A WORKFLOW FOR A SUCCESSFUL DRONE PHOTOGRAMMETRY MAPPING PROJECT

Connie Krampf, Chief Photogrammetrist
Timmons Group
Raleigh, NC 27607
Connie.krampf@timmons.com

ABSTRACT

With the advancements in drone mapping technology, the geospatial industry, especially the photogrammetry mapping business, continues to find options to configure software and hardware to establish a mapping system suitable for the need for highly accurate deliverables. A feasible mapping system is fundamental for production success; a thoughtfully designed workflow and how to implement that workflow in the production of deliverables is increasingly important to ensure production efficiency and accuracy. This article intends to present a workflow that has been implemented to achieve survey grade level accuracy production including flight mission planning, ground control design, aero-triangulation, point cloud quality control and editing, and compilation in photogrammetry mapping production. The software and hardware used will also be briefly mentioned. The article also aims to provide useful resources for those who would like to learn more about drone photogrammetry mapping production. The author intends for the topic to attract peers' attention to engender the sharing of similar experiences and techniques. Drone mapping production remains a work in progress. It is expected that the technology will continue to advance, the costs of production continue to decline, and production efficiency continue to improve.

KEYWORDS: sUAS, photogrammetry topographic Mapping, planimetric mapping, ortho mosaic, point cloud, geotagging, mission planning

INTRODUCTION

Photogrammetry has a long history. Photogrammetry topographic and planimetric mapping has long been widely used in many areas such as engineering design, planning, the oil industry, transportation, construction, mining, utilities, environment, facility management and even law enforcement. Even with its long history and well-defined processing procedures, the photogrammetry mapping technology continues to evolve and advance. Production workflow change depends on the sensors and platforms used for image acquisition. No matter how much technology changes, ultimately, we need to deliver our map products or produced data with satisfactory accuracy and quality to meet the requirements of our clients.

The photogrammetry mapping production workflow we are familiar with generally includes the following procedures:

- Flight mission planning
- Ground control network design
- Aero-triangulation
- Compilation on a photogrammetric softcopy station
- Orthophoto production
- Deliverables

These procedures are very similar in film and manned aircraft large format digital imagery processing. This is also true in drone imagery processing except that different processing tasks have to be added according to the technology utilized. One of these tasks is to handle point cloud that is automatically generated in drone photogrammetry processing. Point cloud is very beneficial for richness and accuracy in mapping production. How to handle or use those points could be challenging because of the "noise" of point cloud. Cleaning and editing point cloud is time consuming and costly but necessary to deliver accurate topographic mapping data such as DTM (digital terrain model) data or a contour map. Despite the challenges we have faced, sUAS(small unmanned aircraft system) has proved an efficient and effective tool for our photogrammetry mapping production. sUAS has become more popular in many industries for various applications due to its low cost, flexibility and low maintenance. With an appropriately configured sUAS and well-designed workflow, we have the ability to deliver very accurate mapping products that meet 15cm horizontal accuracy and 10 cm vertical accuracy class of ASPRS Positional Accuracy Standards for Digital Geospatial Data.

SOFTWARE AND HARDWARE

Needless to say, drone is a fundamental part of a sUAS. The configuration of software and hardware in a drone is crucial to make the drone function properly so that the goals of the application can be achieved effectively and efficiently. The ever-booming drone market offers a variety of selections. The cost of the drone should not be the only factor when considering a drone choice.

During the research of drones, we found that DJI Matrice 600 is suitable for our high accuracy mapping production. Please note that this author does not intend to provide advice for any particular drone or other software or hardware here, only to show what worked for our particular needs. We selected the M600 (a hexacopter), mainly because of its larger body size and multi-rotor design, which helps in stabilizing the aircraft during imagery acquisition so that images can be collected in ways where images can be line up as planned, an important consideration for photogrammetry compilation processing.

Sony A7R with Zeiss 35 mm lens replaces the M600 built in camera because it can provide a larger stereo model area that helps in the compilation processing. This high-resolution, full-frame sensor provides a wide range of lens choices. It is one of the most compact full-frame cameras on the market (O'Connor and Smith, 2016).

Even though the M600 is designed for professional aerial photography and industrial applications, its built-in GPS cannot provide the position that is accurate enough for our high precision mapping. Therefore, a significant number of ground control points has to be used to achieve the expected accuracy of the mapping product, which, of course, is not cost and time efficient.

