Multirotor Shooting

HIGH FLIERS

HOW TO TAKE OFF WITH MULTIROTORS

ROGER RICHARDS

This year at BVE the hot new 'toys' comprised the array of drones and helicams that had landed in town, attracting big crowds around all the stands displaying them. Then a few months later GTC members enjoyed demonstrations by GTC Awards event sponsors Quadcopters and Aerial Vue at the Guild's 'Day in the Country'. But what does it take to fly these multirotors? What do you need to know and how do you get permission to achieve those spectacular shots? GTC In Focus editor Roger Richards has been flying a quadcopter for a while, capturing beautiful stills of his home area, North Wales, while Andrew Schaale uses this technology to achieve high-octane shots for *Top Gear* to complement other specialist camera and minicam sequences provided for the award-winning series by the team at Extreme Facilities.

Roger Richards writes:

UAV, drone, helicam, multirotor, tricopter, quadcopter, hexacopter, octocopter - welcome to the world of radio-controlled (RC) aerial photography. But is this just a passing fad or a genuinely useful tool? Will it rank alongside the Wally Dolly, mini-jib or slider as the 'must have' production tool for the freelance cameraman? Small enough to be stowed in the boot with everyday kit, quick to set up, easy to fly, offering amazing, high-quality, rock-steady aerial tracking shots? Well, not quite.

Light enough to fly

Gone are the days when RC aircraft were the domain of only those adept with balsa wood, glue and tiny little petrol engines; now it's carbon fibre, LiPo batteries, brushless motors and GPS – plus a bigger bunch of new acronyms than even the TV world aspires to. The advent of all this new technology, together with the introduction of new lightweight cameras, means that reasonably priced remote-controlled aerial platforms, capable of carrying broadcast-quality cameras, are rapidly appearing on the market.

So, visually, what can all this new technology achieve? Well, I would place it somewhere between a jib and a helicopter – it certainly doesn't replace either but can produce an added 'off-the-ground' dimension to your production. Having worked on many countryside and walking programmes, it would certainly have helped to be able to obtain views of an area tracked from 100ft above ground (also saving a lot of gear-lugging and panting on my behalf). Being able to fly from zero to a couple of hundred feet enables you to retain a three-dimensional look which is difficult to achieve from traditional height-restricted helicopter shots.

In fact, the more you think about it, the more uses spring to mind – from landscapes to high-level building shots. If you're producing corporate images, then tourism and surveys come to mind. I'm sure you could produce your own lengthy list appropriate to the sort of work you do.

Learning to fly

Sounds great - so what's the catch? Well, to start with you have to learn to fly the thing. Yes, they are easier to control than traditional RC helicopters, but even with all the new technology (assisted by GPS), you really have to know what you're doing. There is a saying in the RC world that it's not *if* you crash, it's *when*! So this is where Health and Safety really comes into play. Perhaps you will be working with actors, presenters and other crew members, and you will basically be putting up in the air a lawn-mower from hell. This machine has between four and eight exposed whirring carbon fibre propellers attached to the same number of heavy-duty and powerful electric motors – all controlled by you and a complex radio link.

So, the main restrictions will be not to fly over people, property, roads or anywhere you might put the general public in danger... meaning you can untick some of those boxes on your list. A recent incident involving a multirotor occurred during the filming of crowds queuing for *X-Factor* auditions outside the O2 arena in London. The aircraft developed a problem but was flying over the Thames, where it was ditched by the operator. If it had been flying over the crowds there would have been a disaster. Unlike a traditional helicopter you can't auto-rotate and bring it gracefully to the ground. In fact, you are flying the equivalent of a household brick with no aerodynamic capability whatsoever. You also wouldn't want to fly in a strong wind. Oh, and to keep weight to a minimum, most multicopter designs leave much of the electronics exposed to the elements, so filming in the snow or rain may be hazardous.

