eBee

senseFly

Extended User Manual

eBee and eBee Ag

Revision 12 / September 2014

senseFly
a Parrot company

GENERAL INFORMATION

READ THIS USER MANUAL CAREFULLY BEFORE USING A SENSEFLY LTD PRODUCT.

senseFly Ltd products are intended for professional use only.

Applicable Regulations

senseFly Ltd products are subject to Civil Aviation regulations. Regulations may vary depending on the country where you intend to operate your product.

ANY USE OF SENSEFLY LTD PRODUCTS IN BREACH OF THE LAW OF THE COUNTRY WHERE YOU OPERATE THE PRODUCT IS UNDER YOUR SOLE RESPONSIBILITY.

INFORM YOURSELF BEFORE USING THE PRODUCT. SOME COUNTRIES MAY HAVE LAWS THAT LIMIT THE USE OF UNMANNED AIRCRAFT TO 'LINE-OF-SIGHT' OPERATIONS AND/OR PROHIBIT THE USE OF UNMANNED AIRCRAFT AT ALL OR IN SPECIFIC AREAS.

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Limited Warranty

SenseFly Ltd warrants that the product will be free from defects in material and workmanship for a period of twelve (12) months from the date of delivery. SenseFly Ltd further warrants that the product will perform substantially in accordance with its specification. During the warranty period senseFly Ltd's sole liability shall be at senseFly Ltd's sole option, either to repair or to replace the defective product with another product or a product with similar specifications, at no charge, or to reimburse the purchase price of the product, or if repair or replacement is not possible, issue a credit note; provided however, that the defect has been confirmed by senseFly Ltd and that the defective product is returned to senseFly Ltd in accordance with the support and repair form together with all required flight logfiles.

Warranty does not apply, without limitation, in case: a) the products are not stored and used according to their specifications, b) the products are damaged due to carelessness, negligence, or wrong use by the user, and c) for defects due to normal wear and tear including, but not limited to, deterioration to the airframe after first flight, normal degradation, misuse, moisture or liquids, proximity or exposure to heat, accidents, excessive strain, abuse, neglect, misapplication, repairs or modifications made by third party other than senseFly Ltd, damage due to manual operation, damage due to take-off or landing location with obstacles, damage due to low altitude flight, damage due to loss of data radio connection, damage due to strong wind, rain or humidity, or other causes for which senseFly Ltd has no control.

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TO THE EXTENT PERMITTED BY APPLICABLE LAW, IN NO EVENT WILL SENSEFLY LTD BE LIABLE FOR ANY LOSS OF REVENUE, LOSS OF PROFIT, LOSS OF DATA, OR INDIRECT, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES, EVEN IF SENSEFLY LTD HAS BEEN NOTIFIED OF THE POSSIBILITY OF SUCH DAMAGES, AND WHETHER THIS LIABILITY ARISES FROM A CLAIM BASED ON CONTRACT, WARRANTY, TORT OR OTHERWISE, WITH THE EXCEPTION OF GROSS NEGLIGENCE AND DEATH.

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Website: http://www.sensefly.com

Technical support

If you have questions on your *eBee* or accompanying software please consult senseFly Ltd's Technical support website at the following address:

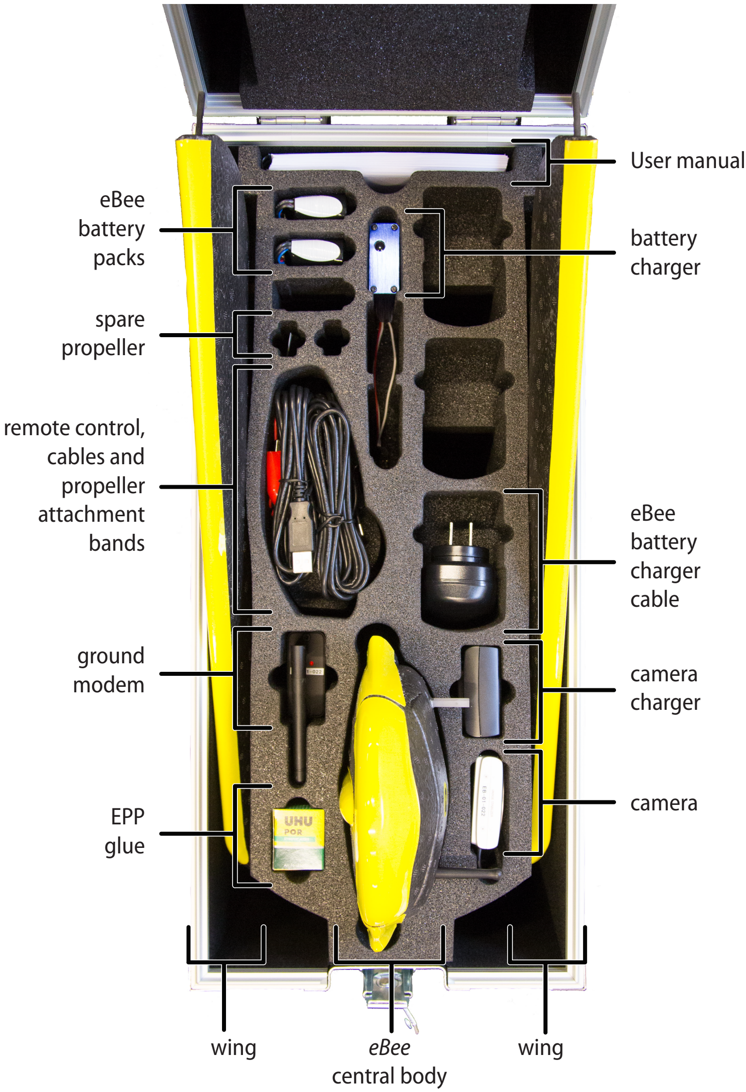
http://www.sensefly.com/support/

Welcome to your *eBee*

Congratulations on your purchase of the *eBee*, a complex and powerful yet intuitive autonomous mapping system. We take great care to develop and design the best possible hardware and software tools for quick, high-quality and easy-to-use 2D and 3D aerial mapping.

Note: This manual refers to the version 2.4 of *eMotion* and version 3.2 of *Postflight Terra 3D* software. Check the software version included in your package and consult the Release Notes for potential changes included in more recent versions of the software.

Package contents



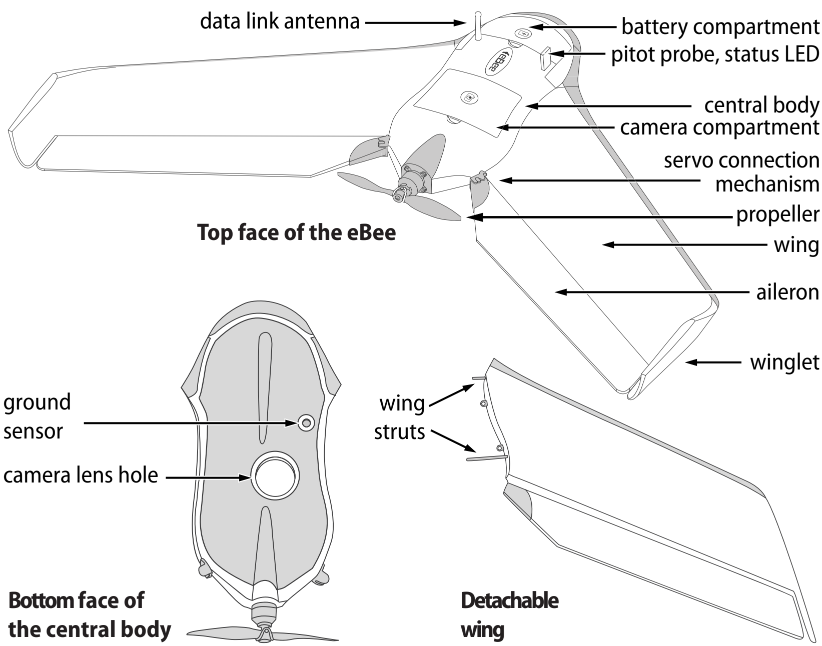
The standard *eBee* package contains the following items:

- 1x carrying case with foam protection
- 1x *eBee* central body with built-in autopilot
- 1x pair of detachable wings
- 1x spare propeller
- 10x spare propeller attachment rubber bands
- 2x Lithium-Polymer battery packs
- 1x Lithium-Polymer battery charger (including cables)
- 1x 2.4 GHz USB ground modem for radio data link (including USB cable)
- 1x 2.4 GHz remote control (including including 3 AA batteries)
- 1x still camera (including memory card, battery and charger)
- 1x USB cable for interfacing with camera and on-board autopilot
- 1x EPP glue
- 1x *eBee* User Manual
- 1x camera User Manual

Depending on your order, your package may also include other items, such as additional payloads. Please verify upon delivery that your package is complete. In case of a missing item, please contact your *eBee* reseller immediately.

Note: Camera user manuals are also available to download from sensefly.com/support/download.

Hardware features



The *eBee* is an autonomous flying drone comprised of the following components:

- **Central body:** This is the core of the *eBee* and includes all the electronics, actuators and communications hardware on-board the drone.

- **Wing:** The two wings of the *eBee* are detachable for storage and replacement. Each wing has two wing struts and two clips to hold it in place within the central body.

- **Winglets:** These structures add aerodynamic stability to the drone while it is in flight.
- **Ailerons:** Used to control the *eBee* while in flight.
- **Servo connection mechanism:** The ailerons are connected to the servo-motors within the central body of the drone through this connection mechanism.
- **Propeller:** Used to generate thrust while it is in flight.

> ⚠ **Caution:** When attached to the motor the propeller spins at high speeds and can be potentially dangerous if it comes into contact with exposed skin. Be sure to always keep your hands clear of the propeller when the battery is attached to the *eBee*.

- **Battery compartment:** The *eBee* is powered by a LiPo (Lithium Polymer) battery stored within the battery compartment.

> ⚠ **Caution:** Proper care of your battery is essential. Please read section 'Proper battery care' on page 135 before using your drone for the first time.

- **Camera compartment:** The *eBee* features a built-in camera for taking aerial images stored within the camera compartment.
- **Data Link Antenna:** Used by the drone to communicate with the *eMotion* software through the USB ground modem.
- **Pitot probe:** This is the sensor used by the *eBee* to detect airspeed, wind and altitude. It must be kept clean and clear of obstructions to function properly.
- **Status LED:** This coloured LED displays the current state of the *eBee*. It is housed underneath the pitot probe and thus illuminates the entire transparent probe in various colours depending on the drone's state.

- **Ground sensor:** The ground sensor, composed of a high-speed optical sensor and lens assembly, is used to detect the proximity of the ground.

Software features

The *eBee* package allows for the download and use of *eMotion* * and *Postflight Terra 3D* * at no extra cost.

eMotion is the integrated software package that allows you to interact with your *eBee*. Its easy-to-use interface allows you to plan a mapping flight intuitively from the comfort of your office or directly in the field. Once the drone is launched, you can use *eMotion*'s wireless connection with your *eBee* to track its position, monitor the progress of your mapping flight and send commands if desired.

Once your *eBee* returns after an aerial mapping flight it is the turn of *Postflight Terra 3D* to process the captured images fully automatically. *Postflight Terra 3D* is a full-featured mapping solution: with just a few mouse clicks it can create high-quality geo-referenced 2D and 3D orthomosaics and digital elevation/surface models (DEM/DSM). While you are still in the field *Postflight Terra 3D* analyses the quality of the captured images and generates an easy to understand report, letting you know immediately if the data you captured meets your mapping requirements.

∗ Software access terms and conditions apply. Postflight Terra 3D is limited to eBee images only.

Contents

Part I
Quick start guide

The first part of this document introduces you to the *eBee* and contains the basic information you will need to plan and execute a simple mapping project. A typical mapping project can be divided into three main phases:

1. **Planning and simulating a flight:** Every project begins with careful planning, whether it is a quick flight over a small area or a multi-stage flight in complex terrain. Section 'Planning and simulating a flight' on the next page describes how to use the Mission Planning feature to quickly generate a flight plan and to test it using the built-in simulator.
2. **Executing a flight:** Once planning is complete, it is time for the drone to perform its flight. In section 'Executing a flight' on page 27 you will learn how to prepare your drone for flight, connect it to *eMotion*, and to monitor it in flight while it gathers images. Though the *eBee* can complete a flight fully autonomously from take-off to landing, you can also modify its flight plan at any point during flight.
3. **Processing image data:** The last step in a project is converting the images taken by your *eBee* into usable products such as precise geo-referenced orthomosaics or 3D terrain models. section 'Processing image data' on page 48 leads you through the process of transferring images from the drone to a computer, checking if the image quality suits your needs while still in the field and producing advanced 2D and 3D maps.

1 Planning and simulating a flight

Goal of this section: This section introduces the *eMotion* software used to interface with the *eBee*. It describes the steps required to plan, simulate, and save a simple mapping flight. A more detailed description of *eMotion* and its advanced functions is presented in section '*eMotion* in-depth guide' on page 83.

1.1 Installing *eMotion*, *Postflight Terra 3D*, and the ground modem drivers

You can download the latest version of *eMotion* and *Postflight Terra 3D* at:

www.sensefly.com/support/download

Use the password provided with your *eBee* to access the download section.

We recommend that you download and install *Google Earth*™ to take full advantage of the features of *eMotion*. You can find more information at the following address:

www.google.com/earth/

To install *eMotion* on Windows, simply execute the provided installers for *eMotion* and *Postflight Terra 3D* and follow the on-screen instructions. The *eMotion* and *Postflight Terra 3D* software will be available in the 'Start' menu. Drivers for the USB ground station ground modem will automatically be installed along with *eMotion*.

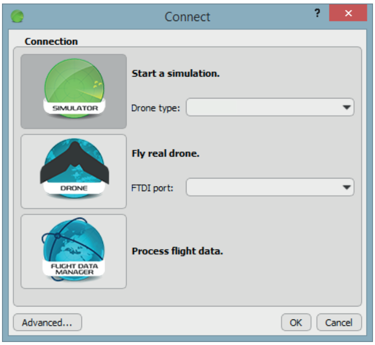
In case a problem arises after connecting the ground modem to the computer for the first time you can find the drivers in one of the following directories (depending on your version of Windows):

```
C:\Program Files\senseFly\eMotion 2\usb_driver\
C:\Program Files (x86)\senseFly\eMotion 2\usb_driver\
```

See section 'Updating the *eBee* software' on page 128 if you have any difficulty with software installation.

1.2 The *eMotion* interface

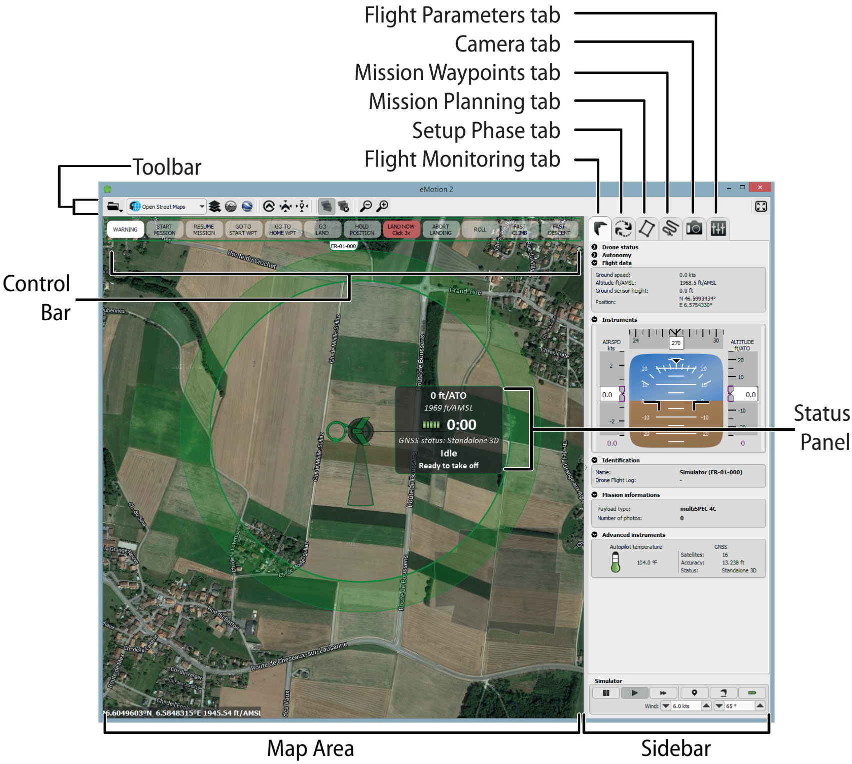
Thanks to the powerful tools available within *eMotion*, designing a mapping flight for your *eBee* is a simple process. To get started, launch *eMotion* and choose what you would like to do...



- To run a simulation, select the simulator, choose the drone you want to simulate and click OK.
- To fly a drone, connect your ground modem to your computer and select Drone. If you have more than one USB device connected to your PC , choose the ground modem you want to connect to from the list and click OK. Otherwise, just click OK.
- To process flight data you already created, select the Flight Data Manager and click OK.

We recommend that you plan flights using a simulated drone. Once connected to a real or simulated drone you will see the main screen of *eMotion*.

The main screen of *eMotion* is split into four sections:



- **Map Area:** The Map Area of *eMotion* displays a map with the drone's current position, indicated by the symbol. A small Status Panel floats beside the symbol, indicating important status information including the *eBee*'s current altitude (both Above the Take-off Altitude, marked as ATO, and Above Mean Sea Level, marked as AMSL), battery level, flight time, and status. The Status Panel can be hidden by clicking on the drone. Moving around the map is done by clicking and dragging at any place not occupied by a symbol (such as a waypoint or the drone symbol).

- **Control Bar:** The Control Bar is used to issue various commands to the *eBee* while it is in flight, such as starting the mission phase or holding position. It is also used to display and acknowledge warnings that may occur either before or during a flight.
- **Toolbar:** The Toolbar contains buttons to control the layers, sources or map information and other display options related to the Map Area. *eMotion* can use many sources of mapping information.
- **Sidebar:** The Sidebar is split into several tabs, each with a particular function. The Flight Monitoring tab is used for monitoring the drone while in flight. The Setup Phase tab controls the take-off and landing portions of a flight plan (referred to as the 'setup phase') whereas the Mission Planning tab defines the image acquisition portion of the flight plan (referred to as the 'mission phase'). The last three tabs are used for advanced waypoint planning and parameter setting. You can hide the Sidebar by clicking on its left edge. The Sidebar also contains controls for the simulator when connected to a simulated drone.

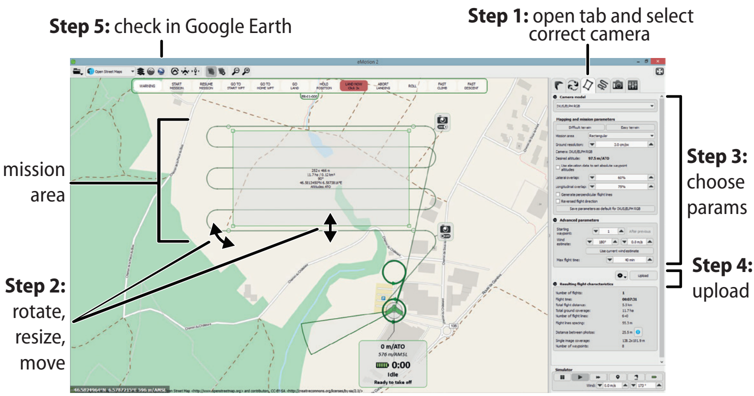
1.3 Creating a new flight plan

Every mapping flight requires a flight plan, which is a path defined by a set of waypoints, or points in 3D space, and a set of actions that can be performed at or in between waypoints, such as taking images, proceeding to the next waypoint or landing. A flight plan is shown in the Map Area using circles to represent waypoints, lines to represent the flight path and arrows to show the direction of flight. The large circle with a thick border illustrates the working area boundaries within which the *eBee* will always remain. See section 'Waypoints and their properties' on page 56 for more information on waypoints and the various symbols presented in the Map Area.

A complete flight plan for an *eBee* is divided into two separate phases: the setup phase and the mission phase. The mission phase includes waypoints and actions related to mapping and capturing images. The setup phase includes waypoints and actions related to take-off and landing. This phase is usually planned directly in the field and is explained in detail in section ‘The setup phase of a flight’ on page 37.

1.4 The mission phase of a flight

The easiest way to create a mapping flight for the systematic coverage of an area is to use the automatic mission planning feature of *eMotion*. By simply positioning a rectangle around the area you would like to cover, *eMotion* will generate a mission plan optimised for the ground resolution that you desire.



> **Note:** For more complex terrain and missions, *eMotion* has the ability to set polygonal mission areas of any size and shape, and to automatically adjust waypoint altitudes based on elevation data. These powerful features are described in more detail in section ‘Advanced polygonal mission area’ on page 60and section ‘3D mission planning using elevation data’ on page 61, respectively.

Follow these steps to automatically setup waypoints for a mapping mission:

1. Select the Mission Planning tab from the Sidebar. A grey zone will appear in the Map Area to designate the mission area to cover. Information such

as size and position is overlaid on the area. A mission plan, including the required waypoints, is automatically calculated and displayed to preview the mission plan that will be created.

2. Adjust the location, size, and shape of the mission area. The area can be relocated by dragging the gray zone. The four square handles on the edges of the area can be used to resize it and the round handles on the corners of the area can be used to rotate it. As you adjust the area the mission plan preview is continuously updated.

3. Adjust the mapping and mission parameters in the Mission Planning tab to suit your terrain and quality requirements[1]. As a first step, *eMotion* provides two predefined set of parameters; ‘Easy terrain’ are the default parameters designed for simpler terrain, such as mines or agriculture, whereas ‘Difficult terrain’ is designed for complex areas, such as forests, and provides higher image overlap at the cost of a lower resolution. Be sure to include an estimated wind speed and direction, as this has an effect on the area that can be covered in a single flight. Once again, the mission plan preview will be continuously updated as you modify the parameters.

4. Check the resulting flight characteristics in the tab. Once you are satisfied, upload the mission plan to the simulated drone by clicking the ‘Upload’ button.

5. Click the button in the Toolbar to open the flight plan in *Google Earth™*[2]. Review the flight plan to ensure that there is sufficient clearance between the flight plan and the ground. Any updates to the flight plan that you make within *eMotion* will be reflected directly in *Google Earth™*.

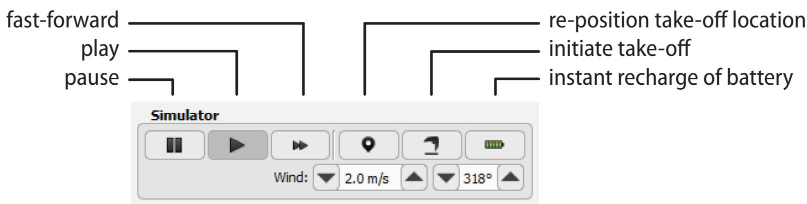
[1] see section ‘Mission Planning tab’ on page 100 for a complete description of available parameters
[2] see section ‘Flight visualization in *Google Earth™*’ on page 64

> **Caution:** *eMotion* as well as the automatic mission planning tool are not aware of any obstacles that may exist in the area. In addition, when not using elevation data, the mission planning tool assumes that the mission area is flat and at the same altitude than the take-off location. It is also not aware of any legal restriction (such as minimum or maximum altitude) that may exist in your region. The resulting flight plan should be carefully reviewed in order to avoid any collision with uneven terrain or tall objects such as buildings, and to comply with local regulations.

The final step after you have prepared a flight plan is to save it to a file that you can load into the *eBee* when you are in the field. Select the Setup Phase tab from the Sidebar, click on 'Save flight plan to file...', choose a filename and location and click 'Save'.

1.5 Simulating your flight

Simulating your flight gives you an idea of the position and size of images that will be taken during the flight. In addition, it allows you to learn to use advanced functions, such as in-flight waypoint editing and camera control, without putting your *eBee* at risk[3]. When *eMotion* is connected to a simulated drone an extra set of buttons appear in the Sidebar:



You can set the take-off location of the *eBee* by clicking on the icon and placing the point on the map. This simulates the action of switching on the real drone

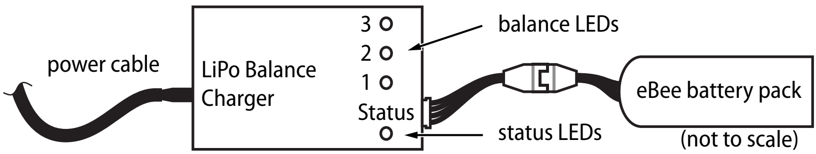
[3] see section 'Simulator' on page 87 for a complete description of the simulator

and letting it acquire GPS signals. You can test your flight plan by clicking the icon, simulating a take-off manoeuvre. The *eBee* will then go through its flight plan in the same way it would in the field. You can pause, play or speed up the simulation by clicking the corresponding buttons in the Toolbar. You can monitor the state of the drone while in flight using the Flight Monitoring tab and the Status Panel[4]. You may also monitor the flight in 3D in *Google Earth^{TM}* by clicking on the button in the Toolbar.

> **Caution:** The simulator is a tool designed to aid with flight planning and to familiarise you with the advanced functions of your *eBee*. The simulated physics, however, are basic and do not always accurately reflect the true behaviour of the drone in flight. In particular, estimates of battery level and reactions to wind are difficult to simulate with high accuracy. You should in no case depend on behaviours seen with a simulated drone to be reproduced exactly in real flight.

1.6 Getting ready for a mission

Before leaving for the field to perform a flight, be sure to fully charge all your *eBee* batteries[5]. When delivered, the *eBee* battery may not be fully charged.



To charge an *eBee* battery pack, connect it to the battery charger as illustrated above. During charge, the status LED on the charger is solid red. Charging is complete when the status LED turns green.

The charger provided independently balances the voltage of each of the 3 cells contained in the battery pack to ensures optimal performance and battery life. If

[4] see section 'In-flight monitoring and control' on page 44
[5] Consult your payload user manual to know if the payload battery is necessary for the flight

any of the cells is unbalanced, its associated LED will be solid red during charging until it is re-balanced. Charging can take up to an hour, depending on the charge level of the battery and the required cell balancing work. See section 'Proper battery care' on page 135 for more information on maintaining your drone's batteries.

