A drone of your own

UK engineers are showing how to bring the cost of UAVs down to earth. Stephen Harris reports

It was just two minutes into the flight when the team realised something was wrong. Huddled around their tiny monitor, Dr Stephen Prior and his PhD students watched the video feed from the craft they had spent so many months building and realised it was heading for a collision. Due to an unfortunate drop in the GPS satellite signal, HALO had lost its orientation and was soon spiralling towards the forest below. The crash broke one of the rotary aircraft's arms, destroyed a motor and snapped all six of its propellers. Due to head back to the UK the following day, Prior and his team didn't have the time or the spare components to rebuild their unmanned aerial vehicle (UAV). Like all the other eight teams who had come to Fort Stewart, Georgia, to take part in the UAV Forge competition, the group from Middlesex University had failed to complete the task set by US military research organisation DARPA and would be returning home without the $100,000 (£62,049) prize money.

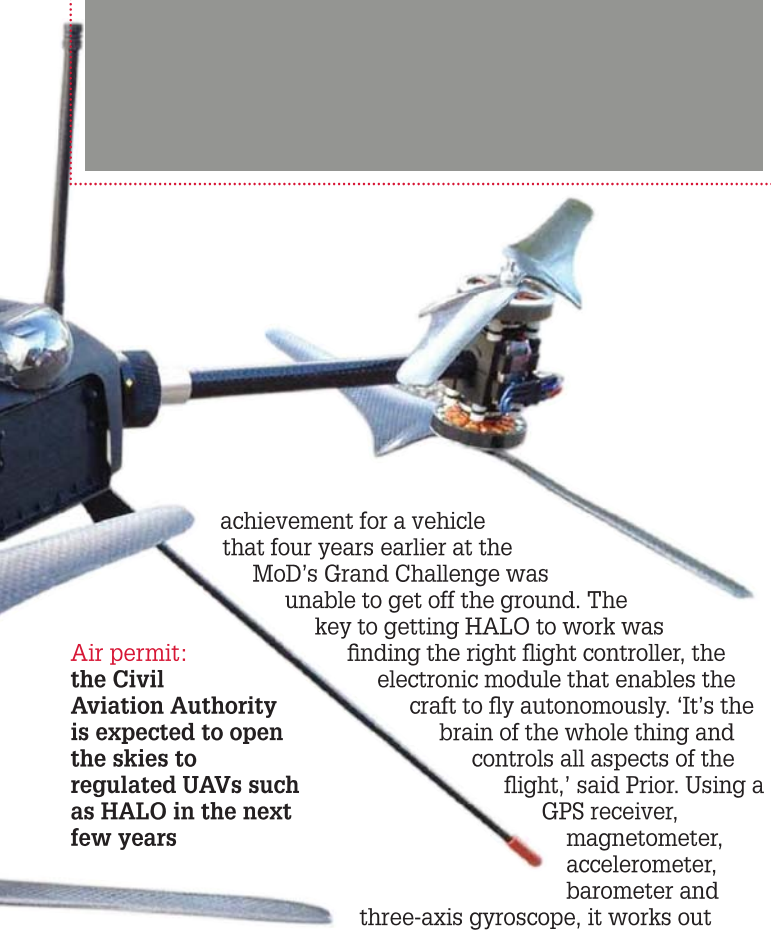
UAV Forge was the culmination of five years' work for Prior's team, which is now based at Southampton University. Back in 2007, the team decided to turn its expertise in robotics to entering another competition held by the Ministry of Defence (MoD) to build an autonomous surveillance robot. Although they were initially unsuccessful in getting it to fly, the group stuck with the craft and by 2012 had proven its abilities enough to get to the final of the DARPA event for UAVs costing less than $10,000. Watching their creation plummet to the ground must have been heart wrenching.

But the crash was by no means the end of the story for HALO. The main body of the craft remained intact and its collision with first the trees and then the ground helped demonstrate its relative durability. 'It was sad to see it that way because we'd put a lot of effort into it,' said Prior. 'But it was almost a good thing because we proved that it can actually disintegrate. We rebuilt it in a day and we were back flying when we got back to prove the point.'

