

Processing UAS Photogrammetric Images in Agisoft Photoscan Professional

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ERIC SACZUK

**BCIT
VANCOUVER, BC**



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Preface

This series of manuals are intended to facilitate the safe use and teaching of unmanned aerial systems (UAS) to a wide variety of programs and teaching areas at BCIT. The ubiquitous and positively disruptive nature of UAS make them an excellent additional tool for the collection of spatially accurate data including photos and videos in a variety of applications. From Geomatics to Forestry and from Marketing to Forensics, UAS are quickly becoming indispensable due to their rapid deployment capability, ability to provide a unique perspective in difficult to reach areas and safely gather a rich data set in a short amount of time.

The demand for data captured by UAS is increasing at BCIT across the province and in fact around the globe. These manuals aim to rapidly and effectively transfer knowledge to those who are interested in leveraging this technology in their specific fields of interest and expertise. The manuals are divided into two main categories; **Image Acquisition** and **Image Processing**. The Image Acquisition manuals are vehicle- and sensor-specific

with the goal of being able to pick a specific unmanned aerial vehicle and sensor combination and fly a pre-programmed, semi-autonomous mission in order to gather a specific set of images or videos. The Image Processing manuals can be used as standalone or as a follow-on from the Image Acquisition manuals. These focus on the most effective photogrammetric processing techniques in Agisoft Photoscan Professional given the specific data set and image type. Each of the Image Processing manuals is accompanied by a sample data set that provides a complete walk-through of the processing steps or they can be used to generate a variety of different 3-D mapping products using a user-supplied images.

Overview

This manual guides you through the steps of processing photogrammetric images using Agisoft Photoscan Professional acquired by a DJI Phantom 3 Professional UAS to create map products including;

- sparse and dense point cloud
- 3-D mesh surface and textures
- digital surface model (DSM)
- true orthophoto mosaic
- 2-D & 3-D Google Earth layers

The following manual Parts provide guidance for each step of the process;

- Project Setup
- Generating 3-D Model
- Creating a DEM and Orthophoto
- Exporting Data

This manual follows from the image acquisition mission described in the manual ***Image Acquisition for 3-D Mapping with DJI Phantom 3 Pro.***

Part 1 – Project Setup

Overview

The main goal of this Part, is to prepare the included images (or any user-captured images) for photogrammetric processing in Photoscan. The steps described in Chapter 1.1 are;

- Photoscan Project Setup
- Import Photos
- Assess Image Quality
- Adjust Altitude & Coordinate System
- Align Photos

Although this manual is written specifically for included set of photos, with some minor adjustments, the steps can be applied to any other set of GPS-tagged, overlapping air photos acquired by an UAS.

Chapter 1.1 - Setting Up Images

Overview

In this chapter, the aim is to ensure that the images captured by the UAS are ready for processing in Agisoft Photoscan Professional (Photoscan). A Photoscan project will be created into which the UAS images will be imported and then aligned.

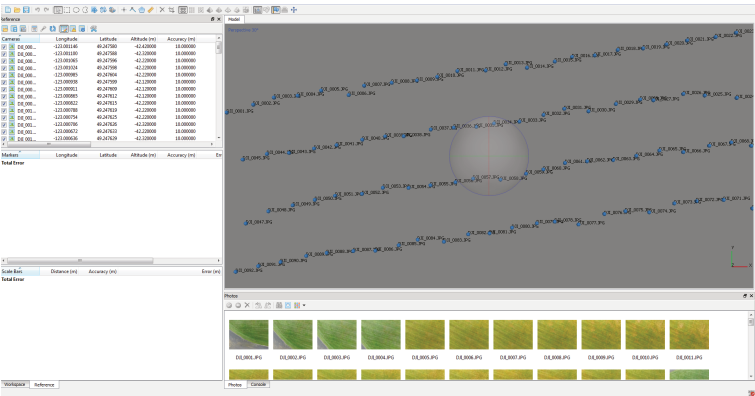
Photoscan Project Setup

Download the UAS images [here](#). Create a folder called **BCIT_Field** in the **Documents** folder on your workstation. Open the **BCIT_Field** folder, create a sub-folder called **Images** and unzip the downloaded UAS images into this sub-folder. You will have to remember the location of the **Images** folder. Ensure that all 83 images are present.

From the **Start** menu, find and launch **Agisoft Photoscan Professional**.

Import Photos

From the **Workflow** menu, select **Add Photos**, navigate to the **Images** sub-folder, select all images and click **Open**. Your window should look similar to the screenshot below.



Initial photo alignment in Photoscan

All of the photos along with their longitude, latitude, altitude and estimated accuracy are listed in the **top left pane**. Each photo thumbnail is also visible in the **bottom pane** and a full resolution image can be opened by double-clicking the thumbnail.

