DRONES

FOR PROFESSIONALS

YOUR GUIDE TO UNMANNED AERIAL IMAGING DRONES AND THEIR BENEFITS

INDEX

Talking accuracy

GSD explained, relative versus absolute accuracy, and tips on working with ground control points.

Safety matters

Explore how a drone's weight affects its kinetic energy and what that means for the potential risk it poses to people and property.

EFFICIENCY FROM ABOVE

WHY PROFESSIONAL DRONE USE IS ON THE RISE

The use of professional civilian drones is increasing rapidly around the world and is expected to explode in the coming years.

Two key factors are driving this growth:

1. A growing awareness of the benefits that civilian drone technology can bring to a wide range of industries and non-commercial sectors.
2. The introduction of pragmatic, business-friendly drone legislation.

In the United States alone, according to the Association of Unmanned Vehicle Systems International (AUVSI), the economic impact of integrated UAS into the country's National Airspace System is expected to total more than US $82.1 billion in the decade from 2015 to 2025.

What benefits do drones provide?

Aerial imaging drones, such as senseFly UAVs or UAS, allow professionals to capture up-to-date, high-resolution and positionally accurate data — either in the simple form of the photos the drone acquires, or by automatically generating advanced data products from these photos, such as orthomosaics (also known as orthophotos), digital surface models (DSMs), 3D point clouds and more.

Using a drone as a tool to collect such imagery typically saves time and money over traditional methods of obtaining such data (see page 6), giving professionals access to the timely data they require to make better decisions and providing a quick return on their investment in the drone itself.

There are numerous fields in which such drones can add value and the number is continuing to grow, hand in hand with increasing cross-industry awareness of such solutions. These applications include:

Drone definitions

Your quick guide to unmanned aircraft terminology

Drone

Strictly defined as 'an unmanned aircraft or ship that can navigate autonomously, without human control or beyond line of sight' (source: Dictionary.com). Drone is increasingly used as a generic, catch-all phrase for any remotely guided aircraft system (including consumer products), whether autonomous or piloted manually.

Unmanned Aerial System (UAS)

Defined as an aircraft operated with no pilot on board, plus its associated elements (such as a ground station and communication link). This term is commonly used in N. America, e.g. by the Federal Aviation Administration (FAA), which defines 'small UAS' as those systems weighing up to 55 lbs.

Unmanned Aerial Vehicle (UAV)

The most commonly-used alternative to 'drone'. Used around the world, UAV refers to aircraft where the flying pilot is not on board (both autonomous/automatic and manually operated systems).

Remotely Piloted Aircraft System (RPAS)

Defined by the International Civil Aviation Organization as a set of configurable elements consisting of: a remotely-piloted aircraft, its associated remote pilot station(s), the required command and control links, and any other system elements required during flight operation.

Land surveying

Using drones in place of, or alongside, terrestrial surveying instruments to create geo-referenced maps, digital surface models (DSMs) and other data products.

Geographic information systems (GIS)

Drone data is increasingly being used in place of satellite or manned aircraft imagery for the creation of up-to-date, high-resolution background maps.

Conservation & environmental science

The use of drones is hugely diverse and continues to grow: from the 3D modelling of glacial features by climate change scientists to animal counting with infrared sensors, forest fire damage assessment, coastal erosion monitoring and more.

Agriculture

Professional, accurate scouting drones provide an efficient way to assess plant health. Simply fly, download the drone's images, and use its software to generate index maps of your fields, which clearly highlight the areas where plants are struggling and need further attention.

Civil engineering

This field benefits from a myriad of UAV applications, from inspecting infrastructure such as bridges, cellphone towers, powerlines and solar fields, to tracking material usage, performing project feasibility surveys and planning transport routes.

Humanitarian aid

Drones are being increasingly used by governmental and charitable organisations around the world to respond to and assess the impact of natural disasters, plan reconstruction efforts, chart informal communities and more.

Mining

Drone technology simplifies the creation of digital terrain models, allowing surveyors and engineers to record accurate, timely data safely, without having to traverse such dangerous sites on the ground. Drone data can also be used for taking measurements, volume calculation, planning blast activities, environmental and compliance reporting and much more.

Other drone applications:

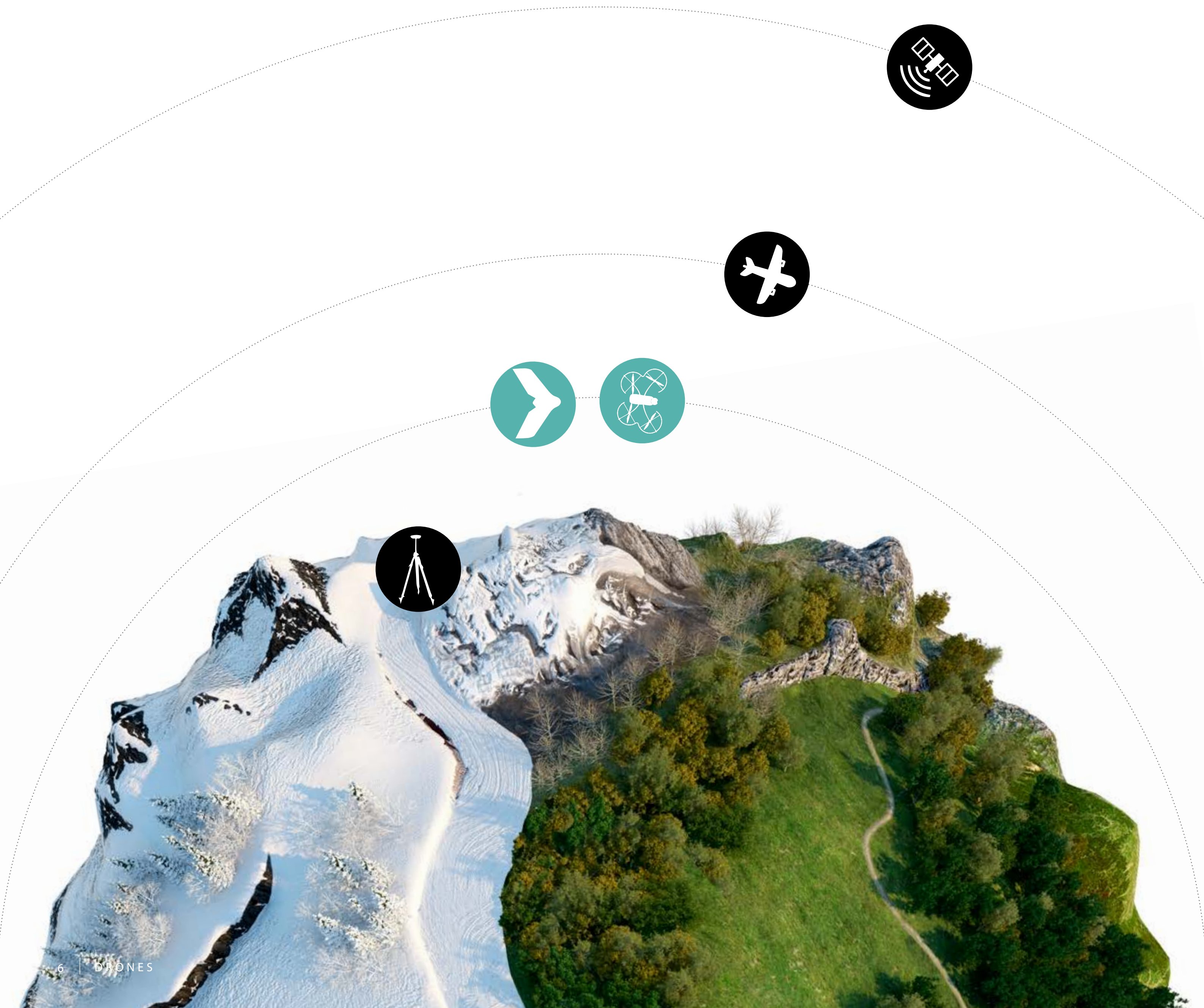
- Forestry
- Construction
- Archaeology
- Emergency response
- Insurance
- Property tax assessment
- Crash reconstruction
- Journalism

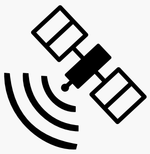
FILLING THE GAP

How drones complement existing methods of geospatial data collection

As a new method of geo-data collection, drone technology complements existing techniques, slotting neatly between large-area imagery (from satellites or manned aircraft), and smaller coverage, time-consuming, but highly accurate terrestrial approaches.

Drone technology offers: high orthomosaic/3D model accuracy, rapid data turnaround times, competitive costs per project when used regularly, and the ability to collect data even when there is cloud cover.





+ Extensive coverage
+ Wide spectral capabilities including lidar

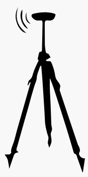
- Relatively low-resolution (down to 30 cm/pixel)
- Image timing controlled by provider
- Limited coverage in some regions
- Imagery susceptible to cloud cover

+ Large single-flight coverage
+ High-resolution (down to 7 cm/pixel)
+ Wide spectral capabilities including lidar

- Typically expensive (not suited to smaller projects)
- Image timing controlled by provider (if external)
- Specific flight approval can be required
- Operations susceptible to weather
- Aircraft availability may be limited in remote regions

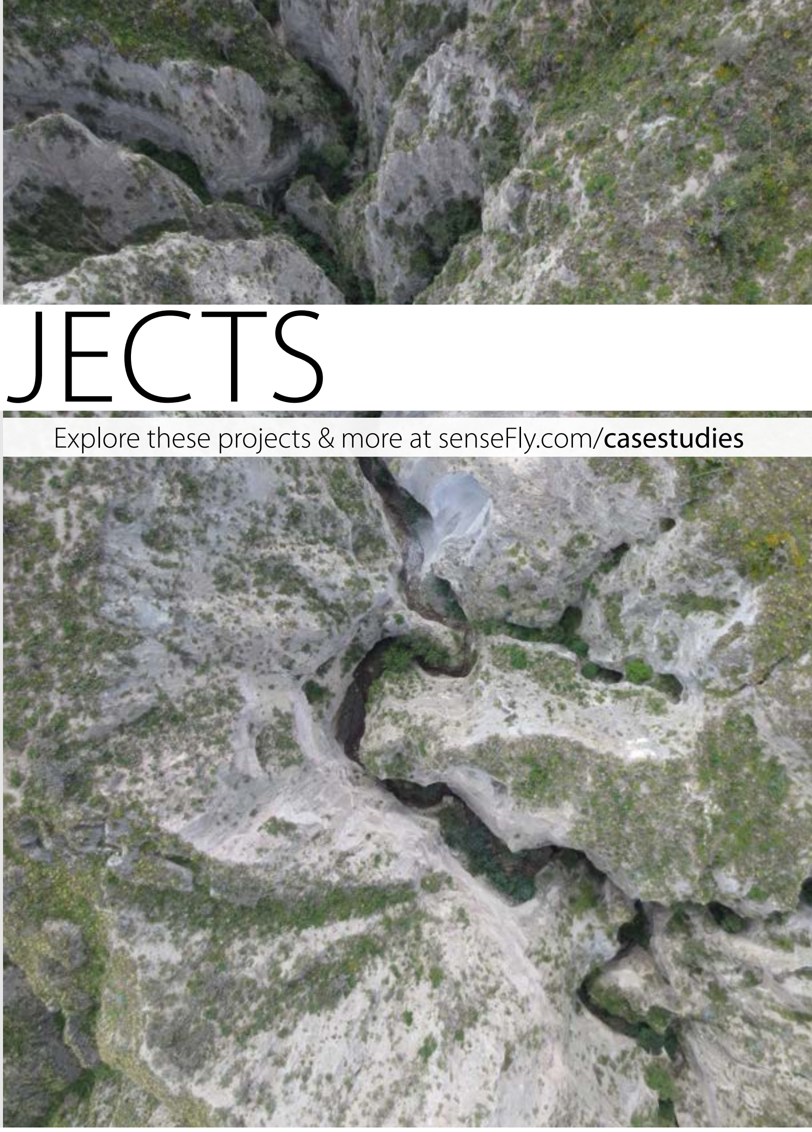
+ Cost-effective (suits smaller projects)
+ Imagery can be acquired on demand
+ Very high-resolution (fixed-wing: 2.5 cm/pixel, rotary: sub-millimetre)
+ Typically unaffected by cloud cover (due to lower flight altitudes)
+ Excellent positional accuracy with GCPs or RTK

- Relatively small single-flight coverage
- Drone regulations or bans can restrict usage
- Operations susceptible to bad weather
- No canopy penetration (unless heavy lidar payload)
- Difficult to reconstruct imagery of homogenous terrain and water



+ Excellent positional accuracy
+ Just the data required (no data overload)
+ Very high resolution
+ On the go data classification (vector/meta data)

- Slow, labour-intensive collection
- Equipment can be expensive (e.g. laser scanner)
- Line-of-sight issues
- Difficult to record tops of features
- Some sites inaccessible on foot
- Limited graphical outputs (depending upon equipment)



EXAMPLE DRONE PROJECTS

Explore these projects & more at senseFly.com/**casestudies**

Corridor mapping in Turkey

Location: Manisa to Uşak
Operator: Artu Harita
Challenges: project size, data processing
Drone: senseFly eBee

Statistics:
· 140 km x 600 m rail line
· 44.5 km^2 (17.2 mi^2) coverage
· 30 flights
· 900 GCPs
· 40 days processing
· 10-15 cm avg. accuracy

Results: orthomosaic, DSM, contour maps, classified point cloud

"Using classical methods we need lots of people, time, and instruments. With the eBee, we just need people to paint and set GCPs, and people to fly the drone."

