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REPORT OF THE DIRECTOR

Annual Report 1997-98

Annual Report 1998-99

Annual Report 1999-00

Annual Report 2000-01

It gives me great pleasure to present the annual report for the year 2001-2002.

HIGHLIGHTS

The 4m x 8m autoclave system, developed by NAL in partnership with BHEL, Trichy and HAL, has finally been commissioned and handed over to HAL, Bangalore on 12 April 2002 (*Figure 1*). The delivery of the mammoth system took much longer than expected, but the autoclave has turned out to be quite an engineering marvel. The autoclave project tested NAL's capability severely and it is a matter of deep satisfaction we successfully passed the test (*Box 1*).

On 22 March 2002, NAL delivered (*Figure* 2) two more HANSA aircraft to the Ministry of Civil Aviation (MCA). MCA has positioned these aircraft at the Trivandrum and Indore flying clubs. Last year MCA had positioned a HANSA at the Hyderabad flying club; three HANSA's are therefore now flying at Indian flying clubs. A fourth HANSA is to fly away to IIT, Kanpur. While we are pleased with the success of the HANSA programme so far, we are aware that many challenges lie ahead of us, notably in marketing and product support (*Box 2*).

⇩ *Figure 1: Mr N R Mohanty, Chairman, HAL "receiving" the 4m x 8m autoclave system from NAL. Dr Kota Harinarayana, Mr D V Venkatasubramanyam and Mr Yogesh Kumar of HAL are also seen.*

Our progress on the SARAS programme has been very heartening (see *Boxes 3,4*). All major technical issues, including those relating to import of subsystems, have now been resolved. Three major activities – equipping of the fuselage at NAL, assembly of the wing at HAL, Nasik (*Figure 3)* and ground testing of structural components and systems at various work centres – are going on simultaneously. This is the phase where one would face maximum problems in any aircraft development programme and we too are having our share! The teams are working very hard and the target date for the first flight is still end December 2002. However, we will have much better clarity in September 2002.

The first block of 12 test flights of the LCA-TD1 aircraft, undertaken during 2001, confirm that the performance of the LCA control laws has been very satisfactory, with test pilots giving a level 1 rating to the aircraft's handling qualities (*Box 5*).

The 12.88 m diameter curved sandwich panel radome to house Doppler weather radars (DWR), developed by NAL teams for ISTRAC, ISRO was installed at the Sriharikota – SHAR Centre in May 2002 (*Box 6*).

⇧ *Figure 2: Mr K Roy Paul, Secretary, Ministry of Civil Aviation, receiving the keys of the HANSA aircraft from Dr T S Prahlad. Mr H S Khola, DGCA, is also seen.*

⇧ *Figure 3: The SARAS wing being assembled at HAL, Nasik*

1. 4m x 8m autoclave delivered to HAL / *D V V Venkatasubramanyam*

A few years ago, NAL undertook the responsibility to indigenously design, develop, fabricate, install and commission a 4m x 8m autoclave system for HAL, Bangalore; HAL needed this massive autoclave to develop carbon composite LCA components. This indigenous effort to set up the nationally important autoclave facility posed many technological challenges — right from the design stage up to performance proving — in view of the complex and stringent requirements to be met. It is a pleasure to report that all technical problems have been successfully resolved and the autoclave system is now fully operational and ready to take up the production of airworthy composite components.

The broad specifications of this autoclave included a 4m diameter x 8m length working space, maximum working temperature of 300^{0}C, maximum working pressure of 10 bar, maximum charge of 12 tonnes, heating and cooling rates of 5^{0}C/min (continuously variable) with full charge, and a pressurization rate of 2 bar/min (average). The specifications also included a vacuum system with 15 independently controllable channels and a programmable control system (with 36 load thermocouples) of temperature, pressure and vacuum.

The autoclave, delivered on 12 April 2002, is provided with state-of-the-art features including a Davit arm suspended quick lock safe door mechanism, a specially designed glandless, pressurized, water cooled, flange mounted dual speed motor and an advanced control strategy to achieve the precise cure cycle.

NAL took the assistance of Bharat Heavy Electricals Limited (BHEL), Trichy for the fabrication and supply of the autoclave shell and other components. The fabrication of the giant vessel involved heavy machining; in particular the quick lock door mechanism and the Davit arm suspended door system posed considerable problems that were resolved by developing innovative fabrication and assembly techniques.

Transporting the main autoclave shell, weighing around 120 tonnes, from Trichy to HAL, Bangalore was itself quite an adventure. An over dimension carrier truck was needed and there was the added risk of crossing several high tension electric wires and many aging bridges. The journey took almost 4 months.

The mammoth autoclave was installed at the HAL composite shop inside a pit of 3.5m depth. The installation was done by skilled hands (without any cranes) and specially prepared mechanical handling tools.

The most challenging task was to meet the stringent performance requirement of realizing the precise cure cycle profiles (pressure, vacuum and temperature cycles). This has been successfully achieved by developing an advanced temperature control strategy which ensures uniformity in temperature even with multiple components

The successful completion of this project has resulted in the development of valuable indigenous capability and savings in precious foreign exchange. It has also opened up the option of designing similar sophisticated equipment for the defence sector which is always a strategic advantage.

⇧ *Figure 4: The Advanced Composites Division has developed a co-cured co-bonded rudder for the LCA aircraft.*

⇧ *Figure 5: The instrumentation system of the 4m x 8m autoclave recently handed over to NAL.*

IN THE DIVISIONS

The activity at the *Advanced Composites Division* largely related to the LCA and SARAS aircraft development programmes. The fabrication and certification of all CFC wing spars, fairing skins, fairing blocks, the co-cured co-bonded fin and centre fuselage components, for use on the LCA PV2 aircraft, are nearing completion. The modified LCA rudder (*Figure 4)* with a composite torque shaft has been fabricated and is to shortly undergo the structural qualification test. For the SARAS, the Division is required to design, develop and supply all the control surfaces; it has already completed the fabrication of ailerons and elevators both for the structural test and the first aircraft. The Division also conducted a 3-day workshop on repair technology for composite structures for IAF teams during the year.

The *Aerospace Electronics and*

2. Three more HANSA aircraft fly away / *Dr K Y Narayan*

NAL has now delivered all the three HANSA aircraft that it was contracted to build for the Ministry of Civil Aviation (MCA). The first of the three HANSA's for the MCA was handed over last year; MCA, in turn, handed this aircraft to the Hyderabad flying club. The next two aircraft were formally handed over to MCA on 22 March 2002 at a special function held at the Rustom B Damania Flight Hangar. These two aircraft will now be with the Trivandrum and Indore flying clubs.

Another HANSA, with additional instrumentation, is headed towards IIT, Kanpur, where it will be used for flight experiments and special airborne studies (see table showing the chronology of events in the HANSA programme).

With three aircraft already with flying clubs, NAL's challenge in the HANSA programme now moves from design and development to support and marketing. We must now consider questions such as pricing and product support. This will be a new experience for NAL and we are getting ready to face this challenge.

