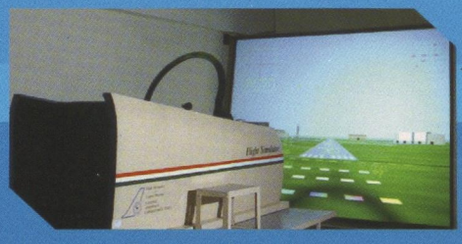
NAL 2008

(Science and Technology)



National Aerospace Laboratories

(Council of Scientific and Industrial Research)

Bangalore

Content

Foreword

The National Aerospace Laboratories (NAL) is celebrating its Golden Jubilee Year from June 2008 to May 2009. NAL was established in 1959 with the objective of developing aerospace science and technology, applying the same for national aerospace programmes and to foster the growth of aeronautics in the country. To achieve this goal, NAL began with a few divisions catering to disciplines such as Aerodynamics, Structures, Propulsion and Flight Systems. With the expansion of indigenous activities both in the defense and space sectors in the 1980's, NAL has further diversified and many more divisions catering to different disciplines, namely, advanced composite structures, high speed computing etc., were formed to meet the various requirements of user departments such as DRDO, ISRO etc., These divisions provided the critical scientific / technological inputs required for the design and development of many of the aerospace vehicles seen in flight currently. Apart from providing the necessary R&D inputs required, the divisions also looked into the future S&T requirements of the country and created the necessary knowledge base. They also kept track of developments elsewhere in the international arena and interacted with different aerospace R&D organizations from abroad. These activities have resulted in several publications in international journals and joint international programs and have made the presence of NAL noticeable in the International Aerospace scene. For promoting civil aircraft development in the country, a Center for Civil Aircraft Design & Development (C-CADD) was established and it has developed two passenger aircraft - HANSA and SARAS, the former a certified trainer aircraft and the latter a 14-seat Light Transport Aircraft (LTA) undergoing certification.

The Science & Technology Divisions of NAL have contributed significantly to indigenous technology and product development and have been the back-bone of many national aerospace programs. This booklet provides a glimpse of the past, present and future activities of these divisions.

Dr. A R Upadhya
Director

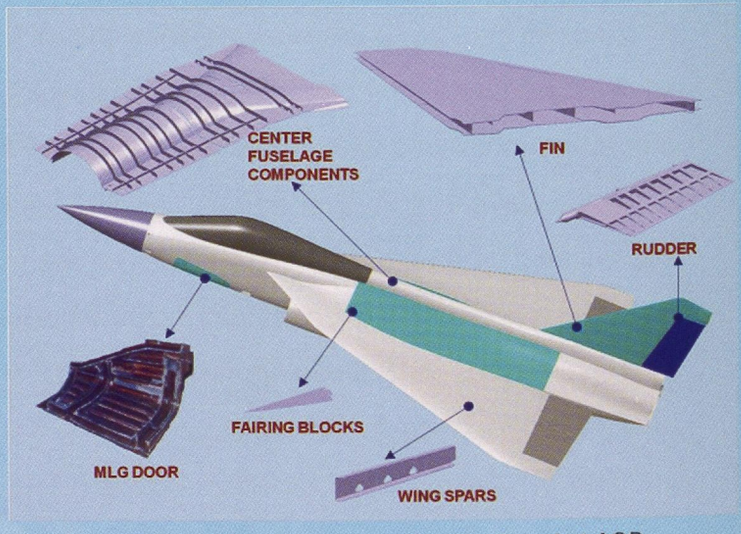
Advanced Composites Division

The focus in the Advanced Composites Division (ACD) is on R&D efforts leading to innovative techniques for the design, development, fabrication, testing, evaluation & certification of airframe structural components using composite materials.

The development of integral carbon composite components through co-curing / co-bonding fabrication technology has had an immense impact on the TEJAS (LCA) programme. This has been achieved through innovative manufacturing methods, novel Non-Destructive Evaluation (NDE) procedures for qualification, and has led ACD to contribute substantially not only to the Technology Development (TD) and Prototype Version (PV) series but also to the Limited Series Production (LSP) Phase of TEJAS involving supply to HAL of 8 sets of certified composite components / assemblies, each set comprising Rudder Assembly, Fin Assembly, Wing Spars, Wing Fuselage Fairing Skins, Wing Fuselage Fairing blocks, Centre Fuselage Components and Under Carriage Doors. ACD also furnished certified composite control surface components & Belly fairing for the prototypes version of SARAS aircraft. ACD has also developed in-house expertise in the development of autoclave technology. ACD has been recognized as a Centre of Excellence in Composite Structures Technology by the Aeronautical Research and Development Board wherein new technologies such as composite stitching, automated tape laying, and fibre metal laminates have been developed.

The need for weight reduction in the proposed Production Standard (PS) SARAS Aircraft has led ACD to take up the substantial tasks of supplying certified carbon composite horizontal & vertical tail, pressure bulkheads & wing besides other control surfaces. The thrust, no doubt, is on the design & development of the carbon wing. A newly evolved cost-effective Vacuum Enhanced Resin Infusion Technology (VERITy) has been proposed to be used for the fabrication of the wing. A test box has been fabricated and has successfully undergone the initial tests. Further work towards its implementation is in progress.

Notable strides have been made in the new and emerging areas of Structural Health Monitoring (SHM) and Adaptive Wing Structures based on Shape Memory Alloys (SMA). Applications based on these are being worked out for future aircraft development programmes. Also, new infrastructure including a state-of-the-art Autoclave Complex & Automated Tape Laying System would be set-up with a view to promote cutting edge airframe composite components development for TEJAS derivatives, SARAS as well as the proposed Regional Transport Aircraft.



Tejas composite airframe components developed at ACD.

Photographs of the SARAS wing testbox fabricated using the new Vacuum Enhanced Resin Infusion Technology (VERITy) Process.

Aerospace Electronics and Systems Division

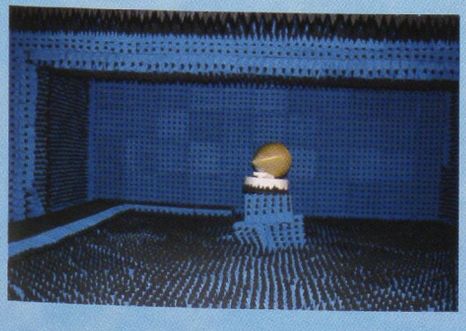
Aerospace Electronics and Systems Division (ALD) core strength is in design and development of flight critical systems with DO 178B safety critical software including Independent Verification and Validation (IV&V). Apart from this, division has major programme on Active Noise Control for aircraft cabin and industrial applications. Electromagnetics is also one of the major activities of the division. Division's focus is on the areas of aerospace electronics, active noise control, Electromagnetics and critical flight data analysis and validation.

Division is involved in aerospace and industrial electronics activities and later focus has been towards the core aerospace activities like the avionics design, active noise control, flight data analysis, Electromagnetics, flight critical software development, design and development of avionics cabinets or called as avionics processing computer. Avionics suite of SARAS was successfully architected, integrated and tested on SARAS Prototypes I & II, which flew about 141 test sorties successfully. The functional and aircraft level tests have helped in establishing in ascertaining the performance of various systems for their qualification. India's' first full life cycle DO 178B level A civil certification for SARAS Stall Warning System (SWS) with indigenous design and development of software. Extensive work has been done in the are of Flight Data Analysis and Animation, successfully completed the NAL Visualization and Animation Software (NALVAS) and its integration with the NAL Flight Operations Quality Assurance (NALFOQA) software. Scientific investigations were pursued in the areas of Active Noise Control and Signal Processing to utilize and expand the capabilities to serve the application requirements aptly backed by concurrent applied research activities. Establishment of Acoustically Treated Room for ANC experiments. Major national radome projects viz., Radome for Jaguar aircraft, Ceramic radome and TU Radome were completed successfully in 2007-2008. SARAS Nosecone radome qualified the lightning protection tests conducted at CABS. Establishment of *NAL-Microwave Anechoic Chamber* (NAL-MAC) is one of the major achievements of the division.

Division is involved in major programmes like Digital Autopilot, Engine Indication Crew Alerting System (EICAS), Flight Data Analysis Software called NALFOQA and NALVAS, Active Noise Control for aircraft cabin and cockpit, Electromagnetics and sophisticated calibration standards. Division is playing a very major role in SARAS for complete avionics system design, integration and flight-testing. Major drive is given for the indigenous development activities particularly the avionics systems that are of flight critical in nature. Efforts are being focused on design of intelligent neural network based intuitive diagnostic and health management system for aircraft systems.

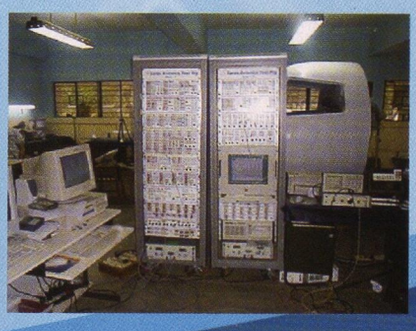
The advances in aviation technologies provided avionics computers with increased processing and communication power and combine multiple federated applications into a single shared platform. The Integrated Modular Avionics (IMA) was developed for integrating multiple software components into a shared computing environment. Division's one of the major planned activity is design and development of open architecture Integrated Avionics Processing System (IAPS) for typical civil aircraft avionics applications. Indian civil aviation industry demands expertise in the area of design and development of flight critical software development for airborne applications. One of the strengths of the division is the design, development and IV&V activities for airborne applications as per DO 178B Level A standards. Other major activities planned are the enhanced active noise control system and Electromagnetics.

NAL-Microwave Anechoic Chamber (NAL-MAC).



ANC setup inside the enclosure.

Avionics Ground Test Rig for integration testing of SARAS Avionics suite.

