishore Kumar Katikani, Sc 'E', NSTL, has been awarded PhD by NIT Warangal, for the thesis entitled "Design and Analysis of Special Purpose Cutter for Machining Solid Propellant Grain."



Shri Rama Krishna Varanasi, Sc 'E', NSTL, has been awarded PhD by NIT Warangal, for the thesis entitled "Prediction and Reduction of Non-Cavitating Noise levels in Marine Propellers."



Shri Manoj Kumar, Sc 'D', Scientific Analysis Group (SAG), Delhi, has been awarded PhD in Mathematics by University of Delhi for the thesis entitled "Design and Analysis of Symmetric Cryptographic Primitives."

VISITORS TO DRDO LABS/ESTTS

ARDE, PUNE

Hon'ble Raksha Rajya Mantri, Shri Shripad Yesso Naik visited Armament Research & Development Establishment (ARDE) on 5 November 2019. The Hon'ble Minister reviewed the major projects underway at ARDE.

DEBEL, BENGALURU

Dr S Guruprasad, DG (PC&SI) and Air Marshal SBP Sinha, PVSM, AVSM, VM, ADC (Retd), DRDO Chair, visited Defence Bioengineering and Electromedical Laboratory (DEBEL) on 5 November 2019 and witnessed the performance evaluation of Integrated Life Support System (ILSS) under Simulated High Altitude Conditions with Pilot-in-Loop. ILSS, comprising 11 LRUs, has successfully undergone trials for its functional performance in simulated environment as a precursor to the actual flight trials. Gp Capt. Gunasekaran, was the subject test Pilot from NFTC. Surg. Cdr. Ranjan Sarkar, Aviation Medical Specialist, IAM, Bengaluru monitored the physiological parameters of the test pilot. The performance of the integrated system was found on par with Liquid Oxygen (LOX) System being used presently in Tejas.

HEMRL, PUNE

Hon'ble Raksha Rajya Mantri, Shri Shripad Yesso Naik visited High Energy Materials Research Laboratory (HEMRL) on 5 November 2019. Hon'ble Minister inaugurated latest state-of-the-art Igniter Processing Facility for design, processing and evaluation of ignition systems. He also visited HD 1.1 Propellant Processing Facility, Multiple Motor Processing Facility, Universal Pilot Plant and various exhibits. Shri KPS Murthy, Director, HEMRL, presented an overview of the activities of HEMRL. Shri PK Mehta, DG (ACE), Dr VV Rao, Director, ARDE, and Shri



Raksha Rajya Mantri Shri Shripad Yesso Naik being briefed about ATGM at ARDE



Dr S Guruprasad, DG (PC&SI) and Air Marshal SBP Sinha at DEBEL



Raksha Rajya Mantri Shri Shripad Yesso Naik inaugurating the Igniter Complex at HEMRL

Aloke Mishra, CCER&D (West), were present during the visit.

* Maj Gen Deepak Obhrai, VSM, ADG, Artillery (A), along with Col. Chirayu Motial, SM visited HEMRL on 29 November 2019. Shri KPS Murthy briefed them on the activities of HEMRL. Presentations on the projects related to Gun Propellants, Solid Rocket Propellants, High Explosives were given by the senior scientists. Maj. Gen. Obhrai evinced keen interest in the exhibits and activities of HEMRL.

INMAS, DELHI

Lt Gen Atulya Solankey, SM, COS, HQ ARTRAC visited Institute of Nuclear Medicine & Allied Sciences (INMAS). Dr Sushil Chandra, Sc 'G' & Head, Deptt of Bio-Medical Engg briefed him about significance of virtual reality/augmented reality-based cognitive training for defence personnel. He also emphasised on cognitive assessment and enhancement for cognitive resilience and readiness of soldiers.

LRDE, BENGALURU

Air Marshal Sandeep Singh, AVSM VM, Deputy Chief of Air Staff, visited Electronics and Radar Development Establishment (LRDE) on 20 November 2019. Ms J Manjula, DS & DG (ECS), Shri SS Nagaraj, OS & Director, LRDE, senior officers and project directors were present during the meeting. DG (ECS) welcomed the Deputy Chief of Air Staff. Shri SS Nagaraj made a brief overview on LRDE radars. Presentations on Radars for IAF, Low Level Transportable Radar (LLTR), Medium Power Radar (MPR), Mountain Radar, High Power Radar (HPR), Aslesha Mk-II, Long Range Tracking Radar (LRTR) and Active Electronically Scanned Array (AESA) Radar were made by the Project Directors. The Deputy Chief of Air Staff also visited the radar technologies display area.



Maj. Gen. Deepak Obhrai being briefed about HEMRL product



Lt Gen Solankey being briefed about augmented reality-based cognitive training at INMAS



Air Marshal Sandeep Singh being briefed LRDE technologies

NPOL, KOCHI

Dr Tessy Thomas, DS and DG (Aero) visited Naval Physical Oceanographic Laboratory (NPOL) on 22 November 2019. She interacted with Shri S Vijayan Pillai, Director, NPOL, and senior scientists of the laboratory. She was briefed about the Airborne Sonar for Coastal Security (ASCS) & Directional Sonobuoy. DG (Aero) visited the integration room of the submarine sonar project USHUS-2 and was presented a comprehensive overview of the project by the Director, NPOL. Dr Thomas delivered a technical talk on "Aerospace Odyssey". She also shared her vast experience in Agni missile programme. She congratulated NPOL for the design and development of indigenous sonar systems.



Dr Tessy Thomas being briefed about NPOL activities

SAG, DELHI

Lt Gen PS Rajeshwar, AVSM, VSM, CISC along with Maj Gen K Narayanan, SM, ACIDS (ICT) and Rear Adm Mohit Gupta, VSM, DG (DCyA), visited Scientific Analysis Group (SAG) for interaction with scientists. Dr Sudhir Kamath, OS & DG (MED&COS)) and Ms Anu Khosla, OS & Director, SAG briefed the visitors on the ongoing research activities of SAG.

* Lt Gen Taranjit Singh AVSM, VSM and team visited SAG on 25 November 2019. Ms Anu Khosla, briefed them about the activities of SAG. Presentations on on-going research activities was followed by demos by the scientists.



Lt Gen PS Rajeshwar in interaction with Dr Sudhir Kamath and Ms Anu Khosla at SAG

**DRDO NEWSLETTER WISHES ITS
READERS BEST WISHES FOR A
VERY HAPPY & PROSPEROUS
NEW YEAR**