1

REPORT OF THE DIRECTOR

It gives me great pleasure to present the annual report of the National Aerospace Laboratories for the year 2006-2007.

HIGHLIGHTS

This year has again been a satisfactory one for NAL and has given us great confidence to meet the challenges ahead as we enter the 11th Five Year Plan(FYP) period. The year witnessed good progress in all the projects and programmes and successful completion of a good number of them. We were also able to deliver some systems of utility to the sponsors and the user agencies.

The Civil Aircraft Programmes of the Laboratories are making good progress. The first prototype, PT1 of SARAS has completed more than 100 flights giving us valuable information on the performance of the aircraft and its systems. The second prototype, PT2 is getting ready for its first flight *(Figure 1)* with most of the system integration tasks on the aircraft having been completed and on-aircraft tests being in progress. Three HANSA aircrafts were delivered to DGCA and two more are in advanced stages of fabrication. A new 4/5 passenger General Aviation Aircraft programme has been launched as a apart of the 10th FYP network programme. Work on preliminary design of the aircraft commenced in October 2006 and the aircraft configuration, numerical master geometry and systems definition have been finalized. This programme is path breaking in nature as we are working for the first time, in equal partnership with a private company, M/s Mahindra Plexion Technologies Private Ltd., a unit of the reputed Mahindra & Mahindra industrial house. This represents the first major public-private partnership programme in aircraft design in NAL and perhaps even in the civil aviation sector in the country, and will help us in achieving faster results with optimised inputs. I also hope that it will herald the dawn of a new era of major private industry participation in the aircraft design and manufacturing sector in the country.

⇩ *Fig. 1 SARAS PT2 - the second prototype of the 14 seater light transport aircraft.*

I am also happy to state that, as a logical extension of its aeronautical technology development and civil aircraft development activities, NAL has, under the 11th FYP programmes, proposed to take up development of a nominal 70-passenger Regional Transport Aircraft with advanced technology features, fuel efficient engines and lower acquisition and maintenance costs. Of course, such an effort needs to have active participation of

both government and private sectors for its success, and we hope to garner such a support for the programme.

Major achievements during the year under sponsored R&D programmes in the Laboratories are summarized in the following paragraphs:

As a part of a major national initiative towards the development of synthetic aviation lubricants and aerospace quality bearings, NAL has established a National Test Facility for Rolling Element Bearings.

Studies on modeling air traffic around airports and air traffic management of the proposed new Bangalore International Airport were conducted.

NAL's contributions to the Tejas programme of DRDO/ADA continue to be significant. The flight control law developed under NAL's leadership has been used by Tejas in all its flights so far. The results from the flight tests are being used to fine tune the control law as well as expand the flight test envelope for IOC configurations. Further, NAL continued to supply major composite structural components to the Tejas programme - both for prototype and Limited Series Production aircrafts. Transfer of related fabrication technology to HAL is also underway in keeping with our commitments. In both these areas (control law and composites) work needed for the naval and the trainer versions of Tejas have been initiated. Considerable testing support has also been given to the Tejas programme through high speed wind tunnel testing including PSP measurements for the first time on a Tejas model, material and structural testing for certification purposes etc. Active noise control studies by the NAL team are aimed at the possibility of incorporating novel design features leading to significant noise reduction in the cockpit for enhanced pilot comfort. Extensive wind tunnel testing support has also been given to various programmes of DRDO involving development of UAVs, missiles, armaments and other weapon systems.

NAL has also contributed significantly to the Indian Space programmes. Acoustic tests were conducted on flight models of INSAT 4C, CARTOSAT 2 and SRE and the structural model of the CARTOSAT 2. Acoustic calibrators designed and developed by NAL have been very useful to the space programme and are in use in ISRO centers at LPSC, SHAR and VSSC. New advanced sun shield mirrors developed by NAL for passive cooling of IR sensors have passed the qualification tests at ISAC. These represent a step increase in our technology capabilities as the surface smoothness of the mirrors is of the order of 2 nano meters compared to current technology of 5 nm. Major inputs to the reusable launch vehicle technology development programme of ISRO have been aerodynamic analysis of the vehicle through CFD and aero-thermo-structural analysis of the vehicle structure using FEM which has made considerable progress.

Another milestone contribution from NAL is the successful demonstration of supersonic combustion technology and establishment of high speed(dual mode ramjet/scramjet) combustor test facilities which will support both the air-breathing propulsion programme of ISRO and the hypersonic technology demonstrator vehicle programme of DRDO. This critical technology which was not available to India, has now been successfully demonstrated by NAL. This puts the nation in the league of a very select group of countries of the world possessing this strategically important technology.

NAL continues to support the defence services, particularly IAF, directly or indirectly(through HAL) in areas such as failure analysis/accident investigation, critical airframe repairs, full scale fatigue testing, flight worthy/ground based structures and systems etc. A major contribution of NAL(along with HAL and CEMILAC) to IAF has been the completion of MiG 21 Total Technical Life Extension Programme which has resulted in recommendations for extension of life of the MiG21 fleet. NAL's project on life extension of MiG 29 aircraft has also made progress on several fronts such as material testing and characterization, aerodynamic model and load generation, fatigue load spectrum generation etc. This project when completed is expected to add substantial life to the fighter aircraft fleet of IAF. Valuable contributions have also been made by NAL teams in extending the life of IAF's helicopters. The nose radome for the Jaguar aircraft designed and developed by the NAL team has been certified flightworthy by the authorities thus successfully indigenising a vital aircraft system. NAL has also designed, fabricated and installed two rigid FRP domes for the air combat simulators at one of the IAF bases.

A major technology achievement of far reaching significance has been in the area of tropical weather modelling and prediction. NAL's software VARSHA1.0 on the 128 node parallel computer system , also indigenously developed in the Laboratories, was a major success as it met all the NMITLI objectives and excelled in a few aspects such as one month in advance monsoon prediction apart from prediction of extreme events. The software has been extensively tested with 20 year meteorological data and has shown to be capable of predicting both lean and excess monsoon periods.

