ENGINEERING OF FLIGHT VEHICLES

Prospectus 2010

TWO YEAR POST GRADUATE RESEARCH PROGRAMME

Fluid sciences and acoustics
Propulsion
Societal missions
Aerospace electronics
Structural technologies
Flight mechanics and control
High-performance computing
Materials science and technology

National Aerospace Laboratories
Bangalore
About the Course:

1. Introduction
2. Eligibility for admission
3. Mode of payment
4. Summary of total credits
5. Summary of course details – Subject wise
6. Summary of course details – Semester wise
7. Syllabus of course subjects
8. Evaluation Procedure and Grading Scheme
9. List of faculty
Two Year
Post Graduate Research Program in Engineering in Engineering of Flight Vehicles
at
National Aerospace Laboratories, Bangalore
(2010 -12)

Configuration design of an aerospace vehicle is important from the consideration of building an efficient vehicle. The efficiency of the vehicle is defined in terms of its stability (for better control), minimum drag at cruise (to reduce the fuel consumption), higher maneuverability (to have air superiority), better engine integration with airframe (to provide higher thrust), better fatigue life (for longer life) etc. All these encompass study in various disciplines of aeronautics namely aerodynamics, propulsion, structures and flight mechanics. A program is designed with the aim to get better understanding of these areas with reference to their application to configure the aerospace vehicle and addressing the R&D challenges associated with it to improve the efficiency of the vehicle.

The program covers broadly, the areas of aerodynamics including computational fluid dynamics and experimental techniques, flight vehicle structures, aircraft propulsion, flight mechanics and control, aerospace vehicles and systems.

The two year Post Graduate Research Training Program aims to provide in depth exposure to the engineering concepts, scientific principles, research methodology and hands on experience on advanced real life R&D projects in different areas related to flight vehicles. Students completing this two years program are expected to be fully research – enabled and industry ready.

The first semester of the program focuses on core subjects covering the basics in each of the area mentioned above and associated practical work in the laboratories. The second semester offers courses which provides further an in-depth understanding of these areas related to their application to flight vehicles. The third semester offers advanced courses which lead to understanding of R&D challenges in the respective areas. In fourth semester students will be utilizing their knowledge acquired through the courses to solve real-world design challenges by working on advanced R&D projects work and for a dissertation in their specialization areas.
Eligibility for Admission

Candidates having BE/BTech or equivalent in Aeronautical/Aerospace/Mechanical Engg, completed in 2009 or graduating during 2010, with minimum 70% marks (Aggregate of all Semester/Year) or 7.0 CGPA (Aggregate of all Semester/Year) are eligible to apply.

Candidates who have passed BE/BTech or equivalent in relevant discipline before 2009 are not eligible to apply.

Desirable Qualification: A valid GATE score will be an added advantage.

Mode of Payment

Tuition fee need to be deposited the fee at NAL, Bangalore before the start of every semester by making payment either by cash at NAL cash counter or through Demand Draft drawn in favour of ‘Director, NAL’ payable at Bangalore. The Demand draft to be sent by speed post or registered letter to ‘Director, National Aerospace Laboratories Bangalore 560 017’ with the name of the student written in pencil on the reverse ride of the demand draft.

For other details (Admission Process, Eligibility, Fellowship, Important Dates, fee structure and online application)

Please visit the CSIR website http://www.csir.res.in/
COURSE DETAILS FOR CSIR PGRPE PROGRAM 2010 ON
‘ENGINEERING OF FLIGHT VEHICLES’

From: CSIR National Aerospace Laboratories

PROGRAMME DURATION: 2 years

Summary of Total Subjects / Total Credits for PGRPE Course on
“Engineering of Flight Vehicles”
to be conducted at CSIR-National Aerospace Laboratory in the year 2010

