EVERYTHING YOU NEED FOR ALL QUADCOPTERS, DRONES AND UAVS

NEW

THE DRONES BOOK

TOP 10 DRONES
Everything you need to know about the best drones on the market

STAY WITHIN THE LAW
Essential rules explained

INcredible ways drones are being used today!

HACK YOUR DRONE
Control your UAV with a joystick!

WHAT DOES THE FUTURE HOLD?
How next-gen drones will redefine UAVs

BUILD YOUR OWN
Find out how to assemble your own quadcopter

5 COOL THINGS TO DO WITH YOUR DRONE
Welcome to THE DRONES BOOK

Drones are everywhere. And while the term ‘drone’ may have picked up negative connotations due to its use by the media when reporting on the role they play in the military, nowadays drones have become part of everyday life for many people. As prices have dropped and availability has increased, the range of affordable drones on offer to people has skyrocketed, meaning anyone can get involved and start flying.

In this book we’ll take you through all the basics, and examine some of the best drones and accessories on the market. You’ll then find inspirational guides to show you what you can do with your drone, and even build your own. On top of that, discover the amazing ways drones are being used today and how they are changing the world, from protecting wildlife to mapping the world. You will find that throughout this book we’ve also referred to quadcopters and UAVs, but in general we’ve included everything under the umbrella term of a drone. And one final thing to bear in mind: it’s important to always stay safe and know the laws related to flying drones, so we have included a feature on that very subject inside. So let’s get started and uncover what the wonderful world of drones has to offer so you can start flying today.
**CONTENTS**
What's in the bookazine and where

8 DRONE CAM
Inspirational images taken by drones and of drones in action

20 GETTING STARTED WITH YOUR DRONE
Understand the basics and find out how to buy, fly and maintain your drone

32 ESSENTIAL DRONE ACCESSORIES
The must-have kit that everyone needs to invest in

34 TOP 10 DRONES
Discover the fantastic range of drones currently on the market

46 BUILD YOUR OWN DRONE
Get hands-on and find out how to construct your very own quadcopter

52 HOW NOT TO GET INTO TROUBLE
Understand the rules and make sure you don’t break any laws when flying

**THINGS TO DO WITH YOUR DRONE**

58 FLYING FOR FUN
Master the basics of flying, teach others and get the whole family involved

64 PHOTOGRAPHING & FILMING
Learn how to create professional-looking videos and photos with your drone

70 EXPLORE WITH YOUR DRONE
Get a whole new perspective and explore the world like never before

76 GETTING STARTED WITH FPV
Upgrade to first-person view and fly your drone in style

82 RACING WITH DRONES
Supercharge your drone and battle it out to find out who’s the fastest

BUILD YOUR OWN DRONE

46

HOW DRONES ARE CHANGING THE WORLD

GET STARTED WITH FPV

32 ESSENTIAL ACCESSORIES

HOW DRONES ARE CHANGING THE WORLD

90 10 AMAZING WAYS DRONES ARE CHANGING THE WORLD
See how UAVs are deployed for an incredible range of tasks

94 FIGHTING WARS
Discover how UAVs are used to assist the military

100 MAKING FILMS
Filmmakers are changing the ways they approach a shoot

106 DELIVERIES, ERRANDS & MORE
Find out how drones can make your life easier and undertake essential tasks

112 PROTECTING WILDLIFE
Drones take to the sky to assist conservationists and help in the fight against poaching

118 AIDING IN EMERGENCIES
Emergency help now comes in drone form

122 REPORTING THE NEWS
Breaking the latest story without risking lives

126 MAPPING THE WORLD
Producing detailed and up-to-date maps

TOP 10 DRONES page 34

EXPLORE THE WORLD WITH YOUR DRONE

70

HACKER DRONE:

142 PROGRAM A RASPBERRY PI QUADCOPTER
Discover how this mini-computer can help you build and program your own drone

148 PROGRAM A DRONE’S FLIGHT PATH
Code a set path for your drone and explore the world of autonomy

152 CONTROL YOUR DRONE WITH A JOYPAD
Connect your drone to a PC and navigate it during flight using a simple joystick

156 UNDERWATER PI DRONE
Find out what it takes to make a fully functional, submersible Raspberry Pi-powered drone

158 BUILDING A SELF-DRIVING RC CAR
Is this self-driving RC car Google’s latest challenger?

THE FUTURE OF DRONES

130
FEAST YOUR EYES ON THIS SELECTION OF JAW-DROPPING IMAGERY OF DRONES IN ACTION AND BREATHTAKING PHOTOS THEY’VE TAKEN FROM THE AIR
Drones can be used to capture otherwise-impossible images, as shown by this group shot on the observation deck in front of the Christ the Redeemer statue in Rio de Janeiro, Brazil.
Drones like this are ideal when you’re looking to explore or photograph remote locations or hard-to-reach places.
Fishermen off one of the islands in Terengganu, Malaysia, cast their nets out as a DJI drone captures this shot.

A remote oasis surrounded by sand dunes is a beautiful sight from above.
A panoramic view of the Hawaiian island Maui surrounded by crystal clear waters taken by a DJI drone.
Drones can even be used to snap a bird’s-eye view of actual birds, as this eagle action shot demonstrates.

This DJI-shot photo shows the spectacular autumn colouring of trees dotting a lagoon.
A drone catches the sun rising over a cloudy Kuala Lumpur, with the Petronas Towers visible in the distance.

A pure white road cuts through a frozen forest. The small black dot is the photographer piloting their drone.
This shot of Ashlett Creek looking out over the waters in Southampton, UK was captured using a DJI Phantom 2 and GoPro Hero3.
A DJI drone helped capture this artistic overhead shot of a maple tree shedding its bright red leaves.

The Oriental Pearl Tower rises above the clouds covering Shanghai.
An adult whale and its calf photographed swimming beneath the waves using a DJI drone.
GETTING STARTED WITH YOUR DRONE

Find out how to buy, fly and maintain your drone, as well as how to get involved in online and real-world communities

You might have heard of drones in the past, but now you’re able to buy them! It’s not uncommon to watch a video shot from a drone and immediately want to do the same yourself. As you’ll have discovered by now, there are so many uses for drones that more and more are being thought of every day, and in addition to their practical uses, they’re also fun devices to play with.

With great fun comes a great range of choices to make. Quadcopters, multicopters and unmanned aerial vehicles (UAVs) are serious tools with specific uses and benefits. Every type has different advantages and disadvantages, but they all share the same issue of security. You won’t be allowed to fly a drone over Downing Street, for example, but you need to understand why this is so.

If you ever visit London, you might notice that police and medical helicopters are allowed to fly wherever they need to, but commercial and private aircraft are heavily restricted to certain routes, and must avoid specific areas. Pilots need to know these things, and you are now a pilot.

You also need to learn how to fly your drone. It might sound obvious, but it is very important, and will take time. You must understand what your drone is capable of and practice flying it. Fortunately, it can be very enjoyable to just fly a UAV around your garden and then up out over your neighbourhood.

Once it is a bore, you could fly your drone up to check out storm damage on your chimney, for example, or check out those hard-to-reach ledges and gutters without spending money on scaffolding. If foxes are getting into your garden, you could fly the perimeter, looking out for where they are coming from. You could drop items off to your neighbors, although you’ll need to be aware of what’s permitted in your specific region or location.

One of the most exciting uses of any drone, though, is video capturing. If you do check out your house’s gutters, you can set up the drone so its camera sends you live images. They can also record, though, and in remarkable quality right up to 4K. Imagine replacing dull estate-
YOU MUST UNDERSTAND WHAT YOUR DRONE IS CAPABLE OF AND PRACTISE FLYING IT

agent photographs with a two-minute flyby around your house.

All of this has now been made possible because of recent technological advances, such as lightweight but strong materials, powerful enough batteries, digital remote-control units, and also the miniaturisation of computers, which means that drones can be exceptionally adaptable.

Thanks to these developments, ordinary people are now able to have a go at flying quadcopters for themselves. Perhaps one of the most exciting things of all is discovering endless new uses.

You might be surprised to hear that drones are both affordable and widely available. You

just need to make a few decisions when it comes to choosing one, because the types differ significantly. You will find that what’s best for someone else might not suit your individual needs.

If you are a hobbyist, you could build your own drone, and would undoubtedly find this a fun and rewarding process. However, if money is an object, it would be cheaper to buy one. If you do purchase a drone, though, bear in mind that some will need more assembling than others. The size, power and number of rotor blades are also important, because they affect what you can do, how you can fly the drone, and also what all this will cost.
THE TYPES OF DRONES

PICKING THE BEST FOR YOUR NEEDS AND BUDGET

Drones are now common enough that there are stores that stock them and, of course, online shops that sell different types. The differences can be as obvious as cost and manufacturer, but more importantly affect how much work you have to do. You’re not likely to ever be able to fly a drone home straight from the shop. There are some that need assembling, and some that just need their batteries charged up first.

Drones are highly complex devices that rely on so many different parts. The more your interest and hobby develops, and the more experience you gain, the more you’re going to be aware of these components. You’ll no doubt start off buying a complete drone, but later on you might prefer to assemble one yourself in order to get precisely what you need.

**RTF**

- RTF means Ready To Fly. It means that you can be up and flying very quickly indeed. It doesn’t quite mean that the drone is ready to fly out of the box, though. If your bus home is delayed, you cannot simply fly it home to tell your loved one. Nor can it deliver itself to you direct from Amazon.

  What it does mean is that you’ll be able to fly it more or less as soon as you have removed its packaging. More likely, you will need to charge up the drone’s batteries first. You’ll perhaps need to put on the rotor blades and bind the drone with the handset. Binding is like the pairing you do with Bluetooth devices.

  Nonetheless, RTF drones are a good choice for beginners, because they mean you can fly the UAV sooner rather than later. They can be more expensive, though, because they’re aimed at a broader range of users and are capable of doing lots of things.

**BNF**

- This stands for Bind-N-Fly. These drones are always sold as complete quadcopters or UAVs, but they don’t usually include the controller. That’s the key difference between an RTF and a BNF. With this type, you need to separately buy your own handset controller.

  You could interpret this as being a way of making a drone cheaper. It’s not necessarily ideal for a complete beginner, but as you get more experienced and try out different models, a BNF is handy. It’s usually always a complete drone, and you might be able to use your old controller. That’s not guaranteed but, in theory, you could keep the same controller forever and use it with many different drones. In practice, not all controllers work with all drones, but you could easily buy alternative ones if you find you need to.

  Anyone can buy a BNF but, given that its big benefit is your re-use of an old controller, it’s probably for someone who has already flown a drone.

**ARF**

- As RTF stands for Ready To Fly, ARF means – you guessed it – Almost Ready to Fly. The only problem with this term is that the word ‘almost’ can be quite subjective. The one thing that you can guarantee is that you will need to work on the drone before you can get it up and running and airborne.

  Beyond that, it can mean as little as needing to assemble it. You don’t usually get a controller or the transmitter/receiver for the drone to be controllable.

  So, an ARF kit might not include the flight control computer that makes flying the drone physically possible, and it might also leave out the motor, but you do get a nice box.

  This isn’t really aimed at a beginner. You’re more likely to choose an ARF drone if you’re a hobbyist who will enjoy learning how to assemble and pilot a flying machine. You’d also opt for an ARF if you’re an existing drone user and therefore already have parts and know how to transfer them to the new machine.
BUYING YOUR FIRST DRONE

WHAT TO BUY AND WHERE TO GET IT

You could go on Amazon right now and take your pick from more than 700 different drones. However, you might encounter a problem when it comes to choosing which one to buy, as you will be swamped with jargon and reviews.

Quadcopters cross lines between electronics, hobbyist products and, in some cases, even toys. So, high-street stores that sell any of these could also sell drones. The retail store Argos, for example, offers a number of UAVs, but not every store will necessarily have every product.

Once you have an idea of the type of drone you want, and the amount of money you can afford to spend on it, use online sites to narrow down your search. Read the reviews on these sites, but remember to read them with a pinch of salt; cheap UAVs might get poorer reviews for not being top of the range, while state-of-the-art drones might also receive criticism for being expensive. It’s not entirely the case that you get what you pay for, but you need to know that not all buyers will be as prepared and researched as you are. Many people buy the first drone they can afford, and don’t appreciate that there are differences in terms of what each type is useful for.

You also need to look at what type of camera comes with the drone, if any. The cheapest drone not only won’t come with a camera, but you also won’t be able to fit one to it. Mid and even low-price drones will include basic cameras, but many people will want the same picture quality that you see on YouTube’s collection of drone videos. If this is the case, it means getting a more expensive camera.

What is often overlooked is getting a drone with a gimbal. This is a mount like a miniature version of the ones used in aerial photography. It offers the camera a wide range of movement, and also enables it to move smoothly. All rotorcraft vibrate, and helicopters have tail rotors specifically to stop the entire machine being flung around in the opposite direction to the main rotors. Gimbals even that out.

UAVs are cheap in the sense that they are affordable, but not cheap in the sense that you can’t casually keep buying them until you find one that you like. Take your time thinking about what you will actually use one for, and at the very least try to talk to someone who already owns and flies drones.

"THERE ARE SIGNIFICANT DIFFERENCES IN TERMS OF WHAT EACH IS USEFUL FOR"
ANATOMY OF A DRONE
ONE MACHINE, SO MANY COMPONENTS

SHELL
- Unless you crash your drone very neatly, you will usually just see this shell. It is the casing: the fuselage of the UAV. Bright colours really help you spot this from a distance.

ROTORS
- You’ll see they’re twisted slightly. Rotors are not straight; they are shaped exactly like aircraft wings, and for the same reason. Their shape affects air flowing over them and that is what produces lift.

BATTERY
- Your drone isn’t going anywhere without a charged battery. This is perhaps the most limiting element you’ll face. Fully charged ones will typically only power the drone for 20 minutes.

LANDING GEAR
- In this example, the landing gear is an extension of the boom, but you can have more elaborate ones. They let the drone set down on the ground without anything hitting the rotors or body.
BODY
- The core of your drone is this hub: all the physical elements connect to this, which is always at the centre of gravity of your UAV. Rotors, landing gear and computer controls connect here.

BOOMS
- The arms of your drone are crucial. They have to be light but strong and thin enough to not get in the way of the rotor’s downdraft. Length determines stability and manoeuvrability too.

GPS AERIAL
- Hopefully you can always see where your drone is, but with GPS it knows exactly, and will make decisions based on that. It may also record GPS data along with your video.

FLIGHT CONTROLLER
- You have positive flight control, so you choose where the drone goes, but this unit handles the conflicting pressures and strains to keep the flight stable at speed and in wind.

"GPS KNOWS WHERE YOUR DRONE IS, AND WILL MAKE DECISIONS BASED ON THAT."

5 Essential safety tips

01 Always ensure you never fly your drone anywhere near people’s bodies and faces.
02 Be sure you’ve switched off the drone’s motor before you switch off the controller handset or remove batteries.
03 Remove the rotors when you’re not using the UAV. Take them off and there is little the UAV can do.
04 Don’t risk flying unless you see weather conditions are good, and you know that this is going to continue.
05 Follow instructions for recharging Lithium Polymer batteries. They need greater care than regular ones.
BEFORE YOU GET STARTED
WHAT YOU MUST ALWAYS CHECK FIRST

ENSURE IT’S LEGAL

* THE LAWS SURROUNDING drones are constantly changing and being readdressed. One of the most important things to do before you even take your drone out for the first test flight is to do some research and understand the basic laws regarding flying a drone in your country. Ignorance is not an excuse, and you don’t want to get on the wrong side of the law before you’ve even got the most out of your drone. There are limits to where you can fly, especially near people, airports and military bases, so check before you head out and about. Use your common sense and always make sure you’re abiding by the rules.

KNOW YOUR BOUNDARIES

* THERE’S A REASON so many stunning drone videos are of landscapes: you cannot fly one within 150 metres (about 500 feet) of a congested area. Similarly, you cannot fly one within 50 metres (around 160 feet) of an individual. There’s also a weight limit: the drone must be less than 20kg (44lbs). Also, if you are doing any flying for commercial reasons, like filming a pop video, for example, you’ll need a licence from the Civil Aviation Authority.

Label your UAV

Label the drone with your name and phone number. Your quadcopter could blow away in the wind. If your controller battery fails or there is some unexpected obstacle between you and the drone, you could lose signal and therefore control.

PICK YOUR SPOT

* YOU’RE NOT GOING to fly your quadcopter around your kitchen. When you take it outside, though, the UAV must remain within your sight at all times. That’s specifically within your unaided eyesight. It’s an easy rule to understand: if you can’t see your drone without binoculars, you’re in the wrong. The rule of thumb is that you are limited to 500m (1,640ft) horizontal distance and 400ft altitude. (Note that the Civil Aviation Authority lists altitude in feet, and 400ft is approximately 122m.)
TRACK THE WEATHER

- THERE’S ALSO A reason those stunning drone videos show perfect weather conditions. You can’t fly a drone in the rain (these are electrical devices you’re putting up there), and you must not fly through clouds.

Sunshine and rain are easy to spot, but wind speed is harder. Drones vary a lot, but typically if wind is below 28mph (45km/h) then most drones will fly. Some can handle 40mph (65km/h) winds, but no matter what drone you have, you’ll struggle to get decent video when fighting against strong winds.

CHARGE YOUR CONTROLLER

- WITH ALL THE concentration on battery power for the quadcopters themselves, you can forget that your controller actually needs it as well. If your controller fails while your drone is aloft, that drone is going to keep on going until its own battery dies and it falls from the sky.

Granted, that’s a worst-case scenario, but avoid any potential problems by taking a portable charger or spare battery. You could also practice changing them quickly, so you’re confident should you ever need to.

TEST THE CAMERA

- YOU KNOW YOU can use drones to do many things now, but perhaps one of the best is for aerial video, and that is completely wasted if your recording doesn’t work.

Some UAV cameras will just transmit video back to your phone to record there. However, high-end ones stream back so you can see what they’re filming, as well as record up to 4K quality video on board. Make sure you have a completely empty SD card, then test it to check it’s working before you pull off a fantastic aerial flyby that doesn’t get recorded.

WATCH YOUR TIME

- YOU'RE CONSTRAINED ON how long you can keep a drone aloft, but it’s not due to legal concerns; it is in fact the limits of battery technology.

We couldn’t do it without them, but batteries are also holding back UAVs. Batteries powerful enough for a drone’s rotors are heavy, so you need more power to lift the drone.

At present, you can expect to get around 20 minutes’ flying time per charge. Professionals keep it to around ten and carry many, many spare batteries that they swap in for the rest of the shoot. The best at present are Lithium Polymer (LiPo).

“WE COULDN’T DO IT WITHOUT THEM, BUT BATTERIES ALSO HOLD BACK UAVS”
THE BASICS OF FLYING

YOU'RE THE PILOT OF AN AIRCRAFT NOW

Hover your drone
- WHEN YOUR DRONE is close to the ground, the downdraft from the rotors is reflected up, and makes it hard to keep the UAV steady. Raise it to 1.5m (5ft) and then practise holding it still. This is known as hovering and you won't manage it at first. You may not manage it for a long time, but practise from the start because when you do get it, it is supremely useful. As difficult as hovering is to do, it means your UAV can get steady video shots and is totally under your control.

Crash occasionally
- IT'S GOING TO happen, so learn how to get it right by letting the drone crash from a small height. You've got to learn how to quickly recognise when a crash is going to happen, then switch off the throttle straight away. The blades will still spin for a while, but they will do less damage to themselves and other people if their power has been cut. This is so important that lesson seven of learning how to fly a full-size helicopter is about doing exactly this.

Beat the wind
- THE WIND WILL always win, but you can make it work for that victory by learning how to counteract sudden gusts. Gusts come from one direction at a time, so if you are buffeted from the right, then you should fly to the right; fly into the wind that's moving the drone. You'll know when this is necessary, as you'll feel your loss of control even quicker than you can see the effect on your quadcopter. Just also be very aware that your best option may be to land the UAV.

Take short hops
- YOU'LL BECOME VERY weary if you spend all your time learning to hover, so make sure you alternate that with learning short hops. If you're in a garden, try to fly the UAV to a bench or a particular open patch of ground. You'll be learning the core controls of turning left and right, moving up and down, forward and back. They're essentials to learn and practise, and if you do them in short hops, the worst that can happen is that you have to walk over and pick it up.

Roll, Pitch, Yaw
- FLYING COMES WITH different axes of movement. If you get your UAV to tilt up and down, that's its pitch. Slightly turning it toward the left and right is called controlling its yaw. Then, imagine wiggling your quadcopter; that's its roll. These movements are significant both for what they are able to do and how you need to control them. Pitch the UAV forward and it will go faster, for instance, because the rotors are pushing it along, but you could also pitch it into the ground if you get it wrong.

Know your equipment
- THE WAY YOU control your UAV is not as black and white as you might imagine. Check whether the drone that you have bought comes with auto-levelling controls. If it does, then as soon as you have tilted the UAV in any direction in order to change course or pick up speed, the drone itself will tilt back and get on the level. You are able to switch off auto-levelling when you want greater precision controls. However, it also handles one of the hardest jobs in flying, so it is advisable to keep it on if possible.
I YOU ARE ABLE to buy drones that will lock on to the GPS signal from your phone and basically fly around you like your personal camera crew, however, selfies are great to take because they require precision controls.

Remember that you are remotely controlling the UAV. When you point it at yourself, its left and right are the opposite of yours. Its forward and back are the opposite of yours. Selfies are fun, but they're also brilliant at getting you to practise using flying controls.

Start small
- YOUR QUADCOPTER IS an aircraft and you are in charge of it. The computers in modern drones save you from many difficulties, but they have their own challenges you'll have to learn to handle.

Go out into a garden and place the drone on the ground with the front (where the camera is) facing away from you.

Then, start the motor and gently increase the throttle until the UAV rises off the ground. Just take it a few inches off the ground and hold it there.

Try a selfie
- YOU ARE ABLE to buy drones that will lock on to the GPS signal from your phone and basically fly around you like your personal camera crew. However, selfies are great to take because they require precision controls.

Remember that you are remotely controlling the UAV. When you point it at yourself, its left and right are the opposite of yours. Its forward and back are the opposite of yours. Selfies are fun, but they're also brilliant at getting you to practise using flying controls.

Maintaining your machine
- YOUR QUADCOPTER IS subject to enormous stresses. Each of its rotors is really trying to spin the entire machine and, although having four or more of them cancels that out, it strains the entire airframe. Drones have to be light too, so there are limits to how strong they can be, and if you want to keep your one working well, you need to know how to maintain it.

There are two things you should always do: check the batteries and bring spares. Batteries decline in power over time and if they are not handled well, so get used to having spares when you can and making sure you use them fully. That’s harder in a drone than, say, a mobile phone because leaving them on means leaving the device flying. Do what you can, though, and that includes regular cleaning of the contact pads between the battery and the UAV.

Bring spares of anything you can. There’s little point keeping spare shells or bodies because, if they are damaged in a crash, then the odds are so is everything else. Rotor blades are an essential spare, because you will get through several of those.

It's going to be obvious when a blade has broken off in a crash, but they can also develop cracks. Test for those by feeling across them, and also by flexing the blades between your fingers.

Before you fly, inspect your UAV. Every pilot in the world does a walk-around inspection of their aircraft before flying it; it's considered their responsibility. In your case, you're looking for any damage to the landing gear, or warning LED lights on the flight computer or GPS equipment. You’re also looking for any damage to the gimbal mount that holds the camera; it’s not a lot of use flying a drone if it’s going to drop the camera.

Keep a track of how long you fly the drone for. Again, aircraft and helicopter pilots do this and are required to, but it’s also an important guide for your maintenance. Your battery will be rated for so many uses and, while typically every battery lasts for many more goes than that, the usable flying time you’ll get will decrease.

At regular intervals, such as every ten flights or few weeks, open up the drone and clean inside. See if you can rotate the rotors by hand without any difficulty or feel of the blades catching. Then, when your fingers are clear, fire up the motor and listen for any unusual sounds that could reveal wear and tear.
Not everyone has caught the quadcopter bug yet, but so many people have that you will be able to find someone out there who has answers to your questions. They’ll have them because they’re likely to have been through the issue you’re facing. Groups are brilliant for offering information on the different types of drones and the best ways to use them. You’ll find that there are groups of people online who are interested in very specific machines or uses, such as owners of Phantom products or people who are into shooting location video. There are also groups that are much more general, and people belong to one or more of both sorts.

Note that not all online groups (for any subject) are always welcoming to absolute beginners. Don’t take it personally, though. The majority will be excited to welcome you on board and show you the ropes. Take your time looking into the various groups out there, and get a feel for which one(s) would benefit you. It’s definitely worth joining one, and a good place to try is the Facebook group My First Drone Beginners Group. It’s a private-interest group, so it’s closed, but you just need to request to join it.

Quadcopter users also tend to go outside into the real world. They would, wouldn’t they? It’s the only place to fly. So, while you will find online resources a boon, use them to find out where there are local flying groups.

If there is anything better than hearing from someone about exactly how they use their quadcopter and what problems they’ve solved, it’s seeing them use it in front of you. You’ll improve your flying skills, and get entirely new ideas for what you can use drones for.

Perhaps consider entering your drone into competitions. It’s about pitching your flying technique against other people and also your brand of quadcopter against others. If you have any competitive spirit, you’ll have a blast, but you’ll also see useful results. For example, if a Phantom UAV wins every time, you know to take a look at that company’s models.

There are more organised events in the USA than anywhere else, but you will find that UAVs increasingly feature in more general shows, such as the annual UK Helicopter Show, which runs every May. Check for details of the next one on www.heliexpo.com/sectors/uv.

Those shows and any local groups you can find will also feature demonstrations of new equipment. You can expect knowledgeable advice about legal issues, which is particularly important as you will find that they’re constantly changing.

These groups are also a first-class source for details about buying and selling UAVs. Members will discuss deals they find, and know where you can get spare parts. They’ll also be a boon to you when you want to move up to a new UAV and keep your controller.

So, it’s clear that joining a group can have lots of benefits, but above all, it can be great fun too. Try one out and you’ll see how you will receive all the practical benefits as well as meeting with like-minded people.
### DRONE GLOSSARY

**Accelerometer**: An electronic instrument used for measuring acceleration on a given path.

**Attitude**: If you’re new to flying, don’t mix this up with altitude (height). Attitude is the orientation of the UAV, whether it’s tilting forward or flying upside down.

**Autonomous**: Not subject to outside control, this refers to when a drone is flying by itself on a set path using GPS or other means, rather than actively steered with a controller.

**Bind**: Connecting your controller to your drone. This is like pairing your phone to your earpiece, except it doesn’t normally use Bluetooth of course.

**CAA (Civil Aviation Authority)**: The UK’s body in charge of all flight issues and licences. When you read American forums or books, you’ll see reference to their equivalent, the FAA or Federal Aviation Authority.

**Controller**: The device you use to fly the UAV. They can be exactly the same as old-style helicopter remote controls, or you can use apps on your phone. Without exception, a device is better than using your phone.

**Downdraft**: The force of the wind from the rotor blades when they’re spinning. It’s partly that which gives lift, partly the shape of the blades and how the air flows over them. But it’s an issue when you’re hovering near the ground, because the force reflects up and makes flying trickier.

**FPV (first-person view)**: A way of controlling your drone which lets you see what the drone is seeing in the air in real-time. By using goggles or a display, the view from the drone’s camera is relayed to you. Particularly useful for racing and to get a view from the sky.

**Gimbal**: The type of mount that lets a camera stay steady on a UAV while turning and when in high winds.

**GPS**: The same as the global positioning system used in your satnav, but here how certain drones can know and record their position. Some will act on the GPS coordinates so that, for instance, they don’t fly too far away from you.

**Gyroscope**: You could not fly your UAV straight and steady if it didn’t include a gyroscope that could detect when it was level.

**Lithium Polymer or LiPo**: Currently the best batteries for drones due to their great power given their relatively small size. They do hold more than a regular battery, though, and they do require some care when disposing or recharging.

**Multirotor**: A general name for a drone with several rotor blades.

**Payload**: Anything a UAV is carrying that isn’t needed for flight, which is usually a camera.

**Pitch**: Together with roll and yaw, this is a description of the UAV’s movement in flight. Pitch is when it is tilted up or down.

**Quadcopter**: A four-bladed drone, perhaps the most common basic type, because that number of blades gives more stability.

**Roll**: Together with pitch and yaw, this is a description of the UAV’s movement in flight. Roll is when you wiggle the drone as if you intend to twist it all the way around its central axis.

**UAV (unmanned aerial vehicle)**: This description covers all drones and is what the Civil Aviation Authority calls them.

**Yaw**: Yaw is when the drone is turning slightly left or right.

**4K Video**: The best (and most expensive) drones come with cameras that will shoot video at 4K resolution. They tend to stream back 1K video during flight so that you can see what you’re filming, but they will be recording full strength on board.
ESSENTIAL DRONE ACCESSORIES

Kit your drone out with these must-have accessories

Drones are a fantastic feat of engineering, but there are always improvements to be made. By carefully hand picking accessories, you can improve your drone. Some accessories, like a secure carry case and propeller guards, are ideal for keeping your drone in tip-top shape, while purchasing a crash pack and tool kit can be a godsend when things go wrong.