If you plan on performing a flight away from an Internet connection it is useful to preload map tiles by selecting 'Download maps...' from the 🗀 File menu. More details on how to take advantage of the various map sources available in *eMotion* can be found in section 'Toolbar' on page 84.

2 Executing a flight

Goal of this section: This section describes how to prepare your *eBee* for flight, launch, monitor and control from the air, and initiate an autonomous landing.

Note: We recommend that you perform your first flight in a large obstacle-free area and limit the length of the mission in order to familiarise yourself with the *eBee* in flight.

2.1 Weather check

Before each flight, you should be aware of the weather conditions. The *eBee* is a small drone that cannot fly in heavy rain or strong wind conditions. In case of doubt, make sure to check a weather bulletin including wind estimations in the flight area. Note that wind is often stronger at higher altitudes and that the wind perceived at the surface is not always a good reference to estimate the wind at flight altitude. Cloud velocity or tall tree movements can help you to estimate the wind speed once you are out in the field.

Weather forecasts may use various units to measure wind speed. As a reference,

$$1 \text{ m/s} = 3.6 \text{ km/h} = 2.24 \text{ mph} = 1.94 \text{ kts.}$$

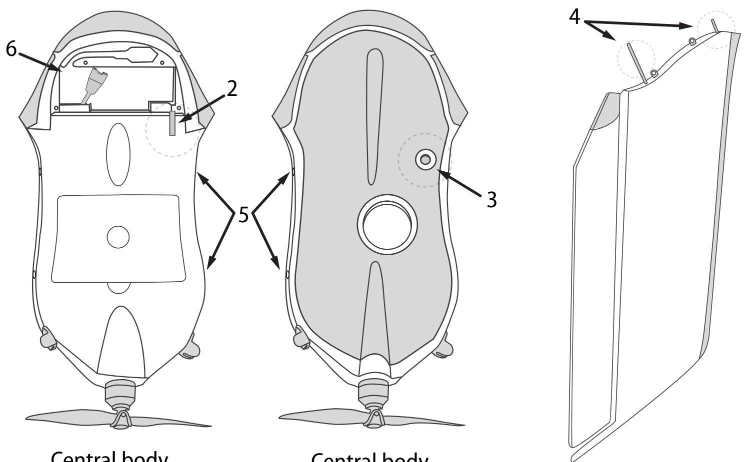
Caution: The *eBee* should not be launched if the wind speed exceeds 12 m/s (in other units: 43.2 km/h, 26.8 mph, 23.3 kts).

Caution: The *eBee* is not designed to fly in temperatures above 35° C. Avoid exposing the drone to high temperature for prolonged periods of time. In particular, leaving the drone exposed to the sun or in a car should be avoided.

2.2 Preparing the *eBee* for flight

The *eBee*'s simple design means it can go from the box to being ready for flight in minutes. We recommend that you perform the following 6 steps before every flight to ensure that the platform is best prepared for flight.

Note: Remove the red warning sticker from the motor before your first flight.



Central body top view

Central body bottom view

Wing - detached

Step 1: Perform a general inspection

Visually inspect the drone for damage or wear using the following steps:

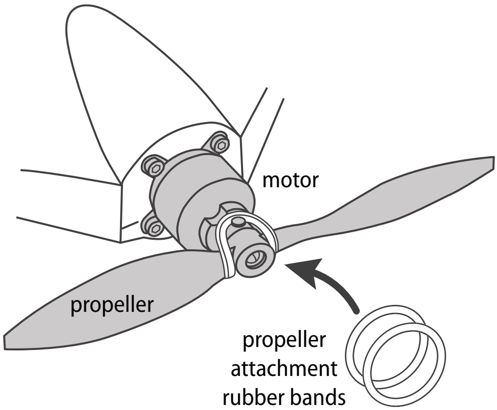
1. Check the foam central body and wings for cracks or other damage.
2. Verify that the pitot probe is properly attached to the airframe and that the holes in the probe are free of obstructions.
3. Verify that the ground sensor is free of obstructions and that the sensor's lens is clean.

4. Verify that the wing struts are not split or damaged in any way.
5. Verify that the tubes within the Central Body that hold the wing struts are not cracked or damaged in any way.

Caution: It is vital to carefully inspect the wing struts and tubes within the Central Body before every flight, as they may cause a crash if they are damaged in any way. This is particularly important if the wings were found separated from the Central Body after a previous flight.

6. Verify that the power cables within the battery compartment are well insulated and not damaged.

Note: A general inspection should be performed before every flight. It is also good practice to perform a full airframe check regularly to keep your *eBee* in good shape. See section 'Full airframe and sensor inspection' on page 131 for more details.

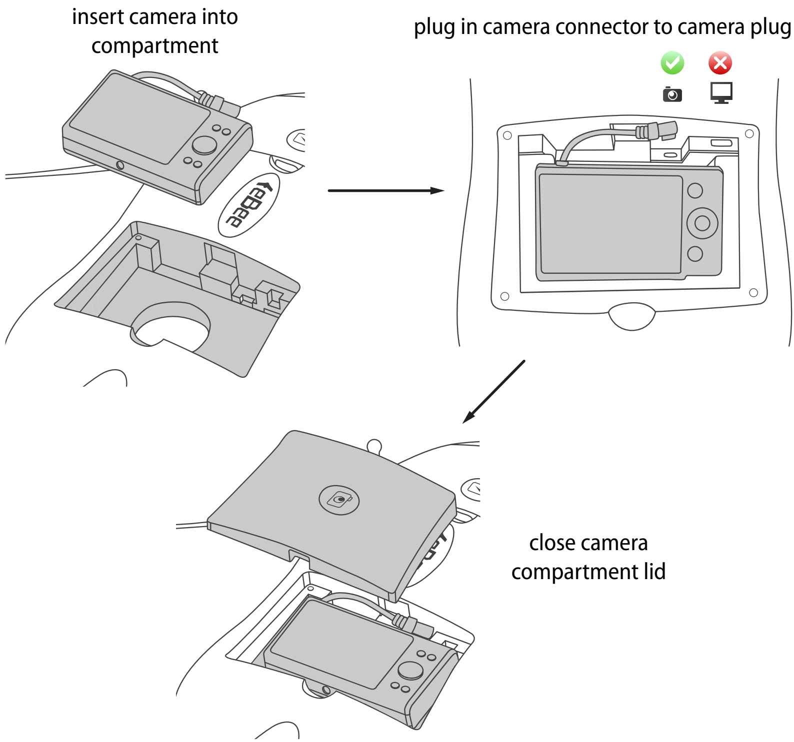


Step 2: Install the propeller

Mount the propeller on the motor axis. Secure the propeller using two attachment rubber bands as illustrated above. Ensure that the propeller is lying flat against the motor mount, and that the rubber bands do not show cracks or any other sign of aging.

> **Caution:** Failure to use two rubber bands may result in the loss of the propeller in flight!

> **Note:** After extensive use, the rubber bands may develop cracks. This is normal and is caused by the ageing of the rubber material. For maximum security, inspect the rubber bands regularly and discard them if they show cracks. 10 spare rubber bands are included in the package.

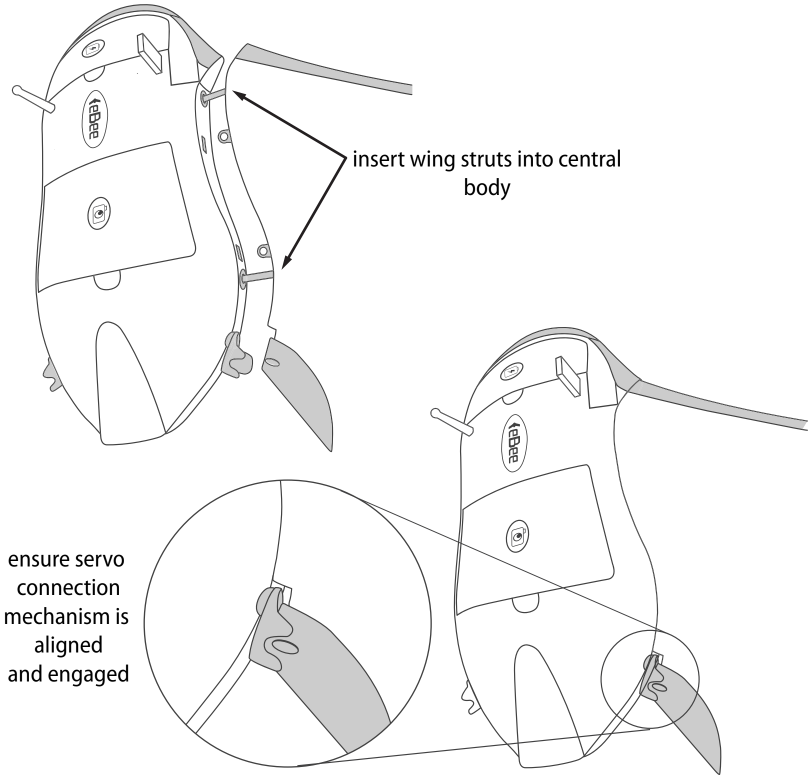


Step 3: Install the camera

Install the camera into the payload bay[6] within the *eBee* and close the camera compartment lid. If the camera connector is not already connected, plug it into the connector with the 📷 icon on the *eBee*.

> **Caution:** The *eBee* has not been designed to fly without the camera. Attempting to fly without the camera may render the drone unstable, which may eventually lead to a crash.

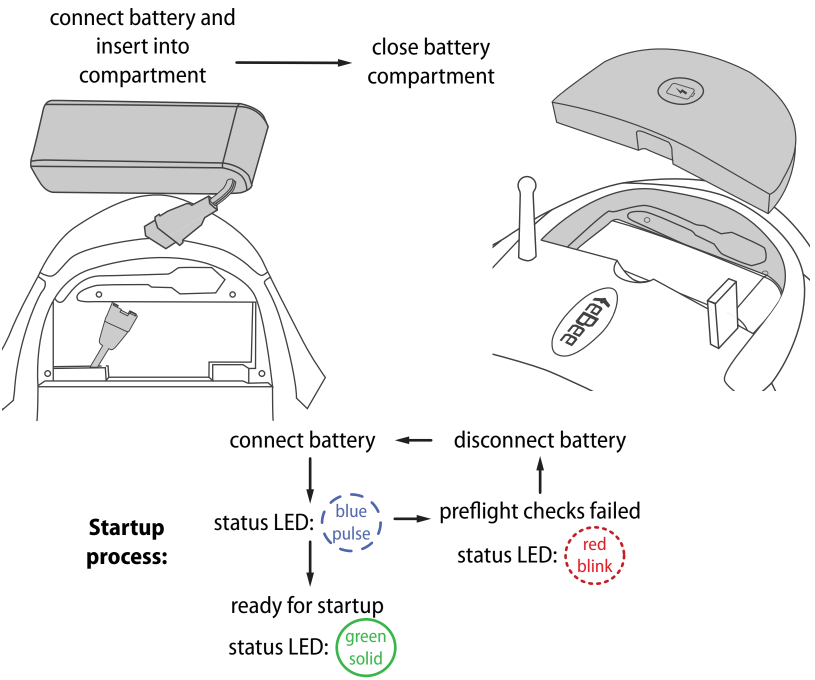
[6] Some payloads may require a separate battery or SD card to operate properly. Please refer to the User Manual of the camera or other payload for proper installation instructions.



Step 4: Attach the wings

Attach the wings to the central body by inserting the wing struts into the receptacles in the central body. Ensure that the ailerons are properly aligned with the servo connection mechanism before pushing the wings fully into the central body.

> **Caution:** Flying with damaged wing struts or a badly engaged servo connection mechanism may cause erratic flight and ultimately a crash. Be sure to properly inspect and attach the wings before flight.



Step 5: Install and connect the battery

Lay the *eBee* horizontally on the ground outside in the vicinity of the take-off location, with the top face up. To install the battery, begin by connecting the power cables to the battery. Insert the connectors firmly to the end in order to avoid undesired disconnection when in flight. Once connected, insert the battery into its compartment and close the compartment lid.

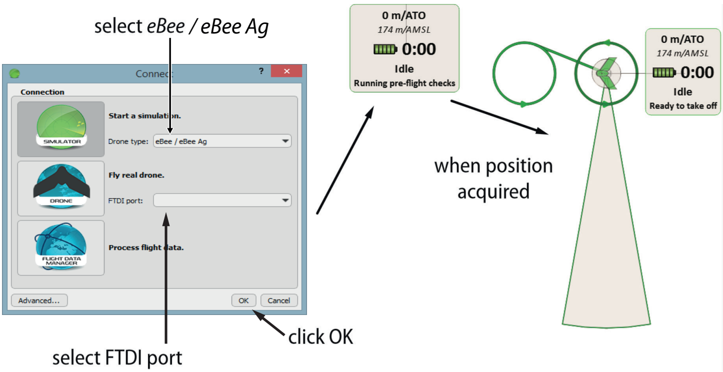
> **Caution:** Take care to keep the propeller area clear, in case it suddenly starts spinning.

Note: Only connect the battery cables to the drone when you are ready for start-up. Do not leave the battery connected for extended periods of time when the drone is on the ground, as this may discharge the batteries and cause irreparable damage. When connected and not in flight, the *eBee* will briefly move its ailerons up and down every minute as a reminder that it is switched on.

As soon as the battery is connected the *eBee* will perform an automatic self-check of its sensors and acquire GPS signals. Be sure not to move the drone during these tests. It is important that the drone is not inclined more than 10 degrees in order to start up properly. Pre-flight checks may last from a few seconds to several minutes in the case of poor GPS signal reception. As these satellite signals are required for the checks to complete, be sure to place the *eBee* outside with a clear view of the sky.

During the pre-flight checks the status LED will pulse blue. Once the pre-flight checks are complete the *eBee* will flip its ailerons up and down and the status LED will turn solid green to indicate it is ready. You may already connect the drone to *eMotion* (Step 6) before pre-flight checks are complete to get a better idea of the status of the checks.

Note: If there was any problem during the pre-flight checks performed by the drone this will be indicated by a Pre-flight error in *eMotion* as well as a by the status LED blinking red. See section 'Pre-flight errors' on page 138 for a description of possible Pre-flight errors and how to handle them.



Step 6: Connect to *eMotion*

Start by connecting the USB ground modem to your computer. Then launch *eMotion*, which will display the Connection window. Select the *eBee* connection profile, choose the corresponding FTDI port and click 'OK'.

> **Note:** Every *eBee* is paired with the ground modem it is delivered with, and will only work with that particular modem. The name of the FTDI port corresponding to the ground modem is labelled as '*eBee*-SERIAL', where SERIAL is the serial number of the drone it is paired with.

When a connection is established *eMotion* will display a map and the Status Panel indicating the current state of the drone. If the *eBee* has not yet detected its location the Status Panel will appear in the top right corner of the Map Area with the text 'GPS: Waiting for signals...'. During this time the status LED on the drone will pulse blue.

Once your drone has set its position using GPS signals, an icon of the drone will appear at its location on the map. If the drone's location is not on the map you can click the button from the Toolbar to centre the map on the drone. The drone's status on *eMotion* will be displayed as 'Idle, Ready to take-off' and the status LED will become solid green.

You can now load a flight plan you prepared earlier by selecting the Setup Phase tab from the Sidebar, clicking on 'Load flight plan from file...' and selecting your flight plan file. Alternatively, you can plan the entire mission in the field, following the same process outlined in section 'Planning and simulating a flight' on page 18.

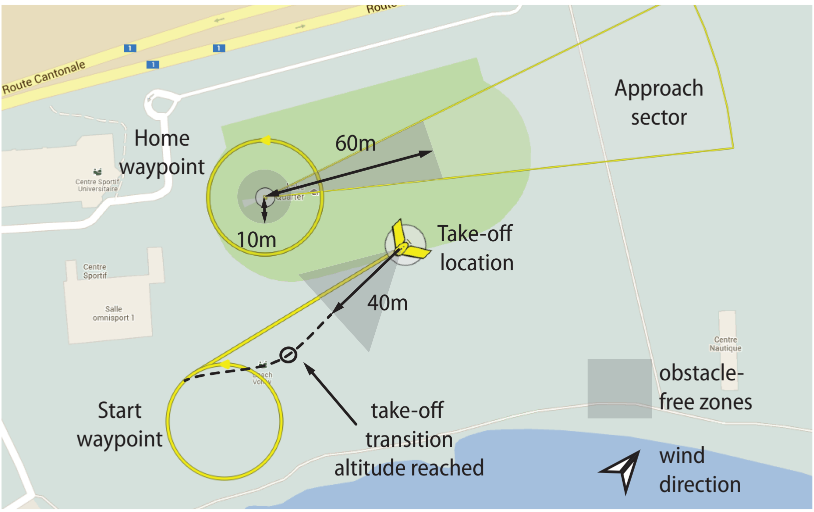
2.3 The setup phase of a flight

The setup phase of a flight includes the waypoints and actions related to the take-off and landing of the *eBee* and includes the following locations:

- **Take-off location:** The point from which the drone is launched, automatically set to the location calculated from GPS signals by the drone when it is launched. This location defines the altitude of 0 m/ATO (ATO stands for above take-off); the altitudes of all other waypoints, when defined in m/ATO, are referenced to the altitude of this location.

- **Start waypoint:** The first point that the drone flies towards when launched (once it reaches the take-off transition altitude).

- **Home waypoint:** The safe point for the drone to circle in case of emergency, as well as its landing position at the end of a flight for both Linear and Circular landings.



It is important to carefully select the take-off location, the Start waypoint and the Home waypoint to ensure your drone remains at a safe distance from obstacles.

The *eBee* should always be launched against the wind. Select a take-off location clear of obstacles (buildings, rocks, power lines, hills, trees, etc.) within a distance of at least 40 m in the upwind direction. Immediately after takeoff it will keep its wings level and climb in the general direction it was launched until it reaches the take-off transition altitude[7], at which point it will start flying towards the Start waypoint.

By default, the Start waypoint is set to a distance of 80 m West of the initial position of the drone and an altitude of 75 m/ATO. It is good practice to move the Start waypoint close to and upwind from the take-off location to allow a smooth transition between take-off and waypoint-directed flight. You can move waypoints by clicking on them and dragging them within the Map Area[8].

The Home waypoint is used both as the landing location and as a safety position in case of an In-flight warning. The *eBee* can perform either a Linear or a Circular landing. Linear landing is the default and recommended landing type, especially in high winds. To prepare a Linear landing, place the Home waypoint centre at a location that is at the same altitude as the take-off location and is clear of obstacles in a 10 m radius. Choose one or several approach sectors that are free of obstacles for at least 60 m from the Home waypoint centre. You can drag the approach sector around the Home waypoint and change its width directly in the Map Area or from within the Setup Phase tab. Make the approach sector(s) as wide as possible to maximize the chance that the drone can subsequently land against the direction of the wind. Ensure that the terrain within the approach sector is flat and contains visual contrast to allow the ground sensor to function properly during landing.

When a Linear landing is initiated (either automatically or by pressing the 'Go Land' button in the control bar) the drone will fly towards the Home waypoint, circle the waypoint (at 75 m/ATO by default) to measure the direction of the wind

[7] By default the take-off transition altitude is set to 20 m. In difficult launch conditions you can set both the take-off heading and the take-off transition altitude in the Setup Phase tab, as described in section 'Setup Phase tab' on page 96.

[8] see section 'Waypoints and their properties' on page 56 for a more detailed explanation on waypoints and how to modify them

at the landing location and choose an approach direction as much against the direction of the wind as possible. It will then fly downwind in the opposite direction of the approach direction, turn 180° and begin descending in the approach direction until it lands on the ground underneath the centre of the Home waypoint. The approach angle is around 20° and the drone will reverse its thrust if needed to maintain a suitable airspeed during this phase.

Note: There are a number of requirements that must be fulfilled to ensure a successful Linear landing. Section 'Linear landing' on page 70 describes in more detail the Linear landing process and how to properly define approach sectors in more complex terrain. In particular, in the case of strong-wind conditions, low light or low-contrast terrain, the precision of the final landing location around the Home waypoint is reduced. Therefore, it is safer to plan for more clearance, especially along the possible landing axes.

If there are no suitable approach sectors to perform a Linear landing the drone can also perform a Circular landing around the Home waypoint. When initiating a Circular landing around the Home waypoint the drone will switch off its motor and glide down while circling around the Home waypoint at the waypoint's radius. During the Circular landing procedure the drone uses its ground sensor to measure the height above the ground, if the ground is well textured and there is enough light. When it reaches an altitude of 25 m above the ground the drone will level out, estimate the direction of the wing and resume its descent so as to touch down against the wind while remaining on the circle defined by the Home waypoint.

Caution: The ground sensor can only provide usable feedback in daylight conditions above flat terrain that contains enough visual texture. If these conditions are not met the drone cannot ensure a touchdown against the direction of the wind. Landing in the direction of the wind in strong-wind conditions may result in a high landing speed and damage to the *eBee*.

To prepare a Circular landing, place the Home waypoint in a location that has no obstacles within a radius of 50 m (or 20 m more than the Home waypoint radius) to give the drone enough space to land. Ensure that the entire landing area is flat to allow the ground sensor to function properly. By default, the radius of the Home waypoint is 30 m. In high-wind conditions it is recommended to increase this diameter[9].

Caution: The radius of the Home waypoint, and thus of a Circular landing, can be reduced to 20 m but should only be done in low wind conditions (<3 m/s). Reducing the radius of the Home waypoint below 30 m in moderate- or high-wind conditions can result in damage to the drone when it contacts the ground during a landing. As indicative values, the Home waypoint radius should be set to 30 m for wind speeds below 5 m/s, 40 m for wind speeds between 5-8 m/s, and to 50 m for wind speeds above 8 m/s.

Note: In case of strong-wind conditions, the drone may drift even further than 50 m away from the center of the Home waypoint when performing a Circular landing. Therefore, it is safer to plan for even more clearance in the downwind direction.

By default, the Home waypoint is set to an altitude of 75 m/ATO. In case a Go to Home Waypoint procedure is triggered during flight[10] the drone will, by default, determine the highest altitude between its current altitude and the Home waypoint's altitude, and climb in a circle towards that highest altitude (if required). Once it reaches this highest altitude it will then fly towards the Home waypoint.

Due to this behaviour, the altitude of the Home waypoint should be selected with care; it should be at least 20 m higher than the surrounding obstacles to avoid the risk of a crash, but should not be set too high to reduce the effect of potentially high winds and altitude and to prevent the drone from getting lost. Alternatively, you can change the altitude transition behaviour within the Setup Phase tab. See section 'Waypoints and their properties' on page 56 for more information on alti-

[9] see section 'Setup Phase tab' on page 96

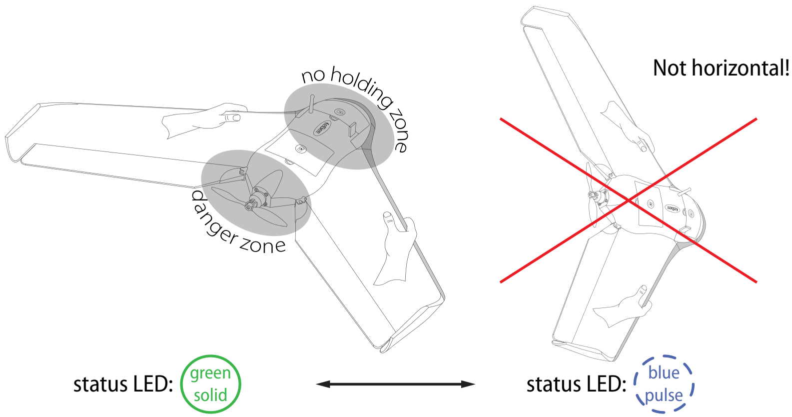
[10] either automatically due to an In-flight warning or manually using *eMotion*

tude transition behaviours and how to modify them.

2.4 Take-off

Once you've planned your mission and the *eBee* status LED is solid green you can launch it using the procedure on the following pages.

> **Caution:** Make sure to keep the propeller area free of all obstructions at all times during the launch procedure.

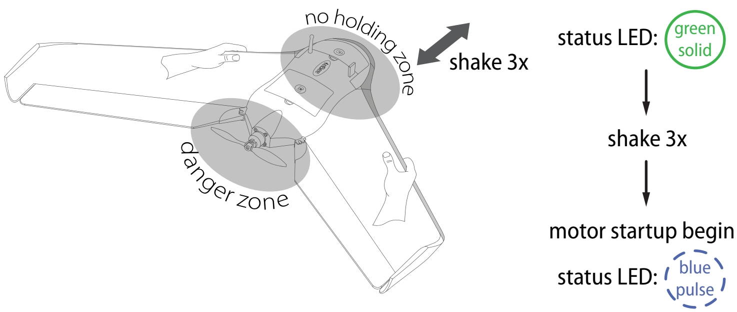


Step 1: Orient horizontally and against the wind

Orient yourself against the direction of the wind, and confirm that the take-off direction in front of you is free of obstacles. Firmly grasp the drone with both hands, one hand on the front of each wing as shown in the figure. Hold the drone horizontally with the nose pointed against the wind and level wings.

Note: If the drone detects a condition that prevents correct take-off a Take-off veto will be displayed in *eMotion* and the status LED will start pulsing blue. Section 'Take-off vetoes' on page 141 describes the possible Take-off veto messages and the user action that should be taken to remove them. For example, if the drone is not oriented horizontally the status LED will start pulsing blue until you re-orient it horizontally, at which point the status LED turns solid green again.