<table>
<thead>
<tr>
<th>Semester</th>
<th>No. of Subjects</th>
<th>No. of Credits</th>
<th>Place</th>
</tr>
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<tr>
<td>1</td>
<td>5</td>
<td>17</td>
<td>NAL</td>
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<tr>
<td>2</td>
<td>5</td>
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</tr>
<tr>
<td>4</td>
<td>1*</td>
<td>15*</td>
<td>NAL</td>
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<tr>
<td><strong>Total</strong>:</td>
<td><strong>16</strong></td>
<td><strong>49 + 15 = 64</strong></td>
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* Project Work
<table>
<thead>
<tr>
<th>Semester</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
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<tbody>
<tr>
<td></td>
<td>Aerodynamics</td>
<td>Applied Mathematics</td>
<td>Atmospheric Flight Mechanics</td>
<td>Aerospace Vehicles and Systems</td>
</tr>
<tr>
<td></td>
<td>Gas Dynamics</td>
<td>Flight Dynamics and Control</td>
<td>Navigation, Guidance &amp; Control</td>
<td>Aircraft Performance</td>
</tr>
<tr>
<td></td>
<td>Computational Fluid Dynamics &amp; Experimental Techniques</td>
<td>Exp. Flight Tech &amp; Data Handling</td>
<td>Flight Vehicle Design</td>
<td>Advanced Control</td>
</tr>
<tr>
<td>PROJECT WORK</td>
<td></td>
<td></td>
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Semester wise subjects

**I SEMESTER**
*(All Courses are Compulsory)*

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<tr>
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<td>3:0</td>
<td>Applied Mathematics</td>
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<tr>
<td>NALEF102</td>
<td>4:0</td>
<td>Aerodynamics *</td>
</tr>
<tr>
<td>NALEF103</td>
<td>3:0</td>
<td>Aerospace Vehicles and Systems</td>
</tr>
<tr>
<td>NALEF104</td>
<td>3:0</td>
<td>Atmospheric Flight Mechanics</td>
</tr>
<tr>
<td>NALEF105</td>
<td>4:0</td>
<td>Aircraft Propulsion*</td>
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</table>

* Includes practical classes

**II SEMESTER**
*(All Courses are Compulsory)*

<table>
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<th>Course</th>
<th>Credits</th>
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<tbody>
<tr>
<td>NALEF201</td>
<td>3:0</td>
<td>Navigation Guidance and Control</td>
</tr>
<tr>
<td>NALEF202</td>
<td>4:0</td>
<td>Gas Dynamics *</td>
</tr>
<tr>
<td>NALEF203</td>
<td>3:0</td>
<td>Flight Dynamics and Control</td>
</tr>
<tr>
<td>NALEF204</td>
<td>4:0</td>
<td>Flight Vehicle Structures*</td>
</tr>
<tr>
<td>NALEF205</td>
<td>3:0</td>
<td>Aircraft Performance Evaluation</td>
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</table>

* Includes practical classes
### III SEMESTER

*(All Courses Compulsory)*

<table>
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<th>Course Title</th>
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<tbody>
<tr>
<td>NALEF301</td>
<td>3:0</td>
<td>Flight Vehicle Design*</td>
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<tr>
<td>NALEF302</td>
<td>3:0</td>
<td>Experimental Flight Techniques and Data Handling*</td>
</tr>
<tr>
<td>NALEF303</td>
<td>3:0</td>
<td>Advanced Control</td>
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<tr>
<td>NALEF304</td>
<td>3:0</td>
<td>Structural Dynamics &amp; Aeroelasticity</td>
</tr>
<tr>
<td>NALEF305</td>
<td>3:0</td>
<td>Computation Fluid Dynamics and Experimental Techniques*</td>
</tr>
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</table>

* Includes practical classes

### IV SEMESTER

*(Project Compulsory)*

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>NALEF401</td>
<td>15</td>
<td>Project work-Thesis</td>
</tr>
</tbody>
</table>
Course Details – I Semester

**NALEF101 3:0 Methods of Applied Mathematics**

Linear Algebra (Matrices, vectors, determinants, linear systems, matrix eigenvalue problems, notion of vector spaces), Vector Calculus (grad, div, curl, integral theorems of Green, Stokes and Gauss and applications), ODEs (First order ODEs, higher order linear ODEs, notion of fundamental solutions and boundary conditions, systems of ODEs, series solutions of ODEs - special functions). Fourier analysis (series, integrals, transforms, applications), PDEs (basic types – elliptic, parabolic, hyperbolic), complex analysis (complex numbers and functions, complex integration, Cauchy residue theorem, power series, conformal mapping, potential theory), numerical methods (general numerics, basic numerical linear algebra like Gauss method / LU decomposition, basic numerics for ODEs / PDEs).