That isn’t to say drone accessories are boring, as that isn’t true. Things like performance gears can almost double your drone’s maximum speed, while attaching a flight recorder will give you a new way to track what your drone sees while in the air. Use this guide to get all the information you need about some of the must-have drone accessories on the market.

MICROSD CARD

- ANY STANDARD MICROSD card will work in your drone, and turn out to be the most important purchase you could make. Not only are you able to store all the captured footage on to one of these cards, but you’re then free to view the footage on any desktop computer.

DRONE CASE

- YOUR DRONE WORKS hard for you, so make sure it’s protected while you take it on epic adventures. If you need to hike out on location, cover difficult terrain or even pack your drone safely in the car, an ordinary backpack just won’t cut it. Invest in a secure carry case today.
Some apps for piloting drones use location services and work with the UAV's GPS, to warn pilots when they are in restricted airspace, but these only notify the user when they are at the location. This may seem like an odd item but one important aspect of being a responsible drone pilot is knowing where you can and cannot fly. It's handy to have an up-to-date map so you can study the areas you would like to fly in and be aware of any restrictions or know where you may come across real aircraft before you go.

**Batteries**

The last thing you want is to halt your flying time due to an empty battery, so purchasing extra batteries will be necessary if you are an avid user. Depending on the voltage and size of the drone that you use, the cost of an extra battery varies significantly. However, you will find that, once purchased, they are very easy to attach to any drone, and most carry cases will include a separate battery compartment for easy storage and transportation. This is well worth investing in.

**Crash Pack**

Purchasing a crash kit is highly recommended if you want to attempt on-the-spot repairs to your drone. Most kits will come with spare propellers and a battery, while certain retailers enable you to purchase kits with an entirely new body shell. Obviously the latter costs more, but if you're a new drone user, it may soon be a valuable resource. Another plus of purchasing a crash kit is that it will help you learn how to repair your own drone and discover how some of the more intricate parts help keep your drone in the air.

**Proper Gears**

Performance gears can dramatically increase the overall speed of your unit, but without compensating on safety. Some can also be used to help increase the dexterity of the drone while in the air, but these changes are often minor and are only really recommended for those who race their drones. It's important to note that these alternate gears can be tricky to attach at first, due to the intricate nature and how they fit into your drone, so make sure you thoroughly research how to fit them before you begin.

**Tool Kit**

It's a safe bet that at some point, something will go wrong with your drone that's beyond your control. Instead of relying on a third-party service to fix it, use a specifically designed toolkit to get your drone back in action in just a few hours. Most kits ship with your standard Phillips screwdriver that can be used to remove and reassemble the motors on your drone. A Torx screwdriver and circlip tool will also be packaged to help gain access to the navigation board and propellers respectively.

**LED Light Kit**

To make your drone stand out from the crowd, equipping an LED light kit could be a good choice. It's worth paying extra for custom-built lights, as you might find that a basic set won't fit too well. Cheaper sets can also be fairly detrimental to the lifespan of your chosen battery, so a replacement will often have to be carried. Arguably, the best thing about attaching a light kit is that they can be as crazy as you like, but they also have a purpose in making using your drone at night a real possibility.

**Decal Set**

Decal sets come in a variety of sizes and designs. You can find online retailers who supply full-body kits for drones, enabling you to transform the look of your drone in one go. Just like many of the other accessories we've covered here, it's also possible to create your own decal and get it shipped to you. Some companies also offer a decal service, where they'll create, print and apply the decal of your choice to a drone - the only choice you'll make is the design you want.

**Proper Guard**

Proper guards are important for any drone user. They protect you and bystanders from potential propeller accidents, and also help deflect collisions with inanimate objects. They are also helpful if your drone constantly lands on its side, as they can prevent the blades taking heavy damage. Although the cheapest accessory you can buy, propeller guards are by no means the least important when it comes to keeping yourself and your drone safe when in use.

**Aviation Maps**

Some apps for piloting drones use location services and work with the UAV's GPS, to warn pilots when they are in restricted airspace, but these only notify the user when they are at the location. This may seem like an odd item but one important aspect of being a responsible drone pilot is knowing where you can and cannot fly. It's handy to have an up-to-date map so you can study the areas you would like to fly in and be aware of any restrictions or know where you may come across real aircraft before you go.
From fun with the family to aerial photography, drones are not only incredibly versatile but also surprisingly affordable.
As technology advances and prices fall, the demand for consumer drones continues to grow. Drones are available in all shapes and sizes from the tiny, entry-level Nano Drone 3.0 to the high-end, professional DJI Inspire 2.

It can all be a bit confusing, as these remote control or autonomous aircraft go by a variety of names, including UAVs, drones, and quadcopters. These are largely interchangeable, although the term quadcopter refers to the number of rotors.

From as little as £40/$60, you can experience the fun and excitement of owning a drone without breaking the bank. Explore, perform stunts, and even play multiplayer games. You can choose from a range of drones to suit your budget and experience level.

With so many drones on the market, it can be hard to find the right one. We have compiled a guide to introduce you to ten of the coolest drones out there at the moment that will suit everyone from first-timers to filmmakers. Whether you are a complete beginner and want to learn how to fly or an expert pilot looking for a high-end camera drone to take photos and record video, we’ve got you covered.
The drone has 24 computing cores to help it avoid obstacles and fly autonomously.

DJI MAVIC PRO

DJI’S LATEST CAN FIT IN YOUR BACKPACK, BUT HASN’T SACRIFICED ANY OF ITS SPECS

The DJI Mavic Pro is being targeted at adrenaline junkies. Most significantly, it’s portable enough to just stick in your backpack and go. To do this, DJI went back to the drawing board on how a drone should actually work. Instead of space-hogging fixed arms, the Mavic Pro has a set of folding arms and propellers that, thanks to a clever configuration, allow the drone to fold down to the size of a water bottle. The Mavic Pro also appeals to action sports fans because it has a toughened hull that can survive multiple crashes and keep up with their extreme lifestyle. The drone can also fly autonomously and track them while shooting their stunts with its built-in camera. However, while the Mavic Pro may be on the wishlist of every skateboarder and mountain climber, the ‘Pro’ in its name hints that the drone can also compete with DJI’s more professional models, and it can. The quadrocopter has a 12-megapixel camera with its own three-axis gimbal that is equal to that of the DJI Inspire 1 and Phantom 4; it has the same battery life as the Phantom 4, but is a sixth of the size; and has an operating range of seven kilometres, which exceeds either of the older models. But the Mavic Pro costs a lot less than most prosumer drones: it retails for £800/$1,000, where most professional photography drones cost around double that.

INTELLIGENT DESIGN

The Mavic Pro is able to fly itself thanks to a powerful combination of smart sensors and software. In fact, the Mavic Pro has double the sensors it needs, if one goes wrong, the other kicks in to take its place. When you’re flying it, these smart sensors allow the drone to avoid obstacles. When performing stunts on your bike (or skateboard, surfboard, etc), you also set the Mavic Pro to use Intelligent Flight Modes. This feature, that’s also available on the Phantom 4, allows it to effortlessly fly itself in different formations to take different shots. In fact, for the launch of the Mavic Pro, DJI have added two more modes: Tekram Follow and Gesture. For the most part though, you control the quadrocopter yourself. To do this, you can use an app on your phone or for more precision and greater range, the Mavic Pro’s controller. Just like the drone, the controller also has foldable antennas for easy storage. You can also insert your phone into the controller to acts as a view screen, displaying a live feed from the drone and vital stats like battery life.

When launching the Mavic Pro, DJI also announced the DJI Goggles, which is a wireless headset that allows you to view a live, bird’s-eye view from the drone’s camera. At time of writing, DJI hasn’t confirmed a price or release date for the headset.

TOP FEATURES

- The drone’s unique design of folding arms and even folding controller make it highly portable.
- Its 12MP camera is the rival of professional models, complete with a three-axis gimbal.
- A forthcoming headset allows you to view a live feed from the camera in first-person view, ideal for drone racing.
When it comes to your first drone, you have two choices. You could spend as little money as you can and not worry about the drone chasing. These cheaper models are usually made of weak plastics and break easily anyway, and they also won’t control well as the more expensive models and don’t have sensors to avoid obstacles. Your other option is to invest in a drone that is easy to pilot for a better learning experience, but has autonomous modes for when you don’t feel like piloting. DJI hopes you go with the latter and has made the Spark to meet this need. While it is an excellent drone for beginners, there are plenty of things for an experienced pilot to enjoy.

The DJI Spark is the company’s smallest drone but the lack of size doesn’t mean this model is lacking in features. The Spark can reach speeds of 30mph, fly for up to 15 minutes and it can go up to a distance of 100 meters, which for some experienced pilots may seem tame but for beginners, it is plenty. There is a selection of intelligent flight modes. If you want to capture video of yourself, the Spark can follow you from a variety of angles or it will fly around you as you stand still. With hand gestures you can make the Spark take a photo of you, or a ‘droneie’, as some are calling them.

But these cool movements mean nothing if the camera isn’t up to the challenge. The Spark can shoot full HD video and capture images with a 12MP camera. The price reflects these features - at £519/$499, it may be hard to justify it as your first drone but you can look at it as an investment.

LEARN TO FLY

You can pilot the DJI Spark using the provided controller, which has a space to hold your smartphone. For your first few flights you will want to ease into things - there’s no need to worry about hitting obstructions as the Spark can detect upcoming obstacles and avoid crashing into them. If you do hit something, the Spark comes with plastic propeller guards to reduce any possible damage.

If the drone loses signal for any reason or is low on battery, it will return to the point it took off from. The intelligent flight modes can all be activated using the smartphone attached to the flight controller. The DJI app has an intuitive interface so finding the flight type you want can be done in a few taps. All you have to do is watch the camera’s live feed and check it’s coming out how you want - you can take back control at any point.

**TOP FEATURES**

- Autonomous flight modes through the DJI app make filming and taking pictures much easier.
- Smart sensors control lift off and help to prevent any possible crashes.
- Move the drone and give it commands using just hand gestures.

"THERE IS A SELECTION OF INTELLIGENT FLIGHT MODES"
The Parrot Bebop 2 Power builds on the success of the Bebop 2 camera drone by featuring a more durable body, higher quality camera lens and longer flight time. The Bebop 2 Power is one of the most advanced drones that you can buy right now, and is absolutely packed with great gadgets and technology.

Keeping all this tech safe is the new and improved carbon-fibre and Grilamid reinforced case. Weighing just 525 grams, the lightweight and compact design makes the Bebop 2 Power surprisingly portable.

The four motors provide enough power for the Bebop 2 Power to reach speeds of up to 40mph horizontally. It’s incredibly fast and thanks to its rechargeable 3350mAh battery, has an impressive flight time of over half an hour. The drone comes with two extra batteries as an added inclusive of the set, so you can fly for a total of up to an hour.

FLYING ACTION CAMERA
One of the key selling points of the drone is its ability to take pictures and record full high-definition video using the 14-megapixel on-board camera. The front-facing camera has a custom-made wide-angle lens and has been specifically designed to produce stabilised, wide-angle shots. The Parrot drone comes bundled with their Skycontroller 2 as well as their FPV headset; the Cockpitglasses 2. Images can be live-streamed to the headset, allowing you to fly the drone while watching through the camera’s view. The two-handed controller features dual-joysticks for unparalleled control. Flying the Bebop 2 Power can also be done with the FreeFlight Pro app available for iOS or Android smartphones and tablets. A powerful on-board computer with a dual-core processor and fast Wi-Fi ensures all the data from the various sensors is instantly relayed back to you through the app, ensuring you remain in complete control. If you prefer to fly by eye, you can use the LED lights on the back of the drone to help you see which direction it’s facing.

If you like to go exploring with your drones, it has palm detection, so you can launch it off your hand from anywhere. With the Follow Me function, the drone can track any object – allowing you to focus on a task while the drone focuses on filming the action.

For those who want to photograph vast landscape, the camera can capture a 360-degree panoramic image.

Available now, the Bebop 2 Power retails for around £629.99/$599.99.
YUNEEC TYPHOON H PLUS

This Six-Rotor Beast Can Take 360-Degree Photos

Yuneec have been making amazing aerial photography drones since before the word ‘drone’ was even in the popular vernacular. Of its many models, the Typhoon line has consistently been one of the best in the business but like every other UAV maker out there, the company has been in the shadow of DJI for the past few years. However, the Typhoon H Plus goes straight for DJI’s jugular.

The first thing you’ll notice about the Typhoon H Plus is that it’s a hexacopter, which means it has six rotors instead of the normal four. What’s more it only needs five to fly – the redundant propeller is for in case of emergencies, so the drone can safely fly back to the home position for repairs. If you think six arms might take up a lot of space, you’ll be happy to hear the arms also fold down for simple storage. The other unique feature of the Typhoon H Plus is that, rather than only panning up and down, the in-built camera’s three-axis gimbal can swivel 360 degrees for maximum scope. The H Plus has upgraded its camera from previous Typhoon models – it can now shoot 4K video at 60FPS and 20MP images, even in low-light situations.

Like the DJI Phantom 4 and 3DR Solo, the Typhoon H Plus also has a range of autonomous features. This includes object avoidance powered by a combination of Intel’s RealSense R200 RealCamera technology, which allows the drone to ‘see’ in 3D, and sonar for added protection in low light and night flights. The Typhoon H can fly itself in a number of preset modes, such as flying a between a series of programmed coordinates, tracking the user and orbiting a single location.

TAG-TEAM FLYING

The Typhoon H is ultimately a prosumer model intended for advanced aerial photography. If you don’t have much experience flying a UAV, it will take you a while to get to grips with Yuneec’s redesigned ST16 ground station controller. While the obstacle avoidance tech will hopefully help you to avoid crashing, the user faces a steep learning curve to master its many switches. The upside of this that once you master it, or if you’re an old pro, you get an unparalleled level of control.

Perhaps because the controls take some work, the Typhoon H also comes with an innovative flight controller. Essentially a smaller, more compact controller, it allows a pilot to operate the drone with simple ‘point-to-fly’ commands that can be executed with just one hand, while a photographer controls the camera separately using the ST16. This ST16 is better suited for manning the camera as it has a built-in digital video downlink that displays a live feed from the drone’s camera in 720p high definition.

The Typhoon H has a flight time of 25 minutes.

The drone’s Wi-Fi controller can display a live feed from over a kilometre away.

“ADVANCED AERIAL PHOTOGRAPHY”

TOP FEATURES

- The Typhoon H’s camera can turn a full 360 degrees for panoramic photo and video.
- 3D computer vision and sonar allow it to avoid obstacles even in low light.
- Fly it as a two-person team for advanced aerial photography.
The DJI Phantom was renowned for offering professional-grade video capabilities and an array of smart features, which put it firmly at the top of the list for any aspiring drone cinematographer.

It improved the range with the Phantom 4 Pro, which was part of a drive to make drones smarter and safer with the addition of autopilot modes and a refined design for more stable flight. If you’re worried it all sounds a bit dull, then don’t be – it’s faster than you would expect!

DJI then improved on this model with the release of the Phantom 4 Pro V2.0 in 2018. The changes don’t warrant a purchase from those who already own a Phantom 4 or Phantom 4 Pro but if you’re new to the range, the newer version is the one to get. Three sets of sensors calculate the drone’s speed and distance from objects to prevent it from hitting obstacles such as trees. The sensors on the Phantom 4 also allow it to manoeuvre around obstacles even when it’s following a pre-set waypoint. The Phantom 4 Pro V2.0 can detect obstacles in five directions thanks to its array of sensors. Amateur pilots can breathe a sigh of relief, as the drone will automatically stop itself colliding with an object, even if the pilot continues to fly it into harm’s way.

Another fancy feature is ActiveTrack, an autopilot mode that makes the drone track and follow you. This, combined with the obstacle avoidance, means that the Phantom 4 Pro can follow you almost anywhere.

The mounted 20MP camera is able to shoot 4K video at 60fps as well as take 4K images. Along with the automated flight modes and obstacle avoidance, shooting professional-looking footage should be stress-free.

FLY FASTER, FOR LONGER

The Phantom 4 Pro V2.0 can reach speeds of 45mph when in S mode, even in winds of up to 10 m/s. The improved Phantom 4 Pro is able to achieve these higher speeds and altitudes thanks to the use of new materials and a more aerodynamic structure, making it lighter than the original Phantom 4 Pro. It’s not just faster either; the Phantom 4 Pro V2.0’s 6000mAh battery provides an extra two minutes of flight time compared to the Phantom 4, boosting it to 30 minutes overall.

Even though the Phantom 4 Pro V2.0 is aimed at the prosumer and professional market, it’s still remarkably easy to fly. A host of flight modes, satellite positioning, and a more stable air frame makes it easier to pilot than ever.

For around £1,590 ($1,500), the DJI Phantom 4 Pro V2.0 is far from cheap. But if you want the very best, look no further.
Most drones built for racing tend to fall short in the looks department, but the Storm SRD 280 has gone for both aesthetics and performance.

Although most expert racers will say that the best drones for racing are not bought, they are made, that doesn’t mean that the ones you can buy are bad and the Storm is an example of this. The SRD 280 has RadioLink AT9S 2.4GHz radio system, Blacksheep Triumph antenna, six-inch propellers, 2000kv motor, 1300mAh battery and weighs 608g with the battery installed.

The Storm has three flight modes: Angle, Horizon and Rate. Each one has their own top speed and different levels of assistance. Angle mode is for beginners, giving auto-level support so flying is simple. Horizon mode enables you to roll and flip but has auto-leveling functions to straighten up after a trick. Rate mode offers no assistance and there are further controls for speed options.

For your first racing drone, you will want one that is easy to repair, because even if you are experienced, the high speeds it can reach simply means you are going to crash it. A lot. The SRD 280’s bonnet opens up, so maintenance or making repairs is simpler.

If you happen to crash the drone while piloting and lose it, the controller has a cool little feature. The drone will send out a signal and as you get closer to it, the controller will detect it and make a beeping noise, helping you to locate it.

On the back of the Storm are LEDs that change colour to indicate whether the motor is locked, unlocked or if the battery level is low. The controller also beeps when battery is low, so you should never unexpectedly run out of power mid-race.

A SAFE FLIGHT
The drone comes with a fixed camera at the front that works well both in light and dark environments with a 90-degree view. If it is FPV flying you’re looking for, the Storm SRD 280 is capable but doesn’t come with goggles, so you would need to invest more for a pair. With a RRP of £385/$499 it may be too expensive for someone who wants to start racing drones as there are cheaper model drones that you can put together yourself. But if you are looking to buy something that can be used out of the box, with a number of flying modes and speeds, and you are willing to commit, then this is a worthy investment.

FOR YOUR FIRST RACING DRONE, YOU WILL WANT ONE THAT IS EASY TO REPAIR.
While professionals might want a giant drone like the Typhoon H, the rest of us need something more portable. When folded, the DJI Mavic Air folds is only 16.8 centimetres long and you can easily fit it into any backpack. But don’t let its compact size fool you into thinking that this drone is a lightweight in terms of what features it offers to the market because it packs enough power to floor the industry’s leaders.

With a range of vision sensors and a 4K camera stabilised by a three-axis mechanical gimbal, the Mavic Air is one of DJI’s most sophisticated drones. It can reach speeds of up to 42.5mph and stay airborne for up to 21 minutes, enabling users to capture true 4K, stabilised, super-smooth footage. DJI’s enhanced Wi-Fi transmission technology means the drone can be controlled from a range of up to 2.5 miles (4km) using a controller so compact that it fits snugly in a pocket. Amazingly, it allows for full HD 1080p/720p video to be streamed straight to the controller’s display over these distances, so you can witness what it sees in startling clarity. Just like the drone itself, the controller can be folded and parts of it can be detached for extra portability.

The Mavic Pro utilises FlightAutonomy 2.0 for a range of purposes. Its built-in sensors can detect obstacles and avoid them accordingly, and it can also hover precisely in certain environments and land almost exactly where it took off, making it hard to lose - which is just as well because it retails at £769/$799.

NEVER MISS A PIXEL
The real beauty of the Mavic Air lies in the quality of the photos and videos that it captures. The device’s integrated high-precision three-axis mechanical stabilisation system makes for smooth video in true 4K at 30fps, slow-motion video in full HD and even 32MP panoramics.

What’s more, you can shoot footage like a pro using SmartCapture. Tell the Mavic Air who it should track and the drone will take care of all the rest, following behind or in front of a subject, circling it as it moves, flying alongside it or just keeping the camera trained on the subject while the drone itself flies almost anywhere. The possibilities are endless and, as you would expect, can make for some truly stunning footage. What more could you ask for?
PARROT MAMBO

ENJOY A BIRD'S-EYE VIEW WHILE YOU SOAR THROUGH THE HOUSE WITH THIS DRONE

Parrot likes to cater to every kind of pilot. Whether you are a beginner or experienced and looking for something to fly around the house for fun or go outside for racing, Parrot's Mambo can do it all.

Today the Parrot Mambo comes in three forms: Fly, Mission and FPV. On its own, the Mambo is a compact and lightweight quadrocopter with two LEDs if you like to fly at night and a camera underneath the body for taking pictures. The drone can reach speeds of up to 18mph for ten minutes, which is good for a model of its price range, and recharging the battery takes only half an hour. It has three piloting settings designed for all skill levels. 'Easy' will limit the speed but keep it stable in the air and the autopilot will assist on any manoeuvres. 'Drift' keeps the Mambo horizontally stable but allows you to make sharp turns. 'Racing', meanwhile, hands all of the controls over to you.

The Parrot Mambo Fly is the basic version of the drone - there are no accessories but you can fly it via Parrot's Freeflight Mini smartphone app. The Mambo Mission comes with the Parrot Flypad controller as well as a cannon and a grabber. The cannon can be loaded with six harmless ball bearings and it can shoot them up to two metres while the grabber can hold onto anything up to 4kg. All of the Mambo's accessories are easily attached to the top of the drone.

THE VIEW FROM THE COCKPIT

The Mambo FPV, as the name suggests, comes with a camera and first-person view (FPV) headset along with the controller. While Parrot’s headset isn't as advanced as DJI's, it is a good entry point as the price is far more affordable. The headset itself is based on the same principle as Google Cardboard or Gear VR and uses your smartphone as its screen, splitting up the feed from the Mambo's FPV camera into two side-by-side streams for each of your eyes. The Parrot Flypad is Wi-Fi enabled, meaning you can fly the Mambo up to 100 metres from the controller.

All of the accessories mentioned are not restricted to their respective models and you can purchase them separately from Parrot’s online store. For example, you could attach the cannon to the Mambo Fly or get the FPV kit for the Mission.

Prices for the Parrot Mambo start from £99/$109 and go up to £199/$179 depending on which version of the drone you're after.

TOP FEATURES

- Fly in first-person view with live video from the drone relayed to a video headset.
- You can switch between three speed modes depending on your skill.
- Its Smart Block system makes changing accessories easy.

"IT IS A GOOD ENTRY POINT"
The Inspire 2 is a premium drone for those looking to film the kind of footage you would expect to see in Hollywood blockbusters. DJI has effectively taken the original Inspire drone and then tweaked it in all the right places to make the absolute best drone for filmmakers.

There are sensors for avoiding obstacles on the top, bottom and front of the drone so you should be able to avert most objects, no matter what direction you are flying in. The Inspire 2 can support two controllers, allowing one person to pilot the drone while another controls the 360-degree gimbal holding the camera. Only one is supplied in the box so you may want to invest in a second controller for capturing the perfect shots, although it comes at a hefty price of £569.

If you are more of the solo filmmaker, there are options to shoot great video footage with just one pilot using the Inspire 2’s Spotlight Pro features. This sets the camera to focus on following a person or object and the pilot only needs to worry about controlling the drone. In this mode the Inspire is still using its sensors for detecting obstacles, so capturing footage should be no problem.

With the Zenmuse X5S attached, the Inspire 2 can shoot 5.2K video at 30fps or 4K at 60fps. But DJI did not just focus on the parts that would make filmmakers happy; the Inspire 2 has also had tweaks made to improve its flying performance. With an impressive maximum speed of 56mph, it can be taken further by going into Sport mode, however all obstacle avoidance software is shut off in this mode, so you may want to only use this when in vast open areas.

It has a dual battery system, allowing it to fly for up to 27 minutes. If one fails, the drone will go into ‘return-to-home’ mode, landing where it took off from.

THE COST OF FILMMAKING
The DJI Inspire 2 does have a very hefty price tag of £3,059 for just the drone, a case and controller. If you want to include the Zenmuse X5S camera, that’s an extra £1,970. To save the footage, you will need to spend £310 for 120GB of CineSSD storage and a further £160 for the CineSSD station to upload footage to your computer. So for a DJI Inspire 2 that can film professional-looking footage, you will be looking to spend around £5,500.
POWERVISION
POWERDOLPHIN

Who said that all drones had to be controlled in the air? PowerVision has shown this definitely isn't the case with their previous model the PowerRay. Unlike the PowerRay, which can submerge and swim around underwater, the PowerDolphin stays on the surface of the water.

Marine Drones at the moment are nowhere near as popular as their airborne counterparts but you may see a few trying to be funded on places like Kickstarter. If companies such as PowerVision can build an audience, then it’s possible more companies may make their own marine drones.

The PowerDolphin's camera is mounted on a dual-joint rotating system so it can change between looking upwards to down, giving it a 215-degree viewing angle. Around the camera lens are four lights to give you a choice in brightness when looking at the camera’s live feed. The brightness level can be controlled through the companion app.

The PowerDolphin has the 12MP still and 4K video camera you would expect from a flying quadcopter. The camera can stream the live feed through the camera to your phone or tablet at 1080p resolution. The drone's battery lasts up to two hours before needing to be recharged. Opening and replacing the battery or SD card has been made simple so you can switch them out and get the drone back in the water quickly.

AUTONOMOUS FISHING
You pilot (or captain) the drone using the provided controller along with a companion app for iOS or Android. This displays a real-time video feed up to 1000 meters away.

For those just wanting to pilot a drone through water the PowerDolphin will suffice but it also has a group of features for fishers. The bait container accessory is connected to the back and releases your bait when you choose, allowing you to be more accurate. You can also connect your fishing hook to the PowerDolphin to catch fish then pilot it back to shore for you to collect. What’s more, if you purchase the PowerSeeker accessory the drone can scan for fish. It can detect fish up to 40 meters (131 feet) away. So if you’re looking to add some new tech to your next fishing trip, perhaps you should try the PowerDolphin.
BUILD YOUR OWN DRONE
This versatile drone can be used for racing, acrobatics or aerial photography. It’s a great way to learn about the hobby.

Three years ago, if you wanted a quadcopter you had to build it. Now there are several companies producing affordable, easy-to-fly multicopters that fly straight out of the box. But that doesn’t mean the days of DIY drones are over. In fact, there has never been a better time to build your own. Drone components have become cheaper and more modular, and the software that controls them is more stable and easier to use than ever before. Even if your ultimate intention is to fly a Parrot ANAFI or a DJI Phantom 4 Pro, there is a lot to be gained from building your own quadcopter first. You’ll end up with a much better understanding of how the different flight systems work together and you’ll have an aircraft that is much more versatile. That gives you a chance to experiment and find out whether you really want a glass-smooth aerial photography platform, or a high-performance racing quad. And a home-built drone is much easier to repair yourself, if you have some crashes along the way.

The steps here will guide you through the process of building a miniquad. This uses the popular ZMR250 frame. All the other components are available from hobbyking.com and hobbyrc.co.uk. It will cost around £300 and take about ten hours to assemble if you’ve never built one before. At the end of it you’ll have a quadcopter that can take HD aerial video, fly at 40mph and stay in the air for over ten minutes on a single battery.

01 Mount the motors

We’re using Emax 1806 brushless motors. These come in clockwise and anti-clockwise flavours, but this only affects the direction of the thread for the ‘prop nut’ that secures the propellor to the top. The actual motors can spin in either direction, but using the opposite thread on the prop nut means that the torque from the motor serves to tighten the nuts in flight. You can just use clockwise threads on all four motors if you like, but make sure you use nyloc nuts instead of the supplied prop nuts, otherwise your propellers will quickly work themselves loose. Mount each motor in the centre of the X-slots, using a dab of Loctite on each screw. Trim and strip the wires so they reach about a third of the way along the frame arm and ‘tin’ the ends with solder.
02 SOLDER THE ESCS

You need one electronic speed controller (ESC) for each motor. These take the low-power control input from the flight controller board and turn this into a high-power output that drives the motor. A quad of this size needs ESCs rated for at least 10 amps, so we have opted for 12A Afro ESCs, which come with the latest SimonK firmware. ESCs come with bullet connectors on the output leads. You can solder corresponding bullet connectors onto your motor leads, but you'll end up with wires that are much too long for a miniquad like this. The neatest solution is to cut the heat-shrink plastic off the ESC, desolder the three motor leads entirely and solder the wires from the motor directly onto the circuit board. Commercial circuit boards use high-temperature solder, which can be tricky to melt using a hobby soldering iron. Melting some extra solder onto the pads helps because the two solder types form an alloy that is easier to melt.

