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Department of Environment and Natural Resources
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MEMORANDUM

FOR : All DENR Regional Executive Directors
All Provincial Environment and Natural Resources Officers
All Community Environment and Natural Resources Officers

FROM : The Assistant Secretary for Policy, Planning and Foreign Assisted and Special Projects and Director, in concurrent capacity

SUBJECT : **TECHNICAL BULLETIN NO. 35: PROTOCOL ON THE USE OF QUADCOPTER REMOTELY PILOTED AIRCRAFT (RPA) IN THE MONITORING AND ASSESSMENT OF FORESTRY, ENVIRONMENT, AND NATURAL RESOURCES PROGRAMS AND PROJECTS**

DATE : APR 30 2021

I. Users of the Technical Bulletin

This technical bulletin shall guide the Department's Community Environment and Natural Resources Offices (CENROs), Provincial Environment and Natural Resources Offices (PENROs), and Regional Offices in adopting the use of Quadcopter Remotely Piloted Aircrafts (RPA) for the monitoring and assessment of forestry, environment, and natural resources programs and projects.

RPAs are more efficient and cost-effective in covering large areas for monitoring and assessment. With the proper sensors onboard, RPAs can capture high-resolution digital images/videos in a single flight. RPAs are also becoming practical solutions for monitoring sites that have limited accessibility due to rough terrain and security issues. RPAs are also being used in a wide range of civilian applications including resource management, precision agriculture, urban planning, and disaster mitigation.

II. Scope and Limitations

Protocols cited in this technical bulletin shall apply to Quadcopter RPAs only. Other types of RPA such as fixed-wing and Vertical Take-Off and Landing (VTOL) aircraft shall not be covered in this technical bulletin.

Moreover, this technical bulletin shall not cover the use of RPAs for video documentation of forestry, environment and natural resources programs and projects.

III. Definition of Terms

For this technical bulletin, the following definition of terms shall be adopted in consonance with the existing rules and regulations of the Civil Aviation Authority of the Philippines (CAAP) Memorandum Circular No. 29 Series of 2015.

a. **Authority:** Refers to the Civil Aviation Authority of the Philippines.
b. **Client:** Refers to any person or organization requesting RPA technical assistance. It may be internal (clients within the Office) and external (clients outside the Office but within the Department).
c. **Department:** Refers to the Department of Environment and Natural Resources
d. **Digital Elevation Model (DEM):** Refers to the representation of the topographic bare-earth surface.
e. **Front Overlap:** Refers to overlap between consecutive photographs captured along the same flight line.
f. **Geographic Information System (GIS):** Refers to the framework for gathering, managing, and analyzing spatial data to generate information, visualize patterns, and make better decisions.
g. **Head of Office (HOO):** Refers to the chief executive of an agency who supervises the office.
h. **Home point:** Refers to the location recognized by the RPA as launching and landing point in case of activation of fail-safe mechanism.
i. **Keyhole Markup Language (KML):** Refers to the file format used to display geographic data in an Earth browser such as Google Earth.
j. **Key Person/s:** Refers to governing bodies (e.g., LGUs and uniformed personnel) that need to be informed prior to the conduct of RPA missions.
k. **Orthomosaic:** Refers to a geographically referenced image product stitched from an image collection, where geometric distortion has been corrected and the imagery has been color balanced to produce a seamless mosaic dataset.
l. **Quadcopter:** Refers to RPAs with four propellers.
m. **Remotely Piloted Aircraft (RPA):** Refers to any unmanned aircraft which is piloted from a remote station. It is also synonymous with aerial drones and unmanned aerial vehicles (UAV).
n. **Resource Manager:** Refers to the person responsible for allocating appropriate resources necessary for the intended conduct of RPA missions.
o. **Side Overlap:** Refers to overlap between photographs in adjacent parallel flight lines.
p. **Target Area:** Refers to the area where the RPA will be capturing images.
q. **Tagged Image File Format (TIFF):** Refers to a common GIS raster data format that can support georeferencing information.

IV. Designation of Resource Manager/s and Creation of Remotely Piloted Aircraft (RPA) Team/s

The head of the office (HOO) shall issue a Special Order designating the Resource Manager/s, and to create the Remotely Piloted Aircraft (RPA) Team/s of the office.

a. Resource Manager

The designated Resource Manager (RM) and an alternate shall act as the property custodian of all relevant equipment to be used and forms to be filled out for RPA missions. Both RM and alternate must hold a permanent position in the Department

and have RPA training certificates issued by a technical service provider certified by the Authority.

b. Remotely Piloted Aircraft (RPA) Team/s

Each RPA Team should be composed of not more than four (4) DENR field office personnel. All members of the identified RPA Team must have RPA training certificates issued by a technical service provider certified by the Authority and have sufficient knowledge on RPA missions to better facilitate flight mission execution. The team members' roles and responsibilities are as follows:

i. **Team Leader** – Responsible for: (1) making critical decisions in the delivery of the mission; (2) ensuring that flight procedures are observed; (3) ensuring that the acquired data is accurate and compliant with the mission objectives; (4) securing the RPA Team's safety; and (5) conduct of overall mission outcomes.

   The Team Leader must hold a permanent position in the Department and preferably has a RPA Controller Certificate issued by the Authority.

ii. **Telemetry Officer** – Responsible for: (1) designing the flight plan; (2) assisting the Controller in monitoring and providing regular feedback on the status of the RPA's power, voltage, location, and other crucial system parameters for the entire duration of the mission; and (3) conducting partial processing of flight logs.

   The Telemetry Officer must have completed at least basic training in Geographic Information System (GIS).

iii. **Controller** – Responsible for: (1) executing the flight plan, (2) launching and manually landing the RPA unit, (3) conducting pre- and post-flight checking, and (4) maintaining and storing the RPA unit.

   The Controller preferably has an RPA Controller Certificate issued by the Authority and knowledgeable in the fail-safe mechanisms of the RPA.

iv. **Spotter** – Responsible for: (1) maintaining the Visual Line of Sight/Beyond Visual Line of Sight (VLOS/BVLOS) of the RPA unit; (2) monitoring the approximate course, heading, and location of the RPA unit based on the horizon and telemetry readings; (3) looking out for surrounding obstructions, obstacles, water/wet areas, and potential crowd sources that could pose threats to the mission during launching and landing.

