# Advanced Research Areas for the Development of Autonomous Micro Air vehicles: An overview

**S. Sankara Narayanan, Dr. G. Ramesh, Roshan Antony and C. S. Suraj**
National Aerospace Laboratories, Bangalore

## I) Introduction and Relevance of the work

For the past one decade great impetus is given to the development of Micro Air Vehicles (MAV). It is an autonomous flying vehicle capable of carrying a payload. The maximum linear dimension of this machine is 150 to 300mm and its weight can vary from 100 to 300 grams. The flight speed is around 10m/s and it operates at Reynolds number in the range of $5x10^4$ to $2x10^5$. MAV flies in the low Re regime and hence there is a marked deterioration of Lift at most operating conditions. This calls for the use of some lift enhancing techniques. Another important criteria is the control aspect of this type tiny vehicles. All these demands can be met only by choosing an appropriate structure/power plant. Flight testing and fabrication of these machines also pose many difficulties and it is a tough challenge to design and fly a MAV in the autonomous mode. MAVs can carry various special sensors as payload to support such civil and military missions as traffic monitoring, weather observation, anti terrorists operations and enemy surveillance. MAVs are equipped with a miniaturized video camera which could locate nearby enemy troop positions .On the civil side, it can be used for disaster management, Traffic control & monitoring, Fire & Flood - Search & Rescue Missions, Land & Forest Survey, Bio-Hazardous Environment Survey, Power line Inspection, Real Estate Aerial Photography and so on. Use of MAVs can also be very cost efficient, once the development unit is achieved. MAVs can be classified under on three primary categories: **1. Fixed wing, 2. Flapping wing, and 3. Rotary wing.** Technologies related to these classes of MAVs are also in the infancy stage and we need to have self sufficient / matured technology to be developed through various R&D programs in the field of Aeronautical engineering in this country. Many research areas related to MAVs have been identified and some of them are presented in this article. The technology development route for MAV is dynamic (in phase with current technology) and to be implemented through one of the methodologies as shown in Figure (1)

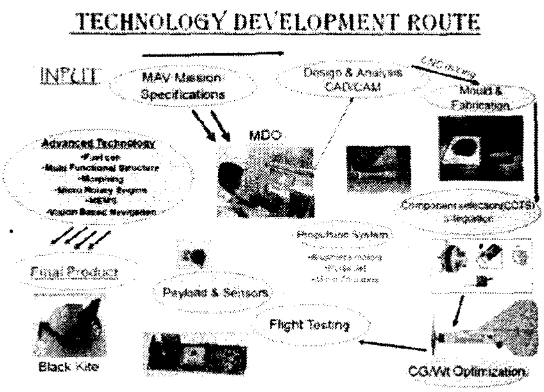


*Figure 1*

## II) Thrust Area

National Aerospace Laboratories is a premier research institution in the country involved in several aerospace programs of its own as well as been the backbone of almost all the aerospace activities in the country. It has the infrastructure and expertise to take up any new challenges in the aerospace programs of national importance.MAV has research areas which are of importance and are given below. NAL is ready to address these problems individually and an integrated manner.

The following are the few important technology development areas which are vital for the future of Micro Air Vehicles. Most of them can be classified under very high technology related work. Some of the critical Technology planned is:

- Aerodynamic design using Computational Fluid Dynamics (CFD) tuned for Low Reynolds numbers applications
- Experimental Aerodynamics, Low Speed Wind Tunnel Testing
- Separation Control, Transition Phenomena & modeling at Low Re numbers
- Power Plant (High speed and high efficient miniature Propellers, miniature Motors, Miniature Pulse Jet, Micro Gas Turbines, Fuel Cells, Unconventional Power Plants)
- Advanced composite materials
- Smart materials like Shape memory Alloys, Shape memory Polymer, Electro active polymers
- Multifunctional and Morphing structures
- Actuators and sensors, MEMS sensor technology including testing and calibration.
- Flight control sensors - testing and integration.
- Autonomous flight for a defined autonomous mission, Processor software
- Autopilot development
- Miniature Camera (Image sensors) and image data processing/Exploitation
- MAV networking (MAV swarms)
- Distributed Propulsion
- Bio-Inspired Propulsion
- Vision Based Navigation and Control
- Onboard Information Storage and Video Processing
- Mapping and Photographing Interiors of Buildings and corridor flight
- Rapid Prototyping
- De confliction and Collision Avoidance
- Cooperatively and Autonomously Flying Group of MAV with intercommunication.
- Acoustic and Chemical Sensing
- Capability to fly both Outdoors and Indoors

## III) Technical Appreciation of Main Areas of Research

The R&D areas identified in various aspects of the MAV are briefly discussed here under:

1) **Experimental Aerodynamics**

- Higher wing loading.
- Low Re number and Low aspect ratio research problems.
- Separation of laminar boundary layer and early stall.
- Lift hysteresis.
- Wind tunnel Experiments for basic studies and for characterization of airframe.

2) **Design and analysis using Computational fluid dynamics (CFD) Tools**

- 3D Navier Stokes code analysis
- The aerodynamic characteristics at low Reynolds number airfoil are:
  - Ø Laminar separation bubble including laminar separation location and reattachment
  - Ø Transition, Turbulent Separation and Re-attachment.

