1

REPORT OF THE DIRECTOR

It gives me great pleasure to present the annual report of the National Aerospace Laboratories for the year 2007-08.

HIGHLIGHTS

The year 2007-08 was an eventful one for NAL. While two Tenth Five Year Plan(FYP) Network Projects(with a total of 65 modules) with NAL as the nodal laboratory and 5 projects where the laboratory was a participant were completed successfully, the third network project related to civil aircraft (with 4 major modules) was proposed to be extended by an year in the Eleventh plan period to meet the modified scope and objectives. The Eleventh FYP projects are at various stages of approval and initiation.

The most important and welcome development for NAL and CSIR for the year is that the Indian Air Force has come forward to make a firm commitment to procure fifteen *SARAS* aircrafts designed and developed by NAL for its operational use, with an indication that it may need thirty more in the next plan period. This is a dream-come- true for NAL. It is the culmination of several years of hard work put in by all those who have been closely associated with this programme. It is a great boost to the Laboratory's civil aviation programme, but at the same time it places a heavy onerous responsibility on our shoulders. We are thankful to the IAF for their confidence and faith in NAL. With the unstinted support and cooperation of CSIR, motivation and commitment of our scientists and staff and the good wishes and support from our close associates, we are confident that we will succeed in meeting the IAF's expectations.

The coming year is a particularly special one for us at NAL, as 2008 marks the beginning of our Golden Jubilee Year. It is indeed a proud moment for all of us (when I say 'us' I also include our predecessors) when NAL completes five decades of dedicated service to the nation. NAL has come to be recognized as a leader in the country in aerospace sciences and technologies, thanks to the single minded efforts and invaluable contributions of its scientists, ably supported by its officers and staff, both technical and administrative. NAL today is recognized internationally for its excellent facilities and the skill and competence of its human resources. We have made significant and valuable contributions to all the major national aerospace programmes, at the same time building within NAL technological excellence. Today our sister organizations look to NAL to provide them advanced technology solutions in strategic and critical areas in their programmes and it is to NAL/CSIR's credit that we have not failed them.

Our achievements during the year have been quite a few and it is difficult to list all of them here. I will only touch briefly on some of them.

In the civil aviation sector, we had the second prototype PT2 of SARAS with its new, more powerful P&W PT6-67A engines making its maiden flight in April followed by a limited number of test flights which showed that the aircraft is now capable of meeting its climb requirement. The two prototypes PT1 & PT2 have together logged in more than 90 hours of flying from more than 145 test flights so far, flown by the flight test team led by ASTE of IAF. Meanwhile, ultimate load test on wing and pressurization test on fuselage have been completed paving the way for flight envelope expansion. We now have to gear up to complete a large number of test flights this year covering the entire flight envelope to show compliance with performance specifications. We are confident of meeting this requirement with the support of ASTE and DGCA. It is also planned to build a new Production Standard Aircraft(PSA) with a new, light weight carbon fibre wing and empennage, a weight optimized fuselage, an advanced autopilot and an Engine Instruments and Crew Alert System(EICAS). The design modifications for the desired weight reduction are complete and the fabrication activities of the PSA have commenced. The autopilot, EICAS and the corresponding control law developments are in an advanced stage of progress. It is planned to get the PSA ready for its first flight by June 2009. The C-CADD and all the other concerned departments of the Laboratories along with our associates have to put in their best efforts

to make this possible.

The work on the first public-private partnership venture in aircraft design in the country, the 4-5 seater General Aviation Aircraft, jointly with Mahindra Plexion Technologies Pvt. Ltd, is progressing well. The detail design is nearing completion and fabrication is being commenced. The first prototype is expected in early 2009.

The Tejas- LCA Limited Series Production (LSP) aircraft composite components have been delivered to HAL on time and technology transfer to HAL is under progress. The new VERITy process has reached a mature stage with the successful fabrication and testing of the SARAS wing test box with complex design features. This has given us the confidence that our decision to adopt the VERITy process for SARAS composite wing fabrication is justified. The SARAS composite wing minimum weight design and skin engineering is complete and the fabrication process has been initiated. This is indeed a new challenge as we are fabricating a full transport aircraft wing for the first time in carbon composite, that too using a new process.

While the NAL designed FRP blades of the 300 kW wind turbine are performing well at Kethanur and three more pairs are getting ready to be installed, the 500 kW wind turbine blade fabrication is nearing completion and the wind turbine is expected to be installed soon. Prof V S Ramamurthy, former Secretary, DST and presently Chairman, RAB, CSIR inaugurated the new Wind Turbine Blade Fabrication Facility and the Wind Energy Laboratory during the year.

The Kaveri engine afterburner flame holder mechanism developed at NAL has been successfully tested in Russia by GTRE showing satisfactory performance. The high speed combustor test facility for the ISRO and DRDO programmes is also nearing completion after a rigorous safety audit and is expected to be commissioned soon. This will be a national facility which will facilitate R&D in high speed combustor design and development.

As part of a major national initiative towards the development of aerospace quality rolling element bearings and lubricants, a National Test Facility for Rolling Element Bearings was commissioned this year at NAL under a multi agency national project and was inaugurated by Shri M Natarajan, SA to RM in April 2007. This facility has been established in accordance with the Joint Service Specifications prepared by the Centre for Military Airworthiness and Certification (CEMILAC), Bangalore, so that it could act as a Centralized Certifying Agency for testing and qualification indigenously developed aerospace quality bearings as well as lubricants.

Another major initiative with support from DRDO is the new activity in the field of Micro Air Vehicles(MAV) which have a great potential in both strategic and civilian sectors. Two MAV flying events were organised at Agra with active participation and support from ADRDE(DRDO), one of them with international participation. Several configurations are under development as a part of the mission oriented MAV programme.

NAL has continued to support the country's space programme in a big way. This included testing of PSLV, GSLV and RLV models in our wind tunnels and also in the design, fabrication and testing of aero-elastic models of GSLV.

In addition to testing of satellites and providing advanced nano-coating based sunshield mirrors for passive cooling of IR sensors in satellites, NAL has also taken up design and commissioning of a state of art nitrogen based new acoustic test facility for ISAC, ISRO. NAL also has successfully developed metallised CFRP components for the SATCOM project of ISRO's Space Application Centre at Ahmedabad. As a sequel to the development of DWR - MARK-II Radome for ISRAD-ISRO, NAL has taken up fabrication of two more MARK-II Radomes for BEL-Ghaziabad which is also expected to lead to Technology Transfer to BEL.

It is our proud endeavor to support the strategic sector in a big way. NAL has completed many DRDO projects like computation of aerodynamic loads on MiG 29 configuration using CFD techniques for the MiG-29 TTLE programme of IAF, wind tunnel studies on Lakshya, Dhanush and HSTDV for DRDO. The development of a 55 HP rotory engine for UAVs is nearing completion. Technology for development of ceramic throat insets for high temperature rocket nozzle applications using a novel centrifugal thermit process has been successfully demonstrated. Our support to the prestigious LCA programme, both airforce and naval versions, in the critical area of flight control law development continues.

