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 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. CSIR-NAL has also developed many critical technologies for the strategic sector and continues to support the mission-mode programmes of the country.

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 and development
- Micro Aerial Vehicle design and development
- Computational fluid dynamics
- Experimental aerodynamics
- Flight mechanics and control
- Turbo machinery and combustion
- Composites
- Structural design, analysis and 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 4 hours.

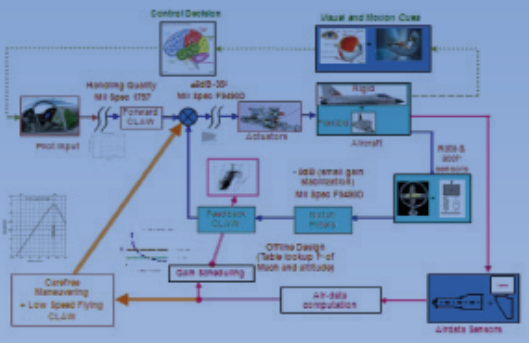
The SARAS - multirole light transport aircraft

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) has an endurance of 5 hours 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, capable of flying upto 10,000 ft altitude and endurance of 6 hours; 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 under FAR23 category.

SUPPORT TO NATIONAL PROGRAMS



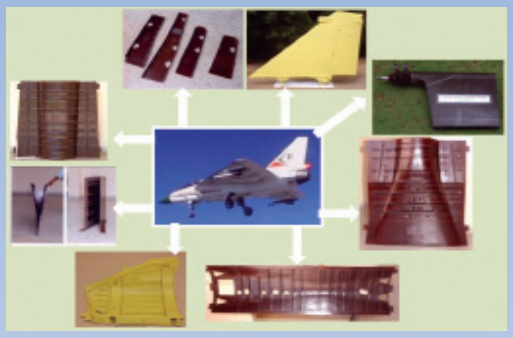
Flight control system structure

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 3100+ successful flights flown on nineteen different prototypes
- Sophisticated Parameter Identification techniques used to Validate and subsequently Update the wind tunnel generated aerodynamic database
- CSIR-NAL has carried out wind tunnel tests for LCA-TEJAS which resulted in aerodata generation & flight validation. Other significant contributions include: CFD analysis, flow diagnostic studies, aeroelastic model studies & dynamic response studies.
- The CLAW team led by NAL together with NFTC, ADA evolved safe and robust procedures for Ski jump launch of LCA Naval variant, successfully demonstrated during December 2014 from the shore based test facility at Goa.

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

- CSIR-NAL successfully led the National Team for the composite wing development for TEJAS
- Tejas airframe is 45% 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. Co-curing technology has resulted in more than 20% savings in cost and about 15% reduction in weight
- Tie-up with Tata Advanced Materials Ltd., for supply of critical CFC components for the series production of LCA



CSIR-NAL developed composite parts for Tejas

Carbon Fibre Plant

Carbon Fibre

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
- MoU with MIDHANI, Hyderabad for development of production technology for aeronautical grade carbon fibers
- Carbon fibre application: defense, wind energy, sports, transportation and infrastructure sectors

Technologies for Nishant UAV

- Wankel Rotary Combustion 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
- CEMILAC certificate for Limited Series Production accorded on 7 February 2013.

Maiden flight of the first ever indigenous rotary engine powering Nishant

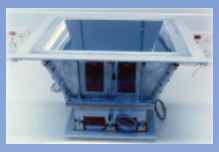
SHM system assembled on Nishant Wankel

Prototypes of Black Kite, Golden Hawk, Pushpak and mini UAV - Slybrid

Development of Micro Aerial Vehicle (MAV) - for strategic & societal applications

- 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. User demonstrations have been carried out jointly with ADE and promotional flight demos given to Chhattisgarh Police, CRPF (Dhantawade), NSG (Manesar), Artillery Center (Deolali) and aerial survey of Muthangya Forest, Kerala Forest Department.
- Development of high altitude mini UAV - Slybird: 1.6m wing span, 1.3m length, 2 kg weight, operating range of around 10 km has been tested successfully at Leh/Ladakah (12,000 ft above sea level)

Acoustic Test Facility



Passive radiative cooler with the four polished mirrors

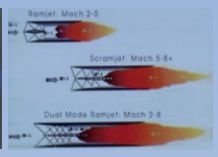
CSIR-NAL and India's Space Programme - a very fruitful association