3) **Propulsion and power**

- High thrust to weight ratio propulsion system, small internal combustion engines to electric motors.
- The power to the motor and the rest of the components is provided by Lithium Polymer (LiPo)

batteries due to its high energy density.

- Motors run by, fuel cells, MEMS based Gas turbine. Ultra miniature Rotary engine generators, thermal photovoltaic generators, solar cells, or beamed energy systems.
- Miniature pulse jet.
- Propeller efficiency enhancement: Any improvement in propeller efficiency will reduce the power requirement, thus reducing the weight of the battery.

4) **Material Selection**

- Material selection for MAV is very important, because the all up weight has been constrained by the size of the MAV.
- Conventional structure Foam, Balsa with reinforcement, high-density foam and carbon fiber. Shape memory alloys, shape memory polymers.
- MAVs will have adaptive wings with frame made of carbon rods and flexible epoxy / Fiber glass skin will cover the structure. The airfoil will be thin with variable cambered configuration. The actuators will be embedded inside the wing structure.

5) **Structures**

- Flexible aircraft wings and morphing techniques are the prime focus areas for improving handling qualities and controllability for small aircraft, especially in gusty conditions.
- Flexible wing and stall delay.
- Morphing is being explored to enhance controllability during agile maneuvers.
- Strategies include wing curling, wing twisting, multi-point wing shaping, leading-edge twisting, variable gull-wing angling, and wing-tail folding. Morphing is not difficult to do because the wings are quite flexible so little energy is required to alter their shape. Morphing is truly a biologically-inspired concept because the MAV is similar in size and speed to a bird and can mimic selected properties of bird shapes.

6) **Flight Control and stability.**

- A flight-control system is required to stabilize the MAV or at least augment its natural stability, and to execute maneuver commands.
- Flight-control components include actuators for aerodynamic controls, motion sensors, and processing.
- Conventional control surfaces with discrete actuators, distributed micro flaps, or warped lifting surfaces, depending on the airframe configuration.
- Piezoelectric actuators (both bulk and thin-film devices) and large number of MEMS devices, which could be electromagnetic, electrostatic, or ultrasonic-wave devices.
- Integrated module (autopilot) with a main processor for the flight control, stability, navigation and guidance of the MAV. MEMs based gyro and accelerometers
- Identification and possibility of Indigenization of autopilot components

7) **Navigation and Guidance**

- GPS, inertial sensors, barometric and dynamic pressure sensors, and horizon sensors. Vision based Navigation.

8) **Payload: Miniature Camera and sensors**

- Testing, integration and image exploitation.

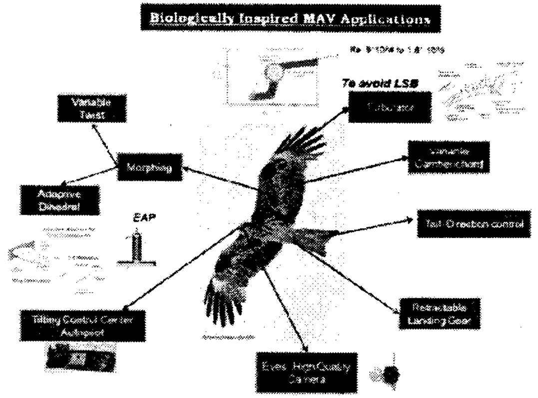


*Figure 2*

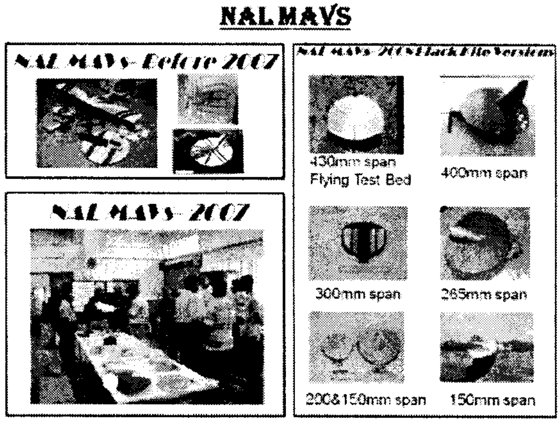


*Figure 3*

- Calibration of the camera in the laboratory and
- Camera on a stabilized platform.
- Sensors: Sound detecting array, bio sensors, Infrared sensors.

From the dawn of flight man has always dreamt of flying like the bird. He has kept his eyes in the sky looking at the bird. It would be interesting to note that man has not been successful in mimicking the bird. But the bird has all wonderful ingredients required for a man who can get bio inspired in designing a flying vehicle. Figure 2 shows the wonderful bird in all aspects.

## IV) MAV developmental work at NAL

At NAL, we are developing "Black Kite"- a 300mm span fixed wing autonomous Micro Air Vehicle (MAV) with an endurance of 30 minutes. The first version of this indigenous MAV has been successfully flight-tested in two modes: radio-controlled, and recently autonomous. The autopilot system used in Black Kite has been developed indigenously and is state-of-the-art. The figure given at the end of this article will show some MAVs going through developmental process from mid 2000 to year 2008