Report of the Director

Anyone who has never made a mistake has never tried anything new.

— Albert Einstein

It gives me a great pleasure to present the Annual Report of the CSIR-National Aerospace Laboratories for the year 2012-13. The report gives glimpses of significant contributions made by the laboratory in the year 2012. The year 2012 was a memorable year for CSIR and its constituent laboratories, as CSIR completed seventy years of its successful journey contributing to the growth of science & technology in the country. Seventy years of existence is a great achievement for any organisation in the world and we are all proud to be members of the CSIR family. I take this opportunity to convey my warm wishes and greetings to all on the occasion of the 70th Foundation Day of CSIR.

Highlights

I wish to start the year's highlights with the most memorable events that have brought pride and satisfaction to our laboratory. The CSIR-NAL led National Control Law Team to develop the fly-by-wire flight control laws and airdata algorithms for LCA Tejas celebrated its 20th Anniversary on June 2, 2012 *(Fig. 1)*. Prof. Samir K Brahmachari, DG-CSIR graced the occasion as the chief guest and addressed the gathering of over 80 Scientists, Engineers and Test Pilots who had contributed to the success of the programme. Another proud moment for the laboratory was when Professor Roddam Narasimha, CSIR-NAL's third Director (1984-1993), received the Padma Vibhushan award from the Government of India in 2013 *(Fig.2)*. This recognition with one of the highest honours is a true tribute to a visionary leader and a great scientist.

I am happy to inform you that during the year, after successful completion of the re-certification audit, CSIR-NAL has received the ISO 9001:2008 Quality Management System(QMS) Certificate of Approval valid up to 14th December 2015 *(Fig. 3)*. This was possible due to the effort by team CSIR-NAL in achieving excellence.

Fig. 1 20th Anniversary of CSIR-NAL led National Control Law team.

Fig. 2 Felicitation for Prof. R Narasimha, in honor of Padma Vibhushan Award.

During 2012, CSIR-NAL celebrated two decades of its Powered Hang Glider activities. It was the vision of Prof. Satish Dhawan of "hands on" flying activities for CSIR-NAL staff to hone their professional skills that was the preamble to the Powered Hang Glider activities celebrations *(Fig. 4)*.

Looking back at the year that has gone by, we can share some notable achievements and good progress in our programmes. The activities of C-CADD during the year were focused on implementing structural modifications to SARAS PT1 standard, servicing of all applicable Line Replacement Units (LRUs), qualification testing of fire resistant coatings for metallic and composite parts of nacelle, installation of a dual – axis telemetry system and wind tunnel testing. Ground test schedule documents (for aircraft system integration checks on ground) were submitted in the reporting period to Centre for Military Airworthiness and Certification (CEMILAC- DRDO) for their approval. A new antenna tracking system has been successfully commissioned at Aircraft & Systems Testing Establishment (ASTE), Bangalore and is working highly satisfactorily with two auto tracking in both azimuth and elevation *(Fig 5)*.

Considerable progress has also been made in the development of the five-seat general civil aircraft CNM5, the country's first civil transport aircraft developed in PPP mode in collaboration with Mahindra Aerospace Private Ltd. A way forward and work share arrangement between CSIR-

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CERTIFICATE OF APPROVAL

This is to certify that the Quality Management System of:

CSIR - National Aerospace Laboratories
(A Constituent unit of Council of Scientific & Industrial Research, New Delhi)
Bangalore – 560 017, INDIA
having Campuses at Kodihalli and Belur (Nilakantan Wind Tunnel Center)

has been approved by Lloyd's Register Quality Assurance to the following Quality Management System Standard:

ISO 9001:2008

The Quality Management System is applicable to:

Research, design, development, testing and qualification of aerospace vehicles/components and spin off products/technologies.

Approval Certificate No: MUM0060372
Original Approval: 22 September 2000
Current Certificate: 15 December 2012
Certificate Expiry: 14 December 2015
Issued by: Lloyd's Register Quality Assurance Limited

Fig. 3 ISO 9001:2008 Quality Management System re-certification.

