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SPY FLIES

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The Microbat weighs 12.5 grams including its radio control system. Future versions could come with a micro-camera for covert snooping.

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SCI-TECH

FLY SPIES

FLOATS LIKE A BUTTERFLY, SPIES LIKE A BEE – THE NEW SURVEILLANCE ROBOTS ARE SMALL AND SMART ENOUGH TO FOOL NATURE AS WELL AS OPPONENTS. BY DANIEL WEISS

For the last five years, the DelFly team at the Delft University of Technology in the Netherlands has been designing miniature insect-like robots that fly around and stream live video back to their base controller. The team's aim is to maximise aerodynamic efficiency and miniaturise onboard instruments.

It got a chance to put one of its creations into action two years ago, when a fire ravaged the university's architecture building. The 14-storey building was beyond repair, but held valuable book and furniture collections. Video footage of the interior could help determine whether it was worth the risk of salvaging them. A week after the fire, team leader Bart Remes sent DelFly II, a 17-gram craft with a 28-centimetre wingspan, flapping up along the side of the building. At each floor, he paused it to peer in at the devastation through broken windows. When the DelFly was at the eighth floor, a crow dove from the roof and attacked it, slashing the thin Mylar film of its wings and sending it tumbling down to the ground. At first, Remes was shocked by the attack, but then he realised that the crow had given the DelFly the ultimate seal of approval. "It was quite impressive to see that nature itself thought we were part of nature," he says.

The DelFly team is just one of a number around the world working to develop ever-smaller flying robots or unmanned aerial vehicles (UAVs). Some mimic insects. Others are miniaturised planes or helicopters. Still others take inspiration from seeds. Ultimately, these miniature flyers could investigate areas too dangerous for humans - burned-out buildings, collapsed mines, chemical spills - and beam back valuable information.

PHOTO: PHOTO RESEARCHERS

This dragonfly-lookalike is being developed by the French company SilMach. Can you tell between the real insect and the micro drone?

AS CRAFT GET SMALLER, MAXIMISING EFFICIENCY BECOMES MORE CRITICAL AND CONSTRUCTION MORE DIFFICULT

PHOTOS: AEROVIRONMENT; REUTERS

The race is on to develop smaller, faster, quieter and smarter UAVs. AeroVironment's Wasp III (left) is currently the smallest UAV used by the US military. Israel's Rafael Armament Development Authority, meanwhile, has a tactical mini-UAV called SkyLite B (above), which uses an electro-optic sensor to gather intelligence for field and special forces.

But first, there are major design challenges to surmount. The DelFly team has made only partial progress towards its goal of a fully autonomous flyer that can survey the interior of an unknown building on its own. Using two miniature cameras - one directed forwards and the other pointed downwards - the DelFly II can avoid some obstacles by recognising how far away they are and by following patterns on the ground, but it still requires significant human guidance via remote control.

The cameras also help the craft to steady itself on turns without the use of an on-board gyroscope. The base controller performs all image processing, further minimising on-board burdens. "We try to avoid adding extra components, which add more weight, consume more power and make the system more complex," says Rick Ruijsink, one of DelFly's developers.

THE SMALLER, THE BETTER

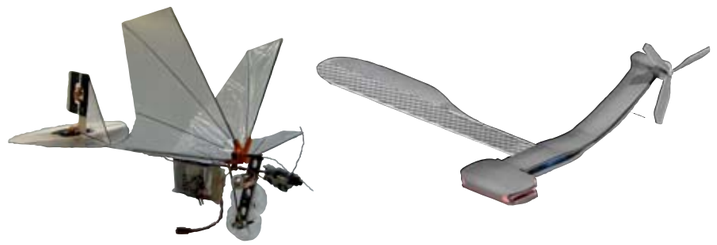
Smaller than DelFly II is DelFly Micro, weighing just over 3 grams - including a camera - and with a wingspan of just 10 centimetres. As crafts get smaller, maximising efficiency becomes more critical and construction more difficult. Modelling of airflow around the wings also remains a challenge. The unusual "clap and fling" motion of the DelFlies, where a pair of wings on each side of the body meet each other and then flap apart, is especially difficult to model. So far, the Micro can fly forwards, but unlike the DelFly II it has yet to master hovering and flying backwards. "We hope to be able to do that this year," says Ruijsink.