During the year, NAL's aerospace technology development efforts, mainly under the three 10th FYP network programmes on advanced

NMITLI mesoscale modelling programme

The NMITLI (New Millennium Indian Technology Leadership Initiative) project on "Mesoscale modelling for monsoon related predictions", involved the development of an integrated hardware software system for meteorological computing. NAL successfully built the 128 processor parallel computing system (with the NAL FloSwitch and NAL FloOptiLink communication devices) and developed the Varsha spectral GCM with new boundary layer and radiation modules appropriate for the tropics. The system performed very well for the specified test cases. In addition, routine five-day forecasts are being performed using the NMITLI system. Also innovative approaches like 30 day deterministic forecasts of All India Rainfall during the monsoon months are being performed and the results have been very encouraging. For conducting research on various aspects of atmospheric flows, an eight processor Flosolver along with Varsha GCM will be supplied to ten academic centres by a private industrial partner.

The second phase of the project was approved by the NMITLI high powered committee (with support from the Ministry of Earth Sciences also) and the project started from April 2007. The major objectives of this phase are the building of a ten teraflop parallel system and an improved version of the Varsha GCM (of higher resolution and with multi-precision capability).

materials, high science and technology(HST) and civil aviation, and also under NMITLI and a few grant-in aid /sponsored projects made major strides and achieved many successes. Some notable ones are :

- Development of gas turbine afterburner (stabilized ignition/ flame holder) technologies
- Improved composites process technologies, in particular, vacuum enhanced resin infusion technology (VERITy) for faster, cost effective fabrication of airframe components
- MATLAB/GUI based software validation tools for application to decision fusion
- Blade design technology for wind turbines specifically suited for Indian conditions
- A cost effective semi industrial magnetron sputtering system
- Magnetic bearings for application in nuclear power plants
- Development of avionics for civil aircraft and many more technology inputs to our own civil aviation programme
- Ceramic material processing techniques

All the programmes were periodically reviewed by expert Steering and Monitoring Committees.

Further, NAL's specialised facilities have provided vital design and testing inputs for all the aerospace programmes of the country as well as our own R&D programmes.

Major facilities completed during the year are:

- National test facility for rolling element bearings
- Large scale rotating rig (LSRR)erected and commissioned in association with Pratt & Whitney Aircraft Corporation, USA for gas turbine developmental testing
- Full scale afterburner test facility
- Test and Simulation facility for impact and crash studies
- Facility for fabrication of ceramic components through CVI process
- Facility for preparing peizo ceramic stacks for actuator/sensor applications
- Facility for aero-acoustic studies
- Distributed PC based Engineer-in- Loop Simulator (DELS)
- 5-axis CNC Machine for advanced manufacturing

An additional model cart for the 1.2m wind tunnel developed under the NTAF augmentation programme was commissioned during the year. Other augmented facilities of the tunnel are undergoing evaluation trials and should be available for regular use in the near future. The VMFN (Variable Mach Flexible Nozzle) designed for adding supersonic testing capability to the 0.6m wind tunnel(project undertaken by L&T) is in advanced stages of fabrication and its commissioning is expected to be completed in 2007.

The IFCAP facility has made signifi-

cant progress during the year with modifications to the plant to facilitate (i) operations in a continuous mode and (ii) improved precursor fibres. With this, the facility is ready to start type certification exercise for its fibres and prepregs.

The updated Drishti system developed by NAL for assessing the visual range at airports has been installed in Goa and Kochi Naval bases and a few other airports in the country. This effort of successful upgrading of the earlier system and demonstration of its field performance has been received well by the users.

Mention needs to be made of the smart materials activity involving development of peizo ceramics and polymers, shape memory alloys and their modeling and applications as sensors and actuators. Significant progress has been achieved in the area of structural health monitoring using fibre optic sensors, and applications to problems of practical flight are under active consideration.

This work in the laboratory has attracted wide attention and is proposed to be used by the Tejas programme for its composite airframe. Success in this area will definitely give an added boost to the programme of composites structural usage in flight vehicles.

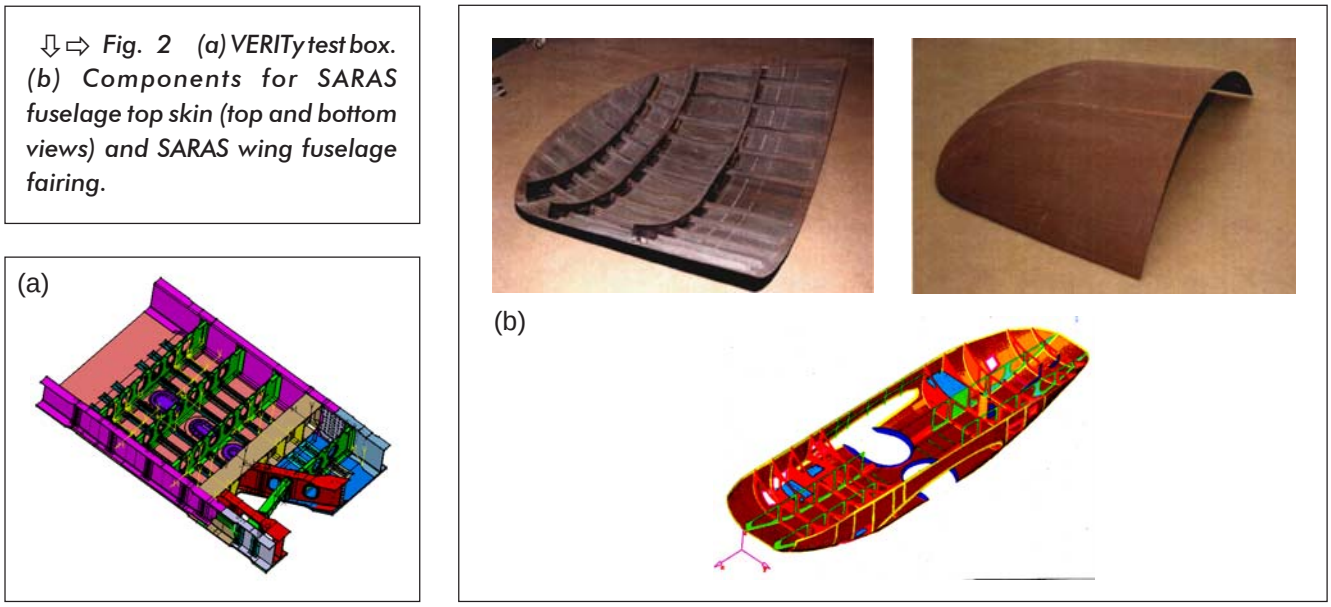
Other R&D successes during the year include:

- Optimisation of 3D wing shapes in transonic flow through CFD
- Performance analysis of GURNEY flap for wind turbines
- Trials of a novel ignition system based on a flame ball concept for gas turbine engines.
- Improvements to flow diagnostic techniques using pressure sensitive paint(PSP), particle image velocimetry(PIV) and background oriented Schlieren(BOS) systems
- Development of a novel ceramic barrier lining material and process for rocket thrusters
- Development of materials for thermo-electric generators with a factor of merit comparable to the best in the world.
- Improvements in ceramic robo casting process.

