Experiences with the eBee Drone

Part II (Part I was featured in the SASSCAL June 2017 Newsletter)

by Dr Ben Strohbach
Namibia University of Science and Technology (NUST)

Under SASSCAL Task 159, Biodiversity monitoring network in Namibia, we are faced with the dilemma that there are more observatories than our human resources are capable of surveying each year. To crown it all - we are able to determine the diversity of species, but are to date unable to track the life history of individual trees and shrubs.

In order to get to grasp with this dilemma, we purchased a survey drone to at least obtain every year a high-resolution aerial image of each observatory. Here is a continuation of the summary of our experiences to help other tasks interested in drone photography make wise decisions. Choices, Choices...

In Part I of this article, Ben explained what control software he has been using, how best to plan your flight, issues with overlap and image quality and the challenges with the start and landing of your flight.

(v) Wind and Weather

One more thing to consider when flying - the weather conditions during flight. Early morning and late afternoon flights produce images with long shadows. These might be ideal to identify animals on the aerial images, but are problematic in mapping other features (e.g. trees, shrubs, infrastructure, etc.). It is generally not recommended to fly before 9h00 in the morning, and no later than 16h00 in the afternoon. Keep this in mind when planning your travelling to and from the site you need to fly at.

Overcast weather eliminates the shadow problem to a large extend, but partially cloudy weather creates another problem - cloud shadows in the images. You can obviously not fly the drone in rainy conditions.

Whilst a bit of wind helps with launching and landing, a strong wind will considerably reduce the flight time of the drone. In the case of strong winds I found the best performance to be actually flying directly into the wind, and returning with the wind. For this purpose, the flight paths are twisted to be parallel with the wind. In this way the least energy is spent in correcting the course - which is disproportionally high with a crosswind. Strong ground winds during start-up will prevent the drone to start - in such cases it is best to set it up, and start with the nose pointing away from the drone, and only turning into the wind once the engine is at full speed and the drone is ready to launch.

In very hot, calm conditions you will have problems launching the drone. Now it will be best to launch from an elevated position - e.g. from the top of a vehicle. Remember also, that the drone has an optimal working temperature, and is not supposed to fly in temperatures over 35° C. The autopilot may not overheat!

(vi) Flying safely

Also consider flight safety and your local air traffic regulations. Avoid flying in built-up areas (i.e. towns, etc.), and avoid flying near airports. Commonly, you are not allowed to fly within a 5 nautical mile radius from the perimeter of the nearest airport (9.6 km) If possible, don't fly nearer than 10 km to an airport (especially in the landing approach areas). Aeroplanes do come in low for landing! Rural air strips which are not often frequented (e.g. on farms, tourist lodges) are mostly OK (we often use them as landing facilities ourselves), but do make sure from the manager that no flight is expected during that particular day.

And lastly, remember to fill in your flight logs. The flight logs as record of where, when and how the flights were. Noting down the date and time, as well as weather conditions, provides information about the quality of the image. In addition to the supplied logbook, I keep a separate sheet, in which I can note additional information like flight height, planned overlap of images, planned footprint size per image, etc. - all information needed for future publications. Here I can also list a number of flights together to complete a specific locality and indicate information about state of processing as well as

The eBee ready for take-off

where and how did I archive the data.

Drone care

(i) Strengthening the air frame

The drone is a light-weight structure made of polystyrene foam ("Styrofoam"). The material is sturdy enough to allow the drone with cargo to fly, but is also easily damaged, especially considering rough landings on difficult terrain. For this reason, the leading edges of wings and body are covered with a reinforcing moulded plastic, and the belly of the body is covered with a plate of the same material. We found that the front of the belly plate tends to scrape off during landing, and thus we pasted it down with reinforced cellotape ("strapping tape") (***Figure 3.1***). As the wing underside is also exposed to damage, we cover these with the same strapping tape to avoid unnecessary damage. The hinges of the wing flap are also strengthened with this tape.

