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# R&D Newsletter

INDIAN INSTITUTE OF TECHNOLOGY KANPUR



Research on UAV Technology

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## Development of Small Sized Fixed Wing Unmanned Aerial System

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Co-PI: Professor Deepu Philip, Department of Industrial and Management Engineering  
Professor J. Ramkumar, Department of Mechanical Engineering  
Professor Nishchal Vema, Department of Electrical Engineering

### Product Characteristics

- Easy to assemble – modular approach, can be carried on the back of a Jeep or Gypsy
- Short take-off and landing: approximately 50 feet of flat surface as runway
- Autonomous flight capability – controlled by on-board autopilot, allows for multiple flight modes
- Navigation and Flight modes: GPS based Waypoint navigation as well as loitering flight mode for target tracking
- Payloads: Multiple surveillance and environmental sensing payloads. Example: EO camera, IR camera, Dual, Aerosol sensors, CO<sub>2</sub> sensors, etc.
- Maximum Take Off Weight (MTOW): 16 to 21 kg
- Propulsion: Electric or Gasoline based on mission requirements
- Endurance (continuous flight): 4 hours to 10h
- Wingspan: 3 – 3.6m
- Length: 2 - 2.30 m
- Redundant communication systems for telemetry and data.
- Time to assemble the system: approximately 20 min
- Cruise speeds: 55 - 120 kmph

The project aimed at developing a small sized Unmanned Aerial System (UAS) based on the fixed wing platform, having long endurance, in a pusher configuration; capable of both civil and defense applications. The platform was chosen specifically to accommodate future modifications to the design; larger wingspan and heavier payloads.

The developed UAS has long endurance - greater than seven hours, and good all-up weight - about 16 - 21 kilograms, in which payload capacity varies from 2-6 kilograms. The UAS propulsion system can be either electrical or gasoline, both mounted in a pusher configuration. The pusher configuration was chosen keeping in mind futuristic application of the UAS in sensitive areas where exhaust fumes from puller engine may affect different environmental sensors. Our UAS is presently operated through a Ground Control System (GCS), with autonomous flight capability using an on-board autopilot that is capable of waypoint navigation and loitering flight; except take-off and landing. The present system is designed and tested for an operational ceiling of 5000 feet from the sea level.

After analysing the defense and civil scenario, it is identified that the low altitude long endurance tactical section of UAV is the most lacking area. Such UAVs find application in border patrol, search and rescue, traffic monitoring, crowd control, environmental studies, asset monitoring, crop monitoring and re-supply.

Initially, multiple configurations were designed and tested for attaining the design specifications. The most important of them were the wing loading and power loading, which was extensively studied. The results are summarized in Figure 1.

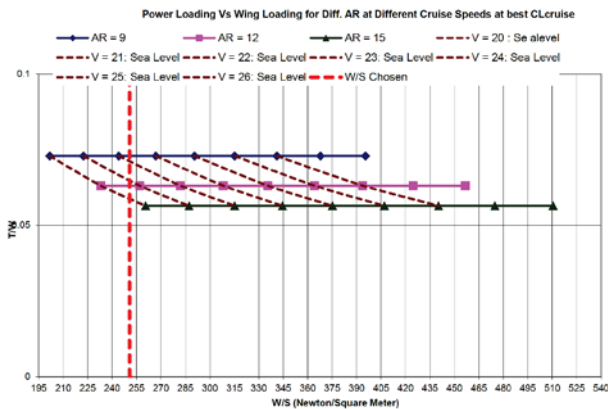


Figure 1: Power loading vs Wing loading graph

Once the airframe design was finalized, the manufacturing of the airframe was researched for rapid production, maintainability, knock-down for easy transportation to mission locations, repairability, along with rapid instrumentation for conversion to a research platform. Considering all aspects, we decided to use composites, mainly of fibre reinforced plastics, Kevlar, and carbon fibre. For example, the fuselage was made as hollow monocoque structure, made of fibreglass sandwiched with 2 mm rohacell. Similar approach was also used for wing manufacturing, where the final surface finish met the aerospace requirements, as shown in Figure 2.



Figure 2: Wing part developed using the manufacturing process

The control system provides integrated miniaturized avionics for autonomous control of micro/mini UAV, which is also capable of automatic take-off, landing, waypoint navigation and steering flight control with manual override. The MIL grade autopilot has integrated INS/GPS and Air data System provide accurate estimates of altitude, velocity and position. The versatile I/O interface provides option to hook up external payloads for user specific requirement. The integrated datalink modem provides communication in excess of 20 kms range. Users can dynamically plan mission, monitor critical flight parameters and adjust UAV parameters through an intuitive graphical user interface (GUI). The system performance was characterized and typical outcome is shown in Figure 3.

