National Aerospace Laboratories, Bengaluru

Shyam Chetty*

CSIR-NAL, Bengaluru 560 017, India

Established in 1959, CSIR-NAL is a high-technology R&D institution focusing on advanced disciplines in aerospace and has a mandate to develop aerospace technologies with strong science content, design and build small and medium size aircraft and support all national programmes. During the year 2014, NAL has made significant contributions especially to strategic sector. For the first time in the laboratory, drop test of stores was carried out from a SU-30MKI aircraft model in NAL's 1.5 m low speed wind tunnel. The other significant contributions include: development of indigenous system for Detection and Hit Visualization using Acoustic N-wave Identification (DHVANI) for locating bullet hits on targets for the Indian Army, support to LCA Tejas programme, acoustic qualifications of subsystems for the indigenous cryogenic stage used in ISRO's GSLV-D5, and acoustic qualification of ISRO's recent successful Mars Orbiter Mission satellite. The significant non-strategic contributions include: MoU with India Meteorological Department for the joint production of NAL developed DRISHTI systems to be installed at all airports in the country, development of lab scale aerospace grade autoclave to meet the needs of academia and R&D institutions, and demonstration of 500 W + 500 W wind solar hybrid system.

Keywords: Aerodynamic, cryogenic, FAI, Froude, IOC, N-wave, Slybird, trisonic.

DURING the year 2014 CSIR-NAL (National Aerospace Laboratories), Bengaluru has continued to make significant contributions to the strategic sector. For the first time in the laboratory, drop test of stores from a SU-30MKI aircraft model in NAL's 1.5 m low-speed wind tunnel has been carried out using Froude scaling principles. This enables the tests to be carried out at low speeds ($M < 0.3$). The study provided the ideal conditions for the store release at actual flight Mach numbers including the deflection setting angles for the fore and aft fins. The software developed allowed tracking of the time-resolved displacement, velocity, acceleration and Euler angles. Figure 1 shows a composite image of the missile recorded at four different instances along the trajectory. The tests used 1/30th scale model of SU-30MKI aircraft and store. Further, tests were also carried out on a scaled, isolated store model in the 0.6 m trisonic wind tunnel to obtain the aerodynamic loads. The same store model was attached to a scaled SU-30MKI aircraft model and aerodynamic loads on the complete configuration were determined in the 1.2 m wind tunnel (Figure 2). Tests were carried out in the Mach number range 0.55–1.2 at various angles of attack and sideslip to ascertain installation effects, store load in carriage position and in aircraft interference flow-field. For this technology development

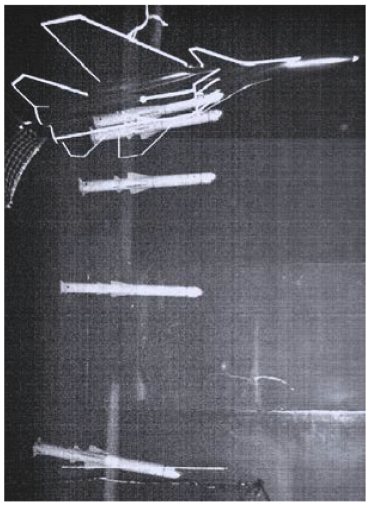

Figure 1. Composite image of store release trajectory.

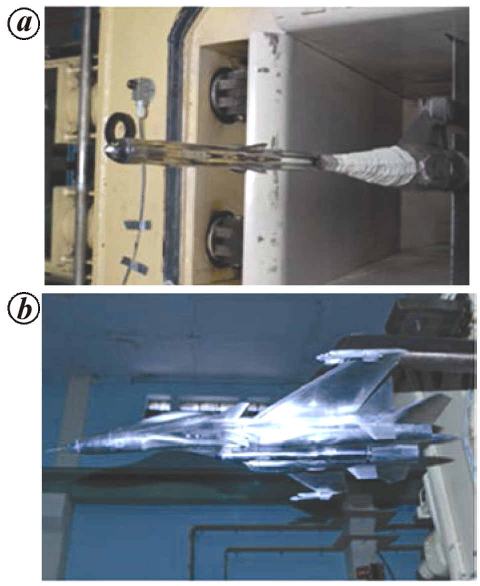

Figure 2. Models mounted in 0.6 and 1.2 m wind tunnels. ***a***, Isolated store model in 0.6 m WT. ***b***, Parent aircraft model in 1.2 m WT.