LoKI by AirGon LLC, a Global Navigation Satellite System (GNSS) Post Process Kinematic (PPK) direct geo-positioning system for drones carrying a digital single lens reflex (DSLR) camera, is a solution to minimize the amount of ground control points in the production. A direct geo-positioning system monitors the position of a drone to a high level of accuracy, synchronizes this position to camera events and records information that can be used, in a post-processing step, to provide a priori estimates of the camera location for each acquired image (Graham, 2018). LoKI provides powerful means for us to use much fewer ground control points while achieving the accuracy our clients need in our mapping production.

We use Pix4Dmapper by Pix4D and sUAS 3D Correlator by simActive for photogrammetry processing. We have Global Mapper by Blue Marble Geographics for point cloud classification and manipulation. LP360 sUAS by AirGon is our core software for point cloud quality control, clean up and editing. We use photogrammetry software Summit by DAT/EM international for compilation and other related tasks. MicroStation and AutoCAD are used for creating vector data and deliverables. With the configuration of our sUAS described above, we have successfully delivered many photogrammetry planimetric, topographic mapping and ortho mosaic projects.

WORKFLOW

As discussed in the Introduction, the methodology used in the workflow for drone mapping is not much different from the one in photogrammetry mapping production in manned aircraft large format digital imagery. With drone photogrammetry technology, more work can be done by the software automatically either in the imagery acquisition or processing. Because of these automatic software processes, we have to develop a related workflow accordingly.

Project Planning

Understand Project Spec

Before we start processing, we need to understand what the requirements of the project will be and the resulting deliverables. These may be planimetric data only, ortho mosaic only, or topographic data only. Or they may be some combination of these. We also need to understand the accuracy requirements of the deliverables. Meanwhile, we need to check the location of the project site to get ideas about the air traffic situation or find out if it is close to an airport or other conditions that may impact the flight so that the FAA regulations can be followed accordingly. With a thorough understanding of specs of the project, we can properly plan and budget a mapping project.

Mission Planning

When we do the drone flight layout, we can use the flight app, for example DJI GS Pro, to draw the flight lines. We also can carry out manual flight mission planning using GIS or CAD software, especially for a larger project, so that we can improve flight planning with better flight overlap design. Drones do have limitations for how many way points or photos that can be taken in one flight. The drone battery is also a factor to be considered in the mission planning. During the planning phase we need to make sure we have a correct project AOI (Area of Interest) and a ground control layout handy to ensure enough coverage. Even though some of the software companies have recommendations for forward overlap and side overlap in the flight, it is good practice that you find out what is the overlap scheme that best fits your production needs based on your own UAS.

Ground Control Design

Ground control is important to ensure and check the mapping accuracy even with a direct geo-positioning system like LoKI on board. At least three ground control points should be used depending on the project size and geometric shape with a direct geo-positioning system. The ground control point should be placed in a flat open area where tree canopy can be avoided and keep a proper distance from any buildings to avoid shadows during ground control selection. The ground control point should be placed where it appears in as many photos as possible for drone processing.

Project Implementation

Imagery Acquisition

Before going to the field for flight, check the weather and flight site condition. The time of of day of the flight is also important. Shadows should be avoided as much as possible. Best time to fly is when the sun is at its highest position, around noon. The flight should not be conducted when there are clouds. Shadows and clouds can have negative effects in downstream photogrammetry processing.

Imagery Geotagging

Geotagging imagery is one of the most important procedures in the entire workflow. Geotagging is the process of adding geographical identification meta-data to an image. This meta-data usually consists of latitude and longitude coordinates, though they can also include altitude, bearing, distance, accuracy data, place names, and perhaps a time stamp. Even though the processing is for the most part automatic, and the software is straightforward and user friendly, effort and care needs to be taken during the processing to correct errors and ensure the imagery is accurately geotagged such that the downstream photogrammetry processing can produce accurate results. With LoKI PPK system, the drone flight trajectory is calculated in the field and can be visualized after a flight finish, which is the step built into the Loki GPS processing software to ensure image acquisition quality. The detailed geotagging process is done in the office when the base station coordinates are processed. After this step, the image should be ready for mapping production.

