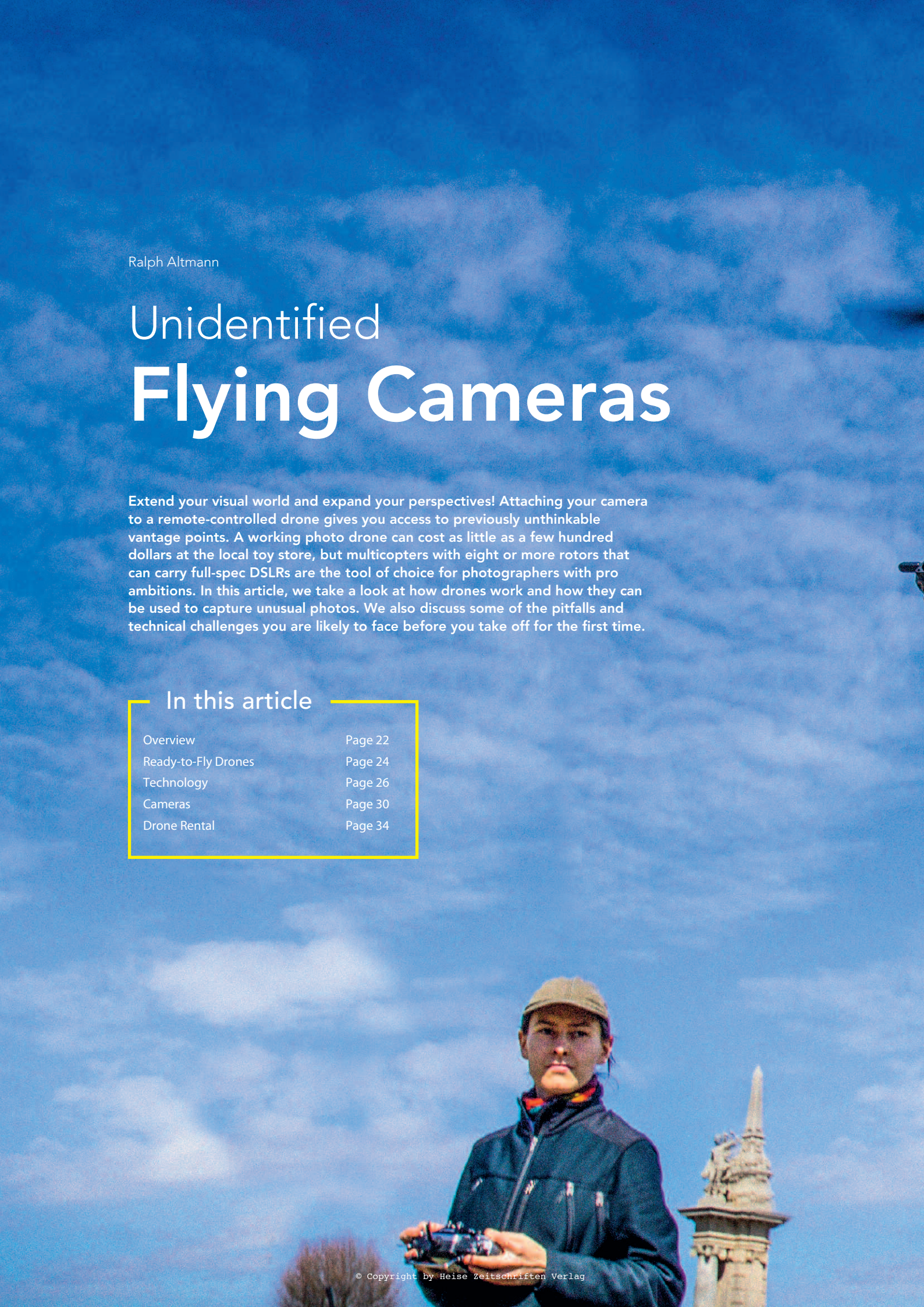
Ralph Altmann

Unidentified Flying Cameras

Extend your visual world and expand your perspectives! Attaching your camera to a remote-controlled drone gives you access to previously unthinkable vantage points. A working photo drone can cost as little as a few hundred dollars at the local toy store, but multicopters with eight or more rotors that can carry full-spec DSLRs are the tool of choice for photographers with pro ambitions. In this article, we take a look at how drones work and how they can be used to capture unusual photos. We also discuss some of the pitfalls and technical challenges you are likely to face before you take off for the first time.

In this article



Most photos are taken at eye level, giving cityscapes and landscapes the same rather predictable vertical perspective, shot after shot after shot. Simply shifting your standpoint by a meter or two can radically change an image, as ground-level worm's-eye view shots prove. Try it yourself and crouch down for your next shot of a building. Farther up, the length of your arms provides a natural limit to how far you can alter your shooting position, making a stepladder a standard piece of kit for anyone shooting at outdoor events. Specialized camera stands can provide shooting heights of 10 meters or more. After that, you need a viewing tower, although there isn't always one handy when you need it.

Get Detached

With a drone, or unmanned aerial vehicle (UAV), you are no longer tied down. The flexibility it provides frees you to realize any number of creative or crazy ideas at relatively little expense. Your next set of photos of a mountain trek is guaranteed to get a viewer's heart beating faster if it seems like you were floating over the abyss. A photo drone makes it quick and easy to produce aerial shots that previously required the use of a helicopter. Drones are agile too, giving you almost limitless access to narrow canyons, glacial crevasses, mountain streams, narrow streets and small indoor spaces that not even a helicopter can reach. Shooting altitudes just above roof height are a drone's natural habitat, and you can even use them to look into birds' nests (making sure, of course, that you don't disturb the residents while doing so).

Drones also come into their own nearer the ground, for shooting footage or stills that normally require the use of a crane or dolly. What's more, drones can simply hover in one place or follow a predetermined route made up of GPS waypoints. GPS also utilizes 'follow me' technology to precisely frame or follow moving subjects such as wakeboarders, snowboarders, sailboats or surfers. Commercial film-makers have been using drones for years now, although it has to be said that commercial, industrial and agricultural users have easier access to an appropriate budget and may be in a better position than most private users to save money, thanks to economies of scale. Drones are used increasingly often by real estate agents, for thermal imaging and a wide range of inspection work. Unlike for stills applications, propeller noise is often a problem when shooting video, and dubbing is required, just as it is for footage shot from a conventional helicopter.