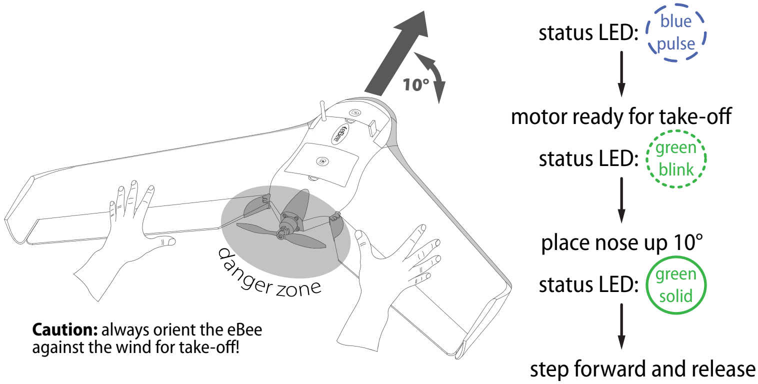
Caution: It is imperative to launch the drone directly against the wind, otherwise it will be unable to gain enough speed during take-off and likely crash. Likewise, launching the drone in high winds above the specified safe wind speed of 12 m/s is dangerous and can result in a crash.



Step 2: Switch the motor on

Shake the *eBee* back and forth 3 times longitudinally (within approx. 3 seconds) to begin the motor power-up sequence. The status LED will pulse blue until the motor is at full power and ready for take-off.

Note: You do not need to hurry to launch the drone. In case you want to shut off the motor, just repeat the back and forth action three times and the motor will stop.



Caution: always orient the eBee against the wind for take-off!

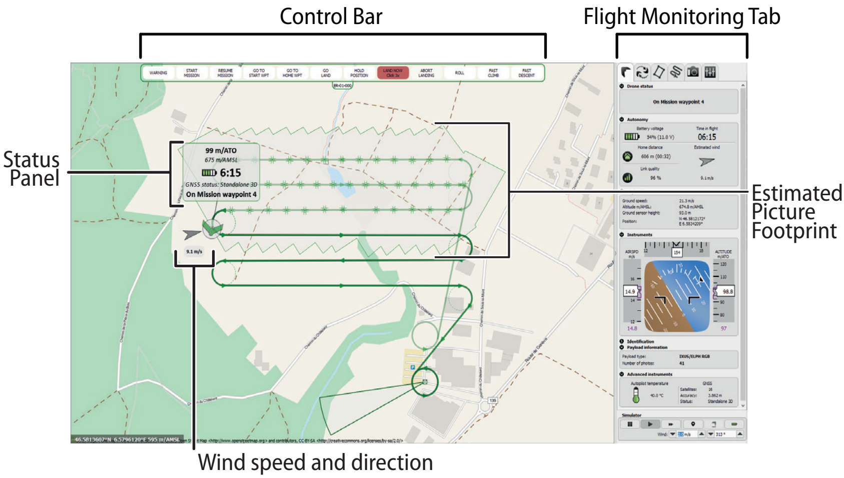
Step 3: Launch the *eBee*

Once the motor is at full power the status LED will blink green. Orient the drone with approximately 10 degrees nose up and level wings. When the angle is correct the status LED will turn solid green, indicating that the drone is ready for take-off. Launch the drone with a gentle push by walking 1-2 steps forward while releasing it with both hands in a purely forward motion.

After take-off, the drone tries to maintain its initial direction, or follow the directional take-off heading you set, by keeping its wings level with full thrust until reaching the take-off transition altitude, by default 20 m[11]. At this point, it will switch into waypoint navigation mode and fly towards the Start waypoint. Once it reaches the Start waypoint location and altitude the drone will circle around the waypoint 1-2 times to estimate the wind and calibrate its sensors before starting the mapping mission[12].

[11] see section 'Flight Parameters tab' on page 116 to change this parameter

[12] The *eBee* may also be programmed to wait at the Start waypoint for a command before starting its mapping mission. See section 'Setup Phase tab' on page 96 for more information.



2.5 In-flight monitoring and control

You can monitor and control your drone while in-flight through *eMotion* using the Map Area and the Flight Monitoring tab in the Sidebar.

The Map Area displays the current position of your drone, updated live as the drone executes its flight. A small arrow and infobox show the speed and direction of the wind as measured by the *eBee*. The Status Panel that follows the position of the drone displays basic flight information including battery charge, flight time and altitude, both above the take-off location (ATO) and above mean sea-level (AMSL). This same information is reproduced in the Flight Monitoring tab, along with other useful flight data .

> **Note:** All waypoints, image locations and flight paths displayed in *eMotion* are a reflection of the data contained within the drone autopilot. If at any point the connection between *eMotion* and the drone is lost, the drone will by default continue its planned flight, including the imaging mission and the selected automatic landing, fully autonomously. If you would like the drone to return to the Home waypoint instead of continuing its mission when it detects a loss of connection you may set the appropriate parameter in the Flight Parameters tab, as described in section 'Flight Parameters tab' on page 116.

During the Mission phase of the flight the *eBee* will automatically take pictures at pre-defined moments based on the parameters that were defined during mission planning. The estimated area captured on the ground is displayed in the form of a continuously-updating polygon in the Map Area.

> **Note:** The *eBee* will not take a picture unless it is in the correct location and altitude. Some reasons for not taking an image are strong head wind, large off-track distance or incorrect altitude. A corresponding message is displayed in the Status Panel if a picture is not taken.

At the top of the Map Area is the Control Bar, which can be used at any time to send commands to your drone as well as to acknowledge warning and failure messages if they occur. During a fully autonomous flight the *eBee* will control its flight autonomously from take-off to landing and you do not need to use any of the control buttons. They can however be useful in unexpected situations to temporarily hold position by pressing the 'HOLD POSITION' button or to send the drone to the Home or Start waypoints with the 'GO TO HOME WPT' or 'GO TO START WPT' buttons, respectively. Alternatively, you can direct your drone to any location by right-clicking in the Map Area and using the contextual menu. We recommend you use the simulator to learn the effects of the buttons on the drone. Detailed descriptions of the buttons and their effects on the drone are described in section 'Control Bar' on page 89.

2.6 Landing

After finishing a mapping mission the drone will, by default[13], return to the Home waypoint and automatically initiate a landing sequence. During a Linear landing, the drone will land in a straight line according to the process described in section 'Linear landing' on page 70. In case of a Circular landing the drone will land in a circle according to the process described in section 'The setup phase of a flight' on page 37.

Disconnect the battery from the drone before picking it up. We recommend you immediately import the images and flight data after each flight (see section 'Importing images and flight data' on page 48) before putting the *eBee* back in its case for storage. When disconnecting the wings, be sure to pull gently in the axis of the wing struts to prevent damage to the wing struts. Check the wing struts for any damage before putting them into the storage case. Remove the propeller if you don't plan on using the *eBee* for an extended period of time.

2.7 Potential in-flight errors

The drone can encounter two types of error messages while flying: In-flight warnings and Critical failures. In-flight warnings typically indicate a dangerous situation such as a low battery or strong winds and typically result in a Security action such as a return to the Home waypoint. In-flight warnings appear in blue or yellow in the Flight Monitoring tab. Critical failures occur only when the drone's ability to fly is severely compromised, such as a loss of GPS signals or an empty battery. The situation will be displayed in red in the Status section of the Flight Monitoring tab. When a critical failure arises, the drone will immediately perform an emergency landing.

[13] see section 'Setup Phase tab' on page 96 for information on changing the default behaviours of the drone

Caution: We recommend that you familiarise yourself with the possible in-flight errors to have a better understanding of what happens if they occur in the field. A full list of possible In-flight warnings and Critical failures and the drone's reaction to them is described in section 'In-flight warnings' on page 143 and section 'Critical failures' on page 155.

Note: It is important to keep track of the location of the drone during a Critical failure until the moment it reaches the ground. Its position's coordinates can aid in finding it afterwards. Instructions on how to find a lost drone can be found in section 'Losing and locating your *eBee* in the field' on page 159.

3 Processing image data

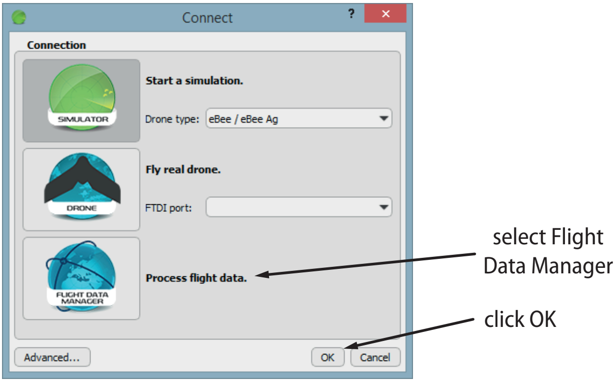
Goal of this section: In this section you will learn how to import images and flight data from your *eBee* and create basic mapping products directly in the field to gauge the quality of the images that you gathered.

3.1 Importing images and flight data

The next step to creating mapping products, after completing a flight, is to import the raw images and log files to a computer. The *eBee* records flight data onboard in a special Drone Flight Log file. The Drone Flight Log tracks important information throughout a flight, such as sensor data, location and control inputs. The file is required for assigning location information (geotags) to the images taken by the drone. The file is also required and must be sent to senseFly Ltd in case an issue occurred during the flight[14]. A similar eMotion Flight Log file is created within *eMotion* during a flight and serves as a backup in case the Drone Flight Log file cannot be recovered.

eMotion features a Flight Data Manager to help you transfer and consolidate all the data related to a mapping mission. Open the Flight Data Manager by clicking on the Flight Data Manager icon when you load *eMotion*. Alternatively, click on the button in the Toolbar and select 'Flight Data Manager...'.

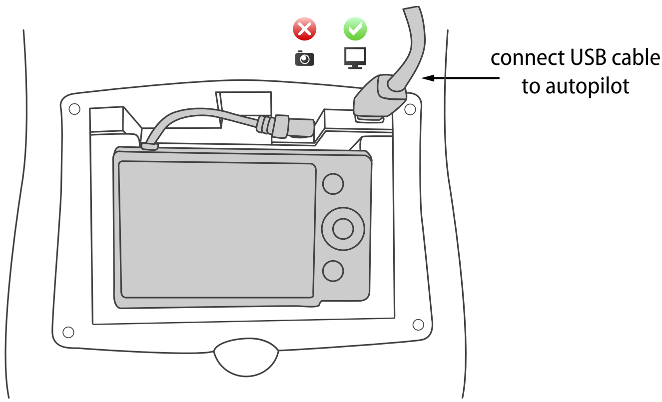
[14] see section 'Reporting a problem with your *eBee*' on page 160



Follow these steps to import data from the drone:

- **Step 1 - Select a flight:** If the flight was monitored from the computer you are using to import images then the flight is saved within the local database. Select the date that the flight took place. A list of flights (including number of images taken) from that date will appear in the combo box, select the one you wish to import.

- **Step 2 - Create a directory:** Choose a directory name that uniquely identifies your flight (e.g. the date, the name of the area, etc.).



- **Step 3 - Prepare data for import:** To import the Drone Flight Log, connect the supplied USB cable to the *eBee*'s autopilot, marked with a icon. Connect the battery to the drone if it is not already connected. The status LED will become white and a new storage drive will appear on your computer.

  To import images, remove the SD card from the camera, insert it into the SD card reader of your computer and select 'Import from SD-card reader'. Alternatively, transfer the images from the camera by lifting it out of its compartment just enough to connect a USB cable to it and turn the camera on. Copy all the images into a temporary folder on your computer. Select 'Import from a specific folder' and choose the temporary folder.

- **Step 4 - Import flight logs:** Confirm that the Drone and eMotion Flight Logs found by the Flight Data Manager are correct. You may select logs manually if they are not correctly detected.

- **Step 5 - Import images:** Confirm that the images corresponding to your flight were found and matched to the Drone Flight Log correctly.

- **Step 6 - Select outputs:** Choose the output actions to execute and files to create. Geotagging images is necessary to create geoinfo, KML and *Postflight Terra 3D* files.

- **Step 7:** You may now disconnect the drone. Eject the SD-card drive and the drone drive before removing the SD-card and the USB cable, respectively. Disconnect the battery and USB cable from the drone. Insert the SD-card back into the camera, put it back properly into its compartment and ensure that it is turned off. You can now open the KML file in *Google Earth™* or the project in *Postflight Terra 3D* for further processing.

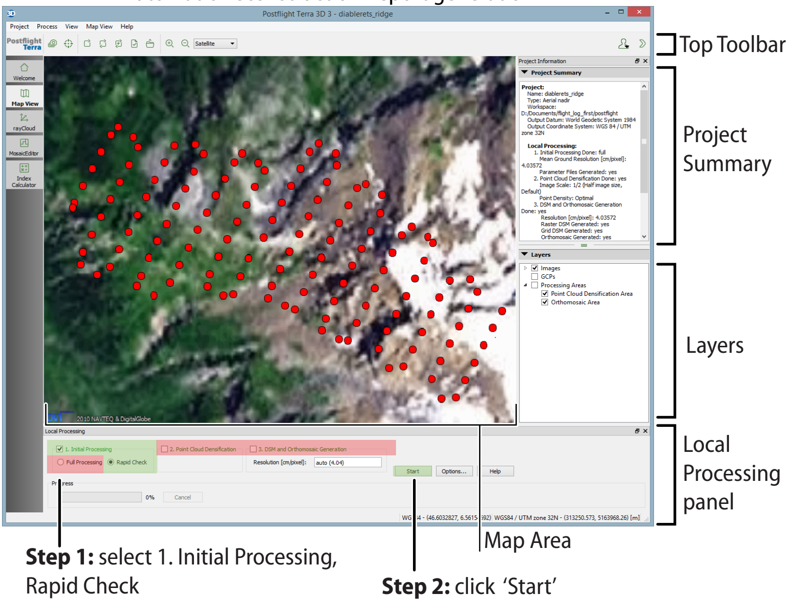
3.2 In-field image quality check

Postflight Terra 3D software[15], available as a free download with the *eBee* package, can be used to rapidly create a Quality Report directly in the field. The Quality Report that is automatically generated as well as the orthomosaic provide immediate feedback on the quality of the images gathered during your mission.

You can open a project for processing in *Postflight Terra 3D* directly from the Flight Data Manager after importing your data by clicking the ‘Open project in Terra’ button. You will now see the main *Postflight Terra 3D* window. The position of your images will appear as red dots in the Map Area of *Postflight Terra 3D*.

[15] powered by Pix4D, see section ‘Installing *eMotion*, *Postflight Terra 3D*, and the ground modem drivers’ on page 18 for installation instructions

Automatic Reconstruction Report generation



To create a Quality Report while in the field bring up the local processing panel by selecting 'Local processing' from the 'Process' menu or by clicking the icon in the Toolbar. Select only the 'Initial project processing' checkbox and the 'Rapid' button. If you wish to create a low-resolution orthomosaic while generating the report, check the 'Orthomosaic and DSM generation' checkbox. Click 'Start' to begin rapid processing.

Postflight Terra 3D will now process the data and produce a report that includes the overall completeness and georeference quality of the images taken during your last mission. You may use this information to decide whether further imaging flights are required while you are still in the field. The quality report will be displayed in a new window (click the icon in the Toolbar if it does not appear).

3.3 Creating advanced mapping products

Beyond Quality Reports and low-resolution orthomosaics, *Postflight Terra 3D* can generate geo-referenced high-resolution 2D orthomosaics, 3D point clouds, triangle models and DSMs or export to common third-party photogrammetry software such as Bingo, Orima or Inpho. Ground Control Points (GCP) can be added to increase the geo-reference accuracy. *Postflight Terra 3D* also includes a mosaic and a rayCloud editor, giving you more control on the quality of your final mapping products, as well as measurement tools.

The resulting orthomosaic and DSM may then be imported as custom background map and elevation data layers in *eMotion*[16]. This data can be used for advanced flight planning in complex or uneven terrain.

Note: You need to either enable tile set generation OR choose Generate Google Maps Tiles and KML from the Process menu before you can push the tileset into *eMotion* by choosing Send Map to eMotion from the Process menu. Alternatively, this data can be imported into *eMotion*; choose Import custom map from *eMotion*'s File menu.

Note: The best way to learn how to use the various features of *Postflight Terra 3D* is to look at the comprehensive online Knowledge Base at my.sensefly.com

[16] see section 'Toolbar' on page 84 for more information on importing layers into *eMotion*

Part II

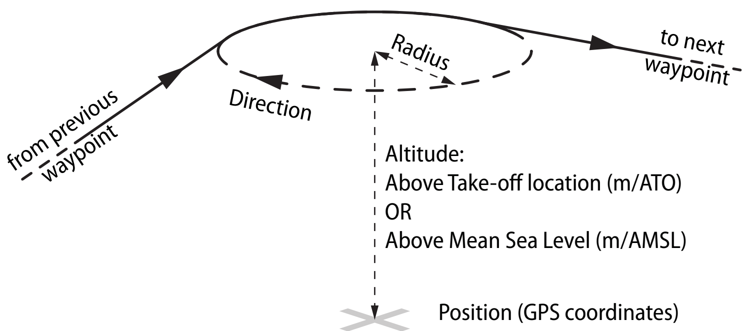
Advanced functionalities

4 Understanding aerial mapping with the *eBee*

Goal of this section: Aerial mapping using the *eBee* is designed to be simple and fully automatic, requiring very little input from the user. Understanding the basics of aerial navigation, however, can help you map more complex terrain and yield higher quality results. This section explains the basics of waypoint-based navigation and the control strategies used by the drone for flight.

4.1 Waypoints and their properties

The *eBee* uses a flight plan consisting of a list of waypoints to navigate. A waypoint essentially consists of a circle about a given position and information that defines how the drone should behave when reaching them. The entire list of waypoints is stored in the drone autopilot and can be remotely edited using *eMotion*.



In *eMotion* every waypoint is defined by the following parameters:

- **ID:** Every mission waypoint has a unique ID, beginning at 1. The *eBee* can store up to 50 mission waypoints. Setup phase waypoints (Start and Home) do not have an ID.

- **Active:** Indicates whether the waypoint is active or not. Deactivating a waypoint by clicking the checkbox beside its ID will remove it from the current flight plan. Setup phase waypoints (Start and Home) cannot be deactivated.
- **Current:** A status that indicates if the waypoint is currently being circled or navigated toward (indicated by > < around the waypoint's ID). Only one waypoint is marked Current at a time.
- **Change altitude:** This parameter defines the way the drone transitions to the altitude of the current waypoint.
  - **During transit:** The drone will fly in the direction of the current waypoint while simultaneously changing altitude by climbing or descending in a linear fashion. If the required climb or descent rate is beyond physical limits, the drone will reach the destination and keep climbing/descending around the destination waypoint. This is typically used to achieve the best efficiency when the altitude between waypoints is not constrained.
  - **Before transit:** The drone will first climb or descend at its current position until it reaches the altitude of the current waypoint, and then fly in the direction of the waypoint at its altitude. This is typically used for 3D mapping.
  - **Keep highest:** The drone will first determine whether its current altitude or the current waypoint's altitude is highest. If the drone's current altitude is highest, it will first fly towards the waypoint and then descent to the waypoint's altitude in a circular fashion. If the current waypoint's altitude is highest, the drone will begin by climbing at its current position until it reaches the waypoint's altitude and then fly towards the waypoint. This is typically useful to avoid hitting the terrain in mountainous landscapes and, in particular, for the Home waypoint when the mission altitude is below the take-off location.
- **Altitude:** The altitude of the waypoint above the altitude reference. The waypoint is considered 'reached' only when the drone starts circling about it at the waypoint's altitude.

- **Altitude reference:** The reference point of the Altitude value. When set to m/ATO, the Altitude value is an Above Take-off (ATO) altitude. When set to m/AMSL, the Altitude value is a Above Mean Sea Level (AMSL). The altitudes of Setup phase waypoints (Start and Home) are always set to m/ATO.
- **Turn direction:** The direction with which the drone circles around the waypoint (clockwise or counter-clockwise).
- **Radius:** The distance at which the drone circles around the waypoint.

> **Note:** The *eBee* has a limited turning radius. Setting this parameter lower than 20 m may cause the drone to significantly deviate from its desired flight path.

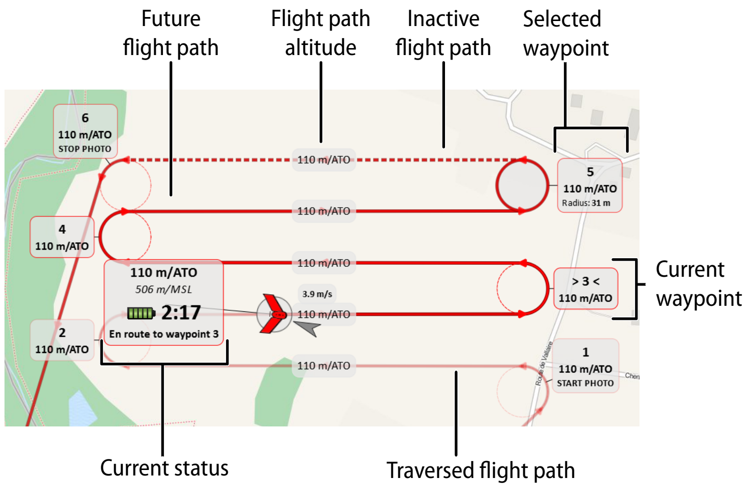
- **Auto-next:** Indicates whether the drone should remain on the waypoint upon reaching it (until a new command is received) or automatically continue to the next active waypoint.
- **Action:** The action (if any) to be performed upon reaching the waypoint. Supported actions include starting and stopping Continuous photo mode[17]. Setup phase parameters (Start and Home) do not have associated Actions.
- **Position (coordinates):** The precise latitude and longitude of the centre of the waypoint.

Waypoints are represented in the Map Area as circles with their actual radius and an arrow to indicate their direction. The flight path of the drone around and in between waypoints is drawn as a line of varying opacity; the path ahead of the drone's current position is dark, becoming lighter the further it is from the current position in the flight plan. The path already traversed is a uniform light colour. If a waypoint's Auto-next parameter is disabled, the path directly after it will be dashed, indicating that a command must be sent for the flight to continue.

Clicking a waypoint in the Map Area will display its characteristics (waypoint ID for mission waypoints or name for setup waypoints, altitude, radius and action)

[17] see section 'Camera tab' on page 111

and will select it for modification. It will also activate the Mission Waypoints tab and highlight the selected waypoint.



You can modify the waypoint's parameters directly in the Map Area using your mouse using the following actions:

- **Position:** Change the position by left-clicking on the waypoint and dragging it around on the map. By default the waypoint snaps to a position in-line with the current flight lines before and after the waypoint. Hold down the 'Alt' button while dragging to disable the snapping feature.
- **Turn direction:** Hold down the 'Shift' button while left-clicking on a waypoint to toggle its turn direction.
- **Radius:** Modify the radius by left-clicking on the waypoint's perimeter and dragging it.
- **Altitude:** Hold down the 'Ctrl' button while left-clicking on the waypoint and moving the mouse up or down to increase or decrease the altitude of the waypoint, respectively.

- **Create new waypoint:** Right-click anywhere in the Map Area that does not contain a symbol to bring up the context menu, then select 'Add waypoint here' to add a new waypoint.
- **Context menu:** Right-click on a waypoint to bring up the context menu. You can then select the following options:
  - **Go to:** Select while the drone is in flight to make this the current destination waypoint.
  - **Auto-next:** Toggle the Auto-next parameter of the waypoint.
  - **Reverse turn direction:** Toggle the Turn direction parameter of the waypoint.
  - **Change altitude:** Set the transition behaviour of the drone when flying towards the selected waypoint.
  - **Remove waypoint:** Remove the selected waypoint.

Any modification will be sent directly to the drone to update its onboard waypoint list. If the message is not acknowledged by the drone (for example due to a temporary loss of communication link), the waypoint will move back to its previous position on the map to accurately reflect the current waypoint list status within the drone's autopilot.

> **Note:** Modification of flight plan parameters can cause the drone to react in unexpected ways. In particular, the drone may have trouble following its flight path when the radius is set very low or if there is high wind. We highly encourage you to test your entire flight plan using the simulator to get familiar with the drone's behaviours before going out into the field.

4.2 Advanced polygonal mission area

The mission area defines the area of interest where the *eBee* will take photos. It appears as a grey rectangle when you select the 'Mission planning' tab and to calculate the flight plan of the drone. For many cases the rectangular-shaped mission area provides the simplest way to quickly create a flight plan. It can be modified as described in section 'The mission phase of a flight' on page 22.

For more complex areas *eMotion* has the option of using polygonal-shaped missions areas. Begin by converting a rectangular area into a polygonal area by setting the 'Mission area' type to 'Polygonal' in the 'Mission planning' tab or by right-clicking on the area and selecting 'Convert to polygon'.

A polygonal mission area is set slightly differently than a rectangular mission area:

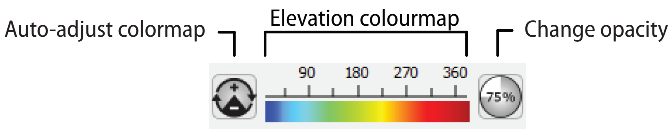
- The edges of the rectangle now become vertices of the polygon. Left-click on a vertex to drag and reposition the vertex.
- Left-click and drag anywhere on the edge of the polygon to create a new vertex and reposition it.
- Right-click on vertex and select 'Remove vertex' to remove a vertex. Alternatively, hold down the 'Ctrl' button and left-click on a vertex to remove it.
- Left-click and drag on the dark-grey area within the polygon to reposition the entire polygon.
- Left-click and drag the circle on the corner of the light-grey rectangle surrounding the polygon to rotate the direction of the resulting flight lines.

You may also set a polygonal mission area directly from a KML file containing a polygon, such as those created by *Google Earth*™. Simply click on the icon in the 'Mission planning' tab, select 'Load mission area from KML file' and choose a KML file that contains the desired polygon.

4.3 3D mission planning using elevation data

eMotion has the ability to take into account elevation data to set the altitude of mission waypoints and the resulting flight lines of a mapping mission. This not only improves the resulting ground resolution but also increases mission safety (particularly in uneven terrain) by keeping a more even height between the drone and the ground.

You can display elevation data by clicking on the button in the Toolbar. *eMotion*'s default Improved SRTM elevation data will be downloaded as tiles from senseFly Ltd servers and overlaid above the map as a colourmap[18]. You can adjust the scale and opacity of the colourmap by using the associated buttons in the bottom-right corner of the Map Area.



