Introduction to drones as tools for research and monitoring

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Abstract

The purpose of this manual is to supplement the already available operation manual from the 3DRobotics Iris+. This manual is intended to provide some more detailed insight on some aspects of the safe usage of drones, compliance with local laws, and effective use of ground station software. The primary aim of this document is to provide the reader with the tools necessary to create meaningful data for spatial ecology using a consumer grade unmanned aerial system (drone). This technical manual encompasses in broad strokes the steps taken to achieve aforementioned goals during the summer of 2015. This technical manual is intended to provide BFS staff as well as future researchers with the tools necessary to employ the UAV as a spatial data collection tool, or other component to their experiments.

Safety & Legal Note

The following are guidelines provided by the AMA in conjunction with the FAA. NOTE: Without a 333 exemption, no one is allowed to operate a drone in the United States Airspace in any capacity other than for hobby or recreational reasons. To clarify the FAA’s interpretation of what constitutes “Hobby or Recreational usage”, please refer to the FAA FAQ webpage: https://www.faa.gov/uas/faq/#qn24

In order to conduct flights for compensation of any kind, there are two different avenues. The first avenue requires the operator to apply for something called a 333 exemption. Details of that can be found at this website: https://www.faa.gov/uas/civil_operations/ The second avenue that may apply to the BFS is to obtain a public certificate of operation (Public COA). This is a special grant of permission to conduct flights that are in the public’s best interest, and these are only available to publicly funded organizations. More details on issues of authorization can be found here: https://www.faa.gov/uas/public_operations/

Public Perception

It is common for some people to become very uncomfortable with the presence of drones in the sky. Their concerns are based largely on fears of invasion of privacy or fears related to their belief that the drones in the sky may be looking for violations. As

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representatives of the Biological Field Station, it is imperative that all interactions with the public be conducted in a friendly, positive and responsible manner. Some people are simply interested in the drone and would like a closer look. The best method for dealing with the curious is to kindly inform them that you will be willing to answer any questions they have after you have landed.

Crew

A drone crew should consist of a minimum of two people:
1. The Pilot In Command (PIC), whose roll is to operate the drone. Note: if the drone is being used for commercial purposes, the PIC must be an FAA licensed pilot.
2. The Spotter: It is the spotter’s job to maintain situational awareness of all activities happening within the active zone of flight, and to alert the PIC of changes to the situation. Examples of changes that the spotter should alert to pilot to are: people approaching the zone of flight, the presence of full-scale aircraft in the sky, and periodic updates from the Ground Control Station.

Know Before You Fly ~ (The following is quoted directly from the FAA Model Aircraft Operations webpage):
"The FAA has partnered with several industry associations to promote Know Before You Fly, a campaign to educate the public about using unmanned aircraft safely and responsibly. Individuals flying for hobby or recreation are strongly encouraged to follow safety guidelines, which include:

- Fly below 400 feet and remain clear of surrounding obstacles.
- Keep the aircraft within visual line of sight at all times.
- Remain well clear of and do not interfere with manned aircraft operations.
- Don't fly within 5 miles of an airport unless you contact the airport and control tower before flying.
- Don't fly near people or stadiums.
- Don't fly an aircraft that weighs more than 55 lbs.
- Don't be careless or reckless with your unmanned aircraft – you could be fined for endangering people or other aircraft “.

Simulation Training

Although the 3DR Iris+ is a very capable semi-autonomous platform, I always recommend that prospective pilots spend some of their spare time using a flight simulator. When the autonomous flight modes are working correctly these drones are very easy to fly, but when faced with an in-flight technical malfunction, it is the capabilities of the pilot that make the difference between a safe return to landing, and a lost drone. One very reasonable and accessible flight simulator is called “Real Flight mobile”, available for IOS devices. The app is free but the multi-rotor is a $2.99 in-app purchase. This simulator is not a perfect physics representation of how a multirotor flies, but it is very good at demystifying the control system of the multirotor, as well as helping
the operator to develop strategies for certain types of spatial disorientation that happen when the drone is far away and silhouetted against the sky.