   The Spotter must have sufficient knowledge of the target area and knowledgeable in the fail-safe mechanisms of the RPA.

In case of a shortage of field personnel, a flight mission deployment shall be composed of not less than two (2) personnel with the following roles: (1) Team Leader also acting as the spotter, and (2) a Telemetry Officer also acting as the Controller.

V. Client Requests and Mission Objectives

Client requests should be properly addressed to the head of the office (HOO) who will endorse the request to the Remotely Piloted Aircraft (RPA) Team for their appropriate action. Clients shall fill out the RPA Data Acquisition Request Form to further evaluate the inquiry (see **Annex 1**).

The RPA Team shall invite the client for a meeting to further discuss the RPA mission's details. The flight mission objectives shall be set based on the client's request and to understand the current situation of the target area. These objectives shall determine if the goal of the mission was attained and the client's inquiry is satisfied. Key persons needed to be informed on the conduct of RPA mission must also be identified to prepare necessary letters and permits before proceeding with the mission (see **Annex 2**).

VI. Pre-Flight Operations

a. Flight Mission Planning

The flight mission planning shall be performed by the designated Telemetry Officer using a combination of a Flight Mission Planning software (e.g., Ground Station Pro, Drone Deploy), a geographic information system (GIS) software (e.g., ArcMap, QGIS), Google Earth Pro and Google Instant Street View.

The target area can be modified using the preferred GIS software while Google Earth Pro will provide satellite imagery for the base map and elevation data, and the potential launching and landing points in the target area. Possible vehicle/s take off and RPA launching and landing sites can be viewed and identified using Google Instant Street View if street view data is available.

Lastly, flight parameters such as flight speed, altitude, angle, camera details, and overlap ratios must be supplied in the flight mission software to generate information such as estimated flight mission duration, number of images, image resolution, and number of strips. These information are essential in determining the number of resources and equipment (i.e., number of batteries, memory card, and backup RPA unit) needed during flight mission execution. **Annex 6** provides images of the flight parameters to be supplied using a flight mission planning software.

Since a quadcopter RPA has its flight limitations, the following parameter settings are recommended to optimize every flight mission:

Parameter	**Setting**
Front Overlap Ratio	At least 60%
Side Overlap Ratio	At least 50%
Flight Height	At least 100 meters above from the highest point within the target area
Flight Distance	At most one (1) kilometer from the home point or within VLOS/BVLOS

Parameter	Setting
Flight Duration	At most twelve (12) minutes
Flight Orientation	Should be along the longer dimension of the target area

Weather conditions in the target area must be checked to determine the approximate time of the day most suitable for flight. Weather forecasts for the area can be obtained from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) website and AccuWeather and Windy.com mobile applications/websites. Aside from the general weather (sunny, rainy, etc.) for each day of the mission, conditions such as the chance of precipitation (rain), cloud cover (percentage), wind direction, and speed must also be considered. It is imperative to regularly check the weather conditions in the target area since it is most likely to change as the target date for the mission approaches.

The Telemetry Officer should come up with at least two flight plans (main and backup plans) for the mission. When covering a large target area, the RPA Team should come up with several sub-flight plans to execute the mission. The Flight Planning Checklist (**Annex 3**) and Actual Flight Plan Form (**Annex 4**) form must be filled out by the Telemetry Officer.

After formulating flight plans, the RPA Team shall discuss the tentative flight plans and modify them as deemed necessary.

b. Pre-Deployment

The Controller shall coordinate with the Resource Manager regarding the number of RPA units and equipment needed for the mission. The Controller shall fill out an Equipment Checklist (see **Annex 5**) to ensure that all equipment needed for the mission are checked.

The RPA Team should ensure that all components of the system are complete and functioning (i.e., fully charged and calibrated). The RPA Team should also consider bringing spare batteries, memory cards and a laptop to be used for the partial processing of the orthomosaic.

Flight plans must be finalized and backed up. Transportation, establishment of headquarters, and other logistical concerns should also be arranged and finalized.

c. Coordination and Site Inspection

Key persons in the target area must be identified and notified on or before the flight day. The RPA Team should first proceed to the respective DENR offices (Regional, PENR, and CENR Offices), then to the local chief executives (municipal- and/or barangay-level) of the area. Other key persons identified should also be properly coordinated with to ensure the safety and flight mission execution of the RPA Team.

Key persons should be informed with the objective/s and logistics of the mission to address other considerations that may have been overlooked by the RPA Team. Key

persons may designate their personnel to accompany the RPA Team on the actual flight day.

Potential launching and landing sites must be inspected prior to the conduct of mission to determine its appropriateness. The following should be considered: launching and landing site dimension; terrain suitability; signal interference; and surrounding obstructions (structures, towers, etc.). Possible sources of crowds such schools or residential areas must also be checked to ensure the safety of the residents within the area. If the most suitable launching and landing sites are within a private property (farm, road, lot, etc.), the owner shall be considered as a key person and must grant the RPA Team permission to enter and use the site before executing the mission.

d. Revision of Flight Plans

Flight plans should be revisited and adjusted based on the coordination with key persons and observed situations during ocular inspection. Weather conditions must be re-checked to incorporate major changes (rain, thunderstorms, etc.).

e. Mission Briefing

The RPA Team shall internally discuss the overall flow of the mission and come up with alternative plans in case the original plan will not materialize due to unforeseen circumstances (security issues, inclement weather, etc.). The roles and responsibilities of each member shall also be revisited by the Team Leader.

f. Launching Sequence

Upon arrival at the launching site, the RPA Team will clear the designated launching and landing area from any debris or obstruction. The Controller and Spotter shall check the RPA parts (propellers, screws, etc.) and payloads (camera, battery, tracking device, etc.) and ensure that these are securely installed. Extra caution must be observed during the installation of the propellers. At this point, the radio-controlled transmitter (RC) should not be in anyone's hands to avoid any untoward accidents while inspecting the installation of the RPA unit. The center of gravity (CG) of the RPA unit must be established through visual inspection and (re)alignment of the battery pack, if necessary.