There are long lists of safety procedures and preflight checks to make and any work being conducted for commercial purposes with any kind of unmanned aerial system is subject to regulations introduced by the Civil Aviation Authority (CAA) requiring operators to obtain permission from them. This involves a few different elements in the form of an initial application for aerial work, an operations manual and proof of pilot competence.

The only CAA specific pilot/crew qualification currently provided by the European Unmanned Systems Centre (EuroUSC) is the BNUC-S (Basic National UAS Certificate) for small UAV (unmanned aerial vehicles). This not only provides excellent background knowledge and training, but may well be compulsory for any commercial activities by next year. EuroUSC is also working with agencies throughout Europe to standardise these guidelines.

You'll need to have at least public liability insurance for operating commercially. It is also recommended that you have indemnity, plus equipment cover for fire and theft. Insuring your equipment against crash damage is more difficult; there are a few companies that offer this, but the premiums are high. The BNUC-S should go a long way to helping you get a good insurance deal. Perhaps one of the insurance companies that sponsor the GTC (see: *www.gtc.org.uk/sponsor-the-gtc/list-of-gtc-sponsors.aspx*) would be able to provide you with some guidelines.

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Modified DJI S800 drone with Panasonic Lumix GH3 camera (Extreme Faciilities)

www.gtc.org.uk

Where do you start?

Your decisions will obviously be based on the type of work you hope to do, and the weight of camera you propose to operate. The heavier the camera, the more powerful a machine you will need to lift it, the more substantial the gimbal to manipulate it, and the bigger capacity battery you need to power it all. Flying time can vary considerably, mostly depending on the power-to-weight ratio, but 8 to 10 minutes of flying time per battery charge seems to be about average.

Start by consulting with one of the many specialist dealers. Quadcopters UK, based in the north-west, is one of the longest established companies, and is where I emailed an ambitious specification for my first flying machine required to lift a medium-weight camera, although I hadn't had any flying experience and my knowledge of the technology was well... nil.

I was advised, in the first instance, to go for a cheaper option with a GoPro camera to practice and hone my flying skills; and to provide a much less costly crash scenario – the best advice ever! From there I quickly discovered that to obtain decent video or stills I needed to acquire a whole bunch of new skills.

Multicopters consist of several parts and each of these needs to be chosen carefully for the proposed job and then assembled. There are many companies who will advise and help you choose the parts, assemble them and, importantly, set up and configure the aircraft correctly for you in a complete RTF (ready to fly) package.

The basic machine comprises a frame (normally plastic or carbon fibre) with a central connecting plate for mounting the electronics and four, six or eight arms, each with its own motor and ESC (electronic speed controller). These are all connected to a main controller, the latest of which also contains a three-axis gyroscope, three-axis accelerometer and barometer, and can measure altitude and attitude of flight. It can also be used for autopilot and automatic control. Attached to all this is a receiver for your ground transmitter (controller), a GPS system with accurate Position Hold, Return-To-Home and IOC (Intelligent Orientation Control). Using the GPS module, the multirotor will have position and altitude locked accurately even in windy conditions, with a hovering accuracy of approximately 2.5m horizontal and 0.8m vertical.

Best mode for the job

In GPS mode, the aircraft is stable and fairly easy to fly – let the controls centre and the multirotor will go into an immediate hover, holding position and altitude. If you lose radio connection, or your aircraft batteries get low, then the aircraft will go into fail-safe mode and fly itself back to where it started and land – unaided. Unfortunately though this is not a suitable mode for video flying because of the 'twitching' caused by the constant adjustments made to the aircraft by the GPS system.

The mode most aerial cameramen prefer is ATTI (attitude), where the controller will maintain the altitude of the aircraft but not the position. Therefore, if, for instance, you apply and release the throttle, the aircraft will drift smoothly to a halt rather than stop abruptly. This makes it harder to fly in windy or even breezy conditions and needs a degree of flying skill to position the craft accurately.