The IFCAP facility has made significant progress during the year and the type certification of aircraft grade carbon fibres produced in the facility and development of space grade fibres would be completed very soon. It is a matter of pride for us that the carbon fibre and aramide fibre technologies have been successfully transferred to industries this year.

NAL has successfully completed development of DRISHTI, a state-of-the-art field transmissometer that has been

Historic Conference on Micro Aerial Vehicle and Unmanned Ground Vehicle Technologies

The National Aerospace Laboratories, Bangalore and the Aerial Delivery Research and Development Establishment, DRDO, Agra, have partnered with the U. S. Army Research, Development and Engineering Command (RDECOM)'s International Technology Center – Pacific to host the first U.S. - Asian Demonstration and Assessment of Micro Aerial and Unmanned Ground Vehicle Technologies during March 10 – 15, 2008, at Agra, India.

The event was sponsored by the US Department of Defence and supported by the Defence Research and Development Organization (DRDO), the Council of Scientific and Industrial Research (CSIR) and the Indo-US Science and Technology Forum (IUSSTF).

The purpose of the Conference was (i) to showcase next-generation , COTS enabled prototype systems of Micro Air Vehicles(MAV) and Unmanned Ground Vehicles(UGV) that are almost ready for end-use and (ii) identify areas for further development of critical technologies.

It may be noted here that two previous editions of the event were held in Germany in the years 2003 and 2005. These events mainly concentrated on proving platform technology. Mission capability and adaptability were the major goals for the Indian event.

Twelve international teams from academia, government and industry (two from the US, one from Germany, France, Spain, Netherlands, Japan, and Australia and four from India) participated in the event. A seminar by experts from abroad and India on current status and future technology needs was also held concurrently.

It is expected that the event would benefit the MAV community in the country and spur speedy developments in this strategically important area.

demonstrated to be on par with the best available counterpart from abroad. The 10th FYP project on advanced aerospace materials has also been successfully completed this year with commendation from the Monitoring Committee. Extensive support in the area of accident and failure investigation continues to be provided to all the concerned organizations by the Laboratory.

The NALFOQA is adapted to new aircrafts like A319 and A321 which are in the service of Indian Airlines. I am happy to state that DGCA has placed an order for a large number of these units to be installed for all the civil aircrafts.

NAL also had many international collaborative and sponsored research programmes in 2007. In addition to the existing programmes with CAE (China), Bell Helicopters (Canada), Boeing (USA) and P&W (USA & Canada), collaborative programmes with ALCOA (USA), UKIERI (UK) and RMIT(Australia) have started this year.

A book titled "Slow Viscous Flows: Qualitative Features and Quantitative Analysis using Complex Eigen function Expansions" by Dr. P. N. Shankar was published by Imperial College Press, UK.

Upgrading of our 0.6 m tunnel to supersonic capability is nearing completion. This will relieve pressure on the 1.2m tunnel significantly. A new flow visualization technique of shear-sensitive liquid crystal, applicable for shear stress measurements in high speed flows has been implemented.

NAL has successfully completed the NMTLI project entitled, "Mesoscale modeling for monsoon related predictions - Phase I" .On the basis of this, a Phase II program has been approved by CSIR and Ministry of Earth Sciences to develop a ten teraflop machine and to further improve the VARSHA model with a 40km grid size. The industrial partner, Encore Software Ltd, has already fabricated and supplied ten machines which are being installed at different nodal centres in India to

run the VARSHA software.

NAL's strength has been its facilities and technological expertise. It proposes to upgrade and modernize its existing facilities as well as build new facilities and technologies in the eleventh plan period to meet specialized national needs of the future. These will aid and support future national programmes in aerospace and defense sectors. Further as a logical sequel to our civil aircraft R&D activity, a multi institutional civil aircraft programme: RTA-70, a cost effective, 70-seat, fuel efficient turbo-prop, Regional Transport Aircraft with many advanced technology features is proposed to be taken up with NAL as the nodal agency, utilizing NAL's core technology, strengths, expertise and networking capabilities. Also advanced centers are planned to be established which will act as referral centers for all future aerospace programmes.

IN THE DIVISIONS

The *Advanced Composites Division (ACD)* has been involved in the design, development, fabrication, testing, evaluation and certification of composites components for the nation's major aircraft programmes such as TEJAS (LCA) and SARAS. In line with these efforts, the year has seen the successful delivery of complex TEJAS

Fig. 1. Wing test box under static test.

LSP components and significant transfer of related technologies to the aircraft industry. A major programme has been initiated to fabricate the SARAS wing with advanced composites using a newly developed innovative vacuum enhanced resin infusion technology (VERITy) process. *Figure 1* shows the wing test box under static test as required by the DGCA. Many other flight worthy critical components are also being made for the SARAS programme. In addition, the Division has made notable strides in the new areas of Structural Health Monitoring and adaptive structures based on Shape Memory Alloys. A state-of-the-art Autoclave Complex is being set-up to cater to the needs of processing of large components such as aircraft wings. Besides this, ACD continues to offer its expertise and specialist services in the areas of

Vacuum Enhanced Resin Infusion Technology (VERITy)

VERITy is a new process developed by NAL for manufacturing composite components at a lower cost without sacrificing the quality demands of aerospace applications. The predominant technology currently deployed for airframe components is with prepregs and autoclave moulding. Prepregs are expensive value-added material systems. They require high-maintenance storage and manufacturing facilities such as cold chests and clean rooms. These also have an out-life window within which the component fabrication has to be completed. This poses a constraint for large components such as the aircraft wing. VERITy is a low cost alternative that overcomes these overheads and constraints. It uses dry performs that need no special storage facilities. The resin is infused after the entire layup is done thus allowing for the manufacturing time required for each component. Autoclave curing with slightly elevated temperature and low external pressure can be adopted in this process. Qualification and validation of the process has been completed in coordination with certifying authorities. A wing test box representing the complexity of the most heavily loaded portion of the wing has been fabricated using VERITy and successfully tested. Based on this, the SARAS wing fabrication process using VERITy is currently in progress.

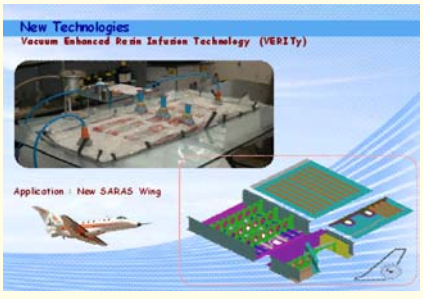


Fig. 2. Typical EICAS display.

Fig. 3. Picture of ETS.

material characterization, testing, non-destructive evaluation and repair technology for aerospace and other engineering applications.