The Controller will turn on the RC first followed by the RPA unit to commence the initialization process. The Telemetry Officer will connect the RC to the RPA unit and observe the parameters (gyro sensor status, GPS reception, etc.). If a parameter is noted as "bad" (ex. "bad gyro health"), re-initializing the RPA unit is necessary. After successful initialization, the Telemetry Officer will check and load the flight plan from the RC to the RPA unit for transmission. The RPA unit will be "armed" by the Controller at this point. Sample images of a successful initialization are provided in **Annex 6**.

The Controller must check if the payload is functioning by triggering the "*Photo Capture*" button using the RC. If the RPA unit is not capturing any photos, re-initializing the RPA unit and re-installing the memory card is necessary.

The Controller will manually launch the RPA unit and execute basic controls and various flight modes using the RC to ensure the RPA unit's excellent response to each command. The Telemetry Officer will confirm if each command was successful. Finally, the Controller must establish the home point before executing the flight mission.

VII. During Flight Operations

The RPA unit should be launched in the opposite direction of the prevailing wind to attain additional lift. As the RPA unit continues to gain elevation, the Telemetry Officer will call out the RPA unit's status such as altitude, power draw, and voltage. He/she will also monitor the progress of the RPA unit and provide regular call outs to the RPA team as the RPA unit enters and exits the flight lines and waypoints in the mission plan. The Spotter will maintain VLOS starting from the launching of the RPA unit.

Once the RPA unit is BVLOS, the Controller will monitor the status and progress of the RPA unit together with the Telemetry Officer. The Spotter will continue to monitor the RPA unit with the aid of ocular instruments to keep it from crowds and other disturbances.

In most cases, the prevailing weather elements (wind, temperature, etc.) in the target area are different from the launching and landing sites. These will influence the movement and performance of the RPA unit. For example, the RPA unit will face resistance from strong winds that may increase in power draw. The Telemetry Officer must be attentive for this increase in power draw. When the battery life of the RPA unit reaches thirty percent (30%), the Team Leader should decide whether to continue or abort the flight mission and recall the RPA unit to the landing site. The Spotter will have to monitor the location of the RPA unit and be prepared for the landing sequence as discussed by the RPA Team. In case of an emergency where flight the must be ended abruptly, the Controller must be prepared to manually take over the RPA unit and land it safely.

In case of signal interference that may or may not result in any untoward incident to the RPA unit during data acquisition, the Controller must remember the last location of the RPA unit before it got disconnected. Disconnection happens occasionally when there is strong signal interference. If the RPA unit does not reconnect with the RC within the next 10 minutes, the RPA Team must prepare for a search and retrieval operation.

In case of loss, stolen, damaged or destroyed RPA unit during flight missions, the RPA Team must comply with the existing reporting rules and regulations stipulated under Section 41 of the Government Accounting Manual Volume 1.

VIII. Post-Flight Operations

a. Landing Sequence

The Telemetry Officer will call out the last strip/portion where the RPA unit will pass. The Controller and the Spotter will acknowledge the signal and prepare for landing. As the RPA unit exits the last waypoint, the Telemetry Officer will alert the Spotter to monitor and estimate the direction where the RPA unit will be arriving.

The Telemetry Officer will call out the altitude of the RPA unit as it descends. The Controller and Spotter must confirm if they both have the RPA unit in visual range. Once the RPA unit is approximately above the home point, the Controller will then switch the RC to "*Attitude*" mode to maneuver the RPA unit into the designated landing area. The Controller will confirm if the landing was successful. The Telemetry Officer will disarm and disconnect the RPA unit upon landing. The Controller and the Spotter must not approach the RPA unit unless it is disarmed to avoid untoward accidents.

b. Partial Processing of Data

The Telemetry Officer will download the flight logs and geotagged photos from the RPA unit. Using the image processing software, the Team Leader will partially process and evaluate the photos for any gaps. Should a re-fly over the target area be necessary, the RPA Team shall decide (based on the weather, remaining equipment charge, etc.) if it will be done immediately, later within the day, or on another day.

c. Decamping

The RPA Team shall ensure that all equipment and components are accounted for and stored properly before leaving the site. The Spotter shall check all the equipment used during the mission. As a courtesy, key persons should be informed of the RPA Team's departure and possible return for a re-fly (if necessary). The output/s of the flight mission may also be provided to the key persons if they requested to obtain the orthomosaic.

IX. RPA Unit Maintenance and Storage

After data acquisition, the Spotter should return the borrowed RPA units and other equipment to the designated Resource Manager. All executed flight forms shall be submitted to the Resource Manager for record purposes. The Resource Manager should check the condition of the RPA unit and other equipment borrowed. The Resource Manager shall affix his/her signature in the equipment checklist to signify that all borrowed RPA units and equipment are still in good condition.

When returning the intelligent batteries, they are highly recommended to have 50 -70% charged status to prolong its battery life. In case of a worn out or damaged propeller, all propellers must be replaced and should no longer be used in any mission.

X. Image Processing

Once the flight mission of the target area is complete, geotagged photos will be processed to produce an orthomosaic using a photo stitching software e.g., Agisoft Photoscan. A step-by-step process of RPA mission, with corresponding photos, is provided in **Annex 7**.

The generated orthomosaic may be given to GIS experts for further analysis. The analysis will depend on the objectives of the mission. Other geospatial software and overlaying of necessary spatial datasets can be used to further examine the orthomosaic.

XI. Data Storage

An RPA data repository must be established to store all processed orthomosaics collected by the office. Each office shall develop a systematic folder system to ease the compilation of the data collected.

XII. Release of RPA data

The level clearance of the data will depend on the type of client. For internal clients, RPA data will be cleared by the RPA Team. For external clients, the RPA data must be cleared by the HOO. All members of the RPA Team must concur with the mission output of the RPA data before presenting the results to the client. The Data Acknowledgement Form (see **Annex 1**) must be accomplished by the client upon receipt of the data.