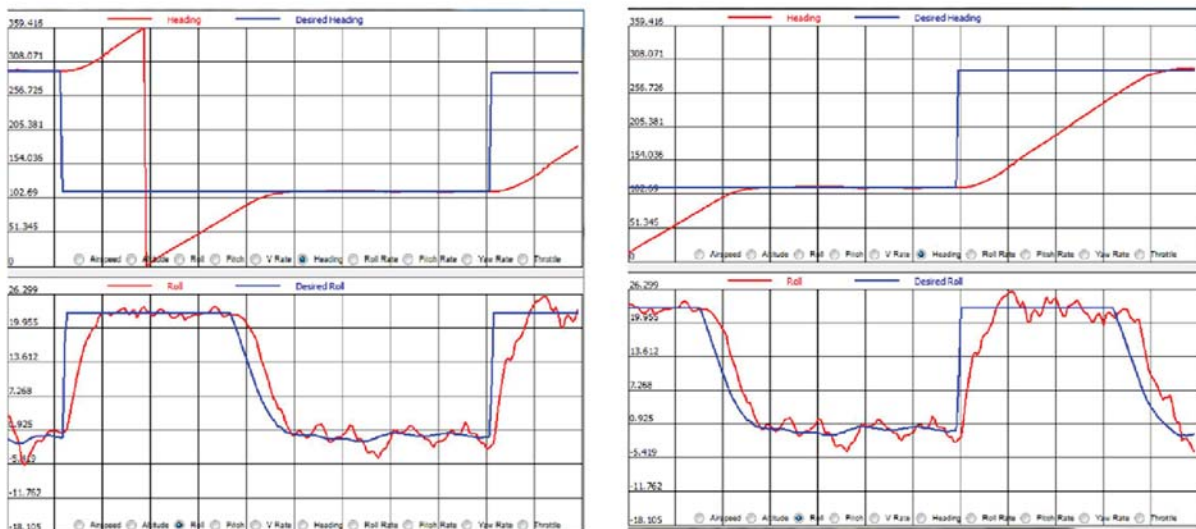


Figure 3: Heading hold and step commands and performance of roll



# Design and Fabrication of Autonomous Flapping Wing Unmanned Air Vehicle for Surveillance and Aerial Photography

PI: Professor Debopam Das, Department of Aerospace Engineering  
Co-PI: Professor Abhishek, Department of Aerospace Engineering  
Professor K.S. Venkatesh, Department of Electrical Engineering

## Specific Objective

- Design and fabrication of an autonomous flapping wing UAV of 1.5m wing span with endurance of 60mins
- Making it autonomous in a communication range of 2km with a image capture and communication module on the airborne platform
- A ground based module that receives the UAV data, processes it, registers the data against the map database.
- Image stabilization



### Model specifications:

- Wingspan 1.6m
- Dry Weight: 400 g
- Endurance: more than 1 hour with 2 batteries (1000mAh each 3 cell)
- Cruise speed: 6 to 8 m/s
- Stiffness: Mylar and LDPE tubes

The project aims to build an autonomous 1.5 m wing span flying bird which will carry a small camera as the payload and will be able to record pictures for surveillance applications. Two other flying models have been constructed of wind span 1.6m with very distinct mechanisms and weight. The use of polythene wing membrane with density  $40\text{gm/m}^2$  has proved to deliver superior performance.

## Technical Results Obtained:

### Flapping wing vehicle:

- Two new flying models have been constructed of wingspan 1.6m each with different mechanism and weight.
- Various materials were tested for a good wing construction and different arrangements of stiffeners.
- Polythene wing membrane (40 grams /sqm ) proved to deliver superior performance than a polyurethane coated nylon fabric (80 grams /sqm)
- Density of the wing membrane is critically important and plays a vital role in the flight performance. The nature of flexibility for the large wing needs to be investigated.
- Wind tunnel testing has been carried on a smaller model of 1 m wingspan (Cleo) using ATI mini 40 6axis load cell at NWTF.