In the main **Model** window, all of the image centers (principal point) are shown lined up according to how the UAS flew the pre-programmed image acquisition mission. The ball in the center of the **Model** window is used to rotate and spin the model in the X, Y and Z axes.

Assess Image Quality

The first quality assurance step is to assess the quality of the input photos. The Photoscan checks basic photo attributes such as blurriness, focus, contrast and exposure. Right-click on one of the photos in the bottom pane, select **Estimate Image Quality...**, select **All Photos** then switch to **Detailed** view to see the quality score. The score ranges from 0 (unacceptable) to 1.0 (perfect) and any photos below 0.6 should not be included in processing and removed.

Adjust Altitude & Coordinate System

By default, the principal points at each photo center are tagged with GPS coordinates in the WGS 84 coordinate system. This means that although the horizontal position (i.e. longitude and latitude) is relatively accurate ($\pm 5\text{m}$), the altitude needs to be adjusted to the actual height that the UAS flew above the ground. This is accomplished by accessing the **Tools** menu, selecting **Scripts** running the following Python script ([PYTHON ALT SCRIPT](#)).

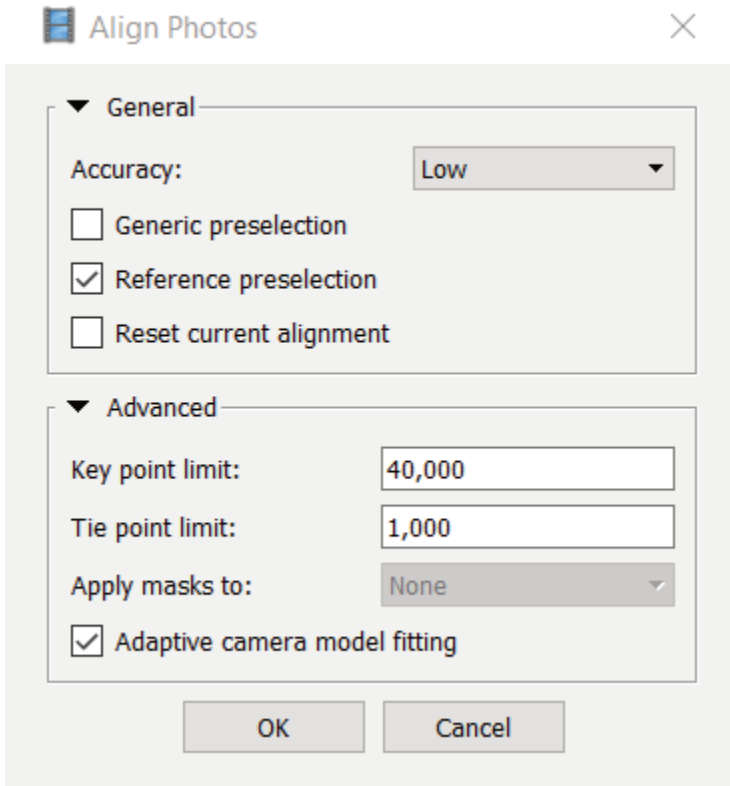
Change Coordinate System

If the coordinate system needs to be changed from the default WGS 84, click on the **Convert** icon in the **Reference** pane and select a new coordinate system of your choice. Apply the conversion to **Photos** only (uncheck **Markers**) and click **OK**.

Aligning Photos

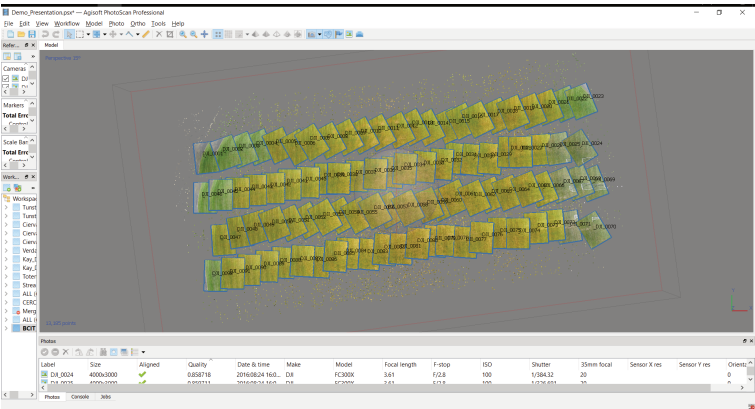
So far, the software only knows where the centre of each photo should be in absolute space (i.e. real-world coordinate system). It doesn't yet know how all the overlapping photos connect or fit together. This is the purpose of the alignment function in Photoscan. Aligning photos is based on a computer vision concept called **Structure from Motion**.

From the **Workflow** menu, select **Align Photos**, adjust the parameters to match the screenshot below and click **OK**.



