The Uses and Abuses of Personal UAS

Nano UAVs promise much in terms of enhanced personal reconnaissance capabilities. But according to Dr Stephen Prior, there are a number of drawbacks to small multi-rotor aircraft, and the cost of procuring them is still relatively high. Does growing civilian use of these systems hold the key?

Small Remotely Piloted Aircraft (RPA) (also known as Micro Air Vehicles (MAVs)) appear to be an all-pervasive technology, which is slowly encroaching into the civilian domain. From 2012 to 2022, the Teal Group forecasts that the worldwide market for Unmanned Aircraft Systems (UAS) will grow to be worth £55 billion. The fastest growth segment within this market is the small RPA sector, which consists of systems typically less than 2kg in mass.

A small but growing subset of this market is nano air vehicles (NAVs) sometimes referred to as personal unmanned aircraft systems, which have a mass of less than 60 grams. A Norwegian company, Prox Dynamics, is already selling a Personal Reconnaissance System (PRS) into the defence and security sector. Named the PD-100 Black Hornet (see below), this system (including the ground control station) has a mass of only 1.3kg, with an air vehicle mass of just 16.5g, making it one of the smallest and lightest in production. This might look like a toy that you would buy for your child; however, with a range of 1.2km and a price tag in the range of £50,000, it is anything but a toy.