This is a very good simulator that should help a new pilot get started. A solution for the PC exists as well. Two such simulators are: Real Flight 7.5 http://www.realflight.com/ and Pheonix RC5 http://www.phoenix-sim.com/
Both of these are higher end simulators that more closely approximate the experience of flying a drone, though both are more expensive than their mobile counterparts. It is recommended that one visit their pages to determine system requirements etc.

Step 1: In the Lab (GCS). The ground station computer should be co-located with the drone. Before leaving for the field make sure that the ground station computer is fully charged.

Ground Control Station (GCS): open GCS computer and log in using the following credentials:
User: BFS Drone
Password: iris

NOTE: 1 As of this latest revision of this document this computer is no longer available at the BFS. It is unknown to me whether or not the BFS has replaced the ground station computer with another system.
2 The following directions are accurate as of the most recent mission planner build at the time of publication.

When the computer starts, open up Mission Planner (MP) which should be located on the desktop. After mission planner has finished loading (it takes a little while) click on the “FLIGHT PLAN” icon located in the upper left hand corner of the screen. Click and drag in the map window to find the location where you intend to conduct your flight. While pressing the “Alt” key on the computer, click and drag a blue rectangular bounding box around the area. With the area selected, right click anywhere inside the map window to invoke a context sensitive menu. Drag down to “maptools” and hover your cursor over that list item until the fly out reveals more options. Select the option “prefetch”. Once this has been done another window will open giving you the status of the map tiles that are being cached for later retrieval in the field. Pay close attention to this dialogue box as it will inform you what levels of zoom are being cached. When you have gotten to zoom level 20, hit escape a few times to stop downloading. There is no point in loading maps that are further zoomed in than 20 as they take a very long time, and they do not provide any useful data in the field. The ground station computer is now ready to work in the field.

Step 2: In the Lab (DRONE)
A. Make sure all batteries are charged. It is a convention of mine that all charged batteries are put in the case with their cables sticking up. It is also a convention of mine to place discharged batteries in the case with the cables sticking down into the holes. As an additional memory aid I have labeled each battery with a number. It is a good practice
for the operator to take notice of the battery number as it goes into the drone; also it is
good practice to run through the batteries sequentially while out in the field. This practice
helps prevent flying away with a battery that has almost no charge. There is a battery
tester included in the case. The battery Charger must be plugged in as illustrated. A full
battery will read around 12.5 (v) (Figure 1). If the battery is reporting anything below
11.5v, take the time to charge it up before the flight. Never start flying with a battery
lower than 11.0 (v) and never run a battery down below 10.7 (v) it risks being destroyed.

Figure 1 Voltage Meter.

B. Remove the drone from its case, turn it upside down on a counter and remove
the GoPro camera using the smallest hex wrench included in the flight case. Make sure
the GoPro is charged, and the micro SD card is in place.

C. Make sure at this time that all mission critical equipment is in the case, and that
it has been checked for operational condition. This inspection should include such points
as damage, battery level, memory storage… etc.

D. Inspect the propellers for damage. Discard any propellers that have been
damaged. Tiny pits on the leading edge of the props are acceptable in some cases, but
notches or cracks, or warped propellers will degrade the flight of the drone.

E. Remove the Remote Control Box from the case, turn it on, check its battery. If
the voltage is lower than 9V do not go flying without first replacing the 8 AA cells in the
back.