Initial photo alignment

Your view should look similar to the one below after the sparse point cloud showing the key tie points is generated within a few seconds.



Sparse point cloud showing key tie points.

Save the project by accessing the **File** menu, selecting **Save As...**, navigating to the **BCIT_Field** folder, naming it **BCIT_Field** and clicking **OK**.

Part 2 – Generating 3-D Maps

Overview

Now that the UAS images have been imported into Photoscan and aligned, the next steps are to create a dense point cloud, and a 3-D surface mesh with textures in the desired projection.

Chapters included in this Part are;

- High accuracy alignment
- Dense point cloud
- Filter dense cloud
- Adjust region
- 3-D mesh surface
- Texture

The items above represent the main 3-D map products from photogrammetric images captured using an UAS. They form the basis for creating other map products which will be further discussed in **Part 3 – Digital Elevation Models & Orthophotos.**

Chapter 2.1 – Dense Point Cloud

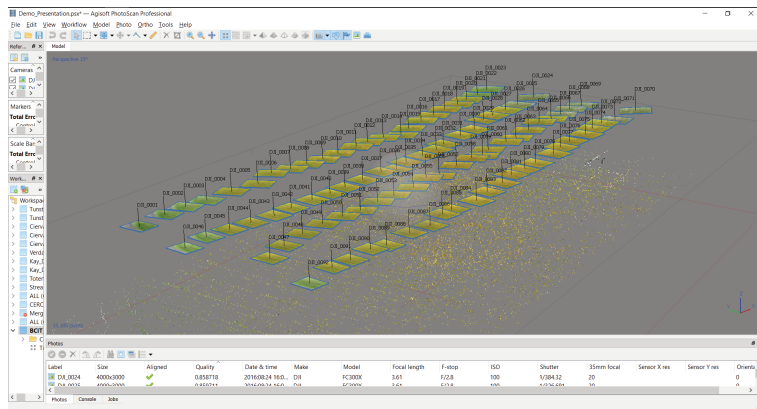
Overview

The steps below, outline the creation of several 3-D map products starting with a low density point cloud (tie points) as a result of a high quality photo alignment.

High Accuracy Alignment

The low quality photo alignment identified approximately 13,185 key tie points between the overlapping photos. These points form the basis for stitching together all 92 photos together into a seamless mosaic.

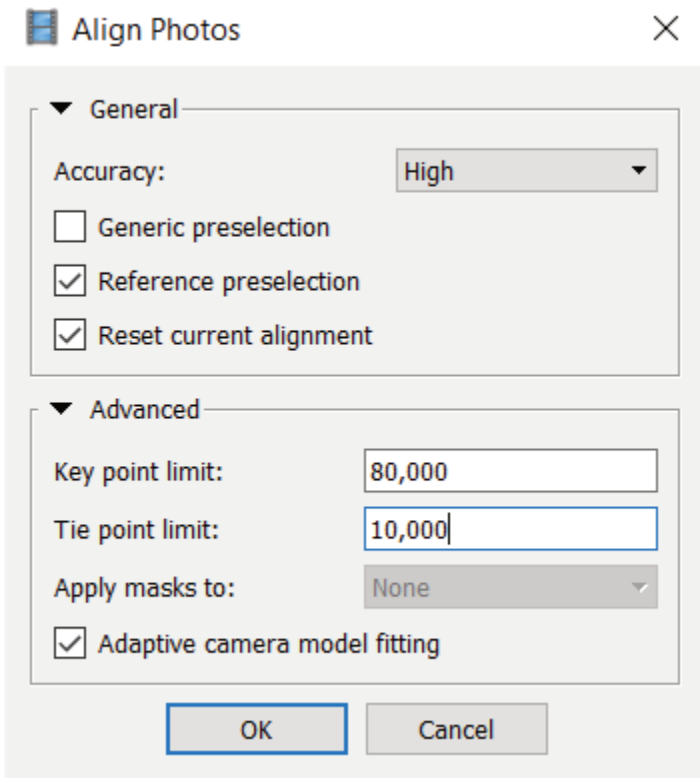
Click **Show Cameras**, rotate the view and you should see a result similar to the screenshot below;



Rotated sparse point cloud showing image footprints.

Recognizing the fact that all cameras exhibit some degree of distortion (e.g. radial, tangential, de-centering, etc.), it's important to run an optimization which minimizes the effects of these distortions on the accuracy and precision of objects in the photos. Click **Optimize Cameras**, accept the defaults and click **OK**.

Once the optimization is finished, select **Align Photos...** from **Workflow** and set the parameters according to the screenshot below;



High alignment parameters

With the key points identified as accurately as possible, the next step is to locate as many of the remaining pixels in 3-D and generate the dense point cloud.

