A

REPORT OF THE DIRECTOR

It gives me great pleasure to present the annual report for the year 2002-2003.

HIGHLIGHTS

On 4 February 2003, NAL's SARAS aircraft was rolled out of its hangar (*Box 1*). It was a wonderful moment as the SARAS, looking resplendent and majestic, made its first public appearance (*Figure 1*). Our efforts to ready SARAS for its first flight are progressing very well; it is now only a matter of months before SARAS takes off.

The HANSA aircraft continues its impressive showing. It was a proud moment when the HANSA float participated in this year's Republic Day Parade. The fabrication of two more HANSA aircraft was completed last year; a private partner manufactured shells for these aircraft. One of these two aircraft (VT-HNW) has already started flying at the Trivandrum Flying Club (*Figure 2*). We estimate that HANSA aircraft have already logged about 2000 hours of safe flying in Indian skies (*Box 2*).

⇩ *Figure 1: Dr R A Mashelkar, DG-CSIR prepares to enter the SARAS aircraft after its roll out on 4 February 2003.*

We continue to contribute very significantly to the Tejas (formerly LCA) aircraft development programme. ADA teams have completed over 80 flights on the two Tejas prototypes (TD-1 and TD-2) and the flight test results are very encouraging. We are particularly happy with the satisfactory performance of the scheduled and fixed gain control laws and level 1 handling qualities exhibited by the aircraft during flight (*Box 3*).

The design and development of composite radomes for a variety of aerospace applications is now emerging as an important R&D activity at NAL (*Box* 4). Nose radomes for the fire control radars on Jaguar maritime aircraft, developed by NAL, have now been cleared for flight evaluation trials.

Several meetings of the CSIR Review Committee, under the chairmanship of Prof R Narasimha, were held last year to study how NAL's management could be re-structured. The Committee has now submitted its final report.

IN THE DIVISIONS

The *Advanced Composites Division* continued to strongly support the SARAS and Tejas programmes; the activity this year included the

⇧ *Figure 2: HANSA VT-HNW getting ready for its first flight on 30 March 2003. The aircraft is now flying at the Trivandrum Flying Club.*

⇧ *Figure 3: Photograph of the 121 cables, each nearly 50 m long, to be used for the Tejas main airframe structural test specimen.*

preparation for a main airframe structural test specimen to prove the design validity of the Tejas structure (*Box 5; Figure 3*). Another interesting innovation in the Division was the development of a portable cure controller that can actually be used in airfields to perform bonded repair work on aircraft structures.

The *Aerospace Electronics and Systems Division* has proved to be a major contributor to the SARAS programme; the Division is developing the complete avionics suite and electrical system for the SARAS aircraft (*Figure 4*). Among the Division's other accomplishments is the development of a microwave anechoic chamber, to study antenna radiation patterns and undertake a variety of other studies, and a software product (FOQA) for routine analysis of flight data

1. SARAS rolls out

The SARAS roll out function on 4 February 2003 was a wonderful moment for NAL. As the big aircraft (VT-XSD; SD in honour of the late Prof Satish Dhawan) emerged from its hangar there were scenes of great jubilation.

The function was very well attended. NAL felt specially honoured that Mrs Nalini Dhawan, Prof Dhawan's wife, agreed to be present. The genesis of the SARAS programme – and indeed NAL's well-planned forays in civil aviation – can be traced to the advice and encouragement that NAL received from Prof Dhawan in the 1980's and early 1990's, and the energy and enthusiasm of the late Mr Raj Mahindra (the second SARAS prototype will be named VT-XRM in his honour).

Dr R A Mashelkar, DG-CSIR and Secretary DSIR – who has been a passionate champion of SARAS – and Prof V S Ramamurthy, Secretary DST and Chairman, Technology Development Programme (TDB) – who was instrumental in facilitating TDB funding at a very difficult phase of the SARAS project – were the two guests of honour. Mr N R Mohanty, Chairman, HAL – HAL is NAL's most treasured partner in SARAS development – and his predecessor Dr C G Krishnadas Nair – who cleared the decks for HAL's participation in the SARAS project as a risk-sharing partner – also graced the occasion. NAL's former Directors: Dr K N Raju and Prof R Narasimha – who led NAL's initial forays into civil aviation and continues to be a valuable adviser to the SARAS team – were also present to share this moment of glory.

