Rev. 12-07-2016

RAPID, REMOTE and REMOTE EXPERT Operating Instructions

Introduction

This document provides step-by-step instructions for the operation of DroneMapper's photogrammetry modules, RAPID for DJI, REMOTE and REMOTE EXPERT. These three modules provide the following functionality –

- RAPID for DJI: Allows input of up to 75 geo-tagged JPEG images of 12 Mpixel format or greater. RAPID will produce a preview orthomosaic, a DEM scaled at X8 of imagery native resolution and an orthomosaic scaled at X4 as output products in GeoTiff format.

- REMOTE: For larger mapping areas, this module allows input of up to 400 geo-tagged JPEG images of 12 Mpixel format or greater. REMOTE will produce a preview orthomosaic, a DEM scaled at X8 or X4 of imagery native resolution and an orthomosaic scaled at X4 or X2 as output products in GeoTiff format.

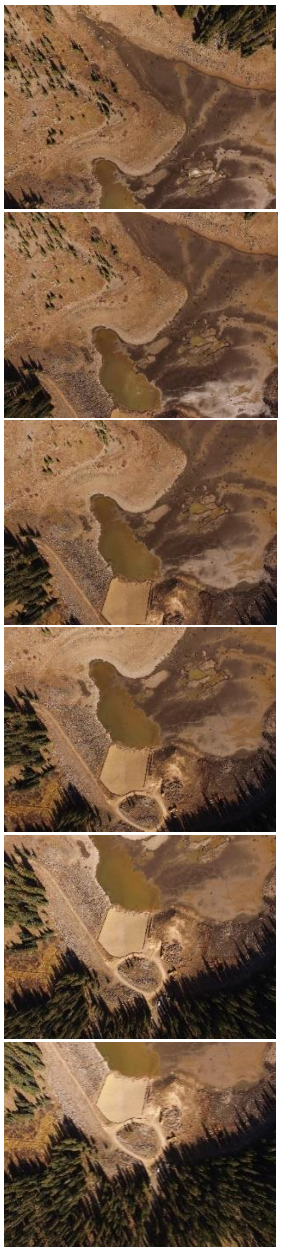
- REMOTE EXPERT: This module provides full photogrammetric functionality and allows input of up to 1000 geo-tagged JPEG images of 12 Mpixel format or greater. REMOTE EXPERT produces a preview orthomosaic, a DEM scaled at X8, X4 or X2 of imagery native resolution (user selectable) and an orthomosaic scaled at X4, X2 or native resolution (user selectable) as output products in GeoTiff format. This module also will perform processing using ground control points (GCPs). This feature requires imagery pre-processing using the included GCP Tool. The module will generate a point cloud of the results in ASCII PLY/XYZ format should the user select that feature.

Imagery Input Requirements

For these modules to function properly all the requirements and guidelines below must be followed:

- Imagery to be collected over the area of interest must have the sensor looking straight down (nadir),
- Only one sensor at a fixed focal length can be used for imagery collection and subsequent processing,
- The sensor must be set-up properly, i.e. shutter speed, ISO, EV, white balance manually set, etc., for the lighting conditions and platform dynamics expected during the collection,
- All images collected will have a forward (within one flight line) and side (adjacent flight lines) overlap of 70-80%. **We recommend use of a reliable mission planner/execution application for autonomous sensor triggering at the appropriate positions to ensure overlaps are met.** We have had success with Map Pilot for iOS & DroneDeploy for Android.
- All images will have unique latitude, longitude and elevation (MSL) geotags,
- All images will have unique file labels and preferably be in chronological sequence, i.e. identical image labels from separate flights cannot be processed together even if in same scene,
- After the collection, it is highly recommended that the images be inspected for the following: blur, over exposure (saturation) and clarity, no obliques, low altitude nadir (take-off and landing), calibration pics and no selfies. Processing could fail if one or more of these conditions exist in the input imagery.
- The following sequence of images is an example of a collect with good overlaps: top left down – 80% forward overlap; bottom right up (next flight line) – 80% side and 80% forward overlaps.

80%
forward



80%
forward

80% side

These images were acquired with a Phantom 3 Advanced. White balance was set to manual – "sunny", ISO was kept at 100 for low noise and the shutter speed was automatically selected. Additional guidelines on imagery collection techniques can be found here:

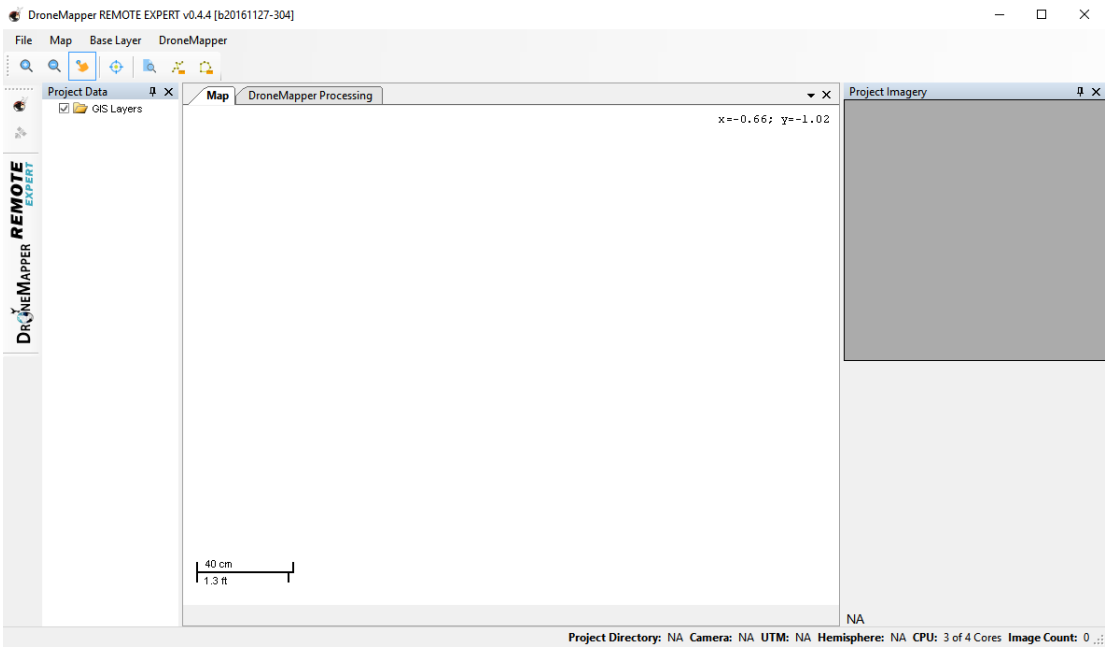
https://s3.amazonaws.com/DroneMapper_US/documentation/DroneMapper_AerialDataCollectionGuidelinesPlanning.pdf.