Stills photographers often use cameras that are too heavy for cheap drones, but you can still produce effective high-resolution images by merging multiple shots from a compact camera. The trend in hobby-grade drones is moving toward the use of ready-to-fly drones equipped with the type of camera usually found in a smartphone. These tiny cameras often produce images that are just as good as those produced by compact cameras.

If you are exploring the idea of acquiring a drone of your own, the following pages will give you all the technical, commercial and practical information you need to get off the ground as soon as possible!

Please note: it is not always possible or legal to use a drone to capture footage of anything you happen to fly over or around. Always check with the local authorities or the owners of property you wish to photograph and always make sure you have appropriate permission before you begin a shoot. Privacy and copyright laws vary from country to country, so check the situation in your location before taking to the air.

If acquiring and flying your own drone seems too complicated, you can always hire one from an agency on a hourly or daily basis. Drones are almost always hired out with a pilot, as flying them requires practice and experience.

The two-dimensional 'Google view' most real estate agents use doesn't make the most of a drone's capabilities. A free choice of perspective from various heights – as shown in the photos of the Einstein Tower in Potsdam, Germany opposite – makes things much more interesting.

Ready-to-fly Drones

Although drone technology is still in its infancy, there is already a wide range of ready-to-fly drones and an even greater range of kits and components available to enthusiasts. Nearly all entry-level drones and kits are based on the two- or three-rotor multicopter principle. Drone mechanics are quite simple compared to those of conventional helicopters with their single lift rotors, because drones don't require the rotor blades to change their pitch (see page 28). Many remote control (and other) components used in drones have been used for model-building for years and are mass produced, making them good value. Standardized components don't require as much customization when you build them into a project, but you may find that the hype surrounding drones makes some items more difficult to get hold of as demand increases.

Pre-built drones that you can fly out of the box are called 'ready to fly' (RTF) and include all the parts you need to get going, including a remote control. Almost ready to fly (ARF) models require some construction work on the part of the purchaser and you will sometimes have to order additional components.

The best way to get yourself a custom multicopter is to purchase a kit, which is often not just cheaper than an RTF model but also cheaper than the sum of the parts it contains. The other major advantage of the kit approach is that you can upgrade your device to provide better performance later on. Well-known and trusted kit manufacturers include Cinestar, Quadrocopter, RC-Drones, Droidworx and SteadiDrone. Many manufacturer websites also offer comprehensive building/flying instructions and really useful user forums in addition to kit and component sales.

Entry-level UAVs (built-in camera)

These devices come ready to fly, have built-in cameras and are controlled either by a simple (supplied) control unit or via Wi-Fi using a smartphone. The borders between 'serious' drones and toys are blurred, and RTF UAVs weighing less than 400 grams (i.e., less than a pound) sell for less than US$300 if you shop around. The 'Parrot' drone shown below belongs to this category and has a camera with a 92-degree angle of view (21mm equivalent) that captures 720p30 HD video and photos. A second QVGA-quality (320×240) camera on the bottom of the hull captures video at 60 fps and serves as a flight control unit. The Parrot does not have GPS and offers a maximum flight duration of 15 minutes and a Wi-Fi control range of 50 meters

Mid-range UAVs (action and compact cameras)

Mid-range UAVs start at between US$500 and US$1,500, although accessories such as a high-end gimbal (see page 31) can add quite a lot to the bill. This type of UAV is usually powerful enough to carry a mirrorless system camera. The DJI Phantom Quadrocopter RTF kit (see opposite) costs around US$700 and includes the UAV, a six-channel GPS control and a manually adjustable mount for GoPro (or similar) action cams weighing up to 200 grams. A two-axis gimbal for the Phantom is available from www.quadframe.us for US$69 (US$140 motorized). The Phantom's successor, the Phantom Vision, has a built-in pivotable 14-megapixel camera.

Pro-grade UAVs (compact and DSLR)

The widest range of drones is available in the US$5,000+ price category. Pro-grade drones can carry cameras weighing up to 2 kg (4.4 pounds), usually have a two- or three-axis gimbal and offer flight durations of 15 minutes or more. Common in the movie and advertising industries, they are now also being used in industrial and policing situations. A complete Aibot X6, with remote control, batteries and charger costs around US$33,000, has a maximum diameter of 1 m, weighs 2.55 kg (5.6 lb) and can carry a 2.5kg (5.5-lb) payload for up to 40 minutes at altitudes of up to 2,000 meters. The Aibot's unique features include eight ultrasonic collision protection sensors with optional support from a smart camera and image processing software, making it extremely safe to use in crowded or remote airspace. The Aibot is controlled intuitively via a standard

Image: Parrot

The 'Parrot' drone from AR.Drone is very good value but provides only limited photographic capabilities

Image: DJI Innovations

DJI manufactures a broad range of components and also markets RFT UAVs like this Phantom quadrocopter

remote control unit or tablet computer interface.

The Microdrone MD4-3000 measures 2 m in diameter, weighs 15 kg (33 pounds) and can fly at altitudes of up to 4,000 meters, while the Skycrane models from service-drone are specifically designed for use with movie cameras, and have eight or 12 rotors that can carry up to 4.5 kg. The Flightcopter FC6-950 RTF hexacopter appears quite cheap in comparison, starting at US$7,000 with a two-axis remote head. Optional accessories include a three-axis gimbal for cameras weighing up to 1.2 kg and video glasses for precision flight control.

Adding your own options to a base model is a great way to save money and end up with a UAV tailored precisely to your own specific needs. For example, the powerful ARF Oktokopter XL from Mikrokopter.de can carry up to 2.5 kg for up to 20 minutes, but costs less than US$6,500 (without a remote control or gimbal). Other manufacturers offer less powerful base-level kits for around US$1,000, while two- or three-axis DSLR-compatible gimbals start at around US$500.

The sections on the following pages explain how the various parts of a multicopter work and what to watch out for when configuring your own UAV.