03 POWER DISTRIBUTION SYSTEM

The bottom plate of the frame will carry the power from the battery to each of the four arms. Because the motors draw significant current, you'll need fairly heavy gauge wire. Use 14AWG (American wire gauge) for the battery connector and 18AWG for the ESC connectors. That's about 1.6 and 1mm diameter respectively. All the arms share a common positive and negative connection to the battery, so the simplest way to connect this is to use two small strips of brass or copper mounted in the middle of the frame, with positive on one side and negative on the other. Cut two 15cm lengths of 14AWG wire and solder one to each plate, so that they run to the back of the quad. Solder a male XT60 connector onto these two wires. This will be your battery connector. Now solder four 18AWG wires to each plate, long enough to reach each arm of the quad. You can either solder these to the power leads coming from the ESCs, or desolder the supplied leads and solder yours directly to the circuit board as before. The clearance between the bottom and middle plates of the frame is very small, so make sure your cables cross each other as little as possible. It's a good idea to connect a spare pair of wires to the plus and minus plates, with a connector on the other end, just in case you want to power any other components directly from the main battery in the future.

04 SECURE THE ARMS

Make sure all the exposed electrical connections are insulated with heat-shrink tubing or electrical tape. This is especially important with a carbon fibre frame, since carbon fibre conducts electricity. Feed four 10mm M3 bolts for each of the arms through from the bottom of the frame and add the mid plate. Make sure the power wires are routed properly with none pinched between the arms and the frame, or crossing the bolt holes. Secure the arms with M3 nylon nuts. The three-wire ribbon cables from the ESCs should run over the top of the mid plate. Feed eight 16mm M3 bolts through the remaining holes in the bottom and mid plates. Screw the tubular aluminium standoffs onto these bolts. Don't overtighten the ends, to avoid bending the plates together.
Propellers come in different sizes and pitches. We used 5030 props for a balance of speed and efficiency.

"THE NAZE32 IS AN IDEAL FLIGHT CONTROLLER FOR SMALL QUADS: CHEAP, EASY TO FLY AND SIMPLE TO CONFIGURE"

Keeping it together
- To avoid your nuts and screws from gradually working loose, use a dab of Loctite fluid on each one. Use blue Loctite, because this can be undone later if necessary.

05 THE FLIGHT CONTROLLER
The Naze32 is an ideal flight controller for small quads. It's cheap, easy to fly and simple to configure. If your Naze32 didn't come with headers pre-soldered, your first job is to solder these pins to the connection pads. It's a good idea to plug some connectors to the other end to hold them in place while you do this, since the heat from the soldering iron can soften the plastic that keeps the pins aligned. You can mount the flight controller on the frame using nylon standoffs or just use a self-adhesive foam pad. A triangle on the Naze32 indicates which way is 'forward', but it is actually easier to mount the board with this facing right. This makes it easier to access the micro-USB port for configuring the board later.
THE RADIO RECEIVER

The radio receiver needs 5V and ground to power it, so we can take this from one of the ESCs. Carefully prise the red and brown wires out of the connector and use heat-shrink tubing or a two-pin Dupont connector to insulate them from each other. We have chosen the FrSky V8FR-II radio receiver, which has eight channels. The top row is for ‘signal’, and the ground and 5V connections are all common again, so you can just plug the power wires from the ESC into any channel. The signal wires run from each channel on the receiver to the block of 2x5 pins on the Naze32. Fix the receiver to the frame with a blob of hot glue.

Choosing a transmitter

- The Turnigy 9X (from hobbyking.com) is a great beginners’ controller for your quadcopter and it's easy to upgrade the radio receiver/transmitter unit if you want to improve the range.

Keep spectators behind you during test flights, especially during takeoff and landing.
07 CONNECT THE ESCS
Each of the ESC ribbon cables has an orange wire for 'signal', red for +5V and brown for ground. Plug them into the block of 3x6 pins on the Naze32 with the signal wire on the innermost pin. Motor 1 is back left, 2 is front right, 3 is back left and 4 is front left. The pins for motor 1 are marked on the Naze32 with a dot. The flight controller can handle up to six motors, but we only have four, so two outputs will be unused. The ground and 5V connectors are all common, which means you actually only need to connect these wires from one of the ESCs, which comes in handy for the next step.

09 CONFIGURE CLEANFLIGHT
To configure the Naze32, you’ll need Cleanflight Configurator from www.google.com/chrome/webstore. On the Welcome tab is a link to install the CP210x driver that allows your Mac or PC to talk to the Naze32. Now click the Firmware Flasher tab and select the most recent Naze32 firmware from the drop-down list. Click Load Firmware [Online]. Now connect your Mac or PC to the Naze32 with a micro-USB cable and click Flash Firmware. Once the board has been updated, the software will connect. There are lots of settings you can play with, but the most important is on the Modes tab. Under Angle, click Add Range and drag the sliders until the yellow bar covers the entire range. This ensures your quad always flies in self-levelling mode, which is the easiest for beginners.

08 CAMERA AND BATTERY
Use the rubber damping washers to fix the camera plate to the top plate of the frame. These can come loose in a hard crash, so it’s a good idea to also use wire or string through the centre as a backup. Now you can bolt the top plate to the aluminium standoffs, using M3 bolts. The Mobius ActionCam and 2200mAh 3S LiPo battery are secured to their plates with Velcro straps.

“WASHERS CAN COME LOOSE IN A HARD CRASH, SO USE WIRE OR STRING THROUGH THE CENTRE AS A BACKUP”

10 CHECK THE MOTORS
Gently test the throttle to check the motors spin the right way. Motors 1 and 4 should spin clockwise, 2 and 3 need to spin anticlockwise. If any are wrong, all you need to do is unsolder and swap any two of the black wires from the ESC to the motor to reverse its direction. If you mounted the flight controller facing right, make sure you set the Board Alignment Yaw adjustment to 90°, otherwise the Naze32 will try to fly your quad sideways. Now you can fit the propellers and take it for a test flight!
The accessibility of drones has exploded in recent years. Once solely a military venture, drones, UAVs, quadcopters, or whatever you want to call them, are becoming commonplace. Crucially, various sets of rules and regulations have been put in place in the wake of this public drone explosion. These guidelines vary from region to region, with some countries more strict than others. The Federal Aviation Administration (FAA) controls everything drone in the USA, while the Civil Aviation Authority (CAA) performs the same role in the UK. Both have devised a series of standards that will allow for close regulation but also the flexibility to accommodate future developments. These laws vary depending whether you are flying for fun or for work, the laws we will be talking about are strictly for recreational flying. The FAA came into existence in 1990 and has sanctioned the use of UAVs for firefighting, policing and border control. Recently, due to the boom in consumer availability, it has had to revise its regulations. Normal police officers out on the beat now have the power to arrest anyone who is breaching the rules, allowing the FAA and other governing bodies to extend their legislation significantly. So, what can you do to stay safe and not get into trouble?
Drone Regulations: The Operator

Technology aside for a second, what rules do the operator of a drone need to adhere to? Well, more than you might think. The FAA states that if you would like to fly your own unmanned quadcopter, you must be at least 16 years of age and able to pass a specific aeronautical knowledge test. Only then would you be able to obtain your Certificate of Authorization (COA) and be able to take your new purchase to the skies. The COA currently lasts for two years and will take 60 days to process, but one-time certificates are also available for what the FAA describes as "time-sensitive emergency missions" such as disaster relief. 609 COAs were issued in 2014 compared to only 146 in 2009, so more and more people are becoming interested in what is a fast-growing pastime. Naturally, when in control, you must always avoid any other aircraft and stop as soon as you become a hazard to people or property. And for any showboaters out there, piloting two UAVs at a time is strictly prohibited. Otherwise, you can only pilot your drone up to 120 metres (400 feet) high and no faster than 160 kilometres (100 miles) per hour. Depending on where you live, you’ll have to be very aware of the limitations on where and when you can fly. It is currently illegal to fly UAVs within 8 kilometres (5 miles) of any airport in the USA, and over national parks and military reservations. These rules prevent the use of drones in many cities, especially the largest ones which have more than one airport. This has proven to be an essential rule, as a survey undertaken by The Washington Post between 2012 and 2014 found 15 cases where drones were caught dangerously close to other forms of aviation. In Britain, the emphasis on the operator is even stronger. In 2017 the CAA introduced new safety rules that stated that every UAV pilot must have to sit a safety awareness test. Failure to comply with the CAA could lead to serious criminal prosecution.

Drone Regulations: The Machine

UAVs come in all shapes and sizes, so regulations need to be flexible so they can represent all drones in airspace. Safety is the primary goal of all aviation organisations, but the guidelines need to be effective and workable, too. The new rules take the rise of commercial drones into account and now allow the free flight of any drone up to 20kg (44lb) in weight. These rules were created by the FAA, whose spokesperson declared them “probably the most flexible regime for unmanned aircraft 55 pounds or less that exists anywhere in the world”. In the UK, the CAA understands that a wide range of tools and agencies are available to repair broken drones and requests that all UAVs be undamaged when airborne. Flying at night is also against the law and "line of sight" is taken as 500m (1,640ft) horizontally and 122m (400ft) vertically. As you can see, there are still some practical issues that stop drones from taking off, but all these regulations don’t stop UAVs being incredibly useful machines. As well as having a bit of fun, they can be used for serious measures. It is hoped that small quadcopters can help spread pesticides and water crops in tricky-to-reach areas, as well as helping out with mountain rescue and other surveillance roles such as checking the numbers of endangered species.
No matter how skilled you are, there’s always a chance of losing your drone when in flight. This is especially so in high winds or heavy rain, as this will only damage the drone and potentially things around it. To improve drone control, a number of clubs have been set up for pilots to meet to discuss their UAV and learn from each other. Several of these societies also provide official training lessons to help you control your drone more effectively. It’s definitely worth having your skills as backup if your quadcopter’s GPS, compass or altitude control decides to stop working! Another place that drone owners meet is the annual UK Drone Show. Showcasing the best in UK UAVs, the latest drone technology is on display and the show concludes in an awards ceremony. This is the place to be for anyone who needs hints and tips in understanding drone flight and operation.

As with almost every new gizmo, worldwide firms are seizing the opportunity to jump on the drone bandwagon. Just look at Amazon who is close to introducing the drone delivery system, Amazon Prime Air. But what about the small time entrepreneur who’s looking to get some extra business with a little advertorial on their quadcopter? Well, the CAA states in its official guidelines that for any commercial activity you must get the correct permission. If you don’t you could face prosecution. So make sure you take the correct measures if you want to give your new business venture a much-needed advertorial boost!

Restaurant chain TGI Fridays got into hot water when a UAV owned by the firm crashed into a diner, cutting her nose open. Meant to be a Christmas publicity stunt, it got the company into big legal trouble and demonstrates the danger of drones — as well as the importance of knowing what you can do — and that mistakes do happen.

Modern drones utilise VTOL (Vertical-Take-Off-and-Landing) systems, allowing them to take off from almost anywhere. This has made enforcing laws much trickier as UAVs can now go wherever they want, whenever they want.
Enrique Iglesias fractured his hand during a performance after attempting to grab a drone.

Privacy is usually a thorny issue but even more so with quadcopters. The majority of drones contain some sort of camera or recording equipment so expect this to be a recurring issue, especially in areas where one can expect reasonable expectations of privacy. Most of it is common sense but expect legislation to get even tougher on this topic if it is not adhered to.

Taking pictures of military locations is a big no-no, as is filming sports events or music concerts. It can also be dangerous, as popstar Enrique Iglesias found out the hard way after he grabbed a drone during one of his concerts, slicing his fingers open.

The operator of the drone is legally responsible for every flight.

Every UAV must be in accordance with the supplier’s user manual and be undamaged when in flight.

Every UAV must be kept in the operator’s sight at all times.

You must not endanger people or property.

It is illegal to fly over airports and congested areas.

You must not fly within 45 metres (150 feet) of a person or building.

Images taken by a UAV can breach privacy laws.

Any UAV must be registered by the country’s governing body to be able to take flight.

Unmanned aircraft must weigh less than 44 lbs. (20 kg).

Maximum airspeed of 100 mph (87 knots).

Maximum altitude of 122 metres (400 feet) above ground level.

What can we expect in the years to come? With the anticipated pressure from the largest companies around the globe, it is likely that commercial and advertising laws on drones will be relaxed. There is also likely to be a greater difference between the laws in rural and urban areas and sparsely and densely populated areas. After all, there are different risks in inner-city London than there are in the Scottish Highlands. Back in March, a US Senator in Oklahoma proposed a bill that would allow for property owners to capture or shoot down drones that are caught flying over their property. The company DroneShield has developed technology for detecting and countering drones. Their DroneGun provides a safe countermeasure by shooting electromagnetic noise up to 2 kilometres away. This interrupts the radio signal being sent from the controller to the drone and causes it to descend safely or return to where it took off from. DroneShield equipment has been used at a number of events such as the 2018 Commonwealth Games and the Boston Marathon, and it could be used in future events.

For more information visit www.knowbeforeyoufly.org
Get inspired and find out what your drone is really capable of. Whether it’s racing or exploring, there’s so much you can do with your drone...

58 Flying for fun
Master the basics of flying, teach others and get the whole family involved

64 Photographing & filming
Learn how to create professional-looking videos and photos with your drone

70 Explore with your drone
Get a whole new perspective and explore the world like never before

76 Getting started with FPV
Upgrade to first-person view and fly your drone in style

82 Racing with drones
Supercharge your drone and battle it out to find out who’s the fastest
Many people see modern drones as something mainly used by filmmakers and hard-core technology geeks. UAVs can be seen as elitist, hard to fly and needing considerable technical skills as well as exceptional hand-eye coordination. In fact, the technology in modern UAVs means that radio-controlled flying is easier and more accessible than ever before. If you’re thinking of investing in a quadcopter of your own, but worry that it may be just a fad and will soon be forgotten at the back of the spare room, here are a few ideas on fun things to do with a drone that anyone can try, which will stop you becoming bored with your UAV.

**ALL THE FAMILY CAN FLY**

Until recently, the best you could expect from any radio-controlled flying device was a scale model helicopter. These could prove almost as difficult to fly as a full-sized helicopter, but without the benefit of the reference points and perspective of actually sitting at the controls. So, while you could possibly manage as the machine was flying away from you, as soon as you bank around to return, everything is reversed and they become even harder to fly. Add in the fact that they have no computer stabilisation, and you will spend a frustrating amount of time crashing and repairing.

**FLYING FOR FUN**

USE YOUR DRONE TO LET LOOSE AND HAVE FUN WITH FRIENDS AND FAMILY WHEREVER YOU ARE
Modern UAVs are a lot different. They have multiple rotors, meaning that there is no requirement for a tricky tail rotor to counteract engine torque. Many of them come equipped with first-person-view cameras that actually put you aboard the machine. Plus, most vital of all, they have incredibly complex stability control systems, which give them the ability to hover at a single point in space without the continuous inputs you would normally need in a conventional scale model helicopter.

What this means is that almost anyone can fly a modern drone, opening up the opportunities to share the fun on a wider scale than ever before. Everyone from the smallest youngsters right through to your most senior family members can try operating the drone without worrying about major damage. You can have a great day of family fun with a drone-flying competition that will challenge your family to find the greatest drone pilot. And while at first you may need to teach your children how to fly a UAV, frustratingly, it won’t be very long at all before they’re the ones doing the teaching as you ask them how they actually did that stunning drone move you just witnessed.

We’re going to outline some great exercises for all the family to try. They’re really good ways
FLYING FOR FUN

GPS mode gives maximum protection and makes sure your drone will return to base.

First, use GPS mode for maximum protection and so it returns to base. Remember, there is no gentle take-off option. This is deliberate in order to take the drone to a safe hover height. Don't try to hover close to the ground; it simply makes it harder than is needed at first. Always fly with the propeller guards fitted, especially if everyone else in the family is looking on.

Start with ‘tail in’ moves. By this we mean that the drone’s nose is facing away from you. This makes everything easier, as your left is the drone’s left and so forth. Have a contest to hold the steadiest tail in hover, then have a series of practice landings.

Build on this with ‘side on’ manoeuvres where you get everyone to fly the drone by looking at it side on. Ensure nobody turns sideways to match the drone’s orientation. That way everyone can develop the skills needed to operate it from any angle. Fly with a nose-in hover. This will sort out the winners, as that can be the hardest to master mentally.

They have incredibly complex stability control systems, which give them the ability to hover at a single point.

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“MOST PEOPLE WITHIN THE INDUSTRY PREDICT THAT WITHIN THE NEXT DECADE, A HUGE NUMBER OF PEOPLE WILL BECOME DRONE OWNERS”

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BECOME A DRONE COLLECTOR

If the UAV-flying passion grips you early on, you’ll soon find that owning just one quadcopter isn’t enough. As you become more accomplished and your skills grow, you’ll soon be casting your eyes around for additional drones. This is where it can become addictive because, while the technology has become more mature in the last few years, it’s still a rapidly developing science. Most people within the industry predict that, just like the explosion in mobile-phone ownership, within the next decade a huge number of people will become drone owners.

There are several ways to expand your drone collection; here are our favourite ideas on how to develop your UAV army.

First, look at the areas you’re not currently active in drone flying, and think of acquiring specialist drones for each task, then learn to become as accomplished as possible in that discipline. Some drone are made, not with practical innovation in mind but with unique aesthetics, such as Propel’s Star Wars range that are modelled alter vehicles from the films. Consider buying drones at different price points for different projects.

For example, there are many drones at very low purchase figures that could almost be considered disposable. In the filmmaking industry, they’re referred to as ‘suicide cameras’, as they’re genuinely not expected to survive. As long as any camera footage can be recovered, that’s what matters. While you may
not wish to harm your faithful drones in such a brutal way, having drones like that will give you the confidence to experiment with sending your quadcopter into areas that you may well not wish to risk your more expensive drone.

If competition is something that excites you, racing drones is a rapidly growing sport. You will definitely need to add to your drone collection for this one, and you will certainly be building some elements of this yourself.

**BE INVOLVED IN DRONE DEVELOPMENT**

You may well become fascinated in the technology behind drones and want to know more. While you can learn a significant amount by building your own drone from a kit, there is a limit to how much you can actually learn from existing technology. New drones are arriving all the time, and you can be involved in their development.

Many fresh drone projects are launched through Kickstarter and other crowd-funding platforms, so this is a great place to get the heads-up on what could be the next cutting-edge advancement in UAV development. To compete with industry giants like DJI, many fresh startup drone companies are looking to crowd-funding platforms to generate enough resources to get their project moving.

**INSIDE DRONE CROWD-FUNDING**

**HOW CROWD FUNDING WORKS AND WHAT TO LOOK FOR**

Many drone projects are crowd-funded. The cutting-edge, global technology lends itself to this method perfectly. If you wish to speculate on a UAV project like this, do it through recognised sources, such as Kickstarter or IndieGogo. They verify that the projects that exist are worth supporting. Most projects offer perks for supporting them, such as special editions or early delivery.

The idea is that, instead of trying to convince one big financial institution to give all the money, they ask lots of people across the world to loan small amounts each. When the project is successful, everyone gets their pledge returned to them in the form of the final product. It pays to read up on each project and check the protections that are on offer from each platform.

- **If you don't want to buy a drone like this DJI Inspire 2, you could make your own**

- **Choosing a large open space will allow you to practise without the risk of crashing into objects or people**
TEACH THE FAMILY TO FLY
MODERN DRONES ARE THE MOST STABLE THEY HAVE EVER BEEN

Modern UAVs have sophisticated software and stability controls that make them extremely easy and stable to fly. You can have great fun teaching everyone in the family to fly a quadcopter, but here are our important tips on how to do it safely:

- Always fly with the prop guards on and stay more than a few metres away.
- Fly with GPS mode enabled and allow the technology to help beginners to fly.
- Fly at no more than walking pace until everyone involved becomes confident.
- Remember, less is more. Make drone movements smooth and slow for the best results.

With many youngsters using drones, the next generation is going to grow up with them.

As well as being great fun, drones can also be commercially beneficial when selling properties, for example.
Crowd funding can be difficult to understand sometimes, so it pays to do some research. Often, the developers are only looking for small sums of money from each ‘backer’. In return for an up-front pledge of funding, you receive one of the very first UAVs when the design comes to fruition. Several leading filmmakers are actively involved in supporting crowd funding drone projects, so it pays to study what their views are. Filmmakers such as Philip Bloom have backed several successful crowd-sourcing UAV ventures, so it’s worth reading his blog on what it takes to see a successful project through to production.

The Nano Drone 3.0 drone, for example, started as a crowd-funding project, and has now shipped thousands of drones around the world. Being involved in a crowd-funding drone project can be an exciting way to feel involved in the development and birth of a new UAV. Look carefully at the small print of each project before committing funds. You will learn an awful lot, not just about quadcopter technology, but also about the stresses of bringing a new product to market and watching the developers strive to be successful. When you receive your first crowd-funded drone, you’ll justifiably feel proud of the fact that not only do you own the latest in drone technology, but you helped start a new business and launch a fresh product into the world.

**BECOME A UAV AEROBATIC PILOT**

As your drone skills reach a high standard, you’ll want to push the envelope of what’s possible. Just like pilots of full-scale aviation, the limits can be exciting places to be. Welcome to drone aerobatics. Many of the moves achievable by aerobatic or acrobatic drones are similar to conventional aircraft. The best way to learn drone aerobatics is to research online for how-to videos. There are experts able to give video walkthroughs of each manoeuvre to help get started. Obvious moves like loops and rolls are within reach of many of the smaller, agile drones. But once you’ve mastered these, it becomes obvious that a quadcopter is capable of far more than this. Acrobatic drones are fast-moving, aerial gymnasts able to undertake moves such as backflips on the spot, upside-down flying and many, many other moves. If an acro-drone is for you, there are specialist drones currently in development that will achieve ever more stunning moves. At some point, perhaps we’ll add smoke to them and start the very first formation drone air show team. Now that would be a project worth supporting.

"WHEN YOU RECEIVE YOUR FIRST CROWD-FUNDED DRONE, YOU’LL FEEL PROUD THAT YOU HELPED START A NEW BUSINESS AND LAUNCH A FRESH PRODUCT"
Drone filming is big news on television right now. Almost every time you sit down to watch, there will be some great sequences showing buildings and places in a way we've never seen before. Many of us would love to try our hand at drone photography and filming, but don't know where to start. So here's our guide to getting started, along with some tips on what to watch for and how to avoid the pitfalls.

CHOOSING A SUITABLE DRONE FOR PHOTOS & FILMING
Drone and camera technology is advancing all the time. There's nothing more frustrating than spending money on a quadcopter and camera that just a few weeks later is replaced by a better model. But quadcopter technology at a price point that's affordable has now matured into a stable platform that is very reliable. Today, there are a number of affordable model UAVs that have cameras capable of shooting in 4K built into them. A filming UAV that allows you to change the camera and the gimbal are harder to come by but they offer more flexibility in shooting.

GoPro cameras were widely known as being the best action cameras to have and for a while it was commonly used by a number of different companies along with their drones as it made a natural fit. Manufacturers would just make gimbals that could house various model GoPros instead of making their own onboard cameras. This has changed in more recent years as the cost for drone companies to make their own cameras has gone down. DJI for example used GoPros on their original Phantom UAV but all follow-up models have instead had their own camera built onto the drone. To try keep a foot in the market, in 2016 GoPro made the natural decision to make their own UAV, the Karma. This included a neat feature where one person could pilot the drone...
LEARNING TO FLY FOR PHOTOGRAPHY AND FILM MAKING

Our number one rule for creating great films from a UAV is really simple: stop thinking about it as a drone and simply think of it as a rock-solid camera without a tripod that can be placed at almost any point of your choosing and moved as if by an invisible hand. At first, there will be some novelty value in seeing your footage from an elevated view, yet, while this is a great feature, it soon wears off. Begin thinking about composition and planning shots from all angles and your skills will quickly move forwards.

UAVs can create great looking film footage even at ground level. Their ability to move in between objects and across scenery as if being operated by the smoothest walking cameraman ever is what makes them so good. So don't just think about high viewpoints.
PHOTOGRAPHING & FILMING

look at how you can fly your drone camera in between archways and trees to create great looking films.

If you only want to shoot still photographs it’s a relatively straightforward skill to learn. Once you’ve mastered your quadcopter flying skills, it’s simply a matter of achieving a composition that you’re happy with and hitting the shutter button. But by just taking still photographs, you’re missing out on the coolest, most creative part of aerial filming – shooting those great, super smooth camera moves. Here’s how you get started.

HOW TO CREATE THOSE SUPER COOL HOLLYWOOD CAMERA MOVES

Chances are that if you’re new to flying a quadcopter, you’re focusing zooming and diving around your patch of sky like a swallow chasing insects. But to create those professional looking aerial drone shots, the mantra is ‘less is more’. Get used to the idea that your UAV movement needs to be a gentle one and that your camera gimbal moves need to be the same; slow and gentle. Start off by practising a simple move past an object such as a car or a building, with the camera set at an angle of 45 degrees to the subject. Don’t even move the camera gimbal, simply roll the camera, then gently ‘walk’ your drone past the object, so that it appears in shot, then steadily moves out of shot as you pass it by. Try this on a large building or something with several objects, such as a row of parked cars. Play it back and just look at how cool such a simple technique can be on camera with a little practice. You see? Less is more. This is called a tracking shot. Now to add in some camera moves.

Once you’re proficient with simple tracking shots, set your drone into a hover somewhere and practise panning and tilting. Panning is swivelling the camera horizontally, just as you would if turning your head to follow a passing car. The drone stays still, the gimbal moves the camera. Pans can be different speeds, from gentle moves as if you were admiring a beautiful landscape right through to ‘whip pans’ which is the type of camera move you’ll see in motorsport when a high speed car flashes past a camera at close range. Try to experiment with different speeds of panning and you’ll see that smooth, gentle pans work best with UAVs.

Now try a tilt. Tilt is taking the camera pointing at the horizon and slowly rotating it downwards, just as you would if you walked to a cliff edge and looked over it. Tilts can start looking out horizontally then smoothly look down. Or you can start looking vertically downwards, before tilting upwards to show the subject. This second shot is called a ‘reveal’ and is the type of move that the Hollywood camera operators use all the time. But you can do the same thing with your drone.

Once you’ve practised these moves, it’s time to bring everything together with combinations of UAV tracking movements with gimbal pans and tilts to create rock solid camera moves that you’d think had been shot from a helicopter. The best way to film a sequence like that is to have a pre-planned idea in your head of what you want the finished sequence to look like. Combining these movements takes practice, but planning in your head where you’re going to fly your drone, when you’re going to move the camera gimbal and where you plan to end can result in some great looking footage.

Once you’re confident with combining drone and camera gimbal moves, it’s time to move on...
Take your drone on holiday
Get some unique photos, but you should go prepared

• Taking drones on holiday with you isn’t as far fetched an idea as you might expect. With drones like the DJI Mavic and Parrot ANAFI having cameras capable of taking good photos and video, while at the same time being incredibly portable, being small enough to fit in most backpacks, why not pack them in a suitcase? Some of these UAVs also have autonomous flying modes that make it so much easy to take photos or video of yourself without a controller in your hand - making your photos look more natural.

A number of companies have developed these modes and will name them differently. DJI named theirs ActiveTrack for example and Parrot calls theirs FreeFlight.

You should only use these modes in wide open areas such as beaches, as you never know what may hit your drone when in busy or tight places. With ActiveTrack you use your smartphone and tap on the person you want to follow. As they walk the drone will either follow at their side, circle around them or staying place as the camera keeps focus.

Before you pack your drone, we recommend that you check up on the laws in the country you are going to visit, the last thing you want is to accidentally break a law you didn’t know existed and have your UAV taken away from you. And if you are travelling by plane, and your drone uses li-ion batteries the batteries should be removed from the drone and taken on as hand luggage. Also, make sure your drone is placed in a hardcase or a study bag; you don’t want to reach your destination to find your drone broken.

• Pack a drone in your luggage for unique holiday snaps

A shot absolutely right, so be prepared to practise and practise some more. The first time you nail a great aerial camera move, you’ll feel a huge smile coming on as you see what you’ve achieved. Next time you’re watching TV, look out for tracking, tilts, pans and reveals in camera moves. You’ll see them employed in every programme you watch – they are the basic tools of any cameraman’s trade.

One final thing about filming; don’t forget to ‘pre-roll’ the camera for around five seconds before you start your move, then hold position for another five seconds with the camera still rolling at the end. This gives what editors call ‘headroom’. It’s that little bit of wiggle room to shuffle a sequence around when editing. Make sure you do this, you’ll thank yourself for it later.

to things like ‘reveals’ and using what is known as the parallax effect. As we mentioned, a ‘reveal’ shot is one that steadily brings into view the main subject. You’re starting with a simple scene, then adding the subject and ‘revealing’ it to the viewer. Some great reveals include running your UAV across an open field, before lifting up your drone and tilting to reveal a magnificent castle.