*e-mail: director@nal.res.in

and associated contributions, NAL has been conferred with the 'Best Laboratory Award 2014' by Abdul Kalam, former President of India, during the BrahMos Day celebrations in New Delhi on 12 June 2014 (Figure 3).

In an another achievement, the indigenous system for detection and hit visualization using acoustic *N*-wave identification (DHVANI) for locating bullet hits on targets developed by CSIR-NAL for the Indian Army, has undergone rigorous field trials at Army ranges in Bengaluru, Secunderabad and Infantry School, Mhow. The formal handing over of DHVANI to Commandant SDD Secunderabad took place on 3 July 2014. This automated and rugged system meets/exceeds the specifications of comparable systems available internationally. The cost of this system is currently about 50–60% of comparable international systems. Considering that there are over 2000 firing lanes all over the country, the savings in foreign exchange to the national exchequer are expected to be significant (Figure 4).

Figure 3. Best Laboratory Award 2014 conferred on CSIR-NAL.

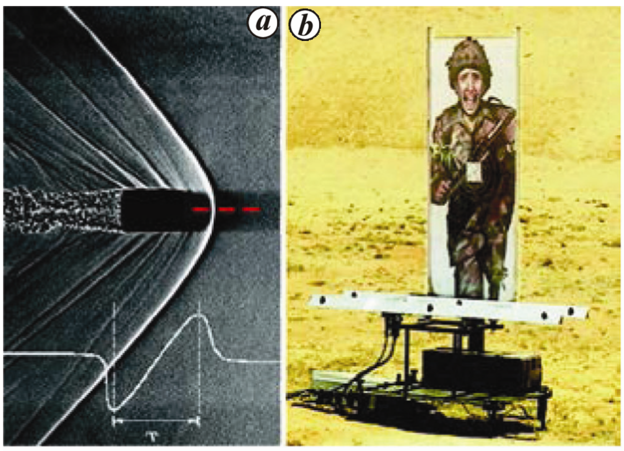

Figure 4. ***a***, 'N-wave' associated with passage of bullet. ***b***, The DHVANI system.

Towards development for the civil aviation sector, a major milestone was achieved in the field of aviation safety. A partnership agreement was signed on 20 May 2014 for joint production of NAL-developed DRISHTI system. Under the MoU, 70 systems are being manufactured at a cost of Rs 18 lakhs each and funded by India Meteorological Department (IMD). These systems will be installed in all the airports of the country. In the first phase, NAL has received an order from IMD for supply of 20 systems at a cost of Rs 3.6 crores. This indigenous product is one-third the cost of similar imported equipment and hence has resulted in significant foreign exchange savings to the country. This is a fine example of collaboration between two government sector entities leading to indigenization and deployment of a technology which so far was the exclusive domain of few developed countries. It is noteworthy to mention that DRISHTI has received many prestigious awards during the past two years which include 'Meritorious Invention' award from National Research Development Corporation (NRDC), 'IETE Corporate Award' from Institution of Electronics and Telecommunication Engineers (IETE), India, and 'Most Innovative Product of the Year' award from Indian Electronics and Semiconductor Association (IESA) (Figure 5).

Figure 5. ***a***, DRISHTI at runway 28 of IGI airport, New Delhi. ***b***, Indian Electronics and Semiconductor Association Technovation Award 2013 for DRISHTI.

CSIR-NAL-led National Control Law Team (CLAW) jointly with different groups of Flight Mechanics and Control Division played a crucial role in Tejas flight envelope expansion and upgradation of the flight control laws for obtaining the aircraft initial operation clearance (IOC). On 20 December 2013, Tejas received the second of three levels of operational clearance (IOC-2). Air data system (ADS) calibration was carried out using the flight data from high AOA PID test experiments. This process has led to the successful clearance of IOC version of the ADS. Using IOC standard ADS as the baseline, ADS for the naval and two-seater airforce (trainer) variants has been developed. After successful ground testing, the Naval ADS version was integrated onto the aircraft and is currently undergoing flight tests. As a part of LCA series production, new production standard tools were designed and fabricated in association with the production partner M/s TATA Advanced Materials Ltd. Two sets of major composite airframe structural components were fabricated and first article inspection (FAI) was successfully carried out on the composite substructures products. The first set of components was also cleared by the Directorate General of Aeronautical Quality Assurance (DGAQA) for aircraft assembly.