Image: Aibotix

Cool-looking, powerful and, most importantly, safe. The Aibot X6 from Aibotix International costs around US$33,000 and provides a glimpse of the future of photo drones

Drone Technology

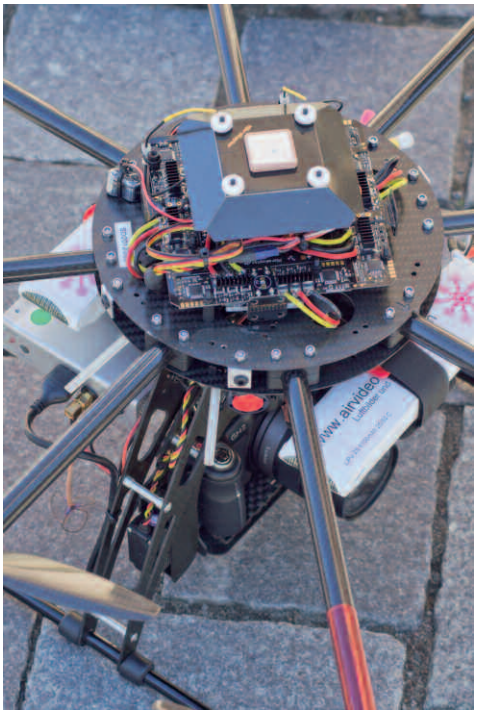
Sleek one-piece photo drones do exist, but most are assembled from random-looking components, often held together with duct tape and cable ties. This DIY approach makes sense when you consider the speed at which drone technology is developing, as it enables you to quickly swap out outdated components or repair damage. It also means you can build your own custom drone to fit your own particular purposes – for example, by adding extra batteries to extend flight times (although more dead weight always means a drone can carry less payload).

You can definitely save money by buying cheap components from Asian manufacturers, but you have to know what you are doing before placing an order. There are dozens of really useful forums on the Web, but take care not to underestimate the time and effort involved in building your own drone. The following sections look at the individual components of a drone and tell you what you can expect them to do and what their limits are.

Chassis

The basic chassis or 'frame' in a drone usually consist of at least two crossed arms to carry the rotors and some kind of landing gear. The number of rotors gives multicopters both their distinctive and their names: a quadrocopter has four rotors, a hexacopter six, an octocopter eight and so on. Even numbers of rotors make it easier to balance the torque produced by the alternating right- or left-rotating propellers. However, three- and five-rotor UAVs do exist and use different control mechanisms or degrees of rotor tilt to balance them in flight. Two motors mounted above one another (i.e., coaxially), let you use twice as many rotors to produce twice as much lift. The more arms (and therefore rotors) your drone has and the greater the distance between them, the smoother its flight but the greater its susceptibility to the effects of wind.

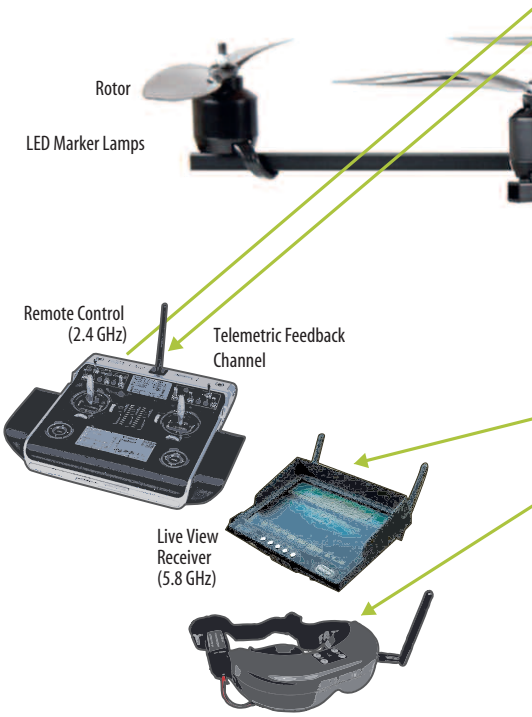
The metal used for the chassis needs to be light and stable and should be capable of damping vibrations. These are the same basic attributes required in a photo tripod, so it is logical that the same materials – i.e., aluminum or plastic strengthened with carbon fiber – are used. Hollow legs are great for mounting cables, while the batteries, control unit and camera mount are usually fixed to the top or bottom of the central point of the chassis, where they are normally covered with some kind of protective casing. Precise distribution of the weight of these components is less important in a multicopter than in a conventional single-rotor helicopter, as any imbalance is easily counteracted by adjusting the individual rotors. It is handy if the arms can be dismantled or folded for transport, especially if you plan to take your drone with you on hike into the mountains. Simple DJI aluminum frames weighing 300 grams start at around US$90, although some basic models can cost as much as US$250.