**NALEF102 4:0 Aerodynamics**

Concept of a velocity field, vorticity, Eulerian and Lagrangian coordinates, streamlines, streaklines and pathlines, concept of a substantial derivative, laws of conservation, elementary applications of continuity and the momentum theorem control volume analysis and its application, inviscid flows and the Bernoulli equations, elements of aerofoil theory. Lift and drag and their coefficients, small perturbation theory; 2-D airfoils in subsonic and supersonic flow, Numerical methods for 2-D airfoils; similarity rules, Multhop's method, vortex lattice and double lattice methods, effects of sweep and AR, Aerodynamics of wing - fuselage system and aerodynamics of control surfaces. High angle of attack aerodynamics: non-linear aero -dynamics, Unsteady aerodynamics. Five laboratory classes to demonstrate the concepts and measurements of some aerodynamics parameters.


**NALEF103 3:0 Aerospace Vehicles and Systems**

Evolution of heavier-than-aircraft for several applications, passenger, transport, freight, military applications, Configurations of various types of aircraft: Fixed wing aircraft, various types of aircraft, identification of various structural parts, materials used and their functions. Interplay of aerodynamics, structural mechanics, propulsion, avionics and controls in their conceptualization and performance. Introduction to aircraft specifications: Standards for both Military and Civil aircraft,
Airworthiness certification aspects aircraft introduction to flight-testing: Purpose and Scope of Flight Testing; introduction to general flying and handling characteristics of aircraft. Flight test plans and procedures, Flight test data acquisition, analysis and interpretation.

Padfield, R R Flying in Adverse Conditions, Tab Books, 1994
McCormick, B W Aerodynamics, Aeronautics and Flight Mechanics, 1995
Gorffin M D, and J R French, Space Vehicle Design, AIAA Education Series
Janes, All the world Aircrafts series.

NALEF104 3:0 Atmospheric Flight Mechanics

Systems of Axes, Euler Angles and quaternions, Axes Transformation, Static Equilibrium and Trim, Aircraft Static Stability, Contributions of Wing and Tail, Neutral Point and Static Margin, Longitudinal Stability and Control, Directional Stability and Control, Roll Stability and Control, Equations of Motion and their alternative forms, Solution of Equations of Motion, elastic airplane equations of motion, Transfer function and response characteristics, State Space Method, Aerodynamic stability and control derivatives, Aircraft modes of motion, Longitudinal and Lateral dynamic stability modes, mathematical model structure, reduced order models, frequency responses and time histories, modal analysis, eigenvalues, eigenvectors and mode shapes, maneuverability, Steady and accelerated flight

RC Nelson, Flight Stability and Automatic Control
Babistor A.H., Aircraft Stability and Control, Pergamon Press,
Elkin B., Dynamics of Atmospheric Flight, John Wiley and Sons

NALEF105 4:0 Aircraft Propulsion

Introduction to propulsive devices; Air-breathing and Non-airbreathing systems. Performance parameters, cycle analysis of ramjet, turbo-jet, turbofan and turboprop engines; Afterburners. Rotating Components: centrifugal and axial compressors, axial turbines; Non-rotating components: combustion chambers, intakes and nozzles. Five laboratory classes for showing the concepts and conducting of experiments.

Mukunda H S, Understanding Combustion.
Course Details – II Semester

NALEF201 3:0 Navigation, Guidance and Control


Introduction to open- and closed-loop control systems and examples, Differential equation models of physical systems and solution methods, choice of linear models, Laplace transforms, transfer functions, and block diagrams, State-variable system models, relative stability, gain and phase margins, Bode plots, Nyquist stability Criterion, Nichols chart, linear design process, Root locus design methods, System bandwidth, Feedback system characteristics, Design of feedback systems in the frequency- and time-domain, Observability and controllability, angle-of-attack limiter, sideslip angle and sideslip rate feedback, roll rate feedback, design of command paths, nonlinear design and verification, basic autopilot control laws.


NALEF202 4:0 Gas Dynamics

Fundamentals of thermodynamics; propagation of small disturbances in gases; normal and oblique shock relations, nozzle flows; one-dimensional unsteady flow; small disturbance theory of supersonic speeds, generation of supersonic flows in tunnels, supersonic flow diagnostics, supersonic flow over two-dimensional bodies; shock expansion analysis, method of characteristics; one-dimensional rarefaction and compression waves; flow in shock tube. Five laboratory classes for demonstrating the concepts and conducting of experiments.