Caution: *eMotion*'s default Improved SRTM elevation data uses a 3 arc-second (approx. 90 m resolution) digital elevation model derived from the SRTM (Shuttle Radar Topography Mission) dataset version 2.1 combined with other data sources (ASTER GDEM, SRTM30, cartographic data, etc.). This data covers nearly all emerged land except the territories below 56° S latitude and the territory of the Russian Federation above 60° N latitude. This data may contain inaccuracies of several meters, and does not contain data on obstacles such as buildings or trees. We highly recommend that you check your flight plan thoroughly in *Google Earth™* and ensure sufficient clearance between the flight plan and the ground. SenseFly Ltd provides no guarantee regarding the accuracy of the elevation data and it is the operator's sole responsibility to ensure a safe flight trajectory and altitude.

Activate the 3D mission planning feature by selecting the 'Use elevation data to set absolute waypoint altitudes' parameter in the 'Mission Planning' tab. Elevation data is used to adjust every mission waypoint altitude as follows:

1. The flight planner uses elevation data to find the maximal terrain elevation

[18] *eMotion* must be connected to the internet. Once downloaded, elevation tiles are cached and can then be used off-line.

under the current waypoint, the previous waypoint and the flight line that connects the two.

2. This maximum value is increased by the target altitude value, and the result is set as the altitude of the current waypoint.

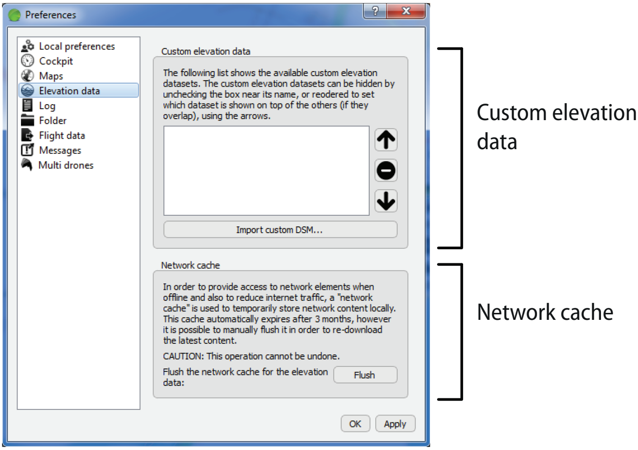
The altitude of every waypoint can always be manually adjusted in the Mission Waypoints tab. By default, the 'Change altitude' parameter for the first mission waypoint is set to 'Keep highest'. For all other mission waypoints the 'Change altitude' parameter is set to 'Before transit' so that the drone climbs or descends to the altitude of the next waypoint (and thus the next flight line) before transiting and taking pictures.

It is important to understand that even if each flight line can have a different altitude, the altitude is constant along a given flight line. If the terrain altitude is uneven along a flight line, the resulting imagery will have varying ground resolution and overlap. When the mission planner computes the altitudes of flight lines it tries to ensure that the required amount of overlap is achieved, possibly leading to a lower ground resolution in some areas. During flight planning the range of ground resolution computed by the mission planner is displayed. For optimal results, it is best to set the orientation of the flight lines as parallel as possible to the terrain's contour lines.

One way to increase the resolution and accuracy of the elevation data is to fly a first mission at high altitude and then create a dataset using *Postflight Terra 3D*. You can then automatically import the data into *eMotion* by selecting 'Send DSM to eMotion' from the 'Process' menu within *Postflight Terra 3D*. The dataset can then be enabled using the menu in the Toolbar. *eMotion* will use this custom dataset (wherever it is available) to set waypoint altitudes instead of its default Improved SRTM elevation data.

> **Note:** It is recommended to visually compare imported elevation datasets with the default Improved SRTM elevation layer of *eMotion* in order to detect possible mismatches. This comparison should be done with a colourmap opacity value of 100%.

More advanced controls of imported datasets are available in the 'Elevation data' panel of the Preferences pane of the menu. From this panel you can add, remove, activate/deactivate or reorder overlays. *eMotion* uses the top-most elevation data layer to calculate altitude for each waypoint and flight line, with *eMotion*'s default Improved SRTM elevation dataset always considered the bottom layer.



4.4 Flight visualization in *Google Earth*™

eMotion includes an interface with *Google Earth*™ to help with flight plan verification and visualization, particularly in uneven terrain. Clicking on the button in the Toolbar will open *Google Earth*™ and zoom to the current position of the drone. The current position of drone, its planned trajectory, the working area circle and all waypoints currently uploaded to the drone (including Take-Off, Start and Home) are displayed within *Google Earth*™. Any changes to waypoints or flight parameters within *eMotion* are updated accordingly within *Google Earth*™.

The interface with *Google Earth*™ is particularly useful to check the drone's trajectory with respect to obstacles in the area[19]. The flight plan is projected onto the

[19] While checking flight plans in *Google Earth*™ is a good safety practice, senseFly Ltd provides no

ground in a darker colour, giving you an idea of the distance between the flight path and the ground. If you connect to a simulated drone you can simulate the entire flight and follow the drone within *Google Earth*^{TM}.

Note: To use this feature *Google Earth*^{TM} has to be installed on the ground station PC, as described in section 'Installing *eMotion*, *Post-flight Terra 3D*, and the ground modem drivers' on page 18. We recommend to use the latest version of the *Google Earth*^{TM} software.

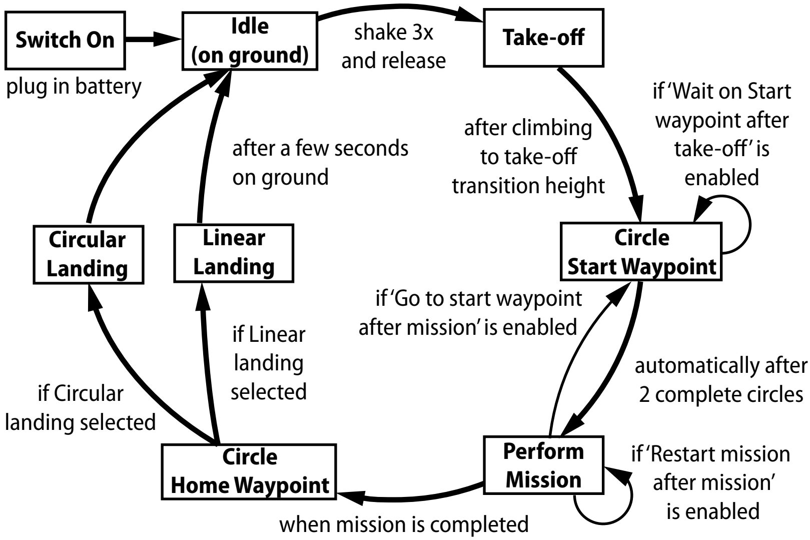
Caution: A flight trajectory visualized in *Google Earth*^{TM} represents the planned trajectory. The real flight trajectory can be different from the planned due to flight conditions such as strong wind.

Caution: The terrain data within *Google Earth*^{TM}, including hills and buildings, may contain significant errors. When planning flights over uneven terrain be sure to keep sufficient distance between the flight plan and the terrain.

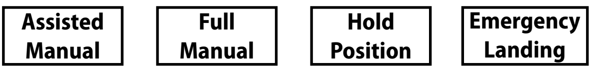
guarantee regarding the accuracy and completeness of the *Google Earth*^{TM} terrain model.

4.5 Autonomous controller and modes of flight

Autonomous operation modes



Manual and emergency modes



During a typical flight the autonomous controller on the *eBee* will switch between various modes depending on its flight plan and the commands that it receives from the Control Bar[20]. The controller changes between modes during a typical mission as shown in the figure above, and as described in more detail in the following list:

- After being switched on and running pre-flight checks the drone will enter Idle mode until it is ready to be launched. Shaking the drone back and forth

[20] see section 'Control Bar' on page 89 for details on the Control Bar

three times initiates the take-off procedure[21] and changes to the Take-off mode.

- After take-off the drone climbs with level wings[22], gaining altitude until it reaches the take-off transition altitude, by default 20 m[23] above the take-off location. At this point the drone heads for the Start waypoint and changes to Circle Start Waypoint mode.
- Once it reaches the Start waypoint, the drone circles the waypoint several times to estimate the strength of the wind. Once it calculates the estimated wind the drone either:
  - heads towards the first mission waypoint, if 'Start mission' is selected in the 'After take-off' panel of the Setup Phase tab, and changes to Perform Mission mode.
  - continues circling the Start waypoint until a command is received from the Control Bar (typically a 'START MISSION' command that is sent once a flight plan is finalized).
- While in Perform Mission mode the drone flies between all enabled mission waypoints, taking images of the ground below. Once it reaches the final mission waypoint the drone either:
  - heads towards the Home waypoint, if 'Land' or 'Go to Home waypoint' is selected in the 'After mission' panel of the Setup Phase tab, and changes to Circle Home Waypoint mode.
  - heads towards the Start waypoint, if 'Go to Start waypoint' is selected in the 'After mission' panel of the Setup Phase tab, and changes to Circle Start Waypoint mode.
  - heads towards the first mission waypoint, if 'Restart mission' is selected in the 'After mission' panel of the Setup Phase tab, and remains in Perform Mission mode.

[21] as described in section 'Take-off' on page 41

[22] or in a given direction when using the Directional take-off feature described in section 'Setup Phase tab' on page 96

[23] see section 'Flight Parameters tab' on page 116 for details on changing this altitude

- Once it reaches the Home waypoint (if in Circle Home Waypoint mode) the drone will either:
  - begin a Linear landing procedure (as described in section 'Linear landing' on page 70) and change to Linear Landing mode, if 'Land' is selected in the 'After mission' list and 'Linear landing' is selected in the Landing type list of the Setup Phase tab.
  - begin a Circular landing procedure and change to Circular Landing mode, if 'Land' is selected in the 'After mission' list and 'Circular landing' is selected in the Landing type list of the Setup Phase tab.
  - circles the Home waypoint and remains in Circle Home Waypoint mode until a command is sent.
- After completing a landing procedure and detecting that it has successfully landed, the drone changes to Idle mode.

- Turning on the remote control will cause the drone to enter either Assisted Manual or Full Manual mode, depending on the setting in the Flight Parameters tab[24]. Turning off the remote control will return the drone to its previous mode.
- Clicking the 'HOLD POSITION' button in the Control Bar at any time will cause the drone to start circling its current position and change to Hold Position mode until it receives a new command from the Control Bar. Alternatively, right-clicking in the Map Area and selecting 'Hold here' will direct the drone towards the selected position and then circle around that position in Hold Position mode. This mode is also enabled automatically after certain In-flight warning or Critical failure conditions[25].
- Clicking the 'LAND NOW' button in the Control Bar three times in quick succession will cause the drone to initiate a Circular landing procedure at its

[24] see section 'Manual control of the *eBee*' on page 120 for information on the various manual control modes

[25] see section 'Troubleshooting' on page 137 for a full list of In-flight warning and Critical failure conditions and the subsequent reactions of the drone

current location with its motor disabled and change to Emergency Landing mode.

4.6 Linear landing

A typical Linear landing follows these steps:

1. The *eBee* flies towards the Home waypoint (defined by the user within *eMotion*; default altitude is 75 m above the landing altitude). The altitude change behaviour between the current location and the Home waypoint depends on the 'Altitude change' parameter of the Home waypoint. By default, it is defined as 'Keep highest', which means that the drone will fly at the highest altitude between its current altitude and the Home waypoint's altitude, climbing in a spiral first if needed.

2. Once the Home waypoint is reached the drone circles the waypoint and descends to a fixed altitude of 75 m above the landing altitude.

3. The drone circles to estimate the wind speed and direction. An approach direction is then calculated as close to the upwind direction as possible within the allowable approach sectors (defined by the user within *eMotion*).

4. The drone flies downwind against the approach direction. After flying for a sufficient distance it turns around to align itself with the approach direction.

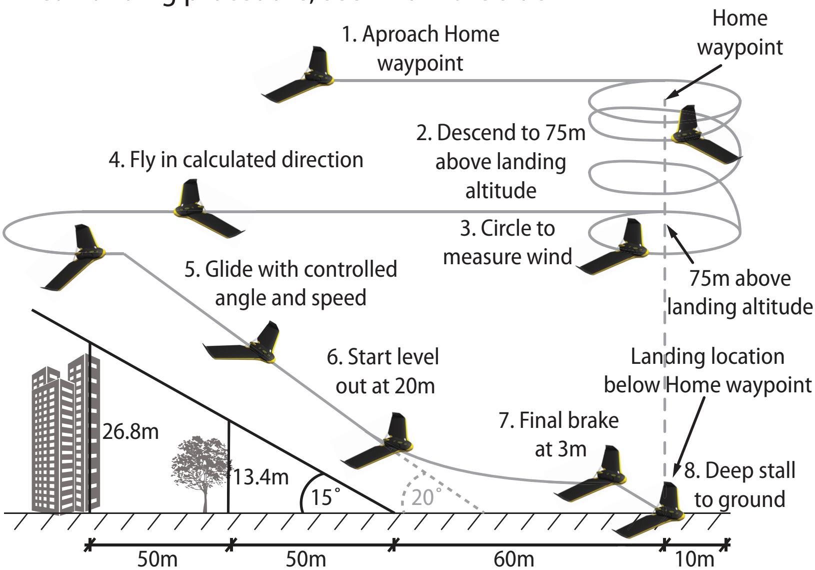
5. The drone glides down in the approach direction at a controlled speed and descent angle of approximately 20°, braking by spinning its propeller in reverse if necessary.

6. When the drone detects a height of around 20 m to the ground it begins to level out its descent.

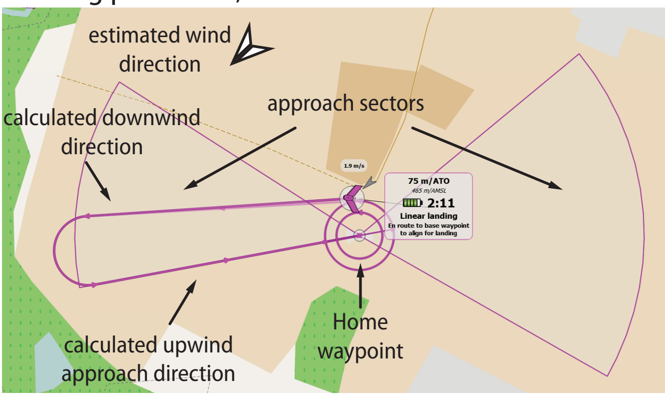
7. When the drone detects a height of around 3 m to the ground it performs a final brake to reduce its speed and lifts its nose.

8. The drone then glides for the final few metres in a deep stall until it lands.

Linear landing procedure, seen from the side



Linear landing procedure, seen from above within *eMotion 2*



The Linear landing process uses an optical-based sensor to detect the proximity of the ground. A number of conditions on the environment and the positions of the Home waypoint and approach sectors must be met in order for the ground sensor to function correctly and ensure the accuracy of the Linear landing:

- If the Linear landing location is not at the same altitude as the Take-off location you must adjust the Landing altitude parameter in the 'Setup Phase' tab, as the drone uses this altitude to level out and slow down before landing (Steps 6-8). Enable the 'Land at a different altitude than take-off' checkbox and set the altitude as an absolute value in AMSL.

> **Note:** When 'Land at a different altitude than take-off' is enabled the Home waypoint's altitude will be converted to AMSL instead of ATO (by default 75m above the landing location).

> **Caution:** Incorrectly setting the altitude of the Linear landing location will decrease the accuracy of the Linear landing and may result in damage to the *eBee*.

- A Linear landing can only be performed over flat terrain. Ensure that the ground is flat and at the same altitude as the Linear landing location for a distance of at least 100 m from the Linear landing location within every approach sector. It is also recommended to have flat terrain in the opposite direction of every approach sector in case a Linear landing is aborted in its final stages.

> **Caution:** Attempting a Linear landing on sloped terrain, the top of a roof or the edge of a cliff or any other terrain that is not flat will likely result in false detection of the height above the ground during the approach and may result in damage to the *eBee*. In particular, landing downhill may cause a large overshoot and should always be avoided.

- Ensure that there are no obstacles within 60 m of the Linear landing location within all approach sectors and within a radius of 10 m around the Linear landing location. If there are some obstacles in the distance, ensure that the top of the obstacles is at no more than a 15° angle from the point 60 m from the Linear landing location, as indicated in the figure on page 71. It is also recommended to not have any obstacles in the opposite direction of all approach sectors, in case the Linear landing is aborted before completion.

> **Caution:** It is not recommended to perform Linear landings between tall obstacles, as they may disturb the GPS signals your *eBee* needs to be able to navigate.

- In order to limit the ground speed when landing and to achieve the best landing accuracy, the *eBee* should only perform a Linear landing against the direction of the wind. Approach sectors should be as large as possible and in as many directions as possible to allow the drone to select the optimal approach direction based on its estimate of the wind. If all of the available approach sectors are in the direction of the wind an In-flight warning[26] will appear in *eMotion* when the drone calculates its trajectory (Step 3).

> **Caution:** If the drone performs a Linear landing in the direction of the wind during strong wind conditions or with certain In-flight warnings or Critical failures it may not be able to slow enough during its descent. It will likely overshoot the Home waypoint location and land at a high speed, potentially resulting in damage.

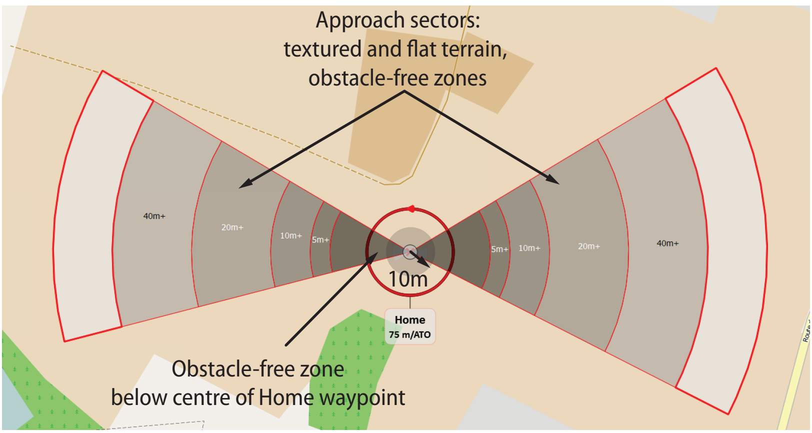
- The ground sensor must have sufficient light and texture to accurately detect the height above the ground. Ensure that the ground sensor lens is clear of dirt or other obstructions. Only attempt Linear landings in full daylight conditions. Ensure that there is high-contrast surfaces in all the ap-

[26] see section 'In-flight warnings' on page 143

proach sectors. Do not define approach sectors over low-texture surfaces such as large bodies of water, snow or sand.

- During a Linear landing the drone requires sufficient energy to slow down its descent and perform its final brake (Steps 5-7). If the Linear landing option is active and the battery descends below 20% an In-flight warning will appear[27] in *eMotion*.

To enable Linear landing select 'Linear landing' from the 'Setup Phase' tab. A single approach sector appears around the Home waypoint. Rotate and resize the approach sector to define the directions around the Home waypoint that are completely clear of obstacles. You can add additional approach sectors from within the 'Setup Phase' tab. These approach sectors will be used by the drone to plan its landing path while taking into account the wind. Defining multiple possible approach sectors can increase the chance that the drone selects a favourable landing against the direction of the wind. Be sure that there are also no obstacles in a 10 m radius circle around the Home waypoint, as the Linear landing process may be effected by wind or positioning imprecision of the on-board GPS.



[27] see section 'In-flight warnings' on page 143

Note: The *eBee*'s ground sensor can typically begin detecting ground proximity at a distance of 40 m. If the drone reaches an estimate altitude of 20 m/ATO (as estimated using the on-board GPS and pressure sensor) without a signal on its ground sensor it assumes there is a malfunction with the ground sensor. This may be due to insufficient light or contrast in the environment, dirt on the sensor's lens assembly or a Linear landing location at a different altitude than the Take-off Location. In this case the drone performs the braking and stall manoeuvre at an altitude of 20 m instead of 3 m. This increased time while stalled can greatly reduce the accuracy of the final landing position and damage to the drone.

If the Linear landing process is aborted (by clicking on the 'ABORT LANDING' button in the Control Bar) before completion the drone will turn on its motor in full thrust and gain altitude while continuing in a straight line in its approach direction. Once the altitude of 40 m/ATO is reached the drone will turn towards the Home waypoint and continue climbing until it reaches an altitude of 75 m/ATO. It then continues circling until it receives a further command.

Caution: Do not abort a Linear landing if there are obstacles in the approach direction behind the Home location, as the drone will continue flying in a straight line after an abort sequence while it gains altitude and may collide with those obstacles.

Caution: It is not recommended to abort a Linear landing when the battery is low, as the drone may not have enough power to attempt a second landing.

4.7 Flying multiple drones at the same time

Operating multiple drones at the same time enables the coverage of larger areas in a shorter amount of time. This can be useful when the mission time must be kept short, for example because of varying lighting conditions. To enable multi-drone operation *eMotion* provides the following:

- When more than one drone is connected at a time, a dedicated interface called the Multi-drone panel is displayed to monitor each drone and switch between them.

- A number of settings are offered to keep relevant flight configurations (such as the Start and Home waypoint) synchronised between all connected drones.

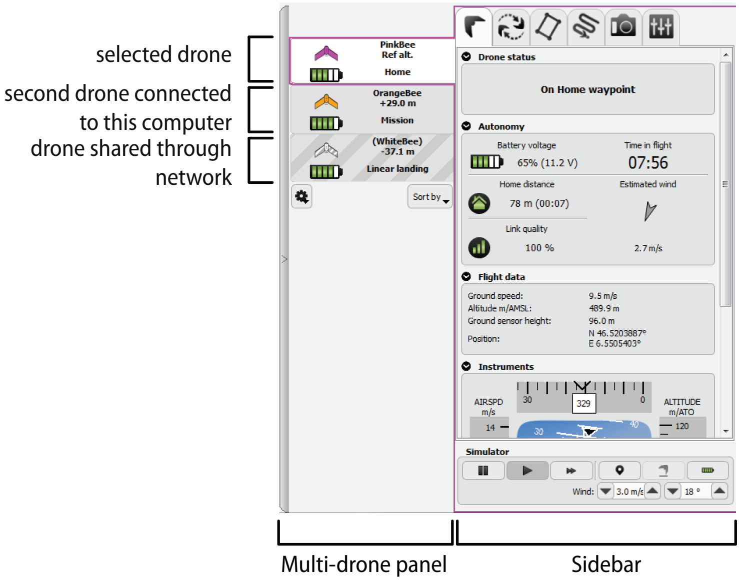
- Missions that require more than one flight can be automatically split and uploaded individually among all connected drones.

- A new Control Bar appears at the bottom of the Map Area. Commands sent using the buttons in this Control Bar, such as 'START MISSION' or 'GO LAND,' are sent to all the drones currently connected to your computer.

- Collision avoidance is provided by *eMotion*[28]. This is done by automatically changing the altitude of the Start and Home waypoints for each drone in order to separate them. Also, the drones are automatically put on hold when there is a collision risk during the mission.

When connecting to more than one drone at a time (real or simulated), a dedicated Multi-drone Panel is displayed next to the Sidebar. Each drone is displayed with its name, battery level and status and can be selected. The rest of the Sidebar and its various tabs are associated to the currently selected drone, as indicated by the colour of the frame. The multi-drone interface also displays the relative altitude of all drones with respect to the selected drone. Since this is a relative altitude, a value close to 0 m means that a drone is at the same altitude as the currently selected drone. Right-clicking on a drone's tab in the Multi-drone Panel allows you to disconnect the drone or change its colour.

[28] if the option is selected in the Multi-drones preference pane



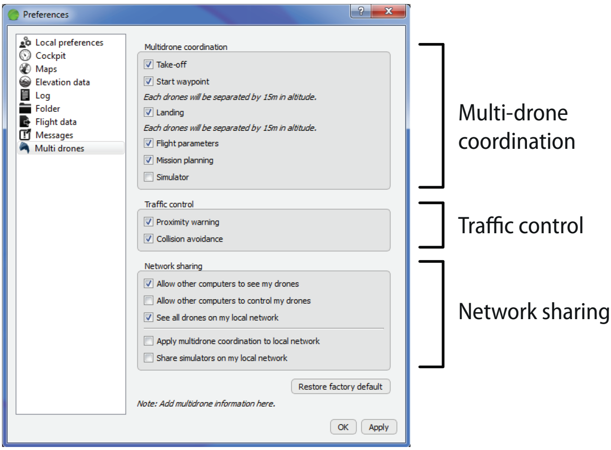
One advantage of flying multiple drone drones at once is to cover more area in less time. *eMotion* can automatically upload a multi-flight mission to all connected drones in a single click. To achieve this, follow this procedure:

1. Go to the Mission Planning tab and prepare the required mission area (this can be done with any of the connected drone selected). Make sure that the number of flights required matches the number of connected drones. If needed, the 'Max flight time' option can be lowered to force the mission planner to split the mission in several flights (see section 'Mission Planning tab' on page 100).

2. Select 'Upload to all' from the drop-down list of the 'Upload button'.

Note: You can only split a mission between drones of the same model and that are using the same camera.

Clicking on the ⚙ icon in the Multi-drone panel allows you to either connect a new drone or to bring up the Multi-drones preferences pane.



eMotion provides Multi-drone coordination options to synchronise various waypoints and parameters among connected drones:

- **Take-off:** Synchronising the take-off applies specifically to Directional take-off heading and transition altitude.
- **Start waypoint:** When the Start waypoint is synchronised, *eMotion* will use the same location and altitude for the Start waypoint of each connected drone. Every modification to the Start waypoint of one drone is thus transferred to all other drones. To prevent collisions between drones, *eMotion* will automatically create a stack by incrementing the altitude of each drone that is currently circling the Start waypoints to ensure a 15 m separation. The base altitude of the Start waypoint, which is the altitude of the lowest drone in the stack, can be set in the Multi-drone Panel.
- **Home waypoint and landing:** Similarly to the Start waypoint, when the Home waypoint is synchronised *eMotion* will us the same Home waypoint

for all connected drones. A stack will also be created to avoid collisions between multiple drones circling the Home waypoint.