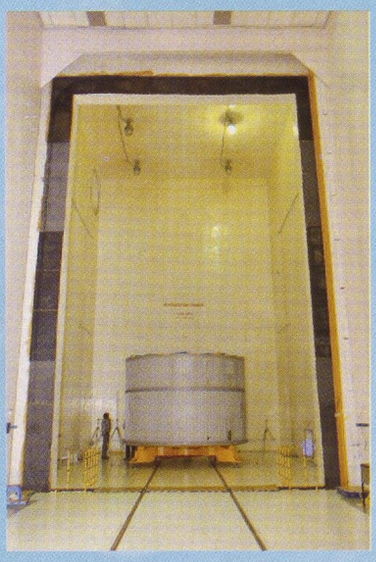


Acoustic Test Facility

The Acoustic Test Facility (ATF) is a national facility for acoustic environmental qualification testing of satellites, launch vehicle stages and their subsystems for the ISRO. The ATF has a 1100 cu.m. reverberation chamber in which a maximum sound pressure level of 157 dB (controlled) can be generated. ATF has conducted more than 120 tests. In addition to acoustic testing, ATF has the following capabilities.

ATF has developed a jet noise generator capable of producing high frequency random noise in the range above 2 kHz, where no generators are available. This device is ideally suitable for simulation of spacecraft/launch vehicle subsystem acoustic environment in reverberant chambers due to the random nature of acoustic energy generated instead of discrete frequency energy. This also finds applications in high frequency noise environment testing for aerospace and automobile industries.

- Vibration and Strain measurements on Spacecraft, Launch Vehicle stages and sub-systems using state-of-art transducers, signal conditioners and analysers.
- Customised design and development of special acoustic instruments like high level, multiple frequency acoustic calibrator.
- Ground vibration, displacement and acoustic measurements for specialised applications-LSI and VLSI equipment installation areas etc., as per customer requirements.
- Experimental support for aero-acoustic and acoustic fatigue activities.
- Noise modelling for area around airports, Noise contour generation and traffic noise modelling.
- Environmental and Industrial Noise pollution measurements.
- Consultancy services for noise reduction in high noise areas.
- Certification agency for noise type approval as well as conformity of production certificates for petrol and diesel generator sets.



Specimen in the Reverberation Chamber.

Jet Noise Generator

- **Reverberation Chamber**

Geometry	: Rectangular
Volume (cu.m)	: 1100
Dimensions, l*b*h (m)	: 10.33 * 8.2 * 13

- **Acoustic Parameters**

Maximum Overall Sound Pressure Level (OASPL) dB	: 157 (Ref. 20 m Pascals)
Frequency Range (Hz)	: 25-10,000
Distribution, OASPL (dB)	: ±1 in central 10% volume

- **Data Instrumentation and recording**

Acoustic measurement	: 13 Ch.
Vibration measurement	: 128 Ch.
Strain measurement	: on request

- **Analysers**

Real-time analysers	: Bruel & Kjaer, L & D, PROSIG

- **Clean room facility**

Class	: 100,000
Clean room area	: 120 Sq. m

- **Specimen handling and transportation**

Monorail crane	: 5 tonne
EOT	: 5 tonne
Specimen transport trolley	: 10 tonne with rail system for movement into the chamber.

Centre for Civil Aircraft Design and Development

Charter and Focus

- To bring under one roof the civil aircraft development project optimally utilising the available resources.
- To plan in advance other projects such as 5 seater general aviation aircraft, regional aircraft etc.
- To study airworthiness and certification aspects and liaison with DGCA.
- To plan technology development and to promote forward looking research relevant to civil aviation.
- To promote development of civil aircraft industries through transfer of technology.

Significant Achievements in the Past

- HANSA –3 obtained its Type certification in 2000.
- 12 HANSA aircraft are produced and delivered to DGCA (total flight hours logged ~300 hrs), IIT Kanpur and one aircraft is presently at Australia for CASA certification.
- SARAS PT-1 first flight in May 2004.
- SARAS PT-2 first flight in April 2007.
- 123 flights completed on SARAS PT-1 and 20 flights on SARAS PT-2 aircraft.
- Participated in all the editions of Aero India, three editions of Singapore Air Show and once each in Dubai Air show and Aviation Airshow in Australia.
- Five seater General Aviation aircraft development jointly with private industry (Mahindra Aerospace Technologies) launched in 2006.

Current Activities

- Production of HANSA –3 and providing product support to users.
- To obtain Australian Type certificate for HANSA-3.
- Continuation of test flights with SARAS PT-1 and SARAS PT-2.
- Manufacture of SARAS production standard aircraft.
- Feasibility studies for development of a Regional Transport Aircraft – RTA70.

Future activities Planned in the 11th Five Year Plan

- To complete all necessary ground and flight tests on SARAS PT-1, PT-2 and PSA required for Type Certification
- Efforts towards finding industrial partner for both HANSA and SARAS.
- To complete design and development of 5 seater general aviation aircraft and obtain its Type Certification in India and outside.
- Development of RTA.

NM5-100

HANSA – 3 in flight with Type Certificate (inset)

SARAS PT-1 in flight.

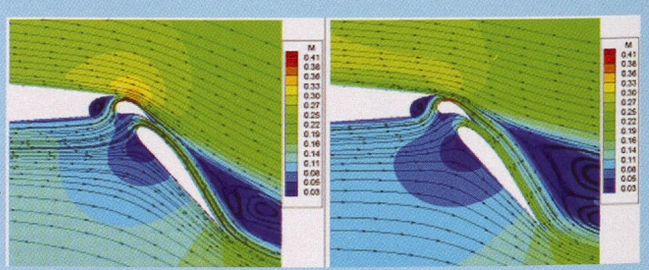
Computational and Theoretical Fluid Dynamics Division

The Computational and Theoretical Fluid Dynamics Division has been engaged primarily in the development and application of Computational Fluid Dynamics (CFD) software for the simulation of complex fluid flows. The emphasis has been in terms of both the complexity of the flow physics as well as geometrical complexity. There has also been a smaller but significant effort in the development of theoretical and analytical techniques for the analysis of certain categories of flow problems.

In the past twenty years, the Division has developed a hierarchy of CFD codes capable of simulating the flow past realistic configurations like aircraft, launch vehicles and naval vessels. The codes range from panel codes to Navier-Stokes solvers and cover the entire flow regime ranging from incompressible flow to hypersonic flow. These codes have been widely used for the analysis of NAL's in-house HANSA and SARAS aircraft projects, as well as for sponsored projects from organizations like DRDO, ISRO, IAF, HAL and ADA. Significant achievements have been the simulation of flow past complete aerospace vehicles like SARAS, Mig-29, RLVTD, LCA etc. The Division has also developed expertise in grid generation for complex configurations, using both in-house developed codes and commercial software. Detailed computational studies have also been carried out for problems like the flow in a driven cavity, where the geometry is simple but the flow is complex. Theoretical and semi-analytical methods have been used for problems like aircraft wake vortex interactions, sloshing of liquids, cavity flows, free surface flows etc.

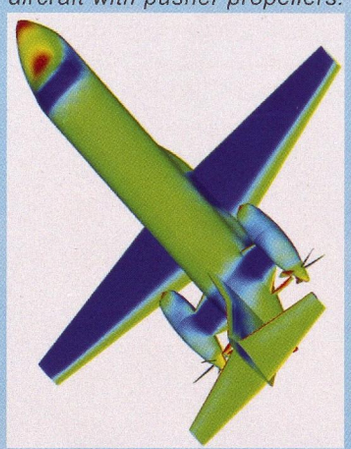
Presently, the Division is involved in many activities including CFD analysis for the design of a 500 kW wind turbine, aerodynamic shape optimization, studies on turbulence models, transition and large eddy simulation, unstructured grid and grid-free computations for complex applications, theoretical methods for surface waves, grid generation for aircraft configurations, and flutter prediction in turbo-machinery. The Division is also supporting the SARAS project in analyzing the propeller effects as well as analysis of aerofoils and high-lift devices for the RTA project.

Activities planned in the near future include the study of free surface effects for flow past ships, grid-free methods, flutter and aero-elasticity problems involving fluid structure interaction, multi-disciplinary shape optimization, unstructured grid based flow solvers for aerospace applications, unsteady flows for three-dimensional configurations, real gas effects in hypersonic flows, computational aero-acoustic methods for jet noise simulations and vortex methods for three-dimensional applications.

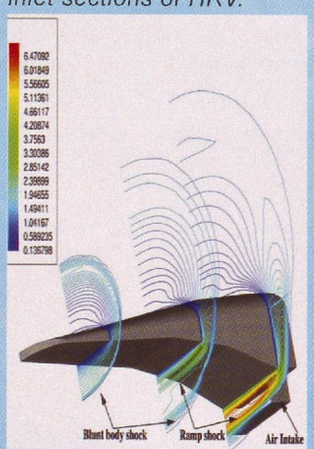


Mach contours and stream lines for double slotted airfoil configuration.

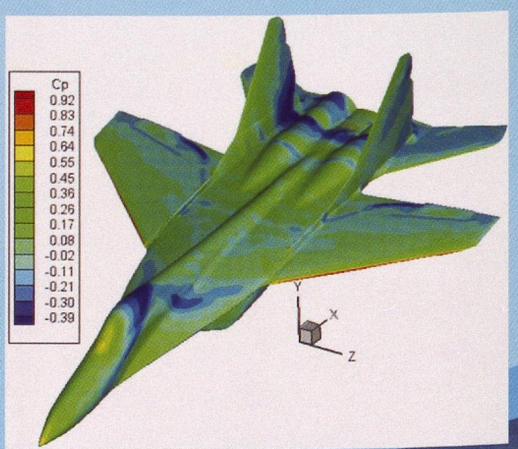
Pressure distribution over SARAS aircraft with pusher propellers.