NALEF203 3:0 Flight Dynamics and Control

Flight Mechanics parameters, aerodynamic database, principles of simulation, sensor dynamics, high-order actuator dynamics, engine model, landing gear model, integration into 6-DOF simulation model, Aerodynamic Modeling, flight path reconstruction techniques, aerodynamic derivative estimation, aerodynamic database validation and update procedures, Statically unstable aircraft, control power requirements for unstable aircraft, control actuator rate requirements, limits on static instability, control surface sizing, center-of-gravity limits, Routh-Hurwitz
stability criterion, root locus plot, inertia cross coupling, roll coupling, autorotation, roll reversal, Longitudinal and Lateral stability Augmentation, Pole placement method,

Schmidt, L.V., Introduction to Aircraft Flight Dynamics, AIAA Education Series.

NALEF204 4:0 Flight Vehicle Structures

Introduction to Aerospace vehicle structures, Aircraft structural components & loads, Aircraft Materials with specific reference to composites, Airworthiness, certification and standards related to aero-structures, Finite element structural analysis, Analysis & design of composites structures, Engineering fracture mechanics & damage tolerance, Impact and Crashworthiness, Introduction to Computer aided design (CAD) and product life cycle, management (PLM), Structural optimization: Size, shape and topology optimization, Smart structures and materials, Active structural control. Five laboratory classes showing the materials, and involvement of students in conducting of experiments.

D.V. Wallerstein, Variational Approach to Structural Analysis, John Wiley and Sons, 2001

NALEF205 3:0 Aircraft Performance Evaluation

Estimation of the performance: Power requirements and engine choice and size, minimum to fly level, power to climb and maneuver with typical power plants

Stability characteristics of the airplane: Longitudinal and Lateral stability analysis, static margin and stabilizer sizing; Sizing and trade studies.

Donald Layton, Aircraft Performance,Matrix Publishers, 1988
NALEF301 3:0 Flight Vehicle Design

Survey of various types of Airplanes, Overview of the design process; preliminary aerodynamic design, take-off weight estimation, selection of wing loading, thrust loading, engine and geometrical parameters of major components Conceptual design of a flight vehicle, Airplane Layout (Three view drawings: Arrangement of surfaces, Mass and Moment of Inertia properties and balance diagram) Design of structural components (fuselage, wing, horizontal and vertical tail). Design aspects of subsystems: Flight control system, Landing Gear and subsystem, Propulsion and Fuel system integration, Air pressurization and air conditioning system, Electrical & Avionic system

J Roskam, Vol 1 to 9 Aeroplane Design
John P Fielding, Introduction to Aircraft Design Cambridge University Press, 1999

NALEF302 3:0 Experimental Flight Techniques and Data Handling

Flight test planning and execution, flight test configurations, maneuver design, data acquisition methods, MIL-F-8785C, MIL-STD-1797, and FAR Part 23 requirements, Pilot opinion rating, Control Anticipation parameters, Flying qualities requirement on s-plane, handling qualities testing and analysis, handling qualities criteria, handling qualities ratings, pilot induced oscillations (PIO).

NALEF303 3:0 Advanced Control

Optimal Control, Robust Control, Modern Linear Control, Back-stepping Design, Feedback Linearization (Dynamic Inversion), Adaptive Control Design, Neuro-adaptive Control Design, High angle-of-attack (AOA) aerodynamics (both upright and inverted), post stall gyrations, spins, deep stall, departure susceptibility, departure criteria, directional departure parameter, lateral control departure parameter, continuation and equilibrium solution.

NALEF304 3:0 Structural Dynamics and Aeroelasticity

Variational principles, Hamilton’s Least Action Principle, Lagrange’s equations; Vibration of multi-degree of freedom systems; Finite element formulation for elasto-dynamics of continuous systems; bar, beam, and plates; Normal mode expansions and direct integrations; Static/dynamic condensation and sub-structuring techniques; Torsion and bending of an aircraft wing; Static aeroelasticity and divergence of a wing; Dynamic aeroelasticity and bending-torsion flutter of a wing; Dynamic response of a wing to gust and atmospheric turbulence; Introduction to nonlinear vibrations.

Clough R W and Penzein J, Dynamics of Structures McGraw Hill, 1993

NALEF305 3:0 Computation Fluid Dynamics and Experimental Techniques


Introduction to aerodynamic testing in various speed regimes; requirements of aerodynamic testing; Design aspects of low speed wind tunnels; flow visualization methods; Measurement methods for flow variables. Wind tunnel balances; Elements of computer based instrumentation; measurements and analyses methods; Model Design, Pressure, Flow, and Shear Stress measurements; Forces and moments from balance measurements, Sources of error in wind tunnel data, scale effects in data usage, general test procedures for aircraft.