Diner Yılmaz, General Director, Artu Harita.

High-altitude land survey

Location: Quito, Ecuador
Operator: AOC Ingeniería
Drone: senseFly eBee
Challenges: topography, attacking hawks

Statistics:
· 39 km^2 (15 mi^2) coverage
· 10 staff
· 78 GCPs
· 31 check points
· 40 flights
· 12,000 images
· 6 week total project time

Results: orthomosaic (8 cm (3.1 in) / pixel ground resoluion), DSM, cartographic map

"The project cost approximately one-fifth of a conventional survey, plus in some areas our data was considerably more precise."

Juan Pablo Solorzano, Director of Transportation, Geomatics division, AOC Ingeniería.

Map creation for Medair

Location: Tacloban, Dulag and Julita municipalities, Philippines
Operator: Drone Adventures
Drone: senseFly eBee

Statistics:
· 6 days
· 29 flights (RGB)
· 11.6 flight hrs
· 48.6 km^2 (18.8 mi^2) coverage
· 5,139 images total

Results: four orthomosaics with average ground resolutions of 5 cm (1.96 in) per pixel for villages, and 8-10 cm (3.1 – 3.9 in) for larger areas.

"We used the images taken by the drones to carry out damage assessments, to identify land that could be safer to relocate families on, and to see where recovery efforts are taking place."

Rob Fielding, Medair.

Forest fire **damage mapping**

Location: Curonian Spit, Lithuania
Operator: Hnit-Baltic
Drone: senseFly eBee
Challenge: quick data turnaround

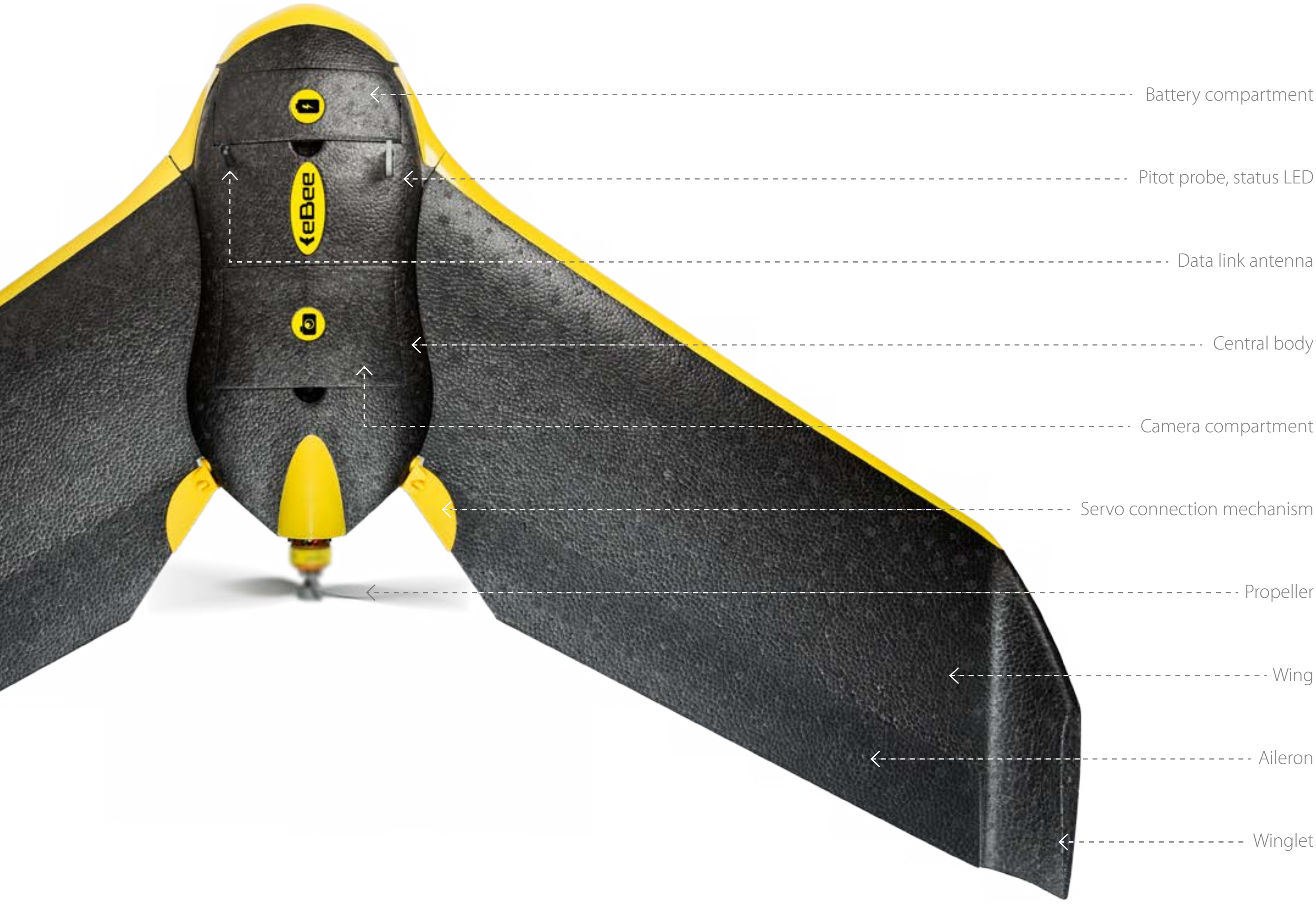
Statistics:
· 2 km^2 (0.77 mi^2) coverage
· 2 flights (1 RGB, 1 red-edge)
· 650 m flight altitude
· GSD: 20 cm (7.9 in) per pixel
· 3 hr data delivery

Results: two orthomosaics (RGB, red-edge), uploaded onto ArcGIS.com

"The eBee is such a simple system to use, any agency or organisation could easily use it to collect this kind of data themselves."

Simonas Guogis, Sales Project Manager, Hnit-Baltic.

DRONE BASICS: FIXED-WING AIRCRAFT



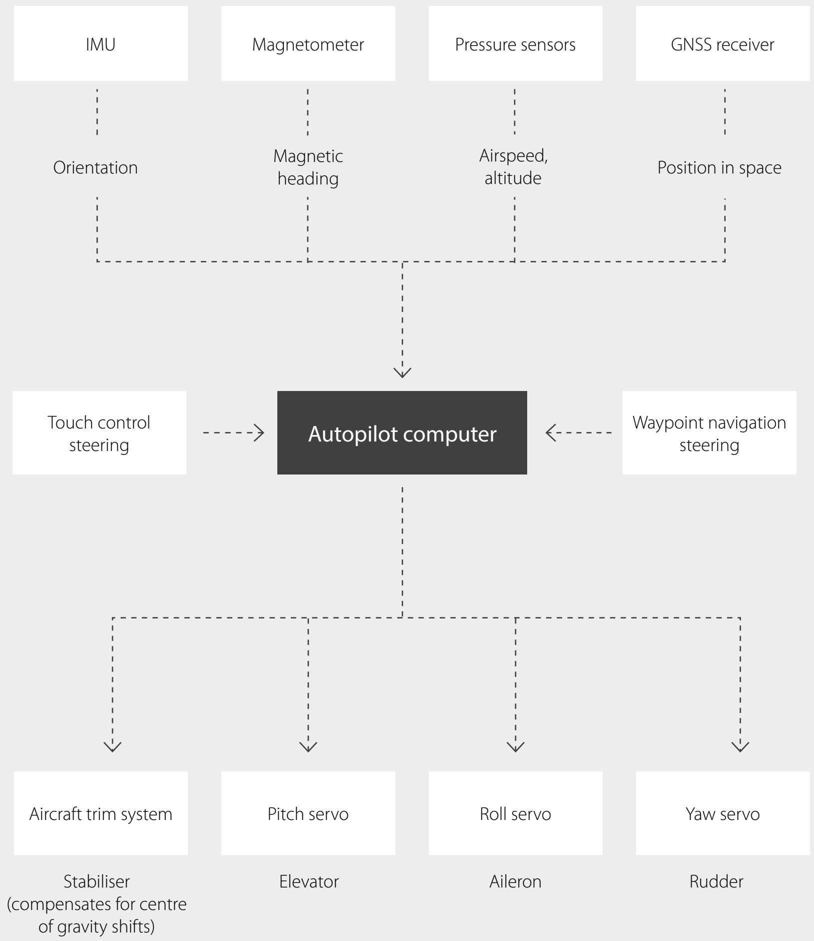
A fixed-wing UAV, such as the eBee above, is generally composed of a central body, which houses all the drone's electronics, and two wings. The aerodynamic profile of the wings enables the drone, once in flight, to generate lift that compensates for the weight of the aircraft.

Like an aeroplane, fixed-wing drones also feature ailerons, which enable the aircraft to steer. Some UAVs also feature a rudder and elevators, sometimes even flaps. However these are not essential to flight for all systems and can present extra sources of failure.

Fixed-wing drones typically feature one engine with a propeller attached, either a forward-mounted (tractor) propeller or a backwards-facing (pusher) propeller. Most propeller-powered drones include a system that folds these components especially if, like the eBee, an aircraft lands on its fuselage. Obviously, forward-facing propellers are inherently more dangerous to third parties during take-off, landing and in the case of accidents.

The autopilot uses an inertial measurement unit (IMU), magnetometer and an air data computer (temperature, static and dynamic pressure), alongside a GNSS (GPS/GLONASS) receiver, to estimate its position and attitude (roll, pitch, yaw).

When it receives flight input from the pilot—either via a pre-programmed flight plan or manually—it controls its altitude and position by changing the position of the drone's ailerons using its servos.

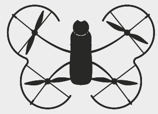


Often a drone's wings can be completely detached, for example, to fit in a carry case for easier transportation.

In addition to a drone's engine and its engine controller, are the electronics. These include: a pitot probe (this measures static and dynamic pressure in order to calculate flight speed and altitude), a radio modem (typically 2.4 GHz), an electric battery (LiPo rechargeable energy source), a GNSS (GPS/GLONASS) receiver (absolute X,Y,Z positioning), a minimum of two servos to control the ailerons (more may be required if the drone includes a rudder) and an autopilot. The autopilot is the computer that integrates all the drone's systems. It acts as the brain between the control station (i.e. a laptop or tablet), the pilot on the ground, the UAV's flight controls and payload, such as a camera. For the most accurate payload control, this component should be fully integrated and controlled by the autopilot.

For optimal durability, a drone's electronics should be well protected, positioned as far away as possible from dust and humidity, inside the fuselage itself.

DRONE BASICS:
ROTARY SYSTEMS

FIXED-WING OR ROTARY?		
Projects	Mapping	Small area mapping & inspection
Applications	Land surveying (rural), agriculture, GIS, mining, environmental mgt, construction, humanitarian	Inspection, real estate, surveying (urban), construction, emergency response, law enforcement
Cruising speed	High	Low
Coverage	Large	Small
Ground resolution	cm/inch per pixel	mm per pixel
Take-off/landing area	Large	Very small
Flight times & wind resistance	High	Low

More: **waypoint.sensefly.com**/buy-fixed-wing-drone-or-rotary

Unmanned rotary drones, also called multi-rotors, are more complex systems than their fixed-wing cousins, both in terms of their mechanics and their control mechanisms.

A rotary system creates the thrust it needs to move through the air by varying the power supplied to the different propellers. This determines their revolutions per minute (RPM) and therefore the thrust these generate.

Two key technical challenges must be met to optimise a rotary system's performance.

First, since rotary drones do not have the built-in aerodynamic stability of their fixed-wing counterparts, to ensure a stable flight they need highly advanced autopilot technology to continually choose the correct RPM for the different propellers; making hundreds of tiny adjustments per second.

Secondly, rotary systems require very fine motor control to rapidly vary the power sent to different motors, ensuring the propellers achieve the exact RPM commanded by the autopilot.

In the case of a four propeller system such as the senseFly albris, diagonal pairs of propellers spin in opposite directions.

A quadcopter climbs and descends by simultaneously varying the RPM, and therefore the thrust, of all four of its propellers. Their combined thrust creates a force that counters gravity, allowing the drone to climb (ascend), hover or descend (depending upon whether this force is greater, equal to, or less powerful than the force of gravity being exerted on the aircraft).

Flying forwards or backwards involves pitching in the corresponding direction. For example, to pitch forwards, the RPM of the front two motors is decreased compared to that of the back pair. With the drone pitched forwards, the combined thrust of its four motors is also pitched forwards, pushing the drone in that direction.

Flying sideways, or rolling, is a case of increasing the RPM of two motors on the same side; increasing the power to the rotors on the left, while decreasing it to the right, will 'roll' and move the aircraft to the right.