Density Contours at different inlet sections of HRV.



Computed Pressure distribution over Mig 29.



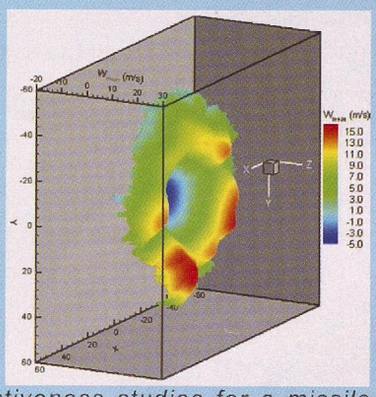
Experimental Aerodynamics Division

In the Experimental Aerodynamics Division, a major emphasis has been to understand the physics of complex flows by the use of novel flow diagnostic techniques and generation of aerodynamic data for the development of advanced design concepts and flow modeling. The division strives to carry out innovative research in three disciplines. These are Aircraft and Spacecraft Aerodynamics, including intake, afterbody and base flows; Civil Aircraft R&D, including high-lift aerodynamics, flow control and drag reduction methods and Flow Diagnostics which involves the development and application of several measurement techniques like Particle Image Velocimetry (PIV), Pressure Sensitive Paint (PSP), Laser Doppler Velocimetry, and Background Oriented Schlieren (BOS), in addition to traditional flow measurement techniques.

The division has contributed significantly to the aerospace projects in the country in addition to basic research in aerodynamics. Important achievements in low-speed flows enumerate successful turbulent skin friction drag reduction on airfoils and wings using riblets; control of flow separation by direct manipulation of shear layer reattachment; understanding scale effects of relaminarization on swept wings and aerodynamic streamlining of transport bus configuration for fuel savings. In high speed flows, boat-tailing concepts to reduce afterbody drag and understanding the onset of buzz in aircraft intakes are among the notable achievements. In addition, work has resulted in the development and extension of several new and novel ideas in flow diagnostics which have resulted in application of these techniques to complex fluid flows relevant to the country's aircraft and spacecraft program for improved understanding. Among others, these comprise of the development of resection-based image processing software for the PSP technique with recent application on the Tejas model and a quantitative Schlieren technique for density measurements in high-speed flows.

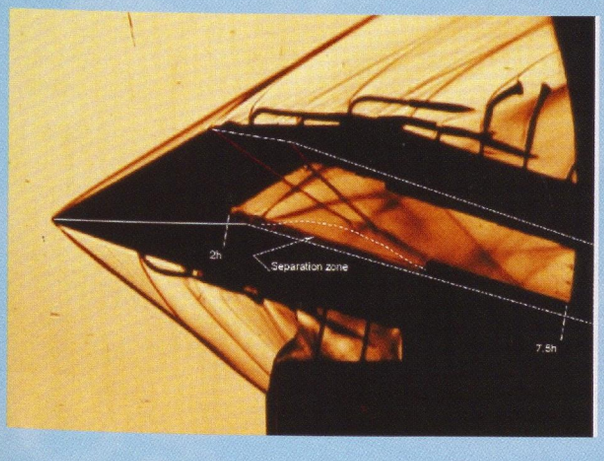
The division is now actively involved in several areas with a focus towards emerging requirements of the country's aerospace programs. Some of these are: high-lift research for the new Regional Transport Aircraft, low-Reynolds number aerodynamics for micro-aerial vehicle (MAV) design, base-flow and nozzle studies for launch vehicle aerodynamics, intake design for hypersonic vehicles and applications of flow diagnostics to understand flow mixing in gas turbines. Additionally the first ever facility in the nation for jet aeroacoustic studies is being set up in the division.

To be prepared for the future needs of the nation, the division is emphasizing new areas of expertise in addition to strengthening the current capabilities. Activities to be taken up include active flow control, jet noise suppression, mixing enhancement in jet flows, improved intake design for space vehicles, airfoil studies for MAVs and novel non-intrusive flow mapping techniques. These efforts will help to provide the forward-looking R&D required for supporting new aerospace activities.

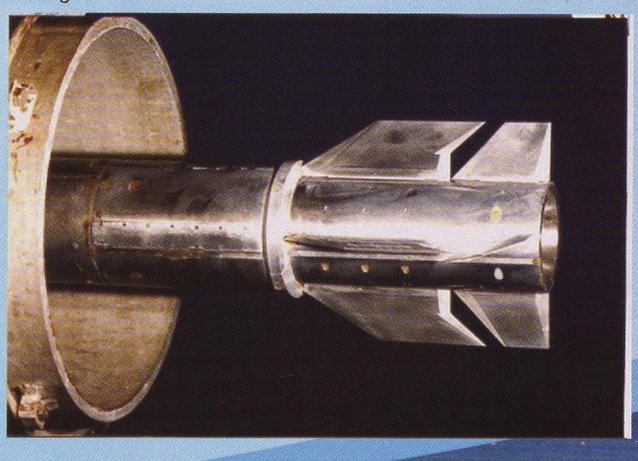


Surface plot of axial velocity field.

Schlieren studies of the flow inside the intake duct.



Control surface effectiveness studies for a missile configuration.



Flight Mechanics and Control Division

In the 1980s, activities in Flight Mechanics & Control were started in the Systems Engineering Division to cover aerodynamic modeling, study of vehicle stability, rigid body trajectory analysis and control system synthesis. The group's collaboration with the Institute for Flight Mechanics, Braunschweig under the CSIR–DLR agreement initiated in 1984 played a major role in maturing the Flight Mechanics activity at NAL. During this decade, the group undertook a number of projects for the nation involving flight test planning, flight data acquisition and analysis for parameter estimation, prior to DOF simulation and control law analysis. Based on the contributions made, Flight Mechanics and Control group became a scientific division of NAL in 1990.

In the Ninties, the division's major contribution was in leading the National Control Law team to successfully design and develop the Control laws and Airdata algorithms for the Light Combat Aircraft. Towards this goal, an Engineer in the Loop Simulator (ELS) was set up and successfully used for CLAW design and evaluation. The successful first flight of LCA in January 2001 and 900 plus incident free flights subsequently on 6 prototypes bears testimony to the competence built up in the area of flight control, simulation, and identification of fixed wing aircraft. The division bagged CSIR technology shield during the year 2003. Two more new research areas namely simulation of Air Traffic Management and Multi Sensor Data Fusion were initiated during this decade.

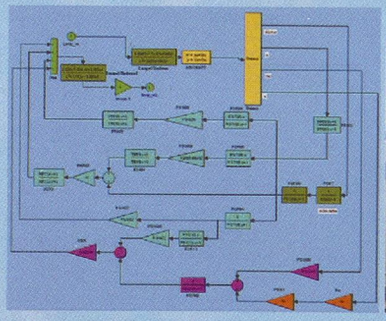
The division is actively engaged in Research, Development and Technology advancements in the areas of Flight Control and Flight Simulation, Modeling and Parameter Estimation, Multi Sensor Data Fusion and Air Traffic Management. It is contributing significantly to two National level aircraft programs namely SARAS and TEJAS.

Design of the SARAS Autopilot is a major program undertaken in collaboration with a private company. SARAS Flight Training Device for Pilot training is also being set-up in the division in partnership with a private company. Well-established parameter estimation techniques developed in the division are being used to estimate the parameters of the aircraft from flight.

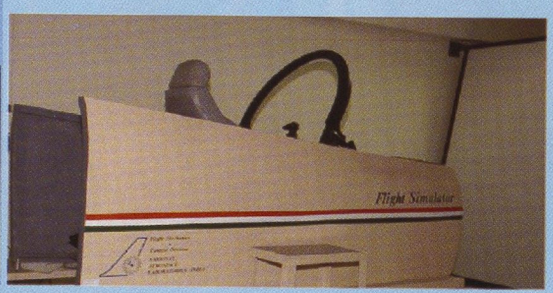
For the Tejas program, the National Control Law Team with NAL/FMCD leadership continues to make significant contributions for both the Air force and Naval Variants. LCA model validation using advanced parameter identification methods is being carried out to allow faster flight envelope expansion. New techniques are being developed for high angle of attack flight, and this poses many scientific / technological challenges, as the dynamics is highly nonlinear.

The current emphasis in national and international aeronautical research and development is towards micro and mini unmanned air vehicles. To meet these requirements, research and development is being initiated in the area of simulation, modeling and control of small air vehicles. This activity is being catalysed by the United Kingdom India Education Research Initiative which has granted a major award to University of Leicester in partnership with IISc/ NAL/IIT(B)/NIT(T).

Control Laws, Auto Pilot Aircraft - Pilot Interaction



Artificial feel Six Degree of Freedom Departure & Spin Studies



Air Traffic Simulation High fidelity visuals Capacity Studies

Flosolver Division

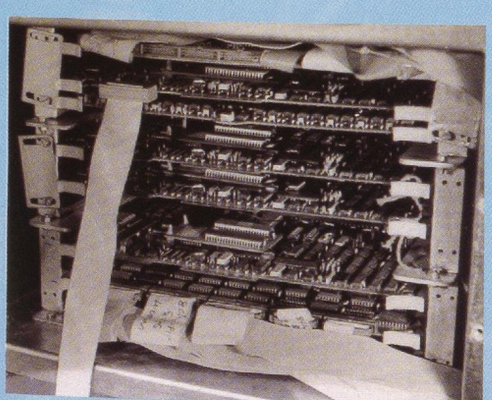
The Flosolver project was started in the year 1986 when the computational fluid dynamists at NAL were starving for computing power due to the restrictions imposed on importing powerful computers to the country. As an indigenous solution to the problem this project was started with an objective to design, fabricate and develop parallel computers, an emerging technology then, for use in fluid dynamical and aerodynamical problems and hence the generic name Flosolver. Thus the first parallel computer of India, Flosolver Mk1, was built in 1986. The charter and focus has been to use state-of-the-art processors and other hardware available to keep developmental cost low, make the best use of available sequential software to obtain quick returns on hardware investments, secure the maximum possible raw computing power for a unit investment, keep in pace with the technology development and achieve concurrent application software.