Experimental Methods for Engineers, Holman
Pankhrust R C and Holder D W Wind-Tunnel technique, Sir Issac Sons Ltd.,London,
IV Semester

NALEF401-Project work-Thesis
The project work is aimed at providing the students to work on practical problem and carry out the work either through analytical/experimental/CFD.
**Evaluation Procedure and Grading Scheme**

The two-year programme is made up of 4 semesters with continuous internal evaluation and a semester-end examination for all courses.

Letter grades will be awarded for each course reflecting the student's proficiency and instructor's expectation. The grades and their description along with their equivalent numerical values, where applicable, are as follows:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Numerical Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
<td>Outstanding</td>
</tr>
<tr>
<td>B+</td>
<td>9</td>
<td>Excellent</td>
</tr>
<tr>
<td>B</td>
<td>8</td>
<td>Very Good</td>
</tr>
<tr>
<td>C+</td>
<td>7</td>
<td>Good</td>
</tr>
<tr>
<td>C</td>
<td>6</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>D</td>
<td>5</td>
<td>Fair</td>
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</table>

Performance of the student will be evaluated by two indices, semester grade point average (SGPA) and cumulative grade point average (CGPA). These will be calculated as follows:

\[
SGPA = \frac{\text{Sum of (Course credit} \times \text{Numerical value of course grade))}}{\text{Total course credits earned in the semester}}
\]
\[
CGPA = \frac{\text{Cumulative points scored in all passed courses}}{\text{Cumulative credits earned}}
\]

A student needs to have a SGPA of over 6.0 (in each of the first and second semesters) and a CGPA of over 6.5 (at the end of the second semester) for continuing beyond the first year.

For distinction, the student need to have CGPA = 8.0 or above.

Students getting E or F grades in a course need to re-appear for the final course examination before the start of the next semester.

I grade indicates the student has not been able to complete the course requirements and needs to take necessary actions as prescribed by the CSIR laboratory.

For more details please visit www.csir.res.in.
<table>
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<tr>
<th>No</th>
<th>Name</th>
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<th>Discipline</th>
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<tbody>
<tr>
<td>1</td>
<td>Dr Sajeer Ahmed</td>
<td>Scientist G</td>
<td>Aerodynamics</td>
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<td>1</td>
<td>Dr L Venkatakrishnan</td>
<td>Scientist E2</td>
<td>Aerodynamics, Measurement Techniques</td>
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<tr>
<td>2</td>
<td>Dr S B Verma</td>
<td>Scientist E1</td>
<td>Aerodynamics, Gas Dynamics</td>
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<tr>
<td>3</td>
<td>Dr Channa Raju</td>
<td>Scientist E2</td>
<td>Aerodynamics, Gas Dynamics</td>
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<td>4</td>
<td>Dr R Mukund</td>
<td>Scientist E2</td>
<td>Low Speed Flows</td>
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<td>6</td>
<td>Dr V Mudkavi</td>
<td>Scientist F</td>
<td>Vorticity Dynamics</td>
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<td>7</td>
<td>Dr Usha Srinivasan</td>
<td>Scientist E1</td>
<td>Fluid Mechanics, Mathematics</td>
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<td>Dr K R Srilatha</td>
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<td>Panel Methods</td>
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<td>Dr J S Mathur</td>
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<td>Dr Rajani</td>
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<td>11</td>
<td>Dr V Ramesh</td>
<td>Scientist E2</td>
<td>Grid free Methods</td>
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<td>Dr. S. Raja</td>
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<td>Aeroelasticity</td>
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<td>13</td>
<td>Mr. S.C. Lakshminarayana</td>
<td>Scientist E2</td>
<td>Airframe Design and Testing</td>
</tr>
<tr>
<td>14</td>
<td>Dr. S. Sridhara Murthy</td>
<td>Scientist G</td>
<td>Aircraft Structures</td>
</tr>
<tr>
<td>15</td>
<td>Mr. Shyam Chetty</td>
<td>Scientist G</td>
<td>Flight Mechanics and Control</td>
</tr>
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<td>16</td>
<td>Dr. G. Gopalaratnam</td>
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<td>17</td>
<td>Dr. Jatinder Singh</td>
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<td>Flight Mechanics and Control</td>
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<td>18</td>
<td>Dr. A. A. Pashilkar</td>
<td>Scientist E2</td>
<td>Flight Mechanics and Control</td>
</tr>
<tr>
<td>19</td>
<td>Dr. H N V Dutt</td>
<td>Scientist G</td>
<td>Mathematics, Flight Vehicle Design</td>
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<td>20</td>
<td>Mr. Bhaskar Chakravarthy</td>
<td>Scientist E2</td>
<td>Aircraft Performance</td>
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<td>21</td>
<td>Mr. Manjunath P</td>
<td>Scientist E2</td>
<td>Aircraft Propulsion</td>
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</tbody>
</table>
About NAL