### Autonomous flight test carried out on this model for loiter mode:

- Flight data (Euler angles and rates) are collected using a NAVSTIK autopilot with onboard data logging.
- Unlike an aircraft, the attitude of ornithopter contains ripples of oscillations which has same frequency as the flapping of the wings and is filtered using a low pass filter to get the attitude of the vehicle.
- The tail movement generates a coupling between

pitch and yaw. To decouple, a mixing is introduced in the tail i.e. when the tail turns to yaw, it also pitches up to compensate for the effective reduction of tail area due to turning.

- The vehicle is further tuned manually by adjusting gains of the autopilot by flying and testing.
- Loiter is accomplished by flying in a circle of given radius.
- Once properly tuned the vehicle was able to fly through the specified path.

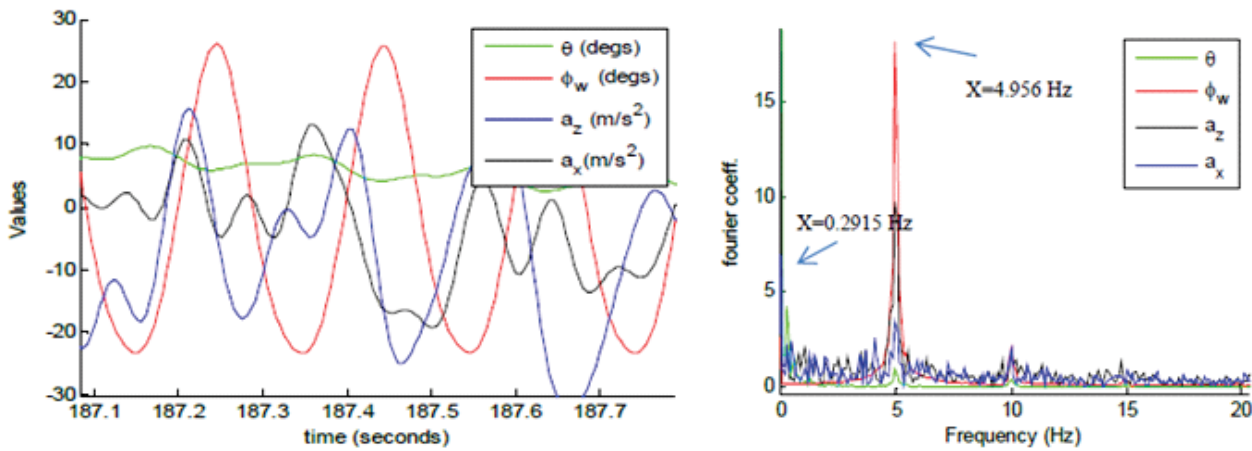


Figure : (a) In flight filtered pitch angle, wing position and accelerations raw data from IMU for the ornithopter Cleo acquired at 200 Hz (b) Fourier coefficients of pitch angle, wing position acceleration. Here flapping frequency is 4.956Hz and pitching heaving oscillations are strongly correlated to this frequency. X=0.2915Hz is the phugoid or long period frequency during flight.

### Requirements:

- For the estimation of inertial force of the wings a vacuum chamber of 2x2m<sup>2</sup> is required.
- A testing facility (an open jet low speed wind tunnel of 3x3m<sup>2</sup> cross section and maximum wind speed of 20-30m/s) for larger models is required to be created. The facility should consist of force measurement devices along with gust generation mechanisms. This can also be used as low speed wind tunnel which finds many applications in the field of aerospace engineering.

# Design and Development of Visually Guided Autonomous Quadrotors: application in surveillance and disaster management



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Co-PI: Professor Sumana Gupta, Department of Electrical Engineering  
Professor K.S. Venkatesh, Department of Electrical Engineering  
Professor Nishchal Vema, Department of Electrical Engineering

## Specific Objective

- Development of a Visually Guided Quadrotor
  - Visual Control
  - VSLAM
  - Trajectory Planner
- Stabilizing Controllers
  - Backstepping
  - Sliding Mode
  - Fuzzy Control
- Formation Control – Theoretical Developments
- Demonstration of Quadrotor formation

The need for unmanned aerial vehicles (UAVs) with greater maneuverability and hovering ability for various military and civilian applications has led to the current rise in quadrotor research. A quadrotor, also called a quadrotor helicopter or quadcopter, is a multi-copter that is lifted and propelled by four rotors. The four-rotor design allows quadrotors to be relatively simple in design yet highly reliable, agile and maneuverable.

### Development of a Visually Guided Quadrotor

The concept of Localization is used for maintaining the quadrotor at a particular point in 3D space. In Figure 1, we demonstrate visual control of a quadrotor (Pelican from AscTec) for hovering at a specific altitude where the current position is obtained by looking at a predefined pattern present on the ground. The control architecture is shown in Figure 2.