Lastly, the process of turning the aircraft on the spot—so-called 'yawing' to the left or to the right—involves increasing the speed (RPM) of one diagonal pair, while reducing the RPM of the opposing pair.

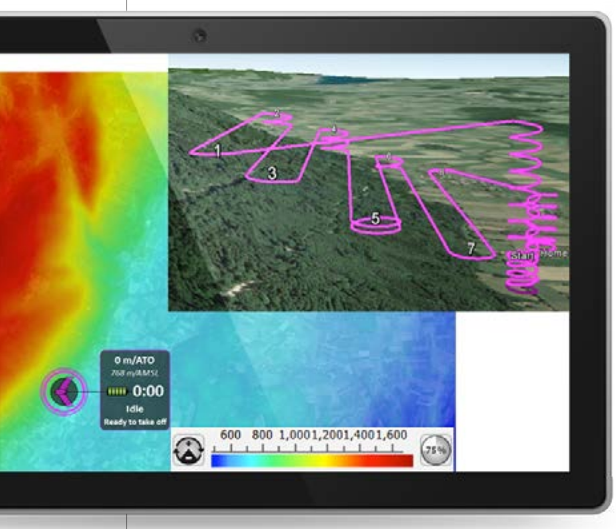
While different multi-rotors feature different numbers of propellers, these basic flight concepts remain the same.

FLIGHT PLANNING

1. Define the mission area, ground resolution and overlap

Most professional drones employ 'waypoint navigation' to define their flight path. However, since this would be highly tedious for drone operators to manage manually, modern flight planning software handles this automatically, incorporating the three pillars of aerial mapping: mission area, image overlap and ground resolution. It is also important to use a high-quality background map, therefore a choice of these and the ability to import custom maps is helpful.

In the case of senseFly's eMotion software, for example, simply load up a background map, draw a rectangle (or create a more complex polygon) over the area to map, then define the required ground resolution and image overlap. From there, eMotion automatically generates a full flight plan, featuring appropriately spaced flight lines, the waypoints at which the drone will perform its turns, and including the drone's required altitude (based on the ground resolution you specified). eMotion can also accept geo-files, in KML format, in order to define the area to map.



2. Generate a 3D flight plan

When flying over uneven terrain, the optimal flight planning approach is for the altitude of each flight line to be adapted to the terrain underneath it. This will ensure a consistent ground sampling distance (GSD), a consistent image overlap, and will increase mission safety by reducing the chances of the drone flying into terrain.

An ideal flight planning system will have a high-quality elevation data set built-in, as well as allowing the operator's own elevation data to be imported. This is the case with eMotion software. An operator can activate built-in Shuttle Radar Topography Mission (SRTM) elevation data with a 90 m ground resolution or import elevation data from other sources, including from an earlier drone flight over the same area (which would be more precise).

Modern flight planning software typically covers the three pillars of aerial mapping: mission area, image overlap and ground resolution

3. Define take-off and landing points

Depending on an area's terrain, it is not always easy to identify convenient and safe take-off and landing points. In the case of the eBee mapping drone, its eMotion software features a separate Flight Setup tab for just this purpose.

When defining the UAV's take-off trajectory, eMotion allows you to define the exact direction the drone will follow after being hand launched. This way you can ensure the eBee will gain altitude safely before starting its mapping mission, climbing away from obstacles such as trees and powerlines.

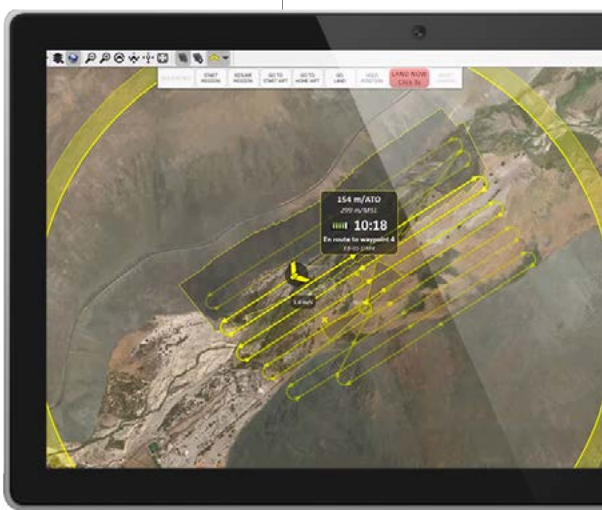
When landing, choose between a circular landing, at a given radius and around a given position, or a linear landing. With the latter, you can set several approach sector directions (like mini runways). With the eBee, this will then automatically calculate which sector to use depending upon the actual wind measured above the landing spot just before the drone engages its landing procedure. During the approach it will use this wind information, in combination with its ground proximity sensor, to adapt its altitude to the terrain, employing reverse thrust at an altitude of five metres to reduce its speed and ensure a short, precise and soft landing.

4. Monitor and adapt during flight

Even with intelligent, automated mapping drone systems, it is crucial to carefully monitor every flight via line of sight and using the drone's ground station software.

The drone's position and important parameters such as its battery's remaining charge, and therefore flight time, should always be visible so that the operator can intervene at any time, as required. An intervention could, for example, be in the case of an unforeseen situation, such as a car parking in the drone's landing zone.

In eMotion, information concerning the UAV's battery status, its current altitude and flight time are visible right next to the drone icon itself as it progresses through its flight. The operator can also intervene in the drone's flight at any time by modifying or uploading an entirely new mission. The software includes direct action buttons such as Hold Position (useful, for example, in the case of another flying object appearing, or simply to give the operator time to think), Go Land and Abort Landing. It is also possible to pilot the UAV manually, using its supplied remote control, which automatically overrides any current pre-planned mission.



THE FLIGHT

1. Launching the drone

Drones are typically launched in one of three ways: by hand; via a rolling take-off on a runway; or using a launching system, most often a catapult.

Rolling take-offs and catapults are generally required by heavier systems whose weight makes hand-launching impossible. When specifying a drone, consider whether it will be convenient to manage bulky accessories such as catapults, especially if you already transport other survey equipment. Drone launch systems not only add extra weight, but increase complexity, which may result in system malfunction to a system which should be a simplifying solution.

System weight and wing surface define the minimum speed at which a UAV will fly and therefore the ease with which it can be launched. A lightweight drone with a large wing surface, such as the eBee, is therefore easy to launch.

2. During flight

After take-off, a drone will quickly gain altitude and travel, either automatically or on command, to its mapping area to start its aerial imaging mission.

With modern mapping drones, images are triggered automatically, at the correct positions and ensuring the correct lateral and forward overlap, so that effective photogrammetric image processing is assured.

Before triggering an image, the drone controls its altitude and position, stabilising its roll, pitch and yaw. In the case of the eBee, it briefly shuts off its engine to remove unnecessary vibration, giving the best quality image possible whilst maintaining the programmed flight plan.

EBEE: GROUND SENSOR INTELLIGENCE

The eBee's ground sensor is composed of a high-speed optical sensor and lens assembly. This points downwards and is capable of detecting the ground from an altitude of 60 metres (196 ft). During flight the eBee employs this sensor to continuously check the proximity of the ground. If it detects a height of less than 30 m, the drone emits an emergency terrain warning, via eMotion, before climbing to a safe height (60 m) before continuing on its mission. The sensor is also used during landing (*see below*).

Over **220,000** flights

senseFly drones have completed over 220,000 flights to date (April 2016) and have been used to collect data across all seven continents, from North America to Antarctica.

3. In-flight monitoring

Typically, an operator will ensure the safety of an operation by keeping the drone in visual line of sight (VLOS). The drone supports this human monitoring by constantly sending status information via its radio link to the ground station (through which it can also receive updates and additional commands).

With the senseFly eBee, you can intervene manually at any time, for example landing the drone or holding its position. Prefer to finish the mission instead? Just click Resume Mission.

4. Landing

After a mapping mission is finished, or in the event of warnings such as a low battery warning, the drone will typically return to its Home waypoint and start its automated landing procedure.

The UAV will measure the direction and strength of the wind over its landing spot and, based on that information, it will choose the best into-the-wind landing sector out of those that the operator pre-defined.

In addition, senseFly's eBee uses a ground proximity sensor to detect the ground and then reverses thrust on landing to slow its speed. Thanks to this approach it is capable of landing in relatively small areas, with a typical accuracy of +/- 5 m.

Safety tip: Always be ready to abort a landing. For example, should a person or obstacle (e.g. a car) appear in the landing zone, click Abort Landing, then either change the UAV's landing zone or restart the landing procedure when the landing spot is clear.

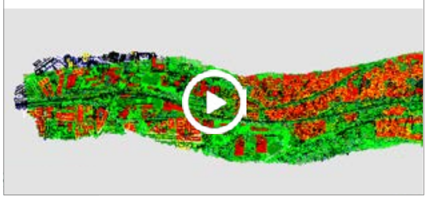
FLIGHT TIPS

Many different factors can influence the success of a drone flight. Even if the flight plan is perfect and flown by a capable operator, the external effects of altitude, humidity and even local birdlife can all have an impact. Here the senseFly team brings you its customers' best hints and tips.

Corridor mapping

- Use an image overlap of >85%.
- Set GCPs using a zigzag pattern (a common approach is to have a GCP team working out in front of the following UAV team).
- Add check points to verify data quality.
- Set the take-off point close to the first waypoint to minimise the drone's flight time prior to starting image acquisition.
- For wider corridors of several hundred metres, divide the corridor into flight sections and set take-off points at the centre of each. Then fly two 'there-and-back' flights from the same spot—one in each direction—with each flight mapping a different side of the central target corridor.
- For narrower corridors, plan flights that 'leapfrog' along the corridor—launching at one location, mapping, then landing further down the corridor, ready for the next linear flight.

Watch Diner Yilmaz's corridor mapping video: http://ow.ly/O3JCC



Mapping large areas

- Don't put yourself through the unnecessary pain of planning numerous individual flights. Instead, highlight the full coverage area in the drone's flight planning software and divide this into several flight plans that can be uploaded to your drone one after the other.
- Alternatively, for owners of more than one UAV, some ground station software programs—such as senseFly's eMotion—also support multiple drone operation. This enables you to cover large areas in less time by flying several drones at the same time.

Read about COWI's huge project mapping Greenland's Zackenberg Research Station: http://ow.ly/RgKEF

High-altitude flying

- Be aware that at higher elevations there is a risk of higher winds, which can reduce a drone's autonomy (flight time) due to using more battery power.
- Due to the lower air density at altitude, give your take-off throw a little more energy than usual.
- When flight planning:
  - Import elevation data in order to set absolute waypoint altitudes that minimise the risk of terrain related crashes.
  - Ensure your mission's flight lines run parallel to any incline. This ensures not only the safety of the drone, but also the consistent ground resolution of all its images.

Watch senseFly drones mapping the Matterhorn (approx. 4,107 m or 13,474 ft above sea level): http://ow.ly/RgKSf

In cold climates

- Batteries are affected by the cold; their capacity reduces as the temperature drops. So it is a good idea to pack additional spare, fully-charged drone batteries (and camera batteries if using a drone that does not power the camera directly).
- The life of a lithium polymer drone battery—such as the eBee's—will typically be reduced by cold by 20%.
  - Be conservative by reducing the planned flight time by 5-10 minutes.
  - To ensure optimal battery life, keep drone and camera batteries as warm as possible, e.g. inside your jacket, until just prior to take-off.
- When flying an eBee over snow:
  - Snow is uniform and visually 'flat'. Improve the landing zone by assisting the drone's ground sensor to achieve a soft landing, by flattening the surface and making artificial landing markers to disrupt the uniform white surface (e.g. using tyre tracks or throwing gravel on the ground).
  - Use a towel to dry your drone after landing.