1. Introduction to NAL
2. Mission
3. Major R&D Disciplines including description of divisions
4. Innovative Developments
5. Thrust Areas
6. Contribution to National Project
7. Collaboration and Partnerships
8. New Challenges, New Opportunities
9. Amenities
About National Aerospace Laboratories

National Aerospace Laboratories (NAL) a constituent institution of the Council of Scientific and Industrial Research (CSIR) under the Ministry of Science and Technology, Govt. of India, is a premier aerospace research and technology development organization of the country. Started as National Aeronautical Laboratory in June 1959 in New Delhi, NAL was shifted to Bangalore in March 1960 and started its operations in the stables of Maharaja’s Palace on Jayamahal Road in Bangalore. Today, its activities and facilities are spread over three campuses located on the Airport Road and behind the HAL Airport. In 1993 it was renamed ‘National Aerospace Laboratories’ to reflect its multidisciplinary contributions to aeronautics and space sectors.

NAL has celebrated its Golden Jubilee during the year 2008-09. Over the last 5 decades, NAL has successfully contributed to the growth of aerospace activities in the country in particular to the projects of national importance in the defence and space sectors. This has been done through building up of expertise and establishing various facilities and needed. In the last decade, NAL has also taken up the mandate for the design and development of small civil aircraft for the national needs. As a result of its successful efforts and significant contributions, NAL has come to be recognized internationally as a major center for aerospace research and development activities.

NAL is the largest laboratory of CSIR and has strength of 1350 people including 330 scientists with 100 or more having Ph.D’s. The mission of the laboratory is a good mixture of various activities, related to technology development, providing services to National programs and design and development of civil aircrafts.

Mission

- **Development of National strengths in aerospace sciences and technologies**, Infrastructure, facilities and expertise
- **Advanced technology solutions to national aerospace programmes**, Fighter aircraft, gas turbine engines, defense systems, defense services, launch vehicles and satellites, space systems
- **Civil aeronautics development (1994 onwards)** Design and develop small and medium-size civil aircraft – Promote a vibrant Indian
NAL’s activities in the area of aerospace have helped the strategic organizations (DRDO, ISRO, DAE, Defence Services etc.) in the country achieve success in their mission mode projects besides building up national technology strengths in the areas of civil aircraft design and development.

**Major R&D Disciplines**

NAL’s core competence spans the entire aerospace sector with the ability to provide complete holistic technology solutions. NAL has had interaction with all the Indian aerospace organizations and has considerable visibility in India and abroad.

- Computational fluid dynamics
- Experimental aerodynamics
- National Trisonic Aerodynamic Facilities
- Flight mechanics and control
- Propulsion
- Composites
- Structural design, analysis and testing
- Structural dynamics and integrity
- Surface modification
- Aerospace materials
- Aerospace electronics and systems
- Civil aviation
- Parallel processing computers
- Meteorological modeling
- Wind energy
- Manufacturing technology
- Information systems

Brief work being carried out in the above disciplines in the various divisions is given below. These divisions mainly provide the critical scientific / technological inputs required of the design and development of many indigenous aerospace vehicles and also look into future S&T requirements of the country to create the necessary knowledge base and to develop further cutting edge technologies.

**Advance 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. ACD has 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 fiber metal laminates have been developed.

A newly evolved cost-effective Vacuum Enhanced Resin Infusion Technology (VERITy) has been developed for wing fabrication. 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).

**Aerospace Electronics and Systems Division**

Aerospace Electronics and Systems Division (ALD) has a core strength 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 a major programme on Active Noise Control for aircraft cabin and industrial applications. The division’s focus is on the areas of aerospace electronics, active noise control, Electromagnetics and critical flight data analysis and validation.

The division has developed the 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 area of Flight Data Analysis and Animation, NAL Visualization and Animation Software (NALVAS) and its integration with the NAL Flight Operations Quality Assurance (NALFOQA) software. Scientific investigations are 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. The establishment of NAL-Microwave Anechoic Chamber (NAL-MAC) is one of the major achievements of the division.