No	*Aircraft*	*First flight/ Hours Flown*	*Test Pilot*	*Remarks*
1	HANSA-2/2RE (VT-XIW)	23.11.93/128 hr	Wg Cdr P Ashoka	Now at HAL Aerospace Museum
2	HANSA-3 Prototype I (VT-XAL)	25.11.96 / 107 hr	Gp Capt A Bhagwat	With Continental Engine IO-240B
3	HANSA-3 Prototype II (VT-XBL)	11.05.98 / 259 hr	Sqn Ldr Baldev Singh	Certified under JAR-VLA with ROTAX 914F3 Engine
4	HANSA-3 Pre-Production (VT-HNS)	14.05.99 / 42 hr	Sqn Ldr Baldev Singh	At IIT, Kanpur
5	HANSA-3 Production 001 (VT-HNT)	10.03.01 / 80 hr	Sqn Ldr Baldev Singh	Flying at Hyderabad
6	HANSA-3 Production 002 (VT-HNU)	15.01.02 / 11 hr	Capt K K Sharma	Flying at Trivandrum
7	HANSA-3 Production 003 (VT-HNV)	08.03.02 / 2 hr	Capt K K Sharma	Flying at Indore

3. Progress of SARAS / *Dr K Y Narayan*

The work on the prototype building of the SARAS aircraft is now going on at a brisk phase at various centres including HAL. Two assemblies of the fuselage have been completed, one of these is being readied at the Structural Integrity Division for structural tests and the second one is being equipped with the various systems. Besides, all the three structural assemblies of the horizontal and vertical tails and rear fuselage, five assemblies of the emergency door and one assembly of the main door have been completed at the Taneja Aerospace & Aviation Limited (TAAL), Hosur. The problems associated with wing assembly have now been resolved by HAL and NAL and the assembly of the wing is progressing well. The first assembly of the wing is expected to be ready by the first week of September 2002. All the composite control surfaces have been fabricated in the Advanced Composites Division and the assembly of the other flap has been initiated.

Structural tests on the horizontal tail and elevator have been completed up to the limit load with the participation of DGCA. Tests on the aileron are in progress. Equipping on the first prototype has commenced. The procurement difficulties faced due to trade sanctions imposed by the United States considerably delayed these equipping activities. The development of various systems at HAL (Lucknow) is nearing completion and the first aircraft units have been assembled and delivered to NAL. Ground test on the wheels and brakes and nose landing gear have been completed at HAL (ARDC). The second phase of the avionic system integration has been completed in the Aerospace Electronics Division and the results are now under review. The electrical system test rig has been commissioned at HAL (Lucknow) and the system qualification tests have commenced. The system reliability and safety assessment of all the systems have been completed in association with ADA. The aircraft reliability level is undergoing tests. The first flight of SARAS is targeted by end December 2002.

Systems Division has configured the avionics suite for the SARAS based on the ARINC-429 digital bus supported by an almost all-glass cockpit. A new avionics test rig (PSTRI-A) is being used to test and certify the avionics system on ground. The Division also had an important role in the HAL autoclave system *(Figure 5)*. Work on active noise control continued and the Division's Electromagnetics (EM) Group is now an important player in NAL's inter-divisional projects to design and develop radomes.

The *Acoustic Test Facility (ATF)*, which has now been delinked from the Aerospace Electronics and Systems Division, carried out several acoustic tests for ISRO, including tests on the INSAT 3C and TES flight models. The air jet noise generators developed by ATF are now attracting international attention; NAL has just received another export order from Wyle Labs, USA to supply these generators (*Box 7*).

I have already talked of the progress of the HANSA and SARAS programmes at the *Centre for Civil Aircraft Design and Development (C-CADD)*. Other activities at C-CADD include HANSA flight operations and the creation of a civil aviation policy research group to discuss critical policy issues in civil aviation. The group has recently released four comprehensive reports on the feeder aviation sector. The C-CADD (F) hangar was renamed the Rustom B Damania hangar to recognize the late Prof Damania's stellar contributions to NAL's civil aviation projects.

The different Reynolds-averaged Navier-Stokes (RANS) codes developed in the *Computational and Theoretical Fluid Dynamics Division* over the years have now attained a certain level of maturity (*Box 8*). These RANS solvers are now being used for computations on complete aircraft configurations such as the SARAS (*Figure 6*) and LCA. The new initiatives in the Division include studies on sloshing under micro-gravity and large eddy simulation (LES) for arbitrary shaped underwater bodies.

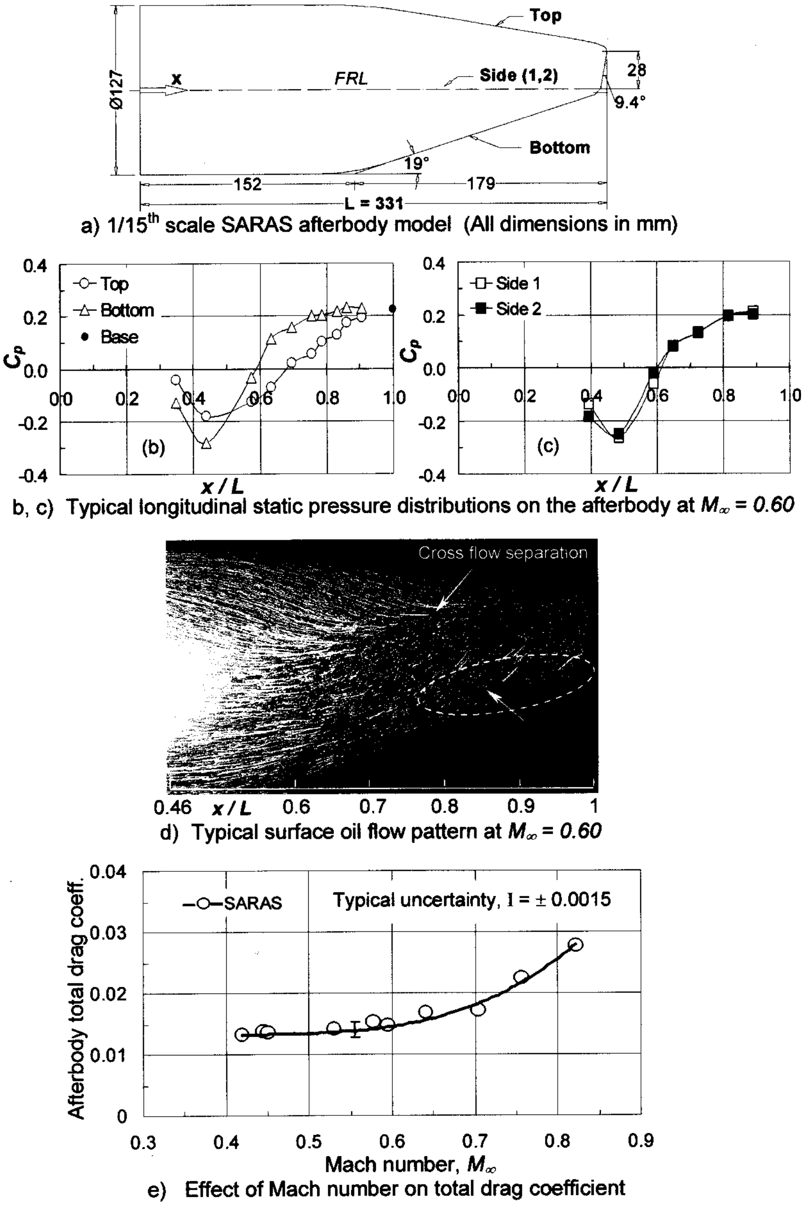
The *Experimental Aerodynamics Division* undertakes R&D work in three major disciplines: flow structure and management, flow diagnostics and aircraft and spacecraft aerodynamics. Recognising that the rear fuselage of a transport aircraft can result in large drag if not optimized properly, the Division has begun an exercise in the base flow wind tunnel to measure the drag characteristics of the SARAS rear fuselage *(Figure 7)*. In the area of flow diagnostics a Windows-based software on pressure sensitive paint (PSP) applications is being developed to incorporate certain improvements such as automatic marker recognition, automatic averaging and temperature compensation. Several interesting software development projects for use with a flush air data system are also in progress.