IOC is another useful function, acting as the panic switch for many pilots. Because a symmetrical object like a multicopter looks basically the same from whichever direction you view it, from a distance it can be quite difficult to see which direction the machine is flying in, sometimes causing you to send it completely the wrong way. This results in pilot panic as you see your precious camera flying off to some unknown destination. It is, of course, also very dangerous as at some point the aircraft will simply crash into the ground – wherever it is. Fortunately, this can be avoided by using the IOC.

Usually, the forward direction of a flying multirotor is the same as the nose direction. By using IOC in 'home lock' mode, no matter which direction the nose is pointing, pulling the stick back will bring the aircraft back towards the point from which it started (its home point and normally you), thus saving the day, your aircraft, your camera, and being sued by someone with a large dent in his car roof!

Another device which may be added is an OSD (on screen display) – I did warn you about the acronyms! This unit can collect real-time video and flight data, which will help you to obtain the aircraft status information during flight. It can overlay your monitor display with information about your power voltage, flight velocity and height, distance from the home point, horizontal attitude and the number of GPS satellites currently connected.

The gimbal

The gimbal is the part of your system that will make or break your ability to produce good, stable video, and this is where the most recent developments have turned even a small quadcopter into a possibility as a stable video platform.

The horror words for aerial cameramen are 'jello', 'vibration' and 'rolling shutter'. Jello is obviously an American term but does accurately describe the wobble effect on images caused by the combination of multicopter vibrations and the camera's rolling shutter. There have been many ingenious ways tried to lessen this effect (including moon-gel and shooting at 50 frames) but this year has been the year of massive gimbal development as brushless motor technology and gimbal controllers, such as the Alexis Mos, have become available at a reasonable price. Although this technology has been around for many years, cost-wise it has only really been available to the high-end professional market. Last year saw the introduction by DJI Technologies of the three-axis Zenmuse Z15 gimbal. Using brushless motors and developed for their S800 hexacopter, it enabled super-smooth, stabilised, jello-free video for just under £3000. This gimbal was designed specifically for the Sony NEX-5, NEX-7 or Canon GH-2 cameras and incorporated full remote control of both the gimbal and the camera.

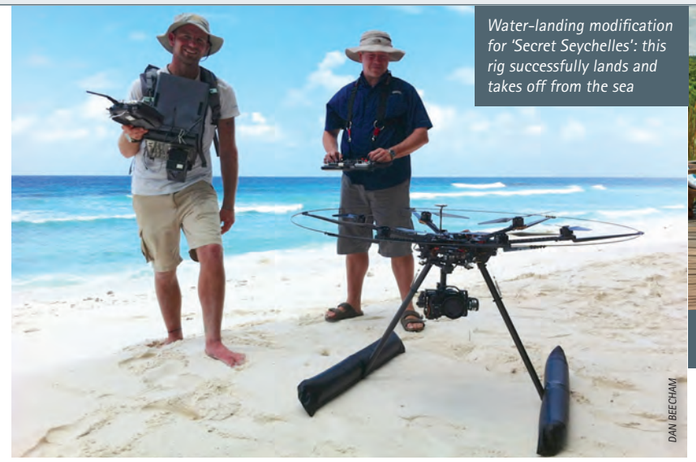
Move on 12 months and DJI have just released a two-axis brushless gimbal (tilt and roll), to fit their Phantom RTF quadcopter. This will carry the GoPro Hero3 and again offers smooth, jello-free video in a plug-and-go system. The gimbal costs £450 but several Chinese companies are already bringing out brushless motor gimbals at just over £200. With the Phantom RTF at around £450, this would give you an up-and-running GoPro aerial system for under £1000.

Don't forget you will also need an FPV (first person view) system – basically a transmitter and receiver – so that you can view the camera output from the ground. Depending on the power and frequency of your video transmitter, you may also need a licence to operate this.

Using a three-axis gimbal often requires the use of a second person: one to fly the aircraft, the other to operate the gimbal. In fact, the use of a second person as a spotter is almost compulsory as it's so easy to misjudge distance when peering at a monitor or using video goggles. You can easily become disorientated, not see power cables, be unaware of things happening around you, or simply be deceived by the ultra wide-angle POV.