The successful SARAS roll out demonstrated the working of the aircraft's systems. The aircraft is now back in the hangar. Every component and sub-system is being rigorously tested in preparation for the first flight.

⇧ *Figure 4: Setup to conduct tests on the navigation systems and primary flight displays of SARAS.*

generated during line operations.

The *Acoustic Test Facility* conducted seven test campaigns for ISRO during 2002-03 and was involved in the acoustic certification process for HAL's intermediate jet trainer (HJT-36). A multifunction acoustic calibrator was also developed for LPSC.

I have already written about the SARAS roll out function (*Figure* 5) and HANSA's growing popularity in Indian flying clubs. The *Centre for Civil Aircraft Design and Development (C-CADD),* which leads the SARAS and HANSA programmes, is working practically round the clock to ready the SARAS for its first flight. I must express my gratitude here for the tremendous quality of leadership that my predecessor, Dr T S Prahlad, is offering to the SARAS programme.

The striking success achieved by the *Computational and Theoretical Fluid Dynamics Division* in computations using RANS solvers for complete

2. HANSA at Indian flying clubs

HANSA's principal role was always intended to be as an *ab initio* trainer. It is therefore a matter of deep satisfaction that five HANSA aircraft are currently operational: one HANSA (VT-HNS) is at IIT, Kanpur and the other four are at various flying clubs in the country. HANSA VT-HNT is at Hyderabad with the Andhra Pradesh Aviation Academy (APAA), VT-HNV is at the Madhya Pradesh Flying Centre (MPFC) in Indore while the VT-HNU and VT-HNW aircraft are at the Kerala Aviation Training Centre (KATC) in Trivandrum. All these aircraft have logged in hundreds of flying hours; activity at Trivandrum in particular is reportedly very intense with quite a few student pilots flying solo on the HANSA. HANSA's climb performance, cockpit visibility and handling qualities are proving to be the aircraft's major attractions.

NAL also continues to shoulder the responsibility of providing maintenance support. Rapid technical and service support (there was an engine replacement at KATC) ensured that all the HANSA aircraft stayed continually airborne.

3. Design of flight control laws for Tejas (LCA) TD-1 and TD-2 aircraft

As part of the Tejas technology development programme significant progress has been made during the year. Six test pilots of the Indian Air Force have successfully completed over 80 flights on the two Tejas prototypes TD-1 and TD-2 and the flight test results are very encouraging. The satisfactory performance of the scheduled and fixed gain control laws and level 1 handling qualities exhibited by the aircraft during flight has enabled the pilots to fully explore the envelopes identified for these blocks of flights. All objectives set out for the first phase of the technology demonstration programme including deployment of slats, airbrakes, evaluation of handling qualities, estimation of stability and control derivatives and airdata system calibration have been successfully completed.

Rapid and cost effective expansion of the flight envelope was made possible due to the commissioning of a novel facility at the National Flight Test Centre, by the Control Law Team, which enables reliable estimation of the aircraft stability margins in near real time from flight motion parameters telemetered to the ground station, i.e. within a few minutes after the pilot completes a flight test manoeuvre. The innovative technique combines FFT and frequency domain parameter estimation algorithms to compute the open loop frequency response generated from piloted 3-2-1-1 inputs. The aircraft response signals due to these pilot inputs have lower bandwidth (< 1 Hz) compared to the typical gain and phase crossover frequencies (1 to 3 Hz) of the airframe + control law loop transfer function, and hence reliably estimating the stability margins in near real time from these low bandwidth closed loop signals is a challenging task.

The method was initially validated using ground simulator responses generated by playing back canned piloted 3-2-1-1 inputs recorded in flight. The method was subsequently refined to estimate the stability margins in near real time during flight using telemetered data.

aircraft configurations has already been widely applauded. The Division continues to provide flow diagnostics and aerodynamic data for all major national projects. In a very valuable exercise, the Division undertook studies that could lead to a significant improvement in the HANSA's flap aerodynamics.

At the *Experimental Aerodynamics Division* an accurate half-model balance system for the 1.5m low speed wind tunnel was successfully commissioned and the direct afterbody measurement technique, available with the base flow facility, was extended to include twin jets. In the area of flow diagnostics, pressure sensitive paint (PSP) measurements on an aircraft model in the 1.2m wind tunnel yielded encouraging results (*Figure 6*).