Watch eBee user Ryan Sales' cold weather tips video: http://ow.ly/RonQO

When birds attack

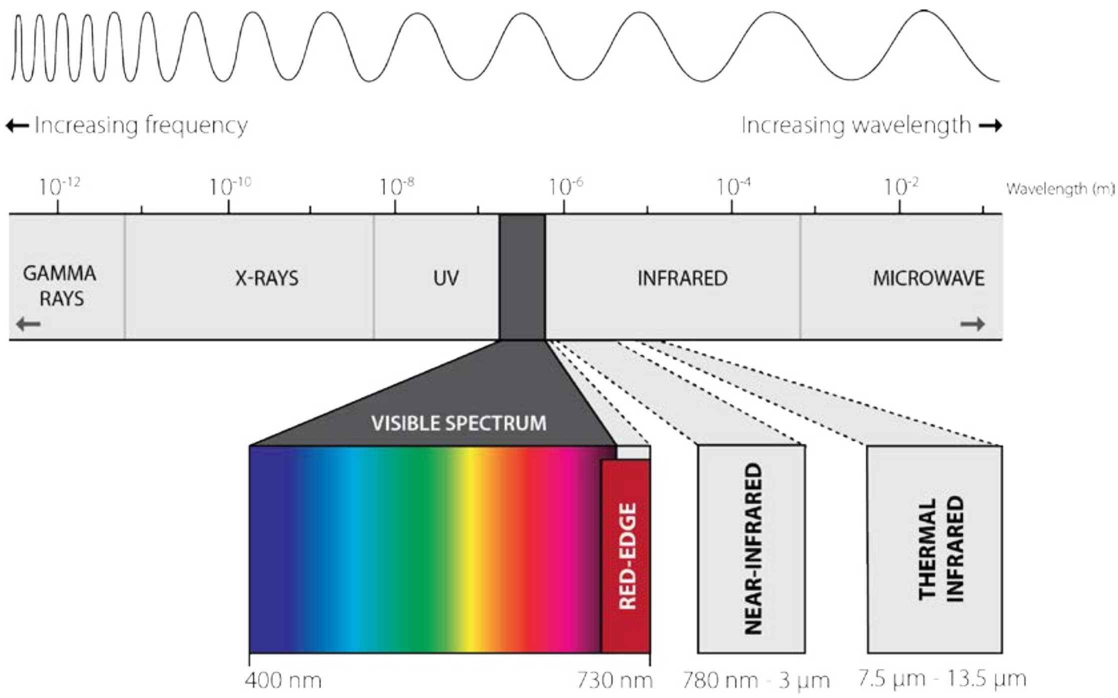
- Remain aware of this possibility; bird attacks do happen, usually from above the drone, and can cause real damage and thus project delays.
- Learn what type of bird life exists around your project site.
- If possible, avoid flying close to nesting areas during breeding season.
- Always try to fly with an additional observer (this is required by law in some countries) to help avoid that first strike—it's usually this attack that does the damage.
- If working regularly in such areas, choose ground station software program—such as senseFly's eMotion—that features built-in bird avoidance manoeuvres, such as dive and fast climb.

Read about a drone survey in Ecuador that was affected by angry birds: http://ow.ly/RgLl6

And generally speaking…

- Avoid flying in high winds, rain and snow—these can damage your drone and affect the quality of its outputs.
- Also be aware of meteorological phenomena such as thermal winds (i.e. high uplift streams). In the event of being caught in such a 'thermal', call the drone home or move a waypoint further away to force the drone to escape the problem region.
- Watch out for updrafts on cliff edges; these can affect a UAV's landing accuracy.
- Always try to download background maps, required for flight planning, before heading into the field.
- Ensure that all batteries—your computer, drone, cameras, backup remote control etc.—are fully charged before beginning a mission.

IMAGING EXPLAINED



Thanks to a range of different camera payloads for today's professional drones, users are able to collect imagery spanning many different sections of the electromagnetic spectrum, from the RGB imagery that us humans can see, to agriculture-focused near-infrared imagery, wide-ranging multispectral imagery and even heat-identifying thermal data.

This spectral range is what opens up modern drone technology to a huge and ever-expanding range of applications.

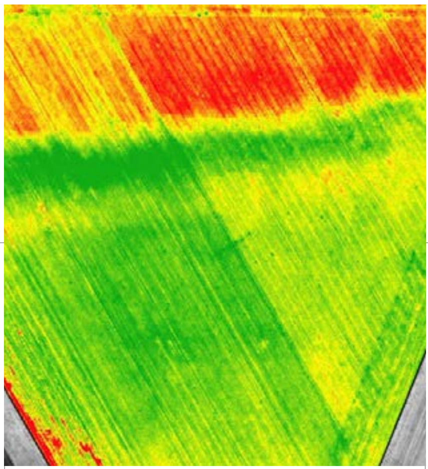
While a farmer might employ a near-infrared (NIR) sensor to create index maps of crops, and a mining engineer will likely get all he or she needs from a UAV's supplied RGB camera, an environmental researcher might need a thermal option, in the case, for example, of conducting an animal count.

In the case of the senseFly eBee, this drone's camera options include: two RGB models, a near-infrared sensor, a red-edge (RE) version, a multispectral payload, and a thermal camera. The senseFly albris quadcopter includes RGB and thermal sensors by default.

The graphic above explains, as simply as possible, where different types of imagery sit on the electromagnetic spectrum.

RGB

Red, green and blue (AKA 'normal' coloured) images are typically used for standard GIS, surveying and mapping projects in which a high-quality digital surface model and 3D point cloud are required.

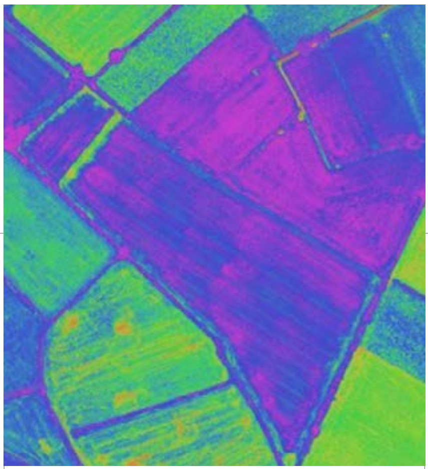


Multispectral

Used most often in precision agriculture, multispectral imagery, featuring four distinct bands (with no spectral overlap) and solar irradiance correction, allows unparalleled accuracy when measuring plant reflectance. As such this imagery is the perfect input for index calculations. The multispectral image above takes the form of an NDVI map, which can be used for optimising the application of nitrogen.

Red-edge

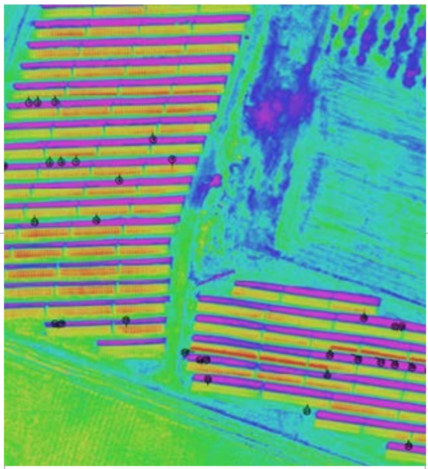
The red-edge band is the spectral region in which plant reflectance changes from low to high. Imagery data acquired in this band can be used to assess plant stress or drought, for senescence, and is also a good chlorophyll indicator. In the image above, red shows live vegetation, while blue shows dead vegetation (captured after a forest fire).



Near-infrared

Near-infrared imagery is often the default in precision agriculture, used most often to produce index maps.

The image above shows a Green NDVI (G-NDVI) index map of a spring barley crop. High reflectance in G-NDVI indicates a healthy and vigorous crop, suggesting correct levels of nutrients in the soil (in this case these were confirmed through soil sampling and lab analysis). Conversely, the area of crop identified by the G-NDVI image as being less healthy or under stress was found to have the least amount of macronutrients in the soil.



Thermal

This type of imagery assigns a temperature value to each individual pixel in an image, spanning temperature differences from -40 °C up to to 160 °C, with a resolution of down to 0.1 °C.

Thermal sensors are used across a range of fields; everything from the checking of solar panel installations (identifying hot spots to detect malfunctioning panels) through to automated animal counting.

DEALING WITH THE DATA

Managing flight data

Organised and methodical data management is key when it comes to collecting and benefiting from aerial imagery.

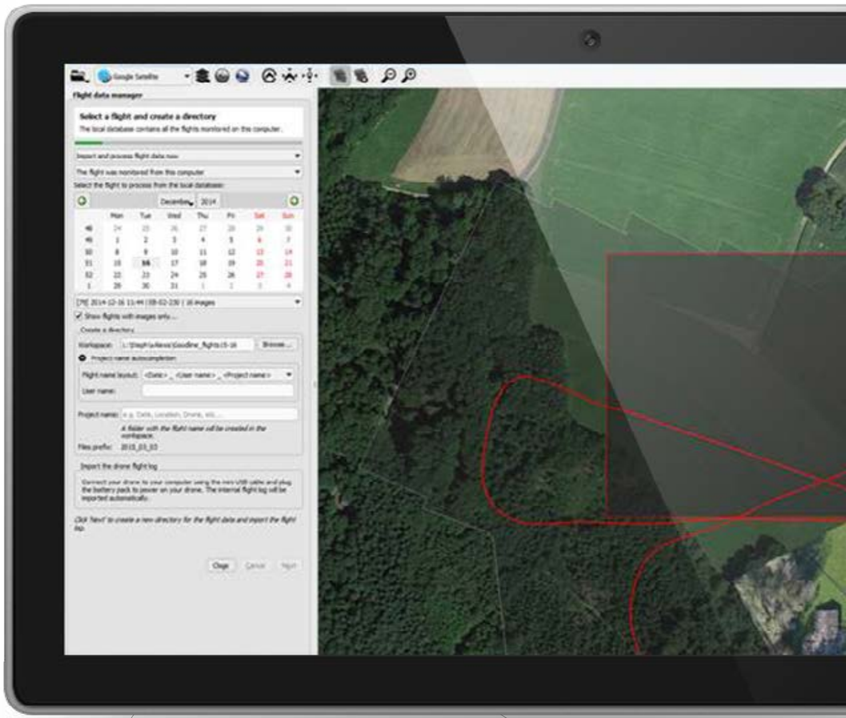
It is recommended to save the drone's flight log and all the aerial imagery it acquired after each flight by downloading this data onto a computer or tablet.

Typically, the next stage of the data management process is then the geo-tagging of the images collected and a project quality check. However these processes can be lengthy without the right tools. Therefore, since a project can easily involve more than 1,000 photos, automation is key.

Ideally, a ground station software program will include a flight data manager that creates a new project for each flight and automatically identifies and copies all the drone's captured images to the new project folder.

Keeping a copy of the original image files, this data manager function will then automatically generate geotags for these images, plus a KML file of the flight, ready for further processing.

With an additional agenda feature, a data manager can also help you to quickly locate all your projects, visually, by date. Each project's data should include such info as the drone's ID (its serial number), its mission area, image footprints, its flight trajectory and start and landing waypoints.

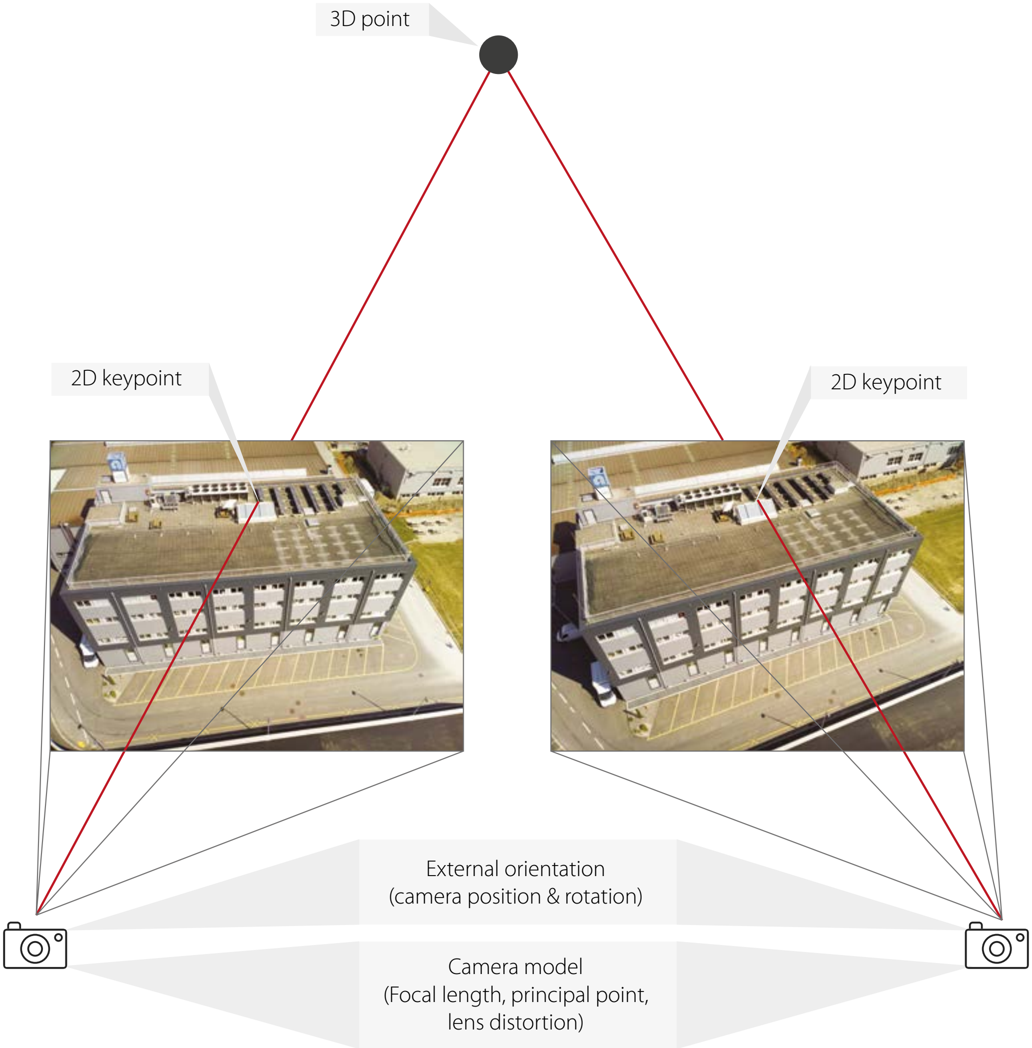



eMotion

	Date	Drone	Version	Duration	Distance	Max Height	Photo count	Home latitude	Home longitude
1	23.06.2014 13:43	EB-02-730	2.3.01681	6 min	4.4 km	166 m	0	46.5771037°	6.5893100°
2	27.07.2014 10:37	EB-99-002	2.3.11754	45 min	34.6 km	203 m	515	46.4412476°	8.0859539°
3	23.10.2014 14:46	EB-03-20776	2.4.11892	3 min	2.3 km	80 m	0	46.5765532°	6.5878053°
4	21.11.2014 15:10	EB-02-642	2.4.22032	16 min	11.7 km	101 m	1120	46.5772756°	6.5890007°
5	16.12.2014 11:44	EB-02-230	2.4.22032	5 min	3.4 km	166 m	16	46.5772261°	6.5889139°

Export Close

With eMotion you can also view and export your flight database. Each flight's listing contains: its date & start time; the drone's serial no. and firmware version; the flight's duration and distance; the maximum flight altitude achieved; the number of photos acquired; and the Home waypoint's coordinates.