During the last two decades the unit has developed six generations of parallel computers, Flosolver Mk1 to Mk6, and customized software applications, each with a performance far surpassing that of the previous generation. On the hardware front the highlights are 1) successful usage of Multibus I & II for communication in Mk1 and Mk2, 2) execution of NAL's first project under the New Idea Fund scheme of CSIR entitled "Alternate design of high performance CPU card without secondary cache", 3) design and development of an intelligent communication device, the FloSwitch which makes the architecture scalable for tightly coupled problems such as global climate models, DNS and panel codes, and 4) design and development of the FloOptiLink, a versatile communication device for large-scale integration. On the software side, a variety of codes from different fields within the country and abroad were parallelized. Mention may be made of 1) PABAS (parallel *ab initio* atomic base simulator) and PACAL (parallel circuit simulator) of Hitachi, Japan, 2) optimization and parallelization of a multi-grid Navier-Stokes solver of JNCASR (Jawaharlal Nehru Centre for Advanced Scientific Research) for calculating internal flow in a pipe with a super-linear speedup of eleven on an eight-processor system, and 3) development of VARSHA GCM, a hydrostatic, spectral weather prediction code which incorporates features of tropical physics, flexibility of scales, higher precision and software engineering.

Under the NMITLI ((New Millennium Indian Technology Leadership Initiative) scheme, Flosolver led a national team *"to design and develop a 128 processor parallel supercomputer incorporating the new high speed switch and optimized to run the new monsoon prediction software and other popular mesoscale codes"* and completed it successfully. This resulted in the award of the second phase of the above program jointly supported by Ministry of Earth Sciences. The objectives are to develop a ten Teraflop parallel computing hardware customized for meteorological applications and an enhanced version of the Varsha GCM for better forecasts of the Indian monsoon, which is important to the country.

The Flosolver Unit will continue its work in the field of integrated development of hardware and software for meteorological computing. Studies in many exciting new directions such as multi-precision computing, coupled models, innovative inter-connect strategies, high performance visualization are being planned. It is evident that the hardware and software developed will find direct use in "flow solvers" used for aerospace applications.

The new FloOptiLink communication device with 16 channels.



Flosolver Mk1. India's first parallel computer developed in 1986.

The 128 processor Flosolver Mk 6 and the results of computations made using the Varsha GCM.

Fibre Reinforced Plastics Division

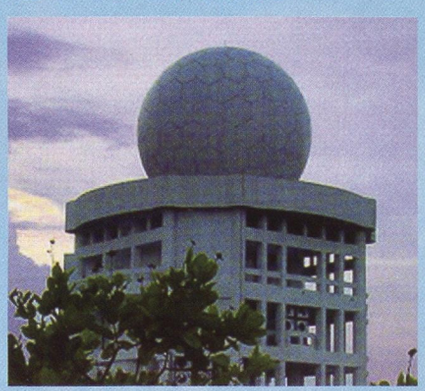
The Fibre Reinforced Plastics Division as the country's premier and multifaceted R&D center indigenized wide spectrum of composite products for the aerospace, non-aerospace and societal sectors, using cost effective home grown technologies, supported through concurrent applied research programmes. The FRP Division continues to perform with its committed motto "simplistic technologies even for high-end composite products", with emphasis on economy and environment. Today, the "cutting-edge technologies" also imply "cost-effective technologies", meaning "the technologies while serving the very purpose of their development, should also offer spin-off benefits, to compensate for their rapid obsolescence on one hand, and serve the socio-economic cause on the other.

Over the past 4 decades, the Division realized products like the all composite 2 seater trainer HANSA-3, variety of Radomes for both ground based and airborne radars, Large Domes for Air Combat Simulators, Carbon Composite High Speed Wind Tunnel Models of the LCA (the TEJAS), Composite Wind Turbine Blades, as well as the CFRP Rotor Blades for high pressure ratio compressor, CFRP Components (viz., the reflectors, antenna feed brackets, feed components), to name a few. In parallel, the Division made quick forays into the emerging and futuristic rapid moulding (resin injection/ infusion) and rapid curing (radiation cure) technologies, coupled with development of associated high performance matrices and special forms of reinforcements. The Division is well equipped with sophisticated material characterization equipments like DSC-TGA, DMA, FTIR, Curing ovens, INSTRON-UTM, DYNATUP-Impact tester, as well as a dedicated Environmental test facility for qualification of aerospace and non-aerospace components.

The FRP Division has initiated R&D activities for the development and application of nano-structural composites, conductive composites, metal-fibre composites, rapid manufacturing technologies incorporating machine impregnated just-in-time prepregs (JIPREGS).

Also the Division is set to initiate developmental activities on new sponsored programs, such as CFRP components for SATCOM program and DMSAR Antenna of SAC-ISRO and MARK-II radomes for the DWRs (BEL-ISRO-IMD). The scientific expertise with a firm R&D base has been established at the FRP Division, to meet these immediate and futuristic challenges posed by the aerospace industry of the country.

Mark-1 Radome for the DWR.



Jaguar Nose Radomes.

Twin Domes for Air Combat Simulator (IAF).

HANSA-3 Aircraft.

300 kW Wind Turbine Blade.

Materials Science Division

The activities of the division is directed towards development of materials for aerospace applications, characterisation of materials and rendering materials related engineering and technological services to aerospace community. The division is engaged in synthesis and processing of metallic materials, ceramics, polymers and fibres. One of the major activities of the division is failure analysis and accident investigation and testing and qualification of materials.

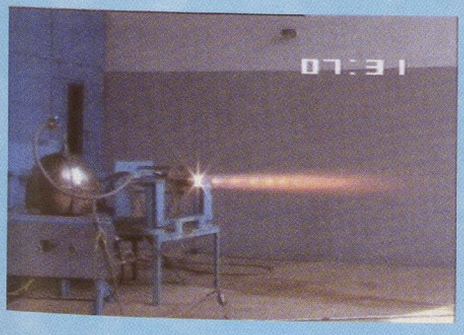
Some of the major achievements of the division was investigation of behavior of various materials under high pressure. Synthesis and characterisation of infra red transmitting and other chalcogenide glasses have been extensively studied. The division has developed a number of high strength, high modulus fibres derived from aromatic polyamide. Several high performance matrix materials like epoxy resins, cyanide ester resins have been synthesized and characterized. Technology for manufacturing of unidirectional carbon fibre epoxy prepregs has been developed. Structural ceramics is another area where the division has made significant progress. The fabrication of ceramic radomes for missiles is one such development. The division has carried over 1100 cases of failures and accidents.

In the recent years, the focus of activities of the division has shifted towards functional and smart materials. Development of products using Shape Memory Alloys is being pursued actively. Products like wires of different diameters, couplings, links, etc. have been developed from shape memory alloys. Preparation of high quality piezo ceramic powders is being carried out on a pilot plant level. Efforts are also on to develop high figure of merit thermoelectric materials, thermoelectric coolers and generators. Novel processing techniques like mould less casting of ceramics are being developed. In the area of high temperature structural materials for aerospace applications, development of ceramic matrix composites is in progress. Chemical Vapor Infiltration method is being adopted for this purpose. A major activity of the division is the development of several grades of carbon fibres. A new state of the art Runway Visibility Range Measurement System – Drishti has been commissioned in several airports. The failure analysis and accident investigation is being continued. A new state of the art laboratory has been set for this purpose.

Several new activities were initiated in the 10 FYP and most of these activities have entered a phase of consolidation. The major thrust in the 11 FYP would be to develop products for specific end uses. R&D activities primarily aimed at improving processing technologies in most of the areas listed earlier will be initiated.

Integrated Facility for Carbon Fibre.

Zirconia based ceremet convergent-divergent nozzle being tested.



NiTi SMA frangi-bolts for space deployment.

Isothermal Chemical Vapour Infiltration reactor facility established at NAL.

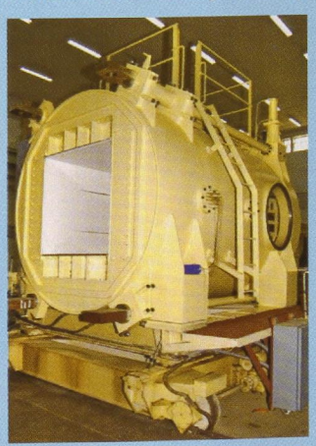
National Trisonic Aerodynamic Facilities

The charter of NTAF is to provide quality experimental aerodynamic data in the range of Mach numbers 0.2 to 4.0, required for the national aerospace programmes such as the Light Combat Aircraft programme of DRDO, Launch vehicle development programmes of ISRO, the SARAS aircraft of NAL and aerospace vehicles being developed by other User organizations. The focus is on experimental technique developments and measurements of aerodynamic force, moment, steady and unsteady pressures as well as mechanical design of models and support systems required to meet the requirements. The 1.2m trisonic blowdown wind tunnel is the main workhorse for all the major national aerospace programmes.

NTAF has contributed very significantly to the Integrated Missile Development Programme of DRDO through extensive wind tunnel tests on all the configurations. Most of the experimental aerodynamic data on the LCA Air Force and Naval versions are from the 1.2m wind tunnel. All the launch vehicles developed by ISRO since inception, such as Rohini, SLV, ASLV, PSLV, GSLV, etc have been thoroughly tested in this facility. Special test rigs and techniques, many of which have been done for the first time in blowdown wind tunnels in the world, have been developed by NTAF. Some of them are, the multi-booster separation trajectory rig and Semi-Captive Technique for the PSLV and ASLV, Forced oscillation rig for measurement of pitch and yaw damping derivatives, Roll damping rig for spinning models. Besides these, special techniques for measurements of unsteady pressures, special balances for hinge moment on components, flexures to measure flow induced unsteadiness, etc. have been successfully developed. Recently, the facility has been augmented with a new compressor house, an automatic balance calibration rig, a twin roll model support system, a spherical pressure vessel, a slotted wall test section, a half-model support system and balance and an additional model cart.