Photo Alignment

Sometimes, especially with large data sets showing complex, variable terrain including trees, not all photos

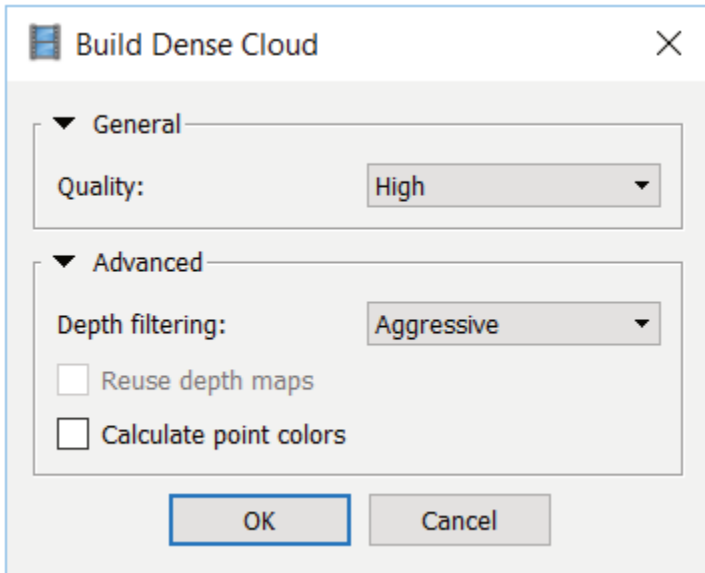
become aligned. If any photos remain unaligned after the initial attempt, several steps can be taken to align them.

1. Re-run **Align Photos...** using higher **Key point** and **Tie point** limits.
2. Select all the unaligned photos (represented as dots instead of footprints in the model) from the **Cameras** folder under the **BCIT_Field** chunk, right-click, select **Reset Camera Alignment** then right-click again and select **Align Selected Cameras**,
3. Running a higher quality alignment (if possible) can also help align photos.

Keep in mind that poor quality photos (quality index <0.6) or photos with very tall structures like trees or buildings that are significantly closer to the camera than the ground, may not align at all.

Dense Point Cloud

From the **Workflow** menu, select **Build Dense Cloud...** The **Quality** setting is directly dependent on available computing power. Reference this [document](#) to determine the suggested highest quality level based on the hardware being used. Set the quality as high as possible given your hardware configuration, as this ensures that the maximum number of pixels will be correlated in 3-D space. Be aware that the higher the quality setting, the longer the processing time. Consider using lower setting for large data sets (i.e. several hundred photos). Suggested settings are shown below;



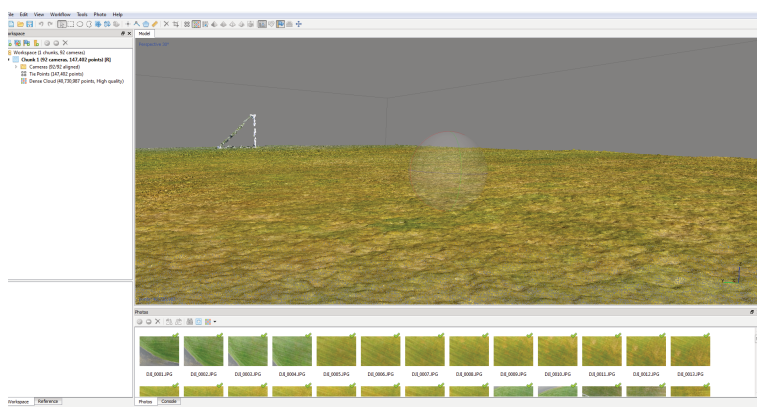
Dense point cloud parameters

Maximum Density Cloud

The approximate maximum number of points in a dense cloud is calculated by multiplying the **number of megapixels** of the camera (e.g. 12 megapixel images are 4000 x 3000 pixels thus contain 12 million pixels each) by the **number of images** (92 in this data set) which equals 110,400,000. It is very rare for all points to correlate and thus the actual number of pixels in a point cloud is generally only a fraction of the total possible.

The resulting dense point cloud is similar to the key point, low density cloud but it contains exponentially more 3-D information. The result should look similar to the screenshot

below, but don't be concerned if the number of points doesn't match exactly.



Dense point cloud

Although from certain perspectives, the dense cloud make look like a “solid” surface, it's still just a collection of pixels positioned accurately ($\pm 5\text{m}$) in space based on the GPS coordinate of the center pixel of each image. Due to GPS error and any remaining distortions in the camera and lens, the actual position may vary.

The next step is to filter any spurious points or outliers which are not representative of the surface being modeled in 3-D.