Processing Hardware Discussion

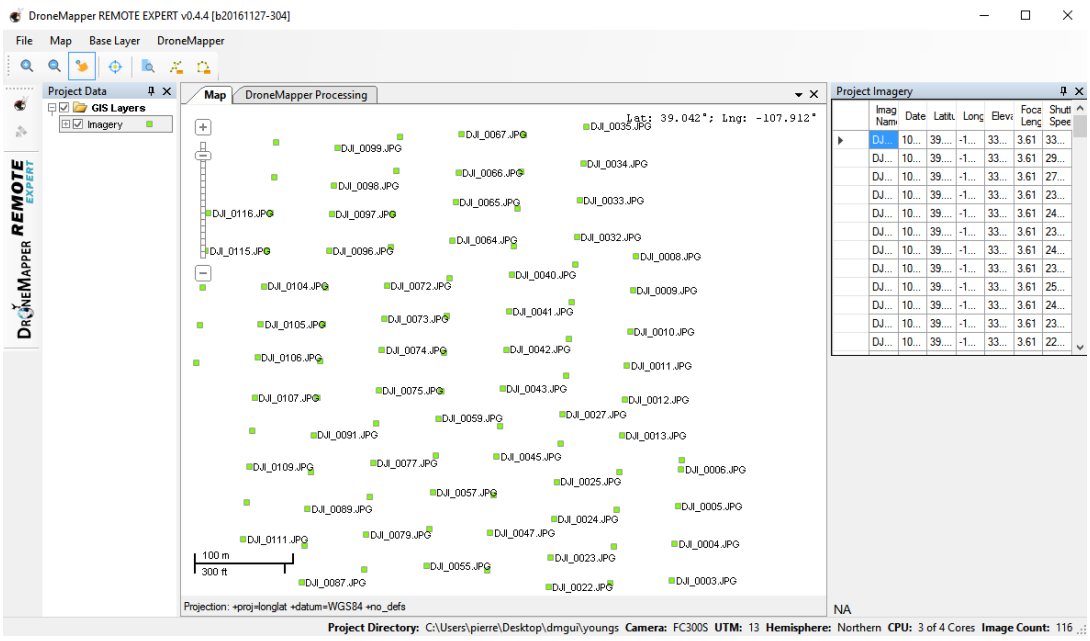
All three versions of the Windows application can be run on a laptop or desktop computer with Windows 10. Processing times reported herein were measured on a desktop with the following hardware configuration: Intel i5-4460 with 4 cores, running at 3.2 GHz. Minimum recommended RAM is 8 GB. The applications utilize (n-1) cores for processing to allow for other computer tasking in parallel. User times to generate the preview, DEM and orthomosaic may differ from what is reported here.

Module Operation

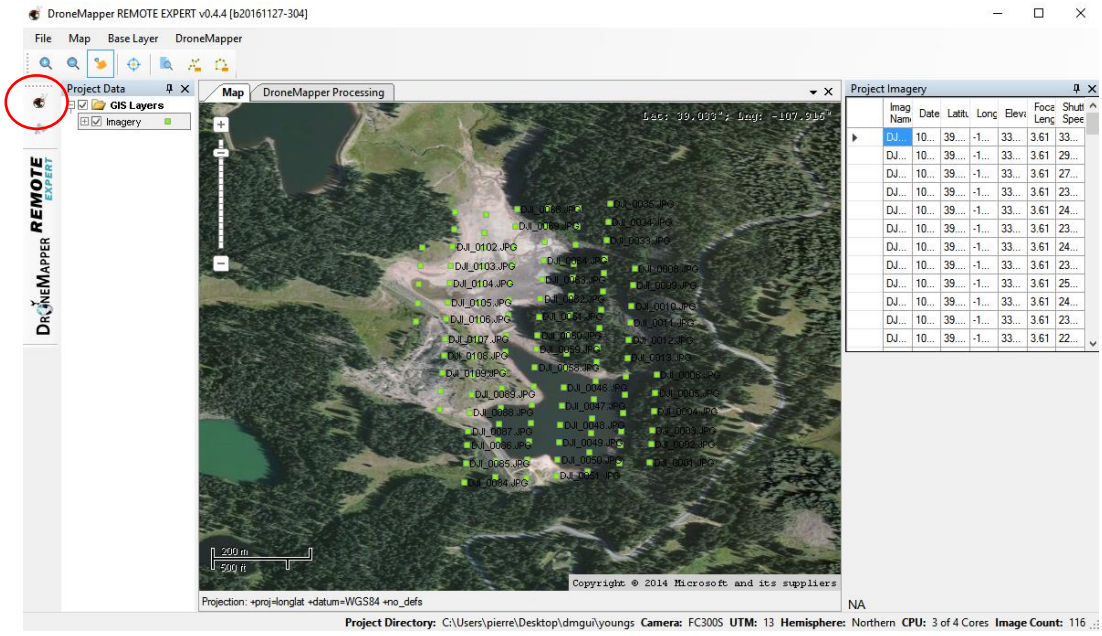
Once you have downloaded the module and activated using the licensing key, the software is ready for processing use. Open *DroneMapper.exe*.



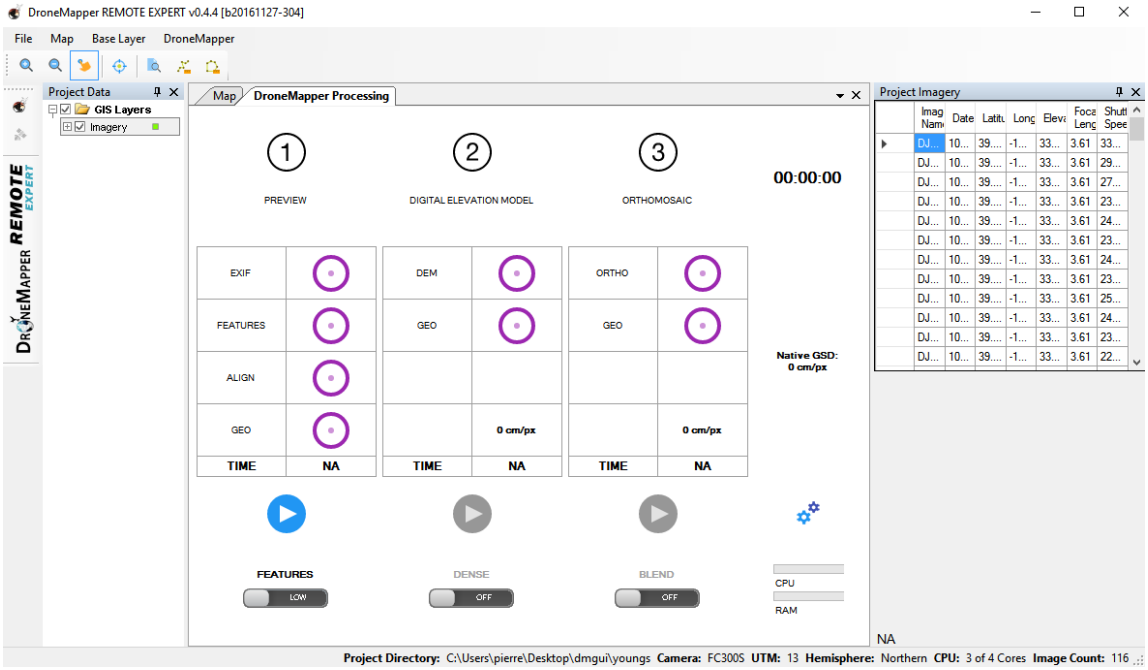
On the "File" dropdown menu select "Open JPGs" (circled in red) and navigate to the project image folder. Select the image folder to be processed.



A GIS layer will open under "Project Data" titled "Imagery" and each of the image geo-tags will be displayed using green markers. You can select a base map (Bing satellite or other) layer to show the image positions over the location on earth, as shown in the next screenshot.



Press the DroneMapper processing icon (circled in red) to launch the processing window. You will see a 3-step processing status table for the preview orthomosaic, Digital Elevation Model (DEM) and final Orthomosaic. Under each product status table there is a processing launch button (blue arrowed go button) and function switch (Features, Dense, Blend).