Step 3: out in the field
Choosing a launch site:

The launch site should be as clear of overhead obstructions as possible. In
general the point of takeoff should be approximately 30 feet diameter minimum. From
this location it should be possible to see a large portion of the sky. A good rule of thumb
for determining this is for the operator to stand in the center of a proposed launch sight,
extend their arm at a 45° angle and make one full rotation while looking at surrounding
clutter. Obstructions, which may include buildings, overhead utility wires, or the tree
line, all should fall below the operator’s outstretched arm. This is both important for
obtaining GPS fixes, and helping in recovery of the drone. The surface from which the
drone is launched should also be stable. During arming procedures it is necessary for the
drone to recalibrate it’s onboard inertial measurement unit (IMU). If the drone is in
motion while this is happening, the drone will not arm and the GCS will return a “BAD
GYRO HEALTH” message.

Also it is important to note that the spot on which the drone is sitting when it
establishes a GPS fix will double as the RTL (Return to Land) waypoint. This means that
this is the spot where the drone will attempt to fly back to if it enters failsafe mode. Since
the drone lacks any ability to detect obstacles, it is imperative that the RTL spot be
extremely clear of obstructions.

Step 4: out in the field (Establish Base)

Open the drone case and start with removing the drone. Place it on the spot where
you intend to become the RTL point. Don’t plug it in or put the propellers on yet. Next
turn your attention to the Transmitter.

a. Carefully remove controller (transmitter) from box.
b. Make sure all switches are in their full back positions.
c. Make sure all sticks are centered except for the left stick, which should be in
   full down position.
d. Turn on transmitter. It will emit one beep to let you know that it is working.
   If the transmitter continues beeping, it is likely that a switch is in a forward position; this
   will prevent the transmitter from initializing.
e. Make note of the transmitter voltage. If it falls below 9 volts, do not attempt to
   fly without first replacing the batteries.
f. Press and hold the button labeled “DN” which is in the 6 o’clock position in the
clover leaf button cluster on the lower left hand side of the controller face. This will open
the controller’s telemetry screen which includes the following information: Altitude
(meters), Speed (MPH), Distance (to ground station), Satellites (how many GPS satellites
are locked in), Battery (The voltage of the drone’s battery), and milliamp hour (record of
battery consumption in milliamp hours).
g. Double check that the two switches in the upper right-hand corner of the
controller are set to STD and RTL=OFF.
h. Install FPV monitor:
   i Fold FPV monitor cleat.
   ii Insert thumb bolt.
   iii tighten with backside of propeller wrench.
Now it is time to plug the drone battery in and let it start acquiring satellite position. Be
careful while doing this, as excessive shaking will prevent the drone from arming.

Readying the ground station:
a. Turn ground station computer on.
b. Attach 915mhz radio transmitter to the Velcro located on the lid of the ground
   station computer and plug into empty USB port.
c. Start “Mission Planner” (Windows) “APM Planner” (MAC) which is the ground station application. While waiting for the mission planner application to boot, return your attention to the drone.

Turn the drone over and make sure that it’s power cords are plugged in for the gimbal, and the video transmitter.

Turn on GoPro.
Turn on the video transmitter, and make sure that it is receiving a strong solid picture.

It is now safe to put the props onto the drone. Refer to the operator’s manual for how to accomplish.

NOTE: Though the use of a ground station is not totally necessary to use the drone, it should be considered mandatory equipment, as it provides a wealth of flight information. This information is often helpful in diagnosing and responding to an inflight problem, which will assist the operator in the task of returning the drone safely to a landing. Mission Planner (windows) receives real time telemetry logs. These logs are like an airliner’s “black box” in that they record the entire flight for playback and analysis. This information is invaluable in locating a lost drone should the unlikely event of a “fly away” occur.