NAL and MAPL has been charted out for certification by the Civil Aviation Safety Authority (CASA-Australia). Two HANSA aircraft at CSIR-NAL (VT-HBL, VT-HOA) have been re-registered for flying under experimental category. These will be extensively used as test bed for R&D purposes as part of the 12th Five Year Plan project.

It is well known that CSIR-NAL has been contributing to the development of carbon composite components for aircraft development programmes in the country. As a part of LCA series production, new production standard tools were designed and fabricated through private partner M/s Tata Advanced Materials Ltd. One set of Centre Fuselage parts

Fig. 5 Dual axis telemetry system.

Fig. 4 Twenty years of Powered hang Glider activities in CSIR-NAL.

(7 nos.) were delivered to the production group of LCA for series production (SP1) assembly. This contribution is a major step in taking LCA from Limited Series Production (LSP) phase to series production (SP) phase. In an another achievement, the Engine Bay door (middle) of LCA using high temperature Carbon/Bismaliemide prepreg system, with a service temperature of 200 deg C, was developed using a novel vacuum bag technique which is currently undergoing testing *(Fig. 6)*.

The CSIR-NAL led National Control Law team (CLAW) continues to play a crucial role in Tejas flight envelope expansion and up-gradation of control laws for obtaining the aircraft Initial / Final Operational Clearance. Control laws for the take-off phase of LCA- Navy (NP1) have been improved following the successful completion of first block of flights of the aircraft this year. Improved Air Data System (ADS) versions have been released for the LCA Air Force and Naval aircraft. Wake trials have been con-

Fig. 6 The Engine Bay door (middle) of LCA using high temperature Carbon/ Bismaliemide prepreg system with a service temperature of 200 deg C.

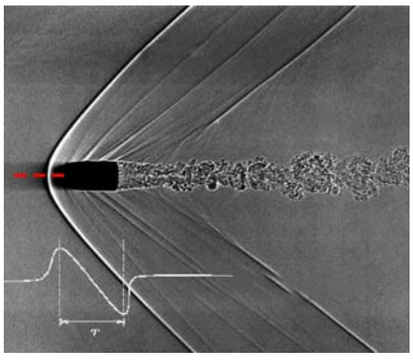


Fig. 7a 'N-wave' associated with passage of bullet.

ducted after incorporating wake identification feature in the ADS.

I wish to highlight some of the other key contributions to the strategic sector which include: development of an indigenous system for Detection and Hit Visualization using Acoustic N-wave Identification (DHVANI) for locating bullet hits on targets for the Indian Army. This involved the deployment of an array of acoustic sensors under the general flight path of such projectiles, acquiring and analyzing the signal in real-time and instantaneous display of results in a graphical form at the shooter's end. The system is cost effective and reduces training time *(Fig. 7a,b)*. A high speed permanent magnet alternator with a power rating of 4.5 kW at 30000 rpm rated speed was indigenously developed for Gas Turbine Research Establishment (GTRE) *Fig 8*. Continuous bump foil bearing for small rotors of micro and small gas turbine were developed by the Propulsion Division *(Fig. 9a,b)*. Further, the second flight test of the indigenous 55 hp Wankel Rotary Combustion Engine (WRCE) was carried out on 20 June 2012 on the Aero-

Fig. 10 CEMILAC accorded the Certificate for NISHANT Wankel engine.

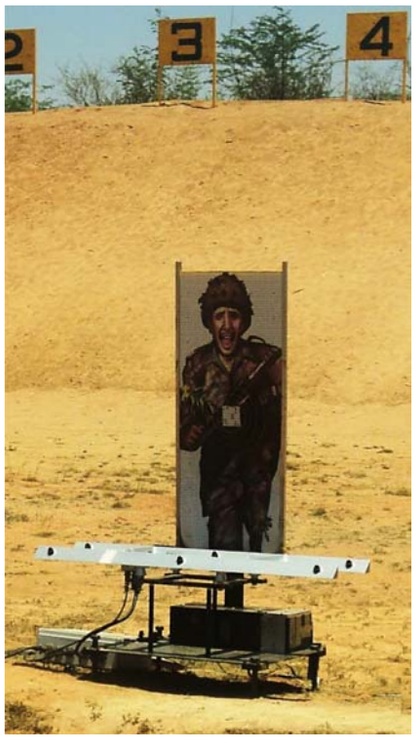


Fig. 7b The 'DHVANI' system.