Finally, one of the trickiest shots to get right is a parallax move. This manoeuvre requires two objects, one in the foreground and one in the background. Fly your UAV past the closest object to reveal the second subject behind it. You’ll see that the addition of the foreground subject adds drama to the shot and makes it look like your drone camera is moving much further than it actually is. Wildlife and nature cameramen use this to reveal one mountain from behind another.

When you’re not flying your camera UAV, a good way to practise is to sit and study television programmes. Drone sequences are frequently used, so watch for them and then try and reverse engineer the shot to work out how it was done and think of locations and situations where you can use those techniques yourself. Filming using drones is an addictive thing and you’ll quickly find yourself mentally planning moves everywhere you go, much to the annoyance of your friends and family.

Above all, don’t be disheartened if you don’t nail the shot right away. It takes professional production companies several ‘takes’ to get a shot absolutely right, so be prepared to practise and practise some more. The first time you nail a great aerial camera move, you’ll feel a huge smile coming on as you see what you’ve achieved. Next time you’re watching TV, look out for tracking, tilts, pans and reveals in camera moves. You’ll see them employed in every programme you watch – they are the basic tools of any cameraman’s trade.

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The DJI Mavic 2 can be fitted with a Hasselblad lens to get some stunning photos.

It’s vital to be able to edit your footage, or at least have a friend who can. Being organised helps. Start by downloading your clips into a separate project folder. Don’t just download everything into your computer’s default photo or video folder. Create a separate folder for the project and name everything there. After this, your editing software will have everything to hand. Once you’re finished, your project can easily be archived to an external hard drive, but if you decide to change something in your edit, everything is still in place and your video editing software will be able to access your clips.

**It’s All in the Edit**

Once you return home with your footage, the work really starts. How do you edit the footage into something that’s coherent and actually good to watch? We don’t have space here for a tutorial on film editing, but there are some techniques to editing aerial footage that are worth considering, especially if you’re starting out learning how to edit your drone footage for the first time.

Rule number one: what’s the story? You don’t need a script or a team of people behind you to create a short film with your drone that tells a story. It doesn’t even need to have actors or action sequences. Your drone can take the viewer on a journey through a scene and reveal the subject in ways they’ve never seen before. Hopefully, as you were shooting you were beginning to see a sequence appearing that you might like to put together that will work well and flow smoothly, while holding your viewer’s attention.

What about sound? The whine of your quadcopter motors just isn’t going to cut it. Good sound is easily 50 per cent of a quality aerial sequence. Decide on sound before you start the edit. There are a great many sources of royalty free music, with Vimeo having a good library of free music or very low licence fees.

**Organising Your Edit**

Learning how to edit can be daunting, so it pays to be organised.

It’s vital to be able to edit your footage, or at least have a friend who can. Being organised helps. Start by downloading your clips into a separate project folder. Don’t just download everything into your computer’s default photo or video folder. Create a separate folder for the project and name everything there. After this, your editing software will have everything to hand. Once you’re finished, your project can easily be archived to an external hard drive, but if you decide to change something in your edit, everything is still in place and your video editing software will be able to access your clips.
Develop a story behind your aerial shooting by planning ahead.

"AS YOU PROGRESS AND BECOME BETTER AT UAV FILMING, YOU'LL START TO PLAN THINGS MORE".

Finding the right soundtrack takes time, but it's worth the effort to find music that fits the pace and context of your film. Stay away from cheesy rock music soundtracks. YouTube is littered with them.

Once you have your music chosen, lay it down on your editing software's timeline and listen to it. Listen for a beat and transitions in the music. Those are the points at which your shots will transition from one to another - on the beat. Your viewers will appreciate being taken on an aerial journey like this when your footage flows with the music. The trick with editing aerial footage is to make your dips fit the beat of the music, not vice versa. Choose a length of only around two minutes and edit your soundtrack to this length. Then start fitting your clips around that. Remember when we talked about pre-rolling the camera before you start a move? Now you'll be glad you did that, as you have excess to trim off and make your job easy. Even so, you'll be surprised at how much footage is needed to hold your viewer's attention even for this short time.

Once you're done, export your movie and upload it to your online account. As well as YouTube, Vimeo is a great free platform for displaying your work, plus it has a community of enthusiastic and creative people who often leave useful comments to help you.

A cool feature coming to newer drones is livestreaming. DJI GO app for example can stream video to services such as Facebook Live, Periscope and YouTube. To make a livestream go more smoothly you should have an idea of what you want to film before you go live to avoid awkward pauses. Livestreaming should become more common in newer model UAVs in the years to come.

Just like learning to fly your drone, aerial filming takes practice. But persevere with it and you'll quickly become accomplished and justifiably proud of your work as you strive to even greater things. It's extremely addictive and very, very satisfying.

BEST KIT TO USE

AVIATION MAPS
This might sound like an odd item to have, but don't forget that you should always fly responsibly. One important aspect of responsible drone operation is knowing where to avoid. Study an aviation map of your area and be aware of prohibited zones and places where you may come into conflict with real aircraft.

BATTERIES
Currently, the longest flight time you will get out of a drone's battery will be around 30 minutes, rather than wait an hour or more for one to recharge go prepared with spares. They're typically easy to switch around, meaning you can land the drone, switch batteries and get back to shooting with little time wasted.

MEMORY AND STORAGE
You'll need lots of storage for your footage, both on location and back at base. Invest in extra memory cards and an external hard drive, otherwise your computer will quickly fill up with chunky aerial footage files and you'll run out of space. Good quality hard drives, such as G Tech, keep your footage safe.
Drones were invented for exploration. From the early Cold War space satellites that photographed our surrounding planets, through bomb disposal robotics to the latest military search and destroy UAVs, we have been sending drones into situations too risky for humans for many years. Drone technology is now accessible to all of us at a price point that we can only have imagined just a few years ago. And while we may not be able to reach up into the stratospheric levels of spy planes, we now have small, ultra-light quadcopters that let us see our immediate surroundings as never before. We take a look at ways to explore your surroundings and discover new viewpoints of the places we've previously only seen from eye level.

**BEST DRONES FOR EXPLORING**

The best drones for investigating new viewpoints are perhaps not the big, half metre diameter octocopters. While they can lift a significant, high resolution camera, there’s little doubt that they’re far more intrusive than their smaller colleagues. Some model of UAVs can generate a significant racket and downdraft, so it pays to give some thought on what type of exploring you may be undertaking. Exactly how you plan to view and record your progress will also need to be considered. If you simply like to take in the view and have a virtual stroll around from a unique perspective, then FPV goggles will give a totally immersive feel to your flight. Fat Shark is the leading drone flight goggle manufacturer. While not cheap, they are high quality with high magnification. DJI also make their own model called the 'Goggles' which can support two pairs for one drone, allowing a spectator to experience what you’re doing.

If you wish to record your exploration for viewing later, a drone with a gyro stabilised camera will be essential. The DJI Phantom 4 Pro and Mavic range come with high quality built-in cameras. If you don’t want to pay for a big-brand drone then there are plenty of cheaper models that can record footage but don’t expect the same quality.

In big, wide open spaces, a ‘standard’ sized quadcopter will be perfectly fine. In fact if it’s a windy day, it’s probably for the best. They have more power giving resistance to winds, plus they have longer endurance enabling you to stay flying and investigating for longer. But as technology advances, we’re seeing more and more nano-drones appearing, plus UAVs with a degree of autonomy.

The Parrot ANAFI, for example, has tiny dimensions yet it has a powerful 4K camera capable of transmitting images back to your iOS or Android device via Wi-Fi. It’s incredibly lightweight (weighing less than 0.3kg) and comes with a carrying case making transporting it convenient. The ANAFI is charged using a USB-C cable so it can be recharged on the go using a portable battery pack or laptop.

DJI’s Mavic series are all ‘self-aware’ drones that are incredibly portable. If you wish to film your own exploration and record yourself as you hike across wide open countryside or climb trees, the drones can focus on you without you needing to be actively involved in flying it. It will fly off, hold position and film you as you explore. And these are easy to start using the DJI GO app - just tap the smartphone and off you go. Perfect for that David Attenborough
Sending your drone exploring can be incredibly informative and gives you an angle on your environment that you’ve never experienced before. But in your enthusiasm, don’t forget several crucial technical, legal and simple common sense elements that are easy to ignore when you’re excited at achieving that first unique viewpoint.

Firstly, the technicalities and legal stuff. Each country has its own rules for drone flying and many of these apply even if you’re flying privately and not as a business. Be sure to obey the rules regarding your UAV’s proximity to other people. For example UK rules state that you should be in control of your drone and it remains a certain distance clear of other people and within your direct sight. If you’re exploring on holiday with your drone, check the regulations in that country.

If you’re sending your drone into an enclosed space, don’t forget that all UAVs depend heavily on GPS for their positional awareness and navigational ability. The Return To Base function will not work if your drone loses its positional fix, so your UAV will panic if the batteries run low and it needs to find somewhere safe to land. Also, don’t forget that most drones are still not self aware. They cannot see obstacles and they rely on you for guidance. We talked to one drone operator who was flying off a coastal pier, exploring the ancient timbers below his feet. His drone panicked about a low battery and activated its return to base function. All was well as it winged its way in a direct line towards the end of the sunny pier, until just a few feet from home it hit the safety railings and bounced into a salty, corrosive ocean. So before you send your UAV on a mission, consider what its escape plan is likely to be if and when things go a bit wrong.

When exploring, be a good neighbour. Don’t forget that not everyone will find the high pitched whine of drone motors and propellers quite so exciting. Many people are worried about invasions of their privacy and indeed some countries, such as France, have quite strict laws on people’s right to privacy, even in a public place. As time passes, people will come to accept drones as just part of everyday life, but as a responsible drone owner you should accommodate other people when out exploring, and always ensure you’re aware of the laws before you start flying.

**WHERE TO EXPLORE**

You won’t need to travel far from home to find some fascinating places to explore with your UAV. Places that you’ve frequently passed by and are considered familiar take on a whole new dimension when you begin to consider approaching them with a quadcopter. Here are our favourite environments for exploration, many of which will be just a short distance from your home.

A great place to practise exploration is a beach or shoreline. If you’re just beginning drone flying, this environment offers a diverse range of things to explore as well as offering you a chance to gradually dip your toes in the water.
Exploring your neighbourhood via drone can be exhilarating, but check that you're not breaking any laws before you start flying.

Take a look around your immediate area on foot. Limit yourself to a one mile radius of your home and make a shortlist of places that would be interesting to explore with a UAV. Once you adopt that open-minded attitude, you'll be amazed at the places that were previously inaccessible that can be viewed and explored with a quadcopter.

Places that you pass by all the time will become interesting once more when you consider the parts of them that you can now access via UAV. Anything from flying off the edge of a multistorey car park to flying up into the tree canopy to watch birds and squirrels in local woodland are all things you've probably seen before, but never from that unique perspective.
Although getting aerial shots like this one is great, bear peoples’ privacy in mind.

GAINING ACCESS TO EXPLORE
NEVER EASY, HERE’S OUR TIPS ON HOW TO GAIN ACCESS AND EXPLORE AREAS IN THE RIGHT WAY

In this modern age, with health and safety being the mantra of every security guard, gaining access to some areas can be difficult, but not impossible. It pays to persevere and try to gain permission to access some areas, but it’s never easy.

Firstly, don’t just try to enter without permission. Not only will you antagonise everyone including security staff, it’s potentially dangerous and illegal. Old buildings are closed off for a reason, generally because there are hazards inside.

On-site staff will rarely be in a position to give permission, so don’t ask. Instead, find out who the owners are and approach them. Give them an upside by offering to document the building for them and ask what its future is. You’re far more likely to be successful if they can see some benefit in it for them.

Choose your locations carefully to get the perfect shot.

and become more adventurous in a progressive way. You can begin by flying safely along the flat, open beach. Start by flying over to piles of driftwood to become confident before venturing into the sand dunes and carefully through the tall grasses. Beach huts and fishing boats in storage are a great subject to fly over and see from a new angle. As your confidence grows, start flying out to places that you genuinely cannot reach. At low tide, many shorelines and estuaries have mud flats. If you’re confident that you’ve set up your return-to-base function accurately, you can fly out across areas that humans would simply sink into and yet you can explore them with ease. Once you become an accomplished shoreline explorer, fly out over the sea and underneath old piers to explore wave tops and the pier superstructure. Why not try hooking up with some local surfers and collaborate by shooting a surf video of them in a way they’ve never been able to before?

If you live miles inland or in a large city, urban areas can sometimes be difficult to explore. Local parks sometimes have restrictions on drone flying at the moment, so instead think outside the box. Consider how your local town might look if explored and filmed at a time of day when few people are around. Okay, so it will mean an early start, but just imagine how you could explore your local area early on a summer’s morning before the rest of the world awakes. If you’re flying away from large groups of people, the chances are that at that time of day you’ll be perfectly legal to fly your drone around your local town before everyone else is awake. Just imagine what local sculptures, monuments and other landmarks will look like when explored by UAV. Even if you think that your local area is not particularly photogenic, don’t be disheartened. You could create a Blade Runner-style video, full of gritty, urban, industrial footage. That area of waste ground can be explored without you becoming covered in grime or twisting your ankle on broken concrete and metal.

For full on urban exploration, try and contact owners of old industrial properties. Disused and derelict industrial property is often awaiting demolition and is a fascinating venue for UAV exploration. Getting permission to fly here is crucial, but also sadly quite difficult. Human nature is such that when asked the question, most employees will say no, simply because they’re worried about the downside of someone getting hurt, either by your UAV or...
EXPLORE WITH YOUR DRONE

EXPLORING WILDLIFE AND NATURE FROM AN AERIAL PERSPECTIVE REQUIRES A LITTLE PLANNING

by you hurting yourself inside the building. Do not annoy security guards by breaking into the property. Instead, use your negotiating skills to explain how they can obtain a unique film of the old building before it is either destroyed or refurbished. Many times, you’ll be told no, but when you’re successful and are given access, you’ll be exploring an old building in ways that the people who lived and worked in it never did.

If you’re lucky enough to have access to a natural environment, you’ll never grow bored of drone exploration. Exploring wildlife and nature from an aerial perspective requires a little planning but is perfectly achievable with most UAVs. Again, consider the places that humans cannot go. We don’t mean the depths of a volcano or flying over an iceberg, but there are sure to be places nearby that you’d love to see. Being able to fly over the edge of a waterfall, then turn around and view it from 50 feet out in the void is a fascinating viewpoint that is great to share with others.

Perhaps surprisingly, wildlife and animals are generally unperturbed by drones. The Royal Society conducted research on bird’s response to drones in their vicinity and over 80 per cent were simply not bothered if you stayed more than four metres away. It’s one of the reasons why wildlife film crews love filming from helicopters. The only time birds showed distress was when approached from above, probably because the UAV took on the appearance of a predator such as a hawk. Stay a respectable distance away and don’t posture your drone as a predator and most animals are quite happy to allow you into their world.

The single biggest thing to consider when drone exploring is to start with a completely clean sheet and an open mind. The areas, landmarks and locations that you have passed by every day for years are actually interesting to explore when using a UAV. You don’t need to be deep in the Arctic or a rainforest to be an explorer – opportunities are all around you.

“EXPLORING WILDLIFE AND NATURE FROM AN AERIAL PERSPECTIVE REQUIRES A LITTLE PLANNING”

BEST DRONE TO USE

PARROT ANAFI
Not only is this drone light and portable, but it has a 4K camera built-in that can tilt up or down 180 degrees allowing you to get creative with filming. It can be charged while out on location, using a USB-C cable and an external power source.

YUNEEC MANTIS Q
This compact drone is small and lightweight, meaning it can stay in the air for over half an hour. A unique feature to this drone is it can be controlled using voice commands such as “start recording” to begin filming or “wake up” to turn it on. It also has the standard controller and app if that is what you prefer.

DJI MAVIC 2
The Mavic is a portable drone, when folded it is about the size of a bottle of water. It is designed with autonomous features to follow you and allow you to explain your surroundings to your viewers. It’s also compatible with DJI’s FPV Goggles but these are bought separately.
GETTING STARTED WITH FPV

First-person view, or FPV, means you see what your drone sees. Instead of just squinting up at your quadcopter from the ground, you can see the live view through the on-board camera, using special goggles or a portable monitor. This lets you fly further, higher and faster without getting disoriented. FPV headsets used to be custom-made devices made exclusively for racing drones by their pilots, today it’s not rare to see goggles advertised as an accessory for some of the biggest drone brands such as DJI. Watching from the ground, it’s all too easy to lose track of which way your drone is facing and whether you need to reverse the stick inputs to make it turn the right way. When you’re flying FPV, left and right never get reversed, because your perspective is the same as your drone’s. Flying FPV is also a lot more immersive. You don’t need to wait until you land to see the aerial footage; you can experience it as you fly. This doesn’t just help frame shots for aerial photography, it makes a whole new kind of flying possible - quadcopter racing.

DIGITAL VS ANALOGUE

Many ready-to-fly UAVs, like the Parrot BeBop and DJI Phantom 4 series, provide high-quality video downlinks that you can watch through an app on your phone or tablet. These use Wi-Fi to transmit the video signal, which requires a special antenna on the control transmitter to be able to reach further than a few tens of metres. But more importantly, Wi-Fi signals experience a slight latency, or lag, in the image that you see on the screen. For framing a shot, or flying fairly
FPV flying doesn’t have to be a single player activity.
The Quanum headset is bulky, but it actually provides a wider field of view than more expensive goggles.

- The view through FPV goggles is always much lower resolution than the HD video your drone records.
- Pointing the video antenna downwards can improve your reception but you need long enough landing legs to avoid squashing it.
- The FPV display shows you some vital information, allowing you to pilot your drone safely and easily.
From this height, your drone might just be a speck in the sky, but FPV lets you stay in full control sedately, this isn’t a problem but for high-speed, low-level flying, especially around obstacles such as buildings and trees, Wi-Fi video isn’t responsive enough. That isn’t a problem for home-built multicopters though, because these almost always use analogue video systems. The picture is sent as a much lower resolution analogue TV signal over 5.8GHz radio frequencies. Although these systems can suffer from ‘snow’ interference and the picture quality is generally worse, it updates virtually instantly. This is ideal for acrobatic flying. Analogue systems are also much cheaper and easier to install yourself.

If you have a simple mini quad, like the one we showed you how to build elsewhere in the book, you can upgrade it for FPV flying for under £110. The Mobius ActionCam can output analogue TV video at the same time as recording its own HD digital video on the memory card. This lets you save weight and money by combining two cameras in one. If you’re already flying with a GoPro camera, it’s better to add a simple front-facing 600TVL (TV lines) board camera, such as the CC1333-B (£23 from www.hobbyrc.co.uk). Whichever camera you use, you will need to connect it to a video transmitter (VTX). We used the 200 milliwatt Aomway mini transmitter, which has plenty of range for park flying. If you need to make up your own cable to connect the two, you can quite easily hack an old mini-USB cable. Ignore the white wire, which you don’t need because it is the audio signal, and connect the yellow wire to the video-in pin on the transmitter, red to +5V and black to ground.

To catch the video signal at the other end, you need a 5.8GHz receiver. FPV goggles such as the FatShark range have a receiver built-in but these goggles cost £200–£300. Until you know for sure that FPV flying is for you, it’s better to start with a separate video

“FOR HIGH-SPEED, LOW-LEVEL FLYING, WI-FI VIDEO JUST ISN’T RESPONSIVE ENOUGH”
replacing both antennas with ‘cloverleaf’ circularly polarised antennas (£10 for two), you will hugely improve your effective range for FPV. This is actually a much better way to improve your range than increasing the power of the transmitter on the quadcopter. The tyranny of the inverse-square law means that doubling the transmitting power only improves your range by about 40 per cent, whereas switching to cloverleaf antennas can double your range without using any more power.

**HEAD-UP DISPLAY**
A more advanced upgrade is to add an on-screen display (OSD). This takes
telemetry from the drone’s flight controller and displays it as text and numbers overlaid over your view through the camera. You can configure what information is displayed on the OSD, from something as simple as just the battery voltage to an entire dashboards’ worth of data, including speed, altitude, heading and artificial horizon. If your quadcopter has a GPS unit fitted, your OSD can also show how far you have travelled and an arrow pointing back to the launch point. This provides a very handy reference point – from 100 metres up, one field looks very much like another! A very popular OSD unit is the £10 Micro MinimOSD. This postage-stamp-sized circuit board plugs into the serial port pins in the centre of the Naze32 flight controller, as well as the video connectors on both the camera and the VTX. The extra data is only added to the transmitted video feed, so the aerial footage that you record on your Mobius or GoPro remains pristine.

Whether you decide to stick with a budget system or to upgrade as far as current technology will allow, flying FPV is a breathtaking experience and definitely something that every drone pilot should try at least once. It isn’t just the closest thing to flying a plane; it’s the closest thing to being a bird.
Drone racing is a 21st century motorsport. A unique and intoxicating combination of PC gaming, gladiatorial motorsport, Hollywood movie effects and, of course, adrenaline. As with any form of competition, the origins of drone racing are unclear. In all probability, it started with a couple of bored guys crashing into each other, then challenging one another to a contest. But just like street racing with cars, drone racing is probably hazardous to bystanders, so recently, drone-racing venues have begun to materialise and, as you’d expect, specialist racing and competition drones are now appearing. It’s not an underground scene anymore, drone racing has exploded in popularity over recent years, so much so that the Drone Racing League’s 2017 Allianz World Championship was broadcast on ESPN and Sky Sports. The global tournaments take place in massive venues such as American football stadiums and abandoned shopping centres, across multiple cities and come with big prizes.

So, what are the appeals of drone racing and how do you get started? Is it expensive or, just like motorsport, is the answer to the question “How much?” the inevitable “How much have you got?” We talked to some drone-racing experts to find out more about this 21st-century phenomenon, and how you can get started with drone racing.

GETTING STARTED

Nearly all drones used for racing have quad rotors. Known as quads, they are lightweight, stripped-down machines in the true motorsport tradition with the absolute bare minimum of equipment. And yes, just like any other form of motorsport, there are varying degrees of machinery, from ‘production’ classes all the way to the Formula One machines of drone combat.

Every drone-racing pilot we spoke to offered the same advice – start with a small, inexpensive drone. For example, the Hubsan X4 is an impressive model of quadcopter that will allow you to practise a range of flight manoeuvres before you move onto a bigger quad down the line. This is very important for three main reasons:

1. Like most sports, the very good guys make it look far, far easier than it really is.
2. You will crash a lot when learning to race a drone.
3. Just like motorsport, crashing a full-size machine is dangerous and expensive.

At the heart of the excitement of all drone racing are the initials FPV. These stand for first-person view, and this is the key to how you will view and experience your drone race. Each drone has an on-board fixed camera, which transmits back a live video signal to your flying goggles. Because the camera is fixed and not gyro stabilised, you experience the full effect of acceleration, and the roll of the horizon as you bank, twist and turn around the course. The view through the goggles can only be described as akin to the Star Wars speeder bike chase in between trees. Inevitably, you will crash your machine. Just try not to jump or flinch too much on your first impact.

Once you’ve mastered flying, it’s time to get competitive and own your first full race drone. You have two options:

Most racing drones have quad rotors, which are lightweight and have minimal equipment.
1. Buy a ready-to-fly (RTF) or almost-ready-to-fly (ARF) quadcopter.
2. Buy parts, such as a frame, motors, props and so on, and build it yourself.

We can’t really say which of these options is better for you. If you like building things, the second option is great. For many people, building the quad is half the fun. The other main advantage of building your own quad is that you’ll have the knowledge and skills to fix it when you crash. As we’ve already said, crashing is inevitable. Get used to it.

ANATOMY OF A RACING QUAD

If you decide to build your own quad racing drone, each one has a series of essential elements that are needed to make it successful. Here’s our guide to the vital things you’ll need to go drone racing.

The frame What would be called the chassis or fuselage were it a car or an aircraft, drone-racing frames are typically all carbon. Two of the most popular are the Blackout Mini H and the Lumenier QAV250. Both retail online at around $150.

Flight controller Most popular, by far, are the Naze32 Acro and the OpenPilot CC3D. You can expect to pay less than $100 for either.

Motors and props You get what you pay for here, just like with full-sized engines. Cobra engines with HQ Props are the premium brands. If you’re on a budget, try Sunny Sky motors with GenFan props. Whichever combination you choose, ensure you order spare props and make sure that you have them to hand. They’re always the first casualties in an accident.

Electronic speed controllers (ESCs) As the name suggests, they control the power output and keep everything running. They’re a bit like an engine-management system.

Battery packs All Lithium Polymer, these are your drone’s fuel tanks. Turnigy Nano-Tech cells are the ones to go for. They employ technology that allows a very high discharge rate. You need this when drone racing, so that when you go for full throttle to accelerate, your engines are getting enough power at a high enough rate. Be very careful when handling these battery packs. Never leave them unattended when charging, and always check them after a crash. It’s been known for crash-damaged packs to burst into flames when subsequently charged.

Flight goggles Fat Shark are the leading brand. Flight goggles are expensive but essential, so look after them. The high magnification screens should always be kept covered when not in use. The magnifying effect of the screens if left in open sunlight can damage them, so always keep them in the protective case.

WHO YOU CAN RACE

There are two main categories for quad drone racing: the Spec Class for beginners and the Open Class for more advanced pilots.

As you’d expect, the Spec Class places restrictions on drone power and prop size to...
Search for local groups on the internet and social media.

This is a new global phenomenon. Each country has its own particular take on it right now, from Australians using disused, dockside warehouses to Scottish drone-race clubs arranging events in the Highlands. It’s not an underground movement, but you won’t find it in the mainstream press. Look online and on social-media platforms to hook up with racers to compete with. We found groups across the world, from Scotland to Australia and across the United States, including Ohio, Los Angeles and Arizona.
Humans love to compete against one another. It’s how we’re wired, and no matter where you go in the world, you’ll find somebody organising a racing series for something. From Formula One cars to snails, we’ll race it. Most competitive sports involve significant costs, but drone racing allows you to feel the full-on adrenaline of competition without massive expense. Perhaps this will change, but we doubt it. Because even the latest technology is relatively inexpensive, drone racing will probably continue to be cost effective for some time to come. It’s in its early stages which, in our view, is the best time to become involved.

How Racing Works
There are several types of competition in which you can get involved. Rotorcross is flat-out, side-by-side drone racing. All you need are two or more pilots to form a grid, then you race in real-time around a pre-set course. The winner, quite simply, is the person who crosses the line first. At the time of writing, first-person-view drone-racing series are rather spread out, but with each passing week, there are new meetings being announced online and on Facebook groups across the world. Drone dragster racing pits two drones against each other in a standing start drag race down a 100 metre track. This is where those high-performance props and that high discharge battery pack really come into their own. Unlike automotive drag racing, many drone dragster races count the time from lift-off to touch down, with no flying finish. Note that we said “touch down”, not crash.

Finally, we have time trial. Just like special stage rallying for drones, you fly individually, against the clock, with the winner holding the fastest stage time. One of the practical things about a time trial is that there are several online communities that allow you to set up your own time trial and then record your efforts using an on-board camera. Upload your video to the time-trial community, and add your score to a global leaderboard. Each month there is a winner announced in the series.

Many people are becoming proactively involved in organising drone racing, as they find more people nearby with similar ambitions. We talked to drone-racing clubs, from the USA to Australia, about what’s needed to organise your own drone-race meet-up:

**A venue** This can be anything from a farmer’s field to an old, underground car park or some woodland. Above all, make sure that you have permission from the landowner to be there and race.
"LIKE ANY COMPETITIVE SPORT IN ITS EARLY STAGES, THINGS ARE ADVANCING VERY QUICKLY"

**Safety** Be organised. Use tape to cordon off pathways where unsuspecting people may stray into the drone-racing area, and be sure to sign-post the area significantly. It's a good idea to post marshals with two-way radios if your course goes out of sight through trees, so that you can be sure the course is clear. With some drones now capable of speeds of 128kph (80mph) or more, they pose a significant hazard. The people at First Person View in the UK have produced flag and banner kits at a low cost to help get grass-roots drone racing off the ground. They're quite happy to help get drone-racing clubs organised.

**Promote your event** With drone-racing forums and Facebook groups in abundance, spreading the word through social media is the best way to promote your drone-racing meeting.

**Risk assessment** Health and safety is a boring subject, but a simple, written risk assessment is a good way to bring to your own attention things that might need to be foreseen. Simply make a list of all of the possible things that could go wrong on a sensible level, and write down solutions for them, or courses of action should they occur. It doesn't need to be a huge document, and you don't need to be a firefighting paramedic, but it's well worth doing, if only to help your event run more smoothly on the day.

Right now is a great time to become involved in drone racing. Like any competitive sport in its early stages, things are advancing very quickly. While some people may think that it's a good idea to sit back and watch before committing time and money, in our view being involved at the beginning of what is almost certain to become a global phenomenon is a far better way. Learning about drone racing by being at the coal face and getting dirty first hand will give you invaluable experience in the technicalities, racecraft and developing winning techniques and strategies that will turn you into a drone-racing champion. You've got to be in it to win it.

**First-Person-View (FPV) Goggles**
Good flight goggles are an expensive but important element of FPV racing. The video feed is projected onto the small screen, but then high-quality magnification gives a stunning, immersive view of your race.