A very real life application of this experiment lies in rescue operations during the event of an environmental disaster. A quadrotor can enter a damaged building and move to places which would otherwise be difficult to access by rescue teams.

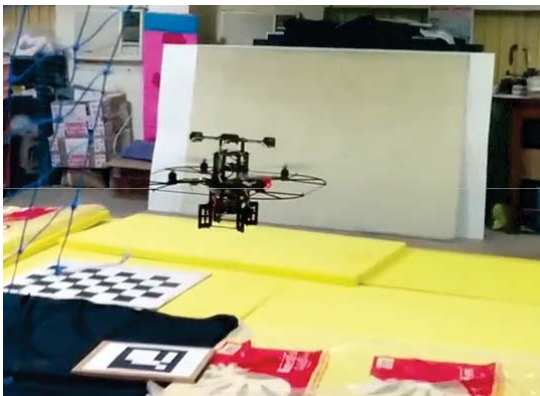


Figure 1: A quadrotor is hovering based on visual feedback

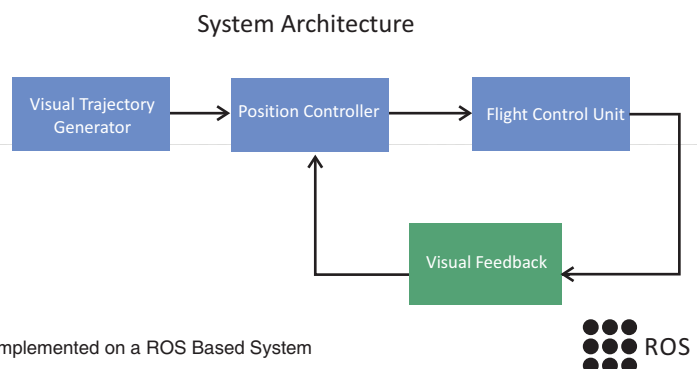


Figure 2: System architecture for Vision Based Navigation

## Visual Navigation of a Quadrotor

Single camera is used to reduce the payload and increase the endurance of the system. The two frames, displaced in time, are taken to simulate the stereo vision for computing the depth of the target/scene. To calculate the correspondence between two frames, feature points detected from the images are matched. We can calculate the disparity between matched points caused by UAV movement by taking the difference between the two coordinate positions in the scenes. Since the UAV can also undergo rotation, we compensate for disparity caused by rotation. The scheme is provided in Figure 3.

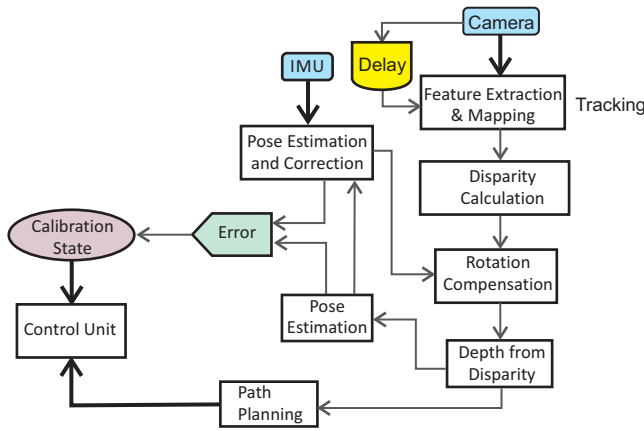


Figure 3: Proposed Visual Navigation Scheme

## Stabilization of Multi-UAV systems and Formation Control

Formation of quadrotors has great applications in precision agriculture, disaster management and crowd control. We consider an  $n$ -agent system where the agents move on a plane. Each agent communicates with its neighbours. The communication topology is fixed and is represented by a completely connected graph  $G$ . The objective of this work is to develop a control law to achieve a desired formation. The control law comprises of two parts: Improve collision avoidance scheme (ICAS) and consensus term. The ICAS has been designed to avoid collision between agents, and the consensus term helps in achieving the desired formation.

We consider a 6-agent system to generate the collision free desired hexagon formation. Figure-4 is presented the trajectories of the six agents and from figure 5 it is

observed that no agents collide with each other as the minimum inter agent distances never goes less than the safety distance  $r_{in}=0.5$ .