The *Flight Mechanics and Control Division* continues to be actively involved with LCA-related work. I have already mentioned the encouraging performance of the LCA control laws in a real-life environment. The Division has also successfully analysed the

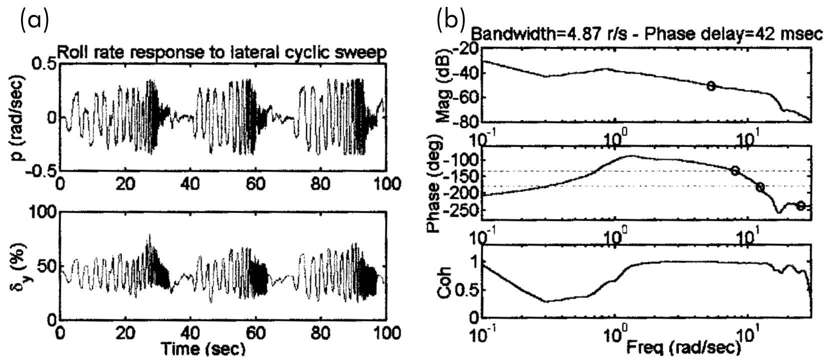
⇧ *Figure 6: A typical computation on the complete SARAS configuration undertaken at the CTFD Division using the JUEL3D code.*

LCA-TD1 flight data to estimate the aircraft's stability and control derivatives. Work on multi-sensor data fusion, initiated four years ago, is progressing well and holds great promise *(Box 9)*. The success of the HQPACK software to study aircraft handling qualities has triggered off a new project (in association with DLR, Germany) to develop similar software for helicopter handling qualities *(Figure 8)*. The Division is also getting deeply involved in studies relating to air traffic management, working closely with the Institute of Flight Guidance, DLR, Germany.

The focus of activity at the *Flosolver Unit* now largely revolves around the NMITLI programme of mesoscale modelling for monsoon-related predictions. The best part of the year was spent in hardware development to optimize the functions of FloSwitch. With FloSwitch, the problem of poor scalability, which is the bane of meteorological computing, will be largely overcome. The road ahead



⇧ *Figure 7: Rear fuselage studies on a 1/15 scale SARAS configuration to measure drag characteristics.*



⇨ *Figure 8: Some early results from HELI-HQPACK, the software to study the handling qualities of helicopters. The plots show roll rate response to lateral cyclic sweep and the roll attitude frequency response.*

4. SARAS avionics system / *N N Murthy*

The avionics system for SARAS has been configured to be of contemporary technology and is based on the ARINC 429 digital bus supported by an almost all-glass cockpit. The aircraft is being equipped with an avionics suite (see table) meant for mandatory two-crew operation in an ergonomically designed flight deck. The system complies fully with FAR Part 25/121 regulations. The design of the avionics system in SARAS is such that no single point failure will result in 'catastrophic' failure or a situation leading to a hazardous condition for the aircraft. All the equipment in the avionics suite will meet the Technical Standing Orders.

The electrical power needed for the entire system, including the avionics suite, will be provided from a 28 volts DC source. Each of the two engines is fitted with one starter-generator of 12 kW capacity. Each is capable of generating 28 volts DC at 400 A. A standard 44 AH Ni-Cd battery is provided as an emergency source.

The integrated avionics suite meets all performance, safety and civil certification requirements under normal and transient conditions. The avionics equipment in SARAS comprises of air data sensors, navigation, communication and surveillance systems, display and recording system and guidance. All the equipment have built-in-test facilities. Wherever applicable, the system status outputs are available for monitoring.

A very sophisticated test rig has been developed to test the entire avionics system either as individual LRU's or as an integrated system. The acceptance tests of all the LRU's have been completed and they are now ready to be fitted on the aircraft.

Systems provided in the SARAS avionics suite

- Dual VHF receiver and mode S transponder for communication with ATC
- Dual VOR/ILS/MKR, single DME, single ADF for navigation
- Dual radio tuning units to tune all the radios
- GPS based flight management system
- Air data sensors like pitot, static ports and AOA, TAT
- Dual air data computer
- Dual attitude and heading reference units
- AMLCD based display system for ADI and HSI indication
- AMLCD based electronic standby instrument system
- AMLCD based radio magnetic indicator
- Caution and warning system with an audio warning generator
- Weather radar with cockpit indicator
- Enhanced ground proximity warning system
- Radio altimeter
- Stall warning system
- Emergency locator transmitter
- Flight data acquisition unit with cockpit voice and flight data recorder and
- other displays like clock, magnetic compass.

5. LCA flight control laws validated / *Shyam Chetty*

The maiden flight of LCA TD-1 took place on 4 January 2001 and the aircraft has successfully completed the first block of twelve test flights with fixed gain control laws (designed and developed by the National Control Law Team–CLAW- comprising of FMCD, CAIR, ADA and HAL- with FMCD being the work centre). The fixed gain control laws rely only on the quad redundant inertial sensor information and are the ultimate reversionary mode for the normal full up air-data based schedule gain controller. There are two sets of fixed gains which get automatically selected based on the under carriage status and were designed to cater for failures in the air-data system.

The first block of twelve flights was carried out basically to calibrate the air-data system and identify the aerodynamic stability and control characteristics of the airframe. The performance of the control laws was found to be very satisfactory and the pilots rated the aircraft as having level 1 handling qualities in all the tasks performed during these flights. The good match in the responses between flight and simulation has given the designers adequate confidence to expand the flight envelope in the subsequent flight tests. These tests will be carried out shortly using the schedule gain version of the control laws that utilize information from the air-data probes and angle of attack vanes in addition to the information from inertial sensors.

for the Flosolver team is long and arduous; but I am confident that the team will eventually emerge triumphant.