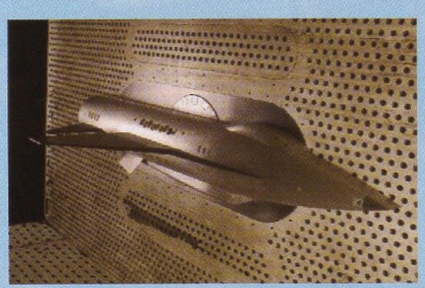
The current activities of NTAF are focused on data generation for the LCA of ADA, RLV of ISRO and HSTDV of DRDO. Special systems needed for these missions are being designed, developed, fabricated and tested.

One of the important activities for the future is to enhance the test envelop of NAL 0.6m transonic wind tunnel to the Mach number range 1.0 to 4.0 using a Variable Mach number Flexible Nozzle (VMFN). The single jack hydraulic drive enables the VMFN to be started at a low Mach number and gradually increase up to 4.0 and follow the reverse path while stopping, to avoid high starting and stopping transient loads inherent with blowdown tunnels. The facility is likely to be operational in a few months.

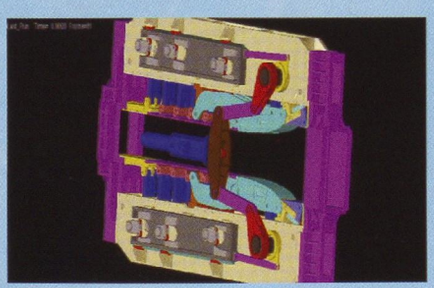


Slotted wall test section for tests at high subsonic Mach numbers.

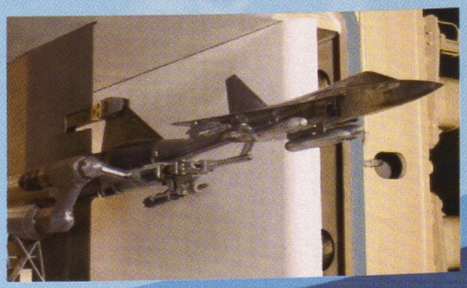
Half-Model Support System.



Variable Mach number Flexible Nozzle.



Captive Trajectory system for studies on stores separation from aircraft models.



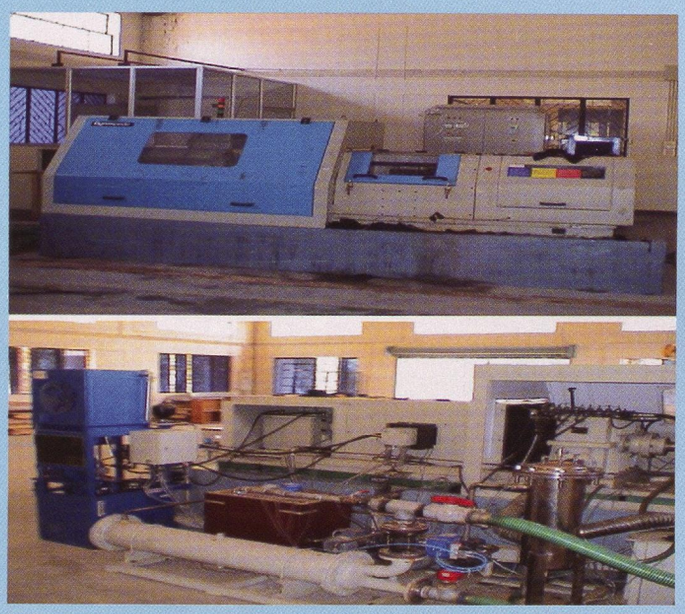
Propulsion Division

The Propulsion Division is involved in applied research pertaining to Turbomachinery, Combustion and Heat Transfer, Mechanical Aspects of Turbomachinery as well as in the Design/Development of Propulsion and Energy Systems. It gives R&D support to the country's National Aerospace Programmes being carried out at the Gas Turbine Research Establishment (GTRE), Defence Research and Development Laboratory (DRDL), Vikram Sarabhai Space Centre (VSSC) and the Liquid Propulsion Systems Centre (LPSC) besides taking up grant-in-aid projects from the Aeronautical Research & Development Board. International collaborative programmes with Pratt & Whitney, USA and Canada are also being carried out.

The Division has made significant contributions to the development of the Kaveri engine for Tejas. These include development of the afterburner flameholder and ignitor, main combustion chamber, controlled diffusion aerofoils for the fan and squeeze film dampers. Advanced supersonic combustors for the High Mach Number Flight Demonstrator Vehicles of VSSC & DRDL have been developed. A versatile High-Speed Combustor Test Facility has also been set-up. A National Test Facility for Rolling Element Bearings with the dual purpose of testing indigenously developed synthetic aviation lubricants and aerospace quality bearings has been commissioned.

The current activities include the development of active magnetic bearings, micro-gas turbines, Wankel engines for UAVs, novel afterburners, advanced ramjet/scramjet combustors, advanced compressors, ultralight helicopters, micro-air vehicles and the testing of synthetic aviation lubricants and rolling element bearings. The collaborative R&D programmes with Pratt & Whitney Canada & USA on gas turbine technologies, specifically related to turbomachinery aerodynamics, combustors and heat transfer are being actively pursued.

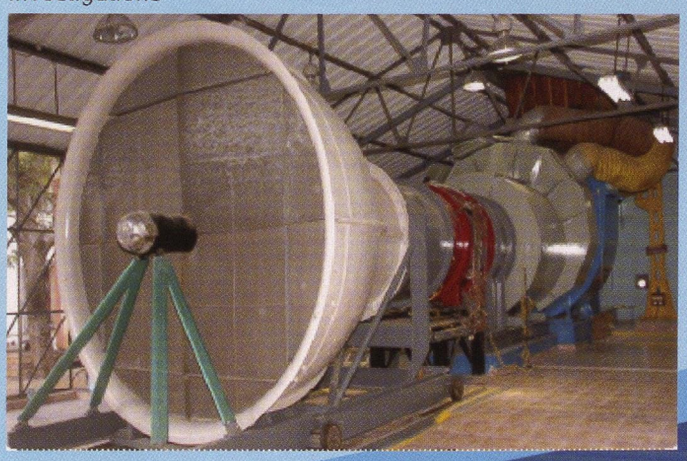
Future activities will include development of technologies for advanced gas turbines and ramjet/scramjet combustors pulse jet and foil/magnetic bearings. A small gas turbine test bed and a versatile turbine test bed will be set up and the high speed combustor test facility will also be augmented.



Rolling Element Bearings Test Facility – Fatigue Rig.

High-Speed Combustor Test Facility.

Test Rig for Turbine and Compressor Aerodynamic Investigations



Structural Technologies Division

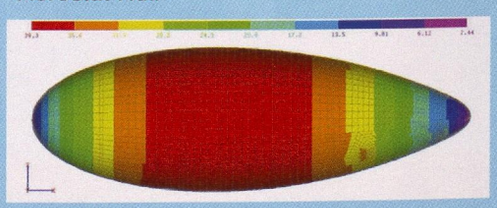
Structural Technologies Division is primarily in Research and Development Programmes in Structural Design, Analysis, Testing and Certification of Aerospace/Mechanical Structures. The specific areas of emphasis are aeroelastic modeling and testing of aerospace vehicles, development of numerical techniques like Finite Element Method with smart material concepts for structural control, state-of-art analysis, testing, design and optimization of aerospace vehicles/structures, impact & crashworthiness studies, evaluation of mechanical properties of aerospace materials, evaluation of airworthiness & flight safety including Full Scale Fatigue Test (FSFT) and Structural Integrity Assessment.

The division has come a long way since its formation and has responded to the changing needs of the aerospace community and has grown to become one of the largest aerostructures establishments in the country. The division has expertise in addressing aeroelasticity problems and has been involved in design, fabrication and testing of aeroelastic models for all the major launch vehicles developed in the country from SLV through gSLVM3. Developmental programmes for structural testing culminated in development of Manual Multipoint Apparatus (MAMPA) through semi automatic to Computer Aided Vibration And Test Analysis System (CAVITAS). Structural analysis activities not only provided support to major aircraft (HANSA & SARAS) and aerospace programmes in the country but also contributed a library of new and powerful family of field consistent elements which served as input library for the Finite Element Package for Analysis of Composite Structures (FEPACS). The expertise of the division in designing scaled wind tunnel models and design & development of indigenous large Autoclave systems are well recognized. The division has made significant contributions in design and analysis of ground based, airborne and missile radomes.

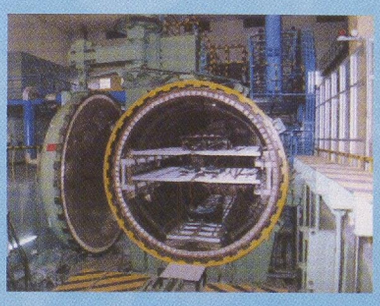
Currently, the division is engaged in SARAS aircraft design optimization studies, testing and certification of airframe structural materials/components of SARAS, HANSA and LCA. The division has built up expertise for dynamic characterization of aerospace/industrial structures using modal analysis and vibration qualification tests and also impact and crash studies on aerospace components. The Re entry Launch vehicle (RLV) design analysis activity is taken up on the proto model to establish not only its strength requirements but also its flutter characteristics in subsonic and supersonic regimes. Smart structure activities for development of multi channel active vibration control system using smart actuators for aerospace applications and investigation of structural health monitoring concepts for aeroelastic instability and active vibration control for Launch vehicle components are also being studied. New infrastructure and facilities are being developed and augmented continuously to meet the demands of structural testing.