ROGER RICHARDS

Left: The Quadcopters team (l to r) Dave Halton, Geoff Turner and Paul Carr at the GTC Day in the Country; Right: Phantom DJI RTF quadcopter mounted with GoPro camera


DAN BEECHAM

Water-landing modification for 'Secret Seychelles': this rig successfully lands and takes off from the sea

Andrew Schaale flying for the 'Top Gear' Africa special in Uganda

Heavier cameras

If you want to lift, fly and use something like a RED camera or full-size DSLR, then you will require one of the heavy-lifters. The increase in power and size obviously means an increase in cost, so a budget of well in excess of £6000 will be required for this level of operation. Like all modern technology you can spend as much as you like – there are systems out there costing over £30,000.

Already many companies in the UK are making a living out of this fast-expanding market. AerialVue, along with Quadcopters UK, demonstrated their impressive skills and products at the recent GTC 'Day in the Country' and drew a great deal of interest from those who attended.

This introduction is a personal overview of the developing technology based on a very few months' experience from a cameraman's perspective (both stills and video). The technology is moving so fast that I can't possibly cover every aspect, but there are many, many forums on the internet and there is no part of the subject that hasn't been written, talked and argued about. Remember though, that although rapidly entering the very professional world of filming, this is still primarily a hobbyist domain, much of which is the inspiration behind many of the new developments in the field. If you are looking to be convinced as to the usability and new dimensions this technology can bring to your production, take a look at *https://vimeo.com/61155597* (or any other by Robert McIntosh video) and admire the skilled camerawork and piloting. It's definitely one of those 'He won't will he?... Yes, he has' videos.

To date, most of my UAV work has been with stills, but somebody who has amassed a lot of video experience on high-profile TV productions, such as *Top Gear*, is Andrew Schaale.

Andrew Schaale writes:

Through Extreme Facilities, I have worked in and around all manner of helicopters and other aircraft for many years, fitting cameras inside and outside, using minicams and remote heads. This kind of filming is not without its scary moments on full-size aircraft, and there have been various close scrapes, including gearbox alerts screaming for an immediate landing, rescues on cliff faces with heavy downdrafts requiring the pilot to fly the aircraft beyond the manufacturer's limits, and needing backup from a Nimrod. I'm sure most pilots have had near misses: our pilot from the cliff face once hit a pylon with his tail boom and got away with it, while the Rochester Air Ambulance had no such luck six months after we had been out with them on every mission (obviously without incident).

Full-size helicopters are impressive machines and their pilots perform spectacular manoeuvres at great speed but, as we have seen, they are not without their risks. The many differences between full-size systems and multirotors start importantly with the fact that no person is on-board to be injured or killed in the event of an accident, and also should anything be hit by a multicopter – if the very worst happens – the risk is at least greatly reduced compared to the impact of a full-size aircraft. These safety benefits are understood by the CAA and are taken into account when permission to fly is requested.

Andrew Schaale pilot and Lec Park on gimbal filming on The Mall for Top Gear with modified DJI S800 with Panasonic Lumix GH3

Dramatic shots of a Ferrari for Top Gear in the mountains of Granada, Spain

Multirotors cannot achieve the same high speeds (for tracking race cars or power boats at over 100mph, for example), but these systems currently manage smooth shots at 30–40mph fully loaded. They should not fly higher than 400ft as a rule. Multirotors can easily soar to over 1000ft but this is prohibited for aviation safety reasons.

Special projects

Shooting with these devices has taken Extreme Facilities to race tracks, football stadiums, deserts, mountains and jungles around the world, sometimes requiring a considerable amount of R&D to ensure the systems work in the extreme environments of heat, cold and humidity. For instance, one project involved modifying a system to fly at Everest Base Camp and even higher, needing mods for the cold and to enable flying in the thin air at high altitude. Using an innovative range of solutions, we can now reliably fly at –25°C, and will soon be testing it in a low pressure chamber to simulate high altitude.