Filtering Dense Cloud Points

The type of surface greatly affects the ability and accuracy of filtering points. For example, the very level and flat playing field (except for the net) means that we shouldn't

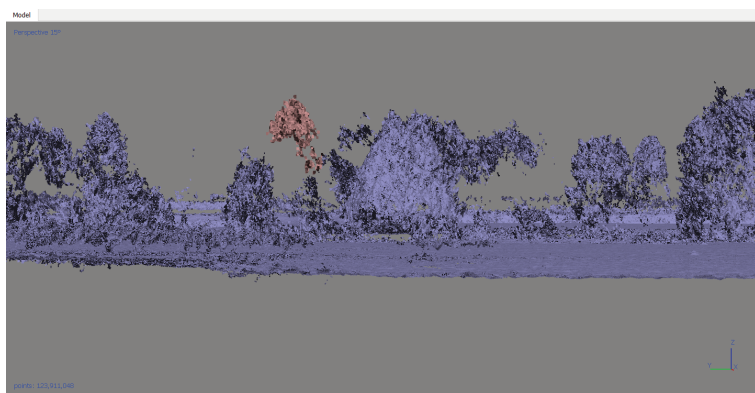
expect much deviation from the “ground” at all. Conversely in heavily treed areas or where there is high frequency, large-scale changes in elevation (e.g. a boulder field), the precision with which outlying points can be effectively filtered declines significantly.

Filter Dense Cloud

There are a number of different approaches to filtering points. They fall into two broad categories of semi-automated and manual. Here, only the manual method is demonstrated as it is the most selective and best applied to specific areas.

The general process involves rotating the dense cloud to identify individual points or groups of points that are not likely to be representative of the surface being modeled (e.g. points floating several tens of meters above the playing field or any points below the “surface” of the field). Once points have been identified, the **Selection (Rectangle, Circle or Free-form)** is used to highlight the suspected outlier and pressing the **Delete** key on the keyboard removes them.

This is an iterative process and done well, greatly improves the quality of the 3-D surface, which is the next step. See below for a sample of outlying points selected using the free-form selection tool.



Example of free-form point filtering

Chapter 2.2 – 3-D Mesh Surface

Overview

Once the dense point cloud is generated and filtered, the next step is create a continuous 3-D surface of the model. This process connects the discrete, 3-D pixels in the dense cloud with vector vertices, resulting in a “solid” without any gaps between points. In areas of the dense cloud where the points are relatively sparse, the surface can be either interpolated or extrapolated.

Adjust Bounding Region

Generate Mesh

From the **Workflow** menu, select **Generate Mesh...** to open the dialogue box. The parameter options are described below.

Surface Type can either be **Arbitrary (3-D)** or **Height field (2.5-D)**. The former retains 3-D pixel information for all points

in the input point cloud. This surface type is suggested for modeling complex shapes with overhangs and images taken at low oblique angles (i.e. less than 30 deg tilt from Nadir). The latter results in a simpler surface as the height field is only interpreted as orthogonal to the horizontal plane (X or Y axis). No overhangs or such complex surface features are retained and thus the processing time is usually shorter.

The **Input Surface** can either be the sparse or dense point cloud (default).

Face Count is a measure of the final complexity of the surface. Higher face counts will result in more detailed morphology of features but sometimes at the expense of noise or artifacts because of the decimation process. This is also dependent on the hardware configuration.

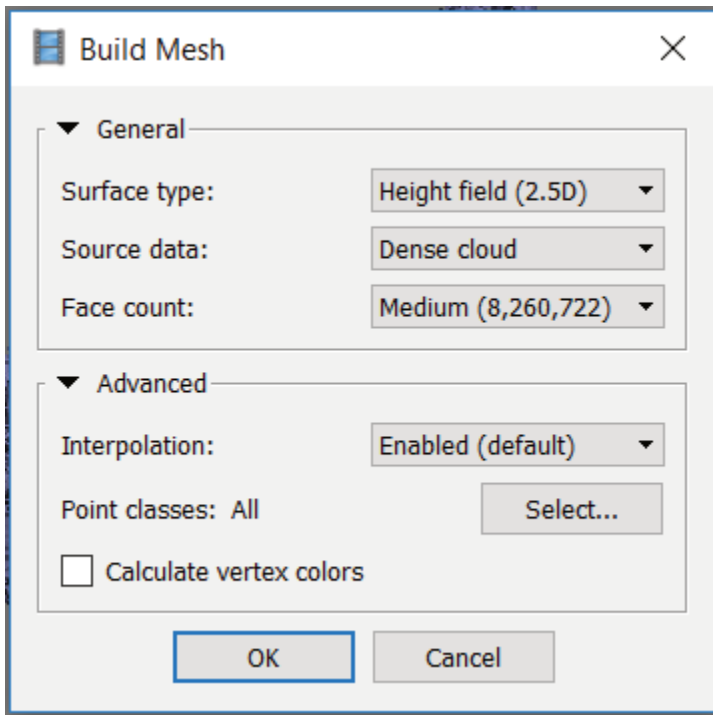
Under the **Advanced** tab, the first setting is **Interpolation** (**None**, **Enabled (Default)**, or **Extrapolate**). None will leave any small gaps or holes unfilled, Enabled will interpolate and fill small gaps and holes and extrapolate will fill small gaps and holes using a simplified algorithm and also fill out the edge of the surface to the extents of the bounding box.

