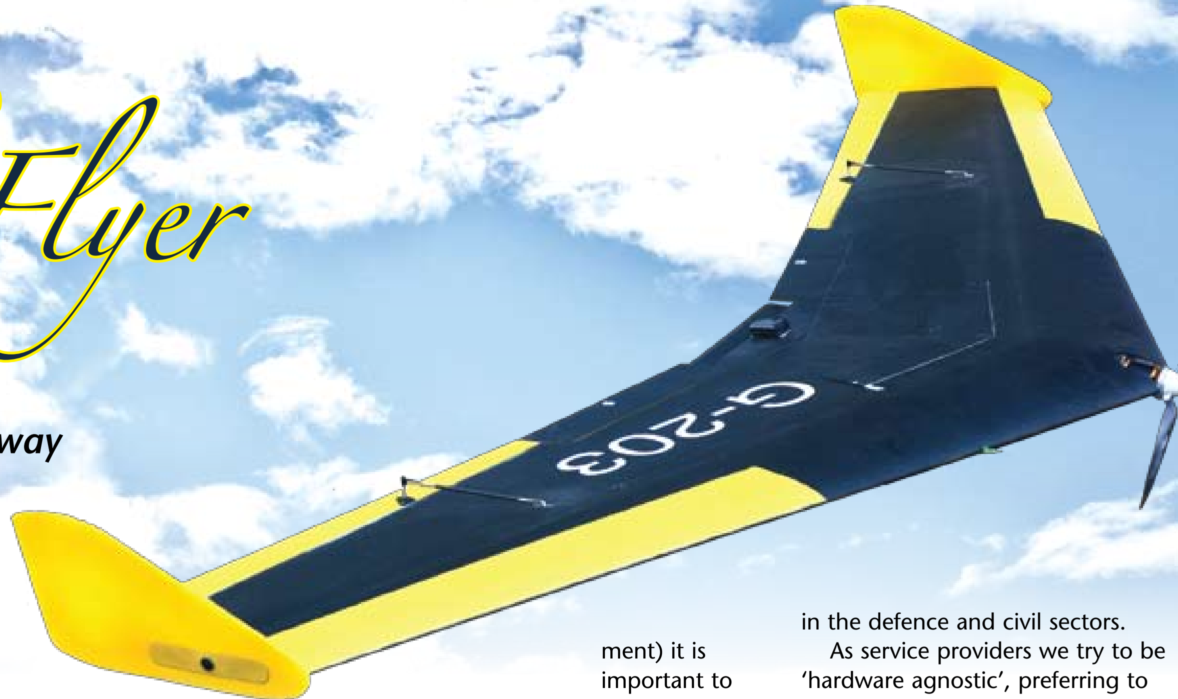
High Flyer



Aerial mapping the easy way

For most people the term 'UAS' is unfamiliar. To us it's an unmanned aircraft system, very much a tool of our trade and now proving to be a worthy forestry tool too.

Our business is all about gathering data from the air, more often than not in the form of some sort of photography. Whilst the use of unmanned aircraft in forestry has been trialled in a few parts of the world, the *Phytophthora ramorum* outbreak here the UK has resulted in a pioneering, commercial application of this technology.

Lee Dawson is the Planning Forester responsible for managing the *P. ramorum* management operations in the Coed Y Cymoedd Forest District for Forestry Commission Wales. A major part of Lee's job is to plan and commission the felling operations necessary to control the disease, and as he states, "In order to be efficient in responsive operational planning, it is necessary first to identify where susceptible species are precisely located, and secondly the extent of an infection throughout any given geographic area."

Lee initially approached us with a view to rapidly obtaining high-resolution, geo-referenced aerial photography to precisely locate diseased trees. This has proved hugely effective and has led to the secondary benefit of the capability, namely the ability to establish exactly what is growing where.

Lee commented, "As any planning forester will know, there are limitations [in the database] caused by erroneous survey data input and by self-seeded natural regeneration which is not identified by standard survey methods. The imagery gathered by the UAS has provided highly accurate information on which to base felling plans."

The forestry environment, particularly in the Afan Valley and Vale of Neath, where much of our work has been done, presents some challenges when operating a small, unmanned aircraft such as our G2 system. Lee provides outlines of the target areas to us and we are able to plan our operations to a certain extent, using maps and existing low resolution imagery.

Since the G2 is operated within line of sight (a UK legal requirement) it is important to establish sites from which it can be operated that allow coverage of as much of the target area as possible.

Now don't be thinking aerodrome here; the G2 is hand launched and landed on its belly, so a flying site might just be a section of gravel track or an exposed piece of rough ground.

What's perhaps more important than the nature of the ground is the visibility from the site, to keep the aircraft in sight as it follows its pre-programmed flight path. Planning from the office only gets you so far, and it's only when you arrive at a site that you can establish the height of obstacles, and true nature of the terrain.

Whilst the G2 is extremely robust, recently felled forest stands with their stumps and debris are avoided if at all possible as landing sites, and in fact as driving and walking sites too!

Safety being the number one consideration, we carry out an on-site risk assessment every time we fly and, if necessary, temporarily block tracks with warning signs. We avoid flying at weekends or public holidays in areas used extensively by the public.

The UAS-operating business is a new industry. We're very lucky that in the UK the Civil Aviation Authority permits commercial operations of unmanned aircraft and is able to formally approve organisations such as ours to conduct this sort of work. In the USA, despite extensive state use of the technologies, no commercial activity is currently permitted.