The following table illustrates which functions are available for each of the three versions of the application, RAPID for DJI, REMOTE and REMOTE EXPERT.

Feature/Function	Application Version		
	RAPID for DJI	REMOTE	REMOTE EXPERT
Image Input	< 75	< 400	< 1,000
Preview Features[1]	Yes	Yes	Yes
DEM Dense[2]	No, DEM at X8 native and Ortho at X4, default setting	Yes, DEM at X4 native when switched on and Ortho at X2	Yes, DEM at X4 native when switched on and Ortho at X2. DEM at X2 available when settings menu is used.
Orthomosaic Blend[3]	No	Yes	Yes
Experimental Image Alignment	No	No	Yes, used to accelerate the alignment process
High Res DEM/Ortho[4]	No	No	Yes, DEM at X2 native and Ortho at native
Generate Point Cloud	No	No	Yes
Histogram Matching	No	No	Yes
Force Image Feature	No		Yes
GCP Distance	No	No	Yes

[1] Feature switch is utilized when the user has an area of interest that is spatially homogeneous like forest or plant canopy, bare

ground, agricultural fields or possibly scenes flown very low that lack features from image frame to frame. The switch increases the image size used for tie point generation and will increase preview generation time if switched on.

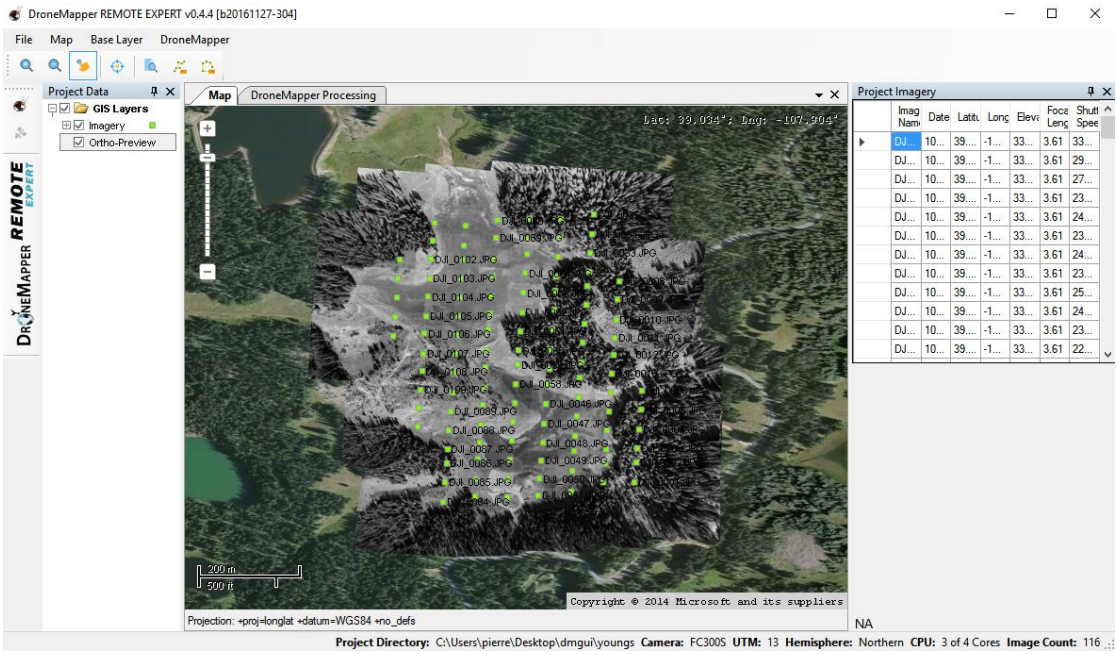
[2] DEM Dense switch toggles the DEM/Ortho from X8/X4 (off) to X4/X2 when switched on at the expense of additional processing time.

3 Orthomosaic Blend is switched on to minimize or remove tile seamlines for Ortho construction at the expense of additional processing time.

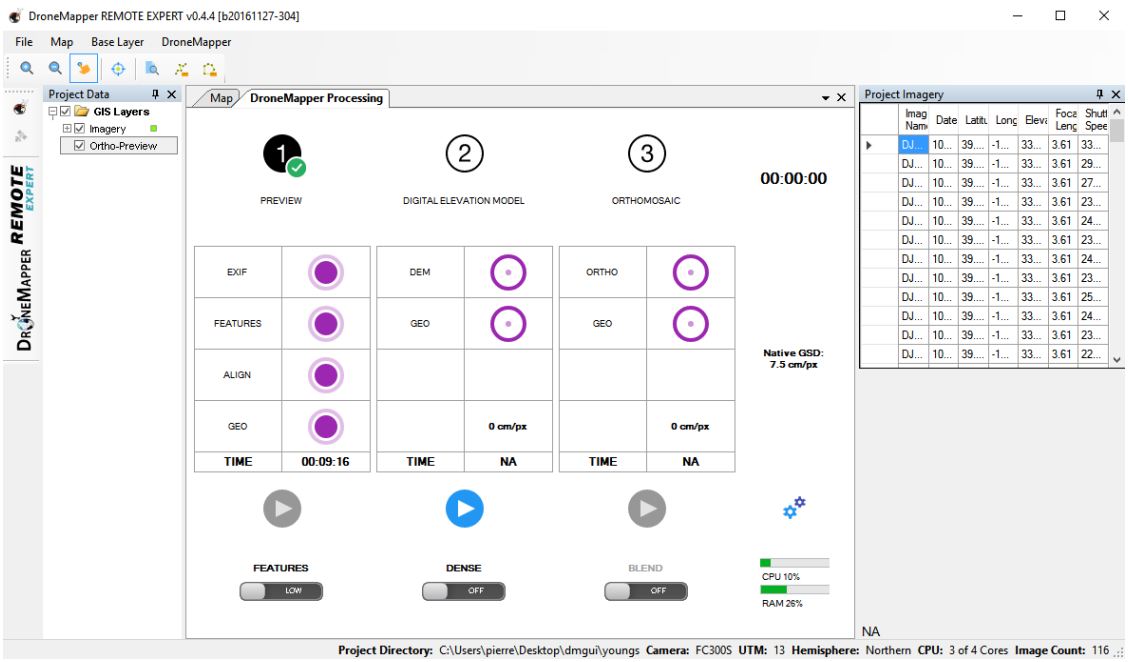
4 High Resolution DEM/Ortho (in settings menu) provides the DEM at X2 and the Ortho at native resolution. Processing will require significant time to complete.

Preview Orthomosaic

When the blue launch button is pressed the preview orthomosaic processing begins and when complete is illustrated in the next screenshot. The ortho preview GeoTiff is written as a GIS layer to the project data and displayed on the map tab.