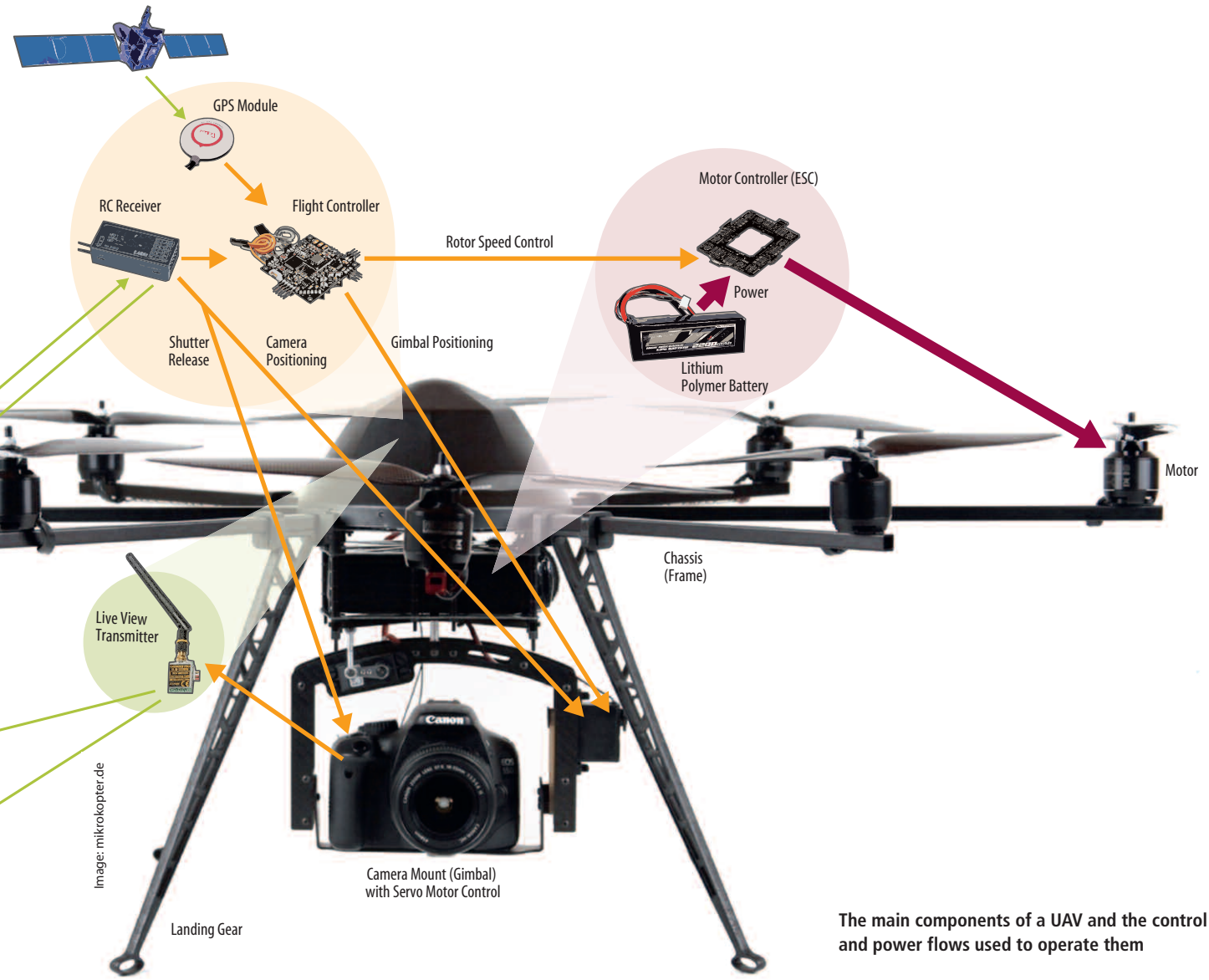
The 'brain' of an octocopter (in this case in an SD 2.0 SE from service-drone) contains a large number of microsensors. The square white component at the top is the vehicle's GPS receiver.

Power Unit

Multicopter motors have to be precision engineered to produce as much power with as little weight as possible. Brushless motors are the most widely used type and usually cost about US$55-75 each. The key metrics are the stated number of watts a motor produces and the number of revolutions per volt (Kv), which, when combined with the power of the onboard batteries, allows us to calculate the maximum number of revolutions at idle. For example, a 1200Kv motor powered by an 11V battery can theoretically be driven at up to 13,000 revolutions per minute (rpm) without a propeller attached. However, the real-world performance of a motor depends on the propeller you use, and the best combination of propeller and motor is what gives you maximum lift.



The two most important propeller metrics are diameter and pitch, both of which are usually quoted in inches as part of a product's name. For example, an EPP1045 propeller has a diameter of 10 inches and 4.5 inches of pitch, which means (theoretically) that one rotation propels it 4.5 inches through still air. The greater the ratio of pitch to diameter, the greater the stream velocity (and therefore



The main components of a UAV and the control and power flows used to operate them

flight speed) a propeller can produce. High velocity is an important factor when combating the effects of wind but makes it more difficult to produce a stable hover position. Most multicopter propellers have a diameter to pitch ratio of 2:1.

Propellers are commonly made of expanded polypropylene (EPP) and are available in stable (but fragile) APC and more expensive carbon-fiber (CF) types. Most multicopters require pairs of clockwise and counterclockwise-rotating propellers, which cost between US$3 and US$30, depending on what they are made of and how well they are made.

The force that lifts a multicopter is called lift and is measured in newtons (N). 1 N can lift about 100 g (3.5 oz) of payload. Doubling the motor speed quadruples the amount of lift but uses eight times as much battery power. The power train is usually set up so that a multicopter can hover at half its maximum motor speed while fully loaded. This leaves enough power in reserve for navigating and flight stabilization.

Motor speed is controlled using electronic speed controllers (ESCs) that regulate the phases of the motors so that one stator moves with the rotating field. Brushless motors are robust but require a complex voltage timing system, making appropriate ESCs more expensive than their conventional counterparts. Each motor requires its own ESC, although combined ESCs designed for use with four or more rotors save space and cabling. ESCs cost between US$30 and US$80 each, although multi-ESCs can work out cheaper (for example, the Hobbywing Skywalker Quattro for about US$40). On the other hand, some multi-ESCs cost far more than the appropriate number of individual components.

Batteries

Drones are powered by rechargeable batteries, which also determine their flight capacity and speed. Battery capacity is measured in milliampere hours (mAh), which, when multiplied by voltage, gives us the maximum amount of storable energy, measured in watt hours (Wh). The lithium polymer (LiPo) batteries used in most drones are rated at 3.7 V and are often mounted in series to provide 11.1 or 14.8 V of power. This nominal voltage declines under load due to the battery's internal resistance, which should, of course, be as low as possible. The maximum amount of power that the battery can provide is measured in terms of a multiple of its nominal capacity, C. For example, the notation '3S 3300mAh 35C' tells us that three batteries are running in series (3S), that they can deliver 3.3 amps for an hour and that the maximum

GPS technology can be used to 'park' a drone in mid-air while you shoot the source images for a panorama. This example shows the Glienicker Bridge between Potsdam and Berlin, constructed from 12 source images.

deliverable current is 115.5 amps (3.3 × 35), which would run this particular battery down in 100 seconds. In practice, each motor uses between five and 20 amps.

One way to increase battery capacity is to run multiple (same voltage) battery packs in parallel, but remember that battery capacity drops significantly in low-temperature environments. Energy density (measured in Wh per kg) is another important indicator of battery performance, as the UAV also has to carry the battery's own weight, further reducing the potential payload it can lift. 130 Wh/kg is a good average value. Prices for a 5000mAh battery pack range from US$45 to US$130, depending on energy density and durability.

The current required to charge a battery is also given as a multiple of its capacity (C). The smaller the charge current, the longer the usable life (and charge time) of the battery. Charge currents of two to four times C are standard, resulting in charge times between 30 and 15 minutes, regardless of battery capacity. If no charge current is specified, use 1 x C, which will take a full hour to charge. To prevent the individual cells in a battery pack from discharging at different rates, their contacts are connected to a balancer, which is an integral part of all good chargers. You can spend as little as US$50 or as much as US$200 on a charger that is worth owning.