FOR INFORMATION AND REFERENCE.

MARCIAL C. AMARO, JR, *CESO III*
Assistant Secretary for Policy, Planning and
Foreign Assisted and Special Projects and
Director, in concurrent capacity

Annex 1

RPA DATA ACQUISITION REQUEST FORM

Form No. : _____ Date : _____

Name : _____ Contact No. : _____

Agency : _____ Email Address: : _____

Purpose : _____ Location : _____

Mode of Sharing : _____ Data Format : _____

_____
Signature of Requesting Party

RPA DATA ACKNOWLEDGMENT FORM

(Fill out upon receipt of data output from the RPA Team)

Form No.: _____ Date: _____

Please tick one box for each row to assess the level of satisfaction with the following aspects of your request:

	Very Satisfied	Satisfied	Neutral	Dissatisfied	Very Dissatisfied	No Opinion
Availability of personnel						
Courtesy						
Helpfulness						
Service Delivery						

Please rate our services from 1 to 5 with 5 being the highest

Overall Satisfaction Rating: _____

The Requesting Party shall not manipulate and/or distribute these data without prior written approval from --------.

_____
Signature of Requesting Party

Annex 2

KEY PERSONS CHECKLIST

1 **DENR**

Regional Office : _____

PENRO : _____

CENRO : _____

Protected Area Superintendent Office : _____

2 **Local Chief Executives**

Governor : _____

District Representative : _____

Municipal Mayor : _____

Barangay Captain : _____

3 **Uniformed Personnel**

Philippine Army Infantry : _____

Philippine Coast Guard : _____

Philippine National Police : _____

4 **Other Government Agencies** : _____

5 **Private Organizations** : _____

6 **Civil Society Organizations** : _____

7 **Peoples Organizations** : _____

8 Others : _____

Note: The suggested number of Key Persons may increase or decrease depending on the target area. The RPA team shall ensure that identified Key Persons are well-informed on the conduct of RPA operations.

Annex 3

FLIGHT PLANNING CHECKLIST

Total coverage of the Target Area (in hectares): _____

Highest point in the Target Area (in masl): _____

Total Estimated Mission Time: _____

Estimated Weather Condition: _____

Source: _____

Date as of: _____

Status

Pre-cache Maps of the Target Area: _____

KML Layer of the Target Area: _____

Flight Plans formulated in app viewer (in quantity): _____

Location of Proposed Launching and Landing Site	1
	2

Prepared By:

_____
Telemetry Officer
(signature over printed name)

Noted by:

_____
Team Leader
(signature over printed name)

Note: The suggested number of Key Persons may increase or decrease depending on the target area. The RPA team shall ensure that identified Key Persons are well-informed on the conduct of RPA operations.

Annex 4

ACTUAL FLIGHT PLAN FORM

Region : _____
Province : _____
Municipality : _____
Barangay : _____
Site No. : _____
Drone No. : _____

Date : _____
Time : _____ AM | PM
Duration : _____ minutes
: seconds
Sub-flight No. : _____
Battery No. : _____

Purpose : _____

Waypoint Quantity : _____
Course Count : _____
Batteries Needed : _____
Shutter Interval (Per second) : _____
Camera Model : _____

Flight Length (m) : _____
Cover Area (Hectares) : _____
Photos Established : _____
Course Angle : _____
Margin : _____
Speed (km/hr) : _____

Shooting Angle		Parallel to Main Path
		Perpendicular to Course
		Course Aligned

Capture Mode		Hover at Point
		Equal Time Interval
		Equal Distance Interval

Course Mode		Scan
		Inside

Capture Interval	Front:	
	Side:	

Overlap Ratio	Front:	
	Side:	

End-Mission Action		Return to home
		Hover
		Land

Signed and Attested by:

_____
Telemetry Officer
(signature over printed name)

_____
Team Leader
(signature over printed name)

Annex 5

EQUIPMENT CHECKLIST

Remotely Piloted Aircraft Box	Quantity	Status
DJI Aircraft		
DJI Remote Control		
Propellers (4 pieces/ set)		
Battery Charger		
Car Charger		
Charger Hub		
Class 10 Micro SD Card		
Micro SD Card Reader		
USB Cable		
Lightning Cable*		
Application Viewer*		
Intelligent Flight Batteries		
Laptop		
Binoculars		

* disregard if aircraft has a built-in application viewer

Prepared by:

_____
Controller
(signature over printed name)

Noted by:

_____
Resource Manager
(signature over printed name)

Fill out upon return of borrowed equipment.

Checked by:

_____
Spotter
(signature over printed name)

Received by:

_____
Resource Manager
(signature over printed name)

ANNEX 6: Flight Mission Planning using Ground Station Pro

Application Interface

Ground Station Pro or GS Pro is a flight mission planning application designed for iPads that provides user-friendly interface for quadcopter remotely piloted aircraft (RPA) operations. Image 1 shows the interface of the application:

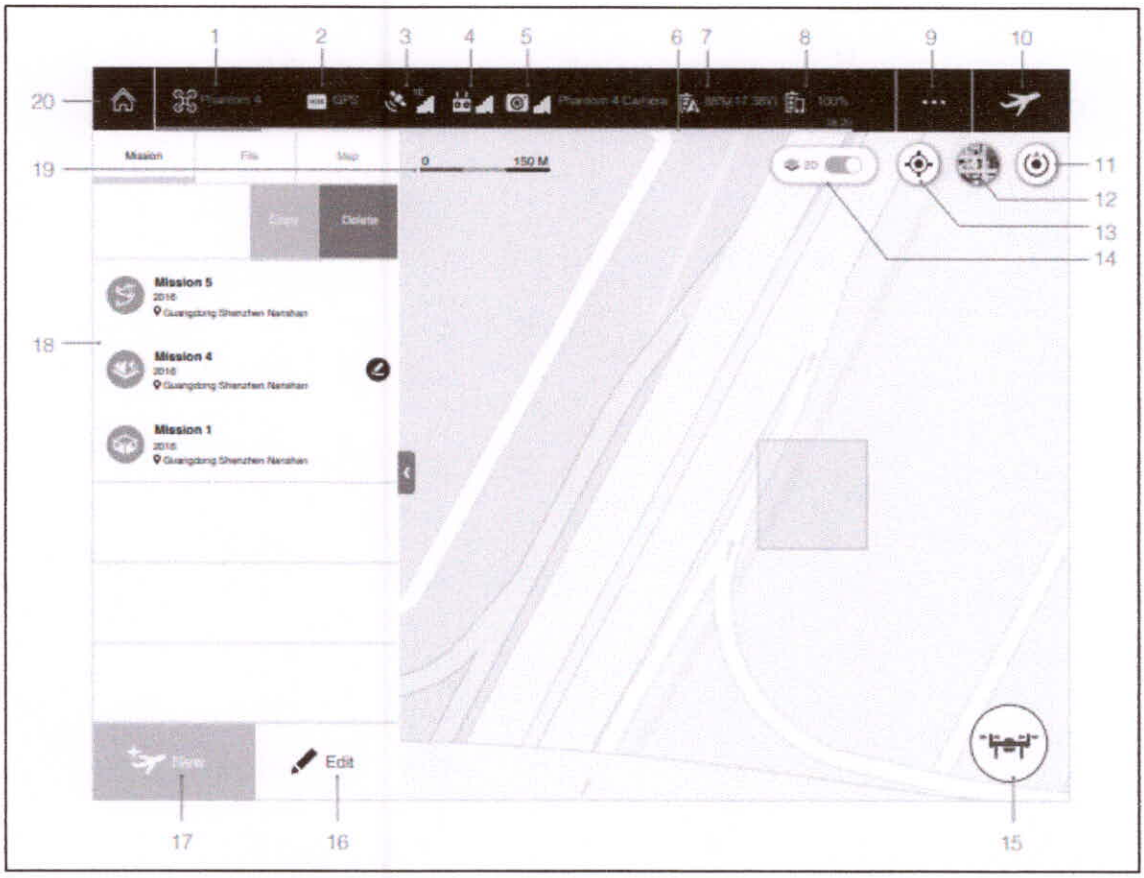


Image 1. Ground Station Pro Interface

1. **Aircraft / Flight Controller Connection:** Shows the current connection status between DJI GS Pro and the aircraft or flight controller.
2. **Flight Mode:** Shows the current flight mode of the aircraft.
3. **Global Navigation Satellite System (GNSS) Signal Strength:** Shows the current global positioning system (GPS) signal strength and number of connected satellites.
4. **Remote Controller Signal Strength:** Shows the strength of the remote controller signal.
5. **Camera Model:** Shows the camera model used and the strength of the video downlink.
6. **Battery Level Indicator:** Provides a dynamic display of the remaining flight time. The red zone represents critically low battery level.
7. **Aircraft Battery Level:** Shows the current battery level and battery voltage if using the DJI Intelligent Flight batteries.
8. **iPad Battery Level:** Shows the current battery level of the iPad.

9. **General Settings:** Used to set compass calibration, stick mode, measurement unit settings, coordinate display and non-free functions.
10. **Flight Mission Button:**
    a. **Prepare for Flight:** Allows the user to view the checklist after setting flight parameters.
    b. **Pause Mission:** Allows the user to hold the mission/s.
    c. **Resume Mission:** Allows the user to continue paused mission/s or carry out a different operation.
    d. **End Mission:** Allows the user to wrap up or disrupt an on-going mission.
11. **Rotation Lock:** Locked by default, i.e., the map view will not follow iPad rotation and North is at the top. Tap during mission editing to unlock rotation and have the map view follow the iPad rotation.
12. **Map Mode:** Allows user to switch between Standard, Satellite and Hybrid Maps.
13. **Location:** Used to center the map around the iPad's location.
14. **2D Switch:** Displays any other interface except the Map tag on the Navigation Pane.
15. **Flight Telemetry and Camera Preview:** Used for viewing the flight telemetry and camera preview.
16. **Edit Mission:** Used for editing existing mission/s.
17. **New Mission:** Used for creating new mission/s.
18. **Navigation Pane:** Includes *Mission* tab (used for viewing, copying, and deleting flight missions), *File* tab (used for viewing imported files and importing files to GS Pro), and *Map* tab (used for viewing all maps generated from imported files).
19. **Scale:** Shows the current scale of the map.
20. **Back Button:** Tap to return to the main menu.

Flight Parameters

During flight mission planning, GS Pro provides several flight parameter settings to be considered for every mission. Each parameter can be adjusted to optimize every flight mission. Image 2 shows the flight parameter setting interface in GS Pro while Image 3 shows a sample flight plan.