The *Aerospace Electronics and Systems Division* played multiple roles resulting in emergence of several new technologies. The SARAS project saw the genesis and development of EICAS (Engine Instrument and Crew Alerting System) and the Autopilot programs *(Fig. 2)*. The SARAS Prototypes flew about 141 test sorties and the functional and aircraft level tests have helped in establishing the performance of various systems for their qualification. NALVAS is successfully integrated with NALFOQA and has features like the altitude mapping, aerial mapping, glide slope and localizer. An engineering test station (ETS) has been established *(Fig. 3)* to test the software developed for autopilot including failure simulation, fault injection, out of bound inputs etc. Scientific investigations were pursued in the area of active noise control and signal processing to utilize and expand the capabilities to serve the application requirements aptly backed by concurrent applied research activities.

The SARAS nosecone radome qualified the lightning protection tests conducted at CABS, Bangalore in February 2008. Activities are now focused on technology assessments and technology exploration in different

NAL Visualization and Animation Software

NAL Visualization and Animation Software (NALVAS) has been successfully completed with flight animation software along with the integration of NAL Flight Operations Quality Assurance (NALFOQA) software.

NALVAS has the following features:

- Configurable aircraft model interface. This enables the user to easily add any aircraft model using the standard model database. The NALVAS software uses open architecture design, which enables the user to interface with any kind of aircraft model compatible with the software design.
- Altitude mapping, aerial mapping, glide slope and localiser.

NALFOQA software is used for DFDR/FDR/SSFDR flight data analysis for all the airlines in India. The deployment of software is done with the configuring of parameters, phases, events and airline configurations. NALFOQA is being used by Indian Airlines for more than a decade for their fleet of aircraft.

Fig. 4. Cartosat -2A at ATF.

areas of electromagnetics for aerospace applications.

The *Acoustic Test Facility (ATF)* is playing a crucial role in catering to the needs of the Indian space programme by conducting dynamic, acoustic environment qualification tests on satellites, satellite sub systems, satellite launch vehicle interstages and their subsystems. Ten acoustic tests including those on two satellites-INSAT 4CR and CARTOSAT 2A *(Fig. 4)* were conducted during the year. Five tests on GSLV subsystems and three tests on satellite subsystems were completed. The Division has taken up a challenging task of design and commissioning of a larger state of art nitrogen based new acoustic test facility for the Indian Space Research Organisation at their site.

It has been an eventful year for *Centre for Civil Aircraft Design and Development (C-CADD),* with the second prototype of SARAS (PT2) making its successful maiden flight, networked projects and the NAL-Mahindra Plexion 5-seater General Aviation Aircraft programme making significant progress. Design and development of the SARAS weight optimized PSA is in full swing. Other development programmes like SARAS autopilot, EICAS and landing gear actuators are nearing completion. The larger diameter propeller tests have been completed and the results submitted to the European Aviation Safety Agency for certification.

After successful completion of engine ground run and taxi trials, PT2 had its maiden flight on 18th April 2007. The most important improvements in PT2 are the installation of two higher powered P&W engines (1200 SHP) and a new MT propeller of larger diameter. Installation of the higher power engines called for modification of the supporting stub wing structure and the engine nacelles. Improvements have also been incorporated in many other system layouts with inputs from flight crew. The design ultimate load test has been completed successfully on SARAS wing *(Fig. 5)* as well as the

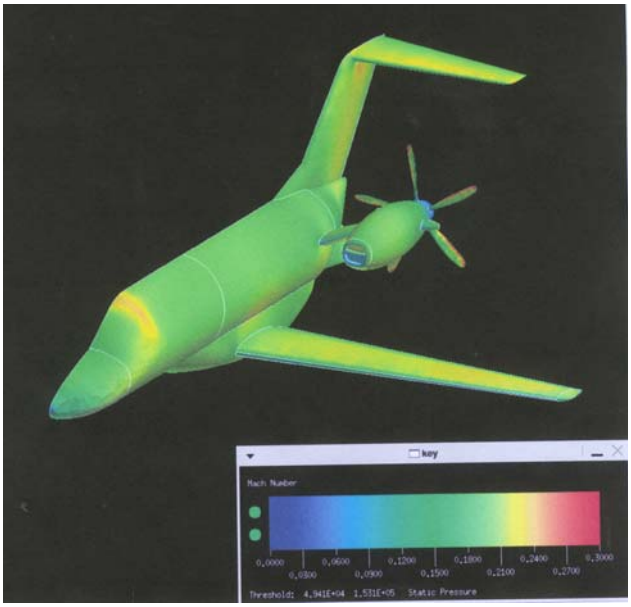
Fig. 5. Saras wing load testing.

pressurization test on structural test specimen of SARAS fuselage. This was correlated with theoretical estimates obtained by the CFS code *(Fig. 6)*. Also the pressure leak test has been completed on PT1 fuselage.

Three HANSA aircraft have been delivered to DGCA for allocation to flying clubs. Further activities to certify HANSA in Australia are underway with coordination from the Royal Melbourne Institute of Technology (RMIT).

Another important activity is the acquisition of land from HAL for a new aircraft hangar. The hangar construction work has started and is expected to be completed in 2008. This hangar can facilitate 3 SARAS aircraft assemblies at a time and has exclusive work areas for various assembly related activities, special air-conditioned laboratory for instrumentation, its own UPS and diesel power supply. When commissioned in 2008, this new hangar will greatly help the aircraft assembly and integration activities.

Fig. 6. Pressure distribution on Saras by CFS code.



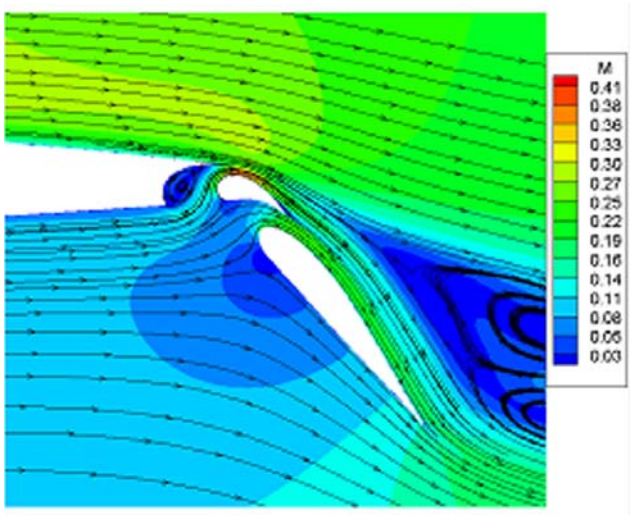
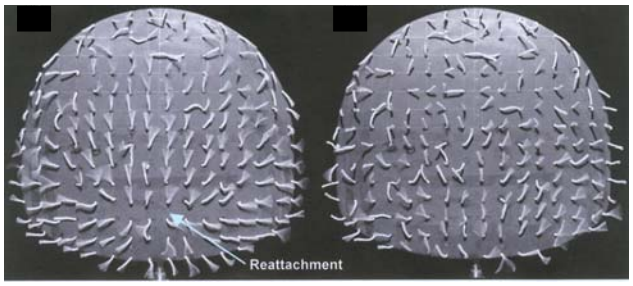


Fig. 7. Mach Contours and Stream Lines Plot for NACA 1410 double slotted airfoil.