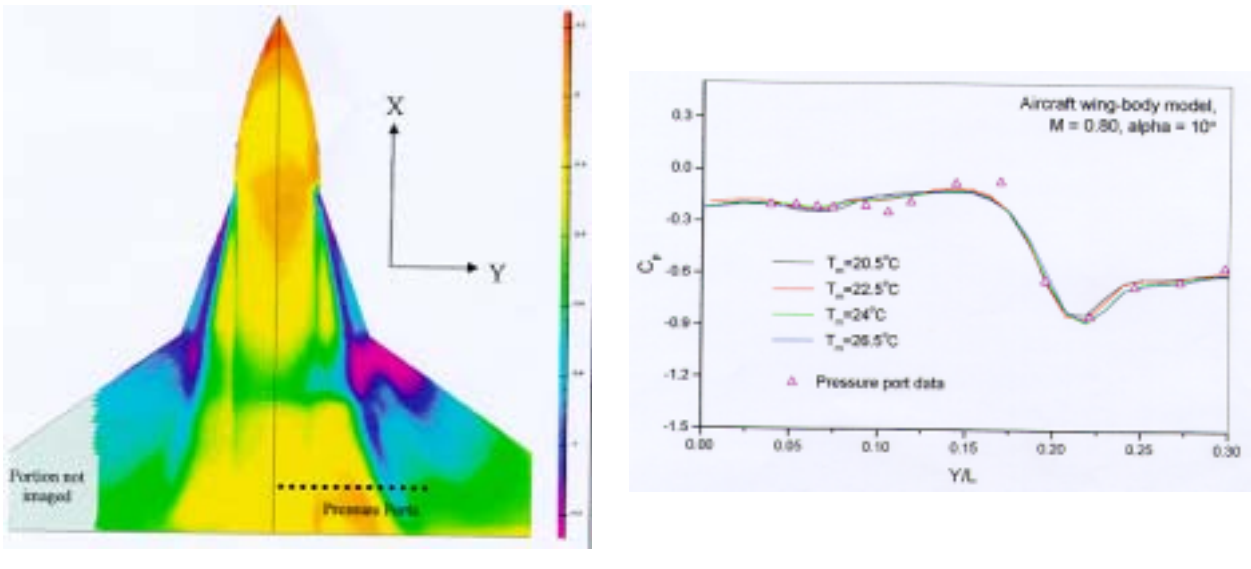
I have already written about the successful validation of the Tejas flight control laws at the *Flight Mechanics and Control Division* after the first two blocks of flight tests. The Division's engineer-in-the-loop (ELS) facility played a significant role in the analysis and evaluation of these flight control laws (*Box 6*). In an interesting exercise in air traffic management, modelling and simulation techniques are being used to study possible ground and airspace delay at Bangalore airport and make predictions of current and future traffic scenarios (*Figure 7*).

⇧ *Figure 5: A photograph of SARAS as it rolled out from its hangar on 4 February 2003.*

The *Flosolver Unit* continues to be very deeply involved in the NMITLI project to develop an Indian 'hardware-software solution' for mesoscale modelling and weather prediction. The best part of the year was spent in hardware development; the effort culminated with the striking success of the optical FloSwitch (*Figure 8*).

The FRP Pilot Plant is now the *Fibre Reinforced Plastics Division*. The Division's major contributions this year include its support in the

⇩ *Figure 6: Typical results showing a comparison between PSP and pressure port data on an aircraft model.*



⇧ *Figure 7: An airspace simulated scenario at Bangalore airport.*

development of composite nose radomes for the Jaguar, Tu-142M and SARAS aircraft and the development of carbon composite blades for the high pressure ratio axial flow fan.

The project to establish an integrated facility for carbon fibres and prepregs at the *Materials Science Division* has entered a critical phase. All the major systems and utilities have been installed and commissioned. Process

⇧ *Figure 8: A preliminary version of the optical FloSwitch. FloSwitch is an exciting idea because it will support message processing, instead of just message passing, and therefore achieve near linear scale-ups.*

trials have just started. Considerable work is going on to deliver automatic visual range assessor (AVRA) systems to Cochin airport and the Indian Navy. 80 failure investigations were also undertaken by the Division *(Figure 9).*

The *National Trisonic Aerodynamic Facilities (NTAF)* continued to undertake aerodynamic tests for various sponsors (ADA, VSSC, DRDL and HAL) at its 1.2m and 0.6m trisonic wind tunnels; 1674 tests were carried out this year in the two tunnels. NTAF's

4. Engineering radomes

Radomes, that protect the antennae or reflectors of valuable radar installations, are critical in aerospace, defence, meteorological and communication applications. The design, fabrication and installation of the fibre reinforced plastics (FRP) radomes, for radars operating over wide ranging frequencies, involves a highly interdisciplinary approach.