Further, the R&D divisions at NAL have significantly contributed towards the advanced medium combat aircraft programme of the Aeronautical Development Agency (ADA). The R&D efforts led to the new configuration and a structurally efficient wing layout with four bending attachment brackets and two shear attachment brackets. For this configuration, structural design, analysis and size optimization were carried out to cater to all critical symmetric and unsymmetric load cases. Finite element models were built separately for each of the fuselage segments and then integrated to build a full fuselage finite element model (Figure 6). Extensive CFD analyses were carried out on Dornier 228B aircraft to assess impact of side and tip-mounted antennae on overall aerodynamics. NAL panel code was used for providing baseline data. The open source SU2 code was deployed successfully for all subsequent CFD analyses (Figure 7). CSIR-NAL has more than four decades of experience and expertise in carrying out investigations of failure in high-technology areas such as aircraft structures and aero engine components/systems. During the year, 53 investigations were carried out for various defence organizations in the country. In most of the cases, the primary factor(s) responsible for the failure was identified and recommendations were suggested so that appropriate actions could be initiated to prevent recurrence of similar failures in future.

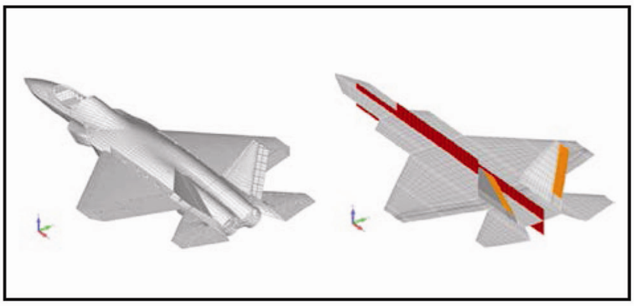

Figure 6. Finite element model and aeromesh of the AMCA Version 3B-08.

The association of CSIR-NAL with the Department of Space (DOS) has always been mutually beneficial. NAL continued its support to major national aerospace programmes of DOS during the year. The ATF Division of NAL has played a crucial role in the acoustic qualification of subsystems for the indigenous cryogenic stage used in GSLV-D5. These tests helped in the first successful flight (5 January 2014) of the GSLV Mark II using the indigenously developed CE-75 cryogenic engine. The LH2 vent and relief line along with the vent valve and the protection plate in the inter-tank truss region were crucial subsystems of the indigenous cryo stage which underwent acoustic qualification at CSIR-NAL (Figure 8). Further, complete aerodynamic re-characterization of the GSLV-D5 vehicle with fully simulated wind-tunnel model has been carried out at National Trisonic Aerodynamics Facility (NTAF) of NAL. The major challenge was to design, manufacture and test models for force measurements, and steady and unsteady pressure measurements in

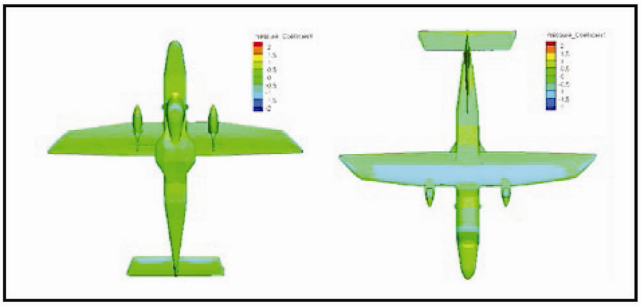

Figure 7. Pressure distribution over the entire aircraft in top and bottom view for clean aircraft in cruise.

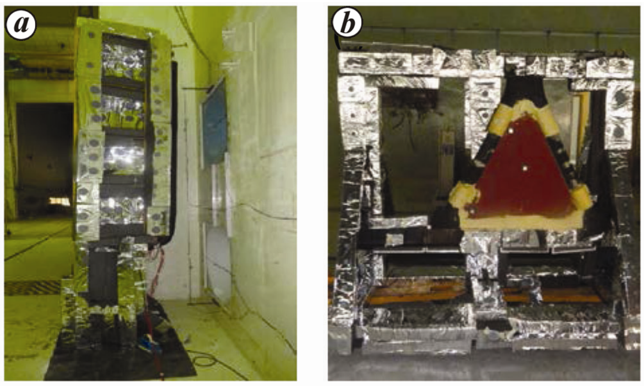

Figure 8. (***a***) GSLV LH2 vent and relief line (***b***) GSLV ITT protection plate ready for acoustic test at ATF.

a very short time-frame (Figure 9). All these studies have given valuable inputs leading to the success of the GSLV project. Further, the acoustic qualification of ISRO's recent successful Mars Orbiter Mission (MOM) satellite has been carried out at the new ATF facility at ISITE (ISRO, Bengaluru), designed, built and commissioned by CSIR-NAL. The ATF NAL scientists were closely associated with these acoustic qualification tests. CSIR-NAL is proud to be associated with the successes of ISRO's GSLV-D5 and MOM programmes.