On the project Blimp, Aerial Delivery Research and Development Establishment (ADRDE), Agra and NAL jointly carried out field trials on tethered blimp during February 2008 at Agra. Also, development of engine vector thrust mechanism (for autonomous navigation) has shown promising results.

The *Computational and Theoretical Fluid Dynamics Division* provided reliable and cost-effective numerical solutions for flow field over complex aerospace configurations. A hierarchy of CFD codes developed over two decades ranging from inviscid Panel code to Reynolds Averaged Navier Stokes (RANS) solvers applicable to the entire speed regime from low subsonic to hypersonic flows have been very successfully used for these simulations. Apart from CFD applications, significant efforts have gone into development of new algorithms, basic research problems like liquid sloshing in oscillating containers and improvement of the existing codes in terms of accuracy, efficiency and capabilities. A noteworthy achievement has been the publication of a book titled 'Slow Viscous Flows: Qualitative Features and Quantitative Analysis using Complex Eigen function Expansions' by Dr P N Shankar, former scientist of the Division and currently CSIR Emeritus Scientist at NAL. Various aerofoil flap configurations considered for the RTA are being analysed using the two dimensional viscous code JUMBO2D *(Fig. 7)*.

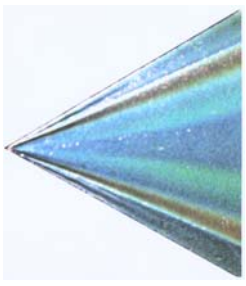
Fig. 8. Experimental studies on MAV planforms.



Research and Development activities are carried out in three major disciplines at the *Experimental Aerodynamics Division;* viz. flow structure and management, flow diagnostics and aircraft and spacecraft aerodynamics. Experimental studies on active control of flow on a cone by blowing were conducted. During the year, steps were undertaken to initiate work in the areas of active flow control and aerodynamic characterization of MAVs. Tuft flow visualization were conducted on MAV models *(Fig. 8).* Other significant studies include density measurements on afterbody flows in the presence of jet exhaust, aerospike nozzle flows, air intake and afterbody-nozzle flow simulation studies on a high speed air-breathing vehicle configuration. Shear sensitive liquid crystal flow visualization techniques were used for high speed flow visualization *(Fig. 9)*. BOEING and Bell Helicopters projects were completed successfully.

The *Flight Mechanics and Control Division* is actively engaged in research, development and technology pursuits in the areas of flight control and flight simulation, modeling and parameter estimation, multi sensor data fusion and air traffic management. It continues to make significant contributions to the SARAS and TEJAS programmes in the critical area of flight controls. The focus for SARAS is on design and development of the Flight Training Device and indigenous development of the Autopilot. For the TEJAS programme, leadership is being provided to the National Control Law Team for development of Control Law. Flight data analysis support is being given to both the aircraft programs on a regular basis. Towards the goals of precision tracking of targets and multi target tracking in air combat situations, the Division is developing state estimation and data fusion techniques to track maneuvering airborne targets. Air traffic management and simulation exercise has yielded good results with high resolution satellite imagery integrated to 3D Airport Visual Simulator facility. Study on control law parameters of MAV and UAV were also initiated. Seeker filter based on Interacting Multiple Model Modified Extended Kalman Filter

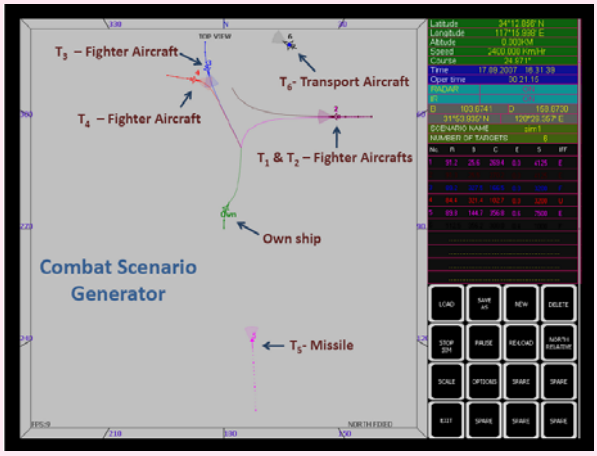
Fig. 9. Flow visualization using shear sensitive liquid crystals.



Multi Sensor Data Fusion

As an application of Level 1 data fusion to air defense, a seeker filter based on Interacting Multiple Model Modified Extended Kalman Filter (IMM-MAEKF) was designed to track air breathing targets. The challenge was to design the filter using RF seeker measurements which are corrupted with non-Gaussian noise due to RCS fluctuations and glint noise and also suffer from data eclipsing problems. The seeker filter was coded in C language for real time applications and integrated with the interceptor simulation code for closed loop performance evaluation using Monte Carlo simulations. The seeker filter exhibited robust performance under different interceptor-target engagement geometries, target aspect ratios, levels of process noise in the filter model and mode transition probability matrix .

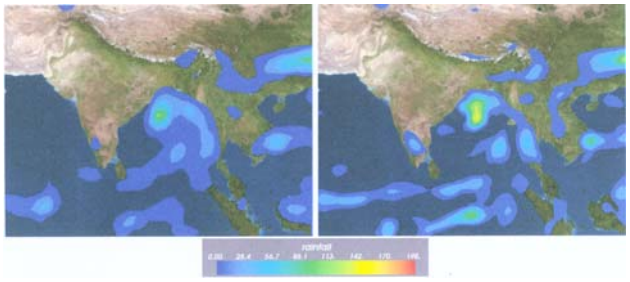
As Level 2 data fusion development, a fuzzy-logic Bayesian network based hybrid situation assessment model to serve as a pilot decision making aid for BVR (Beyond Visual Range) combat has been developed. Typical air to air combat scenarios required for validation of the model were realized using GUI based Software in C++ language as shown. One aircraft (Own-ship) carrying RADAR, Radar Warning Receiver, Electro Optical Sensor and Infra Red sensor models (developed in MATLAB/SIMULINK environment) was used to detect a maximum of six targets (T1-T6) based on their field of view and received power. The states of all the targets in the scenario, at each instant of time were estimated using measured data from the sensors using multi sensor multi target data fusion algorithms. The estimated states processed by Fuzzy Event Detector (FED) were used as inputs to the Bayesian network for situation assessment.



(IMM-MAEKF) was designed for tracking maneuvering air breathing targets using RF seeker measurements.