nautical Development Establishment's (ADE), NISHANT UAV at Kolar airfield. This engine was the second flight worthy prototype delivered to ADE by CSIR-NAL. Two out of three engines produced by DRDO based on the CSIR-NAL design, through a private partner, were also flight tested and shown to meet the requirements of the mission. Based on the performance, CEMILAC accorded the Certificate for 'Limited Series Production' on 7 February 2013 *(Fig. 10)*.

During the year, CSIR-NAL successfully conducted the Static Strength Test (SST) on DRDO's Active Array Antenna Unit (AAAU) for Limit and Ultimate Load cases in July –August 2012 at the Structural Technologies Division *(Fig. 11)*. The static strength

Fig. 11 Static structural strength test setup for AAAU.

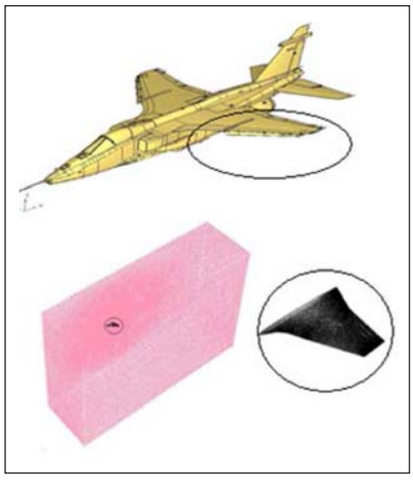
Fig. 8 High speed permanent magnet alternator rotor.

Fig. 9a Continuous bump foil bearing.

Fig. 9b Foil bearing rotor system.

test were witnessed and appreciated by ANAC certifying agency, Brazil for the FAR 25 certification. In flutter research area, flutter characteristics of a combat aircraft wing have been estimated in the subsonic, transonic and supersonic regimes using analysis software along with experimental modal parameters from GVT tests as an input *(Fig. 12)*. The 3-dimensional Euler code JUEL3D was used extensively to compute the flow past configurations being considered for Advanced Medium Combat Aircraft *(Fig. 13)*.

Fig. 12 Flutter Prediction of combat aircraft using EMP.



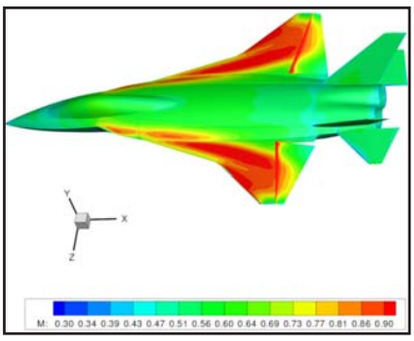


Fig. 13 Flow past AMCA 3B-01 configuration with 10° deflected aileron $M_\infty = 0.5$, $\alpha = 15°$.

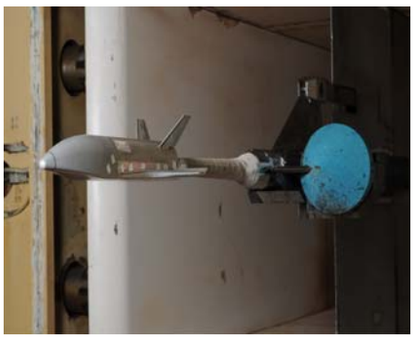


Fig. 14 Photograph of RLV model in 1.2m tunnel.

Fig. 15 GSLV CUS inside the RC of ATF.