IN THE DIVISIONS

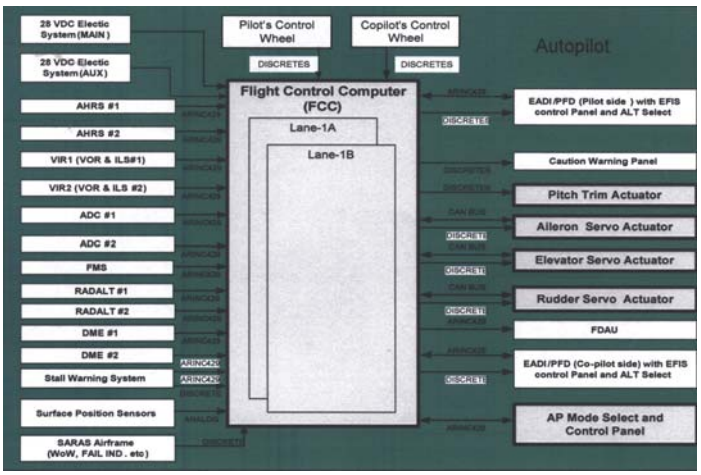
The *Advanced Composites Division (ACD)* has the main responsibility to develop technologies and facilities required for the design and fabrication of superior aerospace structures using advanced composites. ACD has initiated several hardware design and development projects for NAL's SARAS and DRDO/ADA's Tejas (LCA) aircrafts including development of a weight optimized composite wing for SARAS using a new, cost effective fabrication technology called VERITy *(Figure 2a)*. In addition, the division is also concentrating on the smart structures area to develop technologies such as structural health monitoring, shape control, energy absorbing systems etc., appropriate to aerospace applications. The major R&D and other activities undertaken by ACD were mainly related to (a) Tejas projects (b) SARAS programme *(Figure 2b)* (c) ACECOST activities under AR&DB funding (d) HST programme & SMA related activities and (e) other activities of national relevance.

The *Aerospace Electronics and Systems Engineering Division* has five major groups covering different projects and spanning several important areas. The Civil Aircraft Avionics and Electrical Systems Group initiated two major and challenging projects 'Engine Instruments and Crew Alerting System' and 'Development of a Digital Autopilot System' *(Figure 3)* for civil aircraft under the 10th FYP network programmes. A project to develop a 3-axis digital



⇩⇨ *Fig. 2 (a) VERITy test box. (b) Components for SARAS fuselage top skin (top and bottom views) and SARAS wing fuselage fairing.*

autopilot system with automatic elevator trim facility is underway for the civil aircraft being developed at NAL. The Group has also undertaken the development of a stall warning system for SARAS and a smart fatigue meter for civil/military aircraft. The Aircraft Safety Monitoring and Management Group has continued upgrading and demonstration of the in-house developed software for Flight Operations and Quality Assurance (FOQA) and its release to various airline operators in the country. The software is being used and tested for data from different aircraft by Indian Airlines, Air India and Alliance Air. The Active Noise Control (ANC) Group is establishing a design framework for the development of an active control system which can be applied to any complex acoustic system. In the area of Radar Signal Processing the Group's emphasis was on detection and imaging, as well as development of tools and techniques for signal acquisition and interference reduction necessary to perform these tasks. Towards this, modern techniques of spectral estimation methods have been pursued and developed. The Electromagnetics Group was actively engaged in various projects sponsored by national agencies and also in related in-house projects. The areas of research interest were active RCS reduction, low observable technology (LOT), concurrent optimization of RCS and IR signatures, phased array antennas, radomes, EM material characterization, and MW measurements. The Calibration Standards and Maintenance Group was involved in the preparation, calibration, testing and documentation of SARAS related instruments primarily for measurement of pressure and temperature, and avionics equipments.

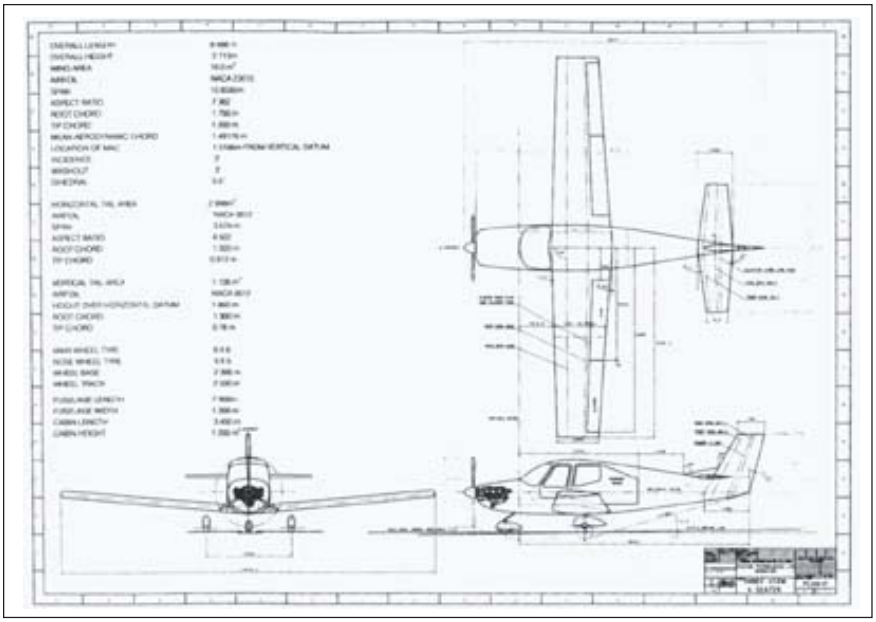


⇧ *Fig. 3 Digital autopilot architecture for typical civil transport aircraft.*

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 subsystems, launch vehicle interstages and their subsystems. Two major satellites *(Figure 4),* their subsystems and a launch vehicle subsystem were qualified during the year. Certification activity of petrol and diesel generators manufactured by different companies were continued as per Central Pollution

⇩ *Fig. 4 CARTOSAT-2 (SM) (flight hardware) in NAL's Acoustic Test Facility.*

⇩ *Fig. 5 Three view drawing of NM5 aircraft.*



Control Board (CPCB) guidelines.