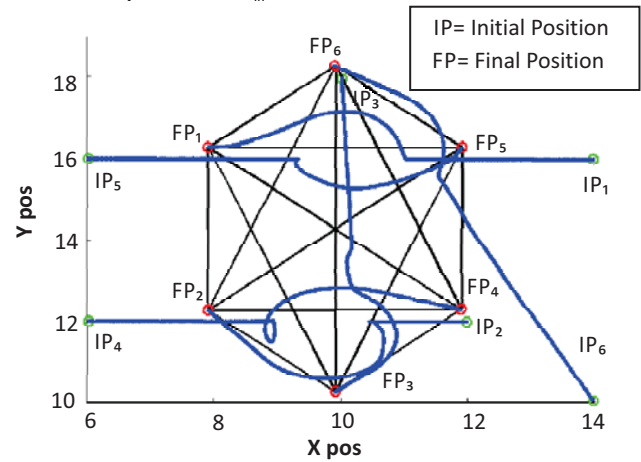


Figure 4: Six agents make a formation

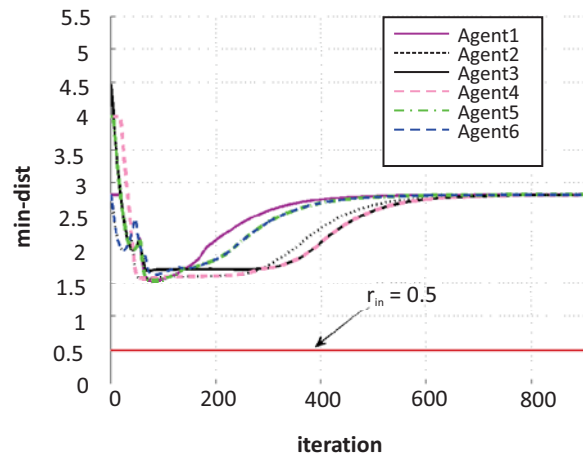


Figure 5: There is no collision during the formation

## Static and Dynamic Boundary Estimation and Tracking:

We consider  $2n$ -agent system where the agents move on a plane. Each  $i$ th agent can communicate with its two neighbouring agents (Backward and Forward agents). The communication topology is fixed and is represented by a connected graph  $G$ . Each  $i$ <sup>th</sup> actual agent is associated with  $(i+1)$ <sup>th</sup> virtual agent (odd index is for actual agents and even index is for the corresponding virtual agent). The objective of this work is to develop a boundary tracking and estimation algorithm to track the static and dynamic boundary. In this work we are assuming that velocity of the dynamic boundary is less than the agent's velocity.

We consider 24-agent system, where 12 are actual agents and 12 are virtual agents. Figure 6 presents the evolution of the dynamic boundary. From figure 7, it is

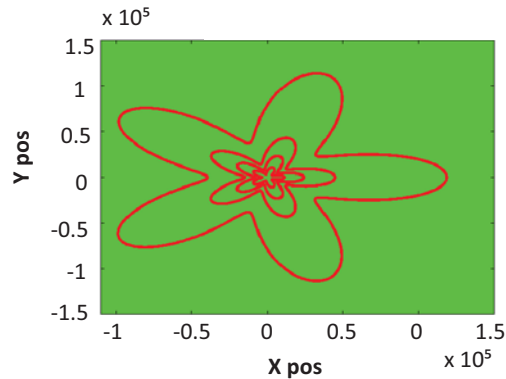


Figure 6: Temporal Evolution of the boundary

observed that the agents are converging to the boundary.

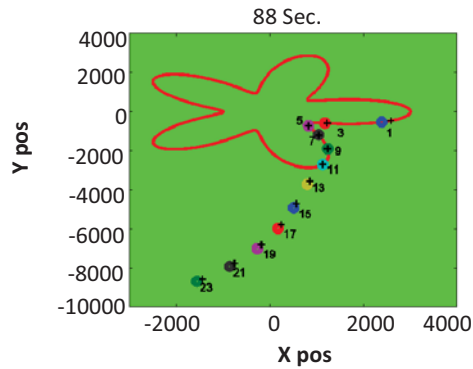


Figure 7: Convergence of the agents to the boundary

## Open-house on UAV Technology

A unique open house demonstration of UAV technology was held on 27th March, 2015 at the Flight laboratory, IIT Kanpur. Working models of flapping wing bird, fixed wing unmanned aerial system and quadrotor were displayed during the demonstration. The progress of the projects was reviewed and appreciated by the subject experts.



### Feedback/Suggestions

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# Wing flapping bird-like drone to give surveillance a new height

**IIT-K'S LATEST** Battery operated machine can go to a height of 500 metres

**HT Correspondent**

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**KANPUR:** Scientists at Indian Institute of Technology, Kanpur on Friday displayed a unique unmanned aerial vehicle (UAV) that mimics a bird and can come in handy during surveillance and disaster management operations.