At the *Flosolver Unit.* the Phase1 program to build a 128-processor parallel computer and a new weather prediction code (VARSHA) was completed meeting all the objectives. Many other studies pertaining to the field and of immediate relevance to the country were also carried out. The important features are customized 5-day weather forecast for the country, long lead forecast covering one month predictions and cyclone track predictions *(Fig. 10)*. These are very useful for calamity predictions like prediction of cyclones and heavy downpours.

Fig. 10. Results of the Varsha2C GCM. Contours of computed rainfall (in mm/day) on the third day of integration for the 1999 Orissa cyclone. Integration was started from 00 UTC of 26 October. Horizontal resolution is varied from Left panel: 150 km, Right panel: 80 km.



A new project to develop a ten Teraflop parallel computing hardware customized for meteorological applications and an enhanced version of the Varsha GCM code for accurate forecasts of the Indian monsoon is undertaken as Phase II, funded by CSIR's NMITLI Cell and the Ministry of Earth Sciences. The hardware platform would consist of 1024 state of the art processors interconnected by the FloSwitch and FloOptiLink in an innovative topology. The new code would incorporate new features such as multi-precision computing.

The proposed integrated weather forecasting system is expected to be valuable for the country both for long-range forecasts of the monsoon and short-range forecasts of extreme weather events. The ability to make weather and rainfall predictions indigenously also confers on our country a strong strategic advantage especially in the wake of global warming/emission protocols.

The *Fibre Reinforced Plastics Division* has today emerged as a multifaceted R&D centre which balances both the scientific and technological aspects of composites engineering. The Division has developed high-end products

Fig. 11. The metallised reflector and feed horn.

with simplistic and appropriate technologies and also made quick forays into the emerging and futuristic rapid moulding (resin injection) and rapid curing (radiation cure) technologies coupled with development of associated high performance matrices and special forms of reinforcements.

A very challenging task was the development of metallised-CFRP reflectors and feed components for the SATCOM program sponsored by SAC-ISRO *(Fig. 11)*. The division has completed fabrication of two numbers of MARK-II Radomes for the Doppler Weather Radar (DWR) project for the Indian coast (in association with ISRAD (ISRO) and BEL). In view of the good results obtained by the highly efficient 300kW wind turbine blades at Indian conditions, six more 11m long GFRP blades for the same wind turbine are under fabrication for field usage at the Kethanur wind farm. It is expected that the new 14m long GFRP blades for the 500kW wind turbine would be fabricated, installed and tested before the end of this year's wind season *(Fig. 12)*. Fabrication of these blades has indeed been a challenging task in view of its large size, weight and complexity.

The FRP Division has made rapid progress in the applied research programmes involving development of nanostructural composites, conductive composites, metal-fibre composites and rapid manufacturing technologies for the immediate and futuristic high performance composite product indigenization programmes.

The *Materials Science Division* is involved in Research and Development in the broad areas of preparation, processing and characterization of materials, failure analysis and accident investigation, design and fabrication of thermo-physical instruments and airport instrumentation.

Some of the notable developments during the year are the successful preparation of SiC fibre-SiC matrix composites using chemical vapor infiltration, fabrication and testing of ceramic inserts for convergent divergent nozzles of rocket thrusters, transfer of carbon fibre technology to industries and improvisation of the state of art transmissometer – Drishti.

Fig. 12. Fabrication tools for 500kW wind turbine blade.

Near net shape convergent divergent nozzles embedded inside graphite holders were successfully fabricated using centrifugal force assisted combustion synthesis. The insert was made of ultra high temperature cermet material. This was tested at 3000K with high heat flux of 18 mega watts per meter square in an oxygen rich corrosion environment *(Fig. 13)*. The material withstood these aggressive conditions for about 20 seconds at a gas velocity of 5 Mach. This successful development is expected to lead to applications on rocket thrusters in the near future.

Following the commissioning of chemical vapor infiltration facility, a number of laminates of SiC fibre- SiC matrix composites have been prepared and characterized. The studies included investigation of the effect of different interface coatings like carbon and boron nitride of varying thickness. With this, the Division has established capability to fabricate ceramic matrix composites for various high temperature applications.

Commissioning of a BET surface area and micro pore analyser augmented the material characterization facility of the division. This is being used for characterization of nano powders, fibres and compacts.

The failure analysis group has been involved in a large number of failure investigations referred by organizations like Indian Air Force, Indian Navy, HAL, ADA, GTRE, etc. Apart from this, the group has made signifi-

Fig. 13. Zirconia based cermet convergent-divergent nozzle being tested.

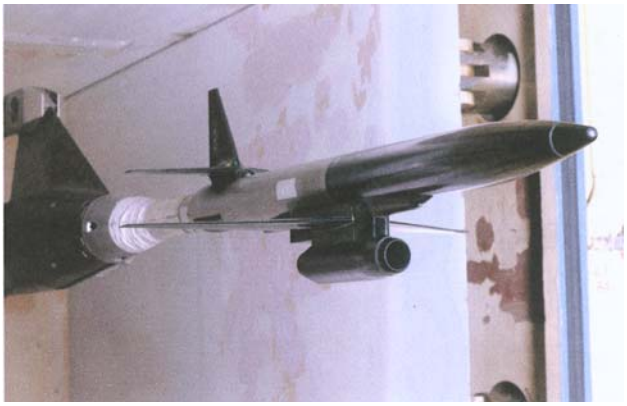


Fig. 14. Photograph of typical aircraft model.

Fig. 15. 2.5" In-house designed integral balances and components.

cant contributions to certification of materials and components and selection of materials for the in-house aircraft programs like HANSA and SARAS.

A major step towards commercialization of carbon fibre technology has been the signing of a technology transfer agreement with M/s. Kemrock Industries and Exports Limited, Baroda. Efforts are also being made to scale up the carbon fibre precursor technology using the plant and machinery at Reliance Industries Limited, Baroda.

The focus of *National Trisonic Aerodynamic Facilities* (NTAF) is to provide experimental aerodynamic data using the 1.2 m and 0.6 m trisonic wind tunnels to the national aerospace projects undertaken by the Departments of Space and Defence. A total of 59 projects involving model design, fabrication and wind tunnel testing were completed. A total of 1624 blowdowns were carried out in the 1.2 m wind tunnel for ADA, VSSC, DRDO and NAL. Tests were carried out on a typical aircraft model to study the effect of changing the location of horizontal tail *(Fig. 14)*. The Twin Roll model support system for the 1.2 m wind tunnel was made operational after performance evaluation and calibrations. Also an Integral balance for tunnel use was designed and fabricated *(Fig. 15)*.