(ii) Birds of Prey

Birds of prey are not very fond of intruders in their hunting grounds. As a matter of fact, numerous police and security forces are known to use larger birds of prey (e.g. eagles) to hunt for intruding, illegal drones (see eg. https://www.youtube.com/watch?v=tKNN49idCUo and others). Unfortunately, the eBee resembles such an intruder. To protect the drone, we glue "Holographic Iridescent Foil Bird Scare Tape" onto the upper wing surface. To date it seems to work - I have watched several larger birds of prey circling the drone, but flying away after a while without attacking the drone. We got a rare upper view photograph of a steppe buzzard in flight this way!

(iii) Monitoring during the flight

As a general rule, the eBee is visible over a distance up to 500 m away. 500 m is also the default safety margin set by eMotion. However, your typical mission area is larger than this - 1,500 m, 2,000 m, even over 3,000 m away. If you follow the drone with binoculars, you can see it roughly 2,000 m away still, but don't dare to take your eyes off the drone! Here the data link between computer and drone is not only handy, but essential - the drone communicates it's present position and status (including pitch, yaw and roll, and photo positions) to the controlling software (eMotion). The software records this data as a second flight log (in addition to the on-board flight log of the drone), and also displays some of the most essential information on the user interface. This includes details on wind speed and direction, flying speed and altitude, en route to which waypoint, number of photos taken as well as battery status. Status alarms are also displayed, and you as operator need to take remedial action on this. Often enough it means an aborted flight - but rather this than a crash-landing kilometres away!

(iv) Oh sh**t!

Murphy's law - "If anything can go wrong, it will" - applies especially to drone flying. We experienced bird attacks, failed batteries during mid-flight, sudden gusts of (side) winds during landing, even a malfunctioning engine during flight.

In case of problems, keep calm, and ...

React to warnings promptly. If in doubt, call back the drone.

If the drone falls, determine the last known position of the drone. It is displayed on the user interface.

Use a GPS to find the drone, and retrieve it

Assess the damage, and decide whether you are able to stick it together again, or if it should rather go to experts for repair.

(v) Repairing minor damages

Normally, damage is limited to a broken propeller, or a piece of the leading edges of the wings broken off. Small pieces of polystyrene foam can easily be glued back. With the drone, a tube of polystyrene foam glue (Uhu POR) is supplied. Similar products are available from other manufacturers in southern Africa - do make sure that you obtain a glue which is safe for use on polystyrene foam. Many glues contain solvents which will damage the polystyrene foam.

Cracks on the fuselage (after a hard landing) can be glued, but do allow the glue to set properly for maximum strength. Additional strengthening with strapping tape is also recommended.

For some damage normal polystyrene foam glue is just not good enough. Small magnets are used

(Top to Bottom)
Figure 3.1: Bottom view of the eBee drone. Note the reinforcing strapping tape on the wing surface and the front of the belly plate.
Figure 3.2: A steppe buzzard in flight.
Figure 3.3: Left: Minor cracks in the fuselage can easily be glued with a polystyrene foam glue. Right: Major damage needs to be professionally attended to. In this case the repairs were undertaken by Sensefly under warranty (proven autopilot failure).
Figure 3.4: Dust in the lens barrel causes amongst others the closure of the lens to jam. This results in faulty pictures as on top, which could not be processed.

to hold down the lids of the battery and camera compartments. These often come loose. Here a bit of hot glue helps. However, make sure that your hot gun does not become too hot - as soon as the glue melts, it is hot enough. Normal operating temperatures of the hot gun will damage the polystyrene foam. With magnets in lids, do make sure about the polarity before gluing!

Broken propellers and torn flaps of wings are not to be repaired – replace these. Keep a few spares for exactly this purpose.

(vi) Servicing the drone

Something which is not clearly spelled out by the supplier nor in the manual, is that the eBee should be serviced once in a while – preferably every 100 flying hours. We are not that far yet – one of our drones has now completed 56 flying hours after 195 flights, the other little bit less. For warranty purposes, however, it is important to observe this warranty requirement.

Figure 3.5: Left - a well-used battery, right: a fairly new battery. Note the bloated look of the well-used battery, indicating the end of its life-span.