Processing options

Drone image processing is based on a classical photogrammetric model, which is enhanced in turn by a powerful computer vision algorithm. This enables the automatic extraction of numerous key points in the images and optimises camera parameters such as external orientation and camera model.

In senseFly's case, once the geotagging of a flight's images is complete, eMotion's built-in Flight Data Manager is able to transfer all relevant flight data and images to start post-flight image processing.

There are several professional software programs capable of such processing work. These include: Pix4Dmapper by Pix4D, APS by Menci-Software, PhotoScan by Agisoft, EnsoMOSAIC by MosaicMill and RapidStation by PIEneering.

To produce non-geographically correct but visually-pleasing orthomosaics, there are several panorama creation tools also available, such as Adobe Photoshop.

PROCESSING THE IMAGES

Initial processing

The first processing phase identifies and extracts matching keypoints in the overlapping sections of the aerial images acquired by the drone. These keypoints are entered into an equation that determines the precise position and orientation of each image, as well as the camera model.

The next step of the process is the densification of the 3D point cloud (the project's full set of data points, defined by X, Y, and Z coordinates, set within a 3D coordinate system). This densification is required to generate a digital surface model (DSM) and an orthomosaic (a reprojection of each image point onto a planar surface, also referred to as an orthophoto or, simply, a map).

Processing times vary widely, depending on the complexity of the dataset (including the number of images to process) and the capacity of the computer being used. Generally speaking however, a dataset of 100 images will take up to one hour.

Introducing ground control points (GCPs)

Professional photogrammetry software such as Pix4Dmapper Pro - an option with all senseFly drones - allows GCPs to be easily introduced, in ASCII file format (ID, x, y, z), following the software's initial processing phase. Such software does not require GCP data prior to this processing as it uses the geotags of the images to scale, position and orientate its results.

After introducing GCPs into Pix4Dmapper, their approximate image projection is displayed in this software's rayCloud Editor, which simplifies the task of positioning each GCP in the corresponding image.

Working in the rayCloud

The rayCloud is a ground-breaking feature inside Pix4Dmapper that combines the 3D point cloud with the original input images. This approach substantially increases the accuracy of 3D point estimates and provides a fuller understanding of 3D results.

With the rayCloud you can view, assess and interpret your data easily. You have full control over all your tie points, GCPs and check points, and you can use the rayCloud to annotate and measure polylines (breaklines), surfaces, volumes (stockpiles) etc. with the highest possible precision.

ANALYSING THE DATA

Types of analysis

The accurate, in-depth analysis of a project's data requires an operator to have professional know-how and experience. This expertise is key to producing the deliverables a client or colleague requires.

Many basic analyses can be performed directly within professional photogrammetry software itself. Such analyses include: taking measurements, basic polygon or breakline digitisation, volume calculations (e.g. of stockpiles), the creation of contour lines, basic editing of the orthomosaic such as seamline, projection and colour editing, or vegetation index calculation.

Software outputs such as 3D PDFs and point-cloud fly-through animation videos can also be helpful for visualising project results. Plus, these outputs allow project details to be shared remotely with project partners and management, enabling quick understanding and facilitating effective decision making — without the need to access or learn how to use an additional software program.

File outputs & compatibility

Professional photogrammetry software enables operators to create a range of outputs in industry-standard file formats. These outputs can then be easily imported into third-party software programs for further analysis.

Orthomosaic raster

GeoTIFF (.tiff), KML (.png/.kml)

Compatible with…

- Esri ArcGIS
- Global Mapper
- QGIS
- Autodesk
- DraftSight
- GeoMedia
- Erdas Imagine
- Google Earth

& all leading brands of remote sensing & GIS software

Digital surface model

GeoTIFF (.tiff)

Compatible with…

- Esri ArcGIS
- Global Mapper
- QGIS
- Quick Terrain
- GeoMedia

& all leading brands of GIS software

3D mesh with texture

Wavefront (.obj)

Compatible with…

- Autodesk
- Bentley MicroStation
- ccViewer
- 3DReshaper

& all leading brands of 3D modelling software

3D point cloud

.las, .laz, .ply, .ascii

Compatible with…

- I-Site Studio
- Esri ArcGIS
- Global Mapper
- Autodesk
- Quick Terrain
- 3DReshaper
- Trimble RealWorks
- Bentley MicroStation

& all leading brands of survey / 3D scanning software

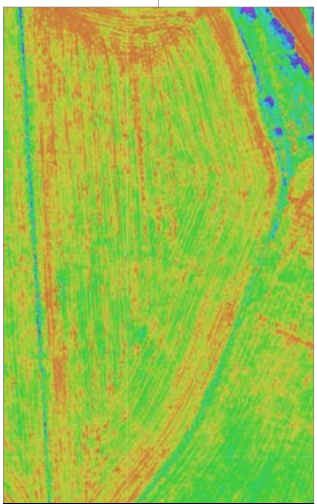
Google Maps

KML tiles (.png/.kml)

Compatible with…

- Google Maps
- Mapbox

& other map servers



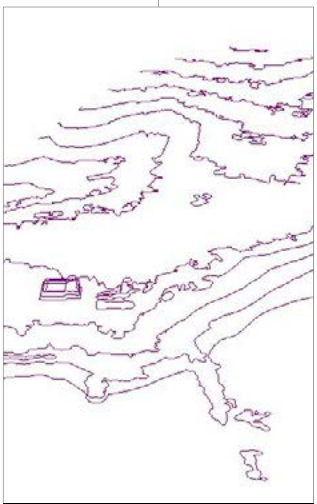
Index map

GeoTIFF (.tiff), .shp

Compatible with…

- SMS (Ag Leader)
- AgPixel
- QGIS
- Esri ArcGIS
- Global Mapper

& all leading brands of GIS software



Contour lines

.dxf, .shp

Compatible with…

- Vulcan
- I-Site Studio
- Autodesk
- DraftSight
- Esri ArcGIS
- QGIS
- Surpac

& all leading brands of mining / survey software

Undistorted images

.tif

Compatible with…

- Trimble Inpho
- Socet Set
- Imagine Photogrammetry

& many other brands of photogrammetry software

TALKING ACCURACY

GSD vs. accuracy

The quality of a project's deliverables will often be linked to its accuracy, referring to the positional accuracy of the final output result; not to be confused with camera resolution or a single image's Ground Sampling Distance (GSD).

The ground sampling distance achieved depends on an imaging sensor's pixel size and lens focal length, and is directly proportional to the drone's flight altitude. For example, a 16 megapixel RGB camera with a 24 mm lens* will achieve the following approximate GSDs:

- At 97 m (318 ft) flight altitude: 3 cm (1.2 in)/pixel
- At 227 m (744 ft) flight altitude: 7 cm (2.7 in)/pixel
- At 325 m (1,066 ft) flight altitude: 10 cm (3.9 in)/pixel

However, data output quality depends on much more than a camera's resolution alone. In fact, the dataset produced by a 12 MP camera will often be hard to differentiate from that produced by a 16 MP model. Other factors that impact the result quality include: image overlap, contrast and correct exposure to name just three. If all these factors are in order, a dataset will typically return enough keypoints and matches to ensure a project can be processed successfully.

* *35 mm film equivalent*

Relative vs. absolute accuracy

A drone mapping project, such as that flown by an eBee, is processed based on the geospatial coordinates (image geotags) automatically acquired during the flight. In this case its relative accuracy will be typically a couple of centimetres (1-3x GSD) while its absolute accuracy (position and orientation) will be less precise (typically 2-5 metres).

For many projects, this degree of absolute precision is perfectly acceptable. However for users such as land surveyors who require more accurate results, this figure can be much improved by introducing GCPs or by using an RTK-ready drone such as the eBee RTK (*see box below*).

Typical fixed-wing mapping accuracy

Geotags only: no GCPs

GSD	Relative orthomosaic/3D model accuracy	Absolute horizontal/ vertical accuracy
Down to 1.5 cm (0.6 in) per pixel	1-3x GSD	1-5 m (3.3-16.4 ft)

Geotags: with GCPs

GSD	Relative orthomosaic/3D model accuracy	Absolute horizontal/ vertical accuracy
Down to 1.5 cm (0.6 in) per pixel	1-3x GSD	Down to 3 cm (1.2 in) / 5 cm (2 in)

RTK geotags or post-processing: no GCPs

GSD	Relative orthomosaic/3D model accuracy	Absolute horizontal/ vertical accuracy
Down to 1.5 cm (0.6 in) per pixel	1-3x GSD	Down to 3 cm (1.2 in) / 5 cm (2 in)

Working with GCPs

To process a project using GCPs, at least five are required. To achieve the best possible results, these GCPs should be spread evenly over the mission area. GCPs should have an accuracy of 0.5-1x GSD, otherwise additional inaccuracy will be introduced into the image processing.

GCPs can be either natural high-contrast points on the ground (e.g. the corner of a road marking, manhole covers etc.), or artificially marked GCPs as shown below. These are commonly measured with survey-grade GPS rovers. The required size of such marks depends upon the drone's flight altitude and as such the expected GSD. A common rule is that these should measure at least 5x GSD.

Meet the eBee RTK

The eBee RTK is a survey-grade mapping drone. Its aerial imagery can produce orthomosaics & 3D digital surface models with absolute accuracy of down to 3 cm, without the need to measure ground control points. To operate the eBee RTK you either require a GPS base station (which can be placed on a known or unknown position) or access to a virtual reference station network to receive VRS/NTRIP correction data (internet connection & VRS/NTRIP subscription required).

Learn more at www.sensefly.com/eBeeRTK

SAFETY MATTERS

A drone operator is responsible for ensuring the safety of every operation, including the protection of nearby people, animals, property and the environment in general.

It is therefore crucial that an operator properly maintains his or her unmanned system and inspects it before every single flight. An operator must also carefully evaluate weather conditions, the terrain (i.e. when flight planning), and choose suitable, safe take-off and landing locations.

Even when such precautions are taken however, critical situations do occasionally arise. This is why it is so important to minimise a UAV's kinetic energy, which is determined by a drone's weight and its flight speed via the following calculation:

$$\textit{Kinetic energy} = \frac{1}{2}.\textit{mass}.\textit{velocity}^2$$

An aircraft's flight speed is a direct function of its wingload (the weight per square metre of its wings) and its aerodynamic profile: the more a drone weighs, the higher its flight speed will be.

In the case of any potential issues, another important factor is the ability to dissipate a drone's kinetic energy, by using materials capable of deformation. One excellent choice of material for this is foam, such as the eBee's EPP foam, in place of hard materials (which maximise the impact factor (g-load impact) and will eventually break).

After all, there is little logic to using a drone to increase a project's safety—as when mapping an open pit mine—just for the product itself to increase risk in another way.

The benefits of professional training

An ideal drone training program starts with education first, before moving on to simulated missions, flight planning and landings, and of course, finally, the most crucial training component: hands-on practical training.

Practical training typically covers evaluating meteorological conditions, understanding what makes a good take-off and landing spot, how to launch, flight monitoring and control, and landing safely. Understanding error messages, a drone's built-in automated behaviours, and manual control inputs should also be a part of any training programme.

The senseFly eBee weighs just over 700 g (1.5 lb) at take-off; approximately one-third the weight of competing systems. This means that at its standard cruising speed, the eBee's kinetic energy is comparable to that of a kicked football. And just like a football, the eBee is made out of flexible materials, which absorb energy by temporarily deforming on impact.

Why it's right to go light

4 reasons to choose a lightweight drone

01

Safe

- Low take-off weight & optimised flight speed ensure impact energy is minimised
- Protecting people & objects in case of a crash

02

Hand launchable

- Quick, convenient use
- Minimal ground space required for take-off

03

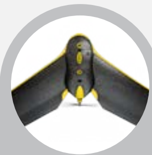
Durable

- Less stress on the aircraft's structure when landing
- Boosted further by use of shock-absorbent, easy to repair materials such as EPP foam

04

Easy to transport

- No launching accessories required (e.g. catapults)
- Leaving more space in the car for other professional equipment



eBee

- Design: modular
- Materials: shock-absorbent EPP foam, carbon fibre
- Take-off weight: 700 g (1.5 lb)
- Impact energy similar to that of a football!