**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.

**Centre for Civil Aircraft Design and Development**

The charter and focus of C-CADD is to bring under one roof the civil aircraft development project optimally utilising the available resources. It is also tasked with to plan in advance other projects such as 5 seater general aviation aircraft, regional aircraft and study airworthiness and certification aspects and liaison with DGCA. It produced 12 HANSA aircraft for delivery to DGCA and CASA Australia and is currently working on a five seater General Aviation aircraft development jointly with private industry (Mahindra Aerospace Technologies) launched in 2006.

**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. 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.

**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 Aircraft and Spacecraft Aerodynamics, Civil Aircraft R&D, and Flow Diagnostics. 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 has been set up in the division.

**Flight Mechancis and Control Division**

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. Design of the SARAS Autopilot is a major program and the SARAS Flight Training Device for Pilot training is also being set-up in the division in partnership with a private company. 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.

**Flosolver Division**

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.
The Flosolver Unit carries out 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 interconnect 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.

**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.

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 prepgs (JIPREGS).

**Materials Science Division**

The activities of the division is directed towards development of materials for aerospace applications, characterization 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 fibers. One of the major activities of the division is failure analysis and accident investigation and testing and qualification of materials.

The focus of activities of the division is currently 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. 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.
**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.

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.

**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 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.

**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 expertise of the division is in designing scaled wind tunnel models and design & development of indigenous large Autoclave systems. The division has made significant contributions in design and analysis of ground based, airborne and missile radomes. 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.

**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.

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 electro deposited 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.

**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 has been installed in Antarctica.

**Other Important Divisions:**

**Knowledge and Technology Management Division**

The mandate of the Knowledge and Technology Management Division is to ensure easy and smooth operation of all the management activities of NAL. It is comprised of four groups.

The Project and Business Management Group (PBMG) carries out both technical and financial management including project planning, costing/budgeting, project monitoring of both externally funded and internal projects, IPR, technology transfer and project evaluation.

Public Relations and Resources Management Group (PRRMG) manages Public Relations - including visitor services, event management, training and coordination.
Media and Publicity Management Group (MPMG) organizes exhibitions, management of NAL Museum, Press and Media, supports publication and dissemination of technical and popular periodicals documenting NAL's R&D effort and offers photography and videography services. Management of Information Systems Group (MISG) undertakes the Design, Development and maintenance of ERP packages, development and maintenance of MIS on intranet and Web-Based information.

**Information Centre for Aerospace Science and Technology**

The Information Centre for Aerospace Science and Technology (ICAST), a state-of-the-art centre with expertise, infrastructure and services caters to the information requirements of the Indian aerospace community in particular and the engineering and technical community in general. ICAST is well known for its exhaustive and rich collection of books, journals and specifically technical reports from NASA, DLR, ONERA, NLR, UTIAS etc, in addition to 50,000 meeting papers of 375 AIAA conferences. The centre offers Online, Web and CD-ROM based literature search services including access to e-journals, News clipping services, Online Public access Catalogue, Union Catalogue of Serials held by CSIR/ Aerospace Libraries. More than 6,000 ejournals from major publishers like IEEE, AIAA, Springer, Wiley, CUP, ASME, ACM, AIP, RSC are accessible through CSIR consortia. Books online from Springer, CUP, Reference Works from Credo are accessible, as are major databases like Web of Science, Aerospace database and J-Gate.

**Innovative Developments**

- Successful development of SARAS Prototypes PT1,PT2-a 14 seater multi-role transport aircraft
- Design and development of HNSA (all composite, 2-seater for day/night operations. DGCA type certified aircraft)
- Technology for production of autoclaves
- State-of-the art transmissometer DRISHTI for measurement of runway visibility at airports as a safety aid
- Manufacture of the fibres and prepregs of strategic importance – R&D in aircraft and space grade fibres
- National Test Facility for rolling element bearings
- Design of India-specific wind turbines
- Hardware and software for weather forecasting relevant to India
- Design and Development of supersonic combustors
- Failure analysis and accident investigation
- Software for flight quality assurance and incident / accident analysis (NALFOQA/NALVAS) for airlines
- Cost-effective rapid resin injection moulding technology for nose radomes of fighter aircraft
- Low cost Vacuum Enhanced Resin Infusion Technology (VERITy) for advanced composites components
- Advanced flow computation and visualisation techniques
- Smart materials and structures (sensors and actuators)
• Nano surface coated mirrors for passive cooling of IR sensors in satellites
• Active noise control for aircraft/helicopter cabins
• Development and validation of the Tejas (LCA) flight control law
• Public – Private partnership to jointly design, develop and certify small general aviation light aircraft (NMS-100) with 4 to 5 seats.