The *FRP Pilot Plant* is now a major player in radome design and development. I have already mentioned the successful installation of the 12.88m diameter radome for Doppler weather radars at Sriharikota, and the plans to build an improved version of this radome. The Pilot Plant is also developing nose radomes for the SARAS and high temperature resistant ceramic nose radomes for advanced applications. In addition, the Pilot Plant played the leading role in fabricating three new HANSA aircraft.

The project to establish an integrated facility for carbon fibres and prepregs is making brisk progress at the *Materials Science Division.* The Division's other major responsibility is in the area of ceramic matrix components where teams are trying to develop technologies for producing silicon carbon fibres from available precursors. The India Meteorological Department has declared the Division's AVRA systems at Chennai and Bangalore airports to be "operational"; finally NAL's automatic visual range assessor is getting the recognition that it deserved. NAL has now received orders for AVRA Mk2 from the Indian Navy and the Cochin international airport. Failure analysis and accident investigation continues to be a core activity of the Division's metallurgy group; 67 cases were investigated in 2001-2002.

At the *National Trisonic Aerodynamic Facilities (NTAF)* activities centred mainly on wind tunnel tests in the 1.2m and 0.6m wind tunnels and facility augmentation. A large number of wind tunnel tests focused on the naval version of the LCA *(*Figure 9*)* and VSSC's launch vehicles. The facility augmentation plan is also progressing well; the new automatic balance calibration system has already been successfully commissioned and purchase orders have been placed for the next five out of a total of eight augmentation tasks.

The design of full-scale combustion facilities for the development of advanced combustors for air breathing propulsion systems, such as the ramjets and scramjets being considered by ISRO, was an important activity this year in the *Propulsion Division.* The Division has convincingly demonstrated the concept of thermal throttling to achieve supersonic combustion in a parallel-divergent duct by using a series of smart cavities through which the fuel is injected. In an interesting study for the aeronautical industry, several indigenously available high temperature elastomeric materials have been characterized from the point of view of vibration damping; this database would give useful inputs for the design of dampers for gas turbine and other applications. The design and development of a lightweight helicopter with weight shift control is progressing well.

⇧ ***Figure 9: A 1:20 scale LCA naval model mounted in the 1.2m trisonic wind tunnel.***

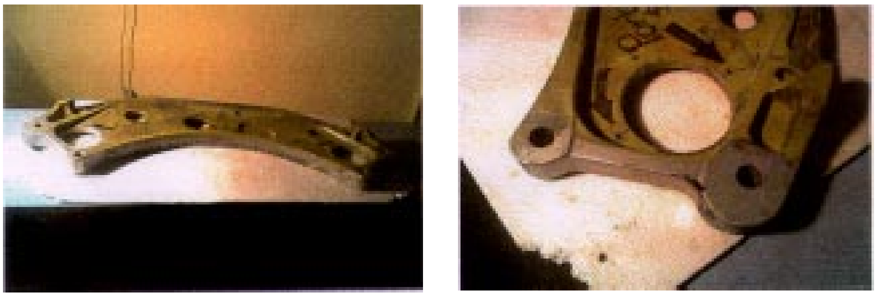
The total technical life extension programmes, both for ageing fighter airframes and helicopters, continued at the Structural Integrity Division. The Division, together with SERC, Chennai, also has a major responsibility in the structural testing and damage tolerance evaluation of

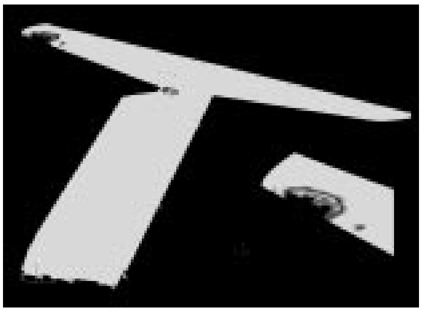
6. 12.88 m dia radome for ISRO's Doppler weather radars / *Dr R M V G K Rao*

NAL teams have successfully developed and installed a 12.88 m diameter curved sandwich panel radome for the Doppler weather radars (DWR) of ISTRAC, ISRO. After being cleared by the qualification agency (LRDE), the radome was installed at the Sriharikota – SHAR Centre in May 2002. Such a geometrically modelled double-curvatured spherical geodesic sandwich panelled radome of a very large size has been realized in the country for the first time.

The highlights of this technological achievement are the use of cost-effective composite fabrication techniques in making the 150 hexagonal or pentagonal curved panels, use of electromagnetic optimization techniques using NAL's *Aavrita* software, precision geometrical modelling to achieve a very good trade off between the least number of panels and the maximum panel area, mechanical and structural design using FEM techniques, innovative use of CFD analysis and appropriate assembling procedures.

This success confirms NAL's core competence in the design and development of radomes spanning almost three decades. A new realization of the radome, with the same diameter but with randomized panel geometries (for improved performance), is now being attempted.





⇧ *Figure 10: Cracked components of the MiG-21 bis after 16 blocks of loading.*

⇧ *Figure 11: Simulation of the damage to the SARAS horizontal tail after a bird hit.*

the SARAS airframe. In the full scale fatigue testing programme of the MiG-21 bis airframe, the half-way mark has been reached after completing 16 blocks of loading. During the inspection at this stage certain serious structural fatigue failures were noticed *(Figure 10)*; the testing programme has therefore been successful in identifying critical locations that can develop cracks when the MiG-21 bis operates beyond its initial fatigue life of 2400 flying hours.

The *Structures Division* had a very successful year. Apart from its role in the design and development of the 4m x 8m autoclave system, the Division made several notable contributions to the SARAS programme, including bird strike studies, using MSC/DYTRAN software, on the SARAS horizontal tail to assess the extent of damage (*Figure 11*). The final phase of the aeroelastic testing of the LCA wing models was successfully completed.

The *Surface Engineering Division* continued its many and varied applications of innovative surface technologies. Following the minor degradation noticed in the binary pressure sensitive paint NAL-G, the Division developed and characterized two improved paints: NAL-G1 and NAL-G2; both these paints performed much better in the wind tunnel tests in the 0.3m tunnel. The fabrication of embossing rollers for ITC has proved to be a success story (*Box 10*). The Division also demonstrated its electrochemically assisted arc machining process with an industrial prototype machine.

The *Wind Energy Programme* continued its wind resource assessment and wind farming studies. The wind energy potential at B R Hills was reviewed; the new assessment suggests that the potential is rather better than what was estimated in the late 1980's. The focus of activity in the programme is now likely to change to windmill design and development.

TECHNICAL SERVICES

The *Computer Support and Services (CSS) Division* has launched an important initiative in network security. NAL's growing presence on the Internet, and its rapidly proliferating e-mail and intranet services, naturally heightens our concerns about information security. The new security system, which largely uses freeware, should guard the campus network from both external and internal threats. CSS teams also played an

7. Jet noise generators for Wyle / *Dr Ranjan Moodithaya*

Jet noise generators to generate high frequency noise between 2.5 kHz and 10 kHz, 1/3 octave bands were designed, fabricated, tested and delivered to Wyle Laboratories, USA.