Camera care

The cameras are off-the shelf cameras modified for the task. Part of the modification are a series of settings to improve the photo quality (high shutter speed, high ISO setting, etc.) as well as settings to save battery power (no zoom, no flash, no red-eye flash, no back-panel display etc.) Full settings (and how to reset these) are described in the supplied manuals. Important to realise is that these settings are saved on the camera as "custom" settings, and that battery power is needed to keep these settings "alive" in the memory of the camera. As the batteries are removed before flight from the S110 camera, and the G9X camera is even issued without battery, it is important to remember to either recharge the batteries of the S110 occasionally, or to hook up the G9X to a computer via a supplied USB cable in order to keep the internal systems going. Also, before using a camera on a mission after a prolonged rest period, do check the date and time settings, as well as the correctness of the custom settings. The drone will not start with the mission if these settings are incorrect.

A killer for any camera lens is dust. Unfortunately, the camera is exposed to dust during landing through the open cargo bay. The newer G9X cameras have a simple, but effective dust proofing installed: a thin glass plate is mounted on the lens barrel, which, once the lens is retracted during camera shut-down, presses against a thin foam rubber ring around the lens barrel. This essentially keeps away dust from the sensitive lens barrel. This technology is unfortunately not available for the S110, and we could not yet trace suitable material for the covering glass plate.

Here are a few suggested measures to keep the camera, if not dust-protected, at least as clean as possible:

- Avoid landing on sandy or dusty sites (not always possible).
- Clean the camera after every flight - also if it has dust protecting.
- Clean also the cargo (camera) bay. Use a compressed air duster, if available.
- Check the camera regularly between flights by switching on and off. If the lens barrel extends with a grinding sound, there is dust inside the barrel. Pay special attention to clean this out.
- Double-check the working of the camera before flight. Once the drone is powered up, you can use eMotion to test the camera by switching on and off, and even taking photos on the ground.

Battery care

The eBee uses 3-cell Lithium-polymer batteries. These are high-capacity batteries, but are problematic to maintain. Recharging batteries takes some time (2 hours or more per single battery), so it is best to have ample charged batteries available for any particular mission. Replacement batteries are fairly expensive, and often there is a lead time in delivery of these because these cannot be transported by regular air freight. Here are a couple of do's and don'ts regarding battery care:

Don't use your batteries to their limit. They last best if you use them to about 20 and 30% capacity after landing.

Don't use a half-used battery for a next mission. Chances are good that the battery will become depleted before the mission is completed.

An easy trick to keep used batteries apart from fully charged batteries is to place a coloured pin next to the battery in the carry case - green for fully charged, red for depleted.

After use, allow the battery to cool down (for at least 30 minutes) before attempting to recharge.

Use your batteries regularly. Prolonged periods of non-use actually degrades the battery (don't ask me why!). If need be, implement a rotation scheme.

Be careful with old batteries. Reduce the maximum flight time to 20 minutes, and call the drone back early once the battery level drops below 40%. Normally, one of the three cells packs up, resulting in a sudden loss in available capacity at that stage.

In high wind conditions, plan for two flights rather than one.

Problematic batteries can be identified by prolonged charging periods (4 or more hours, difficulty in balancing the cells) as well as a permanent bloated look of the battery (***Figure 3.5***).

Do not just throw away old batteries. If these are not handled properly, they can explode and cause fires. For this reason, get a professional waste management company to dispose of these batteries.

Tools and spare parts to take along

I learned to take along a view extras for each mission. It helps to have the spares available on site, rather than having to return to the office halfway through a trip. All are packed in a sturdy plastic box, with custom-made compartments (see ***Figures 3.1***). I am including a list of regular spares and tools in the Appendix.

Data quality and storage

(i) Geolocation and using Ground Control Points

As the drone flies it's mission, the position (determined by regular GPS) of each image is recorded. This is done via a time reference. After the flight, you will download the flight log and the software matches this with the images. In a final pre-processing step, the images are geotagged. In the next processing step (using Pix4D or another suitable software) the images are stitched together based on their geolocation, and point matches. The resulting image roughly has a 0.5 m RSM error - i.e. the exact position of the image in relation to the landscape can vary by roughly 0.5 m. This does not sound like a big deal, but it becomes a problem if repeat photographs of the same area need to be compared, or the images used for engineering and land surveying applications.