The division has identified a number of thrust areas consistent with goals of the Laboratory and its major focus will be on enhancing the performance of civil aircraft structural components. To this end, some of the areas identified include: Design and analysis of smart structural systems, Vibro acoustic modeling and analysis, Advanced studies on the development of impact resistance and crashworthy aerospace components and materials, damage tolerant design concepts of aircraft structures using simulations and tests, Prediction of flutter boundary of an aircraft using experimental modal parameters from Ground vibration Tests, Application of smart concepts for active vibration control of full scale aerospace components, Non linear and transient analysis of flexible structures, Full scale fatigue testing of aircrafts/components.

Hoop stress distribution in 2000 m^3 Aerostat Hull



4m x 8m Autoclave designed and developed for HAL.



Static Structural Testing of SARAS wing.

SARAS Wing 1st Symmetric Bending.

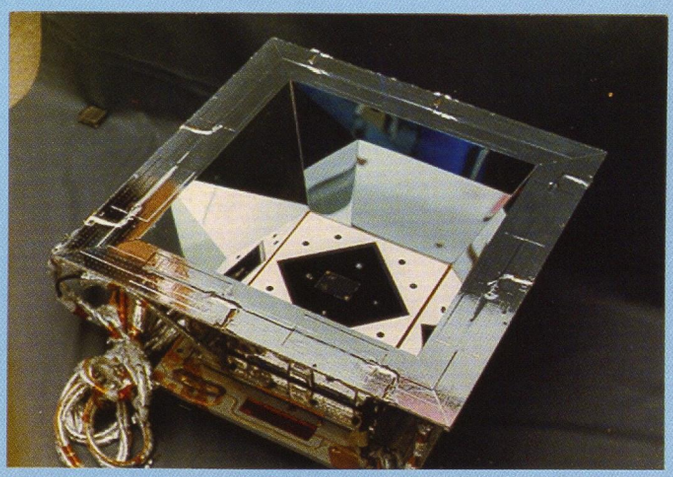
Surface Engineering Division

Surface Engineering Division (SED) devotes itself to develop know-how in surface technologies. The main thrust of SED is aerospace and engineering applications. SED works on import substitution in sensitive and critical areas to provide self-reliance. Besides, SED works on development of innovative technologies driven by the user industries. The division also undertakes research on thrust areas such as nano-scale architecture and energy sector.

The significant achievements of the division in the past are: development of sunshield mirrors for INSAT class of satellites, development of binary pressure sensitive paints suitable for transonic wind tunnel applications, development of a process for internal taper chemical milling of stabilizer spar tube of Cheetah helicopter, development of embossing rollers for wear resistance applications, development of solar selective coatings for hot water applications, development of nanolayered multilayer coatings and superhard nanocomposites coatings, development of seal discs for nuclear power plants and development of an ECAAM (electrochemically assisted arc machining) technology for cutting applications.

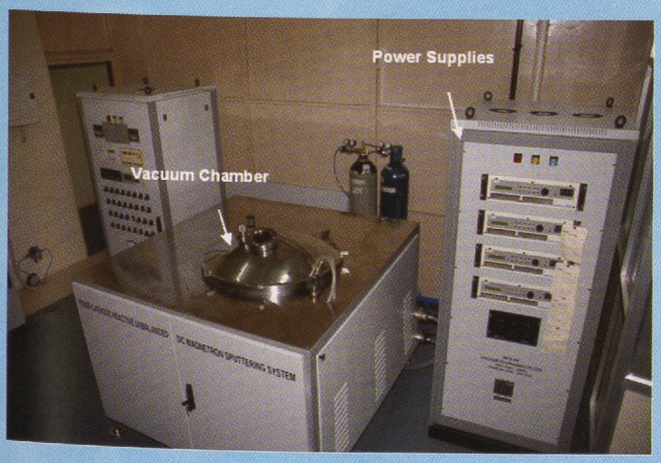
Current activities of the division are: development of sunshield mirror with ultra low roughness, evaluation and certification of the pressure sensitive paint developed in SED, development of plasma nitriding and plasma ion immersion implantation processes for the surface modification of Ti-6Al-4V alloy, Ni-SiC composite coatings for trochoid of Wankel engine, development of plasma sprayed coatings for solid oxide fuel cell applications, development of electrodeposited composite coatings with higher thermal stability, electroless coatings of nickel-based binary and ternary alloys and composites, development of sputter-deposited solar selective coatings, development of high wear-resistant coatings for machining of difficult-to-machine materials.

The following activities are planned for the future: development of superhydrophobic coatings for aerospace applications, development of new generation pressure sensitive and temperature sensitive paints, development of nano-dimensional magnetic structures, development of solid lubricant coatings for aerospace applications, development of eco-friendly coatings for corrosion prevention of aerospace Al alloys, etc.

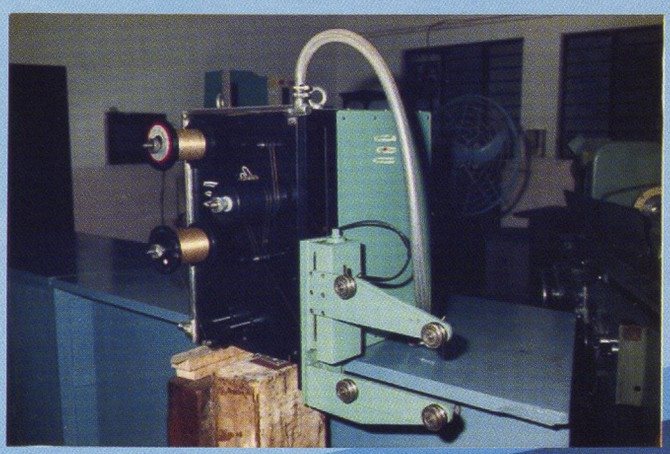


Photograph of sunshield mirrors.

Photograph of magnetron sputtering system.



Photograph of ECAAM.



Wind Energy Division

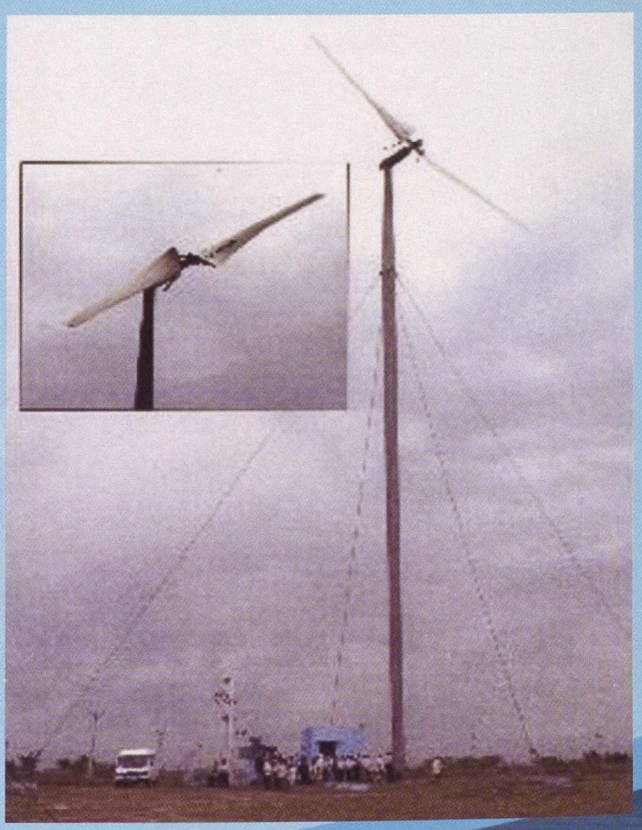
The Wind Energy Division is mainly involved in the design/development of small and medium-scale wind turbines. The special driver of this programme is the application of NAL's aerospace technology to wind turbine development. The Division also has facilities for wind monitoring, wind resource assessment and micro-siting.

The Division has evolved a comprehensive indigenous methodology and created a design database for the development of low cost small and medium-scale wind turbines, specially suited to the Indian wind environment of relatively low wind speeds and dusty conditions. A number of small scale wind turbines, both for power generation and water pumping have been built. A Savonius machine (150W) for electricity generation had been installed in Antarctica. Advanced technology for wind turbine design had been evolved under a programme sponsored by the Centre for Wind Energy Technology (C-WET), Chennai. Under a collaborative programme with the Sangeeth Group of Companies, Coimbatore, a pair of 300kW wind turbine blades had been fabricated, using NAL's special FRP Technology and successfully tested, over three wind seasons, on an available wind turbine platform at the Sangeeth Wind Farm, Kethanur, Coimbatore District.

The design/development of a 500kW low cost, horizontal-axis wind turbine is now being carried out by NAL under a collaborative programme with the Structural Engineering Research Centre (SERC), Chennai and an Industrial Partner, Sangeeth Group of Companies, Coimbatore, with funding under CSIR's New Millennium Indian Technology Leadership Initiative (NMITLI). The wind turbine, which will be 2-bladed, downwind, teetered and stall-regulated with a guyed tilt tower, is expected to be installed at the Sangeeth Wind Farm, Kethanur by early August 2008.

Future activities will include development of novel low cost wind turbine blades and the setting up of a wind turbine wind tunnel, a wind turbine mobile lab and a field test station.

NAL-Sangeeth wind turbine prototype blades undergoing trials at the Kethanur Wind Farm, Coimbatore District.



Wind Turbine Mobile Lab

NAL Kodihalli Campus

NAL Belur Campus

Designed and composed by KTMD. Issued in June 2008.