65,000 flight hours at your service

senseFly systems have accumulated more than 65,000 operational flight hours to date, across seven continents.

Typical automated pre-flight checks (fixed-wing drones)	
Battery level	Ensures battery has enough charge to perform a take-off.
Inertial navigation system calibration & attitude	Ensures orientation sensors are correctly calibrated.
Barometer & magnetometer	Ensures sensors are working correctly.
Ground sensor	Ensures the sensor is working correctly.
Pitot	Calibrates airspeed and pressure.
Wings	Checks wings are correctly attached.
Horizontal to start motor	To initiate eBee's take-off procedure (by shaking it three times), drone must be held horizontal to avoid unintentional powering on of motor.

Any detected pre-flight issue triggers a take-off veto.

Typical automated in-flight checks (fixed-wing drones)	
Battery level	Battery level is monitored constantly and displayed in eMotion software. Low battery charge triggers action.
Geo-tagging	Checks that flight information is saved correctly to drone's onboard storage.
Camera function	Monitors correct camera function, detecting malfunctions and displaying continuous progress of image acquisition.
Barometer, airspeed, motor	Ensures correct function.
Working area boundaries (radius & ceiling)	Drone constantly checks that it is within its working area's horizontal (radius) and vertical (ceiling) limits, as defined by operator.
GNSS	As GNSS is essential for positioning, the drone constantly monitors satellite signal coverage.
Data link	The connection to and from the ground station is constantly monitored to avoid moving out of data link range.
Ground proximity	During flight, the drone checks that it is always a minimum of 30 metres above the ground.
Wind speed	The drone checks that its operational wind limit (12 m/s for the eBee) has not been exceeded.
Landing sector wind direction	Checks the direction of the wind in the user-defined landing approach sectors. In the case of a following wind in one sector, if no alternative sectors have been defined the operator will receive a warning message.

Always read your drone's user manual and keep the system's firmware, its software and your own knowledge up-to-date.

Always **up-to-date**

To keep you at the cutting edge, senseFly drones evolve continually over time, with regular firmware and software updates adding new features and functionality. Plus, every senseFly owner gains access to the Knowledge Base, an educational web resource full of tips, tutorials and webinars (part of the my.senseFly customer portal).

DRONE LEGISLATION

Canada

Commercial use possible.

- Based on the holding of a Special Flight Operations Certificate (SFOC): describes when, where, and how a drone will be used
- Different SFOC application processes: three Restricted Operator processes and one more complex Compliant Operator Application (requires compliant drone)
- 2 interim exemptions for sub-2 kg & 1-25 kg weight categories
- Update of regulations expected in 2016
- Numerous senseFly eBee operators authorised to fly

USA

Commercial drone use is permitted if an organisation has been granted a Section 333 exemption by the FAA, otherwise prohibited until national rules are put in place (most likely in 2016/2017).

- Exempted organisations/agencies/individuals also require a Certificate of Waiver or Authorization (COA) & must register their drone's airframe
- Exempted parties also receive a Blanket COA for operations below 200 ft (61 m) above ground level (AGL)
- A commercial organisation can, alternatively, apply for a Special Airworthiness Certificate (Research Purposes) for testing-only use of a specific UAS
- 'Governmental function' (non-commercial) use possible when in possession of a COA
- Currently 6 authorised UAS test sites across the United States
- The senseFly eBee is the most exempted fixed-wing UAS to date (February 2016)

Mexico

Commercial use possible.

- 3 drone classes, defined by system weight. Each category regulated differently
- Under 2 kg: flights below 120 m (400 ft) AGL, visual line of sight (VLOS) operation, max. 457 m (1,500 ft) from operator
- 2 kg - 25 kg: requires registration and display of registration plates
- Over 25 kg: same requirements as 2 - 25 kg systems, plus type design & operation approval required from authorities

Argentina

Commercial drone use permitted. For sub-10 kg drones:

- Flights below 400 ft AGL (140 ft AGL below controlled airspace)
- Visual line of sight, daylight operations, no simultaneous flights
- No flying over populated areas, not closer than 5 km from runways
- Registration & identification required
- Medical fitness, theory & practice certificates required

The rules vary around the world

When it comes to flying professional drones within the law, the respective rules around the world are varied, complex, and ever-changing.

Some countries, such as Canada, the UK, France and Switzerland, have already put in place specific, concrete rules that safely and pragmatically integrate drones into the national airspace.

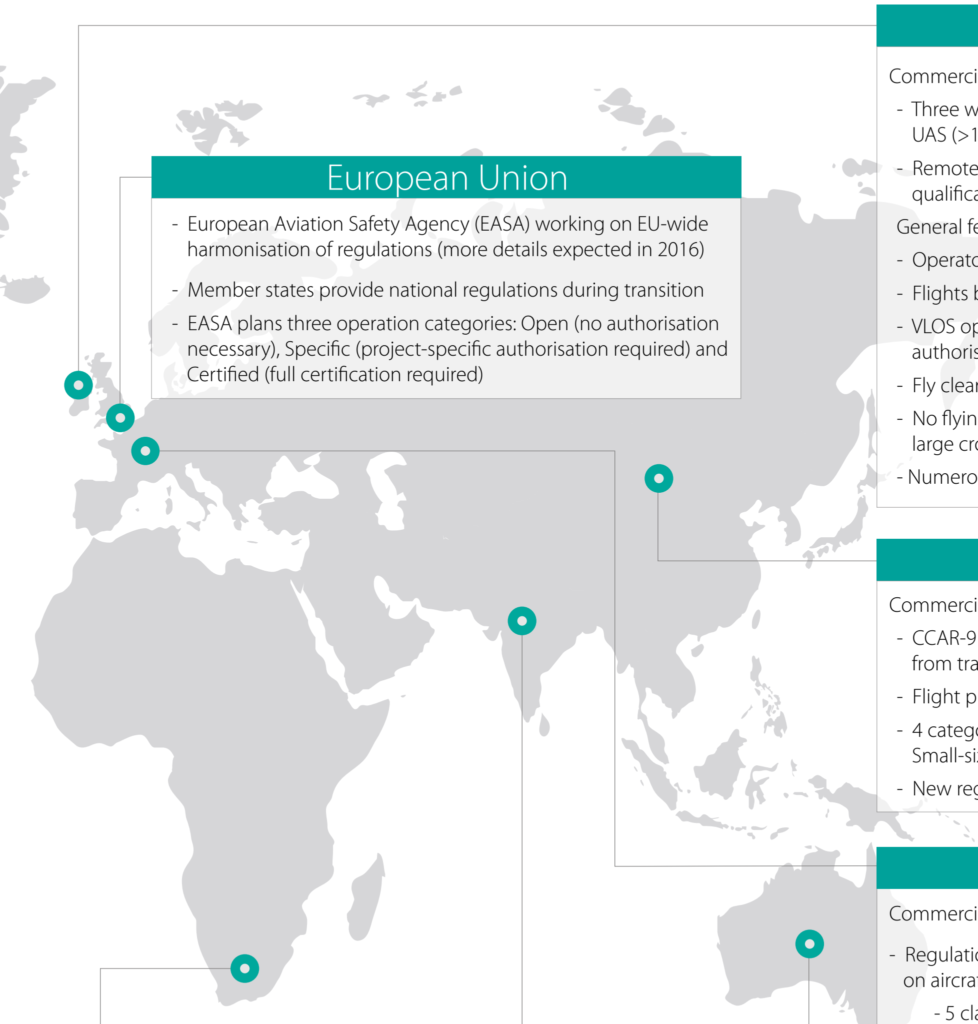
Other countries, such as the US, are currently working on finalising their UAV legislation, while in the meantime offering different types of authorisation or exemption for select organisations.

Elsewhere, there are countries with no existing drone-related legislation—leaving potential operators in a grey zone—and others that have effectively banned all UAS operations.

Typical requirements

While the exact legislation differs between those countries that have rules in place, there are several common requirements that most commercial drone legislation frameworks appear to share. These include:

- Visual line of sight (VLOS) operation, meaning the operator must be able to physically see the drone (unless he/she has additional extended VLOS (EVLOS) or beyond VLOS (BVLOS) authorisation)
- A flight altitude ceiling above the take-off point, for example of 120 m (400 ft), is common
- Maximum UAV take-off weight/weight classes (a lighter weight increasingly equates to more flexible usage)
- No fly zones, such as within several km/miles of an airport and urban areas/over crowds
- An operator certificate/licence of some description is often required
- A second drone observer is sometimes required



European Union

- European Aviation Safety Agency (EASA) working on EU-wide harmonisation of regulations (more details expected in 2016)
- Member states provide national regulations during transition
- EASA plans three operation categories: Open (no authorisation necessary), Specific (project-specific authorisation required) and Certified (full certification required)

India

UAS operation effectively banned (November 2015), unless granted approval from multiple government agencies. Regulations are in the process of being developed.

South Africa

Commercial use permitted.

Requirements:

- Drone must be registered with Civil Aviation Authority
- CAA Letter of Approval (RLA) required for drone
- Organisation must posess Remote Operator Certificate (ROC) & Air Services Licence (ASL)
- Operator must possess valid RPAS Pilot Licence (RPL)
- Flights below 120 m (400 ft) AGL
- No flying within 50 m of people, crowds, buildings etc.
- Flight coordinates reported to local air traffic control

Legal disclaimer

The content on this page is offered only as public general information. This page does not provide legal advice of any kind, and we cannot guarantee that the information is accurate, complete or up-to-date. This page should not be used as a substitute for obtaining legal advice from an attorney licensed or authorised to practice in your jurisdiction. You should always consult a suitably qualified attorney regarding any specific legal problem or matter.

UK

Commercial use possible.

- Three weight categories exist: SUA (0-20 kg), Light UAS (20-150 kg), UAS (>150 kg)
- Remote pilot licence required: BNUC-S (0-20 kg) and BNUC (>20 kg) qualifications exist

General features & requirements:

- Operators must register with Civil Aviation Authority (via EuroUSC)
- Flights below 120 m (400 ft) AGL unless granted special permission
- VLOS operations up to 500 m from operator (unless ELOS/BVLOS authorisation)
- Fly clear of controlled airspace unless Air Traffic Control permission
- No flying within 50 m of persons or structures, or 150 m of large crowds
- Numerous senseFly eBee operators authorised to fly

China

Commercial use possible.

- CCAR-91R2 & 61R2 licences/flight permits required (available from training institutes authorised by AOPA China)
- Flight plans must be reported to Air Traffic Management Bureau
- 4 categories of UAV: Micro-UAV (i.e. senseFly eBee), Light-UAV, Small-sized UAV, Large UAV
- New regulations possible in 2016.

France

Commercial use possible.

- Regulations based on: 4 usage scenarios & 7 classes of UAV (based on aircraft mass)
  - 5 classes for commercial work
  - Inc. sub-2 kg class

General features & requirements:

- Remote pilot qualification required
- Flights below 152 m (500 ft) AGL
- VLOS & BVLOS use possible (even night flights with special permission)
- Aerial work authorisations required for BVLOS/populated area use
- Aircraft airworthiness certification required for UAVs over 25 kg
- Operations manual accepted by French Civil Aviation Authority
- Numerous senseFly eBee operators authorised to fly

Australia

Commercial use possible.

- Operators must take a Controllers Certificate course
- Company must have an Operator Certificate
- Flight & maintenance manuals required
- For operation within unrestricted areas: below 120 m AGL, outside controlled airspace, greater than 5.5 km from aerodrome, no flying over populous areas, no flying within 30 m of people not involved, buildings, vehicles or boats
- For operation in restricted areas or controlled airspace, Civil Aviation Safety Authority & Airservices Australia approval required
- Numerous senseFly eBee operators authorised to fly

FEEDING THE WORLD

Reaping the benefits of scouting from above

What many non-farmers do not realise is that agriculture has, in the last few years, become a true high-tech precision industry, packed full of advanced technologies and scientific protocols spanning modern tractor and combine technology, soil sampling, vegetation indices and more.

Unmanned aerial systems are simply the newest technology to enter this carefully optimised world—bringing the benefits of accessible aerial imagery to farmers, co-operatives, agronomists and crop consultants.

With a drone an agriculture professional can capture highly accurate images of a farm's fields, covering up to hundreds of hectares/acres in a single flight—without the cost and hassle of manned services (typically better suited to covering larger areas) and at a far greater resolution than satellite imagery provides, even when there is cloud cover.