Predators that view the DelFly as an intruder may be less provoked by Roboseed, a small flying robot developed at the University of Maryland in the United States. It is modelled after the maple seed, which is attached to a single wing and is generally allowed to twirl through the air uneaten by birds. University researchers looked to nature for inspiration after attempting to produce a small UAV modelled on a helicopter and finding that the design was too complex and inefficient to be feasible.

"One of the unique things about maple seeds is that they fly with essentially no moving parts," says Evan R. Ulrich, co-inventor of Roboseed and a graduate student of aerospace engineering. "All the other flyers in nature have very, very complicated and not yet fully understood mechanisms at work."

FULLY AUTONOMOUS ROBOTIC FLIES COULD BE DEPLOYED BY 2018

Leonardo da Vinci, who designed his flapping-wing device in 1500, would be thrilled by the Microbat (above), the world's first electrically powered palm-sized ornithopter. If all goes well during the test flights, this micro air vehicle may well be the only bomb disposal unit that's needed.



The Felin infantry combat system comprises clothing, weapons, equipment and a miniature UAV called Odin (hovering in top picture). Hovering is a challenge for the DelFly Micro (above, left) but not for the Roboseed (above, right). But they can still spy.

PHOTOS: US NAVY; MAX S. GERBER; PHOTO RESEARCHERS; COURTESY HIROTAKA SATO AND MICHEL MAHARBIZ / UNIVERSITY OF CALIFORNIA; UNIVERSITY OF MARYLAND; DELFT UNIVERSITY OF TECHNOLOGY

Ulrich and his colleagues first studied the flight of real maple seeds using high-speed video in order to create an artificial replica with the same aerodynamic properties. Then they added a tail with a small rotor to set the craft spinning, allowing it to hover, ascend or descend on command. Finally, they made the angle of the craft's single wing adjustable, enabling it to move horizontally.

Depending on the angle the wing makes with the ground, maple seeds will either fall straight downwards or in a circling spiral. The diameter of this spiral can be controlled on the Roboseed via the angle of its wing, allowing the craft to move in any direction. "If I want it to go in a straight line, I put the wing at an angle so it makes a very large circle," says Ulrich. "The vehicle carves out an arc and goes in approximately a straight line over short distances." Over longer distances, the craft's direction needs to be reset from time to time to correct for arcing.

Ulrich has made Roboseeds in a range of sizes, with the smallest one so far measuring 9.5 centimetres across and weighing 8.5 grams, half of which is accounted for by its lithium polymer battery. The crafts can be made even smaller, although as with all miniature UAVs, battery weight becomes an increasing challenge. Another challenge specific to the Roboseed is capturing video from a craft that spins constantly, which would require cameras able to synchronise with the rate of rotation.

In the drive to develop ever-smaller drones, no one is aiming smaller than Robert Wood, a professor of engineering at Harvard University in the United States. He heads a team at the university's Microrobotics Laboratory, whose goal is to design a fully autonomous robotic fly. Modelled on members of the *Diptera* order, which include houseflies and fruit flies, the current model weighs just 60 milligrams and has a pair of carbon-fibre wings 15 millimetres long that beat 120 times per second. In March 2007, attached to wires that provided

CYBORG INSECTS

The United States Defense Advanced Research Projects Agency (DARPA) is supporting research to create cyborg insects that can be remote-controlled. Since 2006, the agency has spent US$12 million on a Hybrid Insect Microelectromechanical Systems (HI-MEMS) programme. Last year, a DARPA-supported team from the University of California at Berkeley showed that large flower beetles (*Mecynorrhina torquata*) could be controlled remotely via electrodes attached to their brains and flight muscles. The beetles, which measured about 6 centimetres and 8 grams, took flight and landed when their optic lobes were stimulated. Turns were achieved by stimulating flight muscles on the side opposite of the desired turn direction, although this worked only about 75 percent of the time.