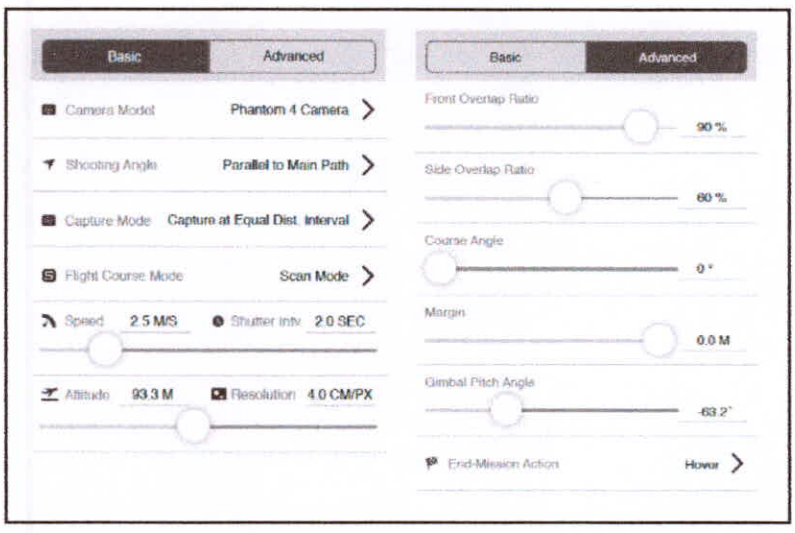
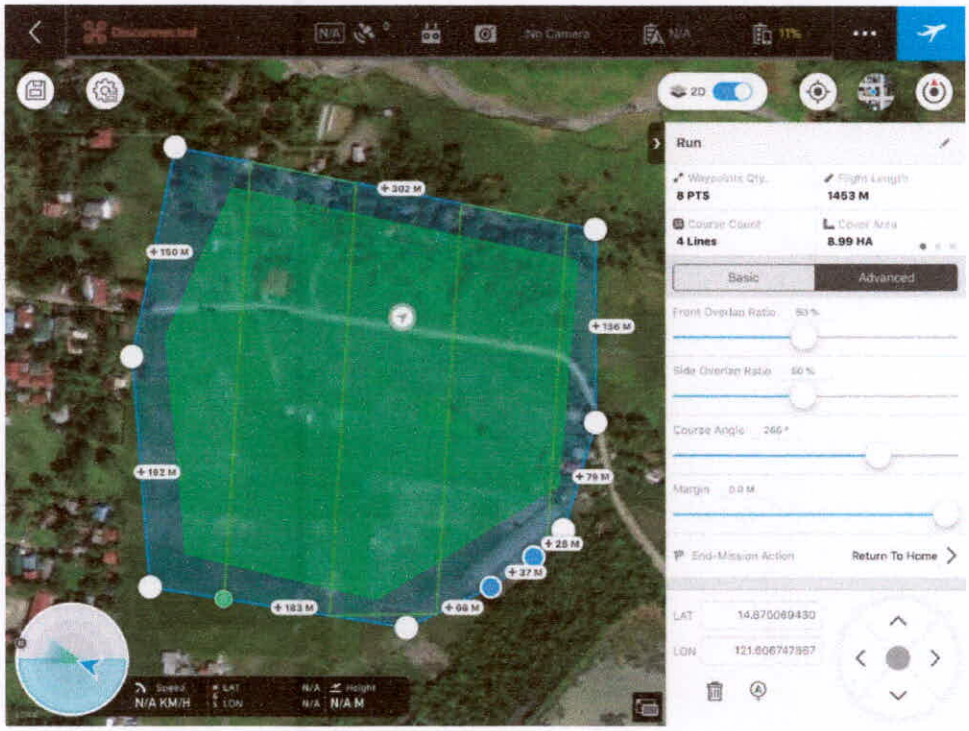


Image 2. Flight Parameter Setting

Image 3. Sample flight plan prepared using Ground Station Pro.



Initialization Process

Image 4 shows a comparison between a failed (left photo) and successful (right photo) initialization between the RPA unit and GS Pro. All observed parameters must turn green to signify success. Further, mandatory inspections, such as checking of controls and camera triggering, are mentioned in the Technical Bulletin after successful initialization.

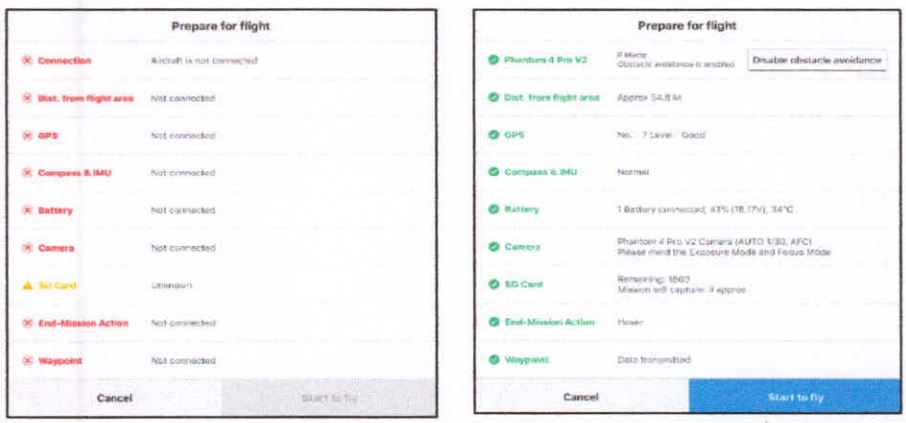


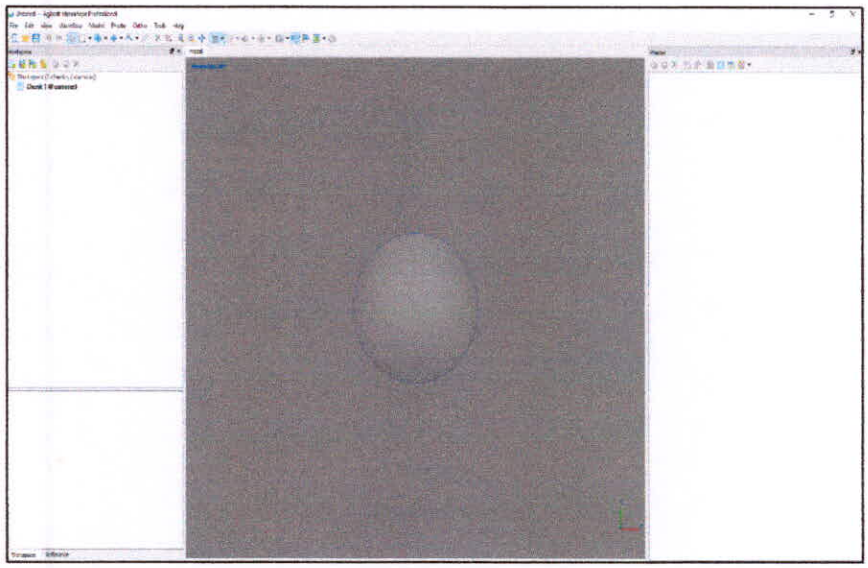
Image 4. Comparison between failed and successful initialization.