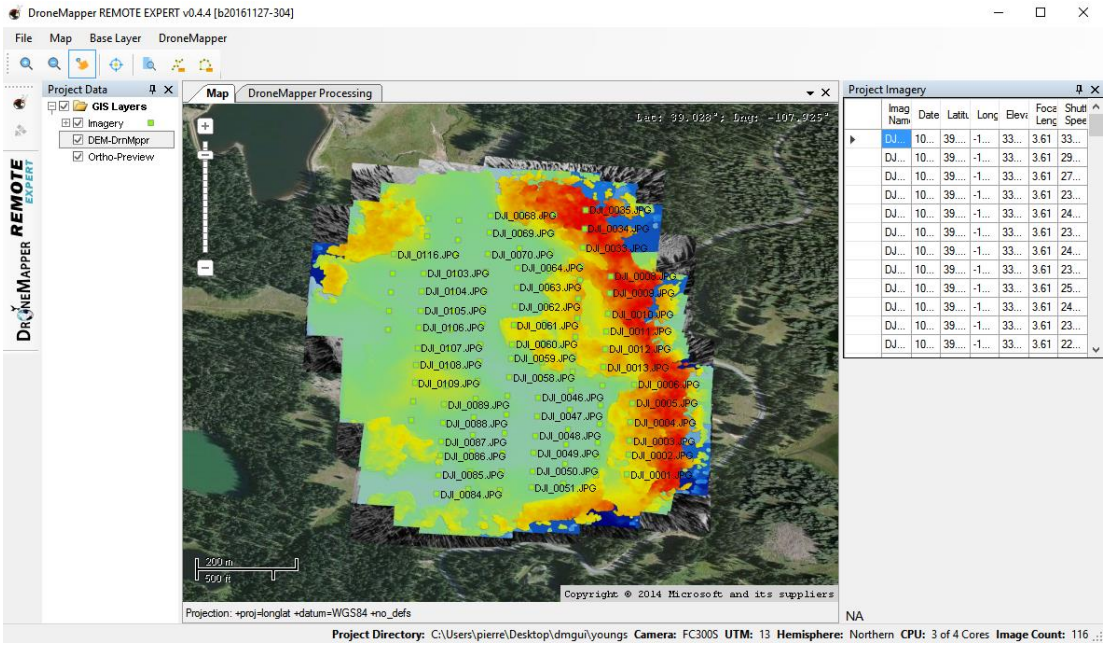
The image geo-tags are also shown superimposed over the ortho pre-view in the screenshot above. When the DroneMapper processing tab is selected the processing status window appears and shows ortho preview completion in 9 minutes, 15 seconds. All preview processing function steps, EXIF, FEATURES, ALIGN and GEO are shown complete using the purple filled targets. The native GSD of the imagery is computed and shown right of the status table. The application indicates that it is ready to go onto the DEM construction by activating the blue go button below DEM status.



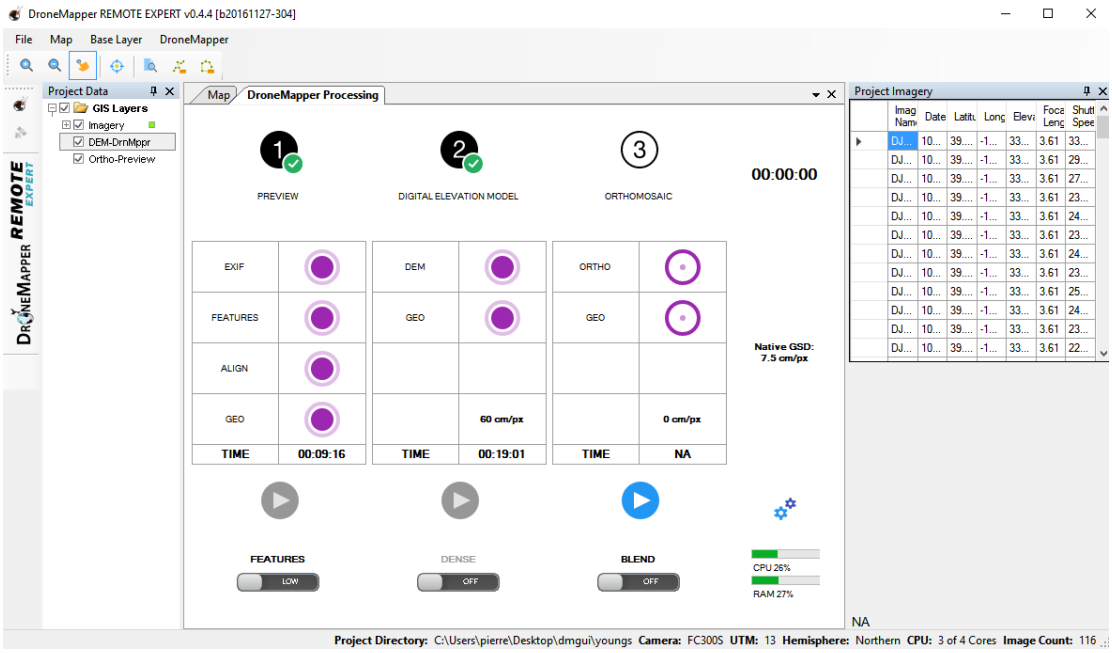
The ortho preview function provides near real time feedback to the user that all went well with the imagery collection by preview initial processing using image exif metadata, tie point generation, imagery alignment, camera calibration and geo-referencing. The user is provided high confidence at the collection site that the final DEM and ortho renderings will provide quality output at any scale selected.

Digital Elevation Model (DEM)

The DEM blue launch button in pressed next. The next screenshot shows the DEM rendering at X8 scale with image geotags superimposed on the map tab.

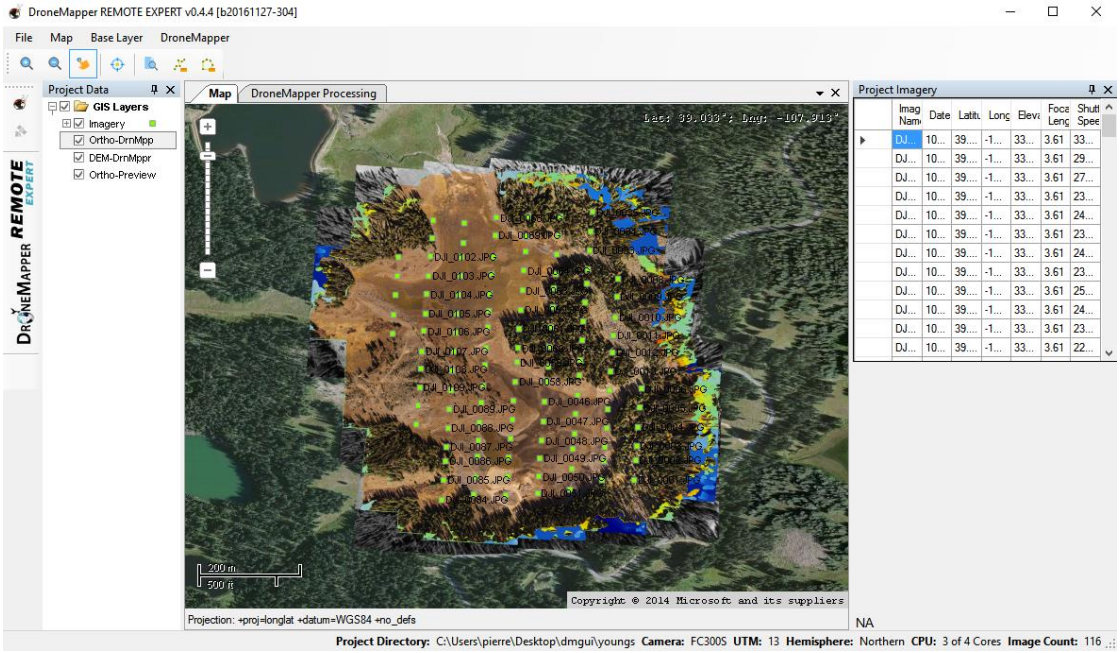


When the DroneMapper Processing tab is selected, the following screenshot shows processing status. DEM processing completed within 19 minutes.

