Unmanned Aerial Vehicle Technology

Innovations in unmanned flight are leading to improved ways of monitoring global warming and the environment, predicting natural disasters, and conducting tasks from crop surveying to border patrol and military reconnaissance. New varieties of autonomous aerial vehicles, and new ways of utilizing them, offer the potential for making unmanned flight easier, safer, less costly, and more effective. At the forefront of this research, scientists at the University of Maryland Department of Aerospace Engineering are breaking down the physics of flight into separate components, and recombining them to create new manmade flight capacities. Taking inspiration from naturally occurring phenomena in the animal kingdom and in the atmosphere, they are assembling prototype models designed to extend both the range and dexterity of autonomous flight.

Through a variety of approaches, these researchers are all asking how biological knowledge can help influence the development of future aerospace systems: what lessons nature teaches us, and whether we can use these lessons to make mechanical systems both more efficient and more effective.

Darryll Pines devises concepts for autonomous bio-inspired micro-vehicles capable of penetrating caves and tunnels, and of reducing the human risk factor in military surveillance.

James E. Hubbard devises and tests large, bio-inspired fixed-wing vehicles that can monitor atmospheric data without using fossil fuels.

J. Sean Humbert tests autonomous micro-air vehicles that replicate the optical and aerodynamic traits of insects and small birds.

Inderjit Chopra refines technology to increase the endurance and out-of-sight navigation capacity of small-scale rotary-wing vehicles.

Derek Paley researches the aerodynamics of multiple autonomous micro-vehicles operating simultaneously, to determine how to increase their coordination and how to expand their data-collecting capacity.

Harnessing the Physics of Bio-inspired Flight

What can hummingbirds and bumblebees tell us about aerodynamics? How can we make man-made vehicles perform mechanically what insects and small birds perform instinctively? Could such vehicles be programmed to crawl, run, hop, and hover via remote control? Darryll Pines, chair of the Aerospace Engineering Department at the University of Maryland, leverages the principles of flapping-wing animals in his conceptions for vehicles many times smaller than conventional scale. His research shows that flight dynamics from the natural world can be translated into mathematical forms, which in turn can be replicated in mechanical microsystems. Pines is tapping into the wisdom of millions of years of evolution to make up-to-the-minute contributions to the fields of flow physics and robotics.

Pines's present work focuses on military applications. For example, he is investigating how to make aerial vehicles autonomous and capable of penetrating tunnels, caves, and buildings, so that surveillance can be done robotically, without putting humans at risk. Another potential application of this research is the diagnosing and combating of biohazards.

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Sustaining Flight with the Atmosphere's Energy

The research of James E. Hubbard, University of Maryland Langley Professor and Director of the Center for Adaptive Aerospace Vehicle Technology, is suggesting more fuel-efficient ways to track environmental changes. The bio-inspired fixed-wing vehicles he creates and tests capitalize on naturally occurring thermal gradients and updrafts that allow birds to stay aloft indefinitely. Hubbard's vehicles, called "ornithopters," have a wing-span of one to four feet, and physically resemble birds; they are simple to operate and safe around humans. Best of all, they are leading to enhanced ways of collecting atmospheric data—primarily because they use no fossil fuels.

Hubbard has conducted hundreds of flights with a fleet of seven ornithopters, in an effort to extend the range and endurance of vehicles which have never been fully autonomous. By devising mechanical processes that automate the motion of birds, Hubbard's goal is to create a continuous autonomous flight using atmospheric energy sources. In addition to numerous military applications, possible civil applications include low-altitude surveillance projects such as aerial-view search and rescue and crop surveying.

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Bio-inspired Flight at the Micro Level

For aerial micro-vehicles to be effective, they need to be able not just to navigate corners but to respond to a number of shifting environmental conditions. J. Sean Humbert looks to the animal kingdom for clues on how to make micro-robotics more sophisticated and air-worthy. Since the principles of small-scale and large-scale flight vary so greatly, aerial micro-systems cannot simply be miniaturized forms of the vehicles that transport humans.

Studying the navigational patterns of insects and small birds, Humbert distills his findings into computational data and theoretical models that can then be applied in small-scale aerial vehicles. Working with the fruit fly *Drosophila melanogaster*, the students in Humbert's lab use high-speed videography to analyze behavioral responses to visual stimuli. Results are used to formulate novel approaches to sensorimotor convergence that will enable robotic microsystems to sense and react to their environments with greater autonomy than was previously possible. Humbert's work in micro-system mechanics is one reason the University of Maryland leads this field.

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Extending the Range and Effectiveness of Micro-vehicle Flight

A great many military and civil tasks could be tackled more effectively through aerial robotics. Monitoring caves and battle environments could be safer and more effective; inspecting hard-to-reach places such as transmission towers and bridges could be less arduous and costly. With such goals in mind, Inderjit Chopra, director of the Alfred Gessow Rotorcraft Center, focuses on refining and improving the design of rotary-wing micro-vehicles.

Chopra's work compares fixed-wing and rotary-wing airflow, and investigates which principles of full-scale aircraft carry over to small-scale aircraft. As the scale decreases, how do the advantages of flapping wings over rotary wings change? Super-lightweight material now permits a helicopter with no dimension larger than 15 cm to weigh in at a mere 100 grams; technology permits it to carry a payload of 20 grams. Chopra synthesizes research in dynamics, aerodynamics, structures, actuators, sensors, and controls with the aim of increasing how long such a vehicle can sustain autonomous flight, and how robustly it can conduct out-of-sight navigation.

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Coordinating the Flight of Multiple Micro-vehicles

Research on climate change could be substantially improved through the simultaneous collection of data from a range of interconnected sources. Toward this and a variety of other practical ends, Derek Paley studies methods of coordinating the behavior of multiple unmanned aerial micro-vehicles. Building on research about how such vehicles move, Paley investigates how we can *control* how they move. For example, in an outdoor setting, how can we keep a series of helicopters, each 17 cm long, in reliable formation, taking into account wind and other atmospheric variables?

By spreading out the data-collecting vehicles over a larger terrain and gauging them in relation to each other and to the environment, Paley wants to gain a broader, more three-dimensional picture of an environment. He currently uses hardware test beds to refine the technology and make micro-vehicles more maneuverable. Paley uses simple mathematical models to design more robust and reliable control laws. His research in theoretically justified control algorithms is widely applicable to unmanned systems in the maritime domain and in space. In addition to climate-change and atmospheric monitoring, next-step applications include military surveillance and reconnaissance.

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