The *Propulsion Division* is involved in applied research pertaining to turbomachinery, combustion and heat transfer, as well as in the design and development of propulsion and energy systems. The Division continues to give R&D support to national institutions like GTRE, DRDL, VSSC and LPSC besides taking up grant-in-aid projects from AR&DB. Collaborative programmes with Pratt & Whitney, USA and Canada are also being carried out. The 500kW wind turbine blade design is complete and fabrication started at FRPD. The internal flow system rig (transferred from Pratt & Whitney,USA) installation is nearing completion *(Fig. 16)*. The Kaveri engine afterburner ignition system designed by NAL worked well while testing at Russia. The national test facility for rolling element bearings was inaugurated by Shri M Natarajan, SA to RM in April 2007. This facility is established in accordance with the Joint Service Specifications prepared by CEMILAC. The National Test Facility for rolling element bearings will act as a nodal agency for testing of indigenously developed Synthetic Aviation Lubricants (SAL) using proven aerospace quality rolling element bearings under real life situations defined in terms of loads, speeds and temperatures as experienced in aircraft gas turbines and indigenously developed aerospace quality rolling element bearings using proven SAL. *(Fig. 17)*. A 55 HP Wankel engine was fabricated and tested. Micro gas turbine design is progressing well.

The *Structural Technologies Division* is primarily engaged in research and development programs in structural design, analysis, testing and certification of aerospace / mechanical structures. The specific areas of emphasis include aeroelastic modeling and testing of aerospace vehicles, development of numerical techniques like finite element method with smart material concepts, analysis & design optimisation of aerospace

Fig.16. Internal flow system rig for turbine rim seal studies.

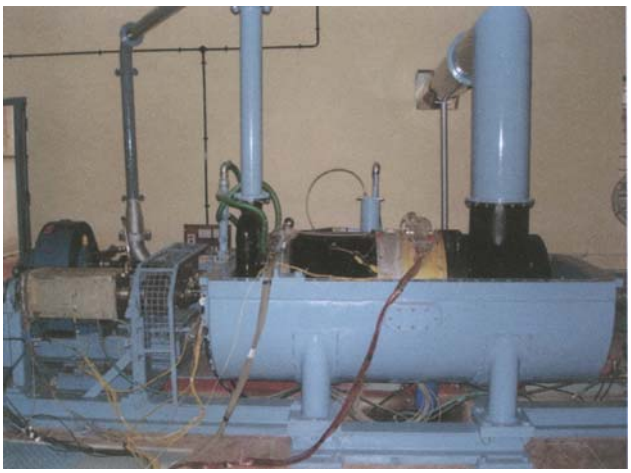


Fig. 17. Rolling element bearing test rig.

vehicles, impact and crashworthiness studies, evaluation of mechanical properties of aerospace materials, evaluation of airworthiness and flight safety including full scale fatigue tests (FSFT) and structural integrity assessment.

The year 2007-08 witnessed significant progress in SARAS aircraft design optimisation exercise, testing and certification of airframe structural materials/ components of SARAS, HANSA and LCA, development of smart structural concepts for active vibration control, and impact and crash studies, both analytical and experimental. Optimisation studies on fuselage and CFC wing of SARAS PSA were completed. The CFC wing study involved both strength and stiffness criteria by deploying the design optimizer. The Reusable Launch Vehicle (RLV) design analysis activity is taken up on proto model and analytical methods are used to establish flutter characteristics of launch vehicles in the subsonic and supersonic regime. Study of aeroelastic characteristics in subsonic regime indicated that RLV model is free from flutter. The detailed stress analysis of 2000m^3 aerostat has been successfully completed *(Fig. 18)*.

With regard to in-flight vibration and temperature measurement task on fighter aircraft, flight trials and data acquisition during flight tests covering critical profiles including gun fire sortie which has bearing on vibration and temperature levels have been successfully completed.

On the smart structure activities, development of a multi

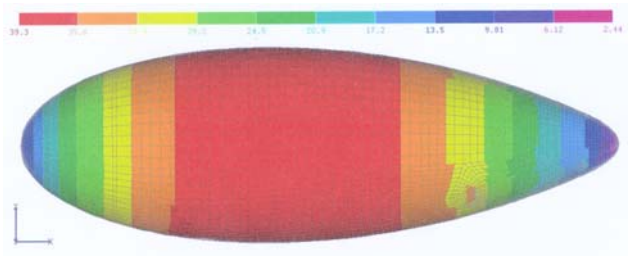


Fig. 18. Hoop stress distribution in the hull for an internal pressure loading.

channel active vibration control system using smart actuators for aerospace applications has been successfully completed. Considerable progress has been made in investigation of structural health monitoring concepts for aeroelastic instability and active vibration of aerospace structures. Transonic buffet response study of gsLVM3 through aeroelastic model testing was successfully completed.

In the area of impact and crashworthiness studies, bird strike tests and simulations of strike on the leading edge of the horizontal stabilizer of a transport aircraft were conducted. Both tests and simulations are found to be useful in establishing compliance with FAR requirements.

Static structural testing of SARAS PT2 wing under Design Ultimate Load (DUL) was successfully completed meeting the FAR 25 requirements. A static test rig was designed, fabricated and LCA elevon box was tested to DLL for one critical load case with satisfactory results.

New infrastructure and facilities developed include a low velocity impact test facility for impact and crash worthiness studies, a 10m high drop test facility to carry out full scale drop tests for aircraft components, installation and commissioning of three servo hydraulic test machines and an 8 channel fatigue test controller. A computer controlled vibration test system has also been commissioned. In addition, Bell Helicopters project was successfully completed.

The R&D activities of the *Surface Engineering Division* are reported in three major disciplines (a) Surface Modification for Aerospace Sector (b) Surface Modification for Energy Sector (c) Nano Scale Architecture.

Under Surface Modification for Aerospace Sector, several technology development programs were taken up. The development of sunshield mirrors for INSAT-3D has reached the final stage. As per ISAC requirement, filter wheel cooler panels for flight model were coated with uniform and defect free nano crystalline polishable nickel. The pressure sensitive paints developed not only

Integrated Facility for Carbon Fibre

Carbon fibre composite has become a material of preferred choice in most of the aerospace structures. In view of this, the development of indigenous technology for the manufacture of carbon fibres was perceived as an important and strategic need for the country with support from ADA, DRDO and ISRO. The process technologies for synthesis of polyacrylonitrile (PAN) copolymer, special acrylic fibres (SAF), post spinning treatment for SAF and conversion of SAF to carbon fibres were developed on a pilot plant scale.

Development of standard modulus carbon fibres for aerospace applications has been completed. This technology is transferred to M/s. Kemrock Industries and Exports Limited, Baroda for the commercial production of standard modulus carbon fibres (250 – 300 tons per annum).

NAL is striving hard to make carbon fibres available for both strategic applications as well as general engineering applications.

improved shelf life but also the adhesion characteristics.

In Surface Modification for Energy Sector, a simple and economical microwave assisted chemical method has been developed for the preparation of plasma grade yttria stabilized zirconia powder useful as electrolyte for applications in solid oxide fuel cells (SOFC). A novel solution combustion synthesis for the preparation of nano composite powders of CeO2 Al2O3 using a 'mixture of fuel' approach was developed. Several nano crystalline coatings based on Ni-P systems were developed with improved wear and corrosion characteristics.