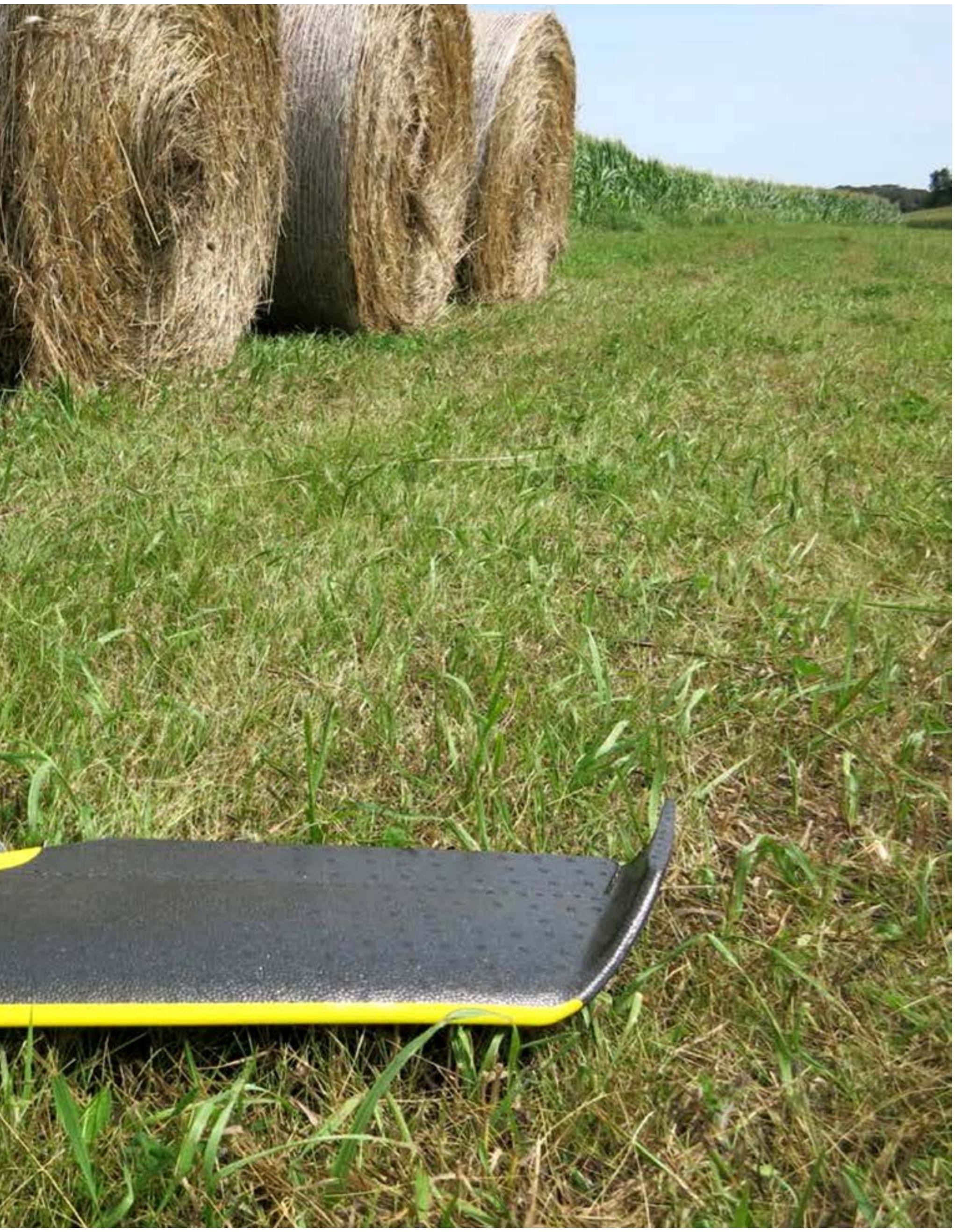
By using powerful image processing software operators can then easily transform these shots into one large 'orthomosaic' image. Then simply apply algorithms such as the Normalized Difference Vegetation Index (NDVI) to this image to create a reflectance map of the crop.

This map is the key to boosting yields and cutting costs, since it highlights exactly which areas of crop need closer examination—meaning less time spent scouting, and more time treating the plants that need it.

The very latest fully-featured crop scouting drones, such as the eBee Ag, include an even more comprehensive 'drone to tractor' workflow: after flying the eBee Ag, use its optional post-flight software to generate quick NDVI maps of your crops, identify problem areas, create application maps and export prescriptions, all on the same day.

"The eBee Ag is our main tool for precision agriculture. We have found it to be a remarkable tool for identifying issues within crops before problems become too severe. When the results from the eBee Ag are coupled with targeted soil testing, exceptionally accurate prescriptions can be made."

James O'Neill, Director, Signpost Surveys



Spring

Tasks

- Prepare machinery
- Apply fertiliser/manure
- Apply herbicide
- Till, prepare seedbed
- Plant seed

Drone usage

- Early analysis of soils, tillage, tile & drainage

Summer

Tasks

- Apply herbicide
- Apply fertiliser
- Apply fungicide
- Apply insecticide
- Irrigation management

Drone usage

- Stand count & gap analysis
- Irrigation management
- Observation of growth variability
- Assess & observe nitrogen needs
- Crop stage monitoring for timing of applications

Fall

Tasks

- Harvest crop
- Manage & till residue
- Apply fertiliser, manure
- Land improvements

Drone usage

- Pre-harvest: dry down & stand consistency observation
- Post-harvest: analysis of soils, tillage and topography

Winter

Tasks

- Machinery purchases
- Input purchases
- Insurance purchase/claims

Drone usage

- Assessment of input & machinery performance

PROTECTING THE PLANET

Image: Joseph Shea

Safeguarding our world with accurate aerial data

Drone technology suits a huge and ever-expanding range of conservation and environmental science applications—offering quick and efficient aerial imagery, on demand.

From glacial feature modelling and erosion monitoring to animal counting and species identification, the list of projects that drones are being used for is already long and continues to grow.

There are many reasons why professionals such as environmental engineers and researchers are increasingly using drones, often in place of terrestrial surveying equipment or traditional aerial imaging services. The benefits these professionals often mention include:

• Flexible

A drone can be launched on demand—weather and regulation permitting—without needing to source and book manned aircraft services (if these exist in the region) or purchase and wait for satellite imagery.

• Timely

A UAV produces completely up-to-date imagery. This makes drones suited to time-sensitive projects and for monitoring locations at regular intervals (i.e. using the same flight plan each time).

• Efficient

Unlike traditional surveying techniques, using a drone is fast and requires minimal staff, plus using an aerial approach overcomes common site access issues such as impenetrable vegetation, boulders, crevasses etc.

• Cost-effective

Used regularly, the per-project cost of a professional drone system is typically lower than third-party alternatives such as manned imaging aircraft, with a drone system often paying for itself in as little as a few months or a few large projects.

• Discrete

Small and light electric-powered drones, especially fixed-wing aircraft, make little noise and are often bird-shaped, meaning animals on the ground are rarely disturbed by these tools, if they notice them at all.

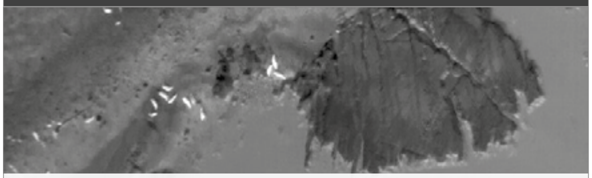
Rotary (helicopter) drone systems are best suited to monitoring and charting smaller areas, enabling operators to capture video imagery and respond to this feedback live, while fixed-wing UAVs—such as senseFly's eBee—allow users to map larger areas in a single autonomous flight.

"With the eBee we could easily identify and map geomorphological features in the New Zealand Subantarctics, which due to thick vegetation and a lack of satellite coverage would have been impossible otherwise. The eBee's low noise and 'natural' appearance was also crucial, since this meant it didn't disturb local bird colonies. This drone has such a wide range of potential applications that it could be a sound investment for many research departments."

Dr. Zoë Thomas, Research Associate, Climate Change Research Centre

EXAMPLE APPLICATIONS INCLUDE:

Animal management & conservation

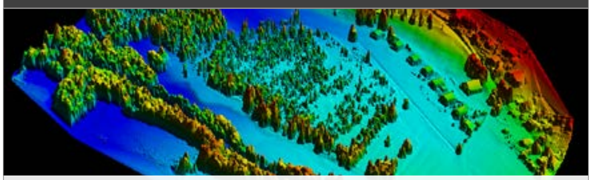


Saddle Island, Canada

Coastal management

Kent, England

Plant conservation

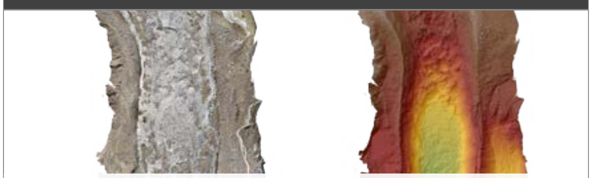


Eigenthal, Switzerland

River & flood assessment

Millet River Basin, Haiti

Change monitoring

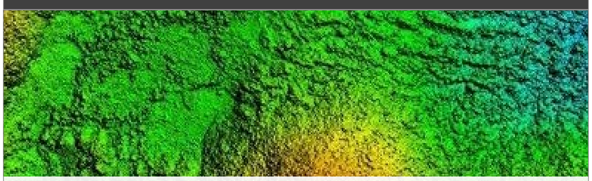


Lirung Glacier, Nepal

Earthwork & rock face management

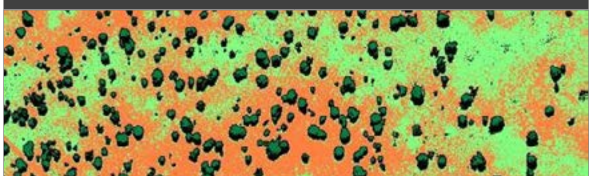
Bavois, Switzerland

Terrain modelling



Subantarctic Islands, New Zealand

Vegetation classification



Savanna, Namibia

MINING MORE DATA, MORE SAFELY

Anyone involved in mining appreciates that worker safety is of paramount importance.

By allowing surveyors to collect accurate spatial data from above, drone technology can vastly reduce risk by minimising the time such staff spend on site (if they even need to enter the site at all).

Drone-based data collection can also boost productivity; surveying projects that once took days or weeks using traditional surveying techniques are now possible in just a few hours. Plus, there is no downtime required while surveyors move around a pit, as can be the case when using terrestrial surveying instruments.

With fewer man hours required to produce large, accurate data sets, and no need for externally-sourced imagery, the result is vastly reduced costs. In fact, many operators report that a single imaging drone—comparable in price to a mid-range GPS rover—can pay for itself in just a few months.

"The eBee is the heart of my operation, allowing me to offer clients an affordable and reliable service that wasn't previously available in this part of the world. My drone has already logged 182 problem-free flights and has proved durable enough to handle the toughest African operating conditions. The best part is the feedback I receive from clients—they love our cost effectiveness and they love reducing the number of personnel working inside their mining sites."

Theo Wolmarans, ICARUS AT Pty Ltd., South Africa

Drones can add value to:

Short-term planning

- Pit & dump management
- Communication of daily/weekly mining plans
- Haul route surface optimisation
- Storm damage assessment & control

Long-term planning

- Haul road, dump and pit design
- Geotechnical
- Surface stability monitoring
- Joint mapping
- Control for mining in void areas
- Mapping of steep inaccessible inclines

Drill & blast

- Up-to-date surfaces for optimised blast designs
- Pre- & post-blast data
- Identification of misfires & wall damage

Geology

- Stock pile management
- Grade control & exploration planning

Hydrology

- Drainage and water management
- Watershed, drainage basin & water flow mapping
- Thermal detection of ground water inflows
- Tailings dam management

Construction

- Feasibility studies
- Leach pad, dam wall & platform construction quality control
- Progress monitoring & reporting

Mineral exploration

- Resource calculation
- Geophysical & watershed/catchment area modelling
- Supporting photography (land usage, SEIA etc.)

Heritage & environmental management

- Reporting
- Erosion detection
- Vegetation change tracking
- Inundation tracking
- Slurry pipeline stability & leakage detection
- Game counting
- Surrounding community mapping

Legal

- Cadastre
- Property rights definition
- Change detection
- Security
- Incident evidence capture
- Corridor & boundary surveillance

Community

- Community relations/marketing
- Impact reporting
- Oblique imagery

Other

- Conveyor belt inspection (thermal)

THE DRONE SERVICE BUSINESS OPPORTUNITY

Profit from the take-off of drone imaging services

As drone regulations continue to evolve around the world, the opening up of the commercial market represents an excellent business opportunity for operators of unmanned aerial systems.