CSIR-NAL continued its support to major national aerospace projects of the Departments of Space and Defense using 1.2m trisonic wind tunnel. The year witnessed the all-time record productivity in the history of CSIR-NAL of 2007 blowdowns. The major users were VSSC with1167 blowdowns (68%) and DRDO with 729 blowdowns (36%). As an alternative to expendable launch vehicles, Reusable Launch Vehicle is being developed to act as a platform to demonstrate various technologies like hypersonic flight, autonomous landing, flush airdata measurements etc. Dynamic tests were performed by the laboratory using forced oscillation rig to determine the pitch/yaw damping characteristics of a scaled model of RLV configuration *(Fig. 14)*. The year 2012-13 has been a very active year for the failure analysis and accident investigation activities wherein 57 failures were investigated for IAF, HAL, ADA DGCA, etc. The Acoustic Test Facility (ATF) continues to play a vital role in bridging the requirements between design and testing/ qualification of launch vehicle stages/ subsystems and spacecraft for the Indian Space Programme. A large number of acoustic test programmes were completed for the GSLV as well as the GSLVM3 projects during the year *(Fig. 15)* . The new state-of-the-art, nitrogen based, acoustic test facility built by CSIR-NAL at ISRO's ISITE Complex is fully operational and acoustic tests on the GSAT 7, GSAT 10, GSAT 14 and SARAL spacecraft were carried out. CSIR-NAL currently supports the operation, maintenance and training of the designated ISRO team at the new facility.

CSIR-NAL has been in the forefront of technology transfers. Under the MoU agreement with Indian Metrological Department, CSIR-NAL has earlier supplied and installed Drishti Systems at IGI Airport. In order to handle the urgent requirement of winter season of 2012-13 three more systems has been installed in the first week of January 2013. Presently there are five Drishti systems installed at IGI Airport, New Delhi *(Fig. 16)*. Also in December 2012, one more system was installed in Netaji Subhash Chandra Bose International Airport, Kolkata. A NALSim Flight Simulator has been developed for the ASTE Test Pilots School. This can be used for the test pilot and flight test engineer training programmes conducted by the Indian Test Pilot School (TPS). Rapid deployment is accomplished in NALSim by closely coupling the simulation hardware to the code generation, simulation, and analysis capabilities of Simulink and Matlab *(Fig. 17)*. In line with this, NALSim Desktop Simulator is being developed for students of IISc for carrying out research in flight mechanics and controls *(Fig. 18)*. During the year, CSIR-NAL has successfully installed 12.88m diameter composite

Fig. 16 Drishti at Runway 28 of IGI airport, New Delhi installed in January 2013.

Fig. 17 NALSim flight simulator for ASTE-TPS.

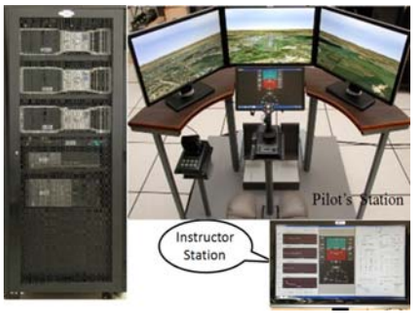


Fig. 18 NALSim desktop simulator for Indian Institute of Science.

Fig. 19 The radome panel assembly in progress at Cherrapunji.

Fig. 21 Integrated advanced display system for regional transport category aircraft avionics.

spherical Doppler Weather Radome (DWR) protecting the weather radar belonging to BEL/ISRO at IMD campus Cherrapunji within a record time. The IMD campus is at a distance of just 30kms from the Indo-Bangla border *(Fig. 19)*. At CSIR-NAL an affordable lab scale autoclave has been conceived, designed and developed to meet the requirements of Academic and Research Institutions working in the area of polymer composites. Orders for this autoclave have been received from premier educational and research institutes such as IIT, Kanpur, MIT, Manipal and VSSC.

I wish to highlight some of the other

Fig. 20 IGAPS integrated with the automated test station.

notable achievements with applications to technology and products. The Integrated Global bus Avionics Processing System (IGAPS) with features like Avionics Full Duplex Ethernet, ARINC 653 compliance and wide bandwidth for communication has been successfully designed, developed and integrated for the first time in India at ALD. It has been integrated with sophisticated real time Automated Test Station for simulation, debugging and application integration *(Fig. 20)*. Further, the widescreen high resolution AMLCD and Advanced Display System (ADS) *Fig. 21* has been successfully realized and integrated with state of the art avionics suite for Regional Transport category aircraft. The Center for Electromagnetics has been actively engaged in the electromagnetic design and development of ground based and airborne radomes for various national programmes. During the year, the applications of Dielectric Frequency Selective Surfaces (DFSS) for the design of airborne radomes and high reflection structures have been explored. This novel DFSS structure exhibits dual-band high reflection characteristics in the millimeter wave and sub-millimeter wave frequency regimes and it has potential applications in the design of dual-band reflector antennas for satellite and terrestrial communications systems.