For more information about the GS Pro Application, download the User Manual through this link: https://dl.djicdn.com/downloads/groundstation_pro/20170831/GS_Pro_User_Manual_EN_V1.8.pdf

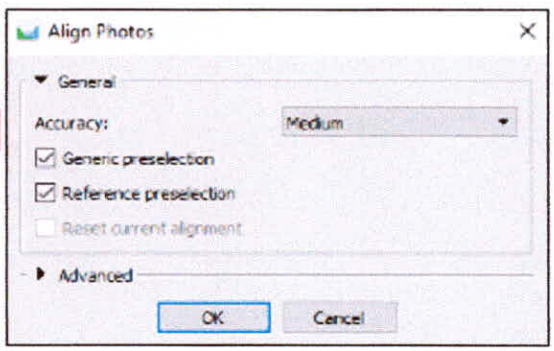
ANNEX 7. Image Processing using Agisoft Metashape 1.4

Agisoft Metashape is a stand-alone software product that performs photogrammetric processing of digital images (aerial and close-range photography, satellite imagery) and generates 3D spatial data to be used in (geographic information system) GIS applications, cultural heritage documentation, and visual effects production as well as for indirect measurements of objects of various scales.

The software allows processing of images from RGB, thermal or multispectral cameras, including multicamera systems, into the spatial information in the form of dense point clouds, textured polygonal models, georeferenced true orthomosaic, and digital surface models (DSM) or digital terrain models (DTM). Further post-processing enables users to eliminate shadows and texture artifacts from the models, calculate vegetation indices and extract information for farming equipment action maps, and automatically classify dense point clouds, among others.

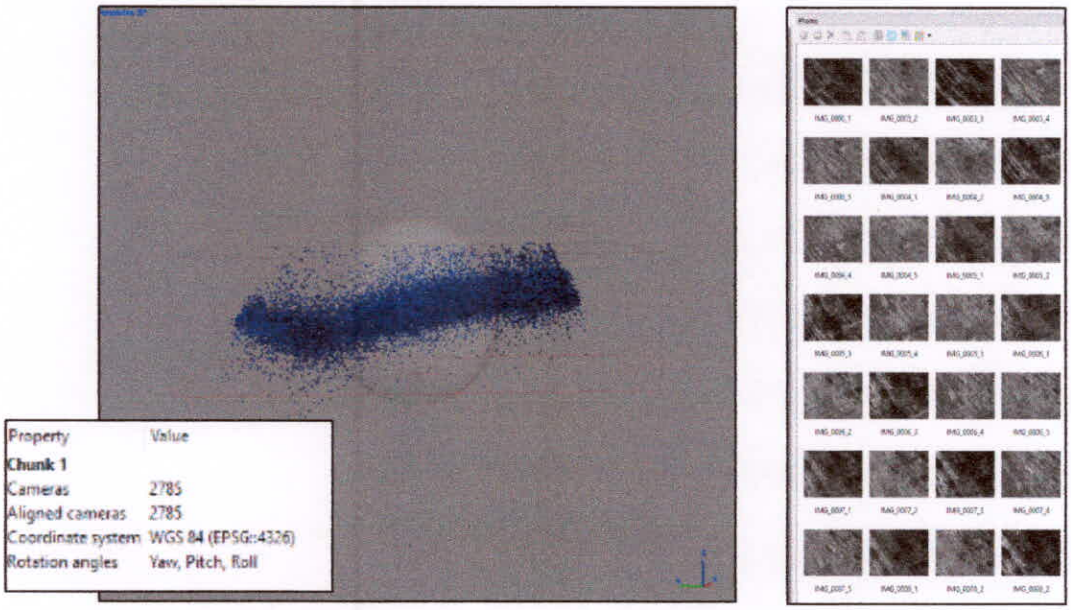


1) Photo Alignment



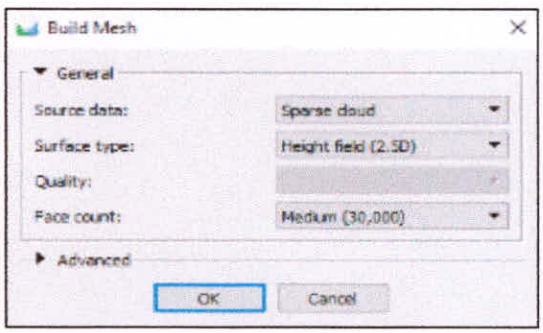
All photographs loaded in the software should be aligned to produce an orthomosaic. *Generic* and *Reference Preselection* must be enabled to speed up the matching of photographs. *Generic preselection* enables the software to select overlapping pairs of photos by matching them using lower accuracy settings first. On the other hand, *Reference pre-selection* enables the software to select overlapping photos based on the measured camera locations. *Accuracy* setting lets the software estimate the location of each camera. Higher accuracy setting means more accurate camera position estimates, but processing of data takes longer. Enabling *Reset Photo Alignment* allows the software to realign loaded photos if it was previously aligned.

Below is an image of successfully aligned photos. The *Properties* pane shows how many photos have aligned during the process. Meanwhile, the *Photos* pane-shows the collection of photos added in the chunk for processing.



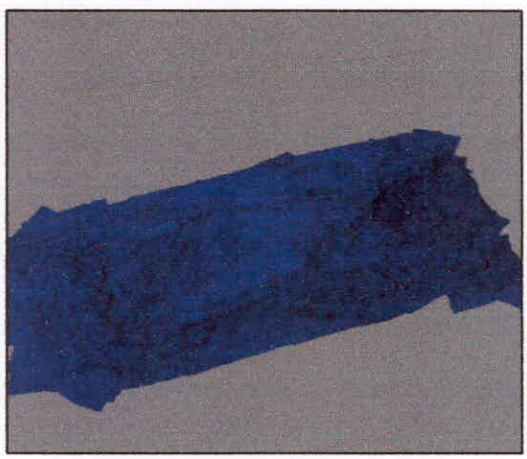
2) Building Mesh

Selecting the *Height field* on the *Surface type* is best suited for aerial photography processing because it is optimized for modeling of planar surfaces, such as terrains or base reliefs.