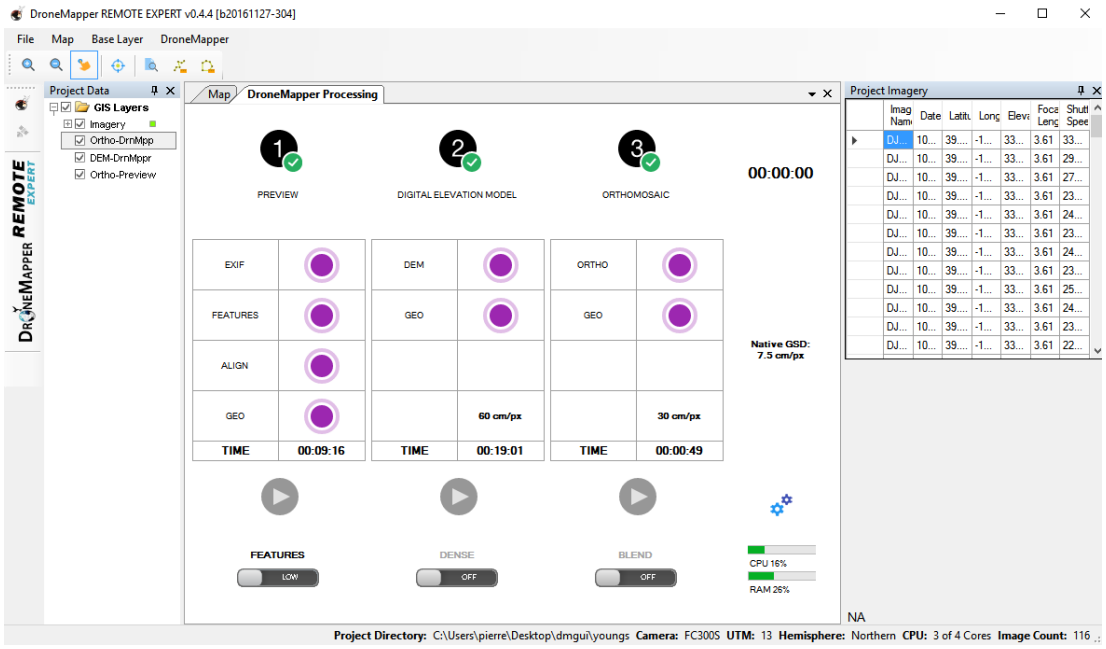


Orthomosaic

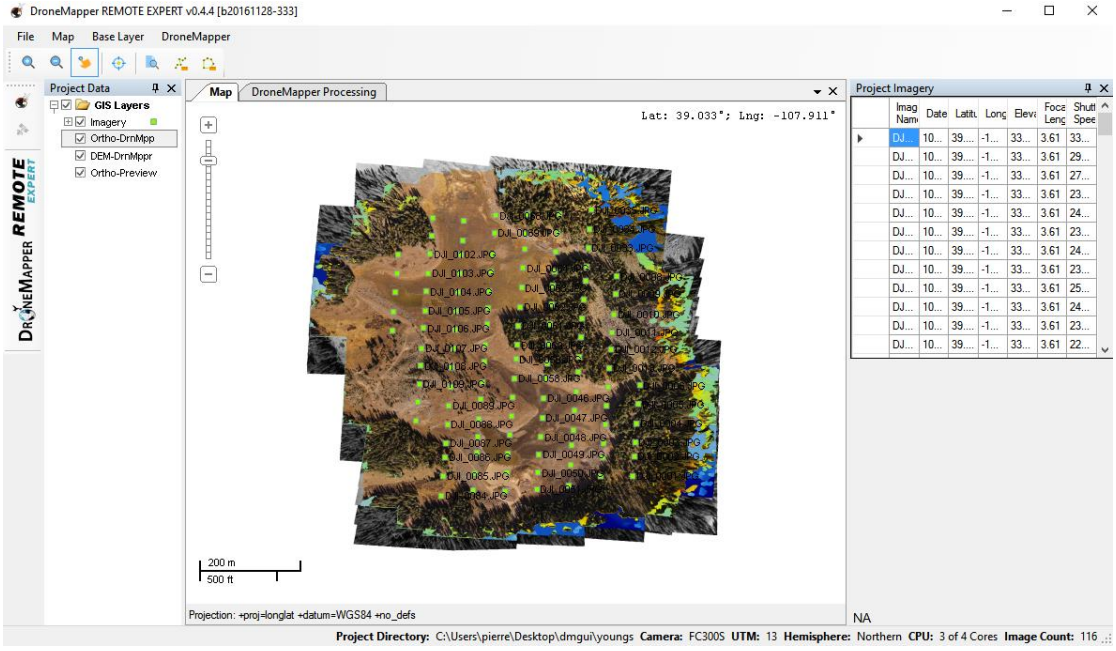
The ortho is ready to be completed by activating the blue go button under orthomosaic status. Completed orthomosaic at X4 scale is shown in the next screenshot.



The blend function was not activated for ortho construction so there are a few seamlines at tile-to-tile boundaries. For this example, the user preferred the fastest product generation possible at the expense of ortho visual quality. The next screenshot illustrates project completion and an ortho run time of 49 seconds. Entire project of 116 images required 29 minutes.



When the blend function is activated for orthomosaic processing the next screenshot illustrates the resulting ortho rendering.



Seamlines have been blended at the expense of an additional 5+ minutes of processing time. The next two illustrations compare the ortho results, unblended and using blending, rendered within Global Mapper.

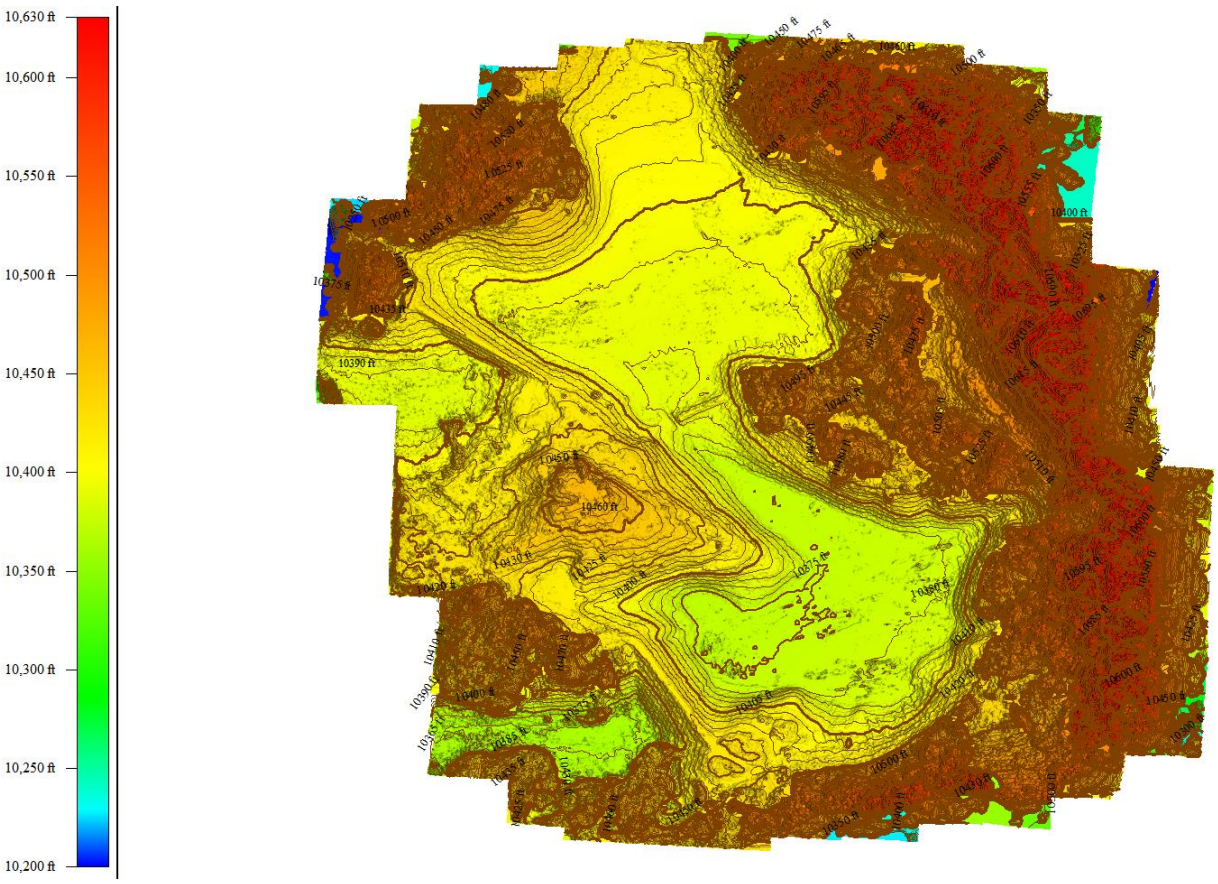
Ortho example unblended: run time – 42 seconds