All our current staff have backgrounds as pilots of manned aircraft, and have many years of experience with unmanned systems in the defence and civil sectors.

As service providers we try to be 'hardware agnostic', preferring to select the right tools for a specific task. However, when we set out to establish a UK-based, unmanned photo-mapping service, we just couldn't find a system that would do the job, day after day.

We always refer to a 'system' (hence UAS) as the radio datalinks and laptop-based ground station are as much an essential part of safe operations as the aircraft itself. The ground elements provide live information to the operator, who is legally the commander of an aircraft and responsible for not endangering anyone on the ground or in other aircraft.

Our solution was to design the G2 UAS for our own needs. The system is a tool tailored for our use rather than a product for manufacture and sale. We liken it to the vans that the AA use – very much tailored for a job, but you wouldn't buy one just because your car needs fixing; you'd call the AA. Hence the 'product' here is really the service rather than the equipment.

The G2 is just over two metres in span and is electrically powered. It uses an 'outrunner' motor, with no brushes – the whole case with fixed magnets rotates around the fixed coils, which can deliver up to 1000 watts. The power comes from 20-volt lithium polymer batteries, and we usually carry enough for about 45 minutes of flight for a typical planned 30-minute flight. 30 minutes is usually enough to cover the whole area of interest within 1km of the operator. For this work we fly the G2 at 1000 feet and at about 40mph.

The main structure of the G2 is expanded polypropylene (EPP). This is the stuff used inside car bumpers and looks a bit like polystyrene foam but is a very different material. EPP is less rigid than

Manual take-off, using a hand-held transmitter. Control is then handed to the autopilot to climb to operating height.

polystyrene and doesn't snap when deformed. It's very tough indeed and is perfect for absorbing the knocks and bumps of landings, protecting the electronics and cameras inside.

The aircraft has a flexible skin, similar to fibreglass, but not rigid, and some carbon fibre stiffeners within the foam.

We can mount up to 2kg of sensors in the G2, which can be infrared, thermal or multi-spectral, but for this work high quality digital stills cameras are used, controlled by the autopilot.

Being a tail-less aircraft, the G2 has to be well balanced, so the variable weights such as the batteries and cameras are located right at the centre of gravity, so that they can be changed or removed without affecting balance.

The autopilot contains a 'nine degrees of freedom' inertial measurement unit. This means that it has an accelerometer (to measure acceleration forces), a gyro (to measure rotation) and a compass for each of the three physical axes. Thus the aircraft always knows which way is up and where it's pointing. A GPS adds the 'where it is' to the mix and you have an aircraft that can find its way around, or rather can go where we want it to.

We plan flights on a laptop, taking into account wind direction and terrain in addition to any other factors on the day.

The flights consist of a series of into-wind lines flown parallel to each other and spaced to provide overlapping photographs. The plan is sent to the aircraft across the radio data-link before flight.

For safety, we usually perform manual takeoff, and use a handheld transmitter, before handing control to the autopilot to climb to operating height. The crew then monitor the aircraft as it performs the flight, taking photographs at predetermined intervals.

Keeping the aircraft in sight is essential in case we need to change course manually to avoid other aircraft. The ground station provides all the essential data such as height, speed and battery voltage to the crew.

Landings are made on the most suitable surface to be found. In an ideal world there would be smooth grass available everywhere, but a few yards of any low vegetation or hard surface is suitable, given reasonable freedom from obstacles.

Images are downloaded from

The G2 coming in to land near the ground station vehicle. Tracks or low vegetation make suitable operating sites.

Strange bird flying over the forest: the system typically maps several hundred hectares a day using a variety or sensors.

An example of an individual photo. These are combined into georeferenced data for customer use.

the cameras and checked for quality before the team moves on to the next site.

A day's flying might cover several hundred hectares and produce a thousand individual photos. Once back at the office, the next tool, a very powerful computer, comes into play. We use a process called photogrammetry to build a 3D model of the terrain using the overlapping images, taken from different locations. The reason for this is that every photo is only looking downwards on the centre of the image. Towards the edge of the image it's no longer a vertical perspective. The aim is to provide the customer with a mosaic of photos, joined together seamlessly as in Google Earth, with a vertical perspective. The 3D model is used to achieve this by virtually 'draping' the images over it to allow the computer to calculate a truly vertical perspective.

The resulting 'orthophoto' is just like a map and can then be given real-world coordinates before being split into manageable files for the customer to view in his geographic information system (GIS). This process means that the precise coordinates of individual trees can be determined, along with comparing the location, size and shape of coupes with database information.

The imagery delivered in this work has a resolution of 10cm/pixel which is normally good enough to identify tree species and certainly good enough to identify diseased trees. The 3D model can also be useful in the forestry planning process as it gives an accurate representation of terrain for planning access works *etc.*

In his Resolven office, Lee receives a disk full of image tiles covering the target area, which he can then import to his own GIS. He can then start to look for diseased trees, or to compare the real-world situation with the sub-compartment database. From his perspective, "The accurate planning made possible by using the images has the potential to save money on harvesting operations as well as inconvenience to the public."

He adds, "The images, after planning initial response operations, can then be very useful for forward and pre-emptive planning, for identifying areas of risk, and for planning the resulting restocking operations."

Whilst the wider economic and ecological aspects of the *P. ramorum* outbreak cannot be ignored, we are pleased that it has led directly to the UK-pioneering exploitation of new technologies in the forestry industry. We expect to continue this work beyond the current *P. ramorum* management task as the benefits of UAS remote sensing in forestry planning and management continue to be revealed.

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