Caution: As *eMotion* defines the Start and Home waypoints in ATO. It is therefore critical for **all drones to take off from the exact same location** to achieve altitude separation and collision avoidance over these two waypoints.

- **Flight parameters:** This option will synchronise all the parameters in the 'Flight parameters' tab across all drones. This includes the Working area radius and ceiling, take-off transition altitude, Security action parameters, etc.

- **Mission planning:** This option will share the same Mission Area among all connected drones.

- **Simulator:** When checked, repositioning a simulated drone on the map will reposition all simulated drones at the same time.

In addition to the altitude separation on the Start and Home waypoints described above, *eMotion* provides two traffic control mechanisms to help avoid collision between drones in flight:

- **Proximity warning:** When enabled, a visual and audible warning will be emitted if two drones are on a trajectory potentially leading to a collision in less than 7 seconds.

- **Collision avoidance:** When enabled, *eMotion* will constantly monitor the trajectory of the connected drones and automatically put one drone in a temporary hold pattern (similar to the HOLD POSITION function, see section 'Control Bar' on page 89) until it is safe to resume the flight. Priority is given to drones with the lowest battery level, engaged in a landing procedure or with an active error or warning.

Caution: All collision avoidance mechanisms are implemented by *eMotion* on the ground computer. The drones' autopilot do not communicate between themselves and do not have knowledge of each other's positions. It is therefore critical to **keep all drones connected to *eMotion* at all times and remain well inside communication range**.

Note: While *eMotion* strives to avoid all collisions, the operator is ultimately responsible to ensure flight safety. In particular, situations involving more that two drones in converging trajectories may not always be handled automatically in a fully safe manner. It is recommended to use slightly different altitudes for each drone when flying more than two drones at a time to limit the risk of collision.

In more advanced scenarios you may wish to share the position and even the control of a drone across a local area network. *eMotion* provides the following Network sharing options:

- **Allow other computers to see my drones:** All computers that are running *eMotion* and are connected to the same network will be able to display the position, status and other parameters of the drones connected to your computer.
- **Allow other computers to control my drones:** All drones currently connected to your computer are not only displayed, but can be fully controlled by other computers running *eMotion* on the same network.
- **See all drones on my local network:** Check this box to display the position and other parameters of drones connect to other computers on the same network.
- **Apply multi-drone coordination to local network:** Check this box to synchronise all the selected parameters in the Multi-drone coordination preferences across all drones that are connected to the same network (provided that they have checked the 'Allow other computers to control my drones' option).

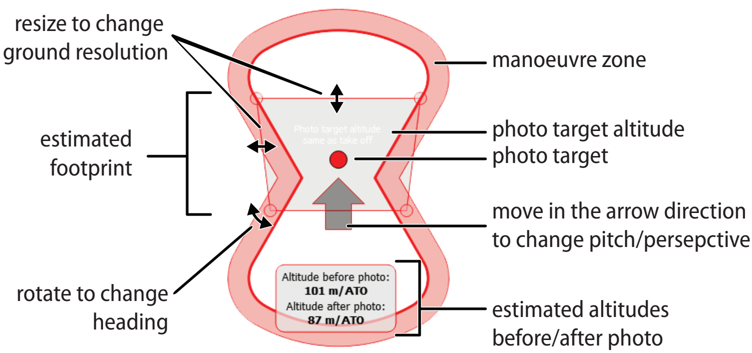
- **Share simulators on my local network:** If this box is checked, all Network sharing options apply to both real and simulated drones connected to your computer. In unchecked, they only apply to real drones.

4.8 Individual photo targets and oblique imagery

In some cases it may be interesting to take oblique photographs of objects, for example to provide a nice image for documentation or to increase the quality of 3D models that contain vertical facades and surfaces. *eMotion* includes a tool for defining photo targets with a specific distance, heading and pitch angle. The drone can then orient itself and capture the image using a patent-pending pitch-down manoeuvre.

Capturing an oblique image can be done easily by following these steps:

1. Add a new photo target by clicking on the + button in the Camera tab. Use the cross-hairs to place the photo target on the location of interest in the Map Area. You may also right-click anywhere in the Map Area and select 'Add photo target here' from the contextual menu. The photo target will appear as a circle in the Map Area with an estimated image footprint, a manoeuvre zone and a status panel with estimated altitudes before and after the image is taken.



2. Select the desired heading and pitch angles of the image by rotating the image footprint and moving the photo target arrow, respectively. The estimated image footprint can help you choose the required angles. You can also set the angles manually in the 'Photo targets' section of the Camera tab.
3. Define the desired ground resolution at the photo target within the Camera tab. You can also adjust the ground resolution by resizing the photo footprint in the Map Area.

Caution: Be sure to define a ground resolution that is high enough to allow the drone to recover from its pitch manoeuvre by paying close attention to the 'Minimum altitude after photo' parameter. We recommend that you do not define parameters that result in an 'Minimum altitude after photo' of less than 30 m, in particular when selecting a high pitch angle.

4. Define the altitude of the photo target, if it is not the same as the take-off altitude. You may use elevation data to define this altitude by enabling the 'Use elevation data to set absolute photo target altitudes' checkbox.

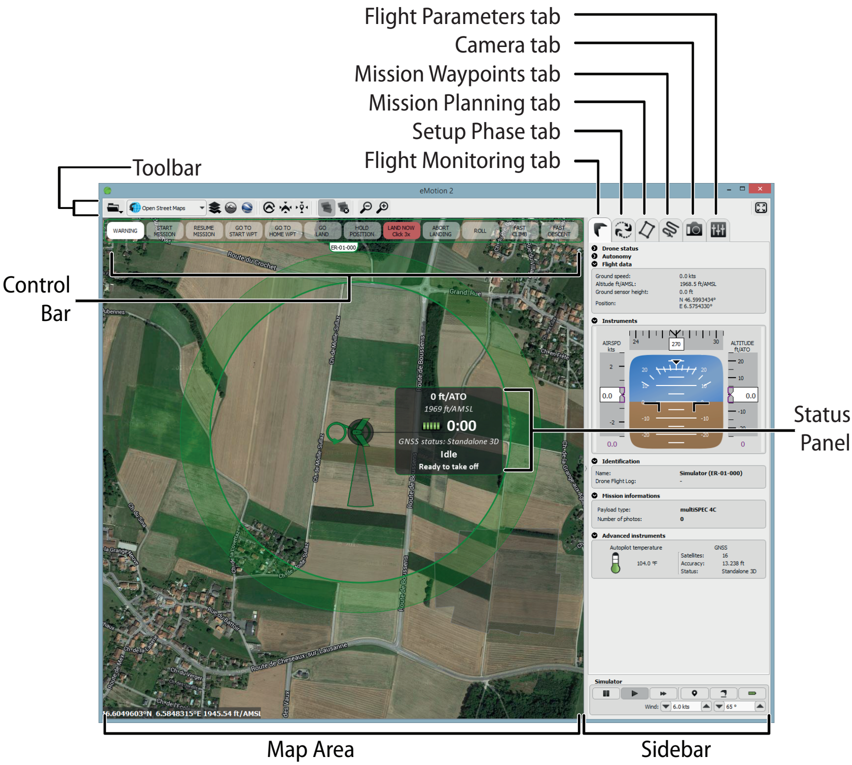
Repeat the above steps to define multiple photo targets. After launching your drone, click on the 'Begin sequence' button in the Camera tab at any time to begin taking the images. The *eBee* will fly to the location of the first photo location, measure the wind above the location, and perform a dive (pitching down) manoeuvre to take the oblique photo. It will perform this for all photo targets until it has completed the entire sequence.

Taking a series of oblique images of the same photo target at regular heading and pitch intervals allows you to create a higher quality 3D model of a photo target. You can use the 'New photo target increment' to define a desired increment angle. Clicking on the ✚ button will then add a new photo target at the same location as the previous target but with an incremented pitch and heading value.

A more detailed description of all the available options for taking images of individual photo targets can be found in section 'Camera tab' on page 111.

5 *eMotion* in-depth guide

Goal of this section: *eMotion* is a powerful tool designed specifically to work with your senseFly Ltd mini-drones. This section includes a comprehensive guide to all the functionalities in *eMotion* to help you plan, simulate and monitor your next mapping flight.

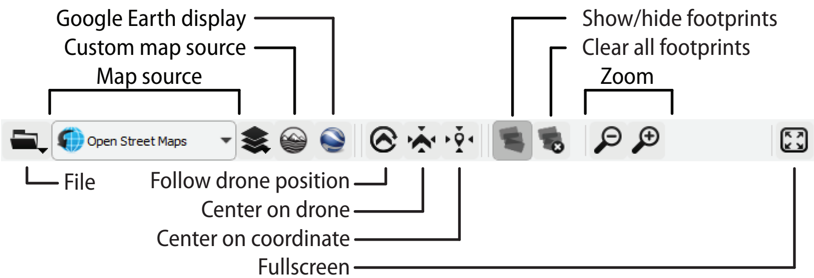


The main *eMotion* interface is composed of a Map Area, a Toolbar and a Sidebar[29]. The Map Area displays the current location of the *eBee*, a Status Panel with important information on the drone's current status, and a Control Bar used to send commands to the drone (section 'Control Bar' on page 89).

The Toolbar above the Map Area includes the File menu, controls for selecting the source of map data, the display of picture footprints and various other controls (section 'Toolbar').

The Sidebar is separated into six individual tabs that are used during different phases of planning and monitoring a flight. The Sidebar tabs can be hidden at any time by clicking on the left-hand edge of the Sidebar. Each tab is described in detail in the following chapter. The Sidebar also contains controls for the Simulator (section 'Simulator' on page 87)

5.1 Toolbar



You can access the File menu by clicking on the button in the Toolbar. From this menu you can connect to or disconnect from a drone, access the Flight Data Manager, change *eMotion* preferences or import custom maps. Clicking the icon will launch *Google Earth*™ and display the current flight trajectories of drones connected to *eMotion*, as described in detail in section 'Flight visualization in *Google Earth*™' on page 64.

[29] for an overview of the *eMotion* interface see section 'The *eMotion* interface' on page 19

You can select the background map source from the drop-down list in the Toolbar, and adjust its zoom level using the and buttons. *eMotion* can use many sources of commercially available and custom mapping information. Tiles from map sources with the icon are downloaded by *eMotion* from the Internet as required and locally cached on the hard drive. Due to regulatory restrictions, map sources with the icon cannot be saved locally and are not recommended for use in the field.

If you anticipate the use of *eMotion* in conditions where connecting to Internet is impossible, you can preload the map data by selecting 'Download maps...' from the File menu. Follow the instructions in the dialog box to select the zone of interest, map tile source and start downloading.

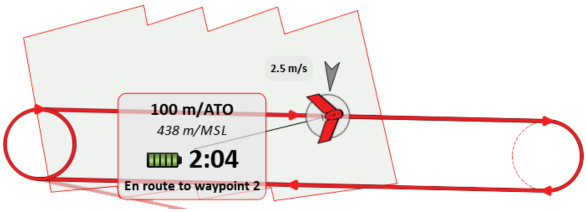
eMotion can also import and display custom layers which may include KML files, custom map tiles and elevation data. To import a KML file, select 'Import KML...' from the File menu and select your KML file. The resulting layer will now be available in the Toolbar by clicking on the icon, and can be clicked to display or hide it. *eMotion* can display lines, polygons, paths and points saved in KML format.

Note: KML files, including associated icons or images included within them, are not copied to the *eMotion* directory and will no longer appear in *eMotion* if the original KML files are deleted.

Custom map tiles can also be added as a layer in *eMotion*. Select 'Import custom map...' from the File menu and select the folder that contains the tile set. The tile set will then appear in the list of layers in the Toolbar, accessible by clicking the button.

Note: If you use *Postflight Terra 3D* (see section 'Processing image data' on page 48), a tile set can be generated for each project that is directly compatible with *eMotion*. You can therefore create your own map background using the *eBee*. You can generate the tile set by selecting 'Generate Google Maps tiles and KML' from the 'Process' menu within *Postflight Terra 3D*.

Whenever the *eBee* takes a picture, *eMotion* records the location and orientation of the drone and computes the approximate span of the photo on the ground (or 'footprint'). All the footprints taken by a drone are added to a shaded polygon outlined with the drone's colour and displayed in the Map Area. This polygon represents an estimate of the area that has been photographed by the drone.



The footprints can be shown or hidden using the button. When hidden, the footprints are kept in memory and new photos continue to be recorded, but nothing is displayed in the Map Area. Footprints for all drones remain in the memory of *eMotion*, even when a drone is disconnected or *eMotion* is shut down. Clicking on the button removes all footprint polygons from the Map Area the memory of *eMotion*. New picture footprints will be created for subsequent pictures that are taken.

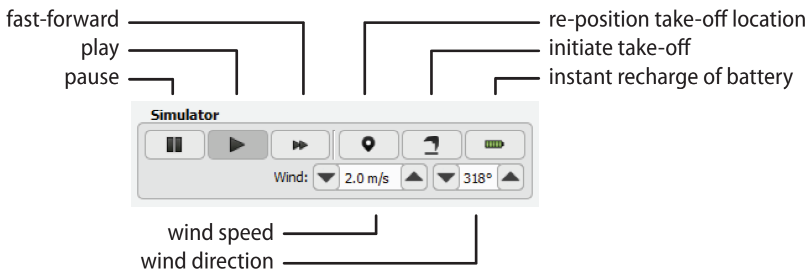
Note: Clearing or hiding the footprints has no influence on what is logged by *eMotion* and on-board the drone during the flight, such as the information required to geotag the images after the flight.

Note: The footprints displayed on the map are only an approximate estimation of the actual ground coverage of the corresponding image. Cross-wind may introduce errors in the orientation of the displayed footprint compared to the actual coverage, whereas inaccurate elevation data may result inaccurate footprint size.

The Toolbar also contains buttons for centering the Map Area on the current position of the drone (button), on a searchable location or coordinate (button) or to continually follow the position of the drone while it is in flight (button). Finally you can view *eMotion* in full-screen mode by clicking the button.

5.2 Simulator

Familiarising yourself with your *eBee* and its features will allow you to more efficiently plan and execute mapping flights, saving you time and improve your imaging results. The Simulator in *eMotion* is designed to help you test the various features of the drone and to better prepare a mapping mission before performing it in the field. Several simulated drones can be connected at the same time, allowing you to test multi-drone functionalities.



The Simulator bar appears at the bottom of the Sidebar of *eMotion* when you connect to a simulated drone. The simulated drone will go through the same preflight checks as a real *eBee*, after which it will update the Home to its current position (typically the last position that was used within the simulator) and the Start waypoint to 80 m West of the Home waypoint. The various buttons available in the Simulator bar are described in table 1 on the next page.

Feel free to modify the wind speed, waypoint positions and other parameters in the Toolbar and the various tabs of the Sidebar in *eMotion* to see their effect on the *eBee* while it is in flight. Also be sure to explore the effects of the various buttons in the Control Bar on the behaviour of your drone. Don't be afraid to push the boundaries! Aborting a flight or causing an emergency landing in the simulator will better prepare you for unexpected circumstances while in the field.

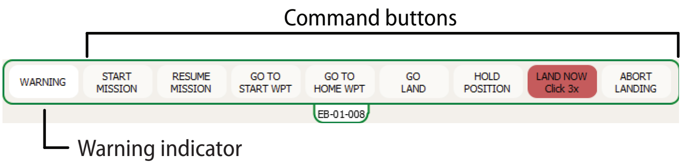
Table 1: Simulator bar buttons

Button	Description
Pause	Clicking the pause button will pause the simulation and thus stop the drone while in flight. This can be useful when you wish to change parameters or waypoints while the drone is already in flight. **Note: this is a simulated action that is not possible with the real *eBee*. Instead of pausing while in flight we recommend that you use the 'HOLD POSITION' function to better simulate real flight conditions.**
Play	Clicking the play button returns the simulation to actual speed from the pause or fast-forward conditions.
Fast forward	Clicking this button increases the speed of the simulation to 4x actual speed. This allows you to shorten the time required to simulate a complete mission.
Re-position take-off location	Clicking this button and then clicking on a location in the Map Area simulates the action of connecting the battery to the drone in a new location. The drone is returned to the ground at the new location and runs through its pre-flight checks before entering Idle mode.
Initiate take-off	Clicking this button simulates a take-off procedure, including the motor power-up sequence and the hand launch[30].

[30] see section 'Take-off' on page 41 for a description of the take-off procedure

Instant recharge of battery	Clicking this button will instantly recharge the battery of the drone. **Note: This is a simulated action that is not possible with the real *eBee* while it is in flight.**
Wind speed and direction	These fields are used to input a simulated wind speed and direction. A random wind speed and direction is set when *eMotion* connects to a simulated drone.

5.3 Control Bar



The Control Bar includes buttons for sending commands to the drone and for acknowledging warnings while it is in flight. Certain buttons can only be used during specific flight modes[31].

The Command buttons allows the operator to directly control the drone while it is in flight. The various buttons are described in table 2 on the following page.

[31] see section 'Autonomous controller and modes of flight' on page 66 for more information on flight modes

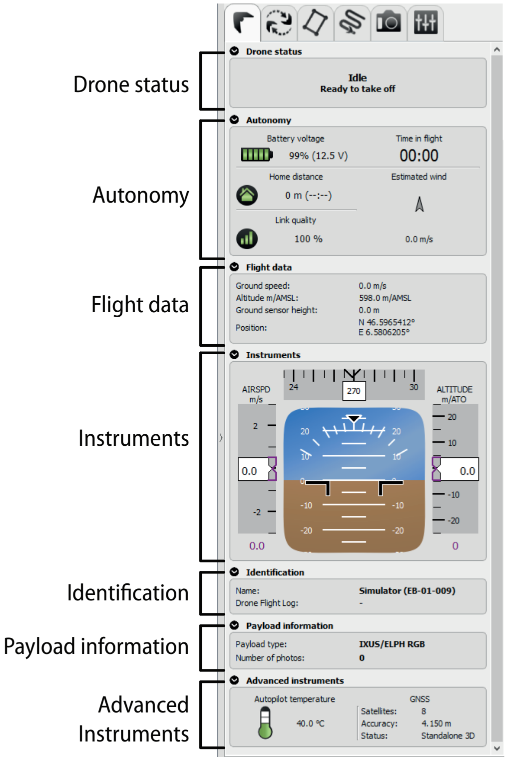
Table 2: Control Bar Buttons

Button	Available	Action
WARNING[32]	Active warning	For yellow In-flight warnings, button text changes to 'ACK WARNING' and clicking will acknowledge the current warning. For red Critical failures, button text changes to 'CRITICAL FAILURE' and cannot be clicked.
START MISSION	No active Security action	Fly towards the first active waypoint in the waypoint list and start the mission from the beginning.
RESUME MISSION	Not in Perform Mission mode	Return to the last position reached during the mission and continue the flight plan.
GO TO START WPT	No active Security action	Fly towards the Start waypoint, circle and wait for next command.
GO TO HOME WPT	Anytime	Fly towards the Home waypoint, circle and wait for next command.
GO LAND	Anytime	Fly towards the Home waypoint and initiate landing procedure.
HOLD POSITION	No active Security action	Create a virtual waypoint at the current location and altitude, circle around this point and wait for next command.

[32] see section 'Troubleshooting' on page 137 for a full description of In-flight warnings and Critical failures that may occur

LAND NOW Click 3x	Anytime	Initiate a Circular landing around a 20 m radius waypoint at the current location. **Must be clicked 3 times in quick succession to be engaged.**
ABORT LANDING	During Circular Landing, Linear Landing, or Emergency Landing mode (if no active Critical failure)	**Circular or Linear landing:** abort current landing procedure, return to the altitude of the Home waypoint, circle the Home waypoint and wait for next command. **Emergency landing:** (only available if there is no active Critical failure) abort current landing procedure, return to the location where the Emergency landing was triggered, circle and wait for next command.

5.4 Flight Monitoring tab



The Flight Monitoring tab can be used to monitor the *eBee* during a mapping mission and is the default tab that is displayed when you click anywhere on the map area that does not have a symbol. The tab is split into the following sections:

- **Drone Status:** The status of the plane keeps you informed on what the drone is currently doing. This can include mission actions such as 'Taking photo' or 'Going to waypoint' as well as warning or failure messages such as 'Out of working area' or 'High wind'[33].

Note: The most important status and warning messages are reproduced in the Status Panel in the Map Area, and thus remain visible even when the Sidebar is hidden.

- **Autonomy:** The battery level displays the current charge and voltage of the battery. As the battery's charge level decreases, the voltage decreases as well. A fully charged battery has a voltage of 12.6 V and is fully discharged when it reaches about 9 V[34].

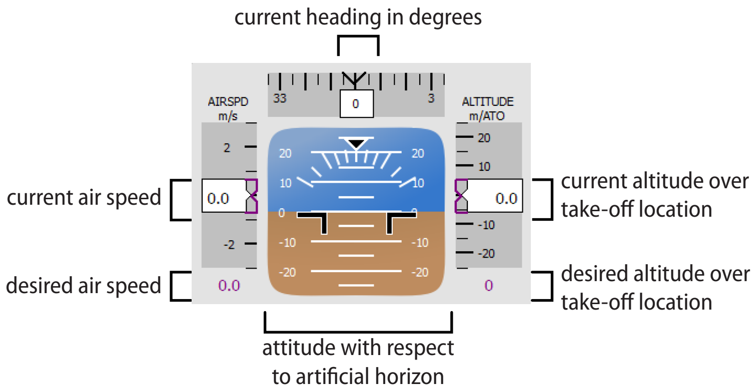
  This section also displays the total time in flight, the straight-line distance to the Home waypoint, the estimated time required to return to the Home waypoint (based on estimated wind strength) and the quality of the radio data link between the ground modem and the drone. The strength and direction of the wind estimated by the drone is displayed with an arrow.

Caution: Lithium polymer batteries are chemical devices whose performance depends on a number of parameters, including temperature, lifetime, number of cycles, mechanical integrity, etc. Estimating the remaining capacity of a battery can thus be tricky and the displayed value may occasionally be inaccurate. It is the operator's responsibility to monitor battery voltage and flight time in addition to the battery level to make sure that endurance is sufficient to complete the mission.

- **Flight data:** This section includes additional information that may be useful during the flight, including ground speed and height, altitude Above Mean Sea Level (AMSL) and the absolute position detected by the GPS onboard the *eBee*.

[33] see section 'Troubleshooting' on page 137
[34] see section 'Proper battery care' on page 135

Note: The ground sensor height indicates the height above the ground detected by the ground sensor. The sensor can typically detect distances below 60 m, depending on available light and surface contrast.

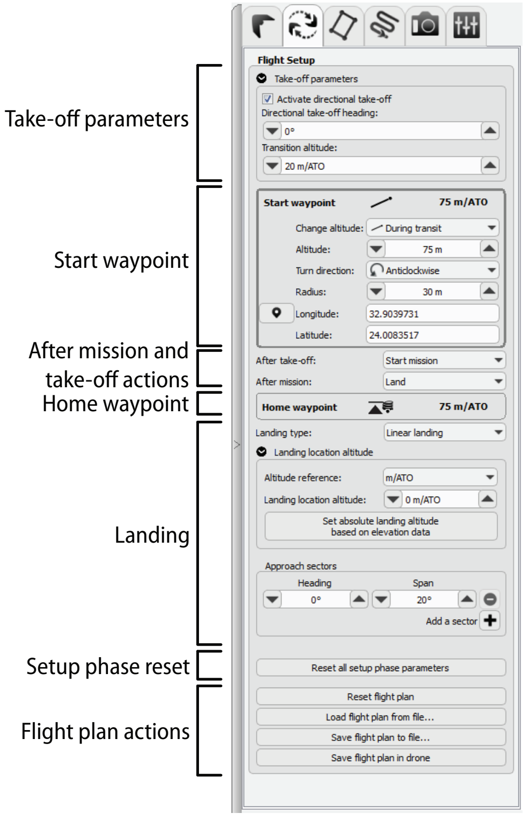


- **Instruments:** This display mimics the classical primary flight display used in manned aircraft. The column on the left displays the current air speed of the *eBee* as well as the desired air speed, in metres per second. The column on the right displays the drone's current altitude over take-off location, as well as the desired altitude over the take-off location, in metres. The bar at the top displays the current heading of the drone[35]. North is indicated as 0°, East as 90°, South as 180°and West as 270°.
- **Identification:** This displays the serial number of your *eBee* and the number of the Drone Flight log for the current flight. This number can be used as a reference when importing flight data after a flight[36].
- **Payload information:** This section displays the payload currently selected and the number of photos that has been taken since take-off[37].

[35] this feature is only accurate when in flight
[36] see section 'Importing images and flight data' on page 48
[37] see section 'Camera tab' on page 111 for instructions on changing the payload type

- **Advanced Instruments:** This section displays the current internal temperature of the drone, the number of GPS signals detected and the estimated accuracy of the the position.

5.5 Setup Phase tab



The Setup Phase tab is used to define the setup phase of a flight plan. This phase includes the definition of the Home and Start waypoints and the actions to be taken before and after the mission phase of the flight plan.

The Setup Phase tab is divided into the following sections:

- **Take-off parameters:** You can predefine a take-off heading and transition altitude. To enable this feature, expand the 'Take-off parameters' box and check the 'Activate directional take-off' check box. A new arrow is now displayed on the map. This arrow defines the take-off heading, the drone will try to stay on the track defined by the arrow.

desired takeoff direction

You can now grab the arrow on the map in order to modify the take-off heading. Furthermore you can also pre-set the take-off direction and the take-off transition altitude in the Setup Phase tab.

Default value: Unchecked, Heading: 0°, Transition altitude: 20m/ATO

Caution: Setting the take-off transition altitude too low may cause the drone to perform a change of direction too early and may result in a crash. Setting the take-off transition altitude too high may cause the drone to drift sideways after take-off if there is too much wind.