CSIR-NAL is one the lead agencies for micro aerial vehicle (MAV) development in the country. In the year 2014, significant efforts have gone towards the product engineering improvements of the fixed-wing MAVs like Slybird of 1.5 m wing span and Pushpak of 450 mm wing span. The Slybird mini UAV and Pushpak 450 micro UAV were successfully demonstrated to CRPF and NSG at Manesar during November 2013. An 150 mm fixed wing MAV named Micro-beacon is undergoing flight trials. Under the CSIR 12th Five-Year Plan project, design of autopilot guidance and control laws for MAVs has been carried out using the Slybird aerodynamics model. Software-in-the-loop simulation was carried out with the designed control laws for various flight phases from take-off to landing. Also, design of autopilot for Black Kite MAV using nonlinear dynamic inversion has been completed. In a notable achievement, NAL has successfully designed and developed state-of-the-art indigenous autopilot hardware using programmable system on chip (PSoC)-based controller, 10 degree-of-freedom (10DoF) sensor suite, pressure altimeter sensor, microSD real-time recording device with interfaces to the servo actuators, GPS receiver, and other on-board sensors/devices (Figure 10). The autopilot hardware has been integrated and test flown successfully in platforms like Slybird, Sky Surfer, and manned powered Hang Glider apart from various ground vehicles (Figure 11).

Figure 9. Models mounted in 0.6 and 1.2 m wind tunnels.

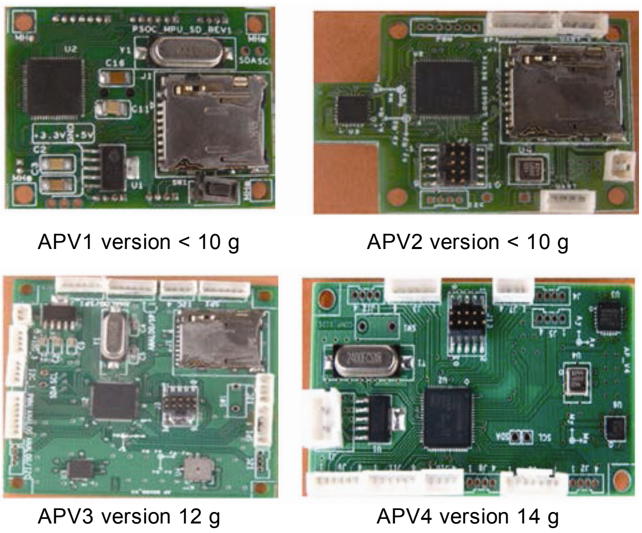

Figure 10. Indigenous PSoC-based autopilot hardware for MAV.

Under the ARDB programme, significant progress has been made towards integrated enhanced and synthetic vision system (IESVS) development for aircraft. The data acquisition system (DAS) and software has been developed to acquire EVS data in time synch with AHRS and GPS data for EVS flight experiments. The Centre for Electromagnetics at CSIR-NAL continued its R&D efforts in electromagnetic (EM) simulation studies for the enhancement of electromagnetic performance of multi-layered radomes using aperture-type frequency selective surfaces (FSS). In one such application, Jerusalem cross FSS array is embedded in the mid-plane of the core of a sandwich radome to enhance the EM performance parameters over the entire X-band. Further, a 3D ray tracing algorithm has been developed for the radiofrequency (RF) field mapping and its analysis inside a space vehicle cabin.

In the recent past, CSIR-NAL in collaboration with VRDE, DRDO has successfully designed and developed a 55 HP Wankel rotary combustion engine for the Nishant UAV. Building on this rich experience, a modified version of the UAV engine has been built for a manned powered hang glider application. The modified engine is more reliable and has additional features like a gear box instead of belt drive, in-built starter motor, larger bearings and silencer (Figure 12).