Cyborg insects, however, have significant drawbacks, according to Professor Robert Michelson, principal research engineer emeritus at the Georgia Tech Research Institute in the United States, who has presented results from the HI-MEMS programme on DARPA's behalf. A key problem is that each insect generation would have to be fitted with electronics to ensure that some were available when needed. "In the big picture, the robotic insect is probably going to be the way to go," says Michelson.

A beetle with neural stimular implants and a radio-control board mounted on its thorax. *Hasta la vista*, baby.

AS SOON AS SMALLER UAVs ARE AVAILABLE, MILITARY FORCES WILL BE EAGER TO USE THEM IN URBAN AREAS AND INSIDE HOUSES

PHOTO: JOEL SAGET/AFP/GETTY IMAGES

"Eye" spy ... a French soldier launching a tactical drone in preparation for a mission.

power and guidance, the robot fly left the ground for the first time.

The project still has a long way to go. In order to achieve full autonomy, the fly will have to be outfitted with directional controls, a portable source of power and sensors to help it stabilise and navigate. Simply adding an adequate-sized battery would almost double the fly's weight. Nonetheless, Wood predicts that fully autonomous robotic flies could be deployed by 2018, although this is an ambitious goal. For now, that fly buzzing around your kitchen is probably interested in tapping your fruit salad, not your conversation.

MILITARY MIGHT

The best-known UAVs used by the military, such as the Predator, can fly for hundreds of kilometres, gather reconnaissance and rain down missiles on targets. But they can't do much for the soldier on the ground.

That's where the remote-controlled Wasp III comes in. Weighing a mere 430 grams and with a wingspan of 72 centimetres, it is the smallest UAV used by the US military. Equipped with daytime colour and nighttime infrared cameras, it allows ground forces to see what is going on ahead of them. "It's their own personal spy plane," says Steven Gitlin, vice-president of marketing strategy and communications for AeroVironment Inc, the company that makes the Wasp III.

With its slim profile and quiet electric motor, the Wasp III is extremely effective at covert monitoring. The noise of larger, gas-powered UAVs, by contrast, often alerts the enemy to their presence. "The ability to see without being seen or heard has helped them get a lot more intelligence than they can with any other asset," says Dr Gabriel Torres, the technical lead for Wasp III at AeroVironment.

The Wasp III comes in four pieces which fit into a small box and snap together easily. AeroVironment also makes Raven, a larger UAV with a wingspan of 1.4 metres and weight of 1.9 kilograms. With 7,000 Ravens in use by the US military as well as the military forces of several other countries, it is the most prolific UAV in the world.

The controller used to fly both the Raven and the Wasp III boasts a joystick for directing the plane's movements and an 18-centimetre screen that displays the feed from the aircraft's camera. (The course can also be pre-programmed using GPS.) The planes are designed to be flown with minimal training. "The plane does all the hard work so the operator can drive it wherever he wants without worrying about things like air speed, stalling and banking too much," says Torres.

INNOVATIVE USES

As these miniature UAVs have become more widespread, troops have found a variety of ways to use them. The Raven's propeller is behind its wings, making it a bit noisier than the Wasp III, but if flown at a high-enough altitude it can remain incognito. However, sometimes operators fly them low at night to draw fire, which reveals the enemy's position. "Once you put this capability in people's hands, they become incredibly creative in how they use it," says Gitlin. None of the currently available miniature UAVs are weaponised, although AeroVironment is developing one called the Switchblade about the same size as the Wasp III that doubles as a missile. When its operator spots a target, the Switchblade can be directed to fly into it and explode.

The miniature UAVs now used by the military are too large for indoor surveillance, but as soon as smaller ones are available, military forces will be eager to use them. "Some of the most dangerous soldiering is clearing urban environments and houses," says Ben Kristy, aviation curator at the National Museum of the Marine Corps in the US state of Virginia. "That kind of terrain favours the defender, and being able to see exactly where the bad guys are without having to go through the front door ... will be very helpful." ■