CSIR-NAL is one of the lead agencies for Micro Aerial Vehicle (MAV) development in the country. During the year, multiple variants of MAV autopilots were successfully designed and developed in-house for NAL programs. The Autopilot hardware has been realized with an optimized weight budget of 6.8 grams and an independent sensor suite of 0.67 grams *Fig. 22*. Slybird mini UAV was successfully flight tested at Leh/ Ladakh region (12,000ft above sea

Fig. 22 MAV autopilot hardware with sensor suite. (a) 6.8 gram autopilot hardware.(b) 0.67 grams 10 DOF sensor suite.

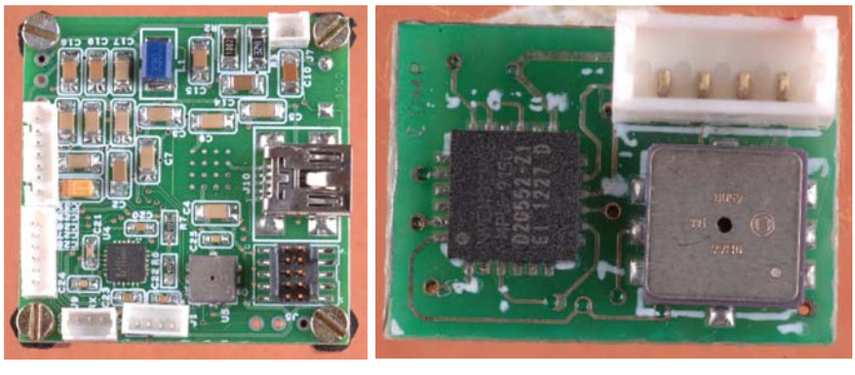


Fig. 23 Flight test conducted at Leh (12,000 ft above sea level).

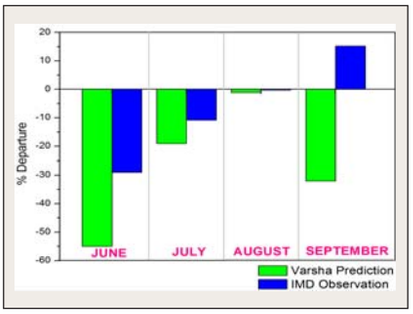


Fig. 24 Percentage departure in all India rainfall on monthly scale for monsoon 2012.

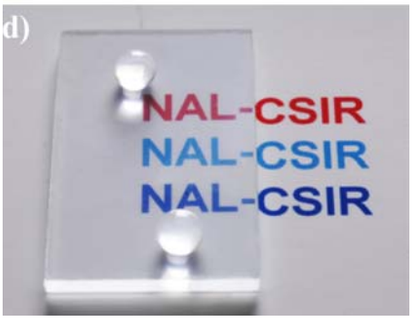


Fig. 25 ZnO multifunctional coating on glass substrate.

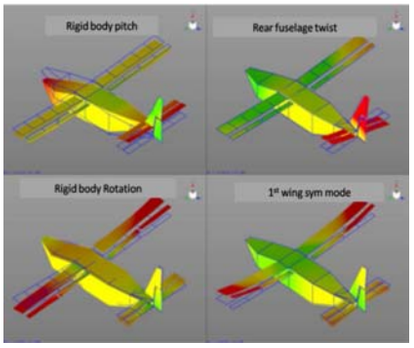


Fig. 26 First four modes of GA10 Airvan and GA10 Engine System.

level) during June 2012 *(Fig. 23)*. Subsequent to the successful completion of the mini UAV, the MAV team is in the process of making engineering improvements towards production quality with public and private partnership.