Along with this autonomous flapping wing drone, the institute has developed two other models that were successfully tested at the airstrip of the institute.

Institute is the first one in the country to have developed such drones. They were developed under a joint project of Aerospace Engineering of IIT Kanpur and Prabhu Goel Foundation.

Speaking about the autonomous flapping wing drone, its creator Joydeep Bhowmick said: "This is best suited for surveillance purposes. It is not possible for anyone to guess if it was a bird or a machine. It can go to a height of 500 metre at a speed of 5 to 10 km per second."

The battery-operated drone could remain in air for about an hour at a time and can take pictures from high-resolution cameras fitted upon it. The drone is



portable and weighs just 1 kg.

"We are also developing autonomous 1.5 m wingspan flying bird. It can carry a small camera and recording device for surveillance. It will a much smaller version of this one," Bhowmick said.

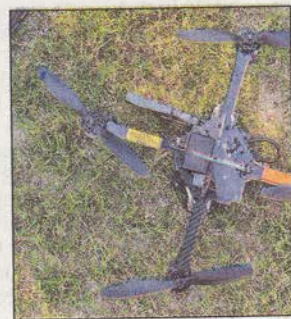
The second UAV named as 'Fixed Wing Unmanned Aerial System (UAS)' could fly with the help of battery or gasoline at a speed of more than 80 km per hour and has an endurance of ten hours, said head of the UAS project and senior professor at the aerospace engineering department Dr AK Ghosh.

The aircraft with a payload

of 20 kg was portable as it could be dismantled completely. The present version of UAV was operated through ground control system with semi-autonomous flight sustainability. The desired data is fed in the UAS system and it followed the directions in an autonomous manner, he added.

The third UAV -- Visually Guided Autonomous quadrotors-- developed by the scientists at the Aerospace Engineering department was a multi copter that was lifted and propelled by four rotors.

The project in charge Dr Nischal Verma said this was very useful for surveillance



■ Unmanned Aerial Vehicles developed by IIT Kanpur were displayed for the media on the campus on Friday. HT PHOTO

purposes and during disaster management. He said the vehicle could enter into buildings and can give detailed information particularly during terror attacks. It weighs one kg and was equipped with sophisticated cameras, he added.

Deputy director of the IIT-KDR AK Chaturvedi said that all these UAVs aimed at making surveillance possible, managing swiftly the natural or man-made (like terrorist capturing the buildings) disasters.

The institute would soon contact various agencies including the Defence Ministry for adopting the UAVs for their operations.

# आईआईटी का 'ड्रोन' परीक्षण में ही क्रैश

अमर उजाला ब्यूरो

कानपुर। आईआईटी कानपुर की एयर ट्रिप पर शुक्रवार को परीक्षण के लिए उड़ान भरने वाले अनमैड एयर व्हीकल (यूएवी) में से फिक्स विंग यूएवी 'ड्रोन' क्रैश हो गया। नीचे आते समय संतुलन बिगड़ने पर वह गिर गया। हालांकि इन यूएवी की अमेरिकी 'ड्रोन' से तुलना करने वाला आईआईटी प्रशासन इसे सामान्य घटना बता रहा है। आईआईटी प्रशासन का दावा है कि इन यूएवी की मदद से सीमा की निगरानी की जा सकती है। इसमें नाइट विजन कैमरा लगा है, जो अंधेरे में फोटो खींचकर भेज सकता है। इसमें लगा सेंसर घुसपैठ और तस्करी रोकने में मददगार साबित हो सकता है। भविष्य में यूएवी का इस्तेमाल सर्च ऑपरेशन के लिए अमेरिकी 'ड्रोन' की तरह किया जा सकेगा। आईआईटी कानपुर के एयर स्ट्रिप पर डॉयरेक्टर प्रो.