- 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, GSLV and RLV-TD) 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

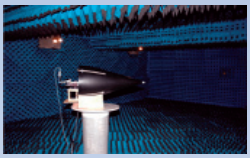
Supersonic Combustion for Hypersonic Vehicles - for advanced flight vehicles

- 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



Airborne and Ground based radomes

12.88 m dia DWR



Electromagnetics Lab

Engineering radomes - protecting sophisticated electronic equipment

- 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

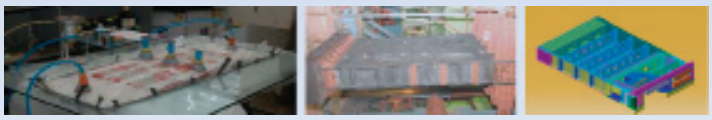
Vacuum Enhanced Resin Infusion Technology (VERITy)

- 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
- JEC Asia 2013 Innovation Award for the innovative composite construction of horizontal tail bottom integrated skin of SARAS

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

Coduring and Cobonding Technology

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



Fully assembled wing test box

Design and Development of Autoclaves - for composite airframe manufacture

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

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

- CSIR-NAL has built one of the largest indigenous autoclaves in the world (size 4x9 mts) with innovative features and an advanced control system. Autoclave supplied to HAL-Bangalore, ASL-Hyderabad, VSSC-Trivandrum and SHAR, Sriharikota for large size Autoclave.
- Cost effective Lab scale autoclave of 0.9m dia and 1 m length developed to cater the needs of R&D institutions and small scale industries. Lab scale autoclaves supplied to IIT-Kanpur, MIT-Manipal, and VSSC-Trivandrum
- PPP with private industries: UCE for manufacturing & marketing and Datasol for fabrication of systems

Actuator, Piezo ceramics sensor/ actuator for vibration control

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.

- 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)

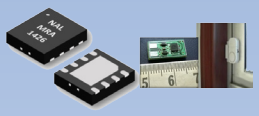
NiTi SMA wires, rods, tubes strips.

ANC system for fighter aircraft

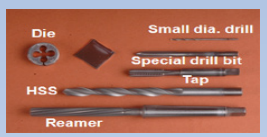
- NiTi-base shape memory alloys (SMAs) in the form of wires, strips, rods, ribbons and tubes suitable for Aerospace and Engineering applications have been developed at CSIR-NAL. Processing technology for commercial production of NiTi SMAs developed jointly with HAL, Bangalore and MIDHANI, Hyderabad.
- SMA wires developed can be used for variety of thermal actuator applications in the temperature range 25 to 200°C and the wires are available in the diameter range 1.5 to 0.1 mm
- NiTi Superelastic (SE) and Shape memory effect (SME) wires/strips developed for R&DE(Engrs.), DRDO, Pune for use in the development of SMA embedded CFRP/GFRP composites for impact energy damping applications

Surface engineering technologies - using nanotechnology to enhance component performance

- Superhard and tough coatings on cutting tools for high precision machining of difficult-to-cut materials. Cost effective plasma nitriding has been developed for cutting tools. Nanostructured solid lubricant coatings with friction coefficient <0.1 are useful for aerospace and automobile applications.
- Apart from cost effective the performance of the plasma nitrided tools is at par with WC tools
- Magnetoresistive thin film technology for automotive and sensor applications. NAL has a proven and patented technology to develop magnetic sensor chip. The sensors have wide band width operation, low power operation (mW), and miniature size (3mm x3mm) with low cost (<INR 20).
- Global Magnetic sensor market revenue estimated to be 2 billion US $. The technology will benefit Two Wheeler & Four Wheeler Automotive Companies in India

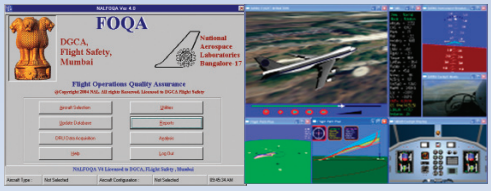


Gear Tooth Sensors based on Giant magnetoresistance (GMR)



High speed drill bits

Drishti installed at Indira Gandhi International Airport



Visualization and animation software

The Avionics challenge - success in electronics and instrumentation

- DRISHTI developed by CSIR-NAL is a fast-acting accurate transmissometer capable of handling both low (<25 meters) and high (>2000 meters) visibility accurately
- The DRISHTI systems have been installed at major airports in the country including 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). Partnership agreement with IMD for installation of 70 systems at all airports in the country.
- MoA with Tata Power Systems for supply 54 nos of Drishti for MoD's IAF airfields.
- 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.
- Designed & developed Autopilot Hardware module version 4.2 (APV4.2). The hardware has been tested on five different platforms viz, SlyBird, Black Kite, Griffin, Pushpak and EasyStar.

