



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

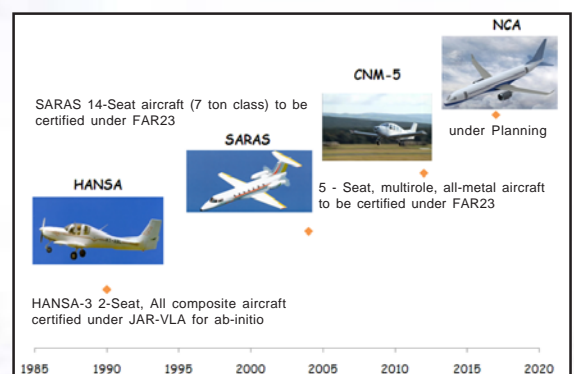
The two seat aircraft, a pioneering *ab-initio* all composite design, was certified by DGCA in the year 2000 under JAR-VLA category. A total of 15 aircraft were built by NAL, out of which several are currently in use with various flying clubs in the country. Powered by Rotax 914 F3 Turbo charged engine with a AWW 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

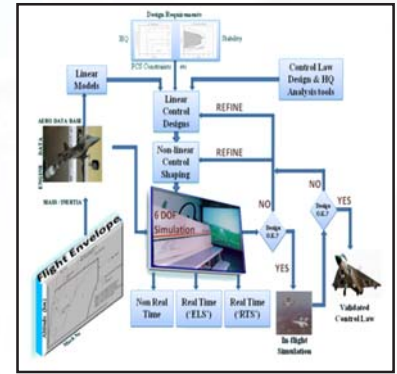
CNM-5, the five seat aircraft has the distinction of being the country's first public-private partnership (PPP) for development of civil transport aircraft. It is being developed by CSIR-NAL in collaboration with M/s Mahindra Aerospace Pvt.Ltd (MAPL), Bangalore. CNM-5 had its first test flight on the 1<sup>st</sup> 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 AWW (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 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

CSIR-NAL developed composite parts for Tejas

### 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

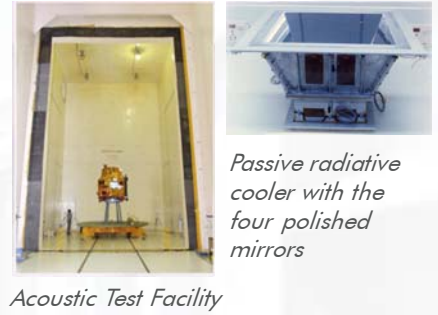


Prototypes of Black Kite, Golden Hawk and Pushpak

- 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

- 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.



Acoustic Test Facility

Passive radiative cooler with the four polished mirrors

## 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 1 km/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

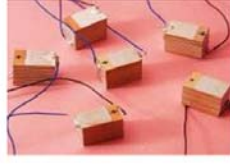
- CSIR-NAL has built one of the largest indigenous autoclaves in the world (size 4x9 mts) with innovative features and an advanced control system
- PPP with private industries: UCE for manufacturing & marketing and Datasol for fabrication of systems



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

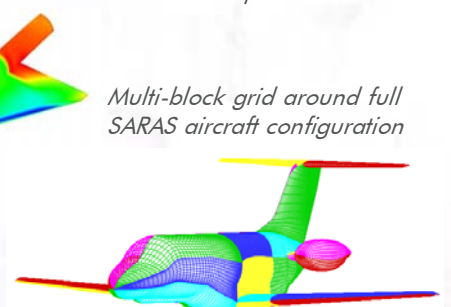
## Expertise and Capabilities

### 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.



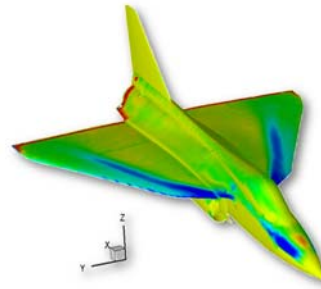
Pressure around fighter aircraft



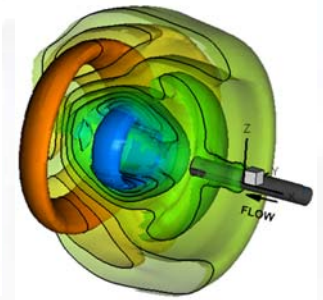
Multi-block grid around full SARAS aircraft configuration

## 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<sup>-2</sup>). 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



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

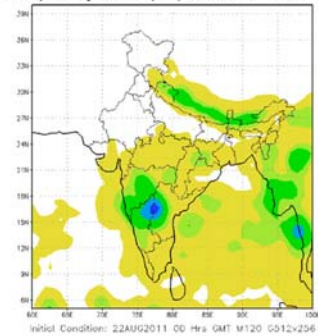
500 kw wind turbine mill

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

Varsha GCM forecast

Flosolver Mk8 - 1024 processor

Weekly Average Rainfall(mm) 22AUG2011–28AUG2011



- 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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