Step 5: Connecting Drone to base station:
After the drone has been made ready for flight, plug in the battery and close the battery door.
a. In Mission Planner: Notice in the upper right hand corner of the screen there are two pull-down menus and a connect button. The pulldown menus should be set at “COM9” and “57600” respectively. Press the connect button.
b. When the drone connects you will see relevant messages in the information display.
c. The most common warning is “bad gyro health”, which appears when the drone is experiencing too much motion during IMU initialization. The remedy for this is to power cycle the drone while keeping it stationary.
d. When there are no longer any warnings in the status window, you are ready to fly.
e. Arm the drone by pulling the throttle stick down and pushing it fully to the right.
f. Hold it there until you hear one long tone.
g. To take off, raise the throttle stick slowly until the drone is light on its landing gear.
h. Be prepared to drop the throttle to land again if the drone is not lifting off in a level attitude.
i. Once the drone is in the air, stabilize it in a hover approximately 10 feet off the ground before continuing with the flight. This safe hover will help the operator determine if the controls are functioning correctly.
Step 6: Landing:

The recovery or landing of the drone is the stage of flight that immediately follows an approach to landing. Since the approach to landing may be flown by either the human pilot or the autopilot, I am not covering that procedure in this manual.

To land the drone manually (recommended), carefully position it 10-20 feet above the landing spot as required to assure horizontal clearance of obstacles as it descends. Lower the throttle stick below the middle position, and let the drone come down gently into its own footprint.

Note: the pilot must keep their thumbs on the controller during this stage, as the drone is susceptible to erratic behavior as it loses altitude. This behavior can be caused by several factors related to operating close to the ground. Among these factors are: ground effect turbulence, descending into the vortices of the drone’s props, glitches in GPS caused by descending below the surrounding tree line, or differences in the wind at ground level versus just above the tree line.

Once the drone is safely settled on the ground, it is necessary to disarm it. To do so, drop the throttle stick all the way down and push it to the LEFT. Hold until you hear multiple tones.

Mapping Configuration:

For mapping, the only required equipment is the mapping camera, the mapping camera mount and the remote camera trigger (see Figures 2 and 3). The mapping camera is mounted on the front via the mapping camera mount; it faces downward so that its photographic plane is more or less parallel to the ground plane. The mapping camera is triggered remotely by the remote camera trigger, which is connected to the power output from the drone and to receiver output channel 7.

It is optional to use the GoPro and video transmitter as an FPV setup. This will allow you to see what the drone sees and in some cases may help to recover the drone if there is a problem with the autonomous mission and the drone needs to be flown home manually. It should be noted that this optional equipment adds a certain amount of weight to the configuration and will result in reduced flight times.
Figure 2 Mapping camera and mount.

Mapping BFS Camera & Mapping Camera Mount:

Optional: First person view equipment (see Figure 4). Required for real time video downlink, but dramatically increases flight time.

- GoPro Hero4 Silver
- GoPro Simple Mount
- Video Transmitter
Figure 3.” First Person View Equipment”.

Equipment to remove:
Tarot Gimbal (The drone cannot lift this and the Mapping camera at the same time).

Mapping Mode (assumes no FPV setup):
1. Remove gimbal.
2. Remove video transmitter.
3. Install remote camera trigger.
4. Secure and attach mapping camera.
5. Plug remote trigger into camera usb.

Video Mode
1. Remove mapping camera.
2. Remove remote trigger.
3. Attach gimbal, being careful to plug in red power cord and the two wire(yellow and brown) connector before screwing the gimbal plate to the drone body.
4. Install Video Transmitter (Velcro).
5. Plug usb into GoPro port and insert GoPro into gimbal cradle.

Flight Planning
It is necessary to obtain as much information as possible about a survey site before conducting any kind of drone related mission. Firstly, the drone operator should consult the “Know before you fly” website available at: http://knowbeforeyoufly.org/ for helpful tips regarding how to maintain safe and ethical operations. There is an interactive map available at the following website: https://skyvector.com/ This map will quickly alert the drone pilot to any potential conflicts with local general aviation traffic. In the case of Cooperstown, there is a small airfield located approximately 8 miles south east of the lake which may cause problems for the drone operator depending on where the survey site is located (Figure 5).
In addition to obtaining the necessary situational awareness to operate safely within the United States Airspace, the operator should also determine what the hazards are in the area including but not limited to land contour and vertical obstacles. Ownerships of properties the operator intends to overfly, and proximity of appropriate launch site, is outlined in Step 3 of this document.