NAL has been an established player in the indigenous development of radomes (of all sizes) both for ground based and airborne radars for nearly three decades. There is now a major upswing in this activity: the important ongoing projects to develop airborne composite radomes include solid monolithic nose radomes for the fire control radars of the Jaguar maritime aircraft for the HAL/IAF, honeycomb nose radomes for SARAS, antenna fairings (radomes) for the Tu-142M Homi aircraft of the Indian Navy, and the ABD-2000 tail radomes of the Mirage.

NAL is using advanced concepts and technologies in these inter-disciplinary radome development programmes: variable thickness radome, electromagnetic (EM) design, FEM analysis coupled with CFD, and composite technologies encompassing material characterization, tooling design, resin injection techniques, contour woven fabric preforms and high temperature polymer matrices.

The Jaguar nose radome, developed by NAL, has just been cleared for flight evaluation trials after completing rigorous safety of flight tests and associated certification processes. Radome engineering looks poised to become another of NAL's major strengths.

5. Strain gauging of the structural test specimen of Tejas (LCA)

The main airframe structural test (MAST) specimen of Tejas was planned to prove the design validity of the structure. The structural testing for different critical loads was considered mandatory before the first flight of the PV1 aircraft. The task of monitoring stress, strain and deflections during the structural testing of the MAST specimen was planned. For monitoring strains at critical locations, strain gauges were chosen as sensors, based on the long term experience gained in their use on several test articles and test boxes during the previous years. The design and the stress groups arrived at a total of 4316 strain gauges to be distributed over the front, central and rear fuselage, the LH and RH wing, the wing fittings and the control surfaces.

The handling of such a large number of strain sensors was a unique and challenging task; work of such a large magnitude was undertaken for the first time in the country. The job involved a thorough study, marking strain gauge locations on the actual aircraft, mounting the strain gauges, proper labelling and routing of cables and planning the proper exit for the cables to facilitate monitoring of strains.

The strain gauging work was started when the component parts of the aircraft were still in assembly jigs. The length of the cables required was carefully calculated in order to provide a sufficient length to run the cables out of the aircraft after its final assembly. The exit for all the cables connected to the strain gauges was chosen to be at the central place of the fuselage for convenience in handling. The ends of these cables brought out of the aircraft were connected to amphenol plugs after proper identification so that they could later be connected to the mating part of the cables coming from the instruments located in the control room. The MAST specimen is getting ready for undergoing structural tests.

augmentation programme is also progressing well.

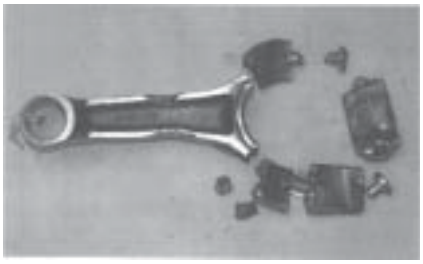
The *Propulsion Division* continues to build on its experimental strength in combustion, turbomachinery and mechanical aspects. A novel method to achieve flame stabilization in ramjet/scramjet combustion using a cavity cascade as the flame stabilizer has been proposed. The Division's axial compressor research rig has been upgraded; the improved configuration can deliver 1.1 MW of power and achieve a maximum speed of 30,000 rpm. The Dawes code was extensively used for performance prediction in turbomachinery components and solutions depicting the details of flow in a three-stage fan, taking into account the rotor-stator interaction, were obtained (*Figure 10*). The dual, coaxial, contra-rotating rotor propeller system for the ultra-light helicopter has also been successfully run.