Ortho example blended: run time – 6 minutes, 26 seconds

If a visually appealing orthomosaic is desired, the user can use this feature to render it with some additional time required in processing.

Scaled DEM Utilization

For applications requiring very quick turnaround (maybe at the site) combined with accurate relative elevation to generate local topography, contours and/or volumetric estimates, the scaled DEM (X8) can be used to provide this. The next illustration shows our example X8 scaled DEM with 5' contours generated within Global Mapper.



Contours are computed within 5-10 seconds and are readily used for generating volumetric capacity estimates as a function of water elevation for this reservoir mapping example.

Selectable Settings

There are two levels of setting configurations that control the processing algorithms and the resultant outputs.

DroneMapper Processing Tab Settings

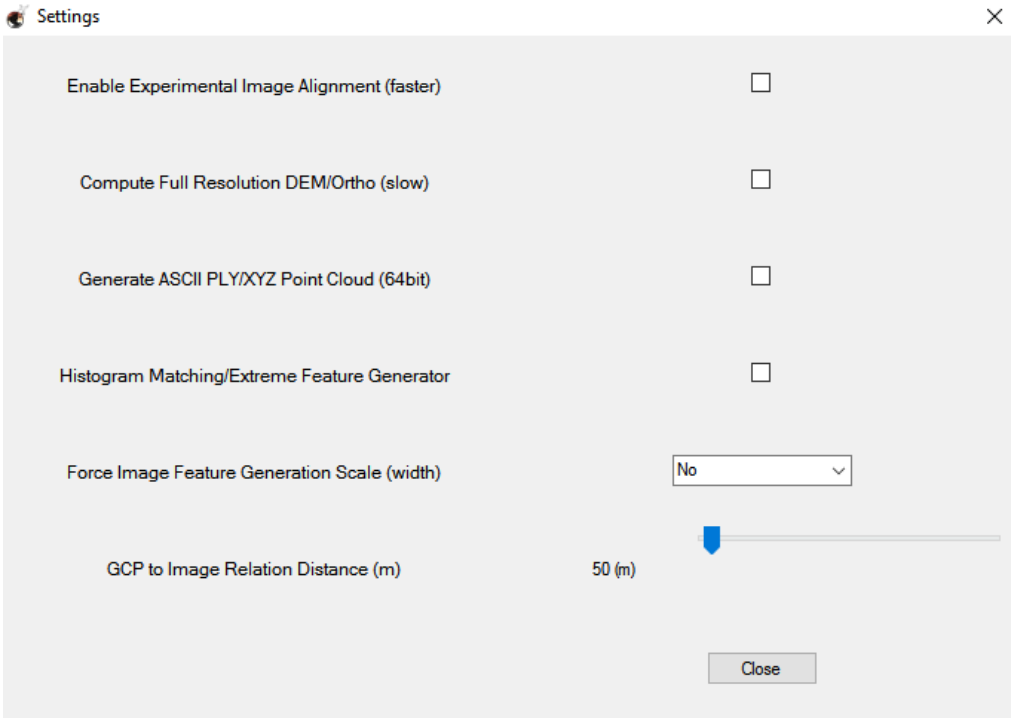
Preview Features allows the user to select between low and high, default is low. The switch from low to high increases the image size used for tie point generation and will increase preview generation time. For scenes that are very homogeneous (lacking features) switching to high may assist in generating image-to-image tie points. All versions of the application provide *Preview Feature* selection.

Digital Elevation Model Dense allows the user to select DEM and ortho construction scale. In the "off" position the DEM will be constructed at X8 and the ortho at X4 native resolution. When switched "on" the DEM will be constructed at X4 and the ortho at X2 native resolution. The resultant time to construct the DEM and ortho will increase. RAPID for DJI is constrained to DEM at X8 and the ortho at X4 scale only. REMOTE DEM/ortho output scale is selectable between X8/X4 and X4/X2 using the *Dense* switch. REMOTE EXPERT provides selectivity of DEM/ortho scale at X8/X4, X4/X2 and native resolution. Additional settings functionality to be used for DEM/ortho construction will be discussed later under *DroneMapper Settings.*

Orthomosaic Blend allows the user to select orthomosaic radiometric blending to minimize/ eliminate tile seamlines at the expense of additional processing time as discussed in the above example. *Blend* would be utilized when the user desires a visually pleasing rendering of the orthomosaic.

DroneMapper Dropdown Settings

By clicking DroneMapper on the top menu banner and selecting "Settings" the user will see the following dropdown menu. All options are available in REMOTE EXPERT.



REMOTE is limited to the *Histogram Matching…* and *Force Image … Scale* functions. RAPID for DJI has all functions shown deactivated. A brief description of the functions follow:

Enable Experimental Image Alignment (faster): If selected this function will shorten the preview ortho generation time by using an alternate image alignment algorithm… (currently disabled)

Compute High Resolution DEM/Ortho (slow): Selection of this function enables the application to fully process the DEM and ortho at the highest resolution available. DEM and ortho generation time will be lengthy dependent on the number of images to be processed.

Generate ASCII PLY/XYZ Point Cloud (64 bit): Selection of this function enables the application to generate a point cloud and write the file to the project folder.

Histogram Matching/Extreme Feature Generator: This function is available in REMOTE and is used when the preview ortho "Features" function in high mode was unable to generate the preview. This can occur when processing very homogeneous scenes that lack features for tie points.