Point Classes defaults to **All** unless a previous step to classify the dense point cloud was performed.

The last option **Calculate Vertex Colors** determines whether the vertices will be colored according to the photo pixel value or not. This can be left unchecked because the following step of

generating the surface textures will handle this in a much more detailed way.

Set the options as per the screenshot below and proceed with generating the 3-D surface mesh.



3-D Surface mesh settings

Part 3 – UAS Operations

Overview

This Part outlines the steps of safely carrying out the pre-programmed image acquisition mission.

Specific sections included in this Part are;

- Operational Briefing
- Pre-Flight Operations
- Flight Operations
- Post-Flight Operations

A safely completed image acquisition mission results in a high quality image data set which can subsequently be used to create accurate, 3-D map products such as point clouds, 3-D mesh surfaces, digital surface models as well as orthophotos.

Chapter 3.1 – Flight Operations

Overview

At this point, all of the preoperational checks have been completed including batteries charged, software and operating system updated, UAS, Controller and intelligent flight battery firmware checked and updated and all mission-critical elements verified for flight worthiness. This chapter takes place outdoors and on location where the image acquisition mission will take place.

Operational Briefing

Be aware that a minimum of two individuals are required to conduct any UAS mission; a pilot-in-command (PIC) and a safety spotter. Additional personnel may be needed as ground access control crew according to the specific mission safety and security plan. Safety spotters and ground access control crew *must* be briefed on their roles and responsibilities prior to heading to the field.

A [weather check](#) must be performed in order to verify the following minimum operational parameters;

- Visibility at least 2 statute miles (3.2km)
- Winds less than 30km/h
- Ceiling at least 1,000ft
- Temperature above 0 deg Celsius
- No icing conditions

Notice to Airmen ([NOTAM's](#)) must also be checked to ensure no conflicts with any other manned or unmanned air operations.

Prior to heading to the mission area, make sure to have with you the following items;

- UAS case with all mission-critical components packed safely inside
- Weather-clothing and footwear
- Valid Transport Canada-approved Special Flight Operations Certificate, Certificate of Completion of UAV Ground School, valid insurance certificate, valid radio operators certificate (if required), current MAAC membership (if required), current Flying Club membership (if required), pre-flight and emergency checklist(s)
- High visibility safety vest
- Protective eyewear (sunglasses are fine)
- Safety cones, signs and flagging tape (if required)

- Two-way radios
- Hand-held anemometer (if available)
- Foldable landing pad

Pre-Flight Operations

Once on site, visually double check the weather conditions. If a hand-held anemometer is available, verify wind velocity and direction. Inspect the proposed take-off landing site to make sure it is clear of any debris and obstacles. Check the proposed mission area to ensure that the planned mission height is sufficiently above any structures or obstacles.

Set up safety cones around the take-off area and deploy the safety spotter and any ground access control personnel to their pre-defined positions. Test two-way radio communication and only rely on cell phone communication as a back up.

Set up the landing pad and unpack the UAS as per the instructions in the [previous chapter](#). Once the UAS and associated components (Controller and iPad) are switched on and connected, proceed to the next section.

Flight Operations

In order to consistently log all UAS flights, locate and launch the **UAV Logbook** app and tap **Quickstart** to start logging the mission.

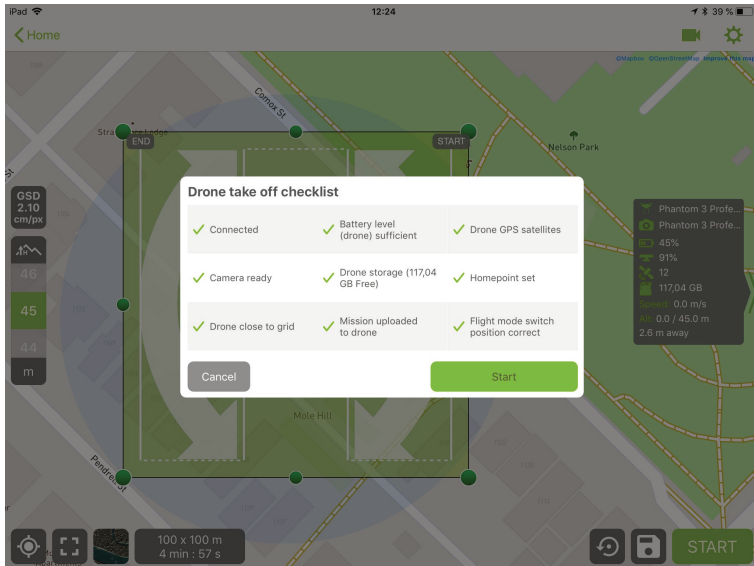
At this point check that the rear green indicator lights on the

UAS is blinking, the green indicator light on the Controller is solid green and the Pix4Dcapture app is open with the appropriate mission as per the screenshot below.