LiPos are more sensitive than other types of rechargeable batteries and shouldn't be overcharged or completely discharged. If damaged or short-circuited, they can swell up or even catch fire, and charging them incorrectly or too fat drastically reduces their usable lifespan. UAV batteries have a shorter usable life than the LiPos used for other applications due to the high loads imposed by flying. Depending on battery quality and the nature of the flights you undertake, you can expect to squeeze between 100 and 500 charge cycles out of a set of batteries. The battery is the weakest link in a multicopter's power train, and users everywhere are waiting impatiently for the battery industry to provide improved energy densities that they hope will massively increase flight capacity without making it necessary to alter any other technical aspects of a UAV.

Flight Control

The flight controller, or 'brain' of a drone uses sensors to ascertain altitude, direction and acceleration, as well as ensuring a stable hover position and translating remote commands into real-world movements. Most drone movements can be executed by altering the speed of one or more of the rotors, which are controlled by ESCs capable of altering the electrical pulses sent to the motor quickly and efficiently.

Altering the speed of all the rotors equally causes the drone to rise or fall vertically. To get it to move forward, you increase the speed of the rear rotors. A drone can be rotated by altering the speed of rotors on opposite sides of the hull, which still provides constant lift, but no longer compensates completely for internal torque. Most ESCs also have additional servo output channels that can be used to tilt the axis of a rotor if required, or control the movements of a camera mount. Other output channels provide visual system information (such as a 'weak battery' indicator) via LEDs.

The sensors built into flight controllers enable relative navigation. If you want to utilize absolute waypoint navigation or return-to-home (RTH) functionality, your drone will also have to have built-in GPS. Some controllers – such as the DJI Naza-M and Wookong-M models – have these functions built in and only require you to attach a GPS antenna, while other models, such as the ArduPilot Mega, require you to purchase an additional GPS module (for example, the 3DR GPS uBlox LEA-6 for about US$75).

The race to create autonomous flight control systems is in full swing, and infrared and ultrasonic collision avoidance systems are already fitted to some high-end drones as standard. Time-of-flight cameras can be used to obtain a 3D image of a vehicle's surroundings, regardless of the ambient lighting conditions, and can thus be used to construct extremely precise flight and position control mechanisms. On a simpler note, one or two cheap cameras mounted on the hull and aimed downward can help to make GPS-based navigation more precise or provide navigation data between high buildings, indoors or in other situations where GPS data is unobtainable.

Shot using an Olympus XZ-1 mounted on a custom hexacopter rented from a local company

Remote Control

Conventional model-shop remote control (RC) units that operate in the 2.4 GHz (ISM) frequency band are well suited for use with multicopters. Such units have a range of 300-1,000 meters, which is quite sufficient for flying a drone by sight. The more channels an RC unit has, the more individual functions you can control. Basic flight requires four channels (up/down, left/right, forward/backward and rotation), and you need additional channels to switch between manual and GPS-based navigation and to release the camera's shutter. Camera position control requires one channel per axis and focus and zoom settings also require their own channels if you want to control them remotely. In such cases it makes more sense to work with a two-person team and two remote control units than alone with a 12-channel RC. This way, one person can concentrate on flying while the other operates the camera.

Prices for RC units range from US$150 for a simple six-channel model to more than US$3,000 for an 18-channel Futaba 18MZ. You will also need to build a receiver into your UAV to transmit control signals to the ESCs and other servos. Servo signals are transmitted either singly or summed, either directly or via a signal decoder. The Futaba S.Bus system is widely used and supported by various receiver manufacturers.

Modern digital RC units designed for use on the 2.4 GHz band use 'frequency hopping' and 'direct sequence' spread spectrum (FHSS and DSSS) techniques to compensate for the short breaks in transmission (dead points) caused by shadowing and destructive interference. 'Diversity' systems with two independent receivers are even safer. High-quality RC systems include a separate channel for telemetric feedback, allowing altitude, speed and battery charge status to be displayed directly in the RC unit's readout.

With appropriate controllers, you can use a GPS module to program a complete flight route in advance, with waypoints, flight segments and hover phases. Some flight controllers have appropriate functionality built in, while others require the use of an additional 'autopilot' board such as the NaviCtrl model from skykopter.com for US$265. The functionality can then be used to perform preprogrammed pans or shoot panoramas while hovering. For advanced users with access to a full-function remote head camera mount, waypoint technology can even be used to shoot multi-row panoramas with ultra-precise rotation increments between shots. The same technology can also be used in reverse to keep a single subject in constant view during a flight. Last but not least, GPS functionality enables you to geotag the route your vehicle takes and record the exact position of the photos you shoot for later use with Google Maps and other map services.

As an alternative to radio control, multicopters can also be flown visually via Wi-Fi using a tablet or smartphone interface. The drawbacks of this approach are the limited range and the comparatively high latency of Wi-Fi, which can take 100 milliseconds or more to execute a command. It is also very difficult to control flight and the camera at the same time, although a Wi-Fi circuit is an ideal medium for (re-)programming waypoints.

Here, the camera operator is using a separate remote control unit with its own live view monitor

Camera Technology

Your choice of camera is limited by the carrying capacity of your drone and the dimensions of its camera mount. Live view image transmission takes place via an AV Out or HDMI connector and a drone-compatible camera must have an electronic or infrared shutter release.

Action cams are perfect for the job as they are designed to take a few knocks. Their image quality is not always the greatest, but is usually quite sufficient for uploading to YouTube or printing in a photo book. Their functionality is reduced to a minimum so that they can be attached to helmets or independent moving objects. Popular among snowboarders, white water rafters, surfers and mountain bikers, they are often either waterproof or include an underwater housing. One of the most widely used models is the GoPro Hero, which is extremely small (59×41×21 mm) and light (73 g), does not have a viewfinder or color monitor and is controlled via a small monochrome display. Framing and composition are done by guesswork, aided by the wide 120-degree angle of view of the lens, which captures just about everything that crosses its path.