- **Start waypoint:** Here you set the position, change altitude parameter, altitude above take-off (m/ATO), turn direction and radius of the Start waypoint. You can set the location by clicking the button and clicking on the desired location in the Map Area.

Default values: Change altitude: During transit, Altitude: 75 m/ATO, Turn direction: anticlockwise, Radius: 30 m, Location: 80 m West of the position calculated from satellite signals on start-up

- **After take-off:** You can either command the drone to start the mission phase immediately after reaching the Start waypoint or to wait for a command from *eMotion*. This second option is useful if you want to modify the flight plan while the drone is already in flight.

  Default value: Start mission

- **After mission:** Use this panel to select the action you wish the drone to execute once it completes the mission phase. The *eBee* can either automatically go to the Home waypoint and land, go to the Home or Start waypoint and wait for a command or to restart the mission phase.

  Default value: Land

- **Home waypoint:** Here you set the position, change altitude parameter, altitude (in m/ATO or m/AMSL if 'Land at a different altitude than take-off' is selected), turn direction and radius of the Home waypoint. You can set the location by clicking the button and clicking on the desired location in the Map Area.

  Default values: Change altitude: Keep highest, Altitude: 75 m/ATO, Turn direction: anticlockwise, Radius: 30 m, Location: position calculated from GPS signals on start-up

- **Landing:** With this panel you can choose between a Circular landing or a Linear landing on the Home waypoint. If you select 'Linear landing' the panel expands to show options on approach sectors. You can define up to four approach sectors, each of which has a heading and a span, either by dragging in the map area or by manually setting parameters in the panel. See section 'Linear landing' on page 70 for details how to correctly select the Home waypoint and approach sectors.

  Default value: Linear landing, Approach sectors: single sector with a Heading of 0° and Span of 20°

- **Landing location altitude:** You can also configure the altitude of the landing location if it is different from the Take-off altitude. Expand the 'Landing location altitude' panel and select an altitude in m/AMSL or in m/ATO. It is also possible to predefine the landing altitude based on elevation data by clicking on the 'Set absolute landing altitude based on elevation data' button. This button will pre-set the altitude each time it is clicked (i.e. if the landing position is changed, the altitude is not automatically pre-set based on the Improved SRTM model, the user has to press the button each time that the landing position is changed).

  Default value: Landing location altitude: 0 m/ATO

- **Setup phase reset:** Pressing the 'Reset all setup phase parameters' will reset the Home and Start waypoints to the take-off location and reset the rest of the parameters on the tab to factory defaults. Clicking the 'Reset all waypoints and photo targets' will remove all the waypoints and photo targets in the currently loaded in the drone.

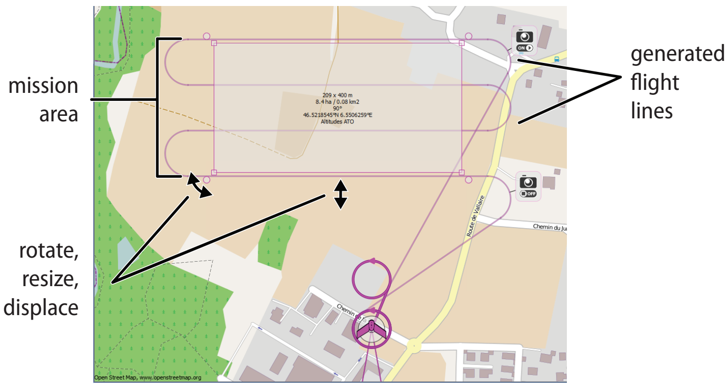
- **Flight plan actions:** A complete flight plan includes all the Setup phase (Start and Home waypoints, Take-off and Landing parameters, etc.), Mission phase (waypoints), Camera (camera model, photo targets, etc.) and Flight (working area radius and ceiling, Security actions, etc.) parameters. The 'Reset flight plan' resets the current flight plan to default parameters[38]. The 'Load flight plan from file...' and 'Save flight plan to file...' buttons load and save the current flight plan (both setup and mission phases) to a XML file for later reuse. You can also save the current flight plan to the *eBee*'s on-board memory by clicking the 'Save flight plan in drone' button. Once a flight plan is saved in the drone's memory, it will become the default flight plan the next time the drone is started and appear in *eMotion* upon connection. The drone also keeps track of its last waypoint during a flight; you can thus resume an incomplete flight after changing batteries.

> **Note:** It is not necessary to save a flight to the autopilot in order to fly! This is an advanced option meant to reduce the preparation time required when the same flight is performed many times.

[38] this action is only available when the drone is not in flight

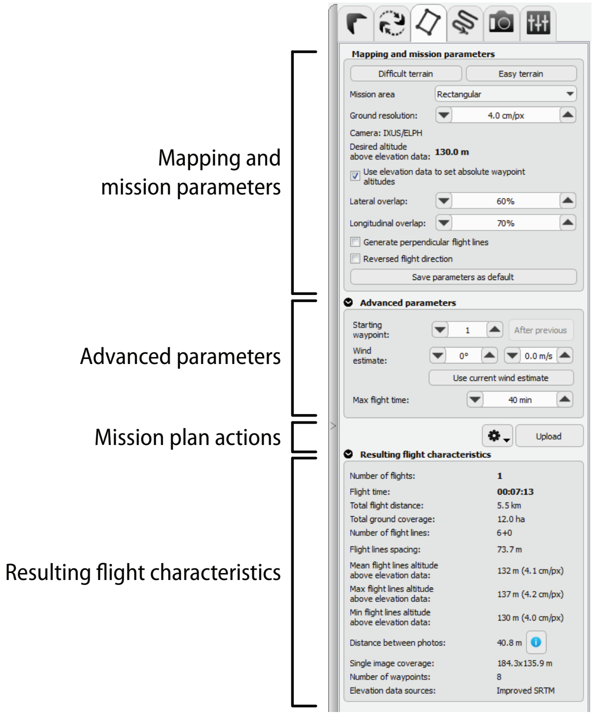
5.6 Mission Planning tab

The Mission Planning tab is used to automatically define a set of waypoints based on a mission area and a set of image parameters. Clicking on this tab will make a grey box appear in the Map Area that represents the mission area to be mapped. You can modify this area's location, size and rotation using the handles around it, as explained in section 'The mission phase of a flight' on page 22.



> **Note:** The quality of the output orthomosaic is usually lower on the outer edges of the area that is photographed, as there is less overlap between images. The area photographed is thus always calculated to be bigger than the mission area selected so as to ensure maximum image overlap within the mission area itself.

> **Note:** If there is no flight plan overlaid on the mission area rectangle then the mission is too large and cannot be flown by the *eBee*. This can be for two reasons: either the distance between two waypoints is too long for the drone to cover in a single flight, or the waypoints are too far from the Take-off and landing locations.



The Mission Planning tab is divided in several panels. The first panel, **Mapping and mission parameters**, contains the parameters that define the requirements of a particular mission:

- **Difficult terrain:** Clicking this button will fill in preset values to the rest of the parameters. The Difficult terrain preset is meant for imaging terrain with complex features such as forests. High image overlap is recommended to increase the amount of features that can be matched between images, though at the cost of lower image resolution (due to higher altitude).
- **Easy terrain (default):** This preset is meant for simple terrain such as quarries or agricultural areas where high-resolution images can be taken with

relatively low image overlap.

> **Note:** The preset values are recommended settings that have demonstrated good results when images are then used in *Postflight Terra 3D* to create orthomosaics. Do not hesitate, however, to modify these parameters to suit the particularities of the terrain you are mapping or the local regulations and airspace constraints.

- **Mission area:** You can select either a rectangular mission area for simple terrain (as described in section 'The mission phase of a flight' on page 22) or a polygonal mission area for more complex terrain (as described in section 'Advanced polygonal mission area' on page 60).

  Default value: Rectangular

- **Ground resolution:** The target ground resolution to be achieved, expressed in centimetres per pixel. This parameter is directly linked to the flight altitude: a higher resolution (few cm/px) requires a lower altitude, while a lower resolution (many cm/px) requires a higher one.

  Default value: 4.0 cm/px

- **Camera:** The camera payload that is currently selected[39]. Make sure the correct camera model is set in the flight planner to correctly calculate the required flight line spacing and distance between photos.

- **Desired altitude:** The target altitude value is the desired altitude above the ground at which the drone will take images. It is automatically calculated based on the Ground resolution and the characteristics of the onboard camera.

[39] see section 'Camera tab' on page 111 for details on changing the camera type

Note: *eBee* has a minimum distance between images that depends on wind strength and direction. The maximum longitudinal overlap depends on this minimum distance as well as the calculated altitude and the camera model. If the calculated altitude is too low the drone may not be able to achieve the required longitudinal overlap. This will be indicated by a ⚠ icon. Flying at an altitude of less than 40 m is potentially dangerous and will be indicated by a ✖ icon.

- **Use elevation data to set absolute waypoint altitudes:** Checking this box will enable the flight planner to adjust the absolute altitudes of all mission waypoints based on elevation data. This advanced planning mode is described in detail in section '3D mission planning using elevation data' on page 61.

  Default value: disabled

- **Lateral overlap:** The percentage of overlap between the ground coverage of pictures from adjacent flight lines. For most mapping purposes, a minimum of 50% is usually required. Higher coverage values may increase the mapping quality but will increase the flight duration.

  Default value: 60 %

- **Longitudinal overlap:** The percentage of overlap between the ground coverage of pictures taken consecutively in the same flight line.

  Default value: 70 %

- **Generate perpendicular flight lines:** Checking this box creates a second pass over the desired area perpendicular to the first pass. This option will significantly increase the overall image overlap and therefore improve the resulting map quality in *Postflight Terra 3D*. It is particularly useful for difficult terrain at the cost of doubling the required flight time.

  Default value: disabled

- **Reverse flight direction:** By default, the flight planner will design a flight in which the drone begins a mission at the farthest waypoint and finishes closer to the Home waypoint. Checking this box reverses the order of the planned mission waypoints. Be cautious, however, to ensure that there is enough reserve battery to return to the Home waypoint at the end of the mission.

Default value: disabled

- **Save parameters as default:** Clicking this button will save the current parameters of the Mission planning tab as the default ones in *eMotion*.

The next panel contains advanced parameters used by the flight planner:

- **Starting waypoint:** The waypoint ID of the first waypoint used to implement the mapping mission, as organized in the Waypoint list in the Mission Waypoints tab. This option is useful when including more than one mission area into a single flight. The default value for a new mission is 1. When planning for a second area to be covered in the same flight, the 'After previous' button sets the starting waypoint after the waypoints used for the previous area.

  Default value: 1

- **Wind estimate:** The estimated wind speed and direction. Incorrectly setting the windspeed affects the estimated flight time of the *eBee* and may cause it to return to Home before completing the desired flight plan. Clicking the 'Use current wind estimate' button will copy the wind speed currently estimated by the drone to the Wind estimate field.

  Default value: direction: 0°, speed: 0 m/s

- **Max flight time:** This parameter sets the maximum estimated flight time for a single flight. If the flight planner estimates a longer flight time for the currently-selected Mission area it will split the mission into two or more flights.

  Default value: 40 min

The third panel, **Mission plan actions**, includes the 'Upload' button which is used to upload the resulting mission waypoints to the autopilot. If there are multiple flights required this button becomes a drop-down list, and you can upload each flight individually.

Caution: Clicking 'Upload' will directly modify the waypoints required for the flight plan in the *eBee*. If the drone is flying towards or around one of these waypoints, its navigation will be affected to reflect the new waypoint parameters.

Clicking the 'More' button reveals several more options:

- **Load mission area...:** Click to load a previously-saved mission area and parameters from an Auto Flight Planner (.afp) file.
- **Save mission area...:** Click to save the current mission area and parameters to an Auto Flight Planner (.afp) file. This can be useful for example to map the same area with different image and mission parameters, or to save and restore a large mapping mission that requires multiple flights. Note that this saves only the mission area shape and location along with the associated mission and image parameters, not the actual list of waypoints that is then generated or the camera payload model used to calculate the mission plan.
- **Load last used mission area:** Clicking will load the last mission area that was successfully uploaded to an *eBee* autopilot, whether it was a real or simulated one. This option is useful when you want to repeat your last mission and did not explicitly use the 'Save mission area...' button.
- **Load mission area from KML file:** Use this option to load a polygonal mission area directly from a KML file (produced in *Google Earth*™ for example).
- **Load mission area from map object:** Use this option to load a polygonal mission area from a previously-imported map object (see section 'Toolbar' on page 84).
- **Reset mission area:** Clicking will reset the mission area to the default rectangular size and reposition it in the centre of the Map Area. It will also reset

all mapping and mission parameters to their last saved default values[40].

- **Restore factory settings:** Click to restore all the parameters of this tab to their default settings.

The last panel of this tab displays the characteristics of the flight(s) resulting from the selected image parameters:

- **Number of flights:** The resulting number of flights that must be performed to cover the chosen mission area. If the mission area cannot be mapped in a single flight, *eMotion* will split it into the minimum possible number of flights. The estimated distance that can be covered in a flight is calculated assuming a fully charged battery and an accurate wind estimate.

- **Flight time:** This is the estimated flight time for *each* of the flights.

- **Total flight distance:** The total distance that will be flown during *all* of the flights.

- **Total ground coverage:** The total area that will be mapped during *all* of the flights.

- **Number of flight lines:** The total number of flight lines in the mission phase of the flight plan, not including flight lines to and from the Take-off or landing locations. The second number represents the flight lines perpendicular to the first number.

- **Flight lines spacing:** The required distance between parallel flight lines, calculated using the Lateral overlap and Ground resolution parameters.

[40] Default values for mapping and mission parameters are set by clicking the 'Save parameters as default' button.

Note: If the flight line spacing is low enough to cause your drone to overshoot the beginning of a flight line, *eMotion* will automatically switch to an alternating flight line pattern. Your drone will fly along every other flight line, then return to fill in the gaps. If the spacing becomes too small even for an alternate flight lines, a ⚠ will appear beside this parameter to indicate the warning. You can remove this warning by decreasing the Lateral overlap or the Ground resolution.

- **Mean flight lines altitude above elevation data:** Mean altitude difference between all flight lines and the ground altitude, based on the top-most elevation data layer (3D flight planning only).
- **Max flight lines altitude above elevation data:** Maximum altitude difference between a flight line and the ground altitude, based on the top-most elevation data layer (3D flight planning only).
- **Min flight lines altitude above elevation data:** Minimum altitude difference between a flight line and the ground altitude, based on the top-most elevation data layer (3D flight planning only).
- **Distance between photos:** The required distance between each consecutive photo taken in the same flight line, calculated using the Longitudinal overlap, Ground resolution and Camera model parameters. The wind also has an influence as the ground speed increases with back wind.

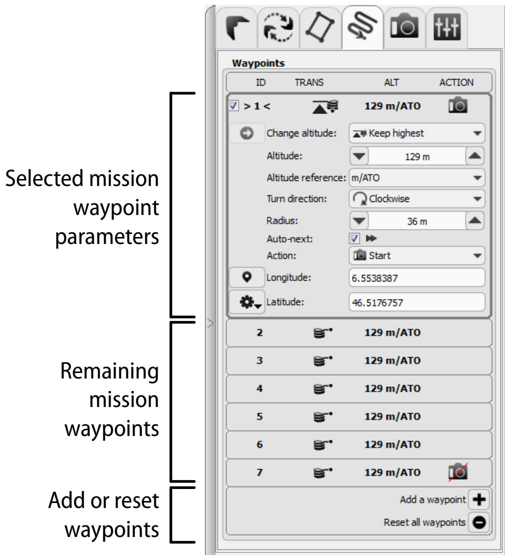
Note: The *eBee* has a minimum distance between photos that depends on the wind speed and direction. If the calculated distance that is too short will be indicated with a ⓘ icon. This is not critical for the flight, but it may reduce the longitudinal overlap of the images. Consider reducing the ground resolution (fly higher) to achieve the selected longitudinal overlap, or reduce the longitude overlap itself to remove this notice.

- **Single image coverage:** The estimated ground area covered by a single image, based on the Altitude over take-off location parameter (assuming flat terrain).

- **Number of waypoints:** The total number of waypoints to cover the mission area.
- **Elevation data sources:** The elevation data sources being used to calculate the altitudes of the waypoints. This can be either the default 'Improved SRTM' within *eMotion* or imported custom data sets, depending on which one is activated and is at the top of the list in the 'Elevation data' Preference pane.

The flight characteristics are updated automatically as you modify the mission area in the Map Area or the parameters in the first panel.

5.7 Mission Waypoints tab



The Mission Waypoints tab contains a list of all mission waypoints currently on the drone autopilot. It can be used for finer control of individual waypoints in the current mission. The list of waypoints displays the ID, Change altitude parameter, Altitude and Action related to each mission waypoint.

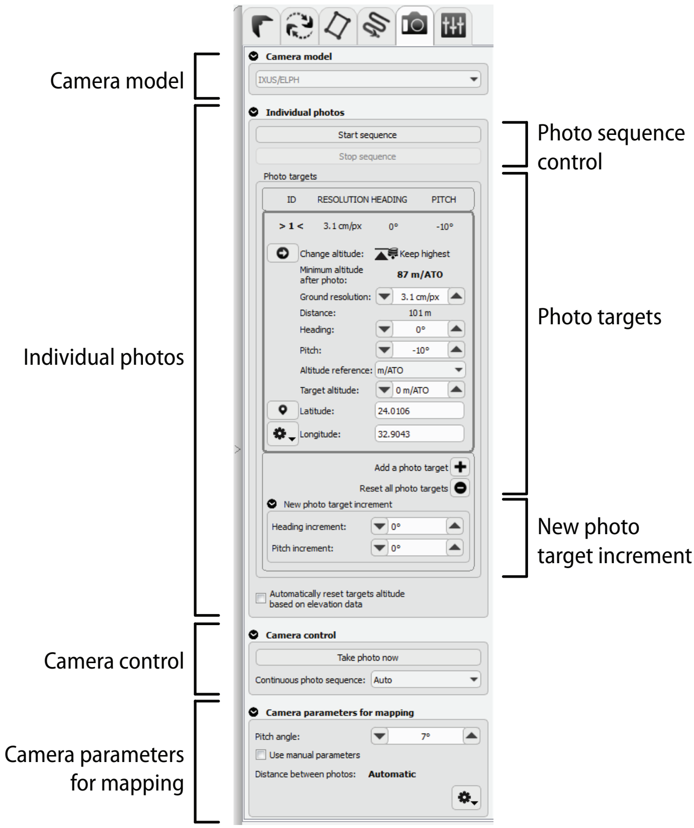
Clicking on a mission waypoint in the list or in the Map Area will expand the panel to display all the parameters related to that waypoint. These parameters are explained in detail in section 'Waypoints and their properties' on page 56. Changes made to the selected waypoint are sent to the drone immediately after selecting an item in the popup menu or upon hitting the 'Enter' key in the text fields. You can reposition the waypoint by clicking the button and then clicking at the desired position in the Map Area. You can make the selected waypoint the current waypoint by clicking the button.

Caution: Any change to the waypoints or their parameters are directly sent to the drone and may therefore impact its flight behaviour. We recommend that you take great care before modifying waypoints while the drone is in flight.

You can add new waypoints by clicking the ✚ button or by right-clicking on the Map Area and selecting 'Add waypoint here'. Clicking the ⊖ button will remove all mission waypoints from the drone.

Note: All modifications made to the waypoint list will be lost when the drone is switched off, unless the list is explicitly saved into the autopilot using the 'Save flight plan in drone' button in the Setup Phase tab (see Section 'Setup Phase tab' on page 96).

5.8 Camera tab



The camera tab is an advanced tab that can be used to precisely control the functioning of the camera. It also contains controls for taking oblique imagery. It is split into several sections: 'Camera model', 'Photo targets', 'Camera control', and 'Camera parameters for mapping'.

The 'Camera model' section is used to define the camera or payload currently connected to the *eBee*. The list contains all payloads currently supported on the *eBee*.

The 'Photo targets' section allows you to program a set of photo targets that the drone will capture with an oblique angle. You can define a photo target location, distance to the object and the heading and pitch of the photograph. The drone will then automatically calculate a flight plan in order to capture the photo with the desired parameters.

- **Photo sequence control:** Clicking the 'Start sequence' button will send the drone to the first photo target location and subsequently take images of all the photo targets currently in the 'Photo targets' list. Clicking the 'Stop sequence' will send the drone back to the Home waypoint.

- **Photo targets:** This panel contains the list of photo targets to be taken in a sequence. Clicking the ✚ button will add a new photo target. You can set the location by using the cross-hairs and clicking in the Map Area. By default, the location of a new photo target is the same as the previous one in the list. Clicking the ⊖ will remove all photo targets from the sequence list. Each photo target has the following properties:

  – **Change altitude:** The way the drone transitions to the altitude of the current photo target. This parameter is set to 'Keep highest' for all photo targets and cannot be modified.

  – **Minimum altitude after photo:** This is the calculated minimum altitude the drone will reach at the end of a photo capture manoeuvre, based on the desired ground resolution.

  – **Ground resolution:** The desired ground resolution in the centre of the image that will be pointed at the photo target position.

  – **Distance:** The calculated straight-line distance between the drone and the photo target, and the defined pitch angle. For a given distance, as the pitch angle increases, the distance to the ground decreases.

  – **Heading:** The heading angle with respect to North of the photo target.

- **Pitch:** The pitch angle with respect to vertical of the photo target.
- **Altitude reference:** The altitude reference of the photo target altitude, either ATO or AMSL.
- **Target altitude:** The altitude of the photo target.
- **Position (Coordinate):** The precise latitude and longitude of the centre of the waypoint.

- **New photo target increment:** This panel makes it easier to make a series of oblique photos of the same target with a regular angle increment in order to aid reconstruction of a 3D model. Every new Photo target that is added using the ✚ button will be placed at the same location as the previous one, but with an increment in heading and pitch angles defined by the 'Heading increment' and 'Pitch increment' parameters, respectively.

  Default value: Heading increment: 0°, Pitch increment: 0°

- **Automatically reset target altitude based on elevation data:** Check this box to use elevation data to set the absolute photo target altitudes. If this box is unchecked, photo targets are presumed to be at the same altitude as the take-off location.

  Default value: disabled

The 'Camera control' section has the following functions:

- **Take photo now:** Clicking this button will send a command to the drone to take a single picture at its current location. This command can be sent during the mission phase of a flight plan.

> **Note:** The 'Take photo now' button has no effect during Take-off, Circular landing, Linear landing and Emergency landing modes.

- **Continuous photo sequence:** These radio buttons define how the drone is taking images. When the default option 'Auto' is selected the drone will start and stop continuous photo shooting based on the actions associated with mission waypoints. Selecting 'On' overrides waypoint actions and enables continuous shooting. Conversely, selecting 'Off' will override waypoint actions and disable continuous shooting.

Default value: Auto

The 'Camera parameters for mapping' section is used to define detailed parameters related to the camera and has the following functions:

- **Pitch angle:** By default the *eBee* takes images at a default estimated pitch angle of 7° relative to the horizon. This angle provides the best compromise between image quality and flight endurance. In some cases, however, you may wish to change this value to suit your imaging needs.

  Increasing this angle to 15° provides a slightly more perspective view of a building. Note, however, that a higher pitch angle will cause the drone to slow down every time it takes an image, losing altitude and decreasing flight time and longitudinal overlap.

  Decrease the pitch angle down to 0° can capture more vertical images of the ground if mapping precision at low altitudes is of utmost importance. However, decreasing this angle will cause the drone to lose altitude with each image taken, requiring it to return to the target altitude before taking another image, once again decreasing both flight time and longitudinal overlap between images.

  Default value: 7°

- **Distance between photos:** Check the 'Use manual parameters' box to manually set the distance between photos in the direction of flight. This option may be used to override the automatic settings based on altitude and longitudinal overlap.

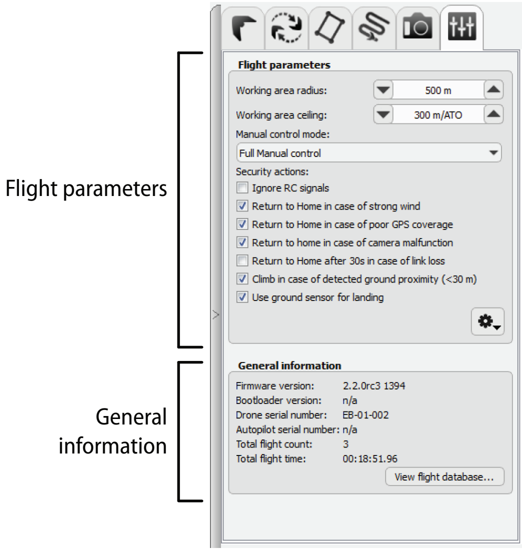
  Default value: Unchecked, Distance between photos: Automatic

Note: Depending on the altitude and the wind the desired distance between images may not always be achievable. The minimum distance with no wind and at sea level is around 35-40 m.

Clicking the ⚙ button will provide further options:

- **Save parameters as default in drone:** Saves the currently-set camera parameters to the *eBee*'s autopilot's memory.
- **Restore factory parameters:** Returns the parameters to their default values and automatically send them to the drone's autopilot.

5.9 Flight Parameters tab



The Flight Parameters tab includes some advanced functions that govern the overall behaviour of the drone while in flight. It is separated into two sections: 'Flight parameters' and 'General information'. The 'Flight parameters' section includes the following items:

- **Working area radius:** This is the radius of the working area around the take-off location. Flying outside of this area will create a warning and cause the drone to return to the Home waypoint.

  Default value: 500 m

- **Working area ceiling:** This is the maximum altitude above the take-off location at which the drone can fly. Flying above this altitude will create a warning and cause the drone to return to the Home waypoint.

  Default value: 300 m/ATO

- **Manual control mode:** Selects between Full Manual control and Assisted Manual control when the remote control is turned on[41].

  Default value: Full Manual control

- **Security actions:** The next checkboxes are used to disable certain Security actions[42].

- **Ignore RC signals:** Checking this option will result in the drone ignoring any signals coming from a remote control (RC) transmitter on the ground.