It has been an eventful year for *Centre for Civil Aircraft Design and Development* (C-CADD) with SARAS prototype PT2 getting ready for its first flight and the 10th FYP networked projects and the 5 seater general aviation aircraft making good progress. NAL signed an MoU with M/s. Mahindra Plexion Pvt Ltd (MP) to jointly develop the 5 seater general aviation aircraft, NM5 *(Figure 5)* and to undertake its production and marketing. SARAS PT2 aircraft integration activities were completed with all the aircraft level ground tests carried out successfully. The Flight Readiness Review Board (FRRB) met twice to review the readiness of the aircraft for its first flight. HANSA-3 and SARAS PT1 aircraft took part in the Aero India 2007 air show and put up impressive flight displays. In fact SARAS PT1 aircraft completed its 100th flight during the air show. Another milestone in C-CADD's activities during the year was the participation of HANSA-3 in the Avalon International Air Show at Melbourne in Australia. It was the first instance ever of an NAL aircraft taking part in flying and static displays outside the country. HANSA-3 made a very good impression at the airshow.

HANSA at Australian Air Show

NAL's all composite 2-seater trainer HANSA aircraft (VT-HOD) took active part and successfully flew at the Australian International Air Show: 2007 at Avalon near Melbourne. The Air Show was held between 20 – 25 March 2007 and HANSA flew on all trade days exhibiting its skills in front of a global audience at the Avalon airport. This is the first time that the HANSA participated in an international air show outside the country.

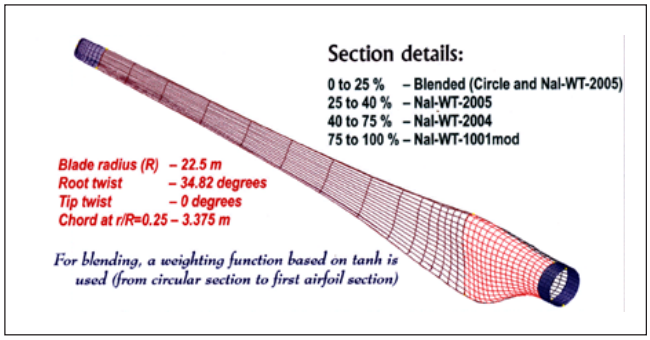
NAL's participation in the air show gave an opportunity to the concerned authorities and operators in Australia to see the aircraft and its flight performance. It also gave an opportunity to the concerned industries / customers to interact on possible manufacture and marketing of HANSA in Australia. This opportunity was also utilised for a detailed discussion with CASA (Civil Aviation Safety Authority of Australia) on the steps towards possible certification of HANSA in Australia. An approach in this direction with a time plan of 6 months has been agreed to by both sides and action has been initiated.

The participation of NAL at the Australian Air Show by conducting the HANSA-3 flight display has given a good exposure to NAL's capabilities in the area of design and development of small civil aircraft.

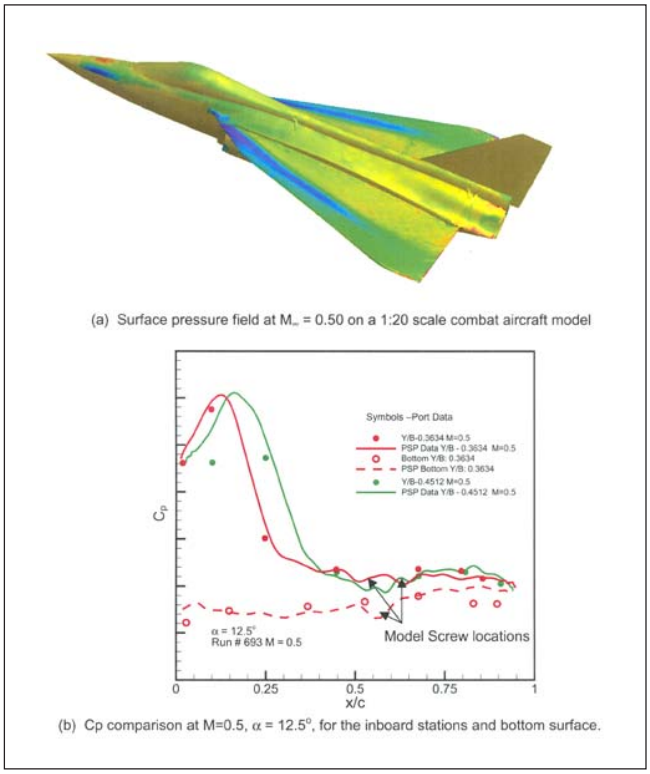
The HANSA aircraft performed very well and was appreciated by all.

The major focus of R&D activities of the *Computational and Theoretical Fluid Dynamics Division* was on efficient and accurate simulation of unsteady turbulent separated flow for various problems of engineering interest. Some of the R&D areas which received special attention this year are efficient and cost-effective algorithm for aerodynamic shape optimisation, novel grid-free solution methods for unsteady flow, unstructured grid-based flow solvers, time-accurate RANS solvers for unsteady flow, panel codes for quasi-steady analysis of flow with rotation, accurate interpolation/approximation schemes for handling complex surface geometry, advanced turbulence models for unsteady separated flow and the dynamics of liquid sloshing phenomenon in oscillating containers. The capabilities of CFD tools like panel codes and the RANS code IMPRANS for three dimensional unsteady flows have been demonstrated with great success in the design and analysis of a 500 kW wind turbine, taken up under the NMITLI project of CSIR *(Figure 6)*. Under a project sponsored by Vikram Sarabhai Space Center (VSSC), Trivandrum, very useful aerodynamic data has been generated using the NAL panel code, for the reusable launch vehicle technology demonstrator (RLV-TD). A book entitled "Eigenfunction Expansions for the Linearized Navier-Stokes Equations" authored by Emeritus Scientist Dr. P N Shankar, has been completed under an EMR project of the Division.

Research and Development activities in the *Experimental Aerodynamics Division* are carried out in three major disciplines, viz., flow structure and management, flow diagnostics and aircraft and spacecraft aerodynamics. Work has been initiated in the areas of jet acoustics and low Reynolds number flows. Other significant studies include pressure field measurements on an aircraft model in the



⇧ *Fig. 6 Blade shape of 500 kW wind turbine with blended root section and rounded tip section.*



⇨ *Fig. 7 PSP measurements on a 1:20 scale combat aircraft model at M_∞ = 0.5, AoA= 12.5°.*

1.2m tunnel using pressure sensitive paint (PSP) *(Figure 7)*, aerospike nozzle flows and drag reduction studies on a launch vehicle geometry.