The Director
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Council of Scientific and Industrial Research
National Aerospace Laboratories
Bangalore, India

National Aerospace Laboratories (NAL), a constituent of the Council of Scientific and Industrial Research (CSIR), India, established in the year 1959 is the only government aerospace R&D laboratory in the country's civilian sector. CSIR-NAL is a high-technology oriented institution focusing on advanced disciplines in aerospace. CSIR-NAL has several advanced test facilities, and many of them are recognized as National Facilities. These are not only the best in the country, but are also comparable to other similar facilities in the world. CSIR-NAL has also provided significant value added inputs to all the Indian national aerospace programmes. Its contributions over the last five decades have enabled it to create a niche for itself in advanced aerospace research and technology development.

The Mandate

CSIR-NAL's mandate is to develop aerospace technologies with strong science content, design and build small, medium sized civil aircraft, and support all national aerospace programmes.

Major Focus / R&D Disciplines

Core competence of NAL spans practically the whole aerospace sector

- ✓ Civil aircraft design & development
- ✓ Micro Aerial Vehicle design and development
- ✓ Computational fluid dynamics
- ✓ Experimental aerodynamics
- ✓ Flight mechanics and control
- ✓ Turbo machinery and combustion
- ✓ Composites
- ✓ Structural design, analysis & testing
- ✓ Structural dynamics and integrity
- ✓ Surface modification
- ✓ Aerospace materials
- ✓ Aerospace electronics and systems
- ✓ Electromagnetics
- ✓ Meteorological modeling
- ✓ Wind energy

A Glimpse of the Significant Contributions to Indian Aerospace

A Milestone in Indian Civil Aviation

The HANSA Success - *flying at four Indian flying clubs*

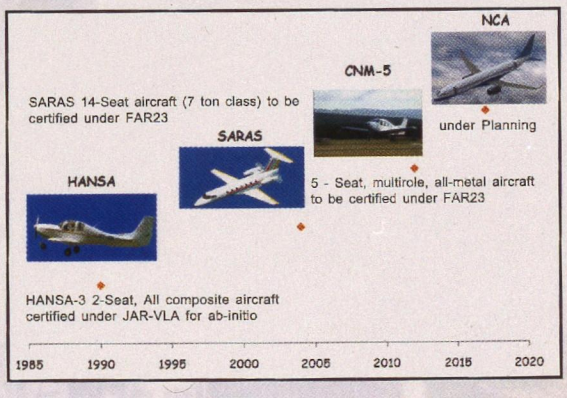
The two seat aircraft, a pioneering *ab-initio* all composite design, was certified by DGCA in the year 2000 under JAR-VLA category. A total of 15 aircraft were built by NAL, out of which several are currently in use with various flying clubs in the country. Powered by Rotax 914 F3 Turbo charged engine with a AUW of 750 kg, it is capable of flying upto 10,000 ft altitude and has an endurance of 6 hours.

The SARAS- *multirole light transport aircraft*

SARAS, the 14 seat (7 ton class) multi role transport aircraft to be certified under FAR 23 category is being designed and built by CSIR-NAL. It had its maiden flight on May 29, 2004. Powered by 2x1200 SHP turboprop PT6A-67A engines (Pratt & Whitney) driving 5 blade MT-Propellers, SARAS is capable of flying up to 30,000 ft altitude (cabin altitude maintained at 8,000 ft) and can operate from short air fields. It has been designed for multiple roles viz, executive transport, light package carrier, remote sensing, air ambulance etc. Indian Air Force is expected to be the launch customer for SARAS with HAL as the production partner.

Five Seat General Civil Aviation Aircraft (CNM-5) - *the country's first public-private partnership*

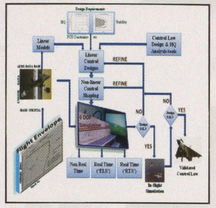
CNM-5, the five seat aircraft has the distinction of being the country's first public-private partnership (PPP) for development of civil transport aircraft. It is being developed by CSIR-NAL in collaboration with M/s Mahindra Aerospace Pvt.Ltd (MAPL), Bangalore. CNM-5 had its first test flight on the 1st of September 2011 in Australia. CNM-5 is powered by a 300 HP piston engine driving a 3-blade propeller cruising at a speed of 160 knots with a maximum AUW (All Up Weight) of 1525 kg; glass cockpit is a customer option. It is an ideal aircraft for air taxi, air ambulance, training, tourism and cargo applications, and is proposed to be certified first under CASA, the Australian Certification Authority.



Support to National Programs

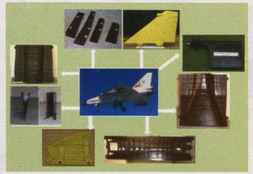
Aircraft Modeling and Control - *understanding the dynamics of flight*

- CSIR-NAL continues to lead the National Team effort on Design, Development and Certification of Fly-by-wire Flight Control Laws (Stability & Command Augmentation with Carefree Maneuvering, Autopilot, Autothrottle modes) and Fault Tolerant Airdata Algorithms for all Air force and Naval variants of the Light Combat Aircraft (TEJAS)
- Over 2000 successful flights flown on twelve different prototypes
- Sophisticated Parameter Identification techniques used to Validate and subsequently Update the wind tunnel generated aerodynamic database



Control law design cycle for Tejas

Composite structures for TEJAS – *forty percent of the TEJAS airframe is fabricated at NAL*



CSIR-NAL developed composite parts for Tejas

- CSIR-NAL successfully led the National Team for the composite wing development for TEJAS
- Tejas airframe is 40% composites (mostly carbon-epoxy) by weight contributing to its reputation as the world's smallest light weight fighter aircraft
- CSIR-NAL has pioneered the development and fabrication of composite structures for the TEJAS aircraft using innovative and cost-effective fabrication technologies including co-curing / co-bonding construction
- Tie-up with Tata Advanced Materials Ltd., for supply of critical CFC components for the series production of LCA

Carbon Fibre technology - *achieving self–reliance*

- India's First High-tech Carbon Fibre Plant of 400 TPA, established by Kemrock Industries, Vadodara with Technical knowhow from CSIR-NAL
- Type certified by Centre for Military Airworthiness and Certification (CEMILAC), Bangalore on September 21, 2011
- Carbon fibre application: defense, wind energy, sports, transportation and infrastructure sectors

Carbon Fibre Plant *Carbon Fibre*

Technologies for Nishant UAV

- **Wankel Engine Development:** Successful test flights of a 55HP Wankel engine, design and developed in collaboration with VRDE for DRDO-ADE's Nishant UAV
- **Structural Health Monitoring:** Demonstration of Structural Health Monitoring technology using fibre optic sensors jointly with DRDO-ADE and Israeli MoD

Maiden flight of the first ever indigenous rotary engine powering Nishant

SHM system assembled on Nishant Wankel

Development of Micro Aerial Vehicle (MAV) – *for strategic and societal applications*

Prototypes of Black Kite, Golden Hawk and Pushpak

- CSIR-NAL is playing a lead role in the National Program on Micro Air Vehicles (NP-MICAV) of DRDO/DST jointly with IIT-Bombay, IIT-Kanpur, Indian Institute of Science (IISc) and a few other academic institutions and private industries
- MAVs Black Kite, Golden Hawk and Pushpak with a 300 mm span, 300 gms weight and endurance of 30 mins have been developed. The MAVs carry a day light camera and provide an operational range of 2 Kms.
- These MAVs are currently undergoing user trials

CSIR-NAL and India's Space Programme – *a very fruitful association*

Acoustic Test Facility

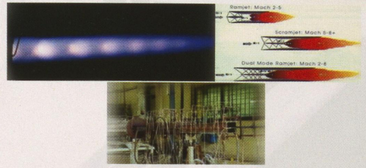
Passive radiative cooler with the four polished mirrors

- The Acoustic Test Facility (ATF) commissioned at CSIR-NAL for ISRO in 1986 has carried out acoustic tests on all of ISRO's launch vehicle stages (ASLV, PSLV and GSLV) as well as satellites(IRS , INSAT series)
- CSIR-NAL has designed and developed a new ATF at ISITE, ISRO with 1500 cu.m reverberation chamber and nitrogen as the medium and a closed loop acoustic drive / control system
- Highly polished aluminum mirrors developed by CSIR-NAL help ISRO to get good satellite pictures
- CSIR-NAL has been supporting the programmes of ISRO including wind tunnel testing of all their flight vehicle models, structural analysis, flight dynamics and control etc.

New Technologies and Systems

Supersonic Combustion for Hypersonic Vehicles – *for advanced flight vehicles*

- Advanced flight vehicles, will in future fly at hypersonic speeds using special engines called scramjets. NAL has successfully developed the vitally critical technology needed to burn fuels at supersonic speeds (around 1km/sec) in such engines



Engineering radomes - *protecting sophisticated electronic equipment*

Airborne and Ground based radomes

12.88 m dia DWR *Electromagnetics Lab.*

- Indigenous technology by CSIR-NAL for design and development of both airborne and ground-based radomes
- Technology transferred to HAL, Bangalore and BEL, Ghaziabad
- The Computational Electromagnetics Laboratory conducts studies related to radome design and characterization, radar cross section (RCS) evaluation of aerospace vehicles, antenna pattern analysis and metamaterials research

A new manufacturing process - *for cost effective high quality composites*

Vacuum Enhanced Resin Infusion Technology (VERITy)

- Lay dry preform on mould + Vacuum bag
- Resin infusion at just above room temperature
- Autoclave cure at low pressure and temperature
- Post cure in oven / autoclave

Cocuring and Cobonding Technology

- Uses Uni-directional Carbon Fiber Prepregs
- Layup Spar/rib/skin on a mould
- Inflatable bags as tooling
- Autoclave curing

SARAS wing, torsional box and trouser duct-top for LCA

Fully assembled wing test box

Design and Development of Autoclaves - *for composite airframe manufacture*

- CSIR-NAL has built one of the largest indigenous autoclaves in the world (size 4x9 mts) with innovative features and an advanced control system
- PPP with private industries: UCE for manufacturing & marketing and Datasol for fabrication of systems

Mark IV *Mark III* *Mark II* *Mark I*

Industrial grade, high temperature (350°C) and high pressure (15 bar) autoclaves for demanding applications

Smart Materials, Systems and Structures

Smart (or multifunctional) materials such as Piezo Ceramics and Shape Memory Alloys are extremely attractive candidates for sensors and actuators. CSIR-NAL in its quest for advanced technologies is involved in the development of these materials and their applications in the aerospace sector.