  Default value: unchecked

> **Caution:** In certain regions it is illegal to disable the remote control connection between the drone and the operator on the ground. Please check the laws in your region before enabling this option.

- **Return to Home in case of strong wind:** Checking this box will enable the Security action related to high wind strength (return to Home waypoint). Un-checking this box will disable the Security action, however the drone will continue to estimate the wind strength and direction and the In-flight warning will continue to appear.

  Default value: checked

> **Caution:** The *eBee* is not designed to fly in winds above 12 m/s. Flying in high-wind conditions increases the chances of a crash that may damage the drone and is done at your own risk.

- **Return to Home in case of poor GPS coverage:** Checking this box will enable the Security action (return to Home waypoint) related to poor GPS signal coverage. Un-checking this box will disable the Security action, however the In-flight warning will continue to appear.

  Default value: checked

[41] see section ‘Manual control of the *eBee*’ on page 120 for more information

[42] see section ‘In-flight warnings’ on page 143 for more information on Security actions related to specific In-flight warnings

- **Return to Home in case of camera malfunction:** Checking this box will enable the Security action (return to Home waypoint) related to a camera malfunction. Un-checking this box will disable the Security action, however the In-flight warning will continue to appear.

  Default value: checked

- **Return to Home after 30s in case of link loss:** Checking this box will enable In-flight warnings and Security actions related to a loss of the communications uplink between *eMotion* and the drone (return to Home after 30 s of link loss). Un-checking this box disables both the In-flight warning and the Security action and will result in the drone continuing on its flight path even if it does not re-connect with *eMotion*.

  Default value: unchecked

- **Climb in case of detected ground proximity (<30 m):** The *eBee* features a ground sensor that continuously checks the presence of the ground. If this box is checked and the ground sensor detects a height above the ground of less than 30 m, the drone will climb to a safe height of 60 m before continuing the mission.

  Default value: checked

- **Use ground sensor for landing:** The *eBee* uses its ground sensor together with its estimate of the wind speed during its landing manoeuvre to calculate the ideal moment to perform a final brake and enter deep stall. If this box is unchecked the drone will ignore the ground sensor during its approach and will assume that the landing location is precisely at the same altitude as indicated in *eMotion*. This will result in a landing precision that is decreased and dependent on the strength of the wind.

  Default value: checked

> **Note:** Un-checking this feature is only recommended when performing a linear landing in uneven terrain where the height measured by the ground sensor during approach would imply an undesired approach slope correction.

Clicking the 'More' list will provide further options:

- **Save parameters as default in drone:** Saves the currently-set flight parameters to the *eBee*'s autopilot's memory.
- **Restore factory parameters:** Returns the flight parameters to their default values and automatically sends them to the drone's autopilot.

The 'General information' section displays information specific to your *eBee*. This includes the current firmware and bootloader versions loaded into the autopilot, the serial numbers of the airframe and the autopilot, the total number of flights performed by drone and the total time spent in the air.

Note: The flight counter is incremented every time the take-off procedure is initiated by shaking the *eBee* back and forth 3 times, even if take-off is subsequently aborted.

Clicking 'View flight database...' will bring up a window that presents a summary of all the flights performed by the drone using this computer.

6 Manual control of the *eBee*

Goal of this section: This section describes how to use the remote control to manually control the drone, either in Full Manual or Assisted Manual modes.

Caution: Operation of the *eBee* in either Assisted or Full Manual mode requires the skills of an experienced RC aircraft pilot. SenseFly Ltd cannot be held responsible for damage caused by manual control of the drone. Any damaged caused by manual control of the drone will void the warranty.

6.1 Enabling manual control

By default, the *eBee* flies autonomously and does not need the provided remote control to be operated. However, by using the remote control, it is possible to override the drone's autopilot by switching to one of two available manual modes: Full Manual or Assisted Manual. In Full Manual mode the sticks of the remote control directly set the motor power and the angle of the ailerons of the drone. In Assisted Manual mode the sticks of the remote control are used to set the speed, turn rate and climb or sink rate.

Note: Ensure that the 'Ignore RC signals' option in the Flight Parameters tab is unchecked[43], otherwise the drone will ignore the commands from the remote control and remain in autonomous operation mode.

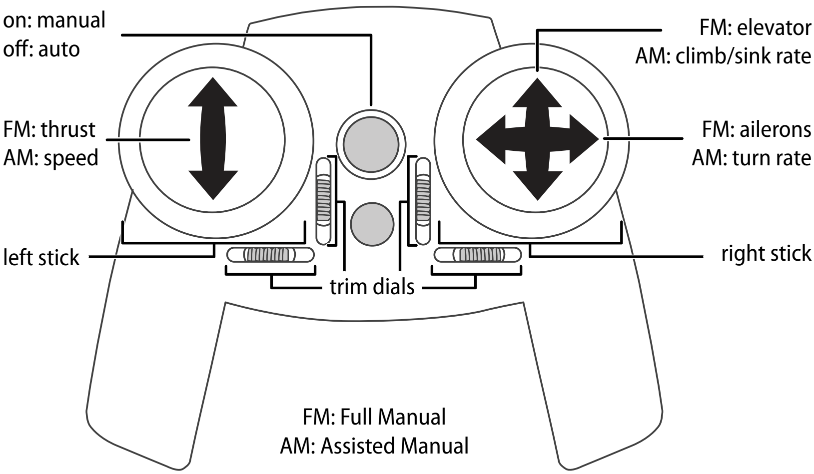
Turning on the remote control will cause the drone to change to either Assisted Manual or Full Manual mode, depending on the 'Enable assisted manual control' setting in the Flight Parameters tab[44] of *eMotion*. Turning off the remote control will cause the drone to return to the last autonomous operation mode it was in

[44] see section 'Flight Parameters tab' on page 116 for more details on this setting

before Manual mode was enabled.

Caution: We recommend that you only turn the remote control on when it is held by a pilot ready to take manual control of the drone, and that you turn it off when putting the remote control down.

Manual control of the *eBee* can be achieved at any time if the drone is within range of the remote[45].



Caution: The remote control is preconfigured for use with the *eBee*. In particular, the trim dials, used to finely adjust the position of the drone's ailerons, are calibrated to ensure optimal flight characteristics and should not be adjusted. Changing the remote control's configuration, including the trim settings, may compromise the flight characteristics of the drone. If, for any reason, the preset settings should be lost, contact your *eBee* reseller.

[45] see section 'Drone specifications' on page 163 for the range of the remote control

6.2 Pre-flight testing of the remote control

If you plan to use the remote control during a flight we recommend that you first test it on the ground. Ensure that the *eBee* is set to Full Manual mode[46] and follow these steps:

1. Check that the left stick on the remote control is in the low position to prevent the propeller from spinning.

2. Turn on the remote control.

3. Turn on the *eBee* by connecting the battery. Once the drone detects the signal from the remote control it will change to one of the manual modes.

Caution: The motor of the *eBee* is now controlled by the remote control and will begin spinning if the left stick is pushed up. Always keep the area around the propeller clear of obstacles and body parts to prevent injury.

4. Move the right stick on the remote control to verify proper reception by the drone and correct servo direction.

5. Turn off the remote control for take-off.

Note: If the remote control is switched on while it is performing pre-flight checks the ailerons will not move when the checks are completed and the GPS signals are acquired.

For more information on using the remote control, refer to the original user manual available in the downloads section of the senseFly Ltd website[47].

[46] see section 'Enabling manual control' on page 120
[47] http://www.sensefly.com/support/download

6.3 Full Manual mode

Full Manual mode allows you to have direct control over the *eBee*'s actuators, overriding all control from the on-board autopilot. The left stick controls the thrust. For safety reasons, the left stick should remain at the lowest position at all times, except during flight.

The right stick controls the elevator and the ailerons in the same way as a typical aircraft control stick (or the joystick with a flight simulator). Note that the drone uses its ailerons to fulfil the functions of both ailerons and elevator in a classical airplane. When the ailerons function in the same direction, they act as the elevator. When the function in opposite motion, they act as ailerons.

We recommend you perform a standard take-off procedure in autonomous mode and only switch to Full Manual mode when the drone is in the air. If you wish to take-off in Full Manual mode, however, you must use the following steps:

1. Prepare the drone for flight as described in section 'Preparing the *eBee* for flight' on page 28 while keeping the remote control turned off and the left stick at its lowest position.

2. Turn on the remote control. You now have manual control over the main thrust motor and the servo-motors.

> **Caution:** The motor of the drone is now controlled by the remote control and will begin spinning if the left stick is pushed up. Always keep the area around the propeller clear of obstacles and body parts to prevent injury.

3. Firmly grasp the *eBee* horizontally with level wings using both hands, one hand on the front of each wing. Shake the drone back and forth 3 times longitudinally (within approx. 3 seconds). The status LED will pulse blue while the drone's autopilot performs a start-up sequence. As the motor is now controlled by the remote control, it will not begin spinning. Once the sequence is complete, the status LED will turn green (solid or blinking, depending on the angle at which you are holding the drone).

> **Caution:** Taking off without performing the motor power-up sequence will result in the *eBee* staying in Idle mode during the entire flight and is not recommended. The drone will no longer be able to enter automatic mode while in flight and must land using manual control.

4. The *eBee* is now ready for manual take-off. Orient yourself into the wind, and confirm that the take-off direction in front of you is free of obstacles. We recommend that you take off at full power and into the wind by setting the left stick to its highest position and releasing the drone when the status LED is solid green.

6.4 Assisted Manual mode

In Assisted Manual mode the sticks on the remote control set the desired speed, turn rate and climb or sink rate. These commands are then transferred to control signals for the individual actuators by the autopilot based on feedback from its sensors. This control scheme simplifies control of the *eBee*.

> **Caution:** Though it may be easier to fly the *eBee* manually when in Assisted Manual mode it remains dangerous and should be used with care. In particular, the pilot must still be aware of obstacles in the area, the altitude of the ground, the inversion of control commands when the drone is flying towards the pilot and the distance between the drone and the pilot. We recommend that you only try Assisted Manual mode when in a large open space with no obstacles and low wind.

In this mode the left stick is used to set the desired speed of the *eBee*. Setting the left stick between 10% and 100% sets a desired speed between 10.5 and 20 m/s. Setting the stick below 10% turns off the motor, allowing the drone to slowly descend in a glide. The drone may even engage reverse thrust to limit its speed during descent.

The right stick is used to set the direction of flight of the *eBee*. Moving the stick left or right will set a left or right roll angle of up to 45°/s, respectively. Moving the stick down will set a climb rate of up to 3.5 m/s. Moving the stick up will set a sink rate of up to 3.5 m/s. Releasing the right stick at any point will return the drone to a straight flight path at a constant altitude.

It is not possible to take-off in Assisted Manual mode. You may only switch to Assisted Manual mode after completing the standard take-off procedure[48].

Caution: There is no clear indication during the take-off procedure that the *eBee* will change to Assisted Manual mode rather than Circle Start Waypoint mode after the take-off transition altitude is reached[49]. For this reason we recommend that you do not turn on the remote control unless you are ready to manually control the drone right after take-off.

To perform a manual landing we recommend the following procedure:

1. The drone should always perform a linear landings into the wind. Face the downwind direction and confirm that there are no obstacles in an area of at least 100 m downwind and a width of 20 m in either direction from downwind.
2. Set the drone to an altitude of around 50 m from the landing altitude by moving the right stick up or down.
3. Fly downwind until the drone is around 100 m away from the landing location.
4. Turn the drone upwind and towards the landing location by moving the right stick left or right.
5. Set the speed to a low value by moving the left stick down to around 25% of its maximum value.
6. Bring the drone closer to the ground by controlling the sink rate with the right stick. Keep the drone descending until it is around 5-10 m from the ground.

[48] as described in section 'Take-off' on page 41

7. Once the drone is around 5-10 m from the landing location, cut motor power using the left stick and allow the drone to glide down to the ground.

Part III

Maintenance, Repair and Troubleshooting

7 Maintenance and repair of the *eBee*

Goal of this section: This section describes how to update accompanying software and on-board firmware, keep your drone in good working condition and perform small repairs such as cracks in the airframe.

7.1 Updating the *eBee* software

Occasionally, senseFly Ltd releases a software upgrade for the *eBee* to provide additional features to our users or to correct potential issues. As of version 2.0.2, *eMotion* will check for new versions during start-up[50] and will display a message with update instructions if a new version is available. We recommend, however, that you check the senseFly Ltd website regularly for updates to ensure you have the latest version of the software.

Caution: We are constantly working to improve the performance of our products and we are dedicated to providing our customers with the newest software as soon as it becomes available. Since the highest level of flight safety can only be achieved with the latest software release, senseFly Ltd can only offer warranty service for products that have been properly updated.

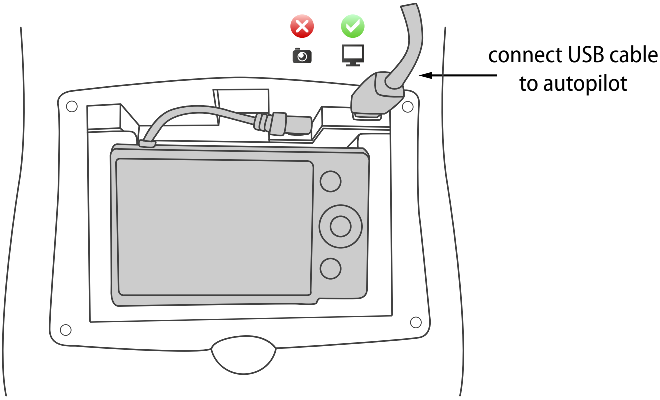
To upgrade *eMotion* or *Postflight Terra 3D* to the latest version, download the installer from the senseFly Ltd website and follow the standard install procedure (see section 'Installing *eMotion*, *Postflight Terra 3D*, and the ground modem drivers' on page 18). It is not necessary to uninstall previous version of *eMotion* before installing the new one.

Every version of *eMotion* is packaged with an accompanying firmware revision which must be installed on the drone before it can be used. To upgrade the firmware of the *eBee* follow these steps:

[50] provided that there is an internet connection

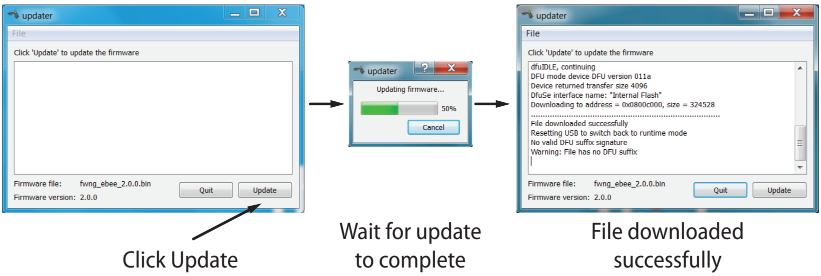
1. Connect the battery to the drone.

2. Connect the USB cable between the computer on which you installed *eMotion* and the autopilot of the *eBee* as shown in the figure. The connector is beside the camera connector and is marked with a 🖥 icon. The status LED will turn white as soon as you connect the cable.



3. Click the icon and select ‘Updater *eBee*...’[51].

4. Click ‘Update’ to begin the updating process. Wait until the process is complete, which is indicated by the text ‘File downloaded successfully’.



Note: You may need to install a driver the first time you upgrade your firmware. The driver will be installed automatically but may cause the firmware update to fail. If this is the case, retry the update process by clicking ‘Update’ again, without disconnecting the battery or cable from the drone or closing the ‘Updater *eBee*’ program.

[51] also available in the ‘eMotion’ folder in the Start menu in Windows

5. Disconnect the USB cable and the battery.

It is important that both the drone and *eMotion* have the same software version for them to work properly together. Make sure that you keep both up-to-date. To check which version of *eMotion* you have installed, use the 'About eMotion...' item in the 'Window' menu. The *eBee* firmware version can be seen in the Flight Parameters tab once connected (see section 'Flight Parameters tab' on page 116).

7.2 Cleaning and storage

Use a damp cloth to wipe off dirt from the *eBee*. In order to avoid structural deformation of the wing, it is recommended to store the drone either in its transport case or on a flat surface at room temperature.

> **Caution:** Never bring the *eBee* into direct contact with water, as this may damage the electronics within the drone airframe.

7.3 Full airframe and sensor inspection

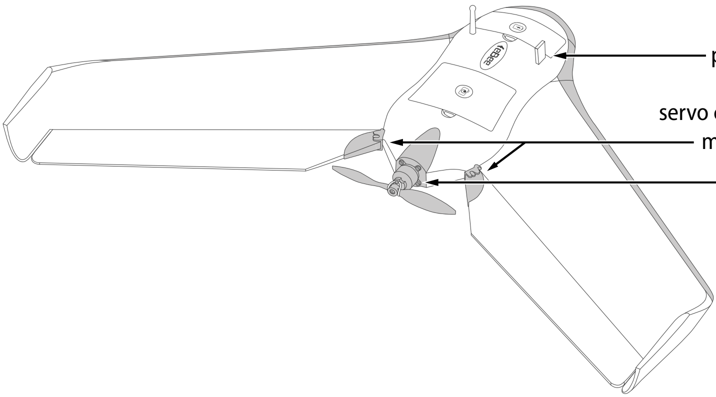
Beyond the general airframe inspection that is performed before every flight, we recommend that you perform a full airframe and sensor inspection regularly to keep your drone in good operating condition.

> **Caution:** The autopilot, sensors and actuators within the Central Body of the *eBee* are specially calibrated and should only be modified by your *eBee* reseller. Opening the Central Body of the *eBee* will void the warranty.

The inspection includes the following checks:

Check 1: Motor and Servos

The *eBee* uses a brushless DC motor to turn its propeller and generate thrust. The servos are the two actuators connected through a servo connection mechanism to both ailerons. Damaged actuators can prevent the drone from flying correctly and thus it is important to ensure their proper functioning.



To check the actuators, follow these steps:

1. The motor must be clean and spin smoothly without friction to function correctly. Ensure that there is no sand or other obstructions within the motor. If there is something blocking the motor from spinning smoothly blow some air through the motor to dislodge the obstruction.

2. Make sure the left stick of the remote control is all the way down to keep the motor off[52]. Place the *eBee* at the edge of a flat surface and keep the area around the propeller clear.

> **Caution:** The propeller on the *eBee* spins at high speeds and can cause deep cuts if it comes into contact with exposed skin. Always wear gloves and glasses when any work is done requiring the battery to be connected to the drone.

[52] see section 'Manual control of the *eBee*' on page 120 for details on using the remote control

3. Switch the drone on by connecting the battery.
4. Connect to *eMotion*. Ensure that 'Manual control mode' is set to 'Full Manual control' and that the 'Ignore RC signals' setting is not checked[53].
5. Switch the remote control on.
6. Move the right stick on the remote control and check the aileron motion. The ailerons must smoothly and quickly follow the stick. When the stick is not moved, the ailerons must stay still. When travelling from one end to the other, fast or slow, the ailerons must smoothly follow without twitching.
7. Hold down the drone against the flat surface with one hand to prevent it from moving. Gently move the left stick on the remote control to spin up the motor and propeller. The motor should run smoothly without making excessive noise.
8. When done, switch the remote control off.

In case of doubt, take a short video and follow the instructions in section 'Reporting a problem with your *eBee*' on page 160 for advice.

Check 2: Inertial sensors

The inertial sensors are used by the autopilot to compute the attitude (i.e. its orientation in space) of the drone. The attitude is displayed by the artificial horizon in the Flight Monitoring tab of *eMotion*. To check the inertial sensors, follow these steps:

1. Switch the *eBee* on by connecting the battery and connect to *eMotion*.
2. Put the drone on a flat surface (typically an office floor) and check that the artificial horizon is level.
3. Take the drone with your hand and put it in different orientation. Make sure that the artificial horizon displays the corresponding orientation.

[53] see section 'Flight Parameters tab' on page 116 for more details on these settings

The artificial horizon should follow smoothly the motion of the *eBee* and it should not drift when the drone is not moving. In case of doubt, take a short video and follow the instructions in section 'Reporting a problem with your *eBee*' on page 160 for advice.

Check 3: Barometric pressure sensor

The barometric pressure sensor is used to measure the altitude from the take-off location. To check it, follow these steps:

1. Switch the *eBee* on by connecting the battery and connect to *eMotion*.
2. Move the drone from your feet to above your head (about 2 m altitude variation).
3. Check the altitude on the vertical bar right of the artificial horizon or in the Status Panel next to the drone icon on the map).

The displayed altitude should follow the drone motion, i.e. if the drone is raised by 2 m, the altitude reading should increase by about 2 m. When the drone is not moving, the altitude reading may slowly drift by up to ±10 m.

Check 4: Air speed sensor

The air speed sensor is connected to the pitot probe by a pair of tubes. To check it, follow these steps:

1. Visually check the pitot probe. Make sure that it is properly fixed to the airframe and that both tubes are properly attached and not damaged). The holes in the probe must be clear and free of dirt or other small obstructions.
2. Switch the drone on by connecting the battery and connect to *eMotion*.
3. Gently blow into the front opening of the pitot tube from a distance of around 5 cm. The airflow direction should match the natural flow experienced in flight.
4. Check the air speed displayed on the vertical bar left of the artificial horizon.

At rest, the displayed air speed should be close to zero (it may drift up to about 2 m/s). When blowing in the pitot probe there should be an air speed indicated in the 'Flight Monitoring' tab of *eMotion* that should easily reach values above 8 m/s.

Check 5: Ground sensor

The ground sensor is composed of a high-speed optical sensor and a lens assembly. The lens assembly must be clean and unobstructed for the sensor to work correctly.

7.4 Repairing the *eBee* airframe

Small repairs of cracks in the airframe can be done using contact glue such as UHU® POR glue. Take care to use only contact glues that are specifically designed for Expanded Polypropylene (EPP). If you have doubts about the extent of the damage, always contact your *eBee* reseller to verify if the damage can be easily repaired by yourself or if you need to send your drone in for repair to.

⚠ **Caution:** Never fly your *eBee* if it has cracks in the airframe.

7.5 Proper battery care

Proper care of your *eBee*'s battery is important to prevent damage to your drone and to maximize flight time. With a fully charged battery, the drone will fly for about 45 minutes. Frequent altitude changes, presence of wind, use of old batteries and/or frequent photo acquisition may significantly reduce the flight endurance. Batteries perform better at medium or high air temperature and it is normal to observe shorter flight times in cold weather.

The *eBee* is powered by a Lithium Polymer (LiPo) battery composed of three cells connected in series. A single LiPo cell can have a range between 3 V (empty) and 4.2 V (full) in its normal operating range. This results in an empty battery voltage of 9 V and a fully-charged battery voltage of 12.6 V. A well-balanced and healthy battery should have all three cells at a voltage very close to each other and between 3 and 4.2 V.

The charger delivered with your drone automatically checks for healthy voltages of all three cells and only attempts charging if they are within limits. If the cells are out of balance, the charger will take care of balancing them. If the charger detects a voltage outside of the allowable range it will indicate an error either by flashing the status LED red, or by the LED staying off. This means that the battery is over-discharged and should be discarded.

Caution: The batteries delivered with your drone are designed to be charged with the charger delivered with your *eBee*. senseFly Ltd cannot be held responsible for any consequences resulting from using a different charger. In particular, using a charger improperly configured or designed for other types of batteries may lead the battery pack to be permanently damaged or to catch on fire.

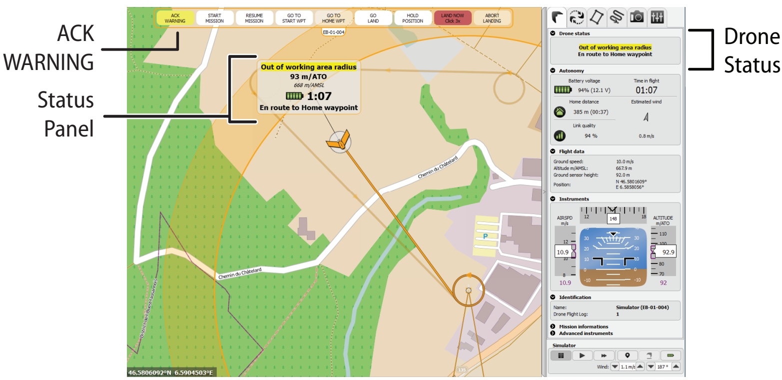
LiPo batteries do not exhibit any memory effect. We recommend that you always fully charge them after use even when they are only partially discharged. When not using the battery store it in the carrying case provided with your drone. Avoid leaving the battery in direct sunlight.

Caution: If any of the cells of your battery pack are overly discharged the battery may be irreversibly damaged and becomes dangerous to charge. If the battery grows beyond its regular size or if any of the cells are punctured it is also likely damaged and should be discarded. Forcefully charging a damaged battery may lead it to take fire. **Do not attempt to charge an over-discharged or damaged battery. Dispose of the battery safely.**

8 Troubleshooting

Goal of this section: This section describes the various error messages that may be displayed during start-up or while the *eBee* is in flight and provides some tips on solving the simplest problems. In the case of a more serious problem, this section describes how to prepare the required data on the problem and report it to your *eBee* reseller.

The *eBee* can generate several types of error messages depending on its flight mode. Some of these messages are minor and simply need to be acknowledged through *eMotion*, whereas others require more specific action from the user. As long as the drone is connected to *eMotion*, error messages will appear in the Status Panel in the Map Area, as well as in the Drone Status panel of the Flight Monitoring tab.



Error messages are divided into four categories: Pre-flight errors, Take-off vetoes, In-flight warnings and Critical failures.

8.1 Pre-flight errors

As soon as the battery is connected to the drone it performs a series of pre-flight checks to thoroughly test its on-board systems. The start-up process is described in detail in section 'Preparing the *eBee* for flight' on page 28. If an error occurs during these pre-flight checks the status LED will blink red and a description of the error will appear in *eMotion*. In most cases, re-connecting the battery will suffice to remove the error. Table 3 presents all the Pre-flight errors that may occur and possible actions to fix the error. If the problem is related to the firmware in the on-board autopilot, try re-loading the firmware using instructions in section 'Updating the *eBee* software' on page 128. If an error persists after reconnecting the battery several times we recommend you report the problem by following the instructions in section 'Reporting a problem with your *eBee*' on page 160.