The US$400 GoPro HERO3 Black Edition weighs just 73 grams 'naked' and includes a simple remote control and an underwater housing that works at depths of up to 60 meters

Some action cams are designed primarily with video in mind. For example, Sony'sHDR-AS15 (US$240) can capture Full HD video at 60 fps, but only 2-megapixel stills. In contrast, the GoPro Hero3 Black Edition (US$400) shoots 12-megapixel images at burst rates of up to 30 fps (or 120 fps in video mode) and captures 4K (3840×2160) video at 15 fps. Both models use Wi-Fi to control their shutter releases and transmit live view images. Unfortunately, cameras as small as this don't support RAW shooting mode.

Compact cameras offer better image quality, zoom lenses and (in some cases) RAW support, but are not so good at capturing video. We used an Olympus XZ-1 (still available for about US$300) to capture some of the photos reproduced in this article. This camera weighs 275 g, has a very bright (f1.8) 4x zoom and captures 10-megapixel stills and 720p video. Its successor, the XZ-2 (US$500) captures 12-megapixel stills and 1080p video at 30 fps. Both cameras support RAW shooting but have a proprietary USB connector for remote release and AV Out, necessitating some creative soldering if you want to use live view and remote release simultaneously. Unfortunately, connecting an HDMI cable is not an option because doing so automatically switches the camera to playback mode.

Canon compacts and some DSLRs present similar connection drawbacks and require the use of a special 11-pin USB/AV combo cable. The well-known CHDK (Canon Hack Development Kit) can be used to add a range of additional functions to most Canon compacts and even enables you to program your own. This makes Canon products more attractive than others for drone-based use. All you have to do to implement the various scripts available on the Web and at the CHDK forum (chdk.setepontos.com) is save them to the camera's SD card. Using these scripts and a little additional electronic trickery, you can release the shutter remotely, zoom in and out or start a continuous shoot. For more details on this and other CHDK functionality, such as RAW and interval shooting, check out the CHDK homepage at chdk.wikia.com.

A drone has to be capable of much heavier lifting if you want to use it to shoot with a DSLR. The Canon EOS 600D/Rebel T3i weighs 500 g (body only), while the EOS 5D Mark III weighs in at 950 g. Adding a bright lens means that your UAV has to be capable of lifting 1.5 kg or more. Zoom lenses are even heavier but are of little practical use in the air, as it is virtually impossible to alter focal length remotely. Mid-range DSLRs with plastic lenses and mirrorless APS-C and Four Thirds cameras are much better suited to aerial use. For example, the Sony NEX models and the Olympus E-PM1 ('PEN mini') both weigh less than 340 g with a pancake lens attached.

Camera Mounts

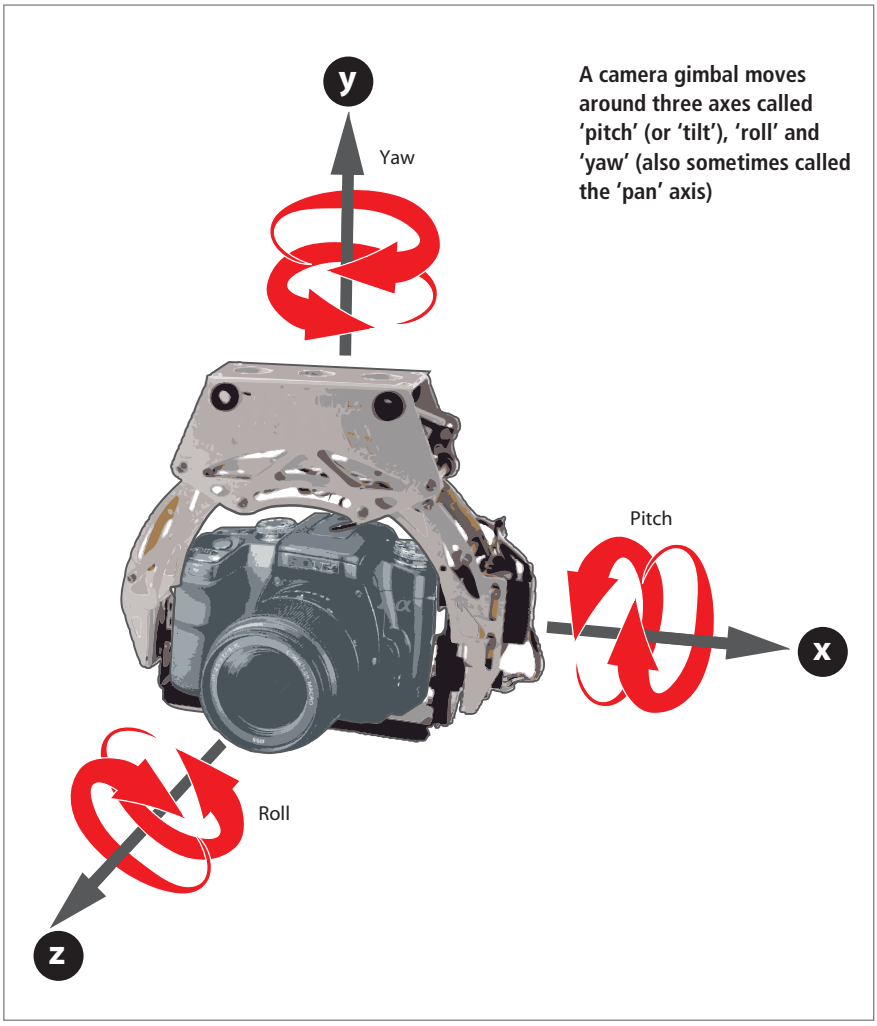
A fixed camera can only shoot in the direction of flight and drone movements – whether part of a predetermined route or executed to compensate for the effects of wind – spoil an otherwise smooth video shot. This makes a servo-controlled gimbal, or 'remote head', indispensable. A gimbal should be capable of performing pitch and roll movements, while yaw capability is useful for shooting complex panorama and the like, but not essential. Most gimbal movements can be duplicated by altering the position of the entire drone, although this is complicated to execute and often results in unwanted judder and overshoot, and is therefore unsuitable for video use. Remote camera control requires one additional RC channel per axis.

The control signals for the servos come straight from the flight controller with its built-in position and velocity sensors, while high-end gimbals have their own stabilizing gyros and stepper motors for fast, precise positioning. Some can even compensate independently for vibrations within the vehicle's spaceframe. The mechanics and electronics built into high-quality gimbals are complex and quite expensive. Two-axis gimbals start at around US$1,000 and a high-end three-axis model such as the Zenmuse Z15 from DJI can cost as much as US$3,500.