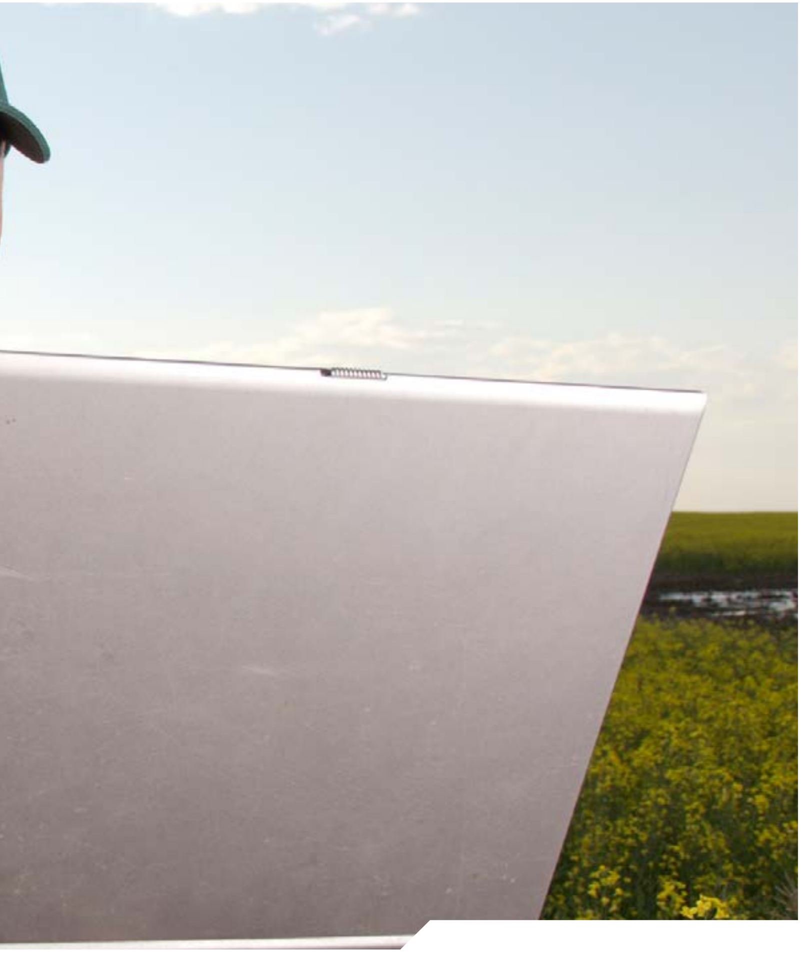
This is particularly true of operators with professional, sector-specific knowledge and experience, who are capable of providing clients with tailored, end-to-end services that include detailed analysis and reporting.

Alongside legislatory change, service operator networks are also growing in popularity. These provide end clients with a hassle-free way of identifying qualified suppliers, while providing operators themselves with a potentially valuable source of new business leads. (Drone Connector is one such network—see opposite page).

Already today:

- In land surveying — organisations in need of accurate ground measurements are using drone operators in place of slower, more expensive terrestrial surveying providers.
- In agriculture — drone companies are being employed to create accurate maps of crop health.
- In geographic information systems (GIS) — drone operators are providing GIS specialists with up-to-date, high-resolution background maps.

Plus, drone service opportunities exist in a wide range of additional fields: forestry, construction, civil engineering, conservation, humanitarian aid, archaeology and many more.



"The senseFly eBee changed the game for us, allowing us to move from being UAV hobbyists into offering professional drone services. We deploy it for many commercial applications, in mining & construction, right around the world. We can deliver highly accurate datasets to customers within days of being on-location, faster, more safely, and more efficiently than previous technology and service providers in these industries were able to provide. This technology has been wonderful to work with."

Brian Deatherage, CEO, Phoenix Drone Service LLC

DRONE CONNECTOR

Meet Drone Connector

Drone Connector is the world's largest network of professional drone operators, comprising over 750 registered members *(as of January 2016)* located right around the world.

Visit www.DroneConnector.com

ABOUT SENSEFLY

senseFly develops and produces aerial imaging drones for professional applications.

Safe, ultra-light and easy to use, these highly automated data collection tools are employed by organisations around the world in fields as diverse as surveying, agriculture, GIS, industrial inspection, mining and humanitarian aid.

senseFly was founded in 2009 by a team of Swiss robotics researchers and pilots. The company quickly became the industry leader in mapping drones and it continues to lead the way in developing situationally aware systems that help professionals to make better decisions.

senseFly drones are available around the globe via the company's ever-growing network of distribution partners. To explore this network visit www.sensefly.com/wheretobuy. senseFly is a Parrot company and a member of the Small UAV Coalition.

senseFly in numbers

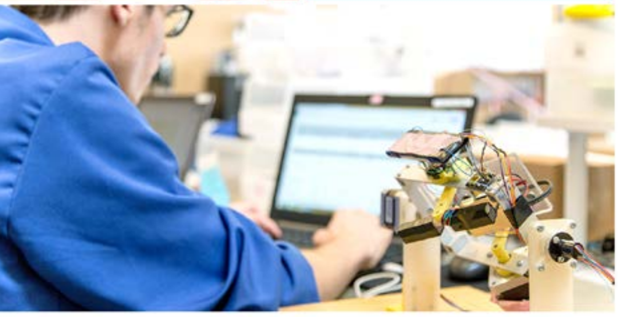
200 *points of sale*

>100 *countries served*

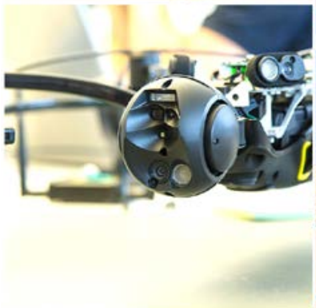
>220,000 *customer flights*

>65,000 *customer flight hours*

QUALITY ASSURED



AT SENSEFLY, ***THE QUALITY*** OF OUR PRODUCTS IS OUR TOP ***PRIORITY***



Inspired by the safety-conscious aviation backgrounds of its founders, senseFly extensively tests both individual drone components and finished systems to achieve the highest possible level of quality and reliability.

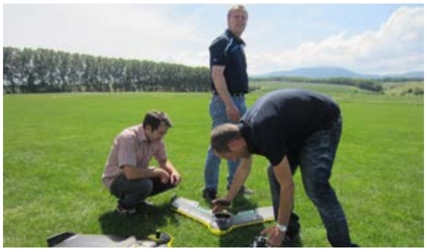
senseFly drones are flying continually, all over the world. They are flown by senseFly staff, distribution partners and thousands of customers. The usage data from these flights, from those operators that agree to provide it, provides senseFly's R&D and production staff with continuous, detailed feedback—a raft of data that is used to further enhance and optimise senseFly systems.

Checked, checked, and checked again

- senseFly drones undergo quality checks at each stage of production
- Every component is individually tested and calibrated, including at different temperatures
- Every finished drone is flight tested
- Each drone & its components are then verified once more before shipping

"We have flown our eBee in all types of weather and have been extraordinarily impressed with its reliability."

Jarlath O'Neil-Dunne,
Director, University of Vermont Spatial Analysis Laboratory



Professional training

Full training on senseFly UAVs is available at every point of sale; including the company's global network of professional distributors, senseFly HQ and a growing number of certified training centres (such as CFAD in France). Training typically lasts one day and covers:

- Flight planning in eMotion
- Field training:
    - Launching the drone
    - In-flight monitoring
    - Landing
    - Safety considerations
- Using eMotion's Flight Data Manager
- Processing with Postflight Terra 3D
- Creating data products

Help is at hand

senseFly is dedicated to making sure every customer receives timely, expert technical support.

Since the best support is local support, the company has created and continues to grow a global network of support service centres. These are typically, although not always, managed by experienced senseFly distributors, who themselves have direct access to senseFly's internal team of experienced support engineers as required.

senseFly support covers not only drones, but also software programs, camera payloads and accessories.

my.senseFly

Meet senseFly's customer portal.

In addition to being the home of senseFly's support ticket management, my.senseFly also includes: the Knowledge Base (packed full in-depth product articles, tutorials, webinars & more), the latest senseFly software download links, downloads such as user manuals, firmware updates, and editable customer and Drone Connector profile info.

albris
senseFly

The sensor-rich drone for professionals, featuring TripleView imaging, advanced situational awareness and a choice of flight modes.

The intelligent **mapping & inspection** drone

eBee
senseFly

The eBee Ag is the only precision farming UAV you need. Scout crops, analyse plant health, create prescriptions and begin treatment all on the same day.

The **precision agriculture** drone

eBee
senseFly

Use this fully autonomous mapping drone to capture high-resolution aerial photos you can transform into accurate orthomosaics & 3D models.

The professional **mapping** drone

RTK
eBee
senseFly

Capture aerial photography to produce orthomosaics & 3D models with absolute accuracy of down to 3 cm - without ground control points.

The **survey-grade mapping** drone

GLOSSARY

This publication's terminology explained

Above ground level (AGL): this term is typically used when describing a drone's flight height.

Background map: a visual 2D map of a region featuring landforms, roads etc., onto which additional data is layered. Often used in the field of GIS. Sometimes called a base map.

Beyond visual line of sight (BVLOS): an operating method whereby an unmanned aircraft is flown beyond visual line of sight of the operator.

Check point: a surveyed point on the ground, used to verify the accuracy of photogrammetric outputs such as DSMs.

Contour map: a topographic map that delineates surface elevation through the use of contour lines.

Drone: an unmanned aircraft or ship that can navigate autonomously, without human control or beyond line of sight (source: Dictionary.com). *See also page 5.*

Digital surface model (DSM): a 3D model of an area that includes the tops of buildings, trees and other ground-based objects.

Expanded polypropylene (EPP): a highly versatile and shock-absorbent type of foam.

Flight log: a record of a single flight. Traditionally this would be written by a pilot. In the case of senseFly drones this is a digital record that is generated automatically.

Ground control point (GCP): a location or object on the ground that has precisely known coordinates. Used to improve the precision of DSMs created by photogrammetric analysis of a series of images.

Geotag: an electronic tag (grouping) of geographic information that is assigned to media such as photographs and videos via the process of geotagging (in the case of senseFly drones this process is handled automatically by their eMotion software).

GeoTIFF: a public domain metadata standard that allows georeferencing information to be embedded within a TIFF image file.

Geographic information system (GIS): a system that lets users visualise, question, analyse and interpret data to understand relationships, patterns, and trends (source: ESRI).

Global navigation satellite system (GNSS): a satellite navigation system with global coverage, such as GPS, GLONASS and the European Union's forthcoming Galileo system.

Global Positioning System (GPS): refers to the United States NAVSTAR Global Positioning System, a space-based navigation system that provides location & time information anywhere on or near the Earth (when there is an unobstructed line of sight to four or more of the system's satellites).

Ground sampling distance (GSD): the distance between two consecutive pixel centres measured on the ground. A GSD of 5 cm means one pixel in the image represents 5 linear centimetres on the ground. Sometimes referred to as ground resolution.

Inertial measurement unit (IMU): an electronic device, used to manoeuvre aircraft, which detects changes in acceleration and rotation. Comprised of sensors such as accelerometers, gyroscopes and sometimes magnetometers.

Keypoint: an identifiable point in an image. The process of photogrammetry involves the matching of common keypoints on two or more images.

Kinetic energy: the energy an object possesses due to its motion.

Keyhole markup language (KML): an XML notation for expressing geographic annotation and visualisation within internet-based, two-dimensional maps and three-dimensional Earth browsers (source: Wikipedia).

Light-emitting diode (LED): a semiconductor device that emits light when an electric current is passed through it.

Lidar: a remote sensing technology that measures distances by illuminating a target with a laser and analysing the reflected light (source: Wikipedia).

Magnetometer: a geophysical instrument that measures the strength of the Earth's magnetic field. Used alongside sensors such as gyrometers and accelerometers to determine an aircraft's attitude (its orientation relative to the Earth's horizon).

Meta data/Metadata: a set of data that describes other data. In the case of a photo, meta data might include: where an image was captured (i.e. its geographic coordinates), who captured it, the camera used and more.

Normalized Difference Vegetation Index (NDVI): one of the most commonly used vegetation indices in precision agriculture.

Orthomosaic/Orthophoto: a large image comprised of adjoining orthorectified images that have been digitally stitched together. A common mapping drone output (often in GeoTIFF format).

Payload: a component or product carried by a drone to fulfil a specific mission. (In the case of aerial imaging drones, the payload is the camera.)

Pitch: describes an aircraft's rotation when the nose moves up or down about a lateral axis (e.g. for fixed-wing aircraft this axis runs from wing to wing).

Pitot probe: the instrument on an aircraft that measures air pressure in order to calculate airspeed. Contains a pitot tube.

Point cloud: a set of data points in a coordinate system. In a 3D coordinate system (as with a 3D point cloud), such points are typically defined by X, Y, and Z coordinates.

Raster data: in its simplest form, a raster consists of a matrix of cells (or pixels) organised into rows and columns (or a grid) where each cell contains a value representing information, such as temperature. Drone-captured digital photographs are rasters (source: esri.com).

Red green blue (RGB): the visible region of the electromagnetic spectrum, from approximately 400 nm to 700 nm.

Roll: an aircraft's rotation about a longitudinal axis, running from nose to tail.

Remotely piloted aircraft system (RPAS): Describes a configurable set of remotely-piloted aircraft elements. *See also page 5.*

Revolutions per minute (RPM): describes the rotation speed of a motor or other machine.

Real time kinematic (RTK): a technique used to enhance the precision of position data derived from satellite-based positioning systems, which relies on a single reference station or interpolated virtual station to provide real-time corrections (source: Wikipedia).

Unmanned vehicle system/vehicle (UAS/UAV): an aircraft operated with no pilot on board, plus its associated elements. *See also page 5.*

Vector data: a representation of the world using points (e.g. featuring x, y, z coordinates), lines, and polygons. Useful for storing data that has discrete boundaries, such as country borders and parcels of land (source: stackexchange.com).

senseFly
a Parrot company

For professional drone updates, subscribe
to our newsletter & blog at
www.sensefly.com