The emphasis in the *Wind Energy Division* this year has continued to be on wind turbine development. The 500kW wind turbine blade fabrication is nearing completion. It is planned to install the wind turbine at Kethanur well before the end of the 2008 wind season. This New Millennium Indian Technology Leadership Initiative (NMITLI) project also involves assistance from the Structural Engineering Research Centre (SERC), Chennai as well as the Sangeeth Group of Companies, Coimbatore, who are the industrial partners. A mobile laboratory is setup to test wind turbine models upto 2 m in diameter *(Fig. 19).*

TECHNICAL AND ADMINISTRATIVE SERVICES

The Support Divisions and Groups and Administration, Finance & Accounts, Stores and Purchase, Security, Horticulture, Medical and other service sections have provided efficient support to ensure speedy implementation of various programmes and regular manage-

Fig. 19. Wind turbine with gurney flap and anemometer on the mobile lab.

ment and upkeep of the Laboratories and service requirements. A number of committees have also helped in the speedy implementation of the projects and programmes throughout the year. The new improved *Khoj* software has been working very well and has made on-line application and recruitment process simple and more efficient. Electronic valuation system enabled speedy tests resulting faster recruitments. The Laboratory received a grant of Rs.11250 lakhs from CSIR for the year which has been fully utilized.

The Computer Support and Services Division, Computer Network and Services Unit, Engineering Services Division, Electrical Sections, Estates and Buildings Unit, ISO9001/2000 Cell and Information Centre for Aerospace Science and Technology continued to provide excellent and timely support services in their respective areas to all the scientific and other divisions and to C-CADD so that the scientific and technical work of the Laboratories could progress smoothly. One five axis and one three axis CNC machines were added to the infrastructure enhancing the in-house machining capability considerably. The networking teams have worked round the clock to ensure safe and efficient network operation in spite of security threats and virus attacks. The legacy backbone net work in the Belur campus was totally replaced by OFC (Optic Fiber Cable) network and the bandwidth has been upgraded to 10 GBPS.

Recognizing the importance of bringing in synergy in their activities and efficient use of available human resources, the laboratory has taken certain initiatives including restructuring of some of the Divisions. The Structures Division and Structural Integrity Division have been merged to form the Structural Technology Division. The *Knowledge and Technology Management Division* (KTMD) formed in October 2006 has led to optimal utilization of available human resources and also efficient co-ordination of various activities. We had 3 license agreements and 12 MOU signed during the year. 8 Indian patents and 3 copyrights were granted, 5 Indian patents and 4 copyrights were filed. One US patent was granted to NAL for the "lightweight helicopter" in 2007. With this additional patent, NAL has a total of 13 foreign patents.

The activities of the *Health Centre* have been completely automated with the implementation of the *Arogya* software at both the Belur and Kodihalli campuses. NAL has received requests from CGHS and other CSIR laboratories for the improved AROGYA software.

OTHER EVENTS

The National Technology Day Lecture was delivered by Air Commodore Dr M Matheswaran VM, PhD, Commandant, ASTE, Bangalore on 11May 2007 *(Fig. 20).* He spoke on "Technology Dimension and National Power" which brought out clear linkages between technology and power of a nation. The Twenty-first NAL Foundation Day lecture was delivered by Air Chief Marshal F H Major, PVSM, AVSM, SC, VM, ADC, Chief of the Air Staff, Indian Air Force on 7 September 2007 *(Fig. 21).* Air Chief Marshal F H Major spoke on "Strategic Aerospace Power: Technological and Maintenance Challenges". Dr Sekhar Majumdar, Head, CTFD of NAL delivered the accompanying NAL Technology Lecture on "CFD Technology – The NAL Experience". Dr V K Aatre (Former Scientific Adviser to the Raksha Mantri) presided over the function.

Vice Admiral Raman Puri (Retd.) PVSM, AVSM, VSM, delivered the CSIR Foundation Day Lecture *(Fig. 22)* on "Strategy for Indigenous Capability Building in Aeronautics" on 26 September 2007. The accompanying NAL Business Lecture was delivered by Dr T G Ramesh,

Fig. 20. Air Commodore Dr M Matheswaran VM, PhD, Commandant, ASTE, Bangalore, delivering the National Technology Day Lecture on 11May 2007.

Fig. 21. Air Chief Marshal F H Major, PVSM, AVSM, SC, VM, ADC, Chief of the Air Staff, IAF, delivering the Twenty-first NAL Foundation Day Lecture on 7 September 2007.

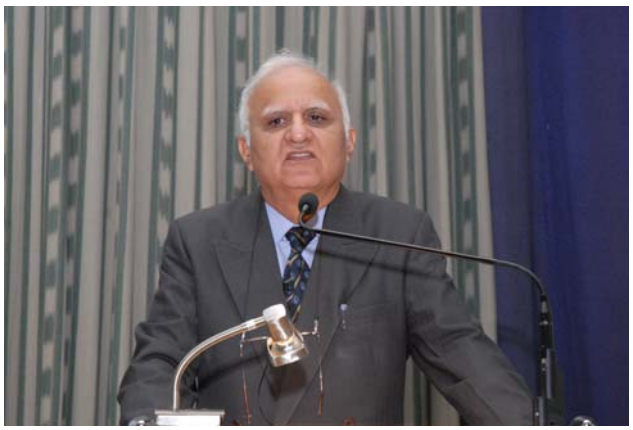


Fig. 22. Vice Admiral Raman Puri (Retd.) PVSM, AVSM, VSM, delivering the CSIR Foundation Day Lecture on 26 September 2007.

NAL who spoke on "Instrumentation and Materials Technology".

Dr Vijayalakshmi Ravindranath, Director, National Brain Research Centre, Gurgaon, Haryana, delivered a scintillating National Science Day lecture on "The Working of the Human Brain - Molecules and Networks to Behaviour" on 28 February 2008 *(Fig. 23)*.

International Women's Day was celebrated on 7 March 2008. Dr Vijayalakshmi Basavaraj, Director, All India Institute of Speech and Hearing, Manasagangothri, Mysore delivered the Women's Day Lecture on "Role of Women in Prevention and Control of Communication Disorders" *(Fig. 24)*.

The 117th Birthday Celebration of Bharath Ratna Dr B R Ambedkar was organized at NAL on 24 April 2008. The chief guest was Mr Shankar Bidari, IPS, Additional Director of Police (Law and Order), State Police Headquarters, Government of Karnataka delivered the year's

Fig. 24. Dr Vijayalakshmi Basavaraj, Director, All India Institute of Speech and Hearing, Manasagangothri, Mysore, delivering the Women's Day Lecture on 7 March 2008.