क्रैश हुआ अनमैड एयर व्हीकल (यूएवी) में से फिक्स विंग यूएवी ड्रोन।



परीक्षण के लिए फिक्स विंग, फ्लैपिंग विंग और क्वाड्रोटर ने भरी थी उड़ान यूएवी को अमेरिकी 'ड्रोन' की टक्कर का बता रहा आईआईटी प्रशासन

इंद्रनील मन्ना, डिप्टी डॉयरेक्टर प्रो. एके चतुर्वेदी और प्रो. एके घोष की मौजूदगी में रेडियो कंट्रोलड यूएवी के फिक्स विंग, फ्लैपिंग विंग और क्वाड्रोटर ने उड़ान भरी। एक घंटे तक उड़ान भरने वाले यूएवी प्रति सेकेंड 8-10 मीटर की दूरी

तय करते हैं। इनका वजन एक किलोग्राम है। पीएचडी स्कॉलर जयदीप भौमिक ने बताया कि आईआईटीयन प्रभु गोपाल फाउंडेशन ने जो प्रोजेक्ट दिया था, उससे यूएवी के तीन मॉडल बनाए गए हैं। फ्लैपिंग विंग चिड़िया के आकार का है,



मॉडल बर्ड ड्रोन को उड़ाते विज्ञानी जयदीप भौमिक और फ्लैपिंग विंग ऑरा का मॉडल दिखाते विज्ञानी सुनील।



जो किसी भी सूरत में उड़ान भर सकता है। क्वाड्रोटर छत पर से उड़ान भरने में सक्षम है। इसकी मदद से घर में घुसे आतंकियों को ढूंढा जा सकता है। डायरेक्टर ने बताया कि चिड़िया के आकार वाले फ्लैपिंग विंग को आटोनॉमस का रूप दिया जा रहा है। यह काम पूरा हुआ तो यूएवी का फ्लैपिंग विंग अमेरिकी

'ड्रोन' की तरह काम करेगा। डिप्टी डॉयरेक्टर ने कहा कि आईआईटी देश का पहला शैक्षिक संस्थान है, जिसने मानव रहित वाहन बनाने में सफलता हासिल की है। शुक्रवार को एयर स्ट्रिप पर डेमोस्ट्रेशन करके इसकी क्षमता का नए सिरे से आकलन किया गया। जल्द ही इसे अपग्रेड करने का काम शुरू होगा।

# मानवरहित छोटे विमानों व पक्षी विमान ने किया अचंभित

■ आईआईटी के फ्लाइट लैब के छात्रों ने शोध परियोजना के तहत किया है इन विमानों का निर्माण

■ शक्तिशाली कैमरों के जरिये सामान्य व दुरूह क्षेत्रों में सर्वेक्षण व सर्विलांस में हो सकते हैं उपयोगी

कानपुर (एसएनबी)। आईआईटी के एयरस्ट्रिप पर शुक्रवार को एयरोस्पेस शोध छात्रों के बनाये मानवरहित छोटे विमानों की प्रदर्शन उड़ान ने सबको अचंभित किया। रिमोट कंट्रोल से नियंत्रित विभिन्न डिजाइनों के लघु विमानों ने सामान्य विमानों की तरह रनवे पर तेज गति पकड़ कर उड़ान भरी व पूरे एयरस्ट्रिप का चक्कर लगा रनवे पर उतर आये। यहां संस्थान के वरिष्ठ अधिकारी, प्रोफेसर व छात्र मौजूद रहे।



आईआईटी में मानव रहित विमान का किया गया प्रदर्शन।

## 30 हजार में बनाया पक्षी विमान

एनआईटी अगरतला से बीटेक करने के बाद आईआईटी कानपुर में एयरोस्पेस रिसर्च कर रहे जयदीप भौमिक ने पहला पक्षी विमान बीटेक की पढ़ाई के दौरान बनाया था। जयदीप ने बताया कि इसके निर्माण पर करीब 30 हजार खर्च आया है।

## प्रभु गोयल फाउंडेशन कर रही मदद

आईआईटी के यूएवी परियोजना को आईआईटी के पूर्व छात्र डा. प्रभाकर गोयल द्वारा स्थापित प्रभु गोयल फाउंडेशन से आर्थिक मदद मिल रही है। फ्लैटिंग विंग विमान के लिए भारत सरकार के विभिन्न विभागों से भी सहायता मिल रही है।