The NAL-ISRO Acoustic Test Facility has a 1100 cu m reverberation chamber with a capability to generate 156 dB spectrum, controllable between 31.5 Hz and 1 kHz octave bands with the help of Wyle WAS 3000 and Ling EPT 200 modulators. The sound pressure levels in the 2kHz, 4kHz and 8kHz octave bands are controlled by a NAL-developed jet noise source using perpendicular air jets. This exercise was undertaken since no noise generators are available in this high frequency range.

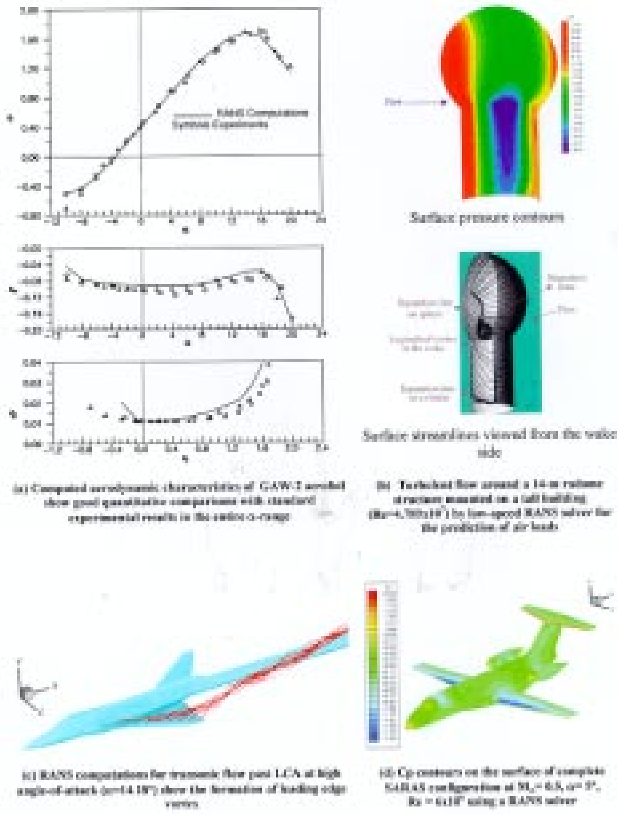
When air or gas jets impinge perpendicularly on each other, they generate a high frequency noise spectrum. As the jets leaves the nozzle an annular mixing layer forms between the moving fluid and its surroundings. The flow in this region becomes turbulent which is nothing but a fluctuating pressure field, i.e., an acoustic noise. The levels are controlled by the velocity of the jet while the spectrum is controlled by various dimensional parameters. Based on this principle, the jet noise generators were successfully developed, tested and delivered.

8. Growth of RANS Solvers at the CTFD Division / *Dr S S Desai*

During the period 1996-2002, the Computational and Theoretical Fluid Dynamics (CTFD) Division achieved maturity in the numerical simulation of dominantly viscous flows through the numerical computation of Reynolds-Averaged Navier Stokes (RANS) equations. This has been a natural sequel to the growth of reliable software in the Division for the solution of Euler equations for complex 3-D shapes during the 1980's and early 1990's. Specific codes have been developed to deal with each of the flow regimes of low-speed incompressible flows, transonic and supersonic flows and hypersonic flows. These codes are based on state-of-the-art algorithms for flow simulations and turbulence modelling.

The figure on the right shows a collection of sample results for the different flow regimes to bring to focus the ability of these codes to deal with complex flow fields over complex real-life geometries.

The demonstrated abilities of these codes include: the much-dreamed high-incidence flows over aerofoils *(Fig. a)* around the stall conditions where complex viscous effects dominate; prediction of air loads on bluff bodies under low speed conditions, a typical practical example of which is a 14m diameter weather radome mounted on a tall building *(Fig. b)*, capturing of leading-edge roll-up from the LCA wing *(Fig. c)* and computation of flow around the complete SARAS aircraft configuration *(Fig. d)*



important role in upgrading NAL's telephone exchange at Belur.The *Electrical Section*, both at Kodihalli and Belur, performed admirably. At Kodihalli, a new 66kV, 10 MVA electrical substation (*Figure 12)* was successfully commissioned; this substation significantly enhances our "comfort factor" with electrical power supply. At Belur, the Section gave very good support to the SARAS programme, especially in the construction of the new C-CADD annexe building and in the establishment of the SARAS electrical test rig at HAL, Lucknow. The *Engineering Services Division* has been exceptionally busy; it has a critical role in the SARAS development programme with responsibility for manufacture of components (*Figure 13*), associated jigs and fixtures, test setups, inspection of SARAS assemblies and the movement of the SARAS fuselage segments to and fro from the coordinating agencies. The *Estates and Buildings Section* was involved in three major building construction projects: the C-CADD annexe, the waste water reclamation and sewage treatment plant and the building for the new 66 kV electrical substation.

The AeroInfo web site of the *Information Centre for Aerospace Science and Technology (ICAST)* has been segregated with separate addresses for the ICAST web site and the AeroInfo portal. The AeroInfo site is promising: it already contains over 50,000 links to aerospace information resources with special emphasis on Indian content. ICAST is also taking a series of steps to offer web-based access to aerospace journals on the campus network. The *Information Management Division* (IMD) prepared two multimedia presentations of contrasting styles: while the tribute to the late Prof R B Damania was intensely moving; the survey of 20 years of NAL-DLR cooperation was very detailed and stylish. The campus intranet, designed and managed by IMD, now has over a 100 links, many of them "interactive" because they connect to backend databases. IMD also published two glossy compilations: the 100-page picture book on NAL's flora and fauna and the 150-page pictorial account of the history of NAL, and edited a touching

⇧ *Figure 12: The new 66 kV 10 MVA electrical substation at the Kodihalli campus significantly enhances NAL's comfort factor vis-à-vis electrical power supply.*

⇧ *Figure 13: SARAS components fabricated by the Engineering Services Division.*

tribute to Prof Satish Dhawan.