Although the team didn't win the prize money, it did score far more points than any other group in the competition. Earlier in the week, HALO had managed to fly the two miles of the course, hover above the target building and return to its launch point. Sadly, it was unable to complete the final requirement of landing on the building and transmitting video footage back to base because the surrounding trees were so high that they blocked its radio signal. Coming first on the scoreboard, however, was an impressive

Ground control: **the craft is controlled via a tablet PC, which doubles as a groundstation**

VIDEO REPORT



Air permit: **the Civil Aviation Authority is expected to open the skies to regulated UAVs such as HALO in the next few years**

achievement for a vehicle that four years earlier at the MoD's Grand Challenge was unable to get off the ground. The key to getting HALO to work was finding the right flight controller, the electronic module that enables the craft to fly autonomously. 'It's the brain of the whole thing and controls all aspects of the flight,' said Prior. Using a GPS receiver, magnetometer, accelerometer, barometer and three-axis gyroscope, it works out where the aircraft is and how to fly to its programmed target. Given the device's importance, the team understandably went for the best, most expensive flight controller it could get hold of. The problem was that the company that provided it hadn't designed it for UAVs. 'What it had to do is take one of its helicopter modules and convert it for something we wanted,' said PhD student Mehmet Ali Erbil, who forms Prior's team together with Mantas Brazinskas and Witold Mielniczek. 'There were about 1,500 variables that we had to calibrate in the system… We weren't flight control experts at the time. We didn't know anything about it. We wanted to plug it all in and off it goes.'

Prior added: 'Back in 2007 there wasn't as much choice as there is now. In the last five years a lot has changed and there are many companies with smaller, faster and cheaper flight controllers… We could make our own flight controller and build the whole thing from scratch. It would take a long time and cost a lot of money but it would be exactly how you want it. What we were trying to do was find something commercial off the shelf that was relatively low cost but had already done all the trial and error, and the user interface was built, making it more practical for the user.'

The DJI Wookong FC controller the team chose was particularly suited to the so-called Y6 configuration of HALO's propellers. The team decided on a rotary rather than a fixed-wing design because of the likely need to hover in the air as it films its targets. After experimenting with different rotary arrangements they settled on a design of three carbon-fibre arms jutting out from a central body, each supporting two co-axial rotors, one above the other and spinning in opposite directions.

'There is a forfeit in that the two rotors do influence each other and do interfere,' said Prior. 'You lose a little bit of power through that mechanism, but it is the small size of the whole thing that allows us to have relatively large props but in a compact configuration.' The design also means that the craft can keep flying and perform a controlled descent if one propeller is knocked out, unlike those UAVs with four rotors. This configuration also helped with the greatest challenge: reducing the mass as much as possible in order to get the greatest use out of the lithium polymer battery, which itself accounts for one-third of the craft's total mass. Through several iterations refining the design down to its most essential features the team was able to get the mass down to 2.5kg and increase time between battery charges to 30 minutes.

The craft is controlled via a tablet PC mounted inside the craft's carry case, which is small enough to be carried on the user's back and doubles as a groundstation by mounting it on the tripod antenna. This setup reflects both the rules of the UAV Forge competition and the application for which Prior hopes that HALO could eventually be used: creating a low-cost, easy-to-use surveillance robot for the British army.'We want to get this into the hands of the user,' he said. 'We see soldiers dying every day for the want of being able to see someone waiting to take a shot at them. These tools are available and capable. They are within reach and there's no reason why — apart from the price tag — they shouldn't have more of these in service with the British military.'

There are many obstacles to overcome to reach this point, of course. As well as battery life and general robustness, the team will have to solve the communications problem that prevented it from winning DARPA's prize money, and there's no easy answer to this. Prior is focusing on creating a more efficient, directional antenna system rather than beaming out signals from the UAV in all directions. With the UK Civil Aviation Authority expected to open the skies to regulated UAV use in the next few years, the HALO team could be well poised to help bring unmanned aircraft into the mainstream if it can crack this problem.

indepth

The ability of HALO to withstand harsh weather conditions is 'more important than regulation'

HALO's flight controller enables the user to set a destination and altitude and the craft will then use GPS to take off and fly to it without further instruction. With access to maps, it can navigate the geological landscape without crashing into a hillside. What it doesn't have is so-called sense-and-avoid technology to enable it to autonomously change direction should it encounter buildings, trees or other aircraft. The user currently has to watch the craft's camera feed and direct it away from such obstacles.

Sense-and-avoid systems will be crucial for craft wanting to operate in civilian airspace at high altitudes and out of the line of sight of the user, once the UK Civil Aviation Authority (CAA) opens up airspace to UAVs. But Dr Stephen Prior believes that this isn't the most important concern for HALO, a surveillance vehicle that is unlikely to fly at high altitudes because of the heavier camera that would be needed to provide better-resolution images. 'Probably more important for us is to be able to cope with weather conditions,' he said. 'Wind is a big thing, and obviously snow, rain, hail and frost. Those are perhaps more pressing issues than the red herring of CAA open space.'

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