Actuator, Piezo ceramics sensor/ actuator for vibration control

Shape memory alloy as control surface actuator / skin morphing

ANC system for fighter aircraft

- Structural Health Monitoring using FBG sensors
- Piezo ceramics sensor / actuator for vibration control
- Shape memory alloy as control surface actuator / skin morphing / vibration damper
- Effecting repair – using SMA actuator
- Active Noise Control (ANC)

Surface engineering technologies - *using nanotechnology to enhance component performance*

- A magnetron sputtering system has been developed that can deposit nitride, oxide, carbide and metallic nano coatings at high growth rates and with good uniformity.
- In contrast to conventional diamond or boron nitride coatings, this method results in better adhesion, and increased thermal and chemical stability

High speed drill bits

The Avionics challenge – *success in electronics and instrumentation*

enhanced Fatigue Meter

Drishti installed at Indira Gandhi International Airport

- DRISHTI developed by CSIR-NAL is a fast-acting accurate transmissometer capable of handing both low (<25 meters) and high (>2000 meters) visibility accurately
- The DRISHTI systems have been installed at Lucknow IGI Airport, Delhi and NSCBI Airport, Kolkata. Suitable for CAT I,II,III A and B airports and it meets WMO and CAO regulations and has been issued International Class I certification (NOTAM)
- enhanced Fatigue Meter (eFM) developed by CSIR-NAL can be housed on platforms like military or civil aircraft for computing the 'g' crossings

The SARAS avionics journey:
Engine Instruments and Crew Alert System (EICAS) and a 3-axes digital autopilot system has been developed for SARAS aircraft

- EICAS has been cleared by DGCA for Aircraft Integration in February 2012
- First of its kind in India
- Potential for use in other aircraft programs in India and abroad
- DO 178B Level A Software

CSIR-NAL's Flight Operation Quality Assurance software (NALFOQA) can monitor the flight performance of aircraft and has been used by Air India, Alliance Air, and DGCA for over a decade.

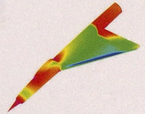
Visualization and animation software

Advanced civil aircraft cockpit

Expertise and Capabilities

The CFD advantage – *to model and optimize the performance*

- CSIR-NAL has used computational fluid dynamics (CFD) to model and optimize the performance of civilian and military aircraft, launch vehicles and missiles
- Some of the other novel studies in this area include internal flows in gas turbine engines, modeling of combustion, flow over wind turbine blades etc.

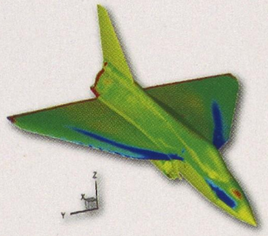


Multi-block grid around full SARAS aircraft configuration

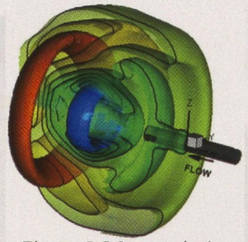
Pressure around fighter aircraft

Advanced Flow Diagnostics - understanding flow through measurements

- At CSIR-NAL several advanced flow diagnostics techniques such as BoS, PIV, PSP etc. have been successfully developed and deployed
- The Background Oriented Schlieren (BOS) technique provides the capability for capturing the three dimensional density fields
- CSIR-NAL developed Pressure Sensitive Paints (PSP) used on wind tunnel models to map the whole-field pressure distribution



Surface pressure field on LCA TEJAS model using PSP



The BOS technique validated for fully 3-D flows

Failure analysis and Accident investigations – *asking why*

Kanishka crash in 1985

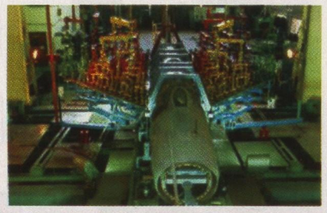
Aircraft crash in 1990

CSIR-NAL's ASM international publication

- CSIR-NAL is recognized as India's premier organisation for carrying out failure analyses and accident investigations, and it has been doing this with distinction for more than 40 years
- More than 1300 accident cases have been investigated by the NAL team. The Air India Boeing 747 Kanishka crash in 1985 was due to a chemical explosion and NAL was closely involved in the investigation

Aerospace Structures – *mastering the art and science of testing*

- CSIR-NAL's full-scale fatigue test facility provides inputs that can lead to a substantial increase in the operational life of airframes
- Over the years CSIR-NAL has built unique capability in the area of aeroelastic testing of SARAS and TEJAS aircraft, and the launch vehicles of ISRO
- CSIR-NAL has also successfully carried out ground vibration tests (GVT) on its SARAS, GA-10 aircraft, and other fighter aircraft



MiG-21 airframe testing

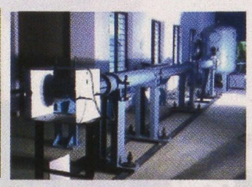
1/42 GSLV MkS model

Major R&D Facilities at NAL

- 1.2m Trisonic Wind Tunnel (M=0.2 to 4.0): Every Indian aerospace vehicle has graduated out of this wind tunnel. The tunnel has completed 40,000 blowdowns on November 2, 2010 and has been performing reliably for over 50 years
- 0.6m Trisonic Wind Tunnel indigenously designed and built by CSIR-NAL
- Fullscale fatigue test facility
- Large Scale Rotating Rig (LSRR) for Turbine and Compressor Aerodynamic Investigations
- Transonic Cascade Tunnel Facility
- National Test Facility for Aerospace Bearings / Lubricants
- High speed combustor test facility (HSCTF)
- Jet Aeroacoustics Research facility
- Flight Simulators and Augmented Engineering Environment (AEE) for modeling and simulation
- Ceramic Matrix Composites through Chemical Vapour Infiltration
- High velocity air gun impact test facility
- The High Performance Computing (HPC) facility along with C-MMACS - fastest system in India
- Computational electromagnetics (CEM) facilities

1.2m Trisonic Wind Tunnel

Air gun impact test facility



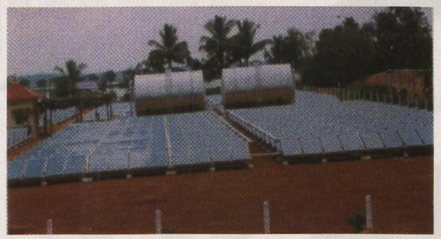
Scramjet test rig

Augmented engineering environment

Technologies for the Society

The NALSUN technology – *solar energy for water heating*

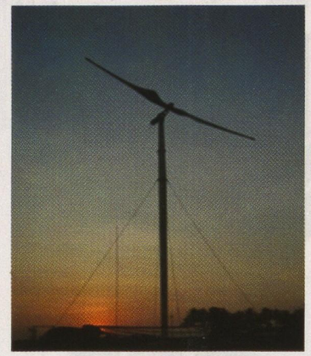
- CSIR-NAL developed cost-effective Electrodeposited Black Chrome Coating. This technology has so far been transferred to many industries
- Commercially successful technology and plating requires room temperature (approx. 30°C) & normal current densities (approx. 10 to 30 Adm^{-2}). Service life of the coating is more than 20 years.
- Widely patented (India, Australia, Canada, Europe and USA)



1.2 lakh litre per day system at M/s Godavari Fertilizers, Kakinada

Medium –scale wind turbines – *harnessing the India's wind potential*

- Development of a 500 kW horizontal axis wind turbine at Kethanur, Tamil Nadu
- Electrical energy generated and fed to the TNEB grid
- A peak power of about 500 kW was achieved

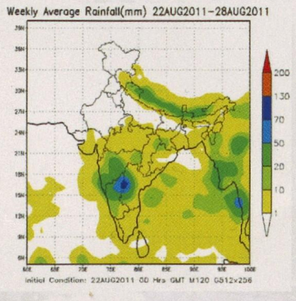


500 kw wind turbine mill

CFRP tip brake operational on the wind turbine system at Kethanur.

Flosolver – *the power of parallel computing for numerical weather prediction*

Varsha GCM forecast



Flosolver Mk8 -1024 processor

- Flosolver Mk8 is a customised parallel supercomputer for numerical weather prediction using in-house developed communication devices
- Hardware-Software modeling platform consisting of 10 Teraflops, 1024 processor parallel supercomputer and Varsha GCM
- Forecast and its validation studies were done for VARSHA GCM with different spatial and temporal resolutions. The onset of Indian summer monsoon and rainfall forecasts using Varsha GCM were fairly accurate and well accepted by the national agencies

Air Ferry system - *for rural applications*

- An air-ferry is a buoyant, self-propelled, multi-terrain vehicle that depends primarily on air thrust for propulsion
- Air ferry system for deployment in rural areas for river crossings, rescue mission operation etc.
- Aam Rath made up of bamboo material base vessel, with 33hP aero-engine; and Lal Hamsa with FRP base vessel and 17hP aero-engine

Aam Rath-6 seat

Lal Hamsa-3 seat

International Collaborations

Long Term Cooperations

- DLR, Germany
- CAE, China
- P&W, USA
- CRIAQ, Quebec, Canada
- MDB, Russia
- Czech Academy of Sciences
- Astronautics Corporation, USA

Collaborative / Sponsored Projects

- Boeing, USA
- P&W, Canada & USA
- BELL Helicopters
- CAE, CANADA
- UKIERI, UK

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