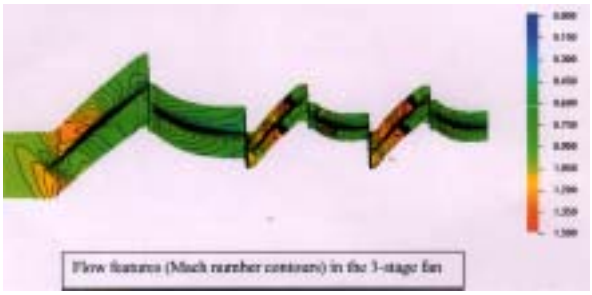
The *Structural Integrity Division* is extremely busy with structural testing and damage tolerance evaluation of all components of the SARAS airframe (*Figure 11*). Total technical life extension (TTLE) of aircraft and helicopters is another of the Division's major concerns (*Box 7*). Test activities relating to the Tejas aircraft also continued right through the year.

6. Modelling, Simulation and Parameter Estimation

The engineer-in-the-loop simulation (ELS) facility with good configuration control, established at FMCD, for carrying out flight simulation and control law design-validation for the Tejas (LCA) has been extensively and successfully used for validation of the design using real flight data of the aircraft. The parameter estimation and flight data analysis procedures have also been fine-tuned using the simulated data generated from the ELS facility for the TD1 and TD2 aircraft. Subsequently, the real flight data from about 55 Tejas flights have been successfully analyzed for estimation of stability and control derivatives of the aircraft that has an inherently unstable/augmented fly-by-wire configuration. This has been a challenging task. The linear models of the aircraft dynamics required for the design of control laws for the Tejas have been generated using the linearising software operating within the ELS environment. The ELS system is being upgraded to have PC-based distributed environment. Work on design and development of a training simulator for the SARAS aircraft has been initiated.

⇩ *Figure 9: The Materials Science Division investigated the connecting rod failure of the Lycoming engine for HAL.*





⇧ *Figure 10: Flow features (Mach number contours) in the three-stage fan.*

⇧ *Figure 11: The SARAS fuselage test article being prepared for structural testing.*

The *Structures Division* played a stellar role both in the structural analysis and testing of the SARAS. The integrated structural analysis, and the dynamic analysis, of the aircraft for all the flight load cases were completed. The Division now also has the additional responsibility of setting up a test facility for static testing of the stub wing and engine mount of SARAS. In another project, the Division undertook in-flight measurements of vibration on the Tu-142M aircraft and the Kamov helicopter. Design work on the ADF antenna radomes to be located on the Tu-142M aircraft wing tips was also completed.

The project on the development of pressure sensitive paints has made good progress at the *Surface Engineering Division*. Two new PSP formulations with significantly lower thermal degradation have now been developed. The Division also worked on the development of sunshield mirrors for ISRO's INSAT 3D satellites.

The emphasis at the *Wind Energy Programme* is now changing from wind resource assessment to wind turbine development. An important event was the signing of an MoU with the Sangeeth Group in Coimbatore district for the development of a medium-scale, low cost, horizontal-axis wind turbine.

TECHNICAL SERVICES

The *Computer Support and Services Division* rendered valuable support in managing NAL's computer network spanning three campuses. A useful web based e-mail service was also introduced last year. The *Electrical Sections* at Belur and Kodihalli did good work, especially in the establishment of a ramjet/scramjet combustor test facility at Propulsion Division and preparing the electrical grounding scheme for the SARAS aircraft. The *Engineering Services*

7. Total technical life extension programmes

The key to total technical life extension is a successful full-scale fatigue testing of the airframe. This identifies all the fatigue critical locations in the airframe. These locations are strengthened in all the aircraft in the fleet at a suitable point of time. This eliminates the problem of fatigue cracking during the period of extended life. NAL successfully extended the lives of Gnat, Ajeet and MiG-21 fleets. Currently the first phase of full-scale fatigue test on the MiG-21 bis has been completed. A life extension of 1000 flying hours has been recommended for the MiG-21bis fleet. IAF desires an additional 600 hours of life extension. This objective will be achieved after carrying out full-scale fatigue test for about 1800 hours of simulated flight.

Encouraged by our participation in total technical life extension programmes, IAF has awarded the life extension plan for MiG-29 to NAL's Structural Integrity Division. This project will be operated in four phases. The first three phases deal with collection of data needed to carry out the full-scale fatigue testing in the fourth phase around 2007.

NAL is now planning to submit proposals to carry out life extension studies on Su-30 and MiG-27 aircraft fleets. The scope of this activity will be much broader and will based on the knowledge gained in the previous full-scale testing programmes.