Smaller, less complex models suitable for use with compact cameras are less expensive, but you should reckon with spending at least as much as the price of your camera if you want to purchase a worthwhile mount. As with many consumer goods, drone accessory prices are falling all the time. At the time of writing, dronesvision.net was offering a two-axis gimbal for use with the DJI Phantom/GoPro Hero3 combo (controlled by the Phantom's Naza-M) for US$50.

Camera Control

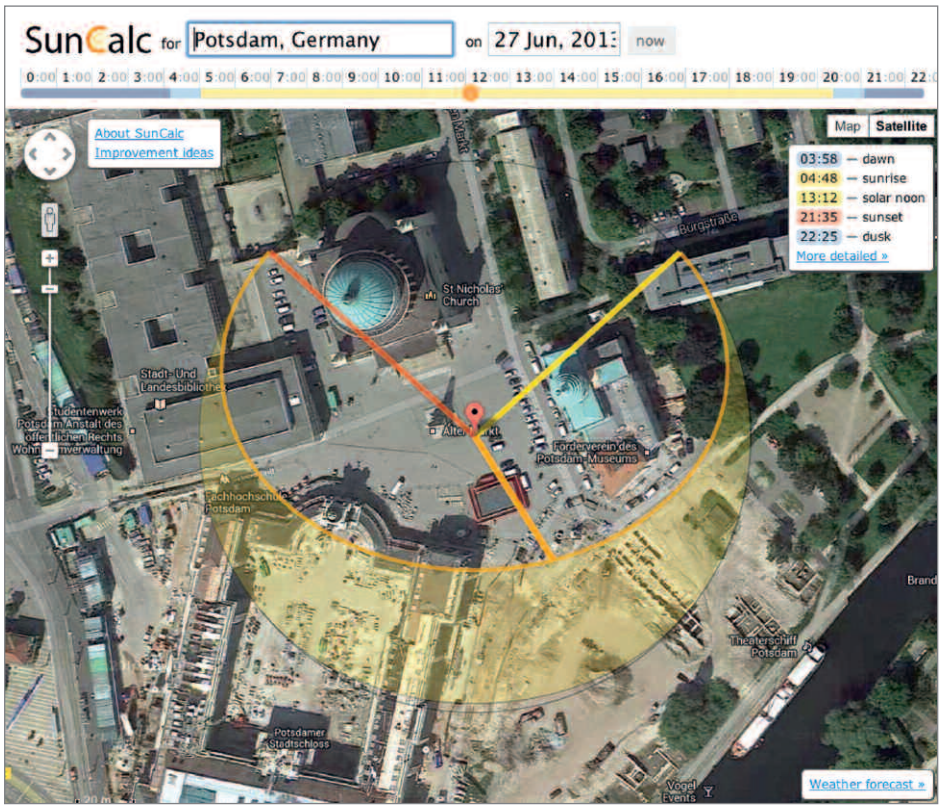
Although it may seem a minor matter, releasing the shutter of a camera in flight can actually be quite tricky. Most conventional wireless releases only work within a very limited range, and it is highly beneficial if you can actually 'see' what is in front of the camera before taking a shot. Not all cameras can transmit live view images via their AV Out connector, but specialized live view transmitter/shutter release units can be used to display the camera image on a remote monitor over distances of 200-300 meters. The transmitter is attached to the camera's flash shoe, and some models even have their own built-in mini-camera to provide a rough view of the surroundings, even if live view transmission doesn't work or is switched off. The units we found only work with DSLRs and some protrude so far that they prevent the camera from being mounted on its gimbal. Better-quality transmitters (such as the 5.8 GHz ImmersionRC EzOSD) can be attached to the camera via a cable. These offer large remote monitors, but rarely include remote release functionality as well.



A camera gimbal moves around three axes called 'pitch' (or 'tilt'), 'roll' and 'yaw' (also sometimes called the 'pan' axis)

Drones are perfect for shooting at fun sport events, allowing you to keep close to your subject without getting in the way or endangering the participants

Image: Airvideo-Service



SunCalc (http://suncalc.net/) is an add-on for Google Maps that displays the position and phases of the sun for a given time of day at a chosen location and can even display the shadows thrown by some well-known objects and buildings. While Google Earth can generate impressive lighting and shadow effects, these are less precise and don't reflect the sun's true position.

A first-person view (FPV) approach offers complete immersion in the flight experience and enables you to use video goggles to follow the flight path of your drone as if you were on board. 'Head trackers' even enable you to alter the position of the camera by moving your head. Always use 5.8 GHz equipment to transmit live view images, as 2.4 GHz gear can interfere with flight commands.

You need to use a free RC channel to release the shutter, either using a relay or a transistor. Construction plans for many RC releases are freely available on the Web, but ready-built infrared models for mounting in front of the camera are available for compatible cameras for as little as US$25 should you prefer. The most complicated approach (but one that works for all cameras) is to release the shutter mechanically using a servo. Again, the Web is the best source for construction plans. Just as complex is the use of airborne follow focus (focus puller) and remote zoom mechanisms. In an ideal world, these settings could be controlled remotely via electrical signals – an approach that is technically possible in compact cameras, but has so far only been realized using CHDK and makeshift mechanics.

The best positioning experience currently available is point-of-interest (POI) or 'follow me' functionality. This latches onto the chosen subject at a constant distance and follows it wherever it goes. The subject must, of course, have its own GPS transmitter or carry a GPS-equipped smartphone that is set up to transmit its position to the vehicle following it. The airborne camera can then use this data and its own position to pinpoint and follow the subject. Comprehensive instructions and a list of the components required are available in the 'International' forum at www.mikrokopter.de.

Shooting in Practice

Once you have solved all your positioning and shutter release challenges, you can concentrate on selecting the right camera settings. Even when stabilized as effectively as possible, a drone is never truly still during a flight, so it is best to use exposure times of 1/500 s or less. The anti-shake systems built into most cameras are attuned to the frequencies produced when humans shoot handheld and are much less effective at higher or lower frequencies. Using shutter-priority mode is the best way to keep the exposure time appropriately short if you are capturing single shots, but the changes in aperture that this mode produces can be a problem if you are shooting a panorama sequence. Most panorama software can handle differently exposed source images, but to be on the safe side, you can use a software-based tool such as Lightroom's *Match Total Exposures* command to balance exposures in a sequence.