Table 3: Pre-flight errors

***eMotion* text**	**Description and User action**
Incorrect firmware detected	There is an error with the current version of the firmware in the *eBee*'s autopilot. **User action:** Re-load the correct firmware[54].
Battery too low for take-off	The battery level is too low to perform a take-off. **User action:** Re-connect a fully-charged battery.
Drone flight log memory full	The memory card used to store the Drone flight log is full. **User action:** Empty the memory card by following the instructions in section 'Importing images and flight data' on page 48.

[54] see section 'Updating the *eBee* software' on page 128

Pitot malfunction	A high airspeed was detected while on the ground. **User action:** Be sure to protect the drone from the wind and re-connect the battery. If the problem persists, perform Check 4 in section 'Full airframe and sensor inspection' on page 131. If this does not solve the problem contact your *eBee* reseller.
High current	A too high current was detected, which may be caused by an internal problem. **User action:** Re-connect the battery. If the problem occurs twice, contact your *eBee* reseller.
Magnetometer malfunction	There is an error with the drone's magnetic field sensor. **User action:** Re-connect the battery. If the problem persists, contact your *eBee* reseller.
EEPROM malfunction	There is an error with the memory chip of the drone's autopilot. **User action:** Re-connect the battery. If the problem persists, contact your *eBee* reseller.
Barometer malfunction	There is an error with the drone's barometer. **User action:** Be sure to place the drone on a flat surface, reconnect the battery and do not move the drone until pre-flight checks are complete. If the problem persists, perform Check 3 in section 'Full airframe and sensor inspection' on page 131. If this does not solve the problem contact your *eBee* reseller.

De-calibrated INS or Attitude malfunction	The orientation sensors were not calibrated correctly. **User action:** Be sure to place the drone on a flat surface, reconnect the battery and do not move the drone until pre-flight checks are complete. If the problem persists, perform Check 2 in section 'Full airframe and sensor inspection' on page 131. If this does not solve the problem contact your *eBee* reseller.
Ground sensor malfunction	There is an error with the drone's ground sensor. **User action:** Ensure that the ground sensor on the bottom of the drone is clear of debris and is not damaged, then re-connect the battery. If the problem persists, perform Check 4 in section 'Full airframe and sensor inspection' on page 131. If this does not solve the problem contact your *eBee* reseller.
Invalid flight controller gains	There is an error with the firmware in the drone's autopilot. **User action:** Re-connect the battery. If the problem persists, contact your *eBee* reseller.

8.2 Take-off vetoes

After successfully completing pre-flight checks the status LED becomes a solid green to indicate that the drone is ready for take-off. At this point the *eBee* continues to monitor its sensors and battery level. If at any point the drone detects a condition that prevents it from beginning the automatic take-off procedure it displays a Take-off veto in *eMotion* and the status LED changes to a blue pulse. Once the Take-off veto is cleared the status LED returns to a solid green colour to indicate that the drone is ready for take-off.

Table 4 on the following page presents all the Take-off vetoes that may occur and possible actions to remove the veto. If a veto persists after performing the suggested action, we recommend you report the problem by following the instructions in section 'Reporting a problem with your *eBee*' on page 160.

Table 4: Take-off vetos

***eMotion* text**	**Description and User action**
Drone not horizontal (roll or pitch)	The *eBee* must be held horizontally with level wings to initiate take-off. **User action:** Hold the drone horizontally.
Motor is blocked	Excessive current was detected from the motor. **User action:** Check that the propeller is mounted correctly and that the motor is freely turning and try the take-off procedure again.
Battery too low for take-off	The drone requires a fully-charged battery for the take-off procedure. **User action:** Change the battery.
Wings not detected	The drone's wings are not attached correctly or the wing struts are damaged. **User action:** Ensure that the wings are fully inserted into the main body and that the wing struts are not damaged, as described in section 'Preparing the *eBee* for flight' on page 28.
USB cable detected	The *eBee* has detected a USB cable connected to the drone's autopilot. **User action:** Remove the USB cable before take-off.

8.3 In-flight warnings

While it is in flight the *eBee* can generate two types of errors: warnings and failures. In-flight warnings occur when there is an event that requires user attention but does not compromise the drone's ability to continue flying.

When an In-flight warning is activated the warning will appear in yellow in *eMotion* and cause the 'WARNING' button in the Control Bar to change to 'ACK WARNING', turn yellow and activate. The drone will then perform a Security action depending on the active In-flight warning. Some In-flight warnings simply need to be acknowledged by clicking on the 'ACK WARNING' button. Others require action by the user before the warning is cleared and the drone can return to full functionality. The full list of possible In-flight warnings and required User actions can be found in table 5 on the next page.

The In-flight warnings marked with a * can have their Security actions disabled, whereas the In-flight warnings marked with a ** can have both the warning and the Security action disabled. See section 'Flight Parameters tab' on page 116 for instructions on disabling warnings and Security actions.

> **Caution:** The Security action for most In-flight warnings is to fly back to the Home waypoint (if Circular landing is selected) or the Home waypoint (if Linear landing is selected). As soon as this Security action is triggered the drone will fly in the direction of the selected landing waypoint while climbing or descending to the waypoint's altitude. It is thus important to ensure that there are no obstacles above the altitude of the selected landing waypoint within the entire flight area to prevent a collision resulting from this Security action.

Table 5: In-flight warnings

***eMotion* text**	**Description and Security action**
Failure occurred: (failure description)	This warning ensures that the user is aware that a Critical failure has occurred even if it is no longer active[55]. **Security action:** The *eBee* flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to 'Highest'). **User action:** Ensure that the failure condition is no longer present before acknowledging the error and continuing normal operation.
Low battery	The remaining battery level is too low to continue the flight plan. **Security action:** The *eBee* flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to 'Highest') and automatically initiates an expedited landing procedure (without performing a full wind estimation) once it reaches the waypoint. **User action:** Land as soon as possible. Re-charge the drone battery before performing another flight.

[55] see section 'Critical failures' on page 155 for a description of possible Critical failures

Drone flight log malfunction	There is an error saving data to the on-board memory card which will prevent the images from being geo-tagged. Images may still be geo-tagged using the eMotion Flight Log file but may be less precise. **Security action:** The drone continues normal flight. **User action:** Land as soon as possible. Once on the ground, connect to the on-board memory card as described in section 'Importing images and flight data' on page 48 and re-format the memory card.
Flight controller malfunction	The flight controller has encountered an unexpected state, such as an incorrect waypoint type. **Security action:** The drone flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to 'Highest'). **User action:** Land as soon as possible and re-start the drone. If the problem persists, contact your *eBee* reseller.
Camera sync malfunction	There is a problem with the wiring of the on-board camera. **Security action:** If required parameter set in the Flight Parameters tab, the drone flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to 'Highest'). Otherwise it continues its mission without taking further images. **User action:** Land as soon as possible and re-start the drone. Reset the camera settings as described in section 'Resetting default camera settings' on page 158.

Camera power malfunction	The camera is no longer responding, most likely because it is no longer powered. **Security action:** If required parameter set in the Flight Parameters tab, the drone flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to 'Highest'). Otherwise it continues its mission without taking further images. **User action:** Land as soon as possible. Check the cable connection between the camera and the drone and charge all the batteries before performing another flight.
Barometer malfunction	The barometer used to sense the current altitude is malfunctioning. **Security action:** The drone flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to 'Highest') using altitude calculated from GPS signals only, potentially causing large fluctuations in altitude. **User action:** Land as soon as possible and perform Check 3 in section 'Full airframe and sensor inspection' on page 131.

Motor malfunction	The motor is drawing too little or too much current. This may be caused by damaged wires or connectors leading to the motor or by sand or other debris within the motor. **Security action:** The drone attempts to re-start the motor. If the first attempt fails a Failure: Motor malfunction Critical failure is announced[56]. **User action:** Land as soon as possible and perform Check 1 in section 'Full airframe and sensor inspection' on page 131.
Battery malfunction	The sensor used to measure the battery voltage and current is registering invalid values, indicating that the sensor is de-calibrated or damaged. **Security action:** The drone flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to 'Highest'). **User action:** Land as soon as possible and re-start the drone. If the problem persists, contact your *eBee* reseller.

[56] see section 'Critical failures' on page 155

Airspeed malfunction	The differential pressure sensor used to measure airspeed is registering invalid values. This may be due to a damaged sensor or to a clogged pitot probe. **Security action:** The drone flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to 'Highest') at a constant thrust value instead of controlled speed, potentially resulting in low or high flight speeds depending on wind. Once it reaches the Home waypoint it initiates a landing procedure. **User action:** Try to provide a maximum amount of approach sectors to ensure that the drone can land against the direction of the wind. Land as soon as possible and perform Check 4 in section 'Full airframe and sensor inspection' on page 131.
Low airspeed	Detected airspeed is unusually low or close to zero. This may be due to a collision with the ground or a clogged airspeed sensor. **Security action:** The drone shuts off its motor and tries to continue its mission. **User action:** If the warning is due to a clogged airspeed sensor it may be due to moisture in the air. Try commanding the drone to descend closer to the ground and out of any cloud cover.

Overspeed	Detected airspeed is unusually high, possibly due to a loss of control. **Security action:** The drone applies a 50% reverse thrust to try to slow down. **User action:** Keep track of the drone's position in case it is unable to slow back down to a regular airspeed.
Ground sensor malfunction	The ground sensor used to detect the proximity of the ground is malfunctioning. **Security action:** The drone continues normal flight. **User action:** Land as soon as possible and perform Check 5 in section 'Full airframe and sensor inspection' on page 131.
Wings detection malfunction	The sensor used to detect the presence of the wings malfunctioning. **Security action:** The drone continues normal flight. **User action:** Land as soon as possible and inspect the wing struts as described in section 'Preparing the *eBee* for flight' on page 28.

Temperature out of working levels	The temperature sensor on the drone is registering internal temperatures of less than -50° C or more than 90° C. This may occur in extremely hot or cold environments or if the on-board autopilot is damaged. **Security action:** The drone flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to 'Highest'). **User action:** Land as soon as possible. If the outside temperature is above 35°C or below -10°C, disconnect the battery and wait until the temperature changes to within these limits.
Above working area ceiling	The drone has passed the vertical boundary of the working area, defined by the working area ceiling. This may occur if waypoint altitudes are set close to or outside the working area or due to strong wind. **Security action:** The drone flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to 'Highest'). It also turns off its motor as long as it remains above the working area ceiling. **User action:** Limit the altitude of all waypoints to less than the working area ceiling.

Out of working area radius	The drone has passed the lateral boundary of the working area, defined by the working area radius. This may occur if waypoints are set close to or outside of the working area or due to strong wind. **Security action:** The drone flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to 'Highest'). **User action:** Limit the planned flight path within the working area boundaries.
Far outside of working area	The drone has passed far outside of the working area. This may be caused by very high winds or due to mechanical failure. **Security action:** The drone tries to orient itself in the direction of the Home waypoint and begins descending immediately until it lands on the ground or returns within the working area. **User action:** Keep track of the location of the drone during landing. If the drone lands outside of view follow the instructions in section 'Losing and locating your *eBee* in the field' on page 159.

Poor GPS coverage*	GPS signal coverage is low. This may be due to mountains or tall buildings blocking satellite signals. If coverage degrades any more a Critical failure will be activated and an emergency landing will be initiated[57]. **Security action (if enabled):** The drone flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to 'Highest'). **User action:** If this occurs once or twice, click 'ACK WARNING' and continue normal flight. If this warning appears more often, land as soon as possible and wait for better conditions for satellite signal reception. Alternatively, move away from objects that may disturb satellite signals such as mountains or cellular antennas.
Data uplink lost** (if enabled)	This warning occurs if the *eBee* does not receive any data from *eMotion* for more than 30 s. This can be due to a large distance between drone and ground station, a problem with the USB ground modem, antenna positioning or interference. . **Security action (if enabled):** The drone flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to Highest). **User action:** Try to improve radio signal quality by following the instructions in section 'Improving radio signal communication' on page 158.

[57] see section 'Critical failures' on page 155

Ground proximity detected** (if enabled)	The ground sensor on the drone has detected a ground height above the ground of less than 30 m during normal flight. **Note: this feature should not be depended on for avoiding obstacles, as the ground sensor may fail to detect obstacles in certain environmental conditions[58].** **Security action (if enabled):** The drone circles the current position while climbing to an altitude of 60 m above the detected ground height. Once this altitude is reached the drone continues towards the next waypoint but sets the waypoint's target altitude at 60 m above the last detected ground height. **User action:** Ensure that there are no obstacles such as hills or buildings higher than the waypoints of your flight plan.
Ground proximity not detected landing precision decreased**	The ground sensor on the *eBee* was unable to detect the proximity of the ground during a Linear landing procedure. This may be due to an obstruction in the sensor, low ambient light or low contrast in the environment[59]. **Security action:** The drone continues the Linear landing procedure but will initiate its final brake at an estimated altitude of 20 m instead of 3 m (assuming the Linear landing location is at the same altitude at the Take-off location), resulting in decreased precision in the landing location. **User action:** Be ready for the drone to overshoot its planning Linear landing location by preparing a larger obstacle-free zone around the location.

[58] see section 'Linear landing' on page 70
[59] see section 'Linear landing' on page 70

Back wind, landing precision decreased*** (in blue)	There are no approach sectors available against the direction of the wind. The *eBee* has calculated a Linear landing approach direction in the direction of the wind. **Security action:** The *eBee* continues normal flight. **User action:** Add a new approach sector against the direction of the wind, if possible, abort the landing and try landing again. If not, be ready for the *eBee* to overshoot its planning Linear landing location by preparing a larger obstacle-free zone around the location.
Strong wind*	The wind is too strong for the *eBee* to navigate safely. **Security action (if enabled):** The *eBee* flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to 'Highest'). **User action:** Land as soon as possible and wait for better flight conditions.
Cannot maintain altitude	The *eBee* cannot maintain the altitude that is commanded by the flight controller. This may be due to a damaged motor, airframe or ailerons or a strong vertical wind. **Security action:** The drone continues normal flight. **User action:** If the condition persists during a flight, land and wait for the wind to decrease, as explained in section 'Weather check' on page 27. If the problem occurs in low-wing conditions perform Check 2 in section 'Full airframe and sensor inspection' on page 131.

Pitch or Roll instability	The orientation sensors on the *eBee* detected unusually high pitch or roll values even after performing stabilization. This may be due to strong winds or damaged airframe. **Security action:** The drone continues normal flight while trying to stabilize the pitch as much as possible. **User action:** If the condition persists during a flight, land and wait for the wind to decrease, as explained in section 'Weather check' on page 27. If the problem occurs in low-wing conditions perform Check 2 in section 'Full airframe and sensor inspection' on page 131.

8.4 Critical failures

A critical failure is an error that occurs in flight that prevents the continuation of normal flight. This is the most serious type of error that can occur with the *eBee*, and is indicated in red in *eMotion*. The 'WARNING' button in the Control Bar changes to 'CRITICAL FAILURE', becomes red and cannot be acknowledged. When a critical failure occurs flight is aborted and the drone initiates an Emergency action in which it is immediately directed to the ground. The Emergency action for each Critical failure is designed to minimize the airspeed and thus impact energy with the ground using the sensors that are still functioning.

Table 6 on the next page describes the critical failures that may occur and what action is taken by the drone. In some cases it may be possible to manually control the drone using the remote control[60]. If such a critical failure occurs that results in an Emergency landing we recommend that you keep track of the drone's last

[60] see section 'Manual control of the *eBee*' on page 120

known position in the air and in *eMotion* if possible and follow the instructions in section 'Losing and locating your *eBee* in the field' on page 159.

Table 6: Critical failures

***eMotion* text**	**Description and Emergency action**
Failure: loss of GPS signals	Your *eBee* can no longer calculate its position, making it impossible for it to know where it is and thus to navigate. **Emergency action:** The drone turns off its motor, sets a bank angle and glides in a large circle towards the ground. If there is a strong wind the drone may be pushed far from its current position. If satellite signals are re-acquired the drone will abort the landing procedure and go to the Home waypoint.
Failure: empty battery	The battery is completely empty. **Emergency action:** The drone turns off its motor and glides towards the ground in the direction of the Home waypoint. This error is always preceded by a Low battery In-flight warning.
Failure: INS malfunction	There is a failure with the orientation sensors which makes it impossible for the drone to stabilise itself and thus initiate a gliding emergency landing. **Emergency action:** The drone turns off its motor and fully deflects its ailerons which results in an uncontrolled descent with limited impact energy (deep stall or spin).

Failure: motor malfunction	The motor is not working even after an attempted re-start commanded by a Motor malfunction In-flight warning. **Emergency action:** The drone orients itself in the direction of the Home waypoint and glides towards the ground while continuously trying to re-start the motor. If motor re-start is successful the drone cancels the landing and flies towards the Home waypoint at an altitude defined by the Home waypoint's Change altitude parameter (by default, set to 'Highest').
Failure: CPU Overload	The autopilot processor is overloaded and can no longer control flight. The drone turns off its motor and fully deflects its ailerons which results in an uncontrolled descent with limited impact energy (deep stall or spin).

8.5 Resetting default camera settings

In case of unwanted configuration changes, the camera can be re-configured to a suitable state. Please refer to your camera user manual in the download section of our website for the procedure.

8.6 Improving radio signal communication

You may occasionally lose the data connection between *eMotion* and your *eBee* while in the field. Whether there is a loss in uplink or downlink communication, the drone will continue flying along its Flight Plan and should re-establish the connection as it flies closer to the base station or changes direction.

If the drone stops receiving messages from *eMotion* (uplink direction) for more than 30 s you will see a 'Data uplink lost' In-flight warning appear in *eMotion*. If for safety reasons you would like the *eBee* to automatically return to the Home waypoint when this warning appears, select the corresponding option in the Flight Parameters tab[61].

If there are no more messages received by *eMotion* from the drone (downlink direction), a 'Data downlink lost' message will appear in *eMotion*. If there is still an active uplink connection you may still command your drone to return to the Home waypoint using the Control Bar.

Data connection range can be effected by many external factors such as antenna height, terrain and obstacles or radio interference. We recommend the following tips to improve the range of your connection in the field:

1. Place the USB ground modem as high as possible (for example, on top of a car, ladder or nearby building). A height of at least 2 m is recommended.

2. Ensure that the USB ground modem's antenna is pointing straight up.

3. Disable any 2.4 GHz-based communication devices (or put them into 'Airplane mode') in the vicinity of the USB ground modem. This includes all

[61] see section 'Flight Parameters tab' on page 116 for more details

Wifi and Bluetooth devices such as the ground station computer or mobile phones.

The strength of the connection between the drone and *eMotion* is indicated in the Flight Monitoring tab[62]. The three LEDs next to the antenna on the ground modem also indicate the strength of the connection. The connection is strongest when all three LEDs are a solid red, and weakest when a single LED is blinking.

8.7 Losing and locating your *eBee* in the field

We recommend that you write your address and phone number on your *eBee* (by putting your business card on top of the camera for example) in case it gets lost and subsequently found by a third party. In case you lose your drone in the field for whatever reason, whether from a loss of communications, a Critical failure or an accidental collision, use the following steps to try to recover it:

1. Do not disconnect the connection in *eMotion*! If it is simply out of communication range the drone should reconnect automatically as it returns to the Home waypoint after completing its mission.
2. Note the last known location of the drone in *eMotion* by printing the screen or writing down the location displayed in the Flight Monitoring tab.
3. Move towards this last known direction with the computer running *eMotion* in the hope of regaining a connection. Be sure to take the remote control with you as well.
4. If you have reached the last known location of your drone and have not yet found it, turn on the remote control.
5. Try moving both the control sticks around. If the drone is within range it may start making noise with its main motor or servo motors.
6. Try moving downwind from the last known location in case the drone was pushed by the wind while still in the air.

[62] see section 'Flight Monitoring tab' on page 92

8.8 Reporting a problem with your *eBee*

If there is a problem with your *eBee*, whether it is a software malfunction, damaged airframe or any other problem, we recommend the following actions:

1. If there is an error message displayed in *eMotion*, begin by checking section 'Troubleshooting' on page 137 to see if there is a solution to the particular message.
2. Check the on-line Questions & Answers section on senseFly Ltd's website[63] to see if there is a solution to your problem.
3. If you have still not found a solution, contact your *eBee* reseller. Please include the following information with your inquiry:
   - The serial number of your drone, in the format EB-XX-XXX. You can find this number inside the battery enclosure.
   - A short description of the problem.
   - The Drone Flight Log file of the flight that had a problem[64].
   - The eMotion Flight Log file of the flight that had a problem. You can find this file in the `eMotion/logs/` directory which is created in `My Documents` on Windows.
   - Photos or video of the *eBee* airframe, if required.

Note: In order to provide support, senseFly Ltd may request the flight log files for inspection.

[63] technical support can be found at http://www.sensefly.com/support/

[64] see section 'Importing images and flight data' on page 48 for information on retrieving this file from the *eBee*

Part IV
Specifications

1 Software requirements

eMotion has the following minimum software requirements:

Operating system	Windows XP / Vista / 7 / 8
Hardware	1.6 GHz processor 2 GB RAM 500 MB free storage space
Screen	recommended resolution: 1920×1080 visible outdoors

Postflight Terra 3D has the following minimum software requirements:

Operating system	Windows XP / Vista / 7 / 8, **64-bit only**
Hardware	1.6 GHz processor (2 GHz Intel i5/i7/Xeon recommended) 4 GB RAM (16 GB recommended for large projects) 10 GB free storage space (1 TB recommended for large projects)
Screen	min. resolution: 1024×768

2 Drone specifications

Size	Wingspan: 96 cm Wing area: 0.25 m^2
Weight without camera and battery	approx. 0.41 kg
Nominal take-off weight (approx.)	*eBee*: 0.69 kg (1.52 lbs) *eBee Ag*: 0.71 kg (1.56 lbs) (with standard camera & battery)
Material	EPP foam, carbon structure & composite parts
Battery	3-cell Lithium-Polymer (0.14 kg)
Nominal endurance (flight time)[65]	*eBee*: 50 minutes *eBee Ag*: 45 minutes (with standard camera)
Propulsion	Electric brushless motor Nominal static thrust: 0.63 kgf (6.2 N)
Nominal cruise speed	40-90 km/h (11-25 m/s or 25-56 mph)
Wind resistance	up to 45 km/h (12 m/s)
Max. single flight coverage[66]	*eBee*: 12 km^2 (4.6 mi^2) *eBee Ag*: 10 km^2 (3.9 mi^2) (on a single battery charge)

[65] can vary greatly depending on external factors such as wind, altitude change and temperature.

[66] calculated based on the following test conditions: GSD of 30 cm (11.8 in) per pixel, no wind, moderate air temp. (18 C/64.4 F), new fully-charged battery, flight altitude of 1,000 m (3,280 ft) above ground & take off at approx. sea level from centre of coverage area.

Communication devices	Ground modem: • Frequency: 2.4 GHz • Range[67]: approx. 3 km • Certification: FCC Part 15.247, IC RSS210, CE Remote control: • Frequency: 2.4 GHz • Range: approx. 1 km • Certification: CE, FCC
Navigation	Up to 50 waypoints
GSD (per pixel)	*eBee*: Down to 1.5 cm (0.6 in) *eBee Ag*: Down to 2 cm (0.8 in)
Absolute horizontal accuracy	*eBee* (with GCPs): Down to 3 cm (1.2 in) *eBee* (no GCPs): 1 to 5 m (3.3 to 16.4 ft) *eBee Ag* (with GCPs): Down to 4 cm (1.6 in) *eBee Ag* (no GCPs): 1 to 5 m (3.3 to 16.4 ft)
Absolute vertical accuracy	*eBee* (with GCPs): Down to 5 cm (2.0 in) *eBee* (no GCPs): 2 to 5 m (6.6 to 16.4 ft) *eBee Ag* (with GCPs): Down to 7 cm (2.8 in) *eBee Ag* (no GCPs): 2 to 5 m (6.6 to 16.4 ft)
Relative orthomosaic/ 3D model accuracy	1-3 times GSD
Carry case dimensions	55 x 45 x 25 cm (21.6 x 17.7 x 9.8 in)

[67] can vary greatly depending on external factors such as cruise altitude, presence of obstacles and radio-frequency interference.

Glossary

AMSL Above Mean Sea Level
Your *eBee*'s altitude can be shown and set in *eMotion* using ATO or AMSL. Your drone uses the EGM96 mean sea level standard for navigation.

ATO Above the Take-off Altitude
Your *eBee*'s altitude can be shown and set in *eMotion* using ATO or AMSL. Altitudes in ATO are relative to the place your *eBee* started its motor just before take-off.

DSM Digital Surface Model
A 3D digital representation of a surface.

FTDI Future Technology Devices International
A Scottish semiconductor device company specialising in Universal Serial Bus (USB) technology. FTDI cables allow serial connections through a USB cable. *eMotion* uses FTDI technology to connect to the ground modem. You can often connect a computer to a GNSS base station using FTDI.

geo-reference A data point associated with a specific location on the earth's surface.

GSD Ground Sampling Distance
The distance measured on the ground between pixel centres in an image or DSM. The smaller the GSD, the higher the spatial resolution of the image. For example, a GSD of 5 cm means that one pixel in the image represents 5 cm on the ground.

mosaic A single map or terrain model created from several map sections that have been placed side-by-side and merged together.

orthomosaic A single, corrected image constructed either from several images taken from different angles, or from several orthophotos. Distortions due to different camera positions, ground curvature and relief are corrected for so that the image displays accurately in the given map projection.

photogrammetry A technique in which measurements taken from photographs are used to reconstruct a 3D surface or a series of points in space.

point cloud A set of data points within a coordinate system.

rayCloud A feature unique to *Postflight Terra 3D* that combines the 3D point cloud with the original images. Multi ray matching with the rayCloud extends the stereo view triangulation and increases the accuracy of 3D point estimates while providing a full understanding of 3D results.

triangle model An approximate representation of a surface, constructed from connected triangles.