**Lithium Polymer Batteries**
The latest in technology, they allow very rapid discharge rates, which give motors the rate of power they need to accelerate fast. Quads are capable of 128kph (80mph) in forward flight, due to them. They can be temperamental; watch them when charging, and discard crash-damaged packs.

**Cobra Engines**
These are tiny, stepless, 8-volt electric engines, weighing just 22.5g (0.8oz). Not all motors are created equal; read the full specification. Some have high peak power, but lack midrange, while others have lots of torque, or midrange power, which will give stronger acceleration.
Thanks to a drop in manufacturing costs, and rapid advances in technology, drones have flown into many professional and recreational areas in the last few years. In the next few chapters you will discover how drones are being used to help keep firefighters safe, assist rangers in spotting potential poachers, enable news gatherers to report from disaster zones, and keep maps up to date. There are also film makers who are using drones to replace traditional filmmaking equipment, such as the steadicam, as well as enabling them to get shots that would be too dangerous and expensive to capture using a helicopter.

With drone technology (and the surrounding legislation on who can fly what where) changing on a monthly basis, discover how a range of pilots are using drones today in a professional capacity. There’s even an insight from a military drone pilot to hear how drones are being used across the globe in intelligence, surveillance, target acquisition and reconnaissance.

We’ll also discover how drones are being embraced by the non-professionals, with the advent of drone racing and the impending invasion of throw-and-go flying cameras that will follow and film the users. Drones are even becoming stars in their own right, with costumed drones performing in the Drone Orchestra.

Although the term ‘drone’ has been embraced by popular culture to apply to any unmanned flying device, many of the professionals that we interviewed for this book preferred names with a less militaristic connotation, so brace yourself for acronyms such as UAV (unmanned aerial vehicle), UAS (unmanned aerial system), RPA (remotely piloted aircraft), multirotor, hexacopter and octocopter.
10 AMAZING WAYS DRONES ARE BEING USED

See how UAVs are deployed for an incredible range of tasks.

AIDING FARMERS
A drone is a cheap and effective way to survey large areas of farmland. With a multi-band sensor on a drone, farmers can capture images of crop using non-visible light. This enables them to produce information about the growth of the crop, and deploy fertiliser precisely where it’s required. These sensors also reveal crop health, so pesticides can be applied strategically rather than universally.

FORECASTING THE WEATHER
Hurricanes and storms often cause loss of life and damage property, but with advanced warning, the damage can be reduced and lives saved. UAVs, such as AeroVironment’s Global Observer, can keep an eye on developing weather conditions in real-time, and supply remote imagery and storm data to assist with life-saving measures. If terrestrial communications equipment, such as cell towers, microwave relays and satellite downlinks, are damaged, the Global Observer’s communications payload can keep the emergency services connected, so that they can continue planning evacuations and relief operations, and coordinate their first response. The Unmanned Global Observer can fly for up to six days at a height of 55,000 feet, and cover an area 600 miles in diameter.
MONITORING COUNTRY BORDERS

Country borders can be vast areas to patrol using conventional technology, so drones are playing an increasingly large part in this role. The US government now uses fixed-wing Predator class UAVs to scrutinise the Mexican border for illegal traffic. Video is recorded in multiple passes, then the footage is mixed together to spot changes that could indicate the presence of drug smugglers, for example. Agents can then be directed to the appropriate areas.

BRINGING AID

One of the challenges of transporting medical aid in developing countries is the lack of roads. Swoop Aero was chosen to deliver vaccines to parts of the Republic of Vanuatu using drones. Vanuatu is an archipelago in the South Pacific Ocean made up of over 80 islands – and not all have roads or an airfield. Parts of the drones used are made from 3D-printed materials so they are quick to produce if more are needed. They can fly up to 100km and carry around 2.5kg worth of supplies. There are risks – drones can get lost in remote parts and storms can interfere. UNICEF has been in the country acclimating the locals to having unmanned vehicles flying in their villages.

“A FARMER CAN CAPTURE IMAGES OF HIS CROP USING NON-VISIBLE LIGHT”

INSPECTING OIL RIGS

UAVS are the perfect tool to make inspections at oil platforms much safer. Cyberhawk is an aerial inspection company that deploys its drones to perform visual inspections of high-value and high-risk offshore assets. By safely inspecting an active platform’s flare (and the supporting structures) from a drone’s live video feed, they can keep the platform online, saving the client time and money. The client can then pre-order and manufacture parts to upgrade the structure and keep it running smoothly. All of Cyberhawk’s UAV pilots need to have offshore survival and medical certifications before they can operate a drone in an offshore platform environment.
10 amazing ways drones are being used

**SURVEYING ARCHAEOLOGICAL SITES**

As many archaeological sites are in remote locations, drones are a cheap and effective way to reach and survey these locations. Drones enable scientists to get a bird’s-eye view that reveals new information about a site. An md4-200 microdrone UAV was used in Tuketa, in Russia’s Altai Mountains, to survey ancient burial mounds (called Kurgans). This resulted in a 3D map of the site that could be used by scientists to measure the volume of the burial mounds. Professor Ian Lindsay from Purdue University used a DJI Phantom 2 to capture aerial data of burial mounds in Armenia.

**DELIVERING PACKAGES**

As the drone started to become a mainstream product, it didn’t take long for forward-thinking companies to start looking at how they could begin integrating them into their businesses. One of the most obvious angles was as a means of delivering small parcels and packages. The potential in this area is huge, and the prospect of reducing the carbon footprint or delays due to traffic – or even the man hours sending people around the country to deliver items by hand – has got some of the big players looking at rolling a drone delivery service out sooner rather than later. Amazon is currently working on Prime Air to deliver small packages in under 30 minutes, and UPS has started testing their delivery drones that deploy from the top of their van.
MEASURING AIR QUALITY

Instead of payloads, such as video cameras, drones can be made to carry a range of sensors to take meteorological measurements, such as temperature, humidity, air pressure and more. They could also carry and use sensors that will detect poisonous particles in the air, as Fire Chief Andy Cashmore explains: “They could look for fibres and heavy metals in the smoke, and that will include asbestos.” In China, a drone is being tested as part of the war on pollution. A parafoil helps the drone stay aloft as it glides through the smog, spraying chemicals that freeze the pollutants in the air and cause them to fall to the ground.

CREATING ART

Drones have inspired musicians to include them as key components in creative projects. In 2015, British rock band Muse released a concept album entitled Drones, about how “The world is run by Drones utilizing Drones to turn us all into Drones.” During the opening ceremony of the 2018 Winter Olympic Games in Pyeongchang, 1,218 drones took to the sky, lit up and formed the shape of a snowboarder before turning into the Olympic rings. This set the Guinness World Record for most drones used in a performance. The drones were controlled by a team of animators from the company Intel, who created a routine that was sent to the drones to perform autonomously.

RACING

In abandoned warehouses or car parks, pilots race their custom-built multirotor rigs around obstacles. Many use First Person View (FPV) goggles to navigate their drone around the course via its on-board camera, taking skills they’ve honed on their video console into the real world. Craig Jump from Sky View Video has been involved in a consultation with the BBC about developing a drone-racing TV show. He explains: “This is something that’s taken off in the last six months, as low-cost kit came in. At night, they race around the tree trunks in forests in the middle of nowhere.” For more on purchasing indestructible sports drones, visit gameofdrones.com.
HOW DRONES ARE CHANGING THE WORLD

FIGHTING WARS
DISCOVER HOW UAVS ARE USED TO ASSIST THE MILITARY IN THE REALMS OF INFORMATION, SURVEILLANCE, TARGET ACQUISITION AND RECONNAISSANCE (ISTAR)

The commercial and hobbyist unmanned aerial vehicles (UAVs) that are in other chapters of this book can trace their ancestors back to a military source. It was the military who were motivated to research and develop UAV technology, and who had the resources to do so. Part of the rationale for using robots in warfare is exactly the same as the justification for using them in other spheres of activity, namely improving productivity.

The term ‘drone’ has traditionally been used to describe military UAVs. This military connotation has been a concern for some civilian UAV users who we interviewed. Craig Jump from Sky View Video explains: “One of the reasons I don’t like to use the word ‘drone’ is because people think of military aircraft with the hellfire missiles on them.” Jump also found that this military heritage can cause practical problems for civilian UAV users: “The technology is actually classified as dual use, which means it can be used as military technology. So, in certain countries, you need an export licence to take the kit there.”

Despite their military heritage, many of today’s drones are used for peaceful purposes, such as assisting firefighters in their assessment of an ongoing incident, or looking for refugees adrift in the ocean. Indeed, to most of us, drones are something that have only appeared on our cultural radar over the last decade or so, with the appearance of multirotors in the civilian sector.

However, the modern military continue to deploy drones in a range of offensive and defensive capacities. They are also a key driving force towards the ongoing evolution of drone technology. Although drones have been around for decades, recent technological developments have seen some dramatic changes, as Chris Cole from Drone Wars UK explains: “Since 2000, the combination of technological miniaturisation and wireless communication has been a real technological leap forward.”

Currently, most military drones are propeller driven, like their civilian multirotor and fixed-wing cousins, but that is set to change, as Cole

The Boeing Phantom Ray is an American demonstration stealth unmanned combat air vehicle that is currently in development.

The term ‘drone’ has traditionally been used to describe military UAVs.
The Taranis features advanced stealth technologies, propulsion systems and next-generation mission systems.

“IT WAS THE MILITARY WHO WERE MOTIVATED TO RESEARCH AND DEVELOP UAV TECHNOLOGY, AND WHO HAD THE RESOURCES TO DO SO”
The Reaper and Predator drones that we have now are comparable to the biplane. We are quickly heading towards faster, more sophisticated and stealthier drones with a low observable profile."

**THE AUTONOMY DEBATE**

Military robots can be divided into three categories – tele-robotic, semi-autonomous and fully-autonomous. Tele-robotic devices are radio-controlled – they are driven by human operators, albeit at a distance, who have control over every aspect of their operation. Fully autonomous robots, on the other hand, require no human intervention whatsoever. Once they are programmed to carry out their task they will perform their assigned duty using inbuilt artificial intelligence. Semi-autonomous robots fall somewhere in between these two extremes and could encompass a whole range of possible scenarios. In a military context, for example, we could envisage a remotely controlled drone which has an auto-pilot that could be enabled by its remote pilot for routine flying operations, just as a pilot would use the auto-pilot onboard a passenger airliner. Alternatively, a robot fitted with a lethal weapon could act autonomously right up to the point of having targeted the enemy but would require human intervention before it is able to fire. As Cole explains: “The big issue in terms of military drones is autonomous launching of weapons. There is a big campaign to stop that, and a lot of military people are very wary about moving from what they call having a ‘man in the loop’ to autonomy in the launching of weapons.”

One of those men in the loop is Waqas Tariq, a drone pilot for the Nigerian Airforce. He explains the human roles involved in safely controlling an expensive military drone, and its various payloads: “Bigger UAVs are not..."
The Lockheed Martin High Altitude Airship is an untethered, unmanned lighter-than-air vehicle. Military robots are already in service in Afghanistan, Iraq, and Syria as they are the ideal tool for disarming bombs or locating landmines.

The PD-100 Black Hornet is a nano air surveillance vehicle that poses little risk to other vehicles or personnel due to its small size and lightweight. It can fly for up to 25 minutes and navigate via GPS, or be manually controlled with the assistance of video feedback. The Black Hornet can fly for up to 25 minutes and navigate via GPS, or be manually controlled with the assistance of video feedback.

flown by one person. They are actually flown by three people: the mission commander, the pilot who is in control of the drone, and the payload operator who controls the gimbal and cameras. 70 per cent of fixed-wing UAV flying is autonomous, with 30 per cent human involvement. Jobs like recording the whole event and moving the cameras are carried out by humans. And obviously the human is the sole person who fires up a weapon on-board; firing is not done autonomously.

"UAVs are sometimes equipped with weapons, such as Hellfire missiles, which are damaging. Obviously UAVs are only flown with missiles when there is confirmed information about the location of terrorists. We have been using UAVs to survey areas for hours and hours, sometimes even days. We have to identify what kind of people are living in the area, and what kind of people are handling the weapons, then we have a ground crew who confirm (or otherwise) that what we are saying is correct. Later on, after confirming everything, we strike."

This 70 per cent autonomy that Tariq mentions is very important, because it reduces the chances of human error in relation to keeping the drone in the air. Large, fixed-wing military drones can cost millions of dollars, with weapons costing hundreds of thousands of dollars. Chris Cole expands on the advantages of autonomy: "The difficulty is in the communication between the person on the ground and the person in the aircraft. If the aircraft is making decisions in terms of where to fly and how to sense and avoid obstacles then that is safer, because communication between the pilot and the drone can get snagged quite easily, or even deliberately by electronic warfare hackers, for example."

**UAVs in the British Military**

As a member of Drone Wars UK, Cole has been keen to monitor the various types of British military drones, as well as their uses: "In its armoury, the UK has the Black Hornet. This is a very small (five or six-inches long) rotor drone that you can put in your hand. It flies in and out of buildings, and sends a video feed. Then there's a lightweight, fixed-wing drone that soldiers just throw into the air."

The UK has other types of drone in its armoury, as Cole continues: "There's a slightly
larger, fixed-wing drone called the ScanEagle, which flies from ships. The ScanEagle is a prop-driven drone with a ten-foot wingspan that can be catapulted into action.

"Then there's the Watchkeeper, which is a very large drone. It isn't armed, but can fly for a couple of hundred kilometres, and it sends video feedback to the army." As their names suggest, the drones Cole has listed so far are used for surveillance and reconnaissance purposes. Military drone pilot Waqar Tariq explains the advantage of using drones in this field: "The Nigerian Airforce uses the UAV in a much more efficient way, because the fighter jets are not able to fly for longer periods of time – they can fly for a maximum of up to one and a half hours. But the UAVs can fly for 16 hours, so there is a huge difference." Drones with more offensive capabilities are given more dramatic names, such as the Reaper. Cole tells us: "The Reaper is the armed drone for the RAF. The UK has ten of those in service. Each Reaper can carry a payload of Hellfire missiles and GBU12 bombs."

PILOT TRAINING

Regardless of whether a military drone has a payload of data acquiring sensors or weapons, its operators require intensive training. Tariq explains: "We use a medium-sized, fixed-wing UAV to teach our new pilots how to 'touch and go' – to take off, stay in the pattern and then land. They learn how to fly in the aerodrome, discover what to take care of when coming in for landing approaches, and other things like that." As you would expect, learning how to pilot UAVs is a challenging task: "Starting off, I had 15 students who were airforce officers, and only nine of them made it to the final to become qualified pilots. There are a lot of situations that we make them go through."

Military drones have been around for decades and, with the ongoing march of technology, they’ll be around for decades more, but with stealth drones like the Taranis demonstrator, you might not see them coming. That’s why people like Chris Cole feel compelled to keep asking questions: "Some people in the military accept the need for scrutiny, and think that it’s a very democratic thing. It’s right that there are organisations like ourselves [Drone Wars UK] who are pushing people on this, as there are moral and ethical questions to ask. But, yes, some people feel we are just there to make their lives difficult. So it can be difficult, but it’s an important thing to do."
Although UAV technology enables the military to fight an enemy at a safe distance, this does raise several important issues, as Chris Cole from Drone Wars UK explains: “One of the restraints on military intervention overseas is the human and political cost of sending young men and women overseas, only for them to come back in body bags. However, if you take that cost away, then it makes it much easier to choose military intervention, because it’s perceived as being low-cost and quicker. Rather than seeking a slow, diplomatic, political solution, there is a concern that the use of these remote systems is actually lowering the threshold for war, making it much easier to get involved in military intervention overseas.

“And we’re already seeing that drones are being used in lots of areas. There have been seven countries so far in which drones have launched strikes. Most of those will be US strikes in places like Pakistan, Yemen and Somalia. The UK has also used drones in Afghanistan and is now involved in Iraq. And drones are flying in Syria. So, there is a concern for the wider aspect of getting involved in military conflicts.”

As well as making it easier for a country to slip into a war, there is the possibility that drones can make it easier for combatants to pull the trigger, as Chris Cole explains: “There is the question of whether drones are lowering the threshold of violence in terms of what’s called the ‘PlayStation mentality’. This is a phrase from the UN special reporter Phillip Alston, who stated that rather than seeing flesh and blood, drone pilots were just seeing pixels on the screen. Now the military very much dislikes and challenges this notion. It says that its pilots are professionals and very much understand the difference between playing a videogame and being in a combat situation in which people are going to die.

“There was an incident in 2011 in which a number of civilians were killed. Because so many civilians lost their lives, the US military investigated it. In their own military language they said that the crew had a ‘propensity towards kinetic operations’. The crew were bored; they wanted something to happen on this mission, and while there was evidence that this particular convoy of vehicles had children and civilians in it, they downplayed or ignored those warnings because they wanted a strike to go ahead. That’s the only example, and we’d need much more evidence. I think there are two questions to ask: Do drones make it too easy to get involved in military action? And, once you’re involved, does this kind of distancing (psychological as well as geographical distancing) make it easier to opt for violence?”

Proponents of using drones in combat may claim that they are an accurate and effective tool at targeting the enemy, but Chris also questions the issue of accuracy: “There are no public figures on the accuracy of these systems, I don’t think there’s any question that weapons are far more precise than they used to be 20 or 30 years ago, but how accurate they are on any given launch is difficult to know. That’s one of the things that we [Drone Wars UK] really push for – much more evidence about accuracy, but it isn’t forthcoming.”
Drones enabled SkyVue Media to see the bigger picture of this off-road track day event for the G4 Challenge group
Making Films
Discover How Drones Are Changing the Way Filmmakers (And Even Their Clients) Approach a Shoot

For decades, filmmakers have enjoyed incorporating technological advances into the way that they work. In the Seventies, the advent of the steadicam rig enabled filmmakers to produce floating shots using a handheld camera.

Long, uninterrupted shots that followed actors as they walked and talked became part of everyday film language thanks to this technology. With the development of drones, filmmakers are discovering more ways to capture distinctive footage for a wide range of film, TV and corporate productions. Indeed, there are now many film-production companies who specialise in drone-based film production, such is the demand for affordable aerial filmography by the industry.

While planning a TV commercial, energy company EDF wanted to show the journey of various energy assets in the UK in a single shot. They tasked UK-based SkyVue Media with the job of capturing drone-sourced aerial footage that would blend seamlessly with handheld steadicam footage on the ground, as SkyVue's Managing Director Dan Shields explains: "That was quite tricky because the shot starts over the back of a house pointing down, and then we tilt up to reveal the horizon. We then pull back over the house, come down the front of it, and zoom right in on an EDF energy van. From there, the steadicam shot takes over, travels down the van, and then we pick up the shot at the other end with the drone, and take it back up and out to the bird's-eye view. They want a seamless transition, so that's what we were aiming for. It's a tricky shot to pull off."

To get the multirotor's footage to line up with the steadicam footage was a challenge, so it took SkyVue's crew a day to get the two aerial shots that would book-end the steadicam tracking shot.

Traditionally, a crane-like rig known as a jib has been used to lift a camera so that it can view its subject from a low to high angle. For decades, track rails enabled a camera to follow a moving subject. A little bit of research, however, will show you that there are many examples of drones being used to replicate these traditional camera moves. "In terms of tracking, steadicam and jib, we can do all of these kinds of shots with the drone," Shields informs us. "With the drone, people tend to think of putting it quite high up in the sky, but if you have a skilled pilot, you can bring it down a metre or a half off the ground to get a nice low shot, and then come out to sweeping wide. We're trying to let potential clients know that this is a very versatile service."

The main downside to using a drone instead of a steadicam is the noise produced by its rotors. This can necessitate some post-syncing if the scene features a speaking part.

Before drones were very readily available, film-production companies needed to hire...
expensive helicopters to get aerial shots. Jeremy Bracers, Director of Photography for Helicopter Services explains: “The most common misconception is that the drone can do everything a helicopter can do - this is simply not true. Neither is it true that a helicopter can do everything a drone can. They are unique tools in a unique environment with their own strengths and weaknesses, and can actually work together.” Drones make these types of aerial shots much more affordable, they can also bring the camera much closer to their subjects than a helicopter could without risking life and limb. Braben says that there are unique tools in a unique environment with their own strengths and weaknesses, and can actually work together. Drones make these types of aerial shots much more affordable, they can also bring the camera much closer to their subjects than a helicopter could without risking life and limb.

It’s not just cameras that filmmakers are mounting on their drones as Shells explains: “You can mount different things on them. You can mount a light on one drone to produce dramatic lighting or to be able to get a light where you wouldn’t normally be able to. When filming, lots of clients say that they would like to get a light moving over a car to see its reflections. An easy way to do that is to put the light on a drone.”

The versatility of drones is inspiring filmmakers with new ways to experiment, as Stef Williams (pilot and owner of Aerialworks) explains: “People I work with have not really grasped what drones are capable of doing. So I do like to push the envelope and give production companies a demonstration at the beginning of the day of exactly what they are capable of doing. A lot of people say to me at that point: ‘Wow! I didn’t realise they could do that!’ So we are experimenting a bit more.”

Indeed, so taken are clients by the versatility of drones that they are keen to use them in place of more traditional filmmaking kit. Where once a camera operator might have filmed a moving car from the window of an adjacent car, now a drone can be used to track alongside the target vehicle. The client’s desire to use drones for everything raises logistical (and stamina-related) challenges for aerial filmmakers such as Williams: “Because drones are the ‘in thing’ at the moment, people just want to use them for everything, so we tend to find that we go through batteries very quickly and have to constantly have them on charge. It’s quite demanding and they just go from one shot to the next. Production companies are now giving a lot more thought to how they use drones, whereas in the beginning (two and a half years ago) they were just bringing the drone along and saying: ‘Let’s see what we can do with it’. We would sit around for maybe two or three

“DRONES CAN BRING THE CAMERA MUCH CLOSER TO THEIR SUBJECTS THAN A HELICOPTER COULD”
SkyVuE Media uses an octocopter to safely capture stunning views of a wind farm for energy company EDF.

hours and then do a couple of shots, whereas nowadays we tend to be flat out all day!"

**FILMMAKING EQUIPMENT**

To produce proper high-definition, aerial footage for production companies, drone pilots like Williams need to get an expensive array of kit into the air. “The most expensive cameras we have flown to date are things like the Epic Red Dragon with some ultra prime lenses. To get the highest resolution we were filming at a resolution of 6K. The camera costs about £65,000. I think the lenses were about £30,000 and we had another £10,000 of ancillaries on there. Follow focus systems enabled us to zoom in and zoom out, so the overall weight of what we were carrying (the payload) was around 6.8 kg.” But Williams was faced with another challenge: keeping this high-end production kit safe. She used a SkyJib octocopter, manufactured by Aeronavics Limited, a New Zealand based company. For more on their range of SkyJib multirotors and accessories, check out www.aeronavics.com.

Drones in filmmaking is not something that will go away soon, as Braben explains: “We do see that drones will continue to have a place in production over the next ten years. As with any new and ‘on trend’ piece of equipment, the use of drones will stabilise to a point where the drone is being used for a specific capability and shot, rather than just for the sake of flying a drone. The drone shot is in danger of being overused and the viewer becoming bored.”

**OTHER TECHNOLOGY**

When flying expensive payloads, professional filmmakers rely on technological developments to protect their airborne assets. Craig Jump from Sky View Video explains some of the key safety features on craft and flight controllers: “The more advanced flight controllers have barometers, which help maintain the craft’s altitude. With the basic controller, you spend most of your time on the throttle trying to keep the altitude level, which gets quite difficult. You then have aircraft with ultrasonics that can sense the ground and help keep a specific distance above the ground or obstacles. GPS will give altitude and location data to the flight controller, so when you’re doing aerial photography or video you can take your hands off the sticks and focus on what the camera is doing while the aircraft stays in one place. Thanks to GPS, if you lose control of the aircraft it will return and land where it took off, or hover in the same location.”

It’s clear that craft such as multicopters are becoming a valuable tool for the production films, and are being used in big-budget Hollywood movies such as Spectre, Jurassic World and Captain America: Civil War. As the technology continues to develop and the capabilities of drones continue to be pushed, don’t be surprised if the next time you see an incredible aerial sequence in the cinema, it is footage that’s been shot using a drone.

Drones are increasingly being used on TV show productions as well as big-budget films.

Pete Stanton pilots Aerialworx’s X6 Hexacopter and controls the camera while Stef Williams monitors footage and directs.
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DELIVERIES, ERRANDS & MORE

CAN DRONES UNDERTAKE TASKS ON OUR BEHALF AND ARE UAVS THE ASSISTANTS OF THE FUTURE?

Most drones in the marketplace today have been designed to lift a simple, fixed payload. That payload is almost exclusively a camera, as we satisfy our obsession on being able to triumphantly look down on the world from above, as never before. But to lift anything other than a lightweight GoPro, drones need to change. Pick up a quadcopter for the first time and you will probably be surprised at how little they weigh. That isn’t the manufacturer frugally skimping on materials – it’s done for a reason. Like anything involving aviation and flying, weight is the enemy. The more your drone weighs, the less of a payload it can accommodate. While we are certainly amazed at the stability and agility of the current UAV generation, it has to be said that each UAV is mainly built to undertake a specific task, with little performance left over to diversify into lifting loads. Most drones cannot multitask. Even adding a few grams of extra weight is enough to make some lightweight drones struggle to be airborne. However, there are ways around this, but they involve a little experimentation.

EXPERIMENTING WITH PAYLOADS

If you’re a drone owner already, the chances are that you probably have a DJI product. The company’s Phantom and Mavic models are market leaders and have been for some time now. While they don’t come with any stated lifting capacity, it’s possible to ask them to do small things. The landing skids of the Phantom are perfect for hooking up small objects and carrying them around the house. The single biggest issue we found when attempting this is the amount of motor power required. Just like a heavily laden cargo aircraft struggling down a runway, the Phantom had to be coaxied off the floor. Gentle control inputs were vital to...
The Burrito Bomber was created by workers at Yelp, and hopes to have tasty Mexican foodstuffs dropping from the sky once given the okay from the FAA.

To keep the machine sitting on its "air cushion", too much sideways movement and it was possible to run out of power, with the Phantom gently losing altitude. While this is challenging and great fun, it's not going to be a practical way of fetching our drinks and snacks from the refrigerator. A simple way to improve a Phantom's performance is using bigger batteries, which can deliver a higher discharge rate and also a longer flight time. But there are limits to what can be done before you simply overheat those hard-working motors and you have a crash. Perhaps your Phantom is best as a household servant delivering lightweight canapes and appetisers at your next garden party?

To lift objects around the home, or be able to send your drone to collect food for the barbecue while you stoke the coals, you really need a payload-lifting drone. The good news is that they're surprisingly inexpensive. UAV Frame in the Netherlands is a leading European payload-carrying drone specialist chassis, while in the USA, Freefly Systems has adaptable UAVs. These companies are able to supply you with everything you need to build a powerful drone capable of carrying loads of several kilos. While you'll need to build a payload-lifting drone yourself, for many people that's part of the fun. A payload-lifting UAV can be modified and upgraded as the technology advances and we find new ways to transport loads remotely. Most cargo quadcopters carry cargo either as an underslung load, in true full-sized helicopter tradition, or on top of the UAV in a cargo tray. A drone such as this one is perfectly capable of conveying a tray of drinks around your garden barbecue guests or even delivering the odd burger or two.

"JUST LIKE A HEAVILY LADED CARGO AIRCRAFT STRUGGLING DOWN A RUNWAY, THE PHANTOM HAD TO BE COAXED OFF THE FLOOR"

Pars is a lifeguard drone that can carry and drop life preservers to people who need rescuing at sea.
The drone deploys from the roof of the vehicle. It can land back on the Land Rover while it is moving.

UAVs can help us in other ways, too. You know that hard-to-reach gable end of your house roof? And that inaccessible area at the highest point? Take your drone and fly yourself up there, recording on camera exactly how bad the condition is to get a clear idea just how much the job will cost. At all times though, make sure you stick to the rules and aren’t breaking any laws when using your drone around the house or others.

DRONES AWAY FROM HOME
Jaguar Land Rover has been a partner with the humanitarian organisation The Red Cross since the mid 1950s and as part of that partnership, the motor company developed Project Hero. This version of the Land Rover Discovery was designed by the company’s Special Vehicles Operation for the Austrian Red Cross and their emergency response team. The Hero Project hopes to save lives in events such as a flood, avalanche or landslide, it has a number of enhancements over the normal Discovery such as LEDs for seeing in the dark, a heavy-duty work surface that slides out from the back but the most significant one is the addition of a drone. The Discovery - or ‘Advanced Communication Vehicle’, as Land Rover called it - can deploy the mounted drone from a compartment in the roof of the vehicle and for returning it has self-centring and magnetic retention technology that makes it the world’s first drone that can land on a vehicle while it is moving.