The simplest type of data to acquire using a drone by far is video, in general. It is sufficient to simply follow the directions outlined in this report to install the video camera, the video transmitter, and the video receiver. The trickiest part is to navigate the various control menus for the GoPro and the video monitor. The manuals for each of these do a very good job orienting the user to the operation of that equipment. Those manuals are located in the manila envelope inside the drone case. Although waypoint missions are not required for video, there are some use case scenarios that may benefit from using them. For instance, a splined waypoint mission may be helpful if one is attempting to acquire quality video overflying a riparian corridor. Since the drone can manage the workload of following the river below this frees the operator to concentrate on camera framing.

To set up a splines waypoint mission (assuming that Mission Planner is open and the drone is connected according to the instructions for doing so earlier in this document), in Mission Planner:

1. Click on the “FLIGHT PLAN” tab.
2. Navigate to the area of interest.
3. Click a rough faceted line on the map to represent the corridor you wish to fly a splined mission along.
4. In the mission outline panel at the bottom of the page, select the pulldown icon next to the words that say “waypoint” and change this to “splined waypoint”.

Figure 5. Sectional chart showing Cooperstown Westfield Airport.
5. Notice that the line you drew becomes more smoothly curved.
6. When you are satisfied with the mission parameters, click the “Write WPs” button. Mission Planner will load the mission to your drone.

When you are ready to execute the mission, simply selecting “auto” for the switch position on the control box will send the drone off to execute this mission plan. For more information regarding the various different styles of flight plan for mission planner, the operator is encouraged to familiarize themselves with the Mission Planner Instructions located online at [http://planner.ardupilot.com/](http://planner.ardupilot.com/) Two other flight modes that may be of use are “Orbit” which causes the drone to fly in a circle around a fixed point, all the while pointing toward the center, and Region of Interest which causes the drone to face the same point on a map regardless of where it is flown.

The Autopilot requirements for mapping are much more crucial than those available for videography. This is mainly because mapping requires repeatability, uniform heading, and uniform altitude above target. To complicate matters further, there is a requirement to achieve a minimum picture overlap of 60% in order to reconstruct orthorectified mosaics. During a mapping mission, the drone is instructed by the autopilot to fly a ‘lawnmower’ pattern over a subject parcel. It does so at a fixed height, with a fixed heading.

To create a mapping mission (assuming Mission Planner is running, and the drone is connected to the ground station laptop):
1. Click on the “FLIGHT PLAN” tab.
2. Navigate to the area of interest.
3. Right click on the screen and select the menu item “Draw polygon> Add Polygon Point (then click ‘OK’ to dismiss the warning).
4. Add red polygon vertices around your area of interest, they can also be grabbed and dragged once placed.
5. When polygon has fully enclosed the target survey area, right click and pull out the menu for Auto WP > Survey (Grid).
6. The window that opens is the Survey grid control panel. Select the simple tab in the upper right hand corner of the screen and make sure that the camera pulldown is selecting the Canon a2400 powershot (or whatever camera you are using for the survey).
7. On the Grid Options Tab, make sure side lap and overlap are set to 60%.
8. In “copter options”, check the heading hold box, then check the Unlock from grid box.
9. Type ‘0’ for North into the heading hold box.
10. Check the window below that survey grid map paying close attention to the Flight Time (est) field make sure that it does not exceed the copter’s battery limitations. ‘It should be less than 15 minutes’
11. Go back to the ‘simple’ tab and adjust the Altitude (in meters) until the estimated mission time under the mapping pane works for the battery. Remember, it is a hard FAA rule that flights not be conducted in excess of 400 (121 meters) feet AGL. As you raise the altitude you decrease the amount of time the survey will take, while also reducing the ground resolution of the survey data. In situations where the ground
resolution or altitude parameters are forcing a smaller survey area, simply plan on doing the surveyed area in multiple parts. Don’t forget to overlap the area of survey so that there are sufficient data to blend them in post production.