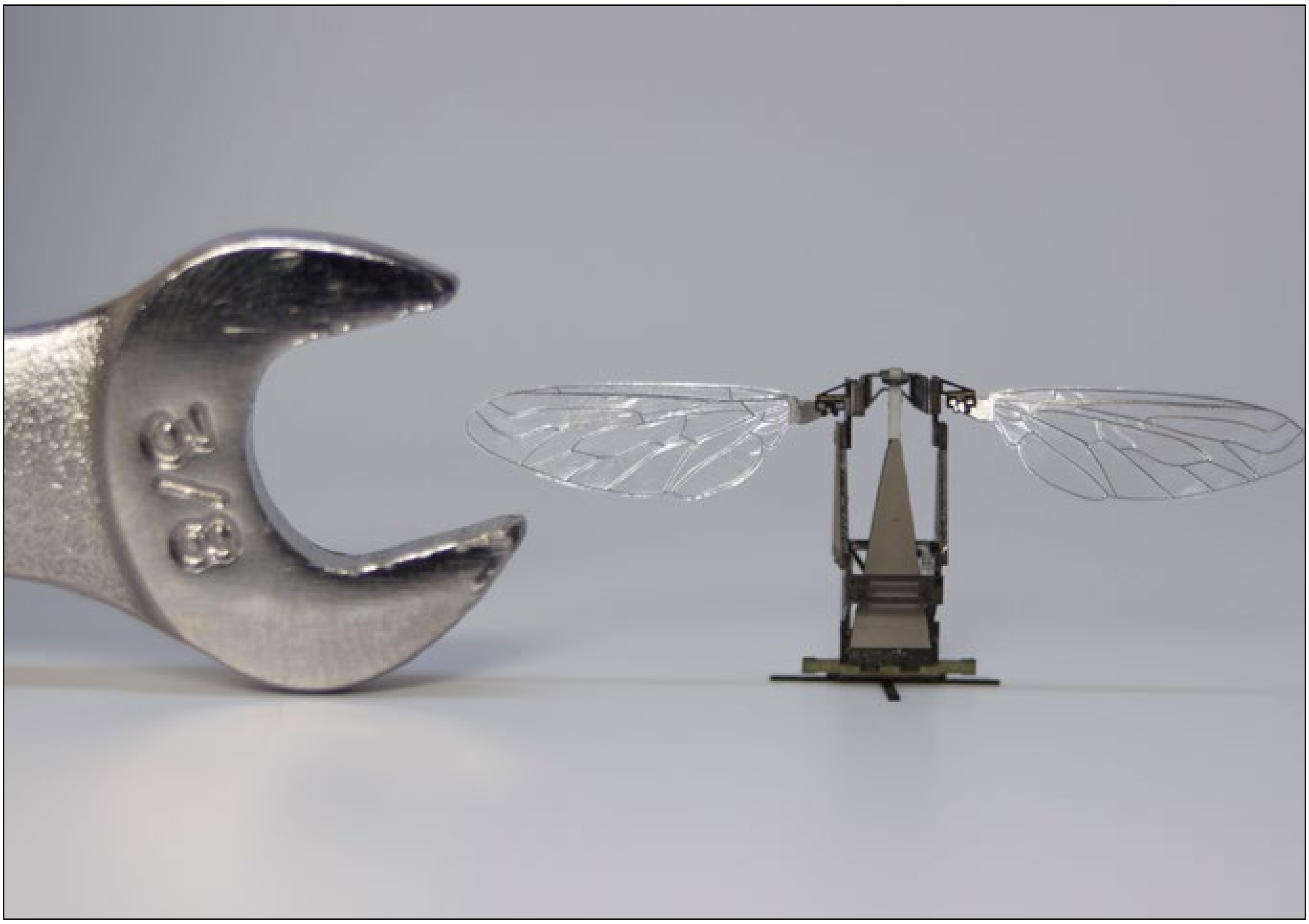
POSSIBLE MISSION SCENARIOS

The possible mission scenarios for such a system are listed below:

- Search and Rescue (D)
- Reconnaissance in Confined Areas (D)
- Look Around Corners and Over Obstacles (D)
- Situational Awareness (D)
- Target Acquisition (M)
- Crowd Control (D)
- Nuclear Inspection (D)
- Environmental Monitoring (D)
- Anti-Poaching (C)
- Crop Analysis (D)

Key: Military (M); Civilian (C); Dual (D).

The PD-100 Personal reconnaissance System (Photo Courtesy of Prox Dynamics)



A RoboBee prototype next to a 3/8" wrench (Photo by Eliza Grinnell, courtesy of Ben Finio)

To date, the market for these types of systems has been thought of as strictly military, with its need for cutting-edge battle-winning technology. However, this is now changing and civilian applications of drone technology are starting to shift the balance away from conflict and towards humanitarian activity. Most of the mission scenarios listed above can be thought of as being dual use. The military-civilian divide is becoming even smaller and new application areas are popping up daily.

Of particular interest to systems developers are small multi-rotor platforms, capable of vertical take-off and landing due to their inherent ability to be launched and recovered from confined locations, together with their ability to perch and stare for extended periods of time.

PROBLEMS WITH SMALL MULTI-ROTOR AIRCRAFT

Although very popular due to their physical size, simplicity and cost, all small multi-rotor aircraft suffer from the following major drawbacks:

- Low Endurance – (typically less than 20 minutes, caused by inefficient small-scale rotors)
- Wind Gust Susceptibility – (at about 8m/s or greater)
- Robustness – (danger from and to the rotor systems)
- Beyond Line of Sight Control – (Greater than about 1km)
- Sense and Avoid – (the ability to avoid colliding with other air users or obstacles)
- Perch and Stare – (the ability to perch on surfaces and natural objects other than flat ground)
- GPS-Denied Environments – (Either through deliberate action or via urban canyons)
- Cost (military grade systems can cost tens of thousands of pounds)

These issues are becoming more important since the United States and the United Kingdom will have an open skies policy towards civilian use of unmanned aircraft from 2015 and 2016 respectively.The development of the Global Positioning System (GPS) has been the key to enable the autonomous behaviours of RPA by providing the external localisation information in the global environment. However, GPS by itself is not very accurate (1 to 2 metres accuracy at best); this is adequate to stabilise a RPA, but is not good enough to enable it to precision land.