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. DO 178B Level A Software
- Potential for use in other aircraft programs in India and abroad
- State of the art Integrated Global bus Avionics Processing System (IGAPS) with ARINC 653 Time and Memory partitioned platform. ARINC 818, ARINC 664 based global bus interconnect. Dual Redundant design with Dual-Dual features. VITA 46- PCIx based backplane communication.
- First of its kind in India, indigenous design for civil aerospace.
- MoU with Tata Advance Systems for Indian and world wide marketing of IGAPS

Autopilot Ver 4.2.

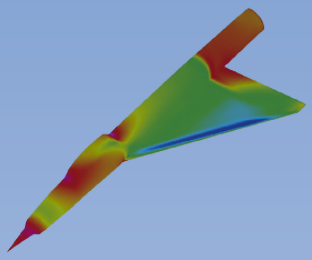
Advanced civil aircraft cockpit

NAL Simulators

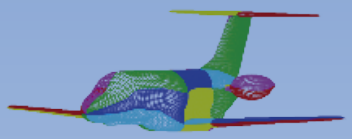
- Based on Matlab Simulink and Real Time Windows Target
- Model based design
- Rapid prototyping tool for control law evaluation and research
- Low cost

IGAPS integrated with the automated test station

EXPERTISE AND CAPABILITIES



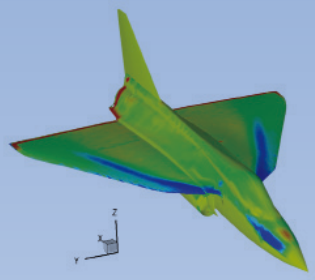
Pressure around fighter aircraft



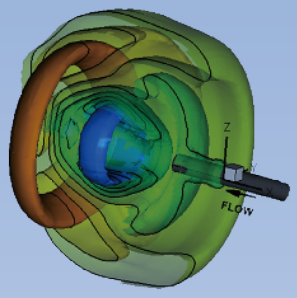
Multi-block grid around full SARAS aircraft configuration

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.



Surface pressure field on LCA TEJAS model using PSP



The BOS technique validated for fully 3-D flows

- 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
- DHVANI - Electronic Target for Marksmanship Training in Indian Army. This cost effective system bagged first major order for twelve lanes from HQ, Sothern Air Command (SAC) Thiruvanathapuram. The order executed through PPP consortium M/s Captronic Systems Pvt.Ltd

Dhvani System

Kanishka crash in 1985

Aircraft crash in 1990

Failure analysis and Accident investigations - asking why

- 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 1500 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 of IAF's Gnat, Ajeet and MiG-21 Bis
- 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, ALH, Jaguar, Mirage 2000 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 NTAF has contributed immensely to all national programmes of DRDO, ISRO, ADA, HAL & NAL 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
- Crashworthiness Forwerd Velocity Sled facility
- Large Scale Rotating Rig (LSRR) for Turbine and Compressor Aerodynamic Investigations
- Transonic Cascade Tunnel facility
- Micro air vehicle Aerodynamics Research 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 4PI (C-MMACS) - fastest system in India
- Computational electromagnetics (CEM) facilities
- Versatile turbine test rig

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

Wind-solar hybrid System at CSIR-NAL

4 kW Wind-Solar Hybrid System (WiSH) for Agri-Pumps

- The present 1 kW class WiSH technology demonstrator system, installed at Renewable Energy Farm, Kodihalli Campus, NAL is of TRL 6 and is designed for remote hamlets.
- Under development - a WiSH system to deliver 4 kW in low wind regimes, at least eight hours in the day to drive agricultural pumps.

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 Corp., USA

Collaborative / Sponsored Projects

- Boeing, USA
- P&W, Canada & USA
- BELL Helicopters
- CAE, CANADA
- UKIERI, UK
- ALCOA, USA
- RMIT, Australia
- NCA&T University, USA

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