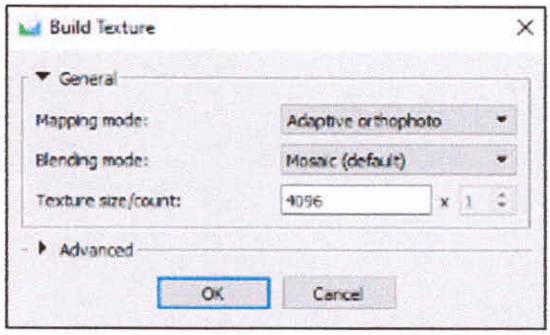
Source data allows you to select the type of point cloud data for mesh generation. *Sparse cloud* is used for three-dimensional model generation dependent on sparse cloud points while *Dense cloud* will take a longer time to process but will generate higher quality of output.

The right photo shows of a model after processing the Mesh.



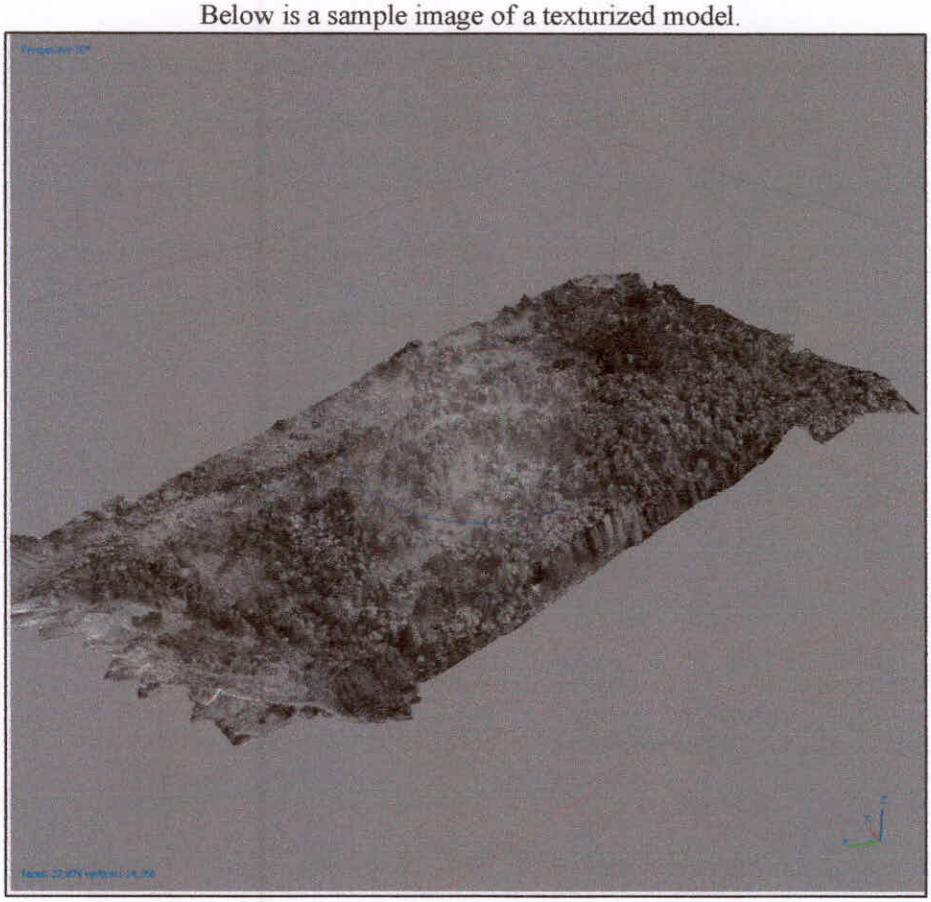
3) Building Texture

Adding texture to the mesh can add photorealistic representation of the object/scene. When building a texture, choosing the *adaptive orthophoto mapping mode* enables the program to produce more compact texture representation for nearly planar scenes, while maintaining good texture quality for vertical surfaces.



Choosing the *Mosaic setting* blends the low frequency component for overlapping images to have a seamless transition, while the high frequency component, that oversees picture details, is taken from a single image.

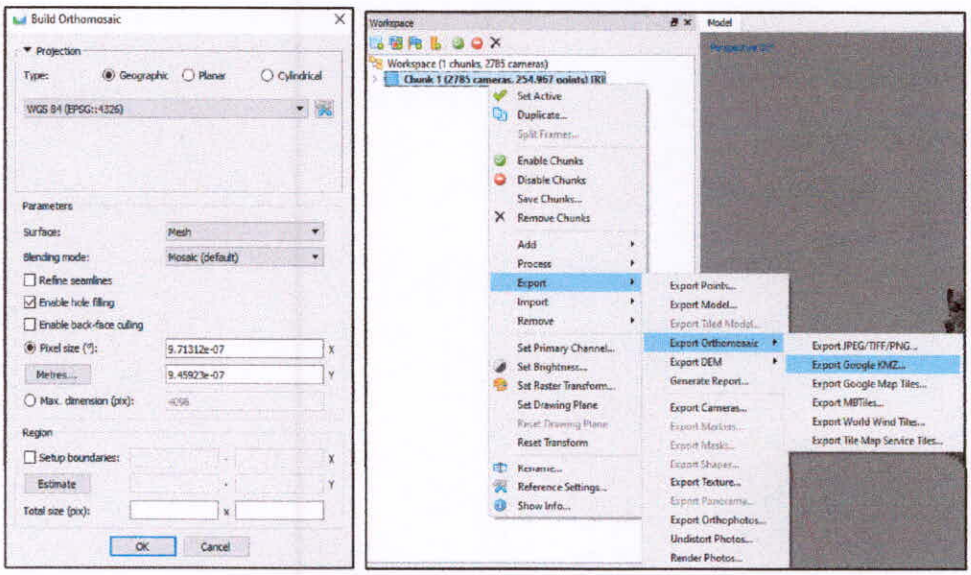
Below is a sample image of a texturized model.



4) Building and Exporting Orthomosaic

Before building an orthomosaic, the document must be saved first. Quadcopter RPAs have a built-in WGS 1984 geographic coordinate system. Choosing the *Geographic Projection* allows the user to choose a geographic coordinate system from the dropdown list or upload parameters of a customized

geographical coordinate system. An orthomosaic can then be exported to various file formats depending on the type of software to be used (e.g., .TIFF for ArcMap and .KML for Google Earth).



Below is an image of a processed orthomosaic.