The *Flight Mechanics and Control Division* is engaged in R&D and Technology pursuits in the areas of modelling and parameter estimation, flight simulation, flight control, multi-sensor data fusion, and air traffic management and simulation. The flight test programme of DRDO/ADA's TEJAS aircraft, for which NAL is leading the flight control law development activity, has been progressing well and a total of 127 flights were successfully carried out by NFTC, ADA on five prototypes of the aircraft during the year. The fly-by-wire control laws and air data algorithms were also redesigned/ updated to match the aerodynamic configuration of the Airforce two-seater variant. The distributed PC based ELS (DELS) system was released for evaluation with the installation of actual pilot controls *(Figure 8)*. The simulator is also being enhanced to facilitate naval control law development. The software package HQPACK was enhanced for analytical evaluation of handling qualities of large transport aircraft as per the MIL-STD-1797A requirements.

The *Flosolver Unit* conducted a rigorous assessment of the effectiveness of the Varsha code for tropical monsoon forecasts. The Varsha code and the associated hardware platform *(Figure 9)* had held out the promise of being useful in monsoon forecasting by stating that it had incorporated many new features, not available anywhere else. Successful development of the integrated system resulted in the idea of supplying an eight-processor machine along with

⇩ *Fig. 8 Distributed PC based ELS facility at NAL.*

⇩ *Fig. 9 128 processor Flosolver Mk6 running VASHA 1.0.*

⇩ *Fig. 10 CEMILAC qualified–flight worthy NAL radomes for Jaguar maritime aircraft.*

the new software to various meteorological centers, to popularize atmospheric models on parallel machines and also to test and validate the software over longer periods. Encore Software Limited, one of the industrial partners of this NMITLI project, has agreed to replicate the systems and install them at the identified centers. A Pentium based Floswitch was designed, developed, tested and incorporated in the Xeon based system. One such system was displayed in the Aero India 2007 at Bangalore. Successful completion of this NMITLI project by the Unit was commended by the Monitoring Committee, and has resulted in the submission of a fresh proposal for the development of a 10 Tflop computing system with upgraded VARSHA software capable of handling a grid size of 20 kms.

The *Fibre Reinforced Plastics Division (FRPD)* has been sphere heading the indigenous development of cost effective composite technologies and products for the aerospace and non-aerospace sectors alike. Considerable spin off benefits have been reaching the societal sector as well. A notable challenge undertaken by the Division is the development of metallised-CFRP reflectors and feed components for the SATCOM program, sponsored by SAC-ISRO, Ahmedabad, thus signifying its contributions to space applications. The Division is also taking up further fabrication of its DWR Mark II radomes for BEL, Gaziabad with eventual ToT to the industry. An ambitious proposal has also been made jointly with HAL, Nashik for indigenous development of nose radomes for the SU-30MKI aircrafts being manufactured by HAL for the IAF.

Other achievements and current activities of the Division include

- Composite nose radomes for the Jaguar maritime aircraft for HAL/ IAF *(Figure 10).*
- Domes for Air Combat Simulator (ACS) for ARDC-HAL / IAF
- 22m long GFRP composite blades for 500 kW wind turbines
- 11m long GFRP composite blades with improved aerodynamics for 300 kW wind turbines
- 2.88m dia MARK-II prototype version radome for the doppler weather radar (ISRAD- ISRO)
- Support services to the Hansa-3 productionisation efforts of NAL
- COMPAC industrial test services (US-AID funded)

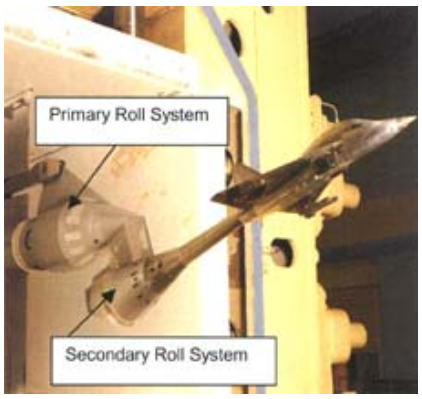
The *Materials Science Division* is involved in R&D related to science and technology of aerospace materials, failure analysis and accident investigation, and airport instrumentation. The programme on Integrated Facility for Carbon Fibres and Prepregs (IFCAP) has made significant progress during the last year. The Polymerization reactor has been modified for continuous operation and process conditions have been optimized to produce ~ 30 kg. of polymer per hour. Rapid strides have also been made in the development of high modulus carbon fibres for space applications. The Airport Instrumentation Group has been vigorously pursuing the development of a state-of-art transmissometer 'Drishti' for visibility measurement in conformity with ICAO and WMO recommendations *(Figure 11).* This system provides information on runway visibility conditions, especially during fog, rain, snow or sand storms, to pilot and air traffic services units (ATS) using a web enabled data acquisition software in LabView environment. The Metallurgical Sciences Group of the Division

⇧ *Fig. 11 Drishti at INS HANSA (Goa).*

Airport Instrumentation: Automatic Visual Range Assessor (AVRA)

NAL has recently developed a state – of – the art transmissometer DRISHTI. Drishti is a runway visual range assessor, which meets ICAO and WMO specifications for visibility measurement. This instrument provides information on runway visibility conditions especially during fog, rain, snow or sand storm to pilot and air traffic services unit (ATS).

DRISHTI is based on field programmable gate array (FPGA) embedded electronic hardware with web enabled data acquisition software in LabView environment. The system facilitates automated measurement of two types of visibility measurement parameters viz., meteorological visibility range (MOR) defined by the maximum distance at which non-luminous objects can be barely perceived (0-10km) and RVR (Runway Visual Range) defined by maximum distance at which a luminous object like a runway lamp can be barely perceived (0-3km). This system has been successfully installed at INS Hansa (Goa), INS Garuda (Cochin), Cochin International Airport Ltd and Lucknow Airport.