Division continues to be a pivotal actor in the SARAS programme while the *Estates and Building Unit* undertook projects to construct 60 new apartments, a test bay for Propulsion Division and additional floors over the existing canteen buildings on the Belur and Kodihalli campuses.

The *Information Centre for Aerospace Science and Technology (ICAST)* continues to provide a large number of web-based information access and retrieval services on its web sites. The *Information Management Division (IMD)* championed the creation of the WebISTAD portal for CSIR and prepared posters and multimedia presentations for NAL's stall at Aero India 2003. IMD also now edits and publishes a new monthly newsletter (AVIA) for the Aeronautical Society of India. The *Project Monitoring and Evaluation Division* had another typically busy year with its involvement in the tenth five year plan proposals, generation of ECF, modernization and augmentation programmes and customer satisfaction evaluation exercises. The *Technical Secretariat* (TS) concluded two licence agreements and seven MoU's and also facilitated the filing and granting of four patents in 2002-03. TS also arranged the NAL open day earlier this year *(Figure 12)*.

⇧ *Figure 12: Visitors at the SARAS avionics rig on the NAL open day.*

OTHER EVENTS

The sixteenth NAL Foundation Day lecture on "Technology and status of the Indian Dhruv and potential for R&D in rotor craft technology from the Dhruv platform" was jointly delivered by Mr K S Sudheendra, Adviser and Wg Cdr (Retd) C D Upadhyay, Chief Test Pilot, of HAL's Rotary Wing Research and Design Centre on 24 July 2002 *(Figure 13)*. Prof H S Mukunda of the Indian Institute of Science delivered the CSIR Foundation Day lecture *(Figure 14)* on 26 September 2002. Prof Mukunda spoke on "Combustion science and technology and India". Mr Shyam Chetty delivered the accompanying NAL Technology Lecture on "Design and development of control laws for modern aircraft".

This year's National Science Day lecture on 28 February 2003 was a splendid narrative on "Materials: from discovery to design" by Prof S Ranganathan of Indian Institute of Science *(Figure 15)*. The 2003 Dr B R Ambedkar Lecture had an intriguing title: "Reservation against reservation". Dr H S Rana of National Textile Corporation delivered the lecture on 24 April 2003 *(Figure 16)*. Finally,

⇩ *Figure 13: Mr K S Sudheendra (left) and Wg Cdr C D Upadhyay (right) delivering the sixteenth NAL Foundation Day lecture on "Technology and status of the Indian Dhruv and potential for R&D in rotor craft technology from the Dhruv platform" at the S R Valluri Auditorium on 24 July 2002.*

⇧ *Figure 14: Prof H S Mukunda's CSIR Foundation Day lecture on "Combustion science and technology and India", delivered on 26 September 2002.*

⇧ *Figure 15: The National Science Day Lecture on "Materials: from discovery to design" being delivered by Prof S Ranganathan on 28 February 2003.*

Dr V Sumantran, Executive Director, TELCO, Pune, delivered a fascinating National Technology Day lecture on "The Indica story" on 11 May 2003. *(Figure 17)*.

The other major events in 2002-03 included the inauguration of the C-CADD annexe building (21 June 2002), the Vigilance Awareness Week that terminated with a scintillating lecture by Mr N Vittal (5 November 2002), the special function to honour Wg Cdr P Ashoka for completing 50 years of flying (12 December 2002), the passing of HANSA float at the Republic Day parade, Aero India 2003 the fifth Bangalore air show (5-9 February 2003) and the completion of 30,000 blowdowns at the 1.2m trisonic wind tunnel (30 April 2003).

STATISTICAL SUMMARY

64 new sponsored projects (value: Rs 27.87 crores) and seven new grant-in-aid projects (value Rs 1.23 crores) were taken up during 2002-03. Our external cash flow (ECF) this year was Rs 28.69 crores (*Figure 18*) with the largest contribution (Rs 6.87 crores; 24%) coming from ADA. The ECF dropped significantly (from Rs 47.82 crores to Rs 28.69 crores) this year; a five-year perspective, however, is more revealing (*Figure 19*): it shows that NAL received a staggering Rs 242 crores as ECF during the last five years! NAL actually spent Rs 64.70 crores in 2002-03. Salaries amounted to Rs 22.68 crores (35%), the expenditure on consumables was Rs 10.95 crores (17%) and on capital equipment Rs 10.73 crores (16.6%).