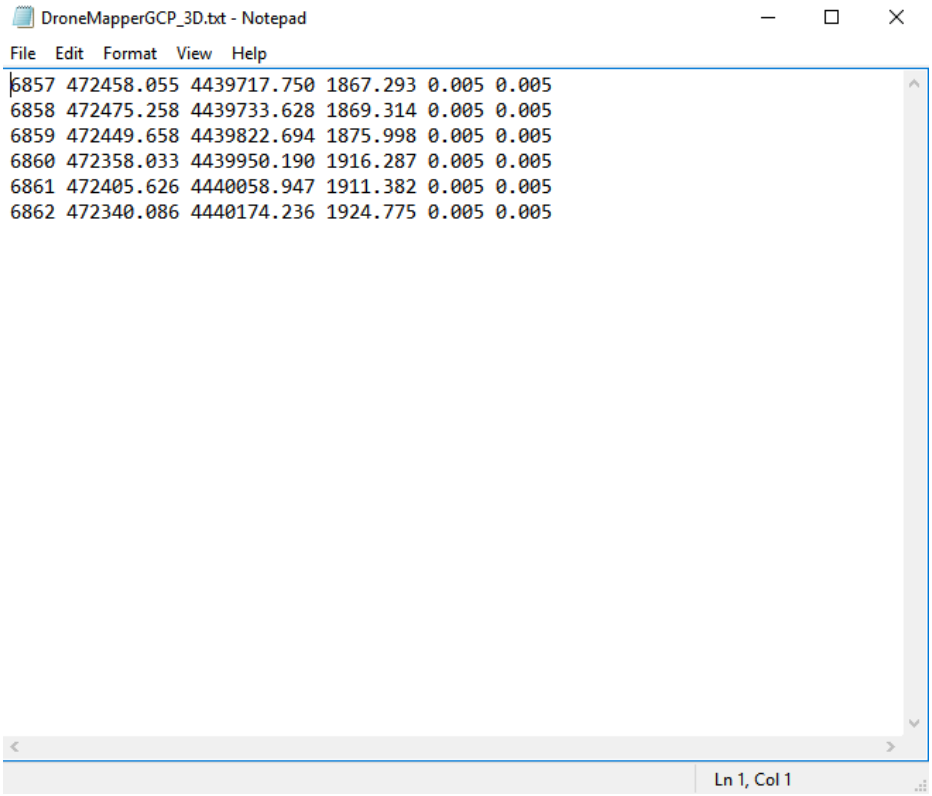
Force Image Feature Generation Scale (width): This function is also available in REMOTE. The function increases the image width to be used for tie point feature extraction. The default mode is 500-pixel width. With "Features" in high mode the image width is increased to 1,250 pixels. User may select from half image to full image width by selecting this function.

GCP to Image Relation Distance (m): Only available in REMOTE EXPERT, this function is used when ground control points (GCPs) are to be incorporated in the image processing. The distance slider is used to set the radius about the GCP for image association or relation during the 2-D GCP file generation function. The smaller the radius selected the fewer the images associated with each GCP. If the slider is set to a very large distance then it is possible to associate all images with every GCP, making the 2-D GCP file generation very time consuming. Example use will be discussed in the next section.

Ground Control Point (GCP) 2-D File Generation

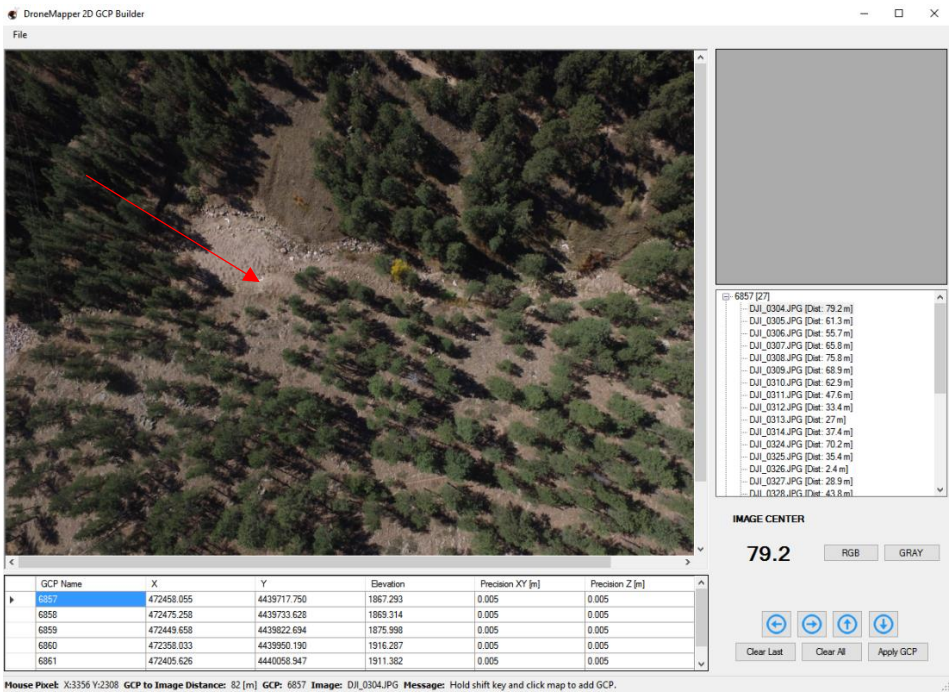
For mapping applications that require absolute geo-spatial accuracy REMOTE EXPERT provides full processing with the use of GCPs. There are two additional files required along with the project imagery to make full use of this important function. The first file is the **DroneMapperGCP_3D** text file.

An example file is shown below:

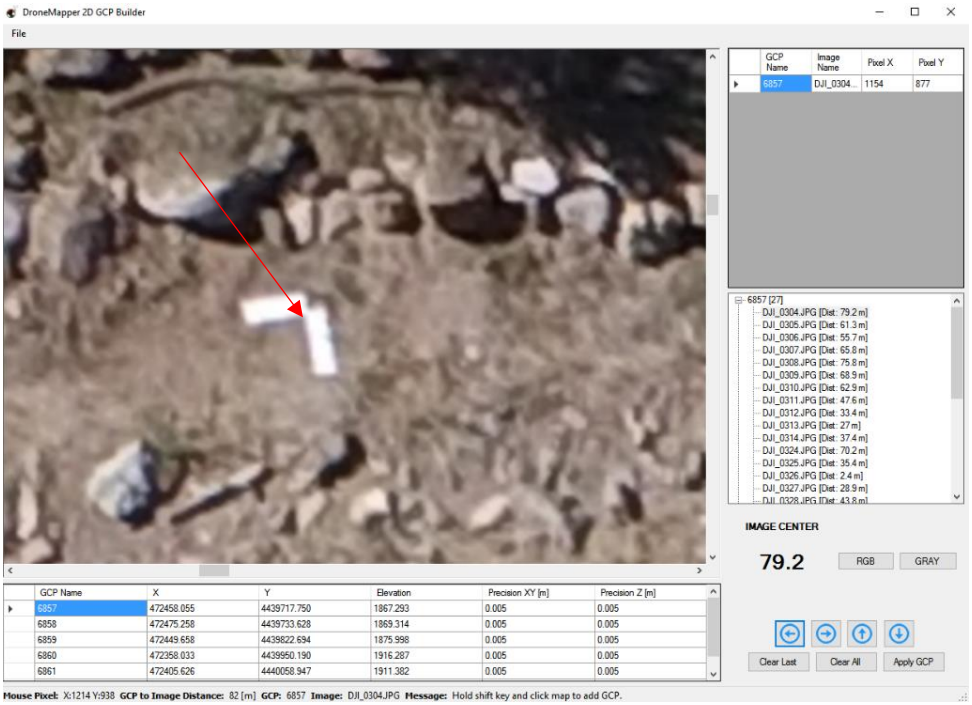


This text file contains 6 columns of data, each row spaced delimited. Let's look at the first row: the first entry is the GCP name (6857), followed by a space. The second entry is the easting coordinate in **UTM (zone) WGS84, meters** (472458.055), followed by a space. The third entry is the northing coordinate in **UTM WGS84** (4439717.750), followed by a space. The fourth entry is the elevation in **meters** (1867.293), followed by a space. The fifth (horizontal) and sixth (vertical) entries are the survey precision (0.005), separated by a space. This point was surveyed with an accuracy of 5 mm. Each GCP to be used in processing is listed in the remaining rows. Once completed, save this file as **DroneMapperGCP_3D.txt** within the project imagery folder.