12. When everything looks correct, click the “accept” button.
13. Click the ‘Write WPs’ button.
14. Click the ‘Read WP’s’ button (this is an extra step). It assures the operator that the drone has accepted the survey mission and is aware of its current location. This will help prevent fly-aways
15. Now you are ready to take off and execute the survey.

Post Processing Data:

After a mission, the operator is left with a number of pictures of their survey area, none of them containing the whole picture. It is necessary to use post processing to turn these data sets into something useful. There are two main choices. If the desired photo absolutely must be ortho-rectified, then the data set needs to be turned into a 3D model from which an orthographic projection of the scene can be produced. In order to produce a truly orthorectified mosaic, the model also needs to have a ground reference plain that is perpendicular to the direction of gravity; in other words, perpendicular to 0 nadir. To achieve this, the photographs in the data set must have a minimum GPS position encoded in the EXIF data.

Mission Planner http://planner.ardupilot.com/ (Application used to create autonomous missions and also georeference photographic datasets):

The camera does not code the positional DATA in, so it needs to be appended to the images. Mission Planner has a powerful tool for doing this. It utilizes the time code from the camera and matches it to the GPS logs kept by the autopilot. By doing this MP is able to mark each picture with a relatively accurate positional code related to where it was when the picture was snapped. To outline this process is not reasonably within the scope of this document, and there are a great deal of online resources to walk the drone user through this process. So for the purpose of brevity I will refer the readers of this journal to the following Youtube video: https://www.youtube.com/watch?v=Vth6LXCIfO0

This is the video I used to learn the process and I can attest that it works as stated.

Photoshop

In use case scenarios where orthorectification is un-necessary, Photoshop has the power to create seamless high resolution aerial mosaics. The gain in using Photoshop over a photogrammetric modeling software package like Agisoft Photoscan is that it does not require the additional step of georeferencing the photograph. Instead the image is georeferenced after its creation by inserting it into a GIS application such as Arcmap, QGIS or Global Mapper. In order to do so (assuming the user has access to Photoshop cs4 or later):

1. Open Photoshop.
2. Go to the File>automate>photomerge pullout.
4. Navigate to the folder containing the photos in your data set and shift+select all that are applicable.
6. Click “OK”.
7. Wait… this is going to take a long time.

When Photoshop is done, it will have made a HUGE and very high-resolution file. It may be necessary to re-size the image in order to prevent the GIS that you put it in from crashing. Save the resulting file as a TIFF. Lastly, import the file into your favorite GIS software and georeference according to that software’s operating procedure.

Agisoft Photoscan. (http://www.agisoft.com/)
Manual for Agisoft can be downloaded at the following link:
http://downloads.agisoft.ru/pdf/photoscan-pro_1_0_0_en.pdf

Photoscan is a photogrammetric modeling software that enables creation of 3d models from aerial photo data sets, provided that there is enough overlap between individual pictures. There are others that are available which can produce the same results. However, Agisoft is the only one that I have used and have had success with. It costs around $500 for an educational license, which is very inexpensive as most others start at around $5000 for annual rental. Describing the steps to process photogrammetric models are similarly outside of the scope of this report and it comes with a very easy to follow manual.

This concludes the Introduction to drones for spatial ecology manual. The knowledge contained herein is enough to turn any drone with ‘waypoint navigation’ capability into a functional spatial analysis data collection tool. Though this report doesn’t probe the absolute depths of what a drone is capable of, it’s intent, which is to demystify and bundle together the essential steps required to create useful data using a small unmanned aerial system is all contained here-in. Special thanks to those members of the BFS that assisted in my research, as well as the Otsego County Conservation Association for providing the funds which enabled my internship. And a special thanks to the Otsego Lake Association who provided the funds which were used to purchase the drone and all ancillary equipment used in this study. This document does not indemnify future operators from litigation resulting from the illegal, unethical, or unsafe usage of drones.