If there is an emergency situation in an area with rough terrain, rather than calling in a helicopter that costs a lot to run and requires more man-power, a drone takes less time to deploy, is far cheaper and can do the same job. The drone, with a maximum speed of 33.5mph and flight time of 20 minutes, can be controlled from the Discovery via an on-board tablet. As the car is travelling, the UAV can fly ahead streaming live video to the response team allowing them to assess situations or survey and map out the environment and respond appropriately. The built-in infrared camera helps identify heat sources and this, along with a bird’s-eye view, means the team can spot possible hazards or people stranded more clearly and from a safe distance.

BIG PAYLOAD DRONES
Using UAVs and drones for automated tasks to make our lives easier is actually nothing new. Many people are unaware that Yamaha has been supplying agriculture specialists worldwide with an amazingly powerful UAV capable of crop spraying. In Japan, UAVs have a far easier life when it comes to legalities. As you may expect from such a technology-driven country, it’s perfectly legal in Japan to operate a payload-carrying drone and use it to deliver that payload from the air.
Takeaway restaurants and drones

Starship Technologies is giving us a taste of the future

We thought robots would be the future of our restaurant dining experiences, with waiters being replaced by ground-based drones who would wheel around and take your order. But it seems that takeaway companies are taking the lead with drones being used for making short deliveries.

In December 2016, Just Eat announced that a restaurant in Greenwich had made its first delivery using a ground-based drone through their website. By the following August, Just Eat had completed over 1,000 deliveries using robots. The drones are made by Starship Technologies. When they arrive at the destination, the customer receives a notification with a code that unlocks the robot’s lid.

Dominos Pizza is also getting in on the drone business. Starting originally with aerial-based drones by Flirtey, they announced in 2016 they had switched and also partnered with Starship Technologies for a series of drones called DRU (Domino’s Robotic Unit). The autonomous vehicles were initially used in New Zealand but it is currently being expanded across other countries such as Germany and the Netherlands.

Starship’s delivery drones have a delivery distance of 3 miles, a top speed of 4 metres a second, and sensors to avoid hitting pedestrians. They are safe, energy-efficient thanks to electric batteries and, best of all, you don’t need to tip.

Expect to see your dinners delivered to your door via drone in the near future.

Sensors make sure that drone doesn’t bump into unwary pedestrians.
PAYLOAD-CARRYING DRONES ARE ALREADY WITH US. YAMAHA’S AGRICULTURE DRONES ARE VERY SUCCESSFUL, BUT HELD BACK BY LEGAL RESTRICTIONS OUTSIDE OF JAPAN. RETAILERS SUCH AS AMAZON ARE ALREADY PLANNING AUTONOMOUS DRONE DELIVERIES AND ARE TESTING RIGHT NOW. BUT DRONE CAPABILITY IS ADVANCING FASTER THAN UAV RULE-MAKING. LEGISLATION IS CURRENTLY TRYING TO MATCH THE PACE OF UAV DEVELOPMENTS AND DEMANDS FROM BOTH CONSUMERS AND BUSINESSES WHO CAN SEE THE POSSIBILITIES.

THE BIGGEST STICKING POINT WILL BE DRONE AUTONOMY. BY THAT, WE MEAN THAT UAVS ARE ARRIVING WITH THE ABILITY TO BE AWARE OF THEIR SURROUNDINGS, WHICH MEANS THAT THEY CAN MAKE DECISIONS TO AVOID OBSTACLES AND PEOPLE. HOWEVER, IN MOST COUNTRIES, DRONE LEGISLATION PROHIBITS DRONE OPERATORS FROM OPERATING THEIR UAVS OUT OF DIRECT SIGHT AND ALSO TO ALLOWING IT TO MAKE FLIGHT DECISIONS.

SO WHILE WE MAY WELCOME THE IDEA OF DRONES MAKING OUR LIVES EASIER, RIGHT NOW WE’RE STILL TETHERED TO THE IDEA OF HAVING TO SUPERVISE THEM. PERHAPS WHEN WE LEARN TO TRUST DRONES AS FUTURE MODELS APPEAR, WE MAY BE ABLE TO RESUME DRONE BEER DELIVERIES.

YAMAHA HAS BEEN OPERATING REMOTELY PILOTED HELICOPTERS FOR COMMERCIAL PURPOSES SINCE 1991 AND HAS AMassed WELL OVER 200 MILLION TOTAL FLIGHT HOURS WITH THESE HELICOPTERS. THE COMPANY’S UAVS ARE KNOWN TO CARRY PAYLOADS OF OVER 25KG IN HOPPERS OR SPRAY TANKS.

IN JAPAN ALONE, THERE ARE OVER 2,500 YAMAHA REMOTELY PILOTED HELICOPTERS UTILISED IN AGRICULTURAL APPLICATIONS, CARRYING OUT PEST CONTROL IN 35 PER CENT OF JAPAN’S RICE PADDIES. FURTHERMORE, REMOTELY PILOTED HELICOPTERS ARE USED IN APPLICATIONS OTHER THAN AGRICULTURE, SUCH AS ACADEMIC RESEARCH, DISASTER PREVENTION, OBSERVATION AND SURVEY WORK. THE YAMAHA DRONES ARE POWERED BY PETROL ENGINES BUT A FULL ELECTRIC DEVELOPMENT PROTOTYPE IS NOT FAR AWAY. THE COMPANY IS CURRENTLY NEGOTIATING WITH THE AMERICAN FAA REGULATORS TO ALLOW IT TO ENTER THE US AGRICULTURE MARKET FOR THE FIRST TIME.

WHAT’S THE FUTURE FOR OUR DRONE ASSISTANTS?

While they may be some way off, mainstream drone assistants are an exciting prospect. As battery technology improves and electric motor power increases, they will be able to
carry greater payloads over longer distances. Add in the fast-developing technology of drone autonomy and self-awareness and they become genuinely valuable assistants. Battery power in the automotive sector has progressed massively in recent years. Just imagine if someone such as Elon Musk, with his combination of Tesla car technology and SpaceX astronautics, became involved in drone development? The future of drone assistants is potentially mind-blowing.

The future could indeed be pretty exciting for drones as personal assistants and minions. In addition to hazardous activities and being able to photograph things from the air, UAVs have the potential to undertake boring and repetitive workload tasks with ease.

The big thing is this: currently, technology is developing far more quickly than legislation. As drones are developed with a greater degree of autonomy, will the rule-makers allow them the legal freedom that’s needed to trust them to complete tasks without constant supervision?

China’s largest online retailers have been conducting tests with drones delivering their packages. JD, the country’s second largest retailer, is testing out heavy-duty drones capable of carrying loads of up to one ton for long-distance deliveries. If countries such as the United States change their restrictions on delivery drones then we could see newer models carrying larger payloads.

While drone technology is advancing at speed, humans and rule-makers perhaps need to take a balanced and considered view on the technology and how best to integrate it in a truly useful way. After all, what is the point in having a UAV to free up more time if you then have to constantly monitor its activities? The time may come when we will be able to leave a task list for one of our UAVs as we head to the beach with its robotic colleagues to enjoy filming ourselves surfing while a third nano-drone flips the burgers on the grill. Drones may well eventually progress to having their own navigation lanes overhead, just in case we are unaware of that six-pack of beer that’s just broken loose.
One of the biggest challenges faced by conservationists and those working with wild animals is how to cover the huge areas of terrain occupied by the creatures that they are trying to protect. Certain habitats, such as dense jungles, are also difficult to traverse. Serge Wich is a Professor in Primate Biology at Liverpool John Moores University and his research often takes him into the wild. He is also the co-founder of ConservationDrones, an organisation whose title does what it says on the tin. Serge explains how the organisation came to be.

“We had been doing survey work for quite a few years in South East Asia and figured that it would be good if there was a more efficient way of doing surveys than just going in on the ground,” he told us. “Ground data is great, but it is often very costly and very slow, so we started to look into other options and drones was the option that we really liked.”

In the early days, the price of drones restricted their use, especially by those from developing countries who were working with wildlife. ConservationDrones were determined to get past this issue of affordability. “We started to develop ‘do it yourself’ drone systems with help from the website DIYDrones.com. From there, we started to build things and started to use them and then our first mission was really successful in terms of video and photo footage. So we started to share that with colleagues and they liked it very much and then we decided to set up a website and share our expertise with others – which is what we are still doing today.” Serge and his colleagues also provide hands-on drone pilot training in a variety of developing countries.

PROTECTING WILDLIFE

DRONES TAKE TO THE SKY TO HELP CONSERVATIONISTS, FIGHT POACHING AND ASSIST IN A RANGE OF WILDLIFE-RELATED PROJECTS WORLDWIDE
“Our first mission was really successful in terms of video and photo footage.”

Drones are able to monitor huge areas of the landscape much faster than rangers could on foot.
to help local conservationists and wildlife rangers use this effective and affordable aerial resource.

**OTHER TECHNOLOGY**

So how are drones being used to help protect wildlife around the world? Serge explains some of the projects that ConservationDrones are involved in: “We are flying quite a bit in Sumatra for a whole array of projects that mainly have to do with determining density and distribution of orang-utans. We are also monitoring the forest that they live in to detect logging as soon as it happens rather than months later. Drones have a role there because they can obtain much more high-resolution data than satellite images. There are satellite warning systems that will give you a deforestation alert when a certain area has potentially been logged, but it is still at a pretty coarse resolution. So drones can fly over key areas every month or every week and try to figure out if there is indeed something going on.”

The higher-resolution images sourced by drones enable pilots such as Serge to spot a single illegally logged tree, which helps the authorities protect the orang-utans’ habitat. Animals such as mountain gorillas and orangutans are usually found in dense jungles that need time to plan. An on-foot expedition can
Drones allow you to get up close to animals, providing valuable data to analyse their migratory patterns and actions.

"Traditionally, you would have to cover vast areas on foot to locate their nests."

be expensive, requires a lot of planning and a number of people but with drones, pilots can deploy them over the forest canopy to gather data and maybe capture high-quality images. And you never know what the animals may do, with an on-foot expedition, getting close to apes is always risky, they could attack but with UAVs that risk is gone. What sensors or payload are used to locate these animals? Serge explains: “At the moment we’re using just photographs, but we are thinking about other sensors. We are also thinking about detecting chimpanzees at night with a thermal-imaging camera, but that’s the next step. We are going to test thermal-imaging cameras in the UK and then using automatic recognition software to detect those animals. Thermal imaging could also potentially help with protecting rhinos from poachers, as they are sometimes active at night.”

Poaching of endangered rhinos is such a problem that the Wildlife Conservation UAV Challenge was created to encourage drone-related counter-poaching techniques. Serge Wich is collaborating with a group of students from the Netherlands who have responded to this challenge: “They are trying to develop a user-friendly system for the park ranger, both in terms of flying the system and also in terms of the feedback to the ranger. It is very difficult at the moment to transmit a lot of data at a relatively narrow bandwidth from the drone to the ground, so it would be much better if you would only send information that is actually needed for the ranger to react upon, not thousands of images of savannah woodland trees. The plan is to get the video analysed on-the-fly so that the ranger looks at a little screen and will see a square around a rhino or a poacher or any other object that needs attention. They can then react much faster to potential threats than they could with other systems. That’s the ultimate aim of the project: to have an interface that does that.”

Thanks to the increasing affordability of UAVs, plus Serge and his colleagues’ passion for training conservationists and park rangers how to use these versatile craft, wildlife throughout the globe can be surveyed and protected from a range of threats.
The future of wildlife conservation

Discover how drones could be used to track illegal poaching and protect endangered species.

Princess Aliyah Pandolfi is the Founder & CEO of the Kashmir World Foundation, and founder of the Wildlife Conservation Challenge.

Can you give an overview of what the foundation does? The Kashmir Foundation is a not-for-profit organisation and through Kashmir Robotics we have a couple of active projects, one of which is the Wildlife Conservation UAV Challenge. It’s a global effort to create drones that would be used to protect endangered species. The first challenge is focused specifically on Kruger National Park in South Africa. Another project of Kashmir Robotics is the Da Vinci Challenge. The focus of the Da Vinci Challenge is to help innovate robotic systems and help people understand the components and the structure and what’s required to create a drone. The first part of the Da Vinci Challenge is to build your drone, and the second one is to learn to operate it as an unmanned aerial vehicle. The third part is helping the students find an application for it. It’s not just creating an aircraft, putting a camera on it and then coming back to watch the video. It’s about being able to create an aircraft that has brains of its own and it can make decisions and give the person on the ground the opportunity to take action.

What sparked your interest in using drones against animal poaching and the illegal wildlife trade? My interest in drones came out of our project Kashmir Rose, which is basically working with Kashmir artists to help them preserve their art. As I was learning about the art, I learned about the pashmina goats which come from Kashmir in the mountains. As I was studying the goats, I learned about the poaching problems with snow leopards. One of the issues I found is that there’s really no actual data being used currently. It’s the same thing as 20 years ago. You go in, put out camera traps in the different areas that you know snow leopards roam and then if you do capture one, you put this horrible collar around their necks which hinders their ability to hunt. I just think that the technology is there now, why aren’t we upgrading to that technology? If we were to use a drone in Kashmir we would be able to not intrude in their domain, and at the same time gather so much more information about them. I then started learning a little bit more about the rhino situation in South Africa. It was the same time I had become involved with the drone technology and wildlife.
Using the ability to identify animal whereabouts and nearby threats will be a boon and it was almost like a natural fit to say that this seems to be a global problem, not just an individual issue. That’s when we started looking about what we could do because there are so many people that are interested in protecting wildlife, and then there’s many people that have the drone technology. I really want to go in and stop the poachers, because I think if you can go in and stop the poachers, it cuts off everything after that.

**Can you outline how drones can be used to tackle poaching?**

With the drones that we’ve been working on, the one difference is bringing computer science into aviation. That means being able to fly your aircraft and as the aircraft is flying, be able to see humans, animals and trees. But we know we can do that just by attaching a camera and watching it on a monitor. What we have an interest for is that the aircraft will be able to determine the difference between humans and animals. That’s the first layer. The second layer is being able to recognise the species of the animal and where it’s located through the GPS settings. Then we talk about the humans, and that’s where most of our interest is: being able to determine if it’s a poacher or a ranger. For example, we already know that the rangers have a preset location that they have to be at every day. With the drones, we’re able to identify a broad area coverage and that’s one thing that the rangers will not be able to do on the ground, ever. Now that we know where the ranger’s stations are, it’s easy for us to say that as we’re flying the aircraft, we know that’s the location of ranger number 31, for example. The drone knows there’s somebody there, and we would have to have a tag on the rangers that the aircraft can scan. We could put those identification tags on the vehicles, on weapons, on anything pretty much in the park.

As for tourists, we know which paths, highways and main roads that the tourists would be taking and it’s more than likely that they’re going to be in a vehicle. From those perspectives, the aircraft can now determine the difference between humans that are rangers or tourists versus humans that would be poachers. The aircraft would then have to send a signal that gives the rangers instructions. Then those officers can communicate with the police. But it’s also about deterring the poachers from the air. We would have some type of non-lethal weapon on board which would allow us to deter the poachers by letting them know that we know where they are. They don’t know what the aircraft is capable of so it’s either a scare tactic or it will get the animals to move away from them. Each scenario is different, which is why the drone would have to have preset scenarios in order to make those decisions based on how it’s been programmed.
AIDING IN EMERGENCIES
WE EXPLORE THE MANY WAYS UAVS ASSIST THE VARIOUS EMERGENCY SERVICES IN PERFORMING THEIR WORK MORE EFFECTIVELY AND SAFELY

Athough the military have been using drones for decades, it’s only in the last few years that drones have been adopted and deployed by emergency services, such as the fire brigade, coastguard and police. This is partly due to recent technological advances that have made drones cheaper to buy and easier to use. However, most emergency services are still not using drones due to legislation that makes it difficult to deploy them in populated areas.

One of the first organisations to add a UAV to their kit list was the West Midlands Fire Service (WMFS) in the UK. We spoke to fire officer Andy Cashmore to see how the WMFS deploys its multirotor to assist the fire service and police. Cashmore filled us in on the history of their aerial acquisition: “I think it’s fair to say that we were the first fire service in the UK, maybe worldwide, to adopt the technology and use it in operational incidents in November 2007.”

As an early adopter of drone technology, WMFS flew a microdrones mD4-200 quadcopter, but they did face a few challenges when using it in the field, as Cashmore explains: “It was a little bit temperamental, and there were some limitations in terms of what wind speed it could operate in, battery life, payload capacity and things like that. We used it very effectively in a number of incidents, but we eventually needed to replace it because it reached the end of its logical life cycle.”

After finding the best replacement drone, Cashmore’s team now use an Aeryon SkyRaider for outdoor work. They also wanted a drone that could operate indoors, so they acquired a DJI Phantom too: “Part of the user requirement was the we may need to operate it indoors, and the Phantom can operate without GPS. It is quite a cheap system and almost disposable, so if we did choose to fly it indoors and it clattered into a wall and got damaged, it wouldn’t cost very much to replace or repair it, whereas the SkyRaider might be a little bit more expensive.”

So in what scenarios does WMFS use its drones? “We tend to use them in distinct areas. The first area is pre-planning for events. If there are any high-risk premises that either store dangerous goods or carry out dangerous processes, we use the drone to produce some site-specific information for crews, as they get mobilised to incidents at such locations. So we will try to obtain some up-to-date imagery from above the

“MOST EMERGENCY SERVICES ARE STILL NOT USING DRONES DUE TO LEGISLATION”
West Midlands Fire Service began with the microdrone md4-200 VTOL (Vertical Take Off and Landing) UAV.

The video feed appears to show that the fire is out and there's just residual smoke. The IR camera shows that fiery 'hot spots' remain within the factory.

West Midlands Fire Service upgraded to the Aeryon SkyRanger, benefitting from extended flight times and a greater manageability in windy conditions.

Fire Chief Darrell Hartmann of the Brookings Fire Department in South Dakota, USA, is keen to utilise developing drone technology to keep his crew safe and effective. He is also using this emerging technology in other ways.

**How does a drone help you in your work at Brookings Fire Department?**

As Fire Chief, my biggest job is the safety of my firefighters. Our drone is a natural fit for the emergency services. During an incident, the commander is seeing live feed information. And with the situational awareness that this unit can give us, it's just another tool to help us be safer.

**What else do you use the drone for?**

There's a myriad of ways to use it. If we have missing people, we can cover large areas very quickly and thoroughly with a drone, whereas in the past we would have to walk it by foot, or take all-terrain vehicles out. We've even worked with horseback searchers. But the drone really gives us another tool to do that.

In hazardous situations, it allows us to send in an expendable tool in order to get up-front information. You can attach a camera so that you can read labels. And if you happen to lose that drone, you can replace it. I do not have to worry about putting one of my personnel at risk.

**Do you share the drone with other emergency services?**

For the law-enforcement side, if we have a subject barricaded in a structure, we could utilise it to go in to look in the windows, though we would only be able to do those things after we had a judge's court order.

**Are there many legal constraints on drone use?**

Right now, the biggest hurdle is making sure that we follow our Federal Aviation Authority (FAA) rules. We're in the process of applying for authorisation as an emergency-services provider, so we are trying to jump through all the hoops and do everything right. There are a lot of people out there in the private sector who have used drones the wrong way, and it makes it more difficult for us.
premises, so that they can get a bird's-eye view as they approach the address.

The second area is actually using live imagery when we are responding to incidents. We will go to the incident at the incident commander's request and get whatever data they require in order to bring the incident to a safe conclusion."

**DETECTING DANGER**

The drones have proved themselves invaluable when attending fires, as they can obtain information that's not available to the fire crew on the ground. Cashmore gives us a specific example: "We attended a large factory that had caught fire during the night, and the fire had spread to the adjoining buildings. The fire crew had been there all evening. It was about 8am and they were preparing to hand over to the day crew. They thought they had got the majority of the fire knocked down and that there was just a bit of smoke and residual heat left in the building, so they were going to scale the operation down. But as soon as we got the drone up there, and used our thermal imaging camera, we were able to identify that there was quite a large area inside the building that was still burning. So, it changed the risk assessment and the strategy that we employed. The drone had a real impact on the incident."

The future of drones used in emergency response looks bright. It's not just specialist companies making these kinds of drones. In late 2018 DJI announced the Mavic Enterprise, a quadrocopter with emergency tools that governments, businesses, police and other professionals could use in their work. The Mavic Enterprise comes with a mount for one of three accessories: a 2,400 lumens spotlight, a 100 decibel loudspeaker that can play up to 10 pre-recorded voice clips and a beacon. Hopefully with a drone like this available from a major manufacturer, the chance of them being used in emergency situations will increase.

The Massachusetts Institute of Technology (MIT) is working to make drones effective tools for search and rescue missions in forests. The hope is that in the future groups of drones can be deployed without the need of piloting; a team could simply launch them, then monitor the search from a base. Drones often use GPS to guide them but this can be difficult as signals get lost in dense forests and helicopters can't see through the canopies. In an attempt to solve these issues MIT is experimenting with mounting LIDAR on a fleet of drones. The technology is similar to that which is used in self-driving cars to detect objects. The drone projects laser beams that are reflected back then the distance between it and the obstacle is calculated. By constantly doing this the drones can create a 3D map of the areas they have patrolled. The system is currently being tested – it needs to be tried with a system to identify different objects so it can tell the difference between a tree and a human. The plan is that when the drone identifies a person it would tag them on the map it has created and the base monitoring and reading the information will know where they are and can then plan the rescue accordingly.
MOVING SUPPLIES
THE DRONES THAT WORK TOGETHER TO MOVE OBJECTS

Stanford University and Ecole Polytechnique Fédérale de Lausanne (EPFL) in Switzerland are working on a drone inspired by geckos and wasps. The drone is called the FlyCroTugs, short for Flying Micro Tugging Robots.

Normally a drone can carry around double its weight, but these micro drones are capable of moving objects that are 40 times their own weight. They anchor themselves onto a surface, and using a small winch on its back, it can pull objects.

The EPFL demonstrated their use by having two working together to open a door. Thanks to their compact size, they could be ideal for delivering bottles of water to people in search and rescue missions when people can’t get through.

HELPING SAVE LIVES
DISCOVER HOW DRONES CAN INCREASE SURVIVAL RATES

The creation of Alec Momont, the Ambulance Drone is a revolutionary way to respond to medical emergencies. Built using 3D printing techniques and a strong but light carbon-fibre frame, this drone is a glimpse of what might become commonplace in the future. Enabling the emergency services to cut average response times from approximately ten minutes to one minute, by getting the right supplies to people in need so quickly, survival rates could be increased from eight per cent to 80 per cent. Momont’s vision – along with Living Tomorrow and the University Hospital of Ghent – is to show how drones can be used for good, and how the Ambulance Drone could be part of a wider network of life-saving drones that could ultimately transform the way emergency response services work to treat those in need of urgent assistance.

Delivering an automated external defibrillator, the drone can get essential medical supplies to a location quicker than an ambulance.
A DJI Phantom 2 with GoPro gets up close to the Holuhraun Fissure Eruption in August 2014

Reporting the News
Discover how RPAs (remotely piloted aircraft) are increasingly being used in the news-gathering field. Mark Corcoran, a veteran news journalist with a particular interest in utilising drone technology for this purpose, gave us an insight into how times have changed.

Mark was a globe-trotting reporter for the Australian Broadcasting Company’s Foreign Correspondent programme for 15 years, and it was while on assignment in South Beirut during the 2006 Hezbollah/Israel war that he first encountered drones. Although the term drone is now used generally for all types of UAVs, it has a military origin. The drones that Mark regularly encountered back in 2006 certainly deserved that designation.

“I was just taken by the sheer number of Israeli drones in the airspace at any one time, with varying capabilities. During one particular lull in the air strikes, our Hezbollah escorts had vanished in an unseen bunker. We found out that there was a warning that there was an Israeli drone overhead but we couldn’t see or hear it. So our escorts had taken cover. We were left out there and were very exposed for half an hour or so. These were fixed wing drones which the Israelis were using for surveillance and for calling in air strikes. I don’t believe any of them were armed, but they were being used for target intelligence purposes for the Israeli attack aircraft. During this high-risk assignment I saw a lot of these kind of drones.”

So how did this experience set him on the path to using drones for news-gathering purposes? “Essentially I took the view that if the militaries around the world could increasingly use drones for this kind of work — reducing exposure of their own people to risk while conducting reconnaissance or surveillance — then why couldn’t we?”

While embedded with a US Army forward surgical team in Afghanistan in 2010, Mark discovered that military drones could also be used to provide unique visual assets for news reports. “We accompanied a helicopter med-evac crew, and when we were out there they actually had wing drones launched by the forward operating base flying overhead. That drone was called the Shadow — it was actually quite large, unarmed and designed for surveillance. We were permitted to use still imagery from the drone in our report. The quality of the actual drone-sourced imagery from a TV point of view wasn’t that good, but it proved a concept.”

After sustaining a permanent voice injury in 2011 while on assignment in Cairo’s Tahir Square, Mark now leads the ABC’s Drone/Remotely Piloted Aircraft Newsgathering Research Project.

Learning the Ropes
Drones are used by ABC to gather content for TV news broadcasts and current affairs programmes, but the challenge is to find...
drone operators who also have the camera skills required for news-gathering work. Mark explains: “There are currently about 200 entities who have permission to operate commercially flying drones in Australia of various shapes, sizes and specialities. Only a few of those are what we would deem as suitable for news gathering. What we have found with this emerging technology is a huge emphasis on the platform — on the flying — and surprisingly few of these companies actually meet our standards in terms of what is required for camerawork. We get down to the basic question of ‘is it easier to teach a drone operator how to shoot at a professional level or is it easier to teach a cameraman how to fly?’”

ABC use many external contractors to fly heavy lift drones in a news-gathering capacity, but there has also been a drive to provide in-house training for ABC employees. Mark fills in the details: “For the training cycle we went for off-the-shelf variants. They offered low-cost, relatively good performance and as they were readily available everywhere we could achieve commonality across the network. We went for the DJI Phantom 2, with a GoPro payload.”

So how did senior camera operators fair when taking a drone to the sky? “What people realise is it’s easy to learn but difficult to master! Flying a small multirotor round the park is one thing, but to do it in a busy location, working to direction and under pressure is another. Often the locations we were choosing were quite difficult. Initially they were roughly doing about five hours’ flying by the end of the two days and this mirrors the qualification for what CASA is now calling the Remote Pilot Certificate in Australia.”

**DOCUMENTING DISASTER**

So once ABC’s camera operators were initially trained to fly the Phantom 2, how are pilot and drone used in news-gathering scenarios? Mark explains: “You have a relatively low cost, simple to operate platform that you can use in high-risk

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“IT TOOK THE VIEW THAT IF THE MILITARY COULD USE DRONES FOR THIS WORK THEN WHY COULDN’T WE?”
assignments. Then you can use drones for local reconnaissance after disasters. Quite often when you’re covering disasters your field of vision is quite limited by debris, wreckage and rubble — so just being able to put a camera up even 40 meters above your position can be of enormous benefit. Both in terms of filming, and in helping you decide movement — seeing what’s around the hill, around the corner, whether the bridge over the hill is still intact or if you’re wasting your time going there. So it’s very much used as an occupational and health and safety tool as well as a filming camera platform for news gathering.

We used the Phantoms operationally in the island of Vanuatu in March 2015 to follow the big cyclone there.” After Cyclone Pam tore through this archipelago in the Pacific, many of the islands suffered from wide-scale destruction. ABC camera operator Brant Cummings was able to show the impact of this cyclone by recording aerial video footage using the Phantom 2. ABC also deployed a UAV in Nepal after the April 2015 earthquake killed 7,000 people and injured thousands more. Once again ABC’s Brant Cummings used a Phantom 2 to record the devastation in the Gorkha district, the epicentre of the earthquake. This footage was broadcast on a range of platforms such as ABC’s YouTube channel.

Some of the locations that ABC has flown in were challenging for different environmental reasons, as Mark Corcoran explains. “We had another Foreign Correspondent team on a job in the Antarctic peninsular and we were keen to see how drones would operate in an extreme environment with high winds and very low temperatures.” One of the team members was camera operator Dave Martin, who faced the Antarctic challenge after completing the training course that Mark spoke about earlier. He was able to capture some stunning aerial video sequences while flying the drone at the edge of its operating capabilities. Due to the remote location Dave was unable to connect the drone to a satellite to use the automated GPS features, so it was just as well that ABC train their operators to fly with the GPS turned off, as Corcoran explains: “Craft such as the Phantom 2 use GPS to make flying easier, but during the training the staff learned to fly without this safety net. Everyone told us how easy they were to fly. When they were while flying in automated mode — everything was working properly. But the minute you switched the GPS off it requires a high skill level. So all our training is done with the GPS off because

The importance of teamwork

HOW DOES ABC’S NEWS-GATHERING DRONE CREW WORK AS A TEAM?

Flying a drone safely while simultaneously capturing high-quality video of a live event would be too challenging a task for an individual. Mark Corcoran explains how a news-gathering drone operating team needs to work together to generate aerial footage in challenging locations: “There is overlap. You’ve got a dedicated pilot, a second person can be calling the shots in a busy environment and there is also someone controlling the vicinity of the pilot.