The *Project Monitoring and Evaluation Division* helps me in a variety of ways: they manage external projects and the external cash flow (we continue to have the highest cash flow among all CSIR labs), they look after the modernization programme (*Box 11)*, NTAF augmentation programme, customer satisfaction evaluation, all activity relating to the Tenth Five Year Plan proposals and performance appraisal exercises. I am also happy to note that the *Technical Secretariat* continues to give a strong fillip to NAL's new thrust in IPR-related activity;

9. Multi Sensor Data Fusion Technology/*Dr J R Raol and Dr Girija Gopalratnam*

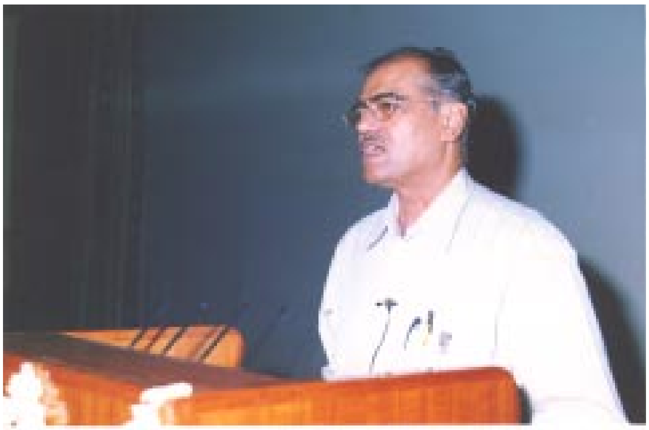
Multi sensor data fusion (MSDF) technology is a rapidly emerging technology and aims at automation of processes to combine diverse sets of sensed information. The objective of DF is to combine elements of raw/pre-processed data from different sources into a single set of meaningful information. Essentially, it is the integration and application of system theoretic approaches, and new areas of mathematics and engineering, to achieve the fusion of data. It provides qualitative and quantitative benefits like improved operational performance, extended spatial and temporal coverage, increased confidence, and reduced ambiguity of inferences.

MSDF activity at FMCD is being pursued for the last four years. It started with the development of dynamic tracking filters and multi-sensor data fusion algorithms /strategies for a single target tracked by multiple sensors as a part of a sponsored project. The algorithms/schemes are working satisfactorily in the evaluation mode during the flight test programmes being routinely conducted at a flight test range in the country. The extension of the work is being pursued to handle multiple targets in the multi-sensor (MSMT) scenario for range safety applications. Towards this aim, the algorithms for characterization of sensors have been developed. The central problem of data association for MSMT situations is being addressed in the context of tracking in the presence of clutter generated by false radar measurements. Algorithms based on nearest neighbour/probabilistic data association are being developed to obtain solutions to this complex problem. Interacting multiple modelling algorithms are also being investigated for tracking of manoeuvring targets.

Novel adaptive/factorization based tracking filtering approaches have also been proposed. Robust sensor data fusion schemes based on square root information filter and H-infinity filters have been developed and validated with simulated/real data. The Group has already published several research papers in many of these areas.

Future applications envisaged are: integration of the identity of targets with the kinematic information, development of algorithms for air/road traffic control, cockpit data fusion and autonomous navigation of vehicles.

⇧ *Figure 14: Dr Kota Harinarayana delivering the fifteenth NAL Foundation Day Lecture on "Technologies behind the LCA programme" at the S R Valluri Auditorium on 20 August 2002.*



⇧ *Figure 15: Mr R V Perumal delivering the CSIR Foundation Day Lecture on "Engineering the Geosynchronous Satellite Launch Vehicle" on 26 September 2001.*

10 patents were finalized and sent to CSIR for filing in 2001-2002.

OTHER EVENTS

Dr Kota Harinarayana, LCA Programme Director, delivered the fifteenth NAL Foundation Day lecture (*Figure 14*) on "Technologies behind the LCA programme". As always, Dr Kota was brilliant, witty and effervescent. Dr R A Mashelkar, DG-CSIR, who presided over the function, remarked that the lecture was one of the most inspiring that he had ever heard. The Fifth NAL Technology Lecture by M Subba Rao highlighted how advanced composites technology grew rapidly at NAL, especially during the last 10 years.

This year's CSIR Foundation Day Lecture (*Figure 15)*, by Mr R V Perumal of VSSC, was a vivid and compelling account on how the GSLV was engineered. Dr Ranjan Moodithaya delivered the fourth NAL Business Lecture on the wonderfully fruitful 15-year long association between NAL and ISRO at the Acoustic Test Facility. Prof M Vijayan, Associate

10. Development of embossing rollers / *Dr K S Rajam*

The Indian Tobacco Company (ITC) uses steel rollers for embossing a pattern on a metal foil and metallised paper. The pattern consists of embossed squares at a pitch of 0.400mm. Its appearance is similar to a knurled surface but it is finer than knurled.

The embossing rollers consist of two cylindrical rods of 60 and 120 mm diameter and have pin like projections on the surface to a length of 100 mm. The pins are very fine and have a tip size of 80 mm and length of 175 mm. The number of pins on each roller is very large; 4,17,500 pins on the smaller roll and 8,35,000 on the bigger one. The shapes of these pins are such that pins of one roll mesh with those of the other, like the teeth of gears when assembled. To emboss, the rolls are meshed and rotated in opposite directions and the paper or foil is fed between the rolls. Embossing takes place as the pins move in and out of the grooves of the counter roller. The profile of the pin is therefore very important.

Paper and metal foil cause severe sliding wear. In the ITC application, the wear is extremely severe because of the high speed operation and large production volumes. Therefore, the pins need surface modification to provide wear resistance.

The development of embossing rollers thus pose two technical challenges: forming the profiled pins with high precision and providing wear resistance. These are not easy challenges because the former needs an accuracy better than 10 mm and the numbers of pins are far too many. The surface modification is rendered difficult by the fact that the pins are slender and the surface modification should not distort them. Such distortion will result in dimensional inaccuracy.

The Surface Engineering Division has successfully met these challenges through an innovative approach. Prototypes made by using this approach are giving a satisfactory performance in the production machine and are in regular use in the production line.

11. Modernisation and Upgrading of NAL's R&D Facilities / *M S Ramachandra*

NAL has a very special place in the aerospace related research and technology development activities in the country. NAL's specialised test facilities established over the years constitute a major strength. Many of these facilities have been in operation for over three decades and have contributed extensively to major national aerospace projects. These programmes include: Light Combat Aircraft (LCA), the Satellite Launch Vehicle Programme (SLV), Integrated Guided Missile Development Programme (IGMDP), Advance Light Helicopter (ALH), Kaveri engine and several strategic national programmes as also NAL's own civil aviation and other initiatives. Keeping in mind the criticality of these facilities, a programme was taken up to modernise and update them. This was necessary as many of these facilities are national assets that need to be protected very carefully in view of their strategic relevance. Major developments in the field of electronics and computers have also made it possible that faster and more accurate data could be generated at greater economy. Hence, after a systematic review, a programme was undertaken to modernise NAL's R&D facilities.

CSIR submitted an overall programme to modernise facilities in all its constituent laboratories including NAL and the Expenditure Finance Committee (EFC) approved the programme in principle. Based on this decision, a more detailed proposal on NAL's facilities was prepared and submitted to the Standing Finance Committee (SFC) for approval. The SFC approved the proposal over a period of 5 years (1997 to 2002) at a cost of Rs. 17.3 crores. The programme was completed in the year 2001-2002.

The programme has been successfully implemented and some major facilities (see table) have been upgraded or added. As part of the modernisation programme, certain new initiatives in the area of flow diagnostics, bearing diagnostics, structural analysis and active noise control were also taken up.

This programme has substantially contributed to enhancing NAL's capabilities and enabled it to reach a higher starting point in technology development programmes which are required for future national aerospace programmes as also to meet the requirements of our strategic sector.