Fig. 23. Dr Vijayalakshmi Ravindranath, Director, National Brain Research Centre, Gurgaon, Haryana, delivering the National Science Day Lecture on 28 February 2008.

lecture on 'Legacy of Dr B R Ambedkar' *(Fig.25).*

The 108th semi-annual meeting of the Supersonic Tunnel Association International (STAI) was hosted by NAL. This was the first time since NAL became a member in 1978, that a STAI a meeting was held in India.

STATISTICAL SUMMARY

Sixteen new sponsored projects (total value: Rs 24.20 Cr) and 21 new grant-in-aid projects (Rs.14.12 Cr) were taken up during 2007-08.

The external cash flow this year was Rs. 28.87 Cr; as usual NAL is among the top ECF earners among the CSIR establishments. The major contributors to ECF were ADA (Rs 5.42 cr; 19%), ISRO/VSSC (Rs 6.14 Cr; 21%), DRDO (Rs 10.52 Cr; 36%) and HAL (Rs 3.94 Cr; 14%). About 3% of the cash flow in 2007-08 came from international sources *(Fig. 26).*

Fig. 25. Mr Shankar Bidari, IPS, Additional Director of Police (Law and Order), State Police Headquarters, Government of Karnataka, delivering the 117th Birthday Celebration of Bharath Ratna Dr B R Ambedkar on 24 April 2008.

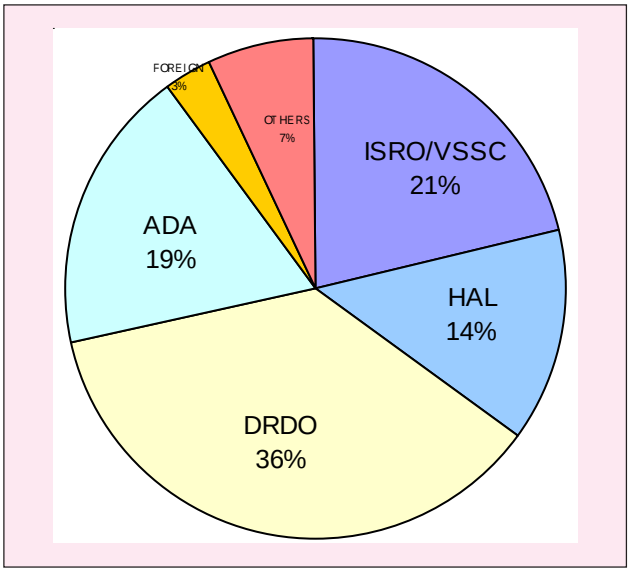


Fig. 26 Chart showing the break-up of NAL's 2007-08 external cash flow of Rs.28.87 Cr.

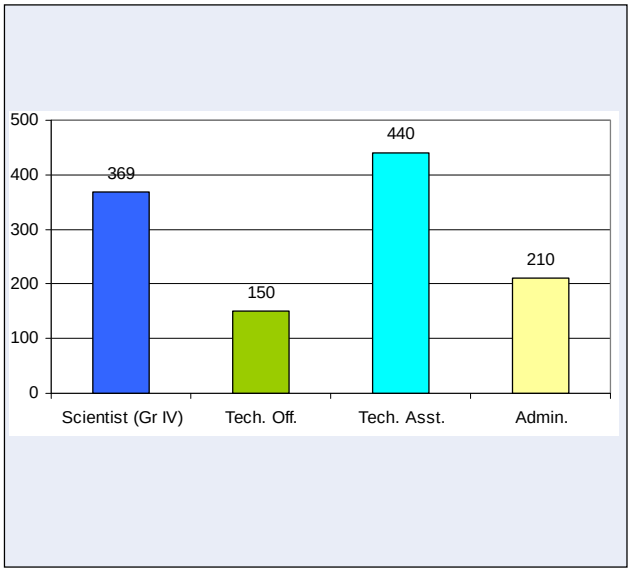


Fig. 27 The break-up of NAL's staff strength of 1169.

The CSIR's annual grant to NAL for 2007-08 was 65.06 Cr. Out of this, Rs.32.26 Cr. was spent on salaries and allowances. NAL received a further grant of Rs 42.35 Cr. during the year for CSIR's "networked projects" of the 10th FYP.

The NAL staff strength is currently 1169. This includes 369 scientists, 150 technical officers, 440 technical assistants and supporting personnel and 210 officers and staff from the administrative cadre *(Fig. 27).* The Laboratories is witnessing superannuation of a large number of senior scientists and staff with domain expertise which is likely to have an effect on the progress of some activities and programmes. However, a serious effort is being made to induct and train new, young scientists. Fifty six recruitments were made against 94 staff superannuating, retiring and resigning.

HONOURS AND AWARDS

It is finally a pleasure to mention the awards and laurels won by my colleagues during the year. 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. Special mention must be made of Mr Shyam Chetty who was awarded Fellowship of the prestigious National Academy of Engineering. Our senior colleague, Dr Gangan Pratap, Head, C-MMACS, has been appointed as the 11th Vice Chancellor of the prestigious Cochin University of Science and Technology (CUSAT). I also compliment the NAL sports teams (volley ball & cricket) for enthusiastically participating in the Zonals of the CSIR Outdoor Sports Tournament held at NBRI, Lucknow and reaching the finals being held at Jorhat. The volley ball team has won the finals of the tournament and two members, Mr R Varatharajan and Mr M Raghavendraswamy have won individual prizes. I congratulate the team and the individuals on their success. CSIR's Prof. M. S. Thacker Memorial Tennis Tournament was organised at NAL on 27-30 January 2008, many sister laboratories participated.

NAL participated in several exhibitions during the year. This included the prestigious International Astronautical Congress (IAC) and Space Conference held at Hyderabad where it received the Best Exhibitor Award in the category "Most Informative Display",

NAL's Rotary Type MAV, 'Ragrota' won a certificate of appreciation and a cash prize at MICAV2007 held at Agra during 21-26 October 2007, and NAL had the unique distinction of being chosen for Performance Audit by the Office of the Principal Director of Audit, Kolkata. The audit has been completed successfully and the recommendations of the PDA are being implemented.

Finally, I take this opportunity to thank our sister institutions, the DGCA and the ASTE,IAF for providing us extensive and valuable support in Certification and Flight testing activities, which have contributed to good progress of our civil aviation programmes. I am thankful to the Chairman and members of the Research Council of NAL for their advice and guidance. A special thanks to all expert members of our Management

Committee and Divisional Scientific Committees for their valuable inputs and suggestions. We thank our associates, ADES and NALTECH for the crucial man-power and project support they have provided us in many of our programmes. We are also grateful to DGAQA and CEMILAC for their help and support in our Defence related projects. We thank all the sponsoring institutions such as DRDO, ISRO, Defence Services and others including international bodies for continuing to repose their faith in us.

I also thank our former Acting DG, Dr T Ramasami, our new DG, Prof S K Brahmachari and the Officers and Staff at CSIR HQ for all the help, encouragement and support extended to NAL during the year which enabled the Laboratory to achieve its targets during the year.

Dr A R Upadhya
Director