An alternative to the eBee RTK (using differential GPS technology) is the use of ground control points. The Biodiversity Observatories have been surveyed by professional surveyors, and the northwestern corner for each individual ha is known. We are presently installing a coloured steel plate onto each outer corner of each observatory (***Figure 3.6***). These are readily recognised on the photographs, and are registered as Ground Control Points during image processing. With these, we are able to improve the average RSM error to below 0.05 m.

(ii) Data storage

The cameras record the photographs on SD cards. One obvious thing to do is to ensure that the currently-used SD card has sufficient capacity for the flight. For a single flight you will need between 3 and 6 GB space, depending if the camera is set to record RAW images as well, and on the amount of images to be taken. Make sure that the SD-card is the camera-type – i.e. the old-fashioned, integrated SD card. I found that the mini-SD cards, in a suitable adaptor, do not work well in the cameras. I had numerous failed flights by using mini-SD cards (in adaptors) in the cameras.

Various camera types record (and convert) various image formats. Typically the CMOS (image sensor) outputs an image in the so-called "RAW" format. And typically, cameras convert and store this RAW-image as the common JPG image format. For NIR, the RAW images are essential, for RGB processing, the JPG images are fine. Many remote sensing professionals however prefer working with the RAW images. If needed, the camera needs to be adjusted to save the RAW images as well.

(iii) Data archiving

The mini SD cards come in handy for archiving the original (unprocessed) imagery and flight data. Once the JPG images are geotagged, these are copied back onto a blank SD card, together with the flight logs (both from the drone and as saved by eMotion), kml track of the flight and Pix4D project. The SD card is labelled and stored in a separate box as back-up of the original data.

Data processing involves the stitching of the images into an orthophoto and an associated DSM (for the standard 3D mapping option of Pix4D). The orthophoto of a 1 km2 Biodiversity Observatory, at 5 cm ground resolution, is equal in size to a 400 Megapixel photo. It is not saved as a compressed JPG image, but rather as a GeoTIFF. Such an image is between 1 and 1.5 GB in size - not viewable with a conventional photoviewer / photoeditor. The image is split also into separate, smaller tiles, allowing for easier handling, also in GIS software. Optionally, GoogleEarth tiles and associated kml files can be created of the orthophoto. This allows the image to be used as additional layer within Google Earth, but also as base map in eMotion for future flight planning. We are planning to systematically obtain 10 cm ground resolution baseline images of our biodiversity observatories and associated areas around it, which we can use to replace the lesser quality imagery available from the internet (normally less than 50 cm ground resolution for most rural areas in Namibia).

The colour orthophoto is good for visual interpretation, but not suitable for advance remote sensing techniques. For this, reflectance maps for the individual bands are required. As an additional step in processing, exactly these are calculated. These are then also used to create the most common index maps: for NIR images the NDVI and the MSAVI2 (Bannari et al., 1995; Qi et al., 1994); for RGB images these include the excessive Green and excessive Red indices (Rasmussen et al., 2016; Woebbecke et al., 1995). A fully processed set of images and indices for a single biodiversity observatory (1 km2) amounts to between 50 and 60 GB of data (compared to roughly 10 to 12 GB of data if only DSM and orthophoto are created).

This amount of data creates a problem for storage and archiving. We have at present 8 TB of data, after one and a half season's flying. The argument was presented whether we should store all the processed data, or rather process data on demand. The advantage would be that less storage space is needed, the disadvantage that the processing needs to be redone - with a considerable time input (it takes between four and eight hours to process the imagery of a single observatory - one camera only). We copy the full data set onto external Hard Disk Drives, with the idea that one copy is stored at NUST (as working copy) and a second copy stored off-site, preferably with the SASSCAL OADC. It is also envisaged that a further safe copy (not working copy) be held at NUST. Obviously, we are presently capturing the full Metadata set for the SASSCAL OADC, so that the data can be seen and can be made available. This is in line with international archiving standards (Olson and McCord, 2000a).

Figure 3.6: A ground control point marked out in the veld (left), and seen from the air at 5 cm ground resolution (middle - RGB, right - NIR).