The R&D achievements in the area of special materials are equally noteworthy. Ni-Ti based shape memory alloys made its impact on the industry with its multiple usage including Biomedical applications. A MoU was signed between CSIR-NAL and Foundry & Forge Division of Hindustan Aeronautics Limited, Bangalore for collaborative development of production technology for NiTi shape memory alloy wires. Insitu PZT based piezoceramic coating has been developed on regular and irregular surfaces of aerospace grade Aluminum metals and composites (CFRP and GFRP) with dual functionality as transmitter and receiver of ultrasonic waves. The coating has been successfully tested for local and global structural health monitoring and found to be very promising for damage detection of composite structures (de-lamination, fibre separation, fibre cut etc.) and metal components. NALSUN coating continued to exhibit its potential by attracting national and international enquiries and the technology has been transferred to one more industry during the year, taking the total to 29.

Societal Mission Activities

The societal mission related activities of the laboratory recorded a good progress during the year. After the implementation of the non crane solution and CFRP tip brake onto the 500 kW Wind Turbine System (WTS), the field trials were carried out during the June-September 2012 wind season. Nearly 3000 units of energy were fed to the TNEB Grid during these field trials. As in the previous years, monthly rainfall forecasts were prepared and circulated among relevant national agencies: PMO office, ministries of Agriculture, Earth Sciences, IMD and DG, CSIR etc. and the verification was carried out in October. The overall performance is summarized in the *Fig. 24*. Varsha GCM predicted signs of departure in the monthly rainfall correctly for all months except September. The departure in September may be attributed to the low pressure systems developed. Further, ZnO coating on a high-temperature solar selective coating, that preferentially exhibits multi-functionalities such as: high spectral selectivity, self-cleaning, broadband anti-reflection phenomenon, etc. has been developed. The photograph of such multifunctional ZnO coating on a glass substrate is shown in *Fig. 25,* displaying good transparency in the visible region. The high temperature solar absorber coating along with a transparent ZnO superhydrophobic coating has a great potential for possible use in linear Fresnel technology.

International Collaborations

The projects sponsored by international companies including Boeing, Pratt & Whitney, and Bell-Helicopters are progressing well. Under the Boeing sponsored project on meshfree computational methods, an automatic process for generation of single large cloud (SLC) of points through merging of individual clouds generated around each component of the configuration was completed. Ground vibration tests were performed for various configurations on Gipps Aero GA10 Airvan in Australia to estimate the experimental modal parameters and were used to estimate the flutter behavior of the aircraft. A series of GVTs including the GVT on engine system was completed in a stringent test schedule of 10 days. The timely and efficient execution of ground vibration tests was appreciated by the CASA officials. An analytical method based on two-degree of freedom model (pitch and yaw) is used to predict the whirl flutter of the engine propeller system *(Fig. 26)*. In view of supporting the RF field simulation studies in aircraft cabins for the CSIR-NAL Boeing collaborative project, the transmission/reflection characteristics of two types of aircraft seats were measured. Further, the collaborative research project titled 'Creation of a synthetic

reconfigurable aerodynamic model demonstrating multiple post stall phenomena and blending it with the validated aerodynamic model at low AoA" between CSIR-NAL and De Montfort University (UK) was successfully completed.

New Facilities

CSIR-NAL has many advanced test facilities that are recognized as National Facilities which are the best in the country and comparable to the best in the world. During the year the damage tolerance facility at the Advanced Composite Division was augmented by installing a servo controlled multichannel hydraulic system. The new system consists of 43 ton servo controlled hydraulic jacks and 50 ton manual control hydraulic loading cylinders, hydraulic power supply unit of up to 100 lpm at 3000 psi, 8 channel servo control system and extendable up to 32 channels. Upgradation of the fiber spinning line with provision for wet and dry jet wet spinning at Centre for Carbon Fibers and Prepregs has also been undertaken. The new Nano-materials Research Laboratory (NRL) was inaugurated by DG-CSIR on June 1, 2012. The new building houses all the state-of-the art characterization facilities for nanomaterials research *(Fig. 27)*. Wind tunnel testing has a key role to play in designing efficient MAVs. Recognising this CSIR-NAL established a Micro Air Vehicle Aerodynamics Research Tunnel (MART) on 11th March 2013 *(Fig. 28)*. The MART is a state-of-the-art facility that would address all the aerodynamic, propulsion and aero-elastic issues related to MAVs. The tunnel has a provision for either closed test section for the study of aerofoil sections/3D wing-body models or open jet test section with Betz chamber for the flapping and rotary wing studies.