Projects over water run the risk that any fault which necessitates an immediate landing will result in the total loss of the system. So, for one project based almost entirely over water we developed a system of ultra lightweight floats enabling landing and take-off safely from the water (see image from *Secret Seychelles*).

Safe operation

Flying one of these devices requires specific insurance, including surprisingly high public liability insurance, and a pilot's licence – the BNUC-S – which can be obtained after successful completion of the Ground School Theory Exam and Operational Assessment and Flight Test Exam.

Flying close to the public or near congested areas, vessels, vehicles or structures not under the control of the person in charge of the aircraft, must be carefully considered and are all covered by the Air Navigation Order CAP 393. This document, along with CAP 722, CAP 403 and others, stipulates the rules and routines to be followed when flying any small unmanned aircraft system (or SUAS - yet another acronym!).

Adhering rigidly to these documents without any further consideration of methods to enhance safety or ways to increase minimum safety areas, would basically result in it being virtually impossible to fly in most cities. Thankfully though, the CAA has a very helpful and experienced team, who will consider additional safety measures to mitigate limitations of the environment. This often enables safe operation in areas not necessarily fitting all the minimum requirements. Mitigating circumstances may include physical barriers and meetings with local people to warn them about forthcoming flights and advise them to stay indoors for the short duration of the flight and about temporary closures of roads or footpaths. To support the operation, production staff, security or police may be required to secure any closures or boundaries.

Flying down The Mall

As an example of how this can work: *Top Gear*, for which Extreme Facilities supplies all specialist cameras and operators, requested us to fly along The Mall for a 'Best of British' item. Our first thoughts were: outside Buckingham Palace, on a busy road just 21.80m kerb to kerb, not to mention flying inside two overlapping heavily restricted airspaces (EGR157 and EGR160) put in place to protect the government, monarchy and headquarters of the Armed Forces - this had all the hallmarks of a completely impossible request. However, working through the project with the CAA, we were delighted and somewhat amazed to achieve permission. This was partly because we could demonstrate a good safety record but also because we were able to provide additional safety methods to mitigate concerns. The procedure included:

- supplying a map with overlaid diagram of our protected safety area and, within that, the flight path;
- confirming there would be hard crowd barriers for the complete circumference of the protected safety area and that these would be manned by private security and the police;
- a successful application to NATS (the National Air Traffic Service) for an 'enhanced non-standard flight';
- reducing the height to 200ft from 400ft and cutting the maximum aircraft distance from the operator to 200m from 500m;
- restricting our maximum wind speed to 10 knots, about half the usual maximum operating wind speed.

With all these safeguards in place, the event went off without a hitch, proving that with the correct approach even the most challenging of briefs can succeed. We have also successfully flown in various other central London areas including Hyde Park, and other city locations including central Turin, Tokyo and Berlin.

Fact File

Contact quadcopter owner Roger Richards (GTC administrator and GTC In Focus editor) on: *infocus@gtc.org.uk*

For EuroUSC and CAA regulations and guidance see: *www.caa.co.uk/uas* and *www.eurousc.com*

See more about Quadcopters at: *http://quadcopters.co.uk* and Aerial Vue at: *www.aerialvue.co.uk*

Extreme Facilities

In addition to its core HD/2K minicam/underwater/specialist high-speed camera activity for TV and film, Extreme Facilities has a fully-fledged aerial camera department with six multicopter aircraft and four BNUC-S qualified pilots who work alongside trained gimbal operators.

The team can fly with Canon 5D Mk II and III and C300, Panasonic Lumix GH3, and Sony FS-700 cameras, and use the Droidworx Skyjib X4 and DJI S800/EVO plus mini-multirotors for gyro-stabilised GoPro 3s.

Extreme Facilities produces innovative reliable solutions and is keen to support new productions and special projects. It has a team of experienced multicopter engineers, who can supply components and build multicopters to the client specification. Contact: Andrew Schaale: 07836 780 040 or 0207 081 9111. or see more at: *www.ExtremeFacilities.com.*