One thing I found is that you get a lot of onlookers; people who want to know what’s going on. They can obstruct the view of the pilot. Sometimes where you are you might get someone who is angry about the fact that there is a drone around. So you have to explain what’s going on. You need a second pair of eyes because the pilot is focused purely on the flying. With the larger, more complex systems (such as heavy lift multirotors and fixed wing RPAs) you have the camera operator, you have the pilot and you effectively have a director.” This division of labour enables the camera operator to follow the director’s instructions and capture relevant footage of an unfolding news story, while the pilot keeps the drone safely in the air and manoeuvres it to useful locations. The three-person team controlling heavier RPAs echoes the way military UAV operators fly drones for surveillance purposes. This need for a tight and coordinated team is not surprising, given the cost of a professional drone and its payload (plus the health and safety regulatory constraints faced by UAV professionals).

When using a sub-2Kg Phantom 2, a two-person team can suffice. In the image shown here, ABC News camera operator Dave Martin uses a controller to pilot a Phantom 2 which is carrying a GoPro. The live feed from the GoPro is being viewed by the producer Brietta Hague, who uses this visual feedback to direct Dave to capture shots for their Southern Exposure documentary on King George Island, Antarctica. Here the drone enables them to get a new perspective on the location (and add extra texture to their documentary) without having to spend thousands of dollars on hiring a helicopter.
The Olympic Broadcasting team used drones during the 2016 games in Rio for unique camera angles during canoe sprint and rowing.

Canadian news channel CBC used footage submitted by people who filmed with their drones to report on the 2017 floods in Quebec.

A drone enables news-gathering crews to augment their reports with a wider perspective of the subject matter, at a fraction of the cost of a helicopter.

We were keen to see how drones would operate in an extreme environment.

We found operator error was the cause of the majority of incidents or accidents and loss of GPS was a factor in that.

AHEAD OF THE CURVE

As Australia’s national broadcaster, ABC needed to provide live TV coverage of the Australia Day flag-raising ceremony in 2014. Drones provided a useful solution to help cover the event as Mark explains: “There’s lots of cameras and prime ministers there – guards of honour that sort of thing – and we incorporated the drone coverage quite successfully. Given the location by Lake Bernard Griffin in the capital Canberra it would be inappropriate to have a low-flying helicopter as close as 30 metres to VIPs.”

So drones offer ABC’s news-gathering teams ways to record informative aerial content for various current affairs and news programmes as well as put eyes in the sky during live broadcasts. As with other professionals in this field, Mark is impressed and encouraged by the advance in drone-related technology and is optimistic about where things are heading.

Citizen journalism is another field that is sure to grow as drones with powerful cameras become more affordable. News outlets are using footage taken by people who went out, filmed with their drone and uploaded the video to social media or channel such as YouTube.

When floods hit Southern Quebec, Canada in May 2017 people living in the area deployed drones to see the severity of the damage; these were picked up by Canadian news channel CBC and used in their broadcasts. Drones provided a useful solution to help cover the events and instead of having to buy their own and train a pilot to use the UAV, they can rely on the local community to get the footage for them.

As with any new form of technology that could be seen as invading privacy, the laws and regulation on these citizen journalists and drones will have to be examined, the constant debate on privacy against the public’s interest.
One organisation that can help us understand how UAVs are being used to aid geographical mapping is the UK’s Ordnance Survey - a British, government-owned organisation that has been producing highly detailed maps for many centuries. Chief Executive Neil Ackroyd explained to us how the organisation is working with UAVs to complement the use of aircraft in producing detailed maps of the UK: “At any one time during the flying season, we are flying around five fixed-wing aircraft, so we cover more than 80,000 km² of the country. These aircraft have very high resolution cameras.”

So, while the organisation’s manned aircraft can produce high-resolution maps of large areas, there are occasions when a UAV is useful to survey a specific area, especially if that location that is changing on a daily basis. As UAVs are a relatively new technology, organisations such as the UK’s Ordnance
Survey are still discovering new and effective ways to integrate them with their existing way of working, Ackroyd explains: "A good example of where we have carried out some work with UAVs – and can see ourselves doing more work in the future – is when we do our coastal surveys of features, such as a cliff collapse. Arguably, you wouldn't want to send an aircraft in just to capture five hundred metres of a collapsed cliff. Likewise, a local field surveyor would generally be quite close, but you wouldn't want him to be walking along a cliff edge. We have done evaluations in those sort of areas."

- By mapping a location using different wavelengths of light, you can discover extra information, such as crop health.
Craig Jump from Sky View Video (Scotland) also finds drones useful in mapping quickly changing (and potentially dangerous) geological features: “Landslides are a big issue in an area called Rest and Be Thankful. I’m actually working with Northumbria University and Transport Scotland at the moment, and we’re looking at using drones to map landslides using software tools that look at the flows of landslides and how big the catch fences need to be. You’re not going to prevent some of these big landslides. It’s more a case of looking at when you need to intervene, or take some material of the slope, or put more barriers in, or even close a road.”

Sky View Video uses a multicopter for their mapping work, whereas Ordnance Survey deploys a fixed-wing GerMap G180 drone (pictured right) to map up to 6km of terrain in one flight. Its payload is a Canon Ixus camera. We asked Ackroyd why Ordnance Survey used a delta wing type drone instead of a multicopter: “The reason that we tended towards delta wing type drones is because they are so light. You have to get a licence to fly for commercial use, so it’s much easier to get licensed because they’re very lightweight. The quadcopters, although much more stable than lightweight drones, are significantly heavier. When we do the risk assessment, which are compulsory as we are a government-owned organisation, we have the obligation to deploy the safest technology that we can. The lighter drones are arguably more sensitive to wind than a quadcopter, but they are actually far less likely to cause damage or injury. So, a serious user has to really look at that as part of their health and safety obligations.”

Delta wing drones are therefore useful for mapping smaller, quickly changing locations in a safe way. However, there are some constraints that can limit their use, as Ackroyd explains: “People have to question whether

- Ordnance Survey map using this lightweight GerMap UAV with either one camera or two facing in opposite directions
- Fixed-wing UAVs can map sites that would be hazardous to survey from the ground, such as Strongford sewage works
they can use drones for survey, because the registration and licensing has quite strong limitations on how close you can fly to people or to a private residential property. If you get the permission of the individuals concerned then, in principle, you can shorten flying distances, but in practice it is hard to prove that you have permission if someone took issue with you. Let’s say that you are a real estate guy and you are flying a drone over a new house to get a photograph, and the next door neighbour decides that they don’t like that – then you could have a problem there. So, generally speaking, where there’s a lot of people in a highly urbanised area, we have found that the practical limitations of even just walking around to try and get permission is as time-consuming as doing a traditional survey job.”

**MAPPING AND SURVEYING**

So, how does the Ordnance Survey’s drone produce data that is transformed into a detailed map? “We generally fly lines, so essentially almost fly a grid with our fixed wing. We are mounting cameras on our drones that are taking sequential shots with a high degree of overlap, both laterally and horizontally. And that high degree of overlap gives us the ability to produce stereo imagery. The stereo imagery is important to us because it gives us the capability to correct the imagery for undulations and contours in the ground. It also gives us the 3D information, which is useful for measuring height and creating high-accuracy mapping. An automated process uses this overlapped imagery to produce a 3D surface, which allows us to produce a better visualisation and more accurate surveyor information out of the imagery.”

So, where does Ackroyd see drones being used in relation to mapping and surveying in the near future? “There are lots of commercial companies of which drones do meet the needs. For example, a smaller survey company that has to monitor a quarry, or an out-of-town shopping development being built will use a drone before the building site is opened. They won’t have the access to fixed-wing aircraft or the same number of field surveyors that we have, so we’re seeing drones being used much more by the smaller, commercial, private-sector surveying companies. Generally speaking with the small ones, it’s an entry-level technology – if you don’t have a large existing field survey force, it can be quite an attractive option.”

**GRAPHIC INFORMATION SYSTEMS**

**ADDING FRESH, DRONE-SOURCED DATA TO EXISTING GOOGLE MAPS**

Sky View Video’s Craig Jump explains how the data captured by drones is converted into maps:

“You can take a number of images – they don’t have to be that accurate in terms of location, or have GPS data – and you can use tools, such as Pix4D, to stitch the images together and create a kind of 3D Google map. This tool will allow you to export to a common graphic information system (GIS), and it will also enable you to do things such as create videos of a virtual fly-through of a landscape, or even a building, like a castle or ruin, for example.

“Now, you can also take that one step further: you can use global-positioning-system (GPS) reference images, which makes it a bit easier on the software side of things. The software is getting so good these days that you don’t have to do much intelligence with the aerial imaging to get really good output from it. When I first started, you had to use pre-programmed flight paths and ground reference points to actually build that imaging up so that the image would be quite accurate, but these days the software is actually doing it all by itself.”

“Most of my clients tend to want a very high-resolution image stitched together in the most simplest form. Some of them will want information in a common GIS format so that they can import it into GIS programs. Most of the architects, councils and public-service bodies use GIS. They have a database of Google maps. They can overlay drone-sourced data on top of these maps, and overlay where there has been flooding or where there has been pollution. GIS has been around for a long time, but the aerial angle brings it into its own.”

**Photogrammetry apps, such as Photosynth 3D, enable you to stitch a series of drone-sourced shots together into an interactive fly-through**

**Sky View Video’s Craig Jump uses two drone-mounted cameras to capture stereo imagery that helps measure topography in 3D**
THE FUTURE OF DRONES

The latest technology could soon open the sky to a new wave of multicopters.

We have reached the tipping point. Drones and UAVs are now cheaper, more accessible and more capable than ever before. Lightweight lithium batteries and high-powered brushless motors already provide enough power to keep sizeable payloads in the air for 30 minutes at a time. Now the focus has turned to adding extra intelligence. Faster and more sophisticated flight controllers will soon allow multicopter drones to fly more autonomously and more safely, and this opens up entirely new possibilities for UAVs.

NO PILOT REQUIRED

The mission to find water and ice on Mars will soon expand to utilise a new generation of drone technology thanks to the scientists at NASA.

A tiny new drone may soon be launched to the Red Planet, and be flown into the most difficult-to-access areas of faraway planets and asteroids to discover resources otherwise inaccessible to land-based rovers. A drone might just discover water on Mars. Drones are already used in space exploration - that is, if you countrovers and balloon-based scanners. But hundreds of thousands of miles away, drones may soon be used to scout new landscapes of planets using lightweight new designs like the Prandtl-D.

This aircraft, currently in development at NASA, may be the future of exploration thanks to a revolutionary design. The new wing is bell-shaped rather than a traditional elliptical shape, and the removal of a tail or flight control surfaces has dramatically reduced the craft's weight. Together, these features result in more than a 30
FOLLOW DRONES ARE PROGRAMMED TO FOLLOW YOU, WHATEVER YOU ARE DOING
per cent increase in fuel economy. The design began with the research of the early 20th-century aeronautical engineer Ludwig Prandtl, and also incorporates conclusions from several other engineers and aerodynamics pioneers. However, the craft’s name, Prandtl-D, also stands for Preliminary Research Aerodynamic Design to Lower Drag.

Saturn’s moon Titan is currently the only Earth-like world within our reach; with its liquid lakes, thick atmosphere and climate system, it’s at the top of many astrophysicists’ ‘to visit’ lists. Until now, the closest we’ve been is a pioneering but brief visit from the Huygens probe in 2005. Scientists have only managed a brief landing on Titan, so we are sadly still years from a mission like this but with the advancement of drone technology, we may soon be exploring Saturn’s moon from the land, sea and air.

AIRMAIL DELIVERY

A camera isn’t the only payload a drone can carry, though. Amazon raised a lot of eyebrows in 2015 when it filed some tentative patents for a drone delivery service. Such a system wouldn’t currently be legal, since most countries require civilian drones to be flown within line-of-sight of their operator. But the US Federal Aviation Administration announced in late 2016 its Pathfinder Program to explore whether these rules could be relaxed. This trial is partnering with three different companies to test applications: CNN for aerial news reporting in cities, PrecisionHawk for surveying crops in rural areas, and BNSF Railroad for inspecting tracks in isolated spots. The findings in these trials could result in a licensing system that allows UAVs to operate beyond visual range within just a couple of years. In December 2016, Amazon delivered its first parcel in the UK using its drone delivery service Amazon Prime Air. The delivery was made in the Cambridge area and took around 13 minutes to complete. Amazon is working with regulators in the UK such as the CAA on the tests with the hopes of one day making it more widespread.

Workhorse Inc has sidestepped the problem of range altogether. Its Horsefly drone is being tested by the US Postal Service. This system will still deliver parcels by van, but the drone will handle the last mile from the van to the front door. This allows the van to...

THE FUTURE OF DRONES

Follow drones can keep pace or orbit as you move and keep their camera facing towards you.

THE HORSEFLY DRONE IS BEING TESTED BY THE US POSTAL SERVICE

NASA is testing a huge ten-engine drone that takes off like a quadcopter and then rotates the wings for high-speed flight.
The European Space Agency is using a quadcopter to test the landing system for Mars rovers. Mars doesn't have enough atmosphere to actually fly a multicopter, but it's a much cheaper way to test the guidance electronics on Earth. The Star/Tiger Dropter has a mass of 16.8kg, including a 3.6kg mini rover, and can fly for up to 15 minutes.

The Horsefly drone scans the barcode on the package, which can weigh up to 4.5kg, and launches from the roof of the van. Initially it flies by autonomous GPS navigation but the final approach and landing is handled by a call centre of dedicated drone operators who make sure it's outside the right address and watch out for power lines and other obstacles.

Horsefly offers a far more realistic approach to drone delivery than Amazon's vision since the drones are only making relatively short trips. Instead of a 50-mile trip from a centralised warehouse, the Horsefly would make at most a two-mile round trip, catching up with the van as it continues on its delivery route. Safely back aboard, it would recharge its batteries from the van, ready to head out into the skies for the next delivery.

**DON'T FORGET TO TIP YOUR DRONE**

While Workhorse, Amazon and Google are waiting for the FAA to grant them permission to begin full-scale outdoor testing, in China they are already flying. JD, the country's second biggest online retailer, has been using small delivery drones since 2016 but now they are planning on deploying heavy-duty drones that can carry up to one ton. In December 2017, JD announced their plan to build 185 drone airports within three years in Sichuan, southwest China. They hope this will help deliveries reach rural parts of the country faster and cheaper and allow agricultural products from Sichuan to be delivered anywhere in China. And in Singapore's Timbre restaurant, quadcopters from Infinium Robotics are acting as flying waiters to bring trays of food and drinks out from the kitchen. The drones have fully guarded rotors to prevent nasty accidents but even so, they don't deliver directly to the tables. The idea is to save the waiters from making trips to and from the kitchen. This allows them to spend more time attending to the diners, as well as providing a touch of theatre.

As quadcopters get cheaper and easier to fly, it's inevitable that criminals and terrorists will begin to explore the possibilities they offer. The US Drug Enforcement Agency estimates that drones are already making more than 150 trips a year across the US-Mexican border, laden with drugs. In May 2017, footage was found of a drone delivering drugs and phones to a prison in London. To prevent further occurrences, Guernsey prison is currently testing a 'Sky Fence'. The virtual anti-drone fence detects drones, blocks the UAV's signal and sends it back out of the field.

Meanwhile, thieves in the UK have begun using quadcopters to case houses in advance of a planned burglary. Security systems that can detect and defend against UAVs are quite difficult to design. Since they are so small, CCTV and radar can't easily distinguish them from birds until they are very close, and their rotor noise is easily drowned out by traffic. Drone Labs is selling a device that listens for the signals sent to and from nearby UAVs and works out where they are being operated from.
THE FUTURE OF DRONES

Three quadcopters coordinate their flight patterns to throw and catch a ball in a net suspended between them.

FOLDING FLYERS

When drones aren't flying, most of them are delicate and difficult to transport. Unless you remove the rotors after each flight, they snag on things and the wide arms take up a huge amount of space. Folding drones offer a way around this. Dr Stefano Mintchev, a professor of bio-inspired robotics at the École Polytechnique Fédérale de Lausanne, in Switzerland, has developed a prototype quadcopter that folds up to one seventh of its deployed size. The tiny quad begins as a 5.6x5.8mm square package, with its arms folded around itself. When it activates, the torque from its own propellers snaps the arms outwards and spring-loaded plates lock the elbow joints in place - all in under a second.

The US Office of Naval Research has developed a winged drone that folds up into a bullet shape and is launched from a cannon that can fire 30 drones in under a minute. These drones communicate with each other to fly as a swarm – the project is called Low-Cost UAV Swarming Technology, or LOCUST. These drones are single-use reconnaissance aircraft that are able to cooperate to provide 360-degree targeting over a wide battlefield.

RISE OF THE MACHINES

The ability to communicate with each other is in fact probably the most significant new trick that drones are learning at the moment. During the opening ceremony of the 2018 Winter Olympics in Pyeongchang, South Korea, 1,218 drones took to the sky, lit up and forming the shape of a snowboarder before turning into the Olympic rings. This display set the Guinness World Record for most drones used in a performance. A team of animators from the company Intel created a routine that was sent to the drones to perform autonomously and they also monitored them.

Researchers at the Swiss Federal Institute of Technology in Zurich have also developed quadcopters that can play catch with each other, bouncing a ball off their top surface from one to other. These quadcopters aren’t just using their own on-board cameras to track the motion of the ball and calculate where they need to be to catch it; they are also constantly talking to cameras positioned around the room to help them precisely locate every moving object.

The algorithms developed in this Flying Machine Arena are so sophisticated that these quadcopters can balance a long stick on its end and throw it from one quadcopter to another without dropping it. Or hold a net stretched between three quadcopters and co-ordinate their movements to toss a ball in the net into the air and catch it. Even at the 200 frames a second that the quadcopters update their position data, these manoeuvres happen too quickly to precisely calculate the required motor inputs in real time. To get around this, they utilise learning algorithms that refine the sequence from one attempt to the next, so the quadcopters get the manoeuvres more accurate on each iteration.
Drones don’t necessarily need four propellers. The Sprite uses contra-rotating coaxial rotors and steers using counterweights.

1,218 drones lit up the sky during the 2018 Winter Olympic Games, setting a world record for most drones flown simultaneously.

Drones and UAVs now are like the worldwide web was 20 years ago - the technology is there and we just need to figure out interesting things to do with it. There are new drones looking for start-up cash on popular crowd-funding websites like Kickstarter, with designs from indoor ping-pong ball bombers to fully autonomous selfie drones and underwater drones for fishing. Ten years ago, most people didn’t think they needed a smartphone and now we all have one, so who knows what the next five years could bring. If Apple decides to make an iDrone, it could end up being almost as ubiquitous as that.

**BOMB DISPOSAL FROM THE SKY**
Imaging company Arch Aerial is using infrared laser ‘LiDAR’ to look for unexploded bombs left over from the Vietnam War in Laos. Multirotor drones can see through the dense jungle foliage to discover old craters and bunkers.

**DRONES AND UAVS NOW ARE LIKE THE WORLD WIDE WEB WAS 20 YEARS AGO - THE TECHNOLOGY IS THERE AND WE JUST NEED TO FIGURE OUT INTERESTING THINGS TO DO WITH IT**
THE FLYING CAR

Meet the Ehang - your personal taxi drone

The dream of having your very own flying car might not have come true just yet, but if Chinese company Ehang has anything to do with it, you won’t be waiting much longer. Its Ehang 184 is a personal drone that will fly you around autonomously – all you have to do is tell it where you want to go, sit back, and relax. The drone is designed for one person, and in theory will work a little like an Uber. Open an app and order an Ehang to see a drone land nearby. You can climb in, tap on the tablet in the cockpit, and the drone will take off. Don’t expect it to take you across the country, though – the 184 will be designed for short trips lasting around 20 minutes in total before needing to recharge. While you fly, a tablet in the cockpit will let you monitor your journey, and enjoy entertainment, just like on an aeroplane.

Ehang claims that the drone will take just a few hours to recharge, and travel at an average of 100 kilometres per hour, but there are several hurdles to overcome before these lofty ambitions can be met. One of the biggest will be to work with aviation authorities to define a new category of flying licence, meaning it will need to pass strict safety tests. Still, it means we’re edging closer to a future with flying cars. We can’t wait!

INSIDE THE EHANG 184

How will this autonomous personal drone actually work?

**Eight motors**
To carry the weight of the passenger, the eight motors will provide 106 kilowatts of energy.

**OPEN AN APP, ORDER AN EHang AND A DRONE WILL LAND NEARBY**

**Power banks**
The power banks and computer systems are stored underneath the drone, under the passenger’s seat.

**You will be able to monitor your route, the climate controls and even more from the built-in tablet**

**Charge it up**
The company claims that the drone will charge in two to four hours, and offer over 20 minutes of flight time from a charge.
The custom-designed interior will feature a tablet interface.

- **Sensors**
  The drone is designed to avoid obstacles automatically using sensors around the nose.

- **Take control**
  The tablet in the cockpit can be used to set destinations, monitor your route, or just chill out with some music.

- **Passenger seat**
  The drone is designed for a single passenger in this sports car-style seat within the cockpit.

- **Baggage area**
  There is a small luggage area at the rear of the cabin that can be used for storage.

- **Fail-safes**
  The drone is designed to be fail-safe, so if one power system fails, the vehicle can still operate to land safely.

- **Weight limits**
  The drone is designed to carry loads of up to 100 kilograms and will fly at altitudes of under 500 metres at all times.

- **Two rotors are housed at the end of each of the four arms.**
THE FUTURE OF DRONES

Companion drone
A colour-matched drone can be used from the car to live stream your drive or go and knock on someone’s front door while you keep the engine running.

Drone-launching pad
As if having a built-in launchpad for a drone wasn’t enough, you can control the 12,000 LEDs in the launch pad to display whatever you like, such as a company logo or a warning alert.

THE RINSPEED ETOS IS A SELF-DRIVING HYBRID WITH ITS OWN DRONE

If you’re eager to stand out in the morning commute then you can’t do much better than the Rinspeed Etos, a jaw-dropping concept car that made its worldwide debut at CES in January 2016. Chief among the vehicle’s most notable features is the drone-launching pad around the back of the car: its makers say that you could use the bundled drone for anything from filming your road trip to fetching a bouquet of flowers from a nearby store.

Oh, did we mention it’s driverless too? The Rinspeed Etos is designed to eventually operate with complete autonomy, with a foldable steering wheel that you can stow out of sight when you want the computer to take over and watch the road for you. Passengers are then moved closer to the windshield for a better view.

Self-driving motors are still a long way from being legal, of course, but we were lucky to get a glimpse of this inspired concept car at CES.

Rinspeed boss Frank M. Rinderknecht, the Swiss visionary behind the car, says he wants to explore the future of digital automotive engineering with the Etos, in concept form at least. The Harman-powered software system acts “just like a personal assistant”. According to Rinspeed: “The system operates in a thinking, courteous and anticipatory manner. In addition, it delivers perfect entertainment, connectivity and maximum safety.”

Superb safety and entertainment technologies are all well and good, but in the Rinspeed you’ll be spending most of your time playing with the open glass behind the wheel.

Where have I seen this before?

Self-driving car
Tech and auto manufacturers are falling over themselves to develop self-driving car technology. Google and Nissan are two of the biggest names working on getting the hardware and software ready for public use.
Gorilla Glass roof
Both the glass roof and drone pad are made from Corning Gorilla Glass, the same material that’s used in smartphone screens because it’s especially strong, but still thin and lightweight.

Panoramic views
The Etos is covered in eight HD cameras to provide you with ISO-degree display when driving and compensate for blind spots in your rear mirror.

Pay as you go
Paying using your iPhone was just the beginning. The Etos automatically pays to park via NFC and can be used to pay small amounts, such as tips, using a swiping gesture on the wing mirror.

Shifting interior
When you’re in autonomous driving mode, the steering wheel retracts into the dashboard so you have more room. The widescreen monitors can also be adjusted so you can sit back and watch videos.

Intelligent assistant
The intelligent Harman-powered car dashboard is designed to respond to your needs whether you’re driving or letting the software do it for you. It’s like Siri for your car.

Eye-tracking camera
When you’re driving, the Etos will track your eye movements and alert you when it thinks you haven’t seen an upcoming obstacle.

Intelligent assistant
The Etos is not the first car to offer a built-in PA. A version of Apple’s Siri known as CarPlay has been rolling out in cars like the Ferrari FF and Mercedes-Benz C-Class since 2014. Google also offers Android Auto.

Hybrid engine
Under the custom bodywork of the Rinspeed Etos lies the carbon-fibre framework of the BMW i8, a hybrid supercar. Able to go from 0 to 60mph in 4.4 seconds, the i8’s average fuel consumption rating is 134.5mpg and CO2 is 49g/km.

Personal drone
As drones become more powerful and less expensive, they’re starting to be seen as mainstream gadgets, with one million expected to be sold last Christmas in the US alone. The Rinspeed Etos drone is made by DJI.
If you’re looking to take things to the next level, this section will show you how to code, program and control your drone in exciting new ways.

142 **Program a Raspberry Pi quadcopter**
Discover how this mini-computer can help you build and program your very own drone.

148 **Program a drone’s flight path**
Code a set path for your drone and explore the world of autonomy.

152 **Control your drone with a joypad**
Connect your drone to a PC and navigate it during flight using a simple joypad.

156 **Underwater Pi drone**
Find out what it takes to make a fully functional, submersible, Raspberry Pi-powered drone.

158 **Build a self-driving RC car**
Is this remote control car Google’s latest competitor?
The Raspberry Pi is a fantastic piece of kit. The possibilities it offers are virtually endless, including taking your skills and programming a quadcopter.

Kits are available as ready-to-fly (RTF) if you just want the joy of flight, but where’s the challenge in that? We started with an almost-ready-to-fly (ARF) kit – the DJI Flame Wheel F450 – all the hardware, but none of the control electronics or software. Many enthusiasts have created DIY quadcopters using Arduino microcontrollers, so we knew a DIY build was possible, but very few, if any, have successfully used the Raspberry Pi.

This article uses the Python code that can be found here http://pastebln.com/dDzLxYQ as a guide through what’s needed to build a quadcopter, metaphorically bolting it together so that by the end, you don’t just understand the code but also the interaction with the real-world to enable you to build your own quadcopter with confidence.

As you read the article, you can follow the corresponding code by searching for an equivalent tag comment; for example, to find the code related to the ‘# Angles’ section of the article, you will simply need to search the code for ‘# Angles’.
**Propulsion**
Here we're seeing the force from the propellers

**Vectors**
Propeller force relative to Earth's axis (horizontal/vertical)

**Gravity**
This term denotes the force of gravity

**Angle**
This is the angle of tilt as defined by the quads sensors

---

a_q = gravitational acceleration
a_q = quadcopter acceleration
a_{qx} = a_q (reoriented to Earth's axes)
a_{qy} = a_q (reoriented to Earth's axes)
θ = angle of tilt derived from accel + gyro

a_{qz} = tan θ
for horizontal flight
a_{qy} = g =>
horizontal accel a_{qx} = g + a

---

**How Sensors in the Quadcopter Point of View Are Converted to the Earth (Horizontal/Vertical) Viewpoint to Provide Horizontal Motion**

---

# Interpreter
The command interpreter converts a series of commands either from a radio control or programmed into the code itself. The commands combine the direction and speed compared to the horizon that the user want the quadcopter to follow. The code converts these commands into a series of targets for vertical speed, horizontal speed and yaw speed — any command from a pair of joysticks can be broken down into a set of these targets.

# Inputs
The inputs to the quadcopter come from a series of electronic sensors providing information about its movement in the air. The main two are an accelerometer which measures acceleration force (including gravity) in the three axes of the quadcopter, and a gyroscope which measures the angular speed with which the quadcopter is pitching (nose/tail up and down), rolling (left/right side up and down), and yawing (spinning clockwise and anticlockwise around the central axis of the quadcopter itself).

# Axes
The accelerometer is relative to the orientation of quadcopter axes, but the command targets are relative to the Earth's axes — the horizon and gravity. To convert the sensor output between the quadcopter axes and the Earth axes needs a little trigonometry and knowledge of the tilt angles in pitch and roll axes of the quadcopter with respect to the Earth.

# Angles
Both the accelerometer and gyro can provide this angle information, but both have flaws. The accelerometer output can be used to calculate the angle by using the Euler algorithm. However, the accelerometer output is plagued by noise from the motors/propellers, meaning a single reading can be hugely inaccurate; on the plus side, the average reading remains accurate over time.

In contrast, the gyro output does not suffer from the noise, but since it is the angular speed being measured, it needs to be integrated over time to find the absolute angle of the
The angle PID takes the desired tilt angle from the horizontal speed PID and feedback from the gyro and the accelerometer combined to produce the tilt angle feedback. This results in the required angular speed.

The angular speed PID takes the required angle out, with feedback from the gyro to apply power to the motors. This produces the required tilt and horizontal movement.

The PID outputs are applied appropriately to each propeller ESC to effect the change defined by the proceeding commands.

The yaw PIDs are used to ensure the quadcopter doesn't rotate its Z-axis while in flight.

The horizontal speed PID takes movement commands and feedback from integrated gyro sensors to define the desired tilt and angle to achieve the required speed.

The vertical speed PID directly controls the desired rate of climb or descent with feedback from integrating Z-axis accelerometer data.