⇧ *Fig. 12 Typical aircraft model mounted on TRMS.*

⇧ *Fig. 13 Large scale rotating rig (from P&W, USA) at NAL.*

⇧ *Fig. 14 Multi-channel AVC system demonstration.*

has been actively involved in the niche area of failure analysis of engineering components, development of shape memory alloy (SMA) wires for actuator applications and studies on diffusion boundary of titanium alloys and aluminides. It is worth mentioning here that a thorough investigation by the Group on the failure of a main rotor blade of a helicopter revealed that pitting corrosion was responsible for fatigue crack initiation. The area of intelligent / smart materials is being pursued by several groups in the Division. The field of structural / functional ceramics is a thrust area of R&D in the Division. The group working in the broad area of combustion synthesis has recently developed a novel process for providing in-situ thermal barrier lining to axi-symmetric metal components using thermit reactions carried out under the influence of a centrifugal force.

National Trisonic Aerodynamic Facilities (NTAF) during the year 2006-2007 actively followed up on the design and fabrication of components of the Variable Mach number Flexible Nozzle (VMFN) by M/s Larsen Toubro PVt Ltd and in-house civil works for installation of VMFN in the 0.6 m wind tunnel to extend its capability to supersonic testing. Exploratory tests on scaled models of slender body and aircraft configurations using the new TRMS in 1.2m trisonic tunnel *(Figure 12)* were carried out to evaluate the system capability. On the main activities front, generation of aerodynamic data in 0.6 m and 1.2 m tunnels was the main focus of the Division. A total of 1287 blowdowns in the 1.2m tunnel and 668 blowdowns in the 0.6m tunnel were performed on various models for sponsoring agencies like ADA, DRDO, VSSC etc. and for NAL's in-house programmes.

The *Propulsion Division* had several major achievements to its credit during the year. The installation and running of a large-scale turbo-machinery rig *(Figure 13)* that has been transferred by Pratt & Whitney, USA to NAL was successfully completed. It was formally inaugurated on 19 October 2006 by Mr Prahlada, CC R&D (SI), DRDO in the presence of Mr. Paul Adams, Senior Vice President, Pratt & Whitney, USA and is now ready for taking up R&D projects on compressors and turbines. The National Test Facility for rolling element bearings with the dual purpose of testing indigenously developed synthetic aviation lubricants and aerospace quality bearings has been completed and will be formally inaugurated shortly. A Pilot Ignition System, which employs a 'flame ball' concept, has been successfully tested on the Kaveri afterburner up to a simulated altitude of 9 km at CIAM, Russia. The large-scale high-speed combustor test facility for testing full-scale ramjet, dual-mode ramjet and scramjet combustors has been completed and awaits safety clearance, before formal commissioning. The design and fabrication of a 55 hp liquid-cooled Wankel engine for a UAV application has been completed and the engine is undergoing trials, fitted with a propeller, on the ADE test bed.

The year was an eventful one for the *Structural Integrity Division* with the successful completion of the life extension programme of MiG-21 airframe resulting in recommendations for significant life extension of the fleet. Other major projects in progress during the year include total technical life extension (TTLE) programme for the MiG-29 fleet and SARAS wing and fuselage certification testing. Analytical capabilities in predicting structural response of airframe components have been fine tuned leading to excellent correlation with static test strain and deflection response. A methodology for the fatigue and damage tolerance qualification of transport aircraft airframes which leads to the demonstration of continued airworthiness of the fleet throughout its service life has also been developed.

During the year 2006-07, the *Structures Division* witnessed significant progress both in R&D and contribution to SARAS development programme. The successful comple-

⇧ *Fig. 15 Nano-structured TiN coated HSS drill-bits.*

tion of design, fabrication and wind tunnel testing of a 1:42 aeroelastic model of gsLVM3 in the transonic region for buffet response and 1:10 SARAS T-tail model for flutter clearance are noticeable achievements of the Division. In the research activities related to the smart structures, a multi channel active vibration control system (MAVCS) was developed and demonstrated on ground on a full scale fin tip of Tejas *(Figure 14)* available in the Deparment of Aerospace Engineering at IISc, Bangalore. The overall output of the division in the design, development, analysis, testing and research relevant to aerospace structures is reflected through the numerous papers published/ presented in national and international journals and conferences.

At the *Surface Engineering Division* the work on the development of new, improved sunshield mirrors for INSAT-3D satellites has made considerable progress. Under standardized conditions diamond turned imager/ sounder cooler panels were given uniform and defect free nano crystalline nickel coating and given to ISAC, ISRO. The work on pressure sensitive paints for wind tunnel applications has reached the stage of qualification and acceptance through wind tunnel tests on models in the Experimental Aerodynamics Division. The development of Ni+SiC composite coating on a complex contour with uniform distribution of SiC was a challenging task which the Division completed successfully. Work in the area of tubular solid oxide fuel cells (SOFC) in association with the Materials Science Division has made significant progress and many of the initial engineering problems have been overcome. Solar thermal application is another area that is gaining popularity all over the world. In the division , the solar absorbers/collectors have been coated with solar selective coatings(with an absorptance of 0.91 and an emittance of 0.06)to maximize the use of solar energy. In the area of nanolayered multilayer coatings of transition metal nitrides promising superhard coatings, CrN/CrAlN multilayer coatings were developed wherein the properties of CrN and CrAlN could be combined *(Figure 15)*. Nanolayered CrN/CrAlN multilayer coatings with a total thickness of approximately 1 mm were deposited on silicon substrates at different modulation wavelengths (L). They offer several advantages such as better adhesion, higher toughness, higher thermal and chemical stability

The major activity of *Wind Energy Division* was design of the NMITLI 500 kW, 2-bladed, downwind, stall-regulated, horizontal-axis wind turbine, which has a tilt-tower. Fabrication of the blades and procurement of major components have been initiated. As part of the NMITLI programme, a Wind Turbine Laboratory and a Wind Turbine Blade Fabrication Facility have been com-

Maiden flight of SARAS PT2

The second prototype PT2 of the 14-seater multi-role light transport aircraft SARAS had its successful maiden flight.

Several improvements have been made in SARAS design from PT1 to PT2. The most important one among these is the incorporation of two higher power engines PT 6A-67A of 1200 hp each in PT2 in place of PT6A-66 of 850 hp each used in PT1 and new propellers of larger diameter. The higher power engines will also improve other performance characteristics of SARAS. The supporting stubwing structure and the engine nacelle were also modified to suit the new engine. Improvements have also been incorporated in flight control system layout, flap operating system, avionics and electrical system layout etc., taking into account the inputs received from the flight crew and maintenance staff. All these improvements have brought PT2 much closer to the final production standard aircraft.