Fig. 27 Inauguration of Nanomaterials Research Lab (NRL) on 1 June, 2012 by DG-CSIR.

Plan Projects

The report will be incomplete without mentioning the plan projects and R&D performance indicators of the laboratory. During the Eleventh Plan period, three plan projects in the categories Supra, Facility and Network were implemented with CSIR-NAL as the nodal laboratory and seven plan projects where CSIR-NAL was the participating laboratory. As on 31st March 2013 all the 11th Plan projects were completed. The plan projects were reviewed periodically by the Task Force and the Research Council, and both the review committees expressed their satisfaction over the progress and achievements.

Under the 12th Five Year Plan, as on 31st March 2013 two projects were approved by CSIR Headquarters for implementation. The project on 'Augmentation and Refurbishment of National Trisonic Aerodynamic Facility' is being implemented in collaboration with ISRO & DRDO. The facility, since its inception in 1967, has completed more than 41000 blowdowns, with the last 5000 having been completed in less than 3 years. Consequently, the downtime of the facility is on the rise, and there is a great need for life-extension of some of the critical and vital systems & subsystems of the facility. Therefore, the augmentation and refurbishment of NTAF has been taken-up in the 12th Plan. The project has 14 modules and the total approved project cost is Rs.73.50 crore (equal sharing by all the three agencies). The second project on 'Technology Solutions for Micro Aerial Vehicle Development' at a total cost of Rs.27.18 crore is being initiated with CSIR-CEERI, Pilani as a participating laboratory. The project aims at developing fully autonomous MAVs of sub 200 mm dimension capable of carrying payloads for surveillance / information gathering with a minimum endurance of 20 minutes and having a range of 1 to 2 Km.

Fig. 28 Mircro air vehicle Aerodynamics Research Tunnel (MART) wind tunnel.

R&D Performance Indicators

The R&D performance indicators of the laboratory during the year are noteworthy. CSIR-NAL was awarded 38 new sponsored projects accruing to Rs. 16.40 crore and 31 grant-in-aid projects resulting in a cash flow of Rs 18.10 crore during the financial year 2012-13. CSIR-NAL's external cash-flow was Rs.43.23 crores, amongst which the receipts from the government and PSUs constituted 99.57%. The year also witnessed twenty four MOUs / NDAs with external agencies and licensed NALSUN Technology to Thermax Ltd., Pune for steam generation application. The IP portfolio was increased by filing of five patents (four in India and one foreign) and three copyrights applications. In the same year three Indian patents have been granted. The total number of publications was 326, with 156 journal papers and 170 conference papers in the year.

It is a pleasure to mention that the laboratory and our scientists continue to get recognition and awards for their noteworthy contributions and individual efforts. Some of our scientists have received fellowships, best paper awards and other national and international recognitions. I congratulate all of them on their success.

CSIR-NAL participated in the prestigious 9th edition of Aero India held during 6 to 10 February 2012 at Bangalore, the technology displays helped in spreading the brand image as a premier aerospace laboratory in the country.

Finally, I wish to sincerely thank the support and cooperation of members of Research Council, Divisional Scientific Committees, and Management Council of CSIR-NAL, DG-CSIR, and staff of CSIR, New Delhi. I also acknowledge our various stake holders; DRDO, ISRO, DGCA, ADA, HAL, Air Headquarters, ARDB, DST, DAE, Defence Services, MoES, and others including international bodies for continuing to repose their faith in us by sponsoring R&D projects. Much of our achievements have been possible due to the efforts, cooperation, advice and confidence of all of them. Last but not least, I take this opportunity to thank all scientists and other staff members of CSIR-NAL for their commitment to this esteemed organization.

Shyam Chetty
Director