The NAL staff strength is currently 1272. This includes 333 scientists and 168 technical officers.

HONOURS

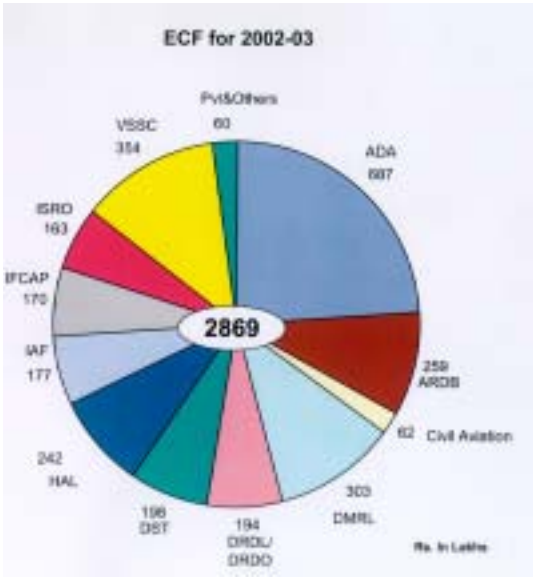
It is finally a pleasure to mention the laurels won by my colleagues. Teams at the Flight Mechanics and Control

⇩ *Figure 16: The tenth Dr B R Ambedkar lecture on "reservation against reservation" being delivered by Dr H S Rana on 24 April 2003.*

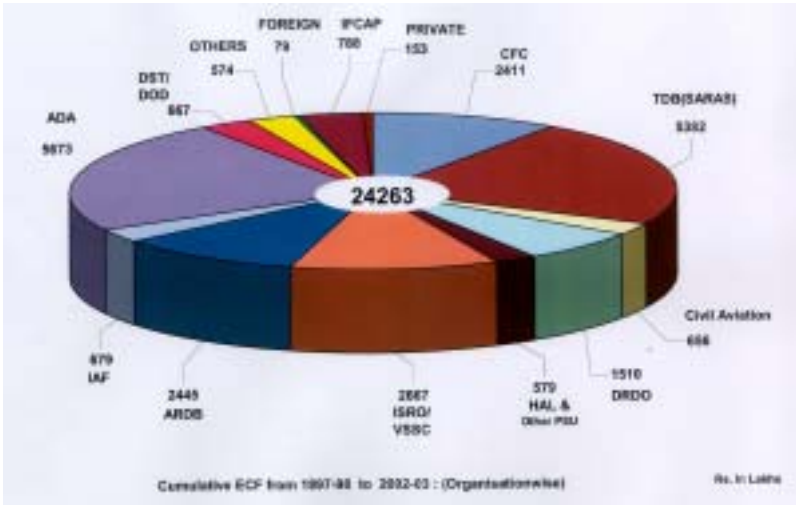
⇩ *Figure 17: Dr V Sumantran in the course of his lecture on "The Indica story" on 11 May 2003.*

Division have just won the 2003 CSIR Technology Shield in the area of engineering technology for developing "integrated flight mechanics and control technology for aerospace vehicles". Dr Manoj Nair received the 2002 CSIR Young Scientist Award, Dr Ramachandra Rao won the 2000 Sir C V Raman Young Scientist Award and Mr Shyam Chetty was one of the winners of the 2002 DRDO award for path-breaking research and technology development. Mr V Kanagarajan, Mr N N Murthy, Mr Shyam Chetty, Dr S Viswanath, Dr S Sridhara Murthy and Dr Satish Chandra were elected Fellows of the Aeronautical Society of India. Dr B K Parida was elected Associate Fellow of AIAA and Ms Poornima Narayan was a winner of the Fulbright Professional Fellowship in information science and technology. Mr K E Girish, Dr K K Brahma and Mr S Kalyana Sundaram won best paper awards at important scientific meetings. I congratulate all of them.

Dr B R Pai
Director



⇧ *Figure 18: NAL's ECF for 2002-03 was Rs 28.69 crores. The chart shows the contributions from different sponsors.*



⇧ *Figure 19: NAL's ECF, with names of contributors, summed over the last five years (1997-88 to 2002-03).*