When the application is opened and JPGs are loaded the user will see the following window after clicking on the GCP tool beneath the DroneMapper go icon:



An associated image (for GCP 6857) is illustrated with all GCPs listed below and all images associated with the GCPs tabulated to the right. The user zooms in on the image and places the pointer on the GCP surveyed position, presses shift and clicks the mouse button for selection as shown in the next screenshot:



The inside corner of the "L" was selected as the surveyed point. At the top right hand corner of the screenshot the pixel selected in that image is recorded. After selection of the pixel the next image in series for that GCP is displayed. The same process is repeated until all images for that GCP have had pixels identified. The blue down arrow is pressed to move onto the next GCP and the process repeated until all images are associated with GCPs and image pixels have been selected. Once completed click on the "Apply GCP" icon and the **DroneMapperGCP_2D** text file will be written to the project image folder.

Tips, Suggestions and Cautions

Here are a few tips/suggestions/cautions to help quickly generate the GCP 2D file without errors. **One error in the file generation will cause processing to abort.**

- Make certain that the GCP the user is zooming in on for pixel selection is correctly identified in each image it is selected. For instance, the GCP example (6857) above is near GCP 6858. See the illustration below:

You'll see a sandy wash area with GCP 6857 on the north side near a few rocks. Another GCP, 6858, is south (near the center of the image) in the sandy area of the wash. Because the GCPs are so close multiple images will contain both – correct identification in each image is critical. One method to help identify the correct GCP is to utilize the estimated distance from frame center (shown in parenthesis) next to each image in the list. Scroll down to the image with the smallest distance and confirm the GCP is near frame center. Take note of any features around that GCP so that it is positively identified in each image it appears.

- For this example, the imagery was acquired at 5 cm GSD using a 12 Mpixel format sensor. The distance slider was set to 80 meters and resulted in approximately 30 images identified with each GCP. If the slider is set to 50 meters approximately 10-15 images would be associated with each GCP, making the pixel selection process more efficient. In any case, at least 5 images should be associated with each GCP.
- Make sure aerial targets are large enough (compared to expected GSD) and their geometry is unambiguous as to where the surveyed point is. In this example, white surveyor tape 6" wide by

1-2' long is used in an "L" configuration. The inside of the "L" is the point that has been ground surveyed and used consistently in picking image pixel location. At least 3 pixels (GSD = 2") fall across the target width and many more along its length to resolve the target.

- Observe where the GCP is located within each image frame. You want to use the GCP and associated image when the GCP falls within the central 75-80% of the image frame height and width. Skip the images that have the GCP near the frame edge or border assuming you can still meet the minimum 5 images per GCP.

Scaled DEM and Orthomosaic Accuracy using GCPs

An open pit mining operation imagery collection is used to demonstrate the use of GCPs and resultant accuracy of the DEM and ortho products. This example consists of 504 images collected with a DJI Inspire I for an area of interest of approximately 257 acres. **The image native resolution was 7.5 cm.** We ran this example in REMOTE EXPERT at two different scale factors – 1) DEM at X8 and Ortho at X4, 2) DEM at X4 and Ortho at X2 and used an existing DEM and Ortho previously run at native resolution. We then measured the GCP geo-spatial positions on the DEM/Ortho and calculated the root mean square errors (RMSEs) for horizontal and vertical positions. The table below shows the results for each of the three cases. The table also shows the run time and resultant DEM/Ortho file sizes.

Parameter/Case	DEM X8/Ortho X4	DEM X4/Ortho X2	DEM & Ortho Native
$RMSE_{horizontal}$	5.7 cm	4.4 cm	3.4 cm
$RMSE_{vertical}$	10.4 cm	6.2 cm	4.5 cm
Total Process Time (hr:min)	2 hr:14 min	5 hr:18 min	~ 23 hours
DEM/Ortho File Size (MB)	11.4/46.3	39.3/159	730/280

As the table indicates all RMSEs are sub-pixel except for vertical for the X8/X4 case. There is some RMSE improvement for the GCP horizontal positions as processing approaches native resolution. For planimetric applications the user may want to choose quicker processing at the expense of horizontal positional accuracy degradation. It depends on the overall positional requirements on a job-by-job basis. For example, if the job requires 6" absolute horizontal positional accuracy for planimetric features then the X8/X4 scaled outputs should suffice with margin. If, however, the positional requirement is 3" or less then the user would either process the imagery at native or would need to collect at higher ground resolution or GSD. In this example the vertical RMSE for the X8/X4 case exceeds one pixel – 10.4 cm with a GSD of 7.5 cm. This may be acceptable if the job required accurate 1' contours. Accurate, smaller elevation interval contours, i.e. 6", would dictate higher resolution processing along with the extended processing time.

Limitations

This application software is designed for projects involving surveying, construction, mining, cadastral, precision agriculture, water resource management, utility management and other markets that require insight into imagery geospatial knowledge for informed decision making. The application, as released, has limitations for scenes that are traditionally difficult for photogrammetry. These may include heavily vegetated and/or extremely homogeneous terrains where feature tie points are difficult to identify and DEM construction is limited by imagery lighting and vegetation obscuration factors. In these cases, please contact DroneMapper either by phone, e-mail or forum to discuss the application, issues encountered and possible solution(s) to consider.

Feature/Function Benefits

• Orthomosaic preview – facilitates review of acceptable imagery collection at the site, prior to equipment pack-up, by generating the preview in near real time. In many cases the preview will help identify holes in coverage, issues with image geo-tagging and poor quality imagery (blur and other imagery artifacts that hamper proper processing) before you leave the scene.

• Lineal and area measurements for overlap verification and scene coverage.

• Selectable scaling of the DEM appropriate for the project requirements. If 1-2' contours and/or volumetrics are required, then a X8 DEM may be suitable for the quickest turn around and acceptable accuracy. If finer detail is desired, then X4 and X2 DEMs are selected at the expense of processing time.

• Selectable scaling and blending of the orthomosaic for scene feature identification and production of a visually pleasing (minimal to no seamlines) scene.

• DEM and orthomosaic sub-pixel root mean square error (RMSE) of GCPs in horizontal and vertical - facilitates accurate planimetric and 3-D measurements.

• 64-bit point cloud provided for feature classification, editing and DTM generation.

• Robust processing algorithms tolerant of minimal imagery overlap. Allows user to close the loop on operations platform, camera/lens and mission planner to minimize overlaps for high efficiency collects over larger areas, quick processing turnaround times and high quality output.

Limitation of Liability

DroneMapper and its affiliates are not liable to you for any consequential, special, incidental, or indirect damages of any kind arising out of the delivery, performance, or use of the RAPID for DJI, REMOTE or REMOTE EXPERT software applications.

REMOTE Support

DroneMapper will provide technical and troubleshooting support for the REMOTE and REMOTE EXPERT applications. You may call, e-mail or visit the REMOTE forum to report any issues observed or make suggestions for changes or new features. DroneMapper will make every effort to respond in a timely manner. We will continue to improve the applications using your feedback.