**Thrust Areas**

• Cutting edge technologies in aerospace
• Centre of Excellence in Flight Mechanics and Control
• Advanced technology solutions for national programmes
• Micro Air Vehicles for strategic / civilian use.
• Production of SARAS aircraft for IAF and other customers
• Development of a regional transport aircraft of 70 -90 seater with turboprop / fan engines under the 11 FYP to promote regional air transportation / economy.

**Contributions to National Projects**

NAL has contributed enormously to virtually all the national projects in both the aeronautical and the space sectors. Among the significant contributions of NAL are:

• Leadership of National Team for CFC Wing
• Advanced Composite Structures
• Carbon Fibers
• Leadership of National Team for Flight Control Law Development
• Wind Tunnel Models & Testing – Aerodynamic Data Generation
• Material / Box level Testing and Characterization for Certification
• CFD Analysis
• Surface coating
• Noise measurement & control
• Flow Diagnostics Studies
• Aeroelastic Model Studies
• Dynamic Response Studies
• Acoustic test facility
• Sunshield Mirrors for IR Sensor Cooling on Satellites
• Composite Radome for DWR
• Thermo - Structural – Aeroelastic Analysis for RLVTD
• High Speed Combustor Design and Testing
• Transonic Buffet Studies on Launch Vehicle Models
• SATCOM Applications
• Special Carbon Fibers
Collaborations and Partnerships

NAL has developed collaborative programs with various Aerospace organisations and R&D institutions abroad mainly to foster the growth of R&D activities and technology developments.

**Long Term Cooperations**

- DLR, Germany
- CAE, China
- P&W, USA

**Collaborations**

- RMIT, Australia
- Boeing, USA
- P&W, Canada
- BELL Helicopters
- NC A&T University
- UKIERI, UK
- ALCOA, USA
- Florida State University, USA

**Interactions**

- CRIAQ, Quebec, Canada
- Bombardier, Canada
- Province of Bavaria, Germany
New Challenges, New Opportunities

Keeping in pace with increasingly globalised aerospace R&D scenario, NAL is exploring new model and structures to fulfill its mandate in the following areas during the 11th Five Year Plan (2008 – 2012). NAL will leverage its diverse and multidisciplinary resource base to the research needs of the national and international aerospace community, and society at large.

- Advanced flow diagnostics
- Advanced structural technologies
- Advanced wind turbines
- Aeroacoustics
- Air traffic management
- Aircraft systems
- Automatic target recognition
- Civil aviation
- Computational sciences
- Crashworthy structures
- Damage tolerant designs
- Data fusion
- Enhanced and synthetic vision
- Flow control
- High performance computing
- High temperature materials and coatings
- Hypersonic propulsion
- Integrated vehicle health management
- Low Reynolds number aerodynamics
- Micro aerial vehicles
- Morphing structures
- Multidisciplinary design optimization
- Multifunctional materials
- Nanotechnology
- Next generation composites
- Precision weather forecasting
- Small gas turbines
- Surface modification
- Ultra – light systems
- Vibration and noise control
Amenities

- **Sports**

NAL has a number of sports activities both for outdoor and indoor games. It has a cricket ground, where a number of matches under Karnataka state cricket association are played; tennis court, a basket ball court and a volley ball court. For indoor games facilities for playing shuttle badminton, table tennis and carrom are available. These facilities are extensively used by NAL staff members during lunch break and after office hours during the weekdays.

- **Health Center**

A health center catering to the employees of the laboratory exists on the campus. The center has five doctors, and operates during the weekdays. Doctors are available at the campus for 24x7 hours.
Some of the activities of the laboratory in pictorial form:

SARAS PT-1 in flight

Specimen in the Reverberation Chamber.

Surface pressure map on TEJAS model using Pressure Sensitive Paint

Computed density contours at different inlet sections of HRV
Artificial feel Six Degrees of Freedom
Departure and Spin Studies

The 128 processor Flosolver Mk 6

Integrated Facility for Carbon Fibre production

Captive Trajectory System for studies on stores separation from aircraft models

High Speed combustor test facility
NAL-Sangeeth wind turbine blades being tested at Kethanur wind farm

4m x 8m Autoclave designed and developed for HAL

Photograph of sunshield mirrors

ICAST website