Major facilities upgraded

Ceramic processing facilities,
Axial compressor rig,
Fatigue test facility,
FRP testing facilities,
Flight mechanics laboratory,
Water jet cutter,
Composite testing systems,
Scanning electron microscope,
X-Ray diffraction system and high pressure liquid chromogograph .

New facilites established

Vector network analyser,
Air breathing propulsion rig,
Surface engineering facilities (like nano-indentor and sputtering unit),
32-node parallel processor and a coordinate measuring system.

Director, Indian Institute of Science, delivered the National Science Day Lecture (*Figure 16*) on "Structural genomics: A new initiative on form and function of proteins" and Mr Justice M Ramakrishna (*Figure 17*), former Chief Justice, High Court of Jammu and Kashmir and Guwahati, delivered the ninth Dr B R Ambedkar Birthday Lecture on "Reservation and the role of Dr Ambedkar in the Constitution of India". Ms B S Shanta Bai, Secretary, Karnataka Mahila Hindi Seva Samithi, was the chief guest at the Hindi Day function on 14 September 2001.

NAL and DLR, the German aerospace establishment, have now completed twenty years of extraordinarily fruitful R&D cooperation (*Box 12*). A special joint symposium was held at Berlin on 25-26 September 2001 to celebrate this momentous event. More than a dozen joint projects in different areas of aeronautics have now been successfully completed. The cooperation has involved exchange visits (about 100 visits from each side so far) and joint NAL-DLR workshops (six so far). I am delighted that this programme continues to be very active.

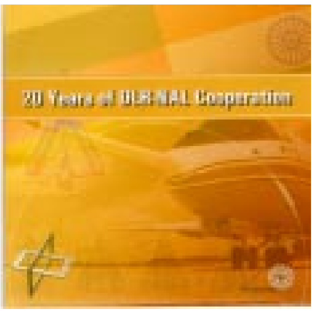
Other important events in 2001-2002 included the XV International Symposium on Air Breathing Engines (XV ISABE) in September 2001 in which scientists from the Propulsion Division played an important role, the Seminar on Women in Aerospace in India organized by NAL on 13-14 December 2001, the XI National Seminar on Aerospace Structures (XI NASAS), which NAL hosted for the fourth time, on 8-9 February 2002 and the NAL-DLR Symposium on Air Traffic Management (1-2 May 2002).

All of us at NAL were extremely

⇧ *Figure 16: The National Science Day Lecture on "Structural genomics: A new initiative on form and function of proteins" was delivered by Prof K S Vijayan on 28 February 2002.*

⇧ *Figure 17: Mr Justice M Ramakrishna delivered the Ninth Dr B R Ambedkar Birthday Lecture on 16 April 2002. The lecture proved to be a thoughtful articulation on the Indian constitution and Dr Ambedkar's many contributions to society.*

12. Twenty years of NAL-DLR cooperation / *Dr P R Viswanath*



The NAL-DLR cooperation dates back to the late 1960's and the 1970's, chiefly in the area of cascade flows and turbomachinery. On 30 January 1982, the CSIR/ NAL and DLR (then called DFVLR) signed a cooperative agreement to promote joint effort and collaboration in the area of aeronautics. It was agreed that special emphasis would be given to civil applications in the area of aerodynamics, structures, turbomachinery, systems and materials.

During the last 20 years this cooperation has flourished; it must surely rank among the most successful and durable international collaborations of all time. More than a dozen joint projects in different areas of aeronautics have now been successfully completed. The major achievements of the NAL-DLR cooperation include:

- Design, development and testing of a flightworthy Do-228 rudder using a novel fabrication technique
- Development of a variety of system identification algorithms for aircraft applications, a flight controller for the ATTAS in-flight simulator and exercises in flight simulation.
- Advanced computer codes for viscous flow analysis relevant to aircraft and application of laser based diagnostic techniques to complex flow problems.

The hallmark of the NAL-DLR cooperation has been the exchange of scientists. Over 100 NAL scientists have visited DLR institutes, for periods ranging from two weeks to ten months, and worked on mutually identified projects. Similarly, over 90 DLR scientists have visited NAL for short periods to work on the joint projects. The NAL-DLR cooperation has resulted in over 90 joint publications.

Another facet of this cooperation has been the organization of joint NAL-DLR workshops. There have been six joint workshops so far: in design aerodynamics (NAL, 1986), system identification (NAL, 1993), experimental fluid mechanics and turbomachinery (NAL, 2000), pressure sensitive paints (DLR, Goettingen, 2000), review of 20 years of cooperation (DLR, Berlin, 2001) and air traffic management (NAL, 2002). The technical seminar at Berlin in 2001 was really to celebrate these 20 wonderful years of cooperation.

The cooperation programme continues to be very active. Currently NAL-DLR joint projects are being pursued in the following areas:

- Air traffic management and simulation
- System identification with application to helicopters
- Multisensor data fusion for autonomous systems
- Advanced flow diagnostics
- Aviation noise.

13. Dr Kalam as President of India / *Dr T S Prahlad*

NAL is indeed very happy that the renowned aerospace technologist of the country, Dr A P J Abdul Kalam, is the President of the Republic of India. The association of Dr Kalam with NAL has been manifold. As Director of DRDL, he was Chairman of the Committee for National Trisonic Aerodynamic Facilities (COM-NTAF) of NAL during June 89 to July 97. As SA to RM, he was the Chairman of NAL's Research Council during Jan 98 to Dec 2000. In these roles, his involvement in the programme and technologies of NAL was very deep and he gave us tremendous encouragement. As Chairman of the Research Council, he appreciated NAL's work, but asked us penetrating questions. He knew what the NAL scientists could achieve given the right impetus. He reposed a great deal of faith in the capabilities of NAL in successfully leading national teams for the development of the LCA control law and the composite wing. I am glad NAL did not let him down in the technological challenges of LCA.

I have known Dr Kalam for a long time and have worked with him, first in VSSC during 1975-1983 and then at ADA after he became SA to RM. Dr. Kalam is undoubtedly a remarkable person; more than anything else, as a builder of great teams and as an integrator of human beings. He knows how to get extraordinary things done through ordinary people. He is a true system integrator, not just with technical elements, but with people whom he identifies as a very important component of the total system integration process. I personally believe that this enormous ability of people integration has been the true key to his success in all his missions. Over the last few weeks he has variously been identified as a 'missile man', a 'nuclear scientist' and by several other names. There is no doubt that his technical and leadership contributions have been immense in these areas. However, he would perhaps have been equally successful in any other mission of equal complexity and magnitude. He is a person who can enthuse people and bring the very best in them in his own inimitable simple and down to earth style.