Manual mode ensures that your shooting parameters remain constant during a shoot but cannot, of course, compensate for changes in lighting. If you use manual mode, set exposure for the brightest scene you think your sequence will contain and always shoot three-shot bracketing sequences whichever exposure mode you use. This gives you backup shots if the lighting does change and increases the chances of capturing at least one sharp image for each exposure.

After take-off, focus is just as difficult to alter as your exposure parameters. Due to the way they are built, compact cameras produce images with relatively high depth of field anyway, so if you are using one, simply set it to manual mode and focus to infinity. If you can, set the lens to its hyperfocal distance, as this provides the greatest possible depth of focus.

Using autofocus only makes sense if you use live view monitoring. Left to its own devices, autofocus can easily produce unforeseen anomalies or simply focus on the wrong subject. Photos shot with specific depth of field effects in mind can be just as interesting when shot from above, although an aerial shooting position makes it more difficult to convey the three-dimensionality of a subject. Not only that, but you will need a large-sensor camera, a bright lens and a servo-driven focus puller if you want to alter focus during a flight and still capture sufficient detail.

Unstable flying conditions and onboard vibrations are much more problematic when shooting video than they are for stills shoots. Because every stabilizing movement is based on calculations made for a system with a specific weight, it can help to alter the low pass filter settings on your flight controller to suit your particular camera/drone combo. If all else fails, video shake can be cured at the post-processing stage using tools such as the Warp Stabilizer included in Adobe *Premiere*

CS6. If you do use software tools, remember that they crop the frames you treat by about 5-10 percent.

For an exacting aerial shoot with specific foreground and background details and pre-planned lighting, it helps to plan your flight time and route in advance. There are various Web services and apps available that help you calculate and display the sun's position for a given location and time. Nevertheless, even the best-laid plans can go awry and it is sometimes quite tricky to find just the right shooting position when viewing a scene from above. When viewing your material after a shoot, you will often find that a slight change in position would have helped capture just the shot you were looking for, so always plan to make at least two flights per location if you can.

The pilots who fly rental drones spend most of their time working with clients in the industrial, farming and real estate sectors and don't yet have appropriate photographic experience. However, this situation is changing, and some drone services now specialize in film and photo shoots.

Image: service-drone.com

Servo-driven follow focus systems like those used in the movie industry can also be used to automate photo drone functionality

Drone Rental

Drone rental services can be found in most major towns and cities but are generally booked out when fine weather beckons.

Rental companies provide the drone, the camera and qualified personnel, as well as looking after details such as insurance and obtaining flight permission. If you use a rental service, you should agree in advance whether you or the service provider is responsible for getting permission to fly over or shoot material of private property. The contract with a drone service will usually give you the rights to the images captured and release the drone company from any liability regarding the content of the resulting material. Reputable companies will refuse to take on jobs that are obviously of a paparazzi or otherwise questionable nature, and it is up to the provider to make sure that any relevant no-fly zones and military regulations are observed. Some companies refuse to fly over crowds or large expanses of water.

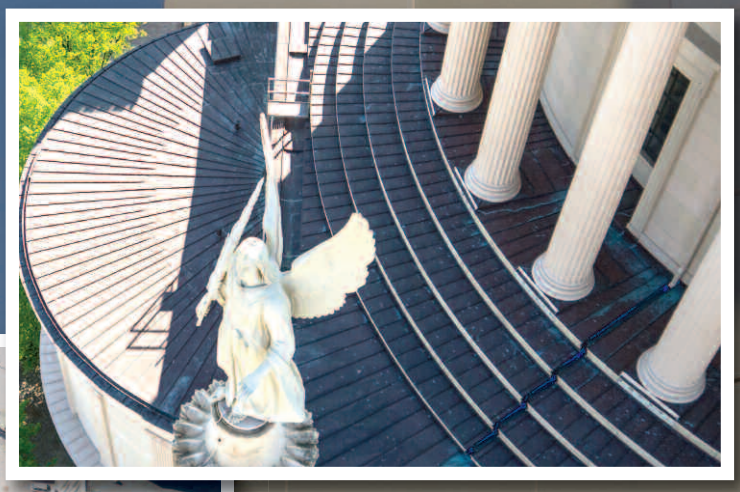
Most companies bill for hourly, half-day or daily rates and sometimes guarantee a minimum number or length of flights or a minimum number of photos. If you book a service, you will generally book the use of a particular camera rather than a specific drone. DSLRs are naturally more expensive than compacts, simply because they are heavier and require more powerful drones to lift them, although some services charge fixed rates up to a certain payload. Likewise, some companies include image processing in their prices while others charge extra for additional services.

Prices for an hour's rental in Berlin using a Panasonic Lumix GH2 start at around US$500, with a half-day rental costing as much as US$1,600. Prices vary according to the specifications of the gear being used and the amount of local competition. We paid EUR800 (about US$1,100) for the half-day shoot that produced the images on the first couple of pages of this article. An Airbot X6 with a pilot and the 36-megapixel Nikon D800 costs about US$2,000 for half a day and US$3,300 for a whole day. Two-person camera/UAV operator teams cost more than a one-person show, and some companies offer a 'sneak peak' trial service, shooting a few pictures of a specified location for a small fixed fee to help you decide whether you want to take on a bigger job. Specialized companies take on complete photo and film projects, with pricing scaled according to the time and effort involved.

Having seen what it can cost to have someone else fly a drone for you, you may be tempted to go out and buy your own, but don't forget that as well as the cost of a new drone with all its associated accessories, there will be additional outgoings for repairs and maintenance and the time and effort it takes to learn to use the device effectively.

On the other hand, a simple, collapsible drone that fits into a backpack could soon become a standard photo accessory that many photographers pack as standard when heading off on vacation or out into the country at the weekend. It isn't hard to imagine visiting well-known tourist attractions in the near future and finding ourselves surrounded by hundreds of autonomous flying cameras. The continuing development of drone technology definitely offers adventurous photographers a whole slew of new and exciting creative opportunities. (anm) c't

The specialist team from Airvideo-Service controls the drone, while the author views the action live via video goggles



A unique view: Our team captured some truly beautiful images of the city of Potsdam.

These images were captured using a Panasonic Lumix GH-2 mounted on an Octokopter SD 2.0 SE provided by Airvideo-Service in Potsdam