With the present boom in civil aviation and the recognized need for air-networking different parts of the country including smaller towns, SARAS will have a distinct role to play in establishing air connectivity, bringing people together and in the overall economic development of the country.

pleted and formally inaugurated on 3rd February 2007 in the Wind Energy Division and the Fibre Reinforced Plastics Division respectively by Prof V S Ramamurthy , Former Secretary, DST and presently Chairman, RAB, CSIR. Further, the 300 kW wind turbine blades fabricated by NAL which have been mounted on an available wind turbine platform at Kethanur, Coimbatore District, showed good blade performance.

TECHNICAL AND ADMINISTRATIVE SERVICES

The technical services divisions/sections/units, namely, Computer Support and Services Division (CSSD), Computer Network and Services Unit (CNSU), Engineering Services Division (ESD), Electrical Sections (EL(K)& EL(B)), Estates and Buildings Unit (EBU), ISO9001/2000 Cell and Information Centre for Aerospace Science and Technology (ICAST) 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. Special mention must be made of notable activities such as completion of Wind Turbine Laboratory and Wind Turbine Blade Fabrication Facility and a 2/3 bedroom housing for staff, computer network augmentation with 10 Mbps link, telephone facility modernization, erection of new buildings and test facilities (high speed combustor, LSRR, bearing test facility etc), introduction of web based library information services and electronic resources etc. The recently set up Institutional Repository of NAL by ICAST already has more than 2500 different types of full text documents in its repository. Special efforts were made by the ISO 9001-2000 cell to ensure that the re-certification exercise goes on smoothly. I am happy to state that the Laboratories have been granted re-certification to BS EN ISO 9001:2000 by the external certifying agency Lloyd's Register Quality Assurance (LRQA). The CNSU not only improved the fibre optic links between the campuses but also has planned strengthening the NWTC network. CNSU also coordinates the CSIR-ICT programme at NAL.

The Project Monitoring and Evaluation, Technical Services and Information Management Divisions were merged to form the Knowledge and Technology Management Division (KTMD) in October 2006. This is expected to lead to optimal utilization of available human resources and also efficient coordination of various activities such as project management, public relations, information management, business development, technology transfer, IPR issues etc. KTMD took constructive steps in the areas of technology marketing and business development, and as a result, 3 license agreements and 9 MOUs were signed. During the period, 5 Indian patents were granted, 1 Indian patent and 3 copyrights were filed.

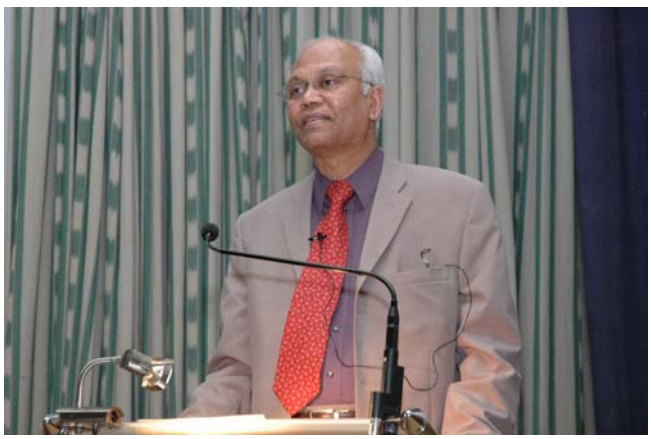
The Administration, Finance & Accounts, Stores and Purchase and other service sections also provided efficient support to ensure speedy implementation of the various programmes and regular management and upkeep of the Laboratories.

OTHER EVENTS

The National Technology Day Lecture was delivered by Dr B G Prakash, Director, India Science Laboratory and Chief Scientist - R&D India, General Motors Technical Centre - India on 11May 2006 *(Figure 16).* He spoke on "Managing innovation at General Motors" which was an eye opener for those

⇩ *Fig. 16 Dr B G Prakash, Director, India Science Laboratory and Chief Scientist - R&D, India, General Motors Technical Centre - India delivering the National Technology day lecture on 11 May 2006.*

⇩ *Fig. 17 Dr R A Mashelkar, FRS, the then DG, CSIR and Secretary, DSIR, delivering the twentieth NAL Foundation Day lecture on 21 July 2006.*



⇧ *Fig. 18 Dr J Narayana Das, Director, Naval Materials Research Laboratory, Ambernath, delivering the CSIR Foundation Day Lecture on 26 September 2006.*

⇧ *Fig. 19 Prof C V Vishveshwara, Emeritus Director, Jawaharlal Nehru Planetarium, Bangalore delivering the National Science Day lecture on 28 February 2007.*

involved in technology management. The twentieth NAL Foundation Day lecture was delivered by Dr R A Mashelkar, FRS, the then Director General, CSIR and Secretary, DSIR, New Delhi on 21 July 2006 *(Figure 17).* Dr Mashelkar's spoke on"CSIR transformation: The phenomenon and the unfinished agenda". Dr U N Sinha and Dr T N Venkatesh of NAL delivered the accompanying NAL Technology Lecture on "Integrated system for meso-scale modelling for weather prediction". Prof U R Rao, Chairman, PRL Council, DOS, presided over the function.

Dr J Narayana Das, Director, Naval Materials Research Laboratory, DRDO, Ambernath, delivered the CSIR Foundation Day Lecture *(Figure 18)* on "Taking technology from laboratory to market"on 26 September 2006. The accompanying NAL Business Lecture was delivered by Dr J J Isaac, NAL who spoke on "High-speed combustor technology".

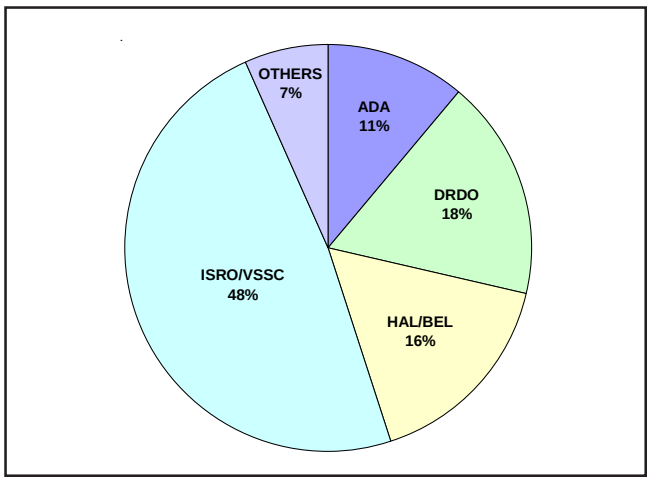
Prof C V Vishveshwara, Emeritus Director, Jawaharlal Nehru Planetarium, delivered a scintillating National Science Day lecture on "Cosmos and Culture" on 28 February 2007 *(Figure 19).*