Pix4Dcapture mission planning screen

Tap **Start** and verify connection with the drone then tap **Next>**.



Pix4Dcapture take-off checklist

Pix4D Capture verifies all mission-critical parameters via the check list above. Conduct one last visual assessment of the take-off zone, announce loudly and over the two-way radio **“TAKE OFF!”** and tap **Start**. The UAS will immediately take-off and proceed to the first way point.

As the mission now proceeds semi-automatically, the main task for the PIC is to maintain visual contact with the UAS at all times and to ensure that the mission is proceeding at the correct altitude, heading in the correct direction along the pre-programmed route and that the camera is being triggered at the desired interval. The main role of the safety spotter during the mission is to maintain visual contact with the UAS and immediately notify the PIC of any hazards or departures from

the pre-programmed flight (e.g. fly away or sudden loss of power/control).

During flight, the camera view can be checked by tapping the camera icon in the upper right which opens a small window which can be expanded by tapping the icon in the bottom left of the window. Exposure can be manually adjusted by rolling the dial accessible by the right index finger on the controller.

Once the image acquisition mission is complete, the UAS will climb to the pre-determined fly-home altitude and return to the take-off spot for automated landing. The main task for PIC is to maintain visual contact with the UAS to ensure there are no obstacles or structures in the path of the UAS as it returns home. Once the UAS begins to descend, the PIC will announce loudly and over the two-way radio “**LANDING!**” and perform a quick visual inspection to ensure the landing zone is clear.

Alternate Landing Zone

If, for whatever reason, the primary landing zone becomes obstructed and the UAS cannot be safely landed there, the PIC will announce loudly and over the two-way radio “**ALTERNATE LANDING ZONE!**” and proceed to guide the UAS to a safe landing in the alternate location.

The UAS will automatically attempt to land where it took off from, but due to GPS errors, this may vary by up to 5m. Thus, the PIC should gently manually guide the UAS as it descends to ensure it lands in the correct spot on the landing pad.

Post-Flight Operations

Once the UAS is safely on the ground and the engines have been shut down, the PIC should perform a quick assessment of the continued airworthiness of the UAS by checking the following;

- Condition of propellers (any nicks or cracks)
- Temperature of motors (check for excessive heat)
- Temperature of battery (does it feel too hot to touch?)
- Condition of the lens (does it need to be cleaned?)

Once the PIC has verified further airworthiness of the UAS, they have two options depending on mission requirements;

1. Complete the mission and proceed to pack up the UAS for transport back to the office, or;
2. Turn around the UAS for another flight.

UAS Turn-around

The PIC will notify the safety spotter and ground access control crew (if present) that the UAS is being turned around and to standby for further instructions.

It is strongly advisable to check the image quality on a laptop by removing the memory card from the UAS and inserting it into a compatible MicroSD memory card adapter. This allows for a better means of assessing image quality than can be done on the iPad in the Pix4Dcapture app. Images should be checked for correct number of frames, exposure, focus and presence of

any motion blur. Should any aspect of image quality not be to the expected standard, the PIC must make the decision whether to re-fly the mission or not.

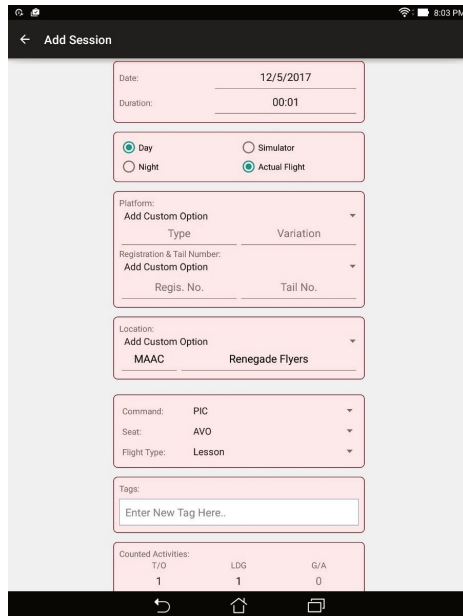
If the next flight is short enough to be carried out using the same battery, the PIC will follow the steps outlined in the [Pre-Flight Operations](#) section. If a battery swap or recharge is required, the UAS will need to be powered off and a fresh battery inserted. Controller and iPad battery status should also be checked along with the remaining capacity of the memory card.