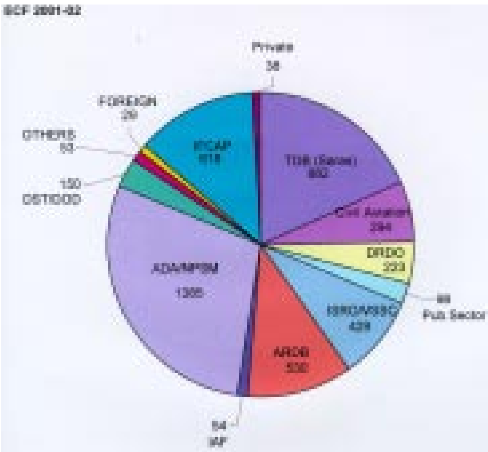
Dr Kalam is essentially a man of action and one hopes that he can do something really significant for the country from the Rashtrapati Bhavan, in addition to his constitutional duties. In the recent past, he has loved to interact with the children and the youth and is trying to kindle their imagination and enthusiasm for building the country. With his track record and his direct-to-heart approach, there is perhaps none better to do that job in the country right now. One trusts that Dr Kalam the President can continue to be Dr. Kalam the visionary and Dr Kalam the system integrator. The country certainly needs it.

delighted when we heard that Dr A P J Abdul Kalam would be elected the eleventh President of India (*Box 13*). Dr Kalam has been intimately involved with NAL for almost 20 years and the aerospace community feels privileged that one of their own has reached the highest office in the nation.

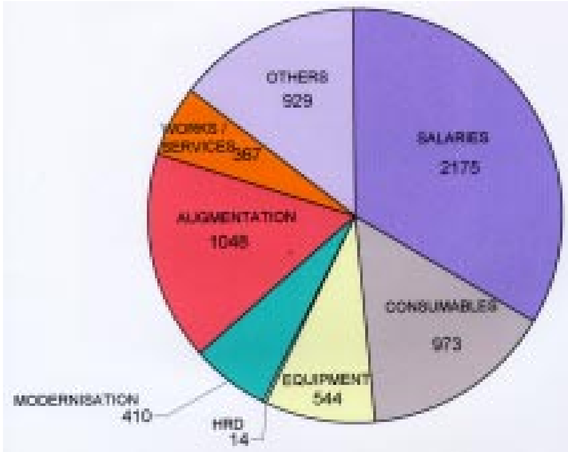
The passing away of Prof Satish Dhawan, the doyen of the Indian aerospace community, on 3 January 2002 has saddened us immensely. NAL occupied a very special place in Prof Dhawan's heart. Prof Dhawan was a father-like figure to me personally and it was my privilege to be his last Ph.D. student. We shall always deeply cherish our memories of this extraordinarily capable and affectionate gentleman (*Box 14*).

STATISTICAL SUMMARY

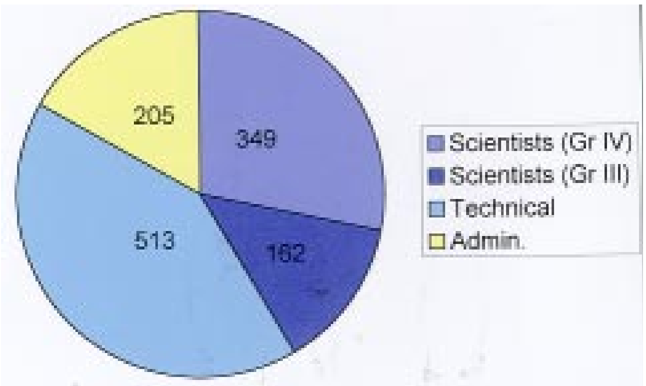
94 new sponsored projects (value: Rs 43.96 crores) and 29 new grant-in-aid projects (value: Rs 14.84 crores) were taken up during 2001-2002. Our external cash flow (ECF) this year was Rs 47.82 crores with the two largest contributions (see *Figure 18*) coming from ADA (Rs 13.85 crores; 29%) and the Technology Development Board (Rs 8.82 crores; 18%). The ECF, which dropped by 4%, continued to hover around the Rs 50 crores mark. NAL actually spent Rs 64.60 crores (*Figure 19*) in 2001-2002 (up 13% from the previous year). Salaries (Rs 21.75 crores; 34%), consumables (Rs 9.73 crores; 15%) and equipment (Rs 5.44 crores; 8%) taken together accounted for just under 60% of the expenditure. We also spent Rs 10.48 crores (16%) to augment our infrastructure; a necessary investment given that NAL is now over 42 years old.The NAL staff strength *(Figure 20)* as on 20 July 2002 was 1229. This includes



⇧ *Figure 18: Rs 47.82 crores were received from external sources in 2001-2002 (down by 4% from last year). The major contributors were ADA (29%) and TDB (18%).*



⇧ *Figure 19: NAL spent Rs 64.60 crores on its R&D programmes in 2001-2002 (up 13% from last year). Salaries accounted for a third of the expenditure; a sixth of the annual expenditure was for infrastructure augmentation.*



⇦ *Figure 20: NAL's manpower distribution. With retirements, the manpower has fallen well below the figure of 1300. 28% of a current total of 1229 employees are Group IV scientists.*

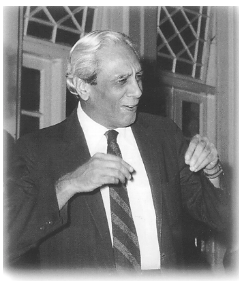
511 scientists (Group IV: 349 and Group III: 162), 513 in the technical cadre and 205 in the administrative cadre.

HONOURS

It is a pleasure to mention the many laurels won by my colleagues. Dr S Srinathkumar and Shyam Chetty (along with other scientists from CAIR, HAL, ADA and IAF) were awarded last year's coveted Aeronautical Prize from the Aeronautical Society of India for their contributions to LCA control law development. Dr Abhay Pashilkar received the 2001 CSIR Young Scientist Award for his work on unsteady aerodynamic modelling of aircraft. C V Srinatha Sastry's significant contributions to Kannada typeface software development and his efforts to popularize science and

14. Professor Satish Dhawan: A cherished association with NAL

Professor Satish Dhawan's passing away, on 3 January 2002 at the age of 81, saddened everyone deeply. He was NAL's best friend, its most respected adviser and a much-loved mentor. In an association spanning over four decades, Prof Dhawan was a member of NAL's Executive Council from 1962 to 1972 and the Chairman of NAL's Research Council from 1980 to 1994. His contributions in shaping NAL's future were decisive.



technology in Kannada received due recognition with the Kempegowda Prashasthi Award that he received from the city of Bangalore. Dr Somenath Mukherjee, Dr Harish Barshilia and Dr K S Rajam were among my colleagues who received best paper awards. Dr B K Parida was elected Professional Engineer and Chartered Engineer by the Institution of Engineers (India), Dr R M V G K Rao was elected a member of the Indian Institute of Chemical Engineers and Mr I R N Goudar took over as the Coordinator of AR&DB's Aerospace Information Panel. I congratulate all of them.

Dr T S Prahlad
Director

It gives me great pleasure to greet my successor Dr B R Pai. Dr Pai has just taken over as NAL's sixth Director. Being NAL's Director is both very challenging and very satisfying. As I vacate the Director's chair I feel confident that under Dr Pai's leadership NAL will scale even greater heights and attain the exalted position it richly deserves in the international aerospace R&D community.