Advanced systems can localise the RPA by fusing measurements from differential GPS and the Inertial Navigation System (INS), called the INS/GPS approach, which brings the precision of position estimation up to decimetres. Nevertheless, in many civil and military applications (such as urban, indoor, desert) the GPS service is not available or is unreliable. Therefore, enabling RPA navigation in a GPS-denied environment is highly desired to enable a larger number of applications.

CURRENT FLAPPING WING RESEARCH

Many research groups round the world are focusing on lessons from nature to develop the next generation of flapping wing unmanned aircraft, called Ornithopters. (An ornithopter (from Greek *ornithos* “bird” and *pteron* “wing” is an aircraft that flies by flapping its wings.) As we all know, flapping-wing insects have an envious flight envelope, being able to hover at will, then dart off in any direction at high speed thus evading capture. They can also fly incredible distances and can find their way home without the use of GPS. Being extremely light, they can perch on almost any object using visual cues derived from their compound eyes, which are comprised of thousands of ommatidia (little eyes) using “optic flow” techniques.

Flight at this very low level of Reynolds number (1,000-20,000) presents immense technical challenges to designers of bio-inspired robotic flying systems. The key appears to be in the flexibility of the wing structure and its ability to generate lift on the way down as well as on the way up. These systems are now approaching the insect scale; 80mg and a few centimetres wide.

Work at the University of Southampton is investigating the use of artificial muscles and electroactive material as embedded actuators, to achieve dynamic integral shape actuation. Efforts are being directed towards developing a fundamental understanding of the dynamics of aero-electromechanical coupling in an integrally actuated membrane wing.

THE DARK SIDE

Technological advances are moving at such a rapid pace that several researchers have predicted a darker side to this research. The ability of a NAV to penetrate even the strictest security and fly direct to its target is obvious to all. Almost invisible to the naked eye, such a system could potentially have the capability to either extract a sample of DNA for analysis or inject a toxin into the person, thus rendering them incapacitated, inept or in the worst-case scenario, dead.There are certain organisations around the world that would like to obtain this type of offensive capability.

CONCLUSION

Whether these systems are used for good or evil depends on legislation, oversight, ethics and public awareness of their capabilities. However, the direction is clear—lighter, smaller, faster, cheaper.

The acquisition by the UK MoD of 164 PD-100 NAV systems was received with great favour by the troops operating on the front line in Afghanistan. However, due to the cost of them, they are in relatively short supply and only used by selected troops. The attrition rate amongst troops using such technology is high and the cost of replacing lost, damaged or destroyed UAVs is not insignificant. A recent report for the UK Commons Defence Committee stated that: *“[Weather] can be particularly difficult for lighter airframes to manage and significantly constrains their flying hours in certain environments, such as areas that suffer from high cross winds, icing or lightning strikes.”*

Future NAV and MAV systems will provide greater capability in almost all areas of ISTAR, for use by individual soldiers, at a price point which reflects their sophistication and complexity. These developments will in time filter down into the civilian domain, thus providing benefits to humanitarian missions and will also help to cultivate new industries and job opportunities for UK citizens. ■

ABOUT THE AUTHOUR:

Dr. Stephen Prior is a Reader in Umanned Air Vehicles at the University of Southampton. He has been working in the field of robotics for the past 25 years. His research interest in autonomous systems relates to a shortlisted entry to the MoD Grand Challenge event in August 2008, where he led a team to design, develop and construct a novel unmanned aerial vehicle, which consisted of a coaxial trirotor (Y6) arrangement. On the basis of this, he founded the Autonomous Systems Lab and has been researching with a small team of staff/students working on defence-related robotic technologies. He is on the editorial board of the *International Journal of Micro Air Vehicles* and has published widely on the subject. Recent work involved developing the winning entry to the DARPA UAVForge challenge, and the design and development of a series of nanotechnology platforms, which were demonstrated and flown at the DSEi exhibition at the Excel Centre in London.

FOOTNOTES:

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