The PID outputs are applied appropriately to each propeller ESC to effect the change defined by the proceeding commands.

The yaw PIDs are used to ensure the quadcopter doesn't rotate its Z-axis while in flight.

# FILTER

Although independently they are both flawed, they can be merged mathematically such that each compensates for the flaws in the other, resulting in a noise-free, long-term accurate reading. There are many versions of these mathematical noise/drift filters. The best common one is by Kalman; the one we’ve chosen is slightly less accurate, but easier to understand and therefore to code: the complementary filter.

Now with an accurate angle in hand, it’s possible to convert accelerometer sensor data to inputs relative to the Earth’s axes and work out how fast the quadcopter is moving up, down, left, right and forwards and backwards compared to the targets that have been set.

# PIDs

So we now have a target for what we want the quadcopter to do, and an input for what it’s doing, and some motors to close the gap between the two; all we need now is a way to join all of these together conclusively. A direct mathematical algorithm is nigh-on impossible – accurate weight of the quadcopter, power per rotation of each blade, weight imbalance and so forth would need to be incorporated into the equation. And yet none of these factors are stable: during flights (and crashes!), blades get damaged, batteries move in the frame, grass, mud and moisture change the weight of the quadcopter, while humidity and altitude would also need to be accounted for. Hopefully it’s clear this approach simply won’t fly.

Instead, an estimation method is used with feedback from the sensors to fine-tune that estimate. Because the estimation/feedback code loop spins at over 100 times a second, this approach can react to ‘errors’ very quickly.
indeed, and yet it knows nothing about all the factors which it is compensating for — that’s all handled blindly by the feedback; this is the PID algorithm.

It takes the target, subtracts the feedback input, resulting in the error. The error is then processed via a Proportional, Integral and a Differential algorithm to produce the output.

# BLENDER
The outputs are applied to each ESC in turn: the vertical speed output is applied equally to all blades; the pitch rate output is split 50/50 subtracting from the front blades and adding to the back, producing the pitch. Roll is handled similarly. Yaw too is handled in a similar way, but applied to diagonal blades which spin in the same direction.

These ESC-specific outputs are then converted to a PWM signal to feed to the hardware ESCs with the updated propeller/motor speeds.

CODE AND REALITY
In this code, there are nine PIDs in total. In the horizontal plane, for both the X and Y axes, the horizontal speed PID converts the user-defined desired speed to required horizontal acceleration/angle of tilt; the angles PID then converts this desired tilt angle to desired tilt rate which the rotation speed PID converts to changes in motors speeds fed to the front/back or left/right motors for pitch/roll respectively.

In the vertical direction, a single PID converts the desired rate of ascent/descent to the acceleration output applied to each plate equally.

Finally, prevention of yaw (like a spinning top) uses two PIDs — one to set the desired angle of yaw, set to 0, and one to set the yaw rotation speed. The output of these is fed to the diagonally opposing motors which spin in the same direction.

The most critical of the nine are pitch/roll/yaw stability. These ensure that whatever other requirements enforced by other PIDs and external factors, the quadcopter is stable in achieving those other targets; without this stability, the rest of the PIDs cannot work. Pitch is controlled by relative speed differences between the front and back propellers; roll by left and right differences, and yaw by clockwise/anticlockwise differences from the corresponding PIDs’ outputs. The net outputs of all three PIDs are then applied to the appropriate combination of motors’ PWM channels to set the individual pulse widths.

With stability assured, some level of take-off, hover and landing can be achieved using the vertical speed PID. Placing

“Both the accelerometer and gyro can provide the angle information, but both have flaws”
"A quadcopter in a headwind will drift backwards due to the force applied by the wind"

the quadcopter on a horizontal surface, set the target to 0.5 m/s and off she zooms into the air, while the stability PID ensures that the horizontal attitude on take-off is maintained throughout the short flight, hover and landing.

Up to this stage, the PIDs are independent. But what about for horizontal movement target, and suppression of drifting in the wind? Taking the drift suppression first, a quadcopter in a headwind will drift backwards due to the force applied by the wind. To compensate, it must tilt nose down at some angle so that some of the propellers' thrust is applied horizontally to counteract the wind. In doing so, some of the power keeping the 'copter hovering at a fixed height is now battling the wind; unless the overall power is increased, the 'copter will start descending.

Horizontal movement is more complex still. The target is to move forwards at say 1 metre per second. Initially the requirement is similar to the headwind compensation – nose down plus increased power will apply a forward force leading to forward acceleration. But once that horizontal speed is attained, the quadcopter needs to level off to stop the acceleration, but at the same time, friction in the air will slow the movement. So there's a dynamic tilting fore/aft to maintain this stable forward velocity.

Both wind-drift suppression and controlled horizontal movement use nested PIDs; the X and Y axes horizontal speed PIDs' outputs are used as the pitch and roll angle PIDs targets; their output feeds the pitch and roll rate PIDs to ensure stability while meeting those angular targets. The sensor feedback ensures that as the desired horizontal speed is approached, the horizontal speed PID errors shrink, reducing the targets for the angular pitch PID, thus bringing the quadcopters nose back up to horizontal again.

Understanding quadcopters...

Although this article focuses on software, a basic background in the hardware from the kit is necessary to provide context. A quadcopter has four propellers (hence the name) pointing upwards to the sky, each attached to its own brushless DC motor at one of the four corners of (usually) a square frame. Two motors spin clockwise, two anticlockwise, to minimise angular momentum of the quadcopter in flight.

Each motor is driven independently by an electronic speed controller (ESC). The motors themselves have three sets of coils (phases), and the ESCs convert a pulse-width-modulation (PWM) control signal from software/hardware to the three phase high-current output to drive the motors at a speed determined by the control signal.

The power for the ESCs and everything else on the system comes from a Lithium Polymer battery (LiPo) rated at 12V, 3300mA with peak surge current of 100A – herein lies the power!
Propellers
The propellers are set diagonally to the x, y axes, and rotate as shown to reduce yaw (rotation about the z-axis).

Orientation
The overall orientation of the quadcopter depicting front, back, left and right in relation to the sensor and propeller layouts.

Sensors
The quadcopters’ sensors report data according to these x, y and z axes.

EXPERIMENTATION AND TUNING
While the code accurately reflects everything we’ve described here, there’s one critical set of steps which can only be found through live testing; these are the PID gains. For each PID running, there is an independent Proportional, Integral and Differential gain that can only be found with estimation/experimentation. The results for every quadcopter will be different. Luckily there is a relatively safe way to proceed.

First, find the PWM take-off speed: this is done by sitting your quadcopter on the ground and slowly increasing the PWM value until she starts looking light-footed – for your expert, this was about the 1590us pulse width (or 1000us + 590us, as shown in the code).

Next, sorting out the stability PIDs – assuming your quadcopter is square and its balance is roughly central, then the result of pitch tuning also applies to yaw tuning. For pitch tuning, disable two diagonally opposed motors and rest these on a surface – the quadcopter sits horizontal in between. Power up the dangling motors’ PWM to just under take-off speed (1550us pulse width in our expert’s case). Does the quad rock manically, wobble in some pretense of control, self-right when nudged, or do nothing? Tweak the P gain accordingly. Once P gain is good, add a touch of I gain – this will ensure return to 0 as well as stability. D gain is optional, but adds firmness and crisp response. Tapping a D-gain stable quad is like knocking on a table – it doesn’t move.

Vertical speed PID can be guesstimated. 1590us is taking off; desired take-off speed is 0.5m/s so a P gain of 100 is okay. No I or D gain needed.

With that a real take-off, hover and landing are safe, which is good as these are the only way to tune the directional PIDs. Just be cautious here – excessive gains lead to quadcopters slamming into walls or performing somersaults in mid-air before overpowering themselves into the ground. Best executed outside in a large open field/garden/park where the ground is soft after overnight rain!

There isn’t a shortcut to this, so just accept there will be crashes and damage and enjoy the carnage as best you can! Assuming all the above has gone to plan, then you have a quadcopter that takes off, hovers and lands even in breezy conditions.
When you really get down to the core process of controlling a drone, it can get a little boring. A button you press relates to a specific bit of code, which then sends a specific signal to the drone. This can translate to ‘make rotor two go faster’ on a quadcopter to rotate or bank the craft slightly.

While that might take away from the fun of actually flying the drone, it does open up many possibilities. How can you tap into that code and fly it yourself more manually? What are the limits of what you can do when not restricted to the controls given to you?

Luckily, some very clever people have thought about this and created modules for the programming language Python; modules that you can then use to control an AR.Drone.

We’ll show you how to use this code to program the drone with your own preconceived flight plan. It will involve a bit of trial and error, but once you have it sorted, it will be a great party piece or a slightly creepy house patrol bot.
For this tutorial, we’re going to be using the python-ardrone module created specifically to program drones using Python. It’s available for free from popular code-sharing website GitHub, and you can download it from this link: github.com/venthur/python-ardrone.

Click the Download ZIP button to do just that, and download it to a new folder which we’ll use to organise the files in this project. Unzip it directly into this folder so that all the files are visible and not in another folder within this folder.

If you don’t have it installed already, you will now need to install Python 2 so you can actually run and test the code. Head to the download page on the Python website (www.python.org/downloads/) and follow the instructions on how to install it on your current system. We’ll be making use of IDLE, the Python development environment that lets you test and run code. You’ll also need to install Pygame (www.pygame.org) for some of the tests we’re going to run; however, we’re not going to make proper use of it in this specific programming tutorial.

Open up IDLE when everything is installed and you’ll get the ‘Python Shell’: this allows you to run lines of Python code, and test Python programs that you’ve written. Go to File>New to open a new script, and save it in the project folder created earlier as ‘route.py’.

Before we start coding and testing, it’s worth actually making sure your quadcopter will fly using this code. You’ll first want to connect to it via Wi-Fi on your PC, so hit the Wi-Fi Sync button on your AR.Drone and connect to it with your computer’s Wi-Fi manager. You would normally do this to upgrade firmware and software; however, the connection still works the same as it does on a phone, and signals to control it can be sent back and forth.

Once connected, go back to IDLE and click on File>Open and navigate to our project folder. From there, select demo.py and it will open up some code that makes use of the library by allowing you to control your drone using your keyboard, while also displaying a feed from the camera. Press F5 to run the code, and then you can use the following commands to control it:

<table>
<thead>
<tr>
<th>Command</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>RETURN</td>
<td>- takeoff</td>
</tr>
<tr>
<td>SPACE</td>
<td>- land</td>
</tr>
<tr>
<td>BACKSPACE</td>
<td>- reset (from emergency)</td>
</tr>
<tr>
<td>A/D</td>
<td>- left/right</td>
</tr>
<tr>
<td>W/S</td>
<td>- forward/back</td>
</tr>
<tr>
<td>1-0</td>
<td>- speed</td>
</tr>
<tr>
<td>UP/DOWN</td>
<td>- altitude</td>
</tr>
<tr>
<td>LEFT/RIGHT</td>
<td>- turn left/right</td>
</tr>
</tbody>
</table>
We've written our code so that we give the drone a fixed movement depending on a number of cycles we put it through. However, the drone does return navigation data based on its position. With enough experimenting and testing of locations, you can set up a 'while' loop where the drone will move to a certain position - give this a try as your next project.

“The drone will take off, rise in height a little, then fly a complete square around an area”

Let’s build a basic script that will show how to use the module. In the blank route.py document, enter the following:

```python
import libardrone

drone = libardrone.ARDrone()
drone.takeoff()
drone.hover()
drone.land()
drone.halt()
```

Run this code using F5. As you might expect from browsing the code, the quadcopter will take off, hover for a moment, and then land again. Let’s break down exactly what each step is doing, though...

We first use the ‘import libardrone’ line to tell Python we want to use libardrone.py. Normally, an imported module would have to be installed into Python, but if it’s not, Python will look in the directory where route.py lives; this is why we put it there in the first place.

All the control code from drone is kept under the ‘class’ ARDrone in the libardrone file. To make it easier to type out, we’ve created the shortcut ‘drone’ to point towards this class whenever we want to use a function from within it.

The takeoff, hover and land commands are exactly as you’d think – they execute the takeoff function, the hover function and then the land function. It will do this quite quickly, which we’ll talk about in a bit. The halt command tells the drone that we’ve stopped commanding it for the moment.

For our little route, we’re going to make something very simple: the drone will take off, rise in height a little, then fly a complete square around an area. We’ll have it rotate left and right on the top-left corner, and do a full 360 on the top right. Refer to the diagram above for a better visualisation of what we mean.

Once you’ve understood what we plan to do, it’s time to plan out our code. How can we make it do a circle or even a full 360 when it will only perform the turn commands for a moment? For this we will use the bit of code:

```python
for i in range(x)
```

...where x is the number of times you want it to repeat a function. If you refer to our full code listing, you can see how we’ve used it. For example, for the first move left we’ve done:
import libardrone

def main():
    drone = libardrone.ARDrone()

    # set initial speed
    drone.speed = 0.5

    # take off
    drone.takeoff()

    # go higher
    drone.move_up()

    # go left a way
    for i in range(5):
        drone.move_left()

    # go forward
    for i in range(5):
        drone.move_forward()

    # turn the drone to move the camera
    for i in range(3):
        drone.turn_right()

    # turn it back to move
    for i in range(3):
        drone.turn_left()

    # go right to complete a square
    for i in range(10):
        drone.move_right()

    # full 360
    for i in range(10):
        drone.turn_left()

    # return to start
    for i in range(5):
        drone.move_left()
        drone.move_backwards()

    # land the drone
    drone.land()

    print "I have landed. I hope you enjoyed the flight. I will now shutdown"

    drone.halt()

if __name__ == '__main__':
    main()
CONTROL YOUR DRONE WITH A JOYPAD
CONTROL YOUR DRONE WITH A JOYPAD

CONNECT A DRONE UP TO YOUR PC AND CONTROL IT WITH A CUSTOM PIECE OF CODE AND A JOYPAD

Controlling drones is usually reserved for the apparatus they're designed for — the AR.Drone requires your iPhone; others will have their own dedicated remote controller etc. As we discussed in the tutorial to create a custom flight path for your drone, these are all controlled by electronic signals.

These signals can be used along with some specific Python modules and purpose-built code to create a custom program that allows manual control of an AR.Drone via a more traditional control pad — the kind you get with a PlayStation or the cheap USB one you may have purchased from Amazon.

Not only can we create a custom control interface, but we can also patch in the video feed from the camera to aid with flying, making it much more advanced than how the route was plotted. We'll be doing this entirely in Python, and it will require a little trial and error to get everything working for your exact setup; however, it's worth it as it will open up a new way to control your drone.

To prepare for coding this project, we're going to need to set up a system to be able to handle what we have planned. If you've already done the route programming tutorial, you won't need to do much more setup-wise; follow along in the setup just to make sure everything you needed was installed. The first thing we need to install is Python itself to your system; find installation instructions for your operating system on the Python website (www.python.org/downloads). We're specifically using Python 2 in this tutorial, so make sure that if Python 3 is already on your system, you write and test your code in the correct version of IDLE.

The two main modules we'll be using are python-ardrone and Pygame. The python-ardrone code allows us to control the drone with simple Python code, whereas we can use Pygame to recognise joystick inputs and display the camera feed. Marrying them together is quite simple once you know how.

First of all, make sure to install Pygame, instructions for which can be found on the module's website (www.pygame.org). Once that's done, head over to the python-ardrone site here: github.com/venthur/python-ardrone.

Use the Download ZIP button on the right and download it to a new project folder, unzipping the files to that folder. You can also optionally install Psyco (psyco.sourceforge.net), which will aid in transcoding the video stream from the drone; however, it's not necessary.

Once it's all set up, launch IDLE (the Python development environment we'll be using to program the drone) and go to File>Open. Navigate to the project folder and open the demo.py file. We'll be using this to test to make sure everything works, but first we need to connect the AR.Drone to your computer.

You connect as you would your phone, or if you were connecting your computer to perform a firmware update, can use Pysame to recognise it.

“We can use Pygame to recognise joystick inputs and display the camera feed”
CONTROL YOUR DRONE WITH A JOYPAD

Full Code Listing

```python
import pygame
import libardrone

def main():
    pygame.init()
    W, H = 320, 240
    screen = pygame.display.set_mode((W, H))
    drone = libardrone.ARDroneQ
    clock = pygame.time.Clock()
    pygame.joystick.init()
    joystick = pygame.joystick.Joystick(0)
    joystick.init()
    drone_speed = 0.3
    running = True
    while running:
        for event in pygame.event.get():
            if event.type == pygame.QUIT:
                running = False
            elif event.type == pygame.JOYBUTTONDOWN:
                drone.hover()
            elif event.type == pygame.JOYBUTTONUP:
                drone.reset()
                running = False
            elif joystick.get_button(0) == 1:
                drone.takeoff()
                drone_speed = 0.3
            elif joystick.get_button(1) == 1:
                drone.land()
                drone_speed = 0.3
            elif joystick.get_button(2) == 1:
                drone.move_up()
            elif joystick.get_button(3) == 1:
                drone.move_down()
            elif joystick.get_button(4) == 1:
                drone.turn_left()
            elif joystick.get_button(5) == 1:
                drone.turn_right()
            elif joystick.get_button(6) == 1:
                drone.pitch() # speed
            elif drone.speed < 1:
                drone.speed += 0.1
                drone.speed = drone_speed
            elif drone.speed > 0.1:
                drone.speed -= 0.1
                drone.speed = drone_speed
            else:
                drone.pitch()
                drone.yaw()
                drone.roll()
                drone.pitch()
                drone.yaw()
                drone.roll()
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Connecting a controller
Depending on what system you're running and what controller you're using, you may have to install extra software for specific joypads. Xbox pads work just fine on Windows, but need to be installed elsewhere, whereas PlayStation pads can require extra software on Windows but are fine on Linux. Most standard USB pads will be fine, though – make sure to Google your controller if you're not sure.

Takeoff
Land
Move left
Move right
Move up
Move down
Move forward
Move backward
Rotate left (counter-clockwise)
Rotate right (clockwise)
Reset (emergency stop, basically)
Increase speed
Decrease speed

Exit the window to stop the program, and add our full code listing into another new Python file, this time called control.py.

First, we call the modules we're using. Pygame is installed to the system, so we can import it and it'll know where to look for it automatically. We've put libardrone into the same folder as control.py, so even though it's not installed, we can make use of it. We then start our main function `def main()`. Here we tell it to create an instance of Pygame, set a small window size (to save on processing and power) and create the window to that size. We then set everything else up: initialise the drone code, get the time for our display, start the joystick code, recognise which joystick to use and set an initial speed of 30 per cent.

We then begin a massive 'while' loop that continually checks the inputs on the controller to see what's been pressed and, in our case, what axes have been moved. We first of all set it so that when there are no other buttons pressed, the drone will automatically hover in place – however, it will still maintain its height even when you rotate it or increase speed while not moving. Each 'if' statement checks the state of the button: 0 is off and 1 is on. Therefore, if the value it sends back is 1, it activates the specific function of the drone module. If button 5 is depressed, for example, it runs drone.move_down() to make the drone descend. Make sure to update all the button numbers with the ones you made a note of earlier.

You may notice that the speed code is handled slightly differently to the rest. It increases the value as long as it's below the maximum, and decreases it when it's above the minimum. This allows for a bit more control of the speed. When a change in the axis is detected by the code, it will check to see if it's the movement axis we found out earlier. This is currently set up for digital control, but if you're having trouble getting a 1 value out of an analogue stick, switch out the `= 1` argument to `> 0.3` or something. Play around to see what best suits your control style.

Finally, it grabs a lot of data and the camera picture from the drone and displays a frame each cycle of the while loop code. This may be slower to update than full video, but it will create a stream of decent enough frame rate to use while flying.

We end the program by allowing the code to disconnect and turn the drone off, and put a statement to start the code on the 'main' function we built (full code at pastebin.com/4uSK2wxyG).

With further modifications, you can have it do a bit more, and work a lot better than the iPhone controls in general.

Full Code Listing (continued)

```python
if event.type == pygame.JOYAXISMOTION:
    # forward / backward
    if joystick.get_axis(0) == 1:
        drone.move_forward()
    elif joystick.get_axis(0) == -1:
        drone.move_backward()
    # left / right
    elif joystick.get_axis(1) == 1:
        drone.move_left()
    elif joystick.get_axis(1) == -1:
        drone.move_right()

    # speed
    # battery status
    hud_color = (255, 0, 0) if drone.navdata.get('drone_state', dict()).get('emergency_mask', 1) else (10, 10, 255)
    bat = drone.navdata.get(0, dict()).get('battery', 0)
    if bat:
        f = pygame.font.Font(None, 20)
        hud = f.render('Battery: %d%%' % bat, True, hud_color)
        screen.blit(hud, (10, 10))
    except:
        pass

    pygame.display.flip()
    clock.tick(50)
    pygame.display.set_caption('FPS: %.2f' % clock.get_fps())

print "I hope you enjoyed the flight. I will now shutdown"
    drone.halt()
if __name__ == '__main__':
    main()
```
**Joystick**
The ROV is controlled via a joystick connected to a laptop. The laptop runs a series of Python scripts, using PyGame to read the signals.

**3D-printed**
A few parts have been 3D-printed, as it proved to be the easiest way to tailor the propellers to the exact size and shape needed.

**Pi**
The GPIOs are used to help control the four main motors that power the ROV. The Raspberry Pi also relays information back to the server.

**Components list**
- Raspberry Pi B+
- Tilt, roll, pressure and temperature sensors
- 3D-printed camera tilt and propellers
- Camera module
- USB joystick control
- Ethernet cable

**Video**
For the time being, Niels has fitted a GoPro Hero to the front of the ROV for recording purposes. A live video stream is fed to the laptop.

- Pressure sensor data is relayed from the ROV to the laptop as the vehicle dives deeper.
- The camera module is sealed behind a waterproof lens on the front of the ROV.
How are the inner components of the ROV kept safe from water damage? Since the Nineties, a lot has changed in the world of RC models. There are now LiPo batteries that give much more energy and power, and brushless outrunner motors that can run submerged in water, making moving parts through the hull unnecessary — this is the key development that makes the chance on leakage very small. The end closure is tightened by external water pressure and happens to be extremely reliable. A lot of the information and lessons I had learned are found on openrov.com, sseeker.com, raspberrypi.org and many other sites with forums about Linux and Raspberry Pi.

How long has the development of the ROV taken? Were there any problems? When I started in December, I had a lot of stuff to learn and decided that purchasing a low-cost driver was where I should start. I opted for a Raspberry Pi instead of the BeagleBoard used by Openrov, or an Arduino board. I had previously learned a little Linux from the workstation my company bought to do stress calculations (using our finite element program ANSYS). We also use Linux to improve daily interaction with third-party software, doing batch runs and fatigue calculations on steel pipelines. For all the functions on this ROV, there are so many options that I always face new challenges; this is what makes this project so interesting.

What role does the Raspberry Pi play in powering the submersible drone? The ROV is controlled with a joystick connected to a laptop. The laptop runs Python scripts, and with PyGame I can read the signals from the joystick. The signals are then translated into servo commands and sent to the Raspberry Pi via a simple socket connection. The Raspberry Pi is the brain of the ROV; it communicates with the surface laptop via Ethernet. Thanks to the OpenROV project, I learnt to implement a Tenda home plug, which reduces the communication lines from four to two wires, increases the reach from about 50 metres with a submerged CAT5 to 300 metres, and makes the signal much less susceptible to noise.

A battery-powered Wi-Fi router (bought for €1 at the local recycling store) then sends the signal to my laptop. The advantage of the Wi-Fi router is that I can attach it to a reel, avoiding the use of sliding contacts. It also reduces tripping risks on shore. The Wi-Fi router can be mounted on a buoy so that the ROV can be launched from a boat. Signals from the ROV are communicated via a web interface, the same way as OpenROV. All sensor data is written to a MySQL database and an Ajax script reads the data out and presents it on a web page. This web page also presents the live video feed from the camera of the ROV. Currently I’m using a RasPi cam, but I have ordered the USB camera used by OpenROV to improve the images.

The GPIO (General Purpose Input and Output) of the Pi is used to control the standard ESC (Electronic Speed Controller) of the four motors by PWM (Pulse Width Modulation), the tilts servos of the camera, relays for the lights, and server communication. Although the Pi now has many libraries for popular sensors, I still need an Arduino to communicate with the depth sensor (MS58Q3-5). This Arduino is connected via the USB of the Pi and its analogue port is used to measure the voltage of the battery (using two resistors in series to drop the voltage to a safe 2-3V).

Since there is little space inside the ROV, the standard (USB) power connection on the side cannot be used. Therefore I inject power via the GPIO board at the 5V pin. This isn’t a fused connection, imposing some risk, but it has worked perfectly for me.

How deep can the ROV currently travel? The tested depth is 13 metres. I took it down to a lake without the electronics and lowered it packed with lead. The collapse pressure determines the maximum depth of the ROV. I design offshore pipelines at INTECSEA and collapse pressure calculations are my everyday work. I made a simple finite element model of the ROV and applied external pressure to see how it would behave. Currently the 6mm-thick end caps are the bottleneck. At 30-40 metres they deflect so much that I anticipate they can start tearing. The lakes in the Netherlands are normally a few metres deep, at a few places 15-25 metres. Even the North Sea here is only 20-30 metres deep, so extending the depth limit has not been my priority.
**Camera**
The camera module is the focal point for object detection. Input data is collated then put through a client program running on the Pi.

**Ultrasonic sensor**
This senses angles and surface conditions to determine the stopping distance relative to an oncoming object.

**Arduino**
This simulates the button presses of the RC car controller. Four pins connect to pins on the controller, for forward, reverse, left and right.

**Components list**
- Raspberry Pi B+
- Arduino
- Camera module
- HC-SR04 ultrasonic sensor
- OpenCV

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*Above:* Once an object is detected, the ultrasonic sensor relays this information and helps the RC car come to a stop.

*Right:* The Arduino board simulates button presses, helping the RC car drive on its own.
Where did the idea to develop a self-driving car first come from?
Believe it or not, I actually did this for a school project. A lot of my interests centre around machine learning, so I decided to do something that heavily involves machine learning and the concepts that surround it. I did some research online and found a very inspiring self-driving car project made by David Singleton, which showcased what he was able to achieve with just an Arduino board and a few other items. I was amazed to see that the RC car can drive itself along the track without aid and wondered if I could replicate a similar project.

After that, I took out my Raspberry Pi and made up my mind to attempt to build my own self-driving RC car that could do even more. The aim was to include things like front collision avoidance, stop sign and traffic light detection. It took me a while to develop the project to anything more than an idea, just because there are so many factors that needed to be considered.

Could you give us an overview of how the self-driving system works?
The crux of the system consists of three subsystems that work seamlessly in sync together. These systems consist of an input unit for controlling the camera and ultrasonic sensor, a processing unit and also the main remote control car control unit.

Firstly, live video and ultrasonic sensor data are streamed directly from the Raspberry Pi to the computer via a strong Wi-Fi connection. I was quick to recognise that it was imperative to create as little latency as possible in the streaming, so in order to achieve these goals, the video resolution is dramatically scaled down to QVGA (320x240). It provides that smooth streaming experience that I was after. The next step is for the colour images received on the computer to be converted into greyscale and then fed into a pertained neural network to make predictions for the car; so whether it should go straight ahead, or make a left or right turn at the correct moment. These same images are used to calculate the stopping distance between the car and the stop signs, while the Raspberry Pi alerts the system of the distance to an upcoming obstacle. The object detection in this project is primarily learning based.

The final part of the system consists of outputs from the artificial neural network that are sent to the Arduino via USB, which is connected directly to the RC controller. The Arduino reads the commands and writes out LOW or HIGH signals, simulating button-press actions to drive the RC car. With so many sensors and data feeds consistently taking place, there was a lot of initial trial and error involved, but it didn’t take me an overly long period of time to get the project running completely independently.

What sort of role did the Raspberry Pi play in the grand scheme of things for your self-driving car?
The main benefit of using the Raspberry Pi was that it’s the perfect piece of apparatus to help collect input data, which is a massive part of this project. With the Raspberry Pi in place, I connected a Pi camera module and an ultrasonic sensor, which work in tandem to help the Pi collate its data.

There are also two client programs running on the Raspberry Pi that help with the streaming side of things. One is solely for video streaming and the other is for the data streaming from the ultrasonic sensor. To be honest, I didn’t stray too far from the official Raspberry Pi documentation when using it, as all the guidelines for video streaming are all in there. When I needed some help with measuring distance with the ultrasonic sensor, there were some handy tutorials on the web for fellow enthusiasts to follow and there’s other reference material all over the place.

Can you tell us more about the ultrasonic sensor? Can it detect collisions at a full 360 degrees?
For this project, I chose to use the HC-S404 ultrasonic sensor, as it’s one of the most cost-effective and user-friendly pieces of kit on the market. It can be a bit fiddly to set up from scratch, but as I mentioned previously, I was able to source help from the internet whenever I had a problem that I needed solving. For this sensor in particular, the manual lists its best detection is within 30 degrees, which would seem about right based on the tests that I have run with it. There are numerous sensors on the market, so a complete 360-degree detection seems like something that would be plausible.
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