यहां शोधरत छात्रों द्वारा निर्मित अनमैड एयर व्हेकिल (यूएवी) में फिक्स्ड डैने, फड़फड़ाते (फ्लैपिंग) डैने व चार पैर (रोटर) वाले छोटे विमान मल्टीकाप्टर क्वाड्रोप्टर शामिल हैं। फड़फड़ाते डैने वाले पक्षी विमान उड़ान भरते समय दूर से लोगों को पक्षी होने का अहसास कराते हैं। आसमान में उड़ते समय यह जानना आसान नहीं है कि यह चिड़िया है या विमान। पक्षी विमान हाथ में लेकर चिड़िया की तरह उड़या गया। कुल 400 ग्राम वजन के इस पक्षी विमान में 200 ग्राम तक वजन वाले कैमरा फिक्ट करने पर शोध चल रहा है, जिसमें शुरुआती सफलता मिली है। पक्षी विमान से शहरी व दुरूह क्षेत्रों में हवाई फोटो सर्वेक्षण का काम लिया जा सकता है। पक्षी विमान की उड़ान गति 8 से 10 मीटर प्रति सेकेंड है। प्रायोगिक अनमैड विमानों के उड़ान प्रदर्शन के मौके पर मौजूद आईआईटी के उप निदेशक एके चतुर्वेदी ने बताया इन विमानों का उपयोग खतरनाक क्षेत्रों में परियल फोटोग्राफी कर वहां के हालात जानने के लिए किया जा सकता है। सीमावर्ती क्षेत्रों में पक्षी विमान से सर्विलांस संभव है। आईआईटी एयरोस्पेस विभाग के प्रो. देवोपम दास ने बताया अभी छात्रों द्वारा निर्मित यूएवी रिमोट से कंट्रोल है लेकिन इसे स्वतंत्र-स्वायत्त डिवाइस से कंट्रोल करने पर शोध चल रहा है। उन्होंने कहा कि आटोनॉमस डिवाइस से कंट्रोल होने के बाद इसका उपयोग विभिन्न कार्यों में आसानी से हो सकता है। आईआईटी के शोध छात्रों द्वारा निर्मित विभिन्न डिजाइन के यूएवी के मॉडल प्रदर्शनार्थ भी रखे गये थे।

## तीन डिजाइन के अनमैड विमान

आईआईटी के छात्रों ने तीन डिजाइन के अनमैड विमान विकसित किये हैं। एक फिक्स्ड डैने वाला विमान है, जबकि दूसरा फ्लैपिंग डैने व तीसरा क्वाड्रोप्टर डिजाइन वाला है। फिक्स्ड विंग वाले विमान का वजन 20 किलो है। इस विमान को 80 किमी प्रतिघंटा तक उड़ान भरने व 10 किमी से ज्यादा दूरी तक की उड़ान भरने में सक्षम बनाने का लक्ष्य है। इस विमान का नामकरण स्माल साइज्ड फिक्स्ड विंग अनमैड एरियल सिस्टम (यूएएस) रखा गया है। तीसरे डिजाइन का नाम विजुअली गाइडेड आटोनॉमस क्वाड्रोप्टर्स है।

शुक्रवार 28, मार्च 2015

## अब आईआईटी जांचेगा हवा

कानपुर, जागरण संवाददाता : कानपुर प्राणि उद्यान को इंटरनेशनल ऑर्गेनाइजेशन फॉर स्टैंडर्डाइजेशन 'आईएसओ' प्रमाणित कराने के लिए जांच शुरू हो चुकी है। केंद्रीय भूमि जल बोर्ड चिड़ियाघर में पानी की जांच कर चुका है। अब हवा की जांच हो रही है। इसका जिम्मा आईआईटी को दिया गया है।

परिसर में वाहनों की आवाजाही बंद कराने के कारण चिड़ियाघर प्रशासन सकारात्मक परिणाम आने की संभावना जता रहा है। निदेशक मुकेश कुमार ने बताया चिड़ियाघर में बाल ट्रेन, कैटीन व शौचालय समेत लोगों की जरूरतों से जुड़ी व्यवस्थाओं को पिछले वर्ष शुरू किया गया है। घूमने आने वालों से फीड बैक लेकर अन्य व्यवस्थाओं को रूपरेखा तैयार की जा रही है। कैटीन की संख्या बढ़ाए जाने के साथ इस साल फूड कोर्ट को शुरू करवा दिया जाएगा। वहीं मई से लोग वाच टावर से चिड़ियाघर का नजारा ले सकेंगे। झील के किनारे इसका निर्माण अंतिम चरणों में चल रहा है। उन्होंने बताया जो उपलब्धियां चिड़ियाघर ने हासिल की हैं उसे देखते हुए इसके आईएसओ प्रमाणित होने की संभावना है। अभी चिड़ियाघर में 65 पिंजड़े हैं, जिनमें 250 जानवर हैं। चिड़ियाघर में इन जानवरों को देखने व अपने परिवार के साथ घूमने के लिए योजना ढाई से तीन हजार लोग आते हैं।

दैनिक जागरण, 28.3.2015