CSIR-NAL has made significant contributions in the area of special materials over the years. Superelastic NiTi shape memory alloy (SMA) wires are being developed at CSIR-NAL in collaboration with Foundry and Forge Division, HAL (BC) and MIDHANI, Hyderabad. These are intended for applications in both biomedical and engineering fields. The alloy chemistry, and the thermo-

Figure 11. Integration of autopilot hardware with data logger to the powered hang glider.

Figure 12. PHG version of Wankel engine.

Figure 13. Ni–Ti wire (1 mm *ϕ*) spools processed in collaboration with Foundry and Forge Division, HAL (BC) and MIDHANI, Hyderabad.

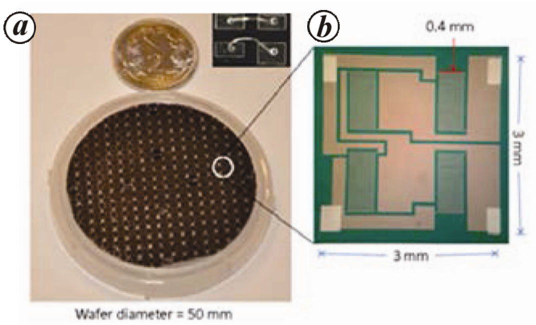

Figure 14. ***a***, GMR% for CoFe/Cu multilayers for samples annealed at different temperatures. ***b***, The 2 inch wafer-level deposition and sensor patterning along 1.2 μm Al bond pads and wire bonding.

physical, functional and mechanical properties of the processed wires conform to the ASTM F2063 specification for 'medical devices and surgical implants' (Figure 13). A high-temperature adhesive capable of withstanding 300°C dry and 180°C wet, with a Tg of 280°C has been developed for use as a laminating resin and also for structural joints in aerospace industry. It has shown good lap shear (14 MPa) and peel strength (170 N/inch) at room temperature. The property retention at 300°C is over 90% of its room temperature value. The adhesive has tested positive for its film-forming capability. Further, a magnetoresistance element-based gear-tooth sensor for industrial applications has been developed using GMR films deposited on 2-inch SiO_2 and Si_3N_4 coated substrate consisting of more than 200 sensors (Figure 14). Giant magneto-resistance (GMR) is a quantum-mechanical magneto-resistance effect observed in thin-film structures composed of alternating ferromagnetic and non-magnetic conductive layers. The main application of GMR is in agnetic field sensors, which are used to read data in hard

Figure 15. Aerospace-grade laboratory scale autoclave commissioned at IIT Kanpur.

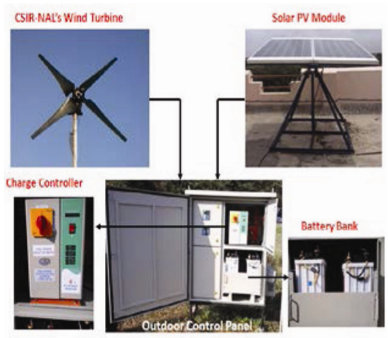

Figure 16. Wind solar hybrid systems at CSIR-NAL renewable energy farm and on the rooftop of SSB, NAL.

disk drives, biosensors, microelectromechanical systems (MEMS) and other devices.

The societal mission activities during 2014 have yielded good results. An affordable laboratory-scale aerospace grade autoclave was conceived and designed with state-of-the-art features to meet the growing needs of the academia and R&D institutions. The first order was received from IIT Kanpur and the second from MIT, Manipal. It was indeed a proud moment as the first aerospace grade laboratory-scale autoclave was formally handed over to IIT Kanpur on 25 March 2014 and the second to MIT, Manipal on 26 August 2014. The compact, laboratory-scale autoclave (0.9 m diameter and 1.0 m length workspace) provides all the features of a large industry standard autoclave (Figure 15). The laboratory-scale autoclaves were delivered by the CSIR-NAL-led PPP consortium consisting of M/s Unique Chemo Plant Equipments, Mumbai and M/s Datasol India Private Ltd, Bengaluru. In another notable achievement, CSMST of NAL has designed and demonstrated a 500 W + 500 W wind solar hybrid system at the renewable energy farm at the NAL Kodihalli Campus on 23 May 2014. This hybrid system is ideally suited to address the energy needs of remote areas, and particularly in off-grid locations of the country. The challenges of integrating these two devices (wind turbine and the solar PV bank) were addressed and the necessary electronics hardware was developed by working jointly with M/s Aparna Renewable Energy Sources (P) Ltd. ARES (Figure 16).