Women's Day was formally included in NAL's Calender of Events this year. The day was celebrated on 8 March 2007 with Dr(Mrs) Sudha Murty, Chairperson, Infosys Foundation, Bangalore, as the Chief Guest. Dr Sudha Murty's lecture "To be a Woman in a Man's World " was a true life personal experience of her voyage and struggle as a woman and her keen observations as the Chairperson of the Foundation, and was very well received *(Figure 20).*

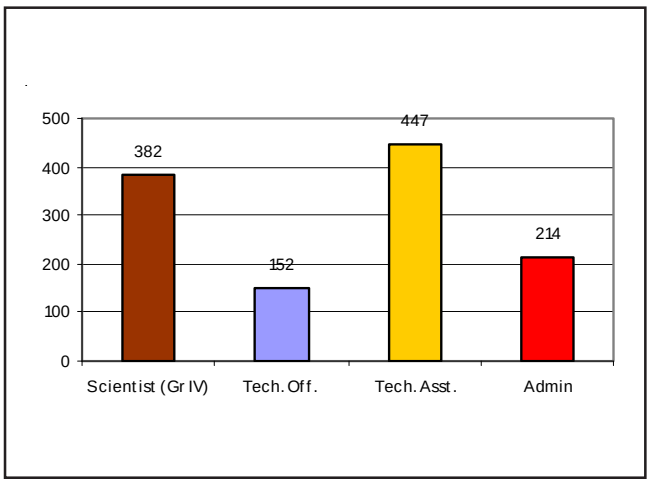
The 116th birthday celebration of Bharath Ratna Dr B R Ambedkar was organized at NAL on 27 April 2007.

⇩ *Fig. 20 Dr Sudha Murty, Chairperson, Infosys Foundation, Bangalore, delivering the International Women's Day (IWD) lecture on 8 March 2007.*

⇩ *Fig. 21 The 116th birthday celebration of Bharath Ratna Dr B R Ambedkar on 27 April 2007.*



⇧ *Fig. 22 Chart showing the break-up of NAL's 2006-07 external cash flow of Rs.33.37 cr.*



⇧ *Fig. 23 The break-up of NAL's staff strength of 1195.*

The chief guest, Dr Ruth Manorama, well known social activist, Member, National Commission on Population and Steering Committee of Women in the Planning Commission of India, Govt. of India delivered this year's lecture on "Dr B R Ambedkar's life and Mission and its relevance in today's context" *(Figure 21).*

STATISTICAL SUMMARY

36 new sponsored projects (total value: Rs 15.77 cr) and 12 new grant-in-aid projects (Rs.2.81) were taken up during 2006-07.

Our external cash flow this year was Rs. 33.37 cr; as usual NAL continues to be among the largest ECF earners among the CSIR establishments. The major contributors to ECF were ADA (Rs 3.68 cr; 11%), ISRO/VSSC (Rs 16.15 cr; 48%), DRDO (Rs 5.84 cr; 18%) and HAL/BEL (Rs 5.46 cr; 16%). About 1-2% of the cash flow in 2006-07 came from international sources *(Figure 22).*

The CSIR's annual grant to NAL for 2006-07 was 58.72 cr. Out of this, Rs.29.82 was spent on salaries and allowances. NAL received a further grant of Rs 41.10 cr during the year for CSIR's "networked projects" of the 10th FYP.

The NAL staff strength is currently 1195. This includes 382 scientists, 152 technical officers, 447 technical assistants and supporting personnel and 214 officers and staff from the administrative cadre *(Figure 23).* The scientific and technical human resources is becoming a matter of serious concern in the Laboratories with retirement on superannuation of a large number of senior scientists(some with specific domain expertise), movement of several lower and middle level scientists to the private sector, and the difficulty in attracting good fresh talent from the universities, again because of the many opportunities in the private sector. Challenging R&D programmes, scientific freedom and flexibility to experiment, coupled with reasonably attractive remunerations appears to be the only way to retain existing talent and attract fresh talent. This, together with outsourcing/public-private partnership appears to be the direction for successful implementation of future programmes.

HONOURS

It is finally a pleasure to mention the many awards and laurels won by my colleagues in 2006-07. DAAD, Germany honoured Dr G K Suryanarayana, Scientist, NTAF with the title of "Honorary DAAD Advisor (2006-2009) for his "outstanding commitment and leadership in promoting Indo-German relations in education". NAL was awarded the First IETE Corporate Award for Performance Excellence in the field of Electronic Instruments and Instrumentation for the work of Dr V Shubha and Dr T G Ramesh on Thermophysical Instrumentation. The Aeronuatical Society of India awarded National Aeronautical Prize 2006 to the Team from NAL, HAL and CEMILAC in recognition of their contributions in the field of Life Extension Testing of Fighter Aircraft. Dr R Ramachandra Rao, Scientist Materials Division bagged the Sri Rama Satyanarayana Memorial Award 2006 for popularizing ceramic science in the local language. Dr M R Nayak, Head, ALD has been invited by the Royal Aeronautical Society to become Associate Editor of the Aeronautical Journal. He has also been invited to serve as an Associate Editor of the International Journal of Systems Science (IJSS) for a period of two years from 1 January 2007. Mr Shyam Chetty, Scientist, FMCD has been conferred with the "Distinguished Alumni Award" of the National Institute of Technology, Tiruchirappalli. Mr S Raja, Scientist, Structures Division was awarded the JSPS Post Doc-

toral Fellowship at Nagoya University, Japan for the year 2006-07. Dr Kota Harinarayana, Raja Ramanna Fellow of DAE at NAL was conferred with the 2006 Gujar Mal Modi Award "for his important role in the development of India's light combat aircraft, Tejas".

I would like to end my report by thanking Dr R A Mashelkar, who laid down his office as Director General, CSIR on 31 December 2006 on reaching superannuation for his unstinted support to NAL during his entire tenure as Director General from which NAL has benefited greatly. I also thank Dr MK Bhan and Dr T Ramasami for continuing the tradition during their tenures at CSIR in the period January-March 2007 with additional Charge as Director General. I am also grateful to the Chairman and members of the Research Council of NAL for their advice and guidance, and to all the organizations within the country and from abroad who have continued to repose their faith in NAL by sponsoring major R&D projects during the year.

Dr A R Upadhya
Director