Complete Mission

Prior to ending flight operations, it is strongly advisable to check the image quality on a laptop by removing the memory card from the UAS and inserting it into a compatible MicroSD memory card adapter. This allows for a better means of assessing image quality than can be done on the iPad in the Pix4Dcapture app. Images should be checked for correct number of frames, exposure, focus and presence of any motion blur. Should any aspect of image quality not be to the expected standard, the PIC must make the decision whether to re-fly the mission or not.

Once the images are deemed to be of sufficient quality, the PIC will notify the safety spotter and ground access crew (if present) that the mission is complete and to rendezvous at the landing or alternate landing zone.

Switch to the **UAV Logbook** app and enter in as much of the pertinent information as possible referring to the sample screenshot below.



← Add Session

Date: 12/5/2017
Duration: 00:01

☒ Day ☐ Simulator
☐ Night ☒ Actual Flight

Platform: Add Custom Option
Type Variation
Registration & Tail Number: Add Custom Option
Regis. No. Tail No.

Location: Add Custom Option
MAAC Renegade Flyers

Command: PIC
Seat: AVD
Flight Type: Lesson

Tags:
Enter New Tag Here..

Counted Activities:
T/O LDG G/A
1 1 0

Sample of UAV Logbook app

With the mission complete, follow the steps in the [Packing Up UAS](#) section and proceed back to the office for the Operational Debrief.

Chapter 3.2 – Post-Flight Operations

Overview

Once the mission is flown and images safely acquired, the next step is to head back to the office for an operational debrief. The main purpose is to verify that the mission proceeded according to plan and that the correct data set was acquired. Equally important are the things didn't go quite as planned in order to improve the safety and efficiency of the operation in the future.

Assessing Mission Success

There a number of factors determining mission success;

- Safety
- Image quality
- Communication
- Efficiency

Safety

Safety is of utmost importance because it directly affects the ability to carryout subsequent missions. This is why it is imperative that all UAS operations are conducted with safety first and foremost in mind. Safety itself can be evaluated based on a number of criteria such as equipment, personnel, property and the public. It is worthwhile to discuss any areas where safety may have been compromised and where it can be improved.

Image Quality

The main goal of a photogrammetric image acquisition mission is to safely and efficiently collect the correct number of high quality images for subsequent processing. Thus, even though a mission may have been deemed successful from a safety standpoint, it could be a failure if the right number of quality images are not captured. Any areas or procedures that may have compromised capture of quality images, should be evaluated.

For example, the effect of manual versus automatic photo capture settings in DJI GO app may result in images that are too dark, over exposed or blurry. Also using JPG versus RAW image format can affect post-processing steps. Images with insufficient overlap, taken at an altitude that is too high to see objects of interest or where the ground isn't clearly visible due to trees, shadows or other obstructions may negatively affect the outcome of a mapping project.

Communication

Communication between the PIC and team should not be

underestimated. If the PIC does not clearly communicate what they are presently doing and their next intentions, the safety spotter and possible ground access control crew may be left wondering what stage the operation is at. Simple, frequent updates as to what is happening with the UAS will help the ground crew understand what they should be doing at any given moment.

This becomes even more important when the ground access control crew is managing access to the flight area. It is helpful to brief the crew when to expect communication and what is expected of them at each stage of the operation.

Mission Efficiency

Efficiency of the operation cannot take priority over safety, image quality or communication and yet it can definitely affect mission success. If the mission cannot be completed in the allotted time or at a certain time during the day, it can result in mission failure. For example, if a planned daytime flight cannot be organized with sufficient time before sunset, it will have to be aborted. Rapidly changing or deteriorating weather conditions can also cause inefficiently planned or executed missions to be grounded. Sometimes equipment issues will require re-flights (e.g. blurry images due to improperly focusing camera) or a software app becomes unresponsive.

One of the main benefits of post-operational debriefs is to improve safety, ensure quality image, improve communications and raise the level of efficiency of future UAS operations.

Post-Operational Debrief

Once the UAS and crew are back in the lab or office, the UAS and components need to be removed from the case and cleaned of any debris (dust or grass). Batteries need to be connected to chargers and images downloaded to a workstation from the memory card. Any equipment issues need to be documented in the **UAV Logbook** app under the correct mission.

Once the data have been downloaded and verified, the memory card should be formatted in preparation for the next mission and inserted back into the UAS slot. When the flight batteries, Controller and iPad have been fully recharged, all components need to be securely placed back in the case and the case returned to the safe storage area.

Official DJI Phantom 3 Professional website for manuals, documents, firmware updates, software and drivers

Official DJI GO app website

Official Pix4Dcapture website