Imagery Processing

With the geotagged images, imagery processing takes place using drone photogrammetry software such as Pix4DMapper, sUAS 3D Correlator by SimActive, or other similar software. Unlike traditional photogrammetry processing software, the drone software consolidates multiple processing procedures into one package, which delivers several kinds of solutions for downstream processing. For example, Pix4D can provide the aerial triangulation solution (interior orientation and exterior orientation information) for setting up photogrammetry compilation on a photogrammetry softcopy station, point cloud (las format) for 3D terrain modeling, ortho mosaic and more.

Typically, drone imagery processing includes the following steps:

- Automatically extract ground feature points (so called keypoints) on one image and match them in all images in which the same feature point can be found. In this step, the ground control points are measured so final bundle adjustment can be done to provide the aerial triangulation solution. The camera is calibrated, and the exterior orientation parameters are created so that the results can be used for photogrammetry compilation.
- Generating a point cloud by densifying the tie points created in the first step. The point cloud output is a las file. The software for processing LiDAR data can be used in point cloud processing such as classification and editing. The ground data classified from the point cloud can be used for creating 3D surface, contours and 3D visualization.
- Creating ortho mosaic and DSM. For our drone mapping, ortho mosaic is our main focus because it is one of our standard deliverables. With DSM, the volume calculation can be done accurately depending on the project requirements.

Point Cloud Quality Control and Editing

Point cloud is a necessary and important product of imagery processing. Just like any other automatically generated data, it is not useful without checking quality and editing to remove noise points. Thankfully, there are software packages like LP360 by AirGon and Global Mapper by Blue Marble that provide effective and affordable tools to check the accuracy, classification and editing of the point cloud so that those automatically generated points become a more valuable data resource in production.

In the process, the experience and understanding of data characters and the terrain situation by the professional who works on the project is important in making decisions on how to handle the tasks efficiently. The quality of point cloud depends on the many factors involved in a project. The quality of imagery such as flight overlap, clouds, wind and shadows, ground control layout (if the ground control points are evenly distributed) and ground conditions (vegetation field, an open land, or a parking lot, etc.) all have significant influence on how the point cloud turns out. Regardless, manual work is unavoidable even with some automatic tools provided in the software mentioned above. Cleaning point cloud can be very time consuming but a must-do for accurate mapping.

Drone Photogrammetry Compilation

Some might argue that the compilation should be no different between large format manned aerial imagery and drone imagery. It is a similar process but there are differences.

As discussed in the section on Imagery Processing, automatic aerial triangulation is done and the interior and exterior orientation solutions are generated in the process so they can be used to set up a photogrammetry compilation project on a softcopy workstation. Traditionally, after the project setup, the compiler can work on one model for a while to digitize what is seen from this stereo model until the compilation is completed. With a good AT solution, adjacent models should be able to be tied up accurately. This is not necessarily true in the drone compilation. In order to find a stereo area that can be compiled to make the compiled data match the drone imagery processing results, compiler would have to search several adjacent models. This can sometimes be frustrating even for an experienced compiler.

Drone compilation requires not only the skills to do the job properly but also an understanding of drone photogrammetry technology and experiences. Even though photogrammetry compilation technology has matured and has been widely used in photogrammetry production for some time now, the drone photogrammetry compilation cannot be taken for granted. There are new technologies and associated skills that need to be learned in the compilation. Even so, compilation is still the best method for producing accurate planimetric and topographic vector data using new technology and advanced software and hardware.

Produce Deliverables

In each stage of production, quality control is always necessary. Even work done by experienced professionals can have flaws, especially in the compilation process. QA/QC should necessarily be budgeted in a project planning. Final editing is also an important part of deliverables production. Each project has different requirements and deliverables. When developing a mapping project, keep in mind that accuracy of product is key to meeting the needs of the customer.

CONCLUSION

Accurate (sometimes it is called survey grade level) drone photogrammetry mapping can be delivered with appropriate software and hardware configuration in a sUAS. More importantly, a well-organized workflow will produce a mapping product efficiently and successfully.

CASE STUDY

Project Specs

The example demonstrated here is a project with deliverables of 1’ contour mapping and a 0.25’ resolution ortho mosaic. The project covers an 85-acre area.

Figure 1. Project area in red

Mission Planning

Flight Specs:

Flight altitude: 375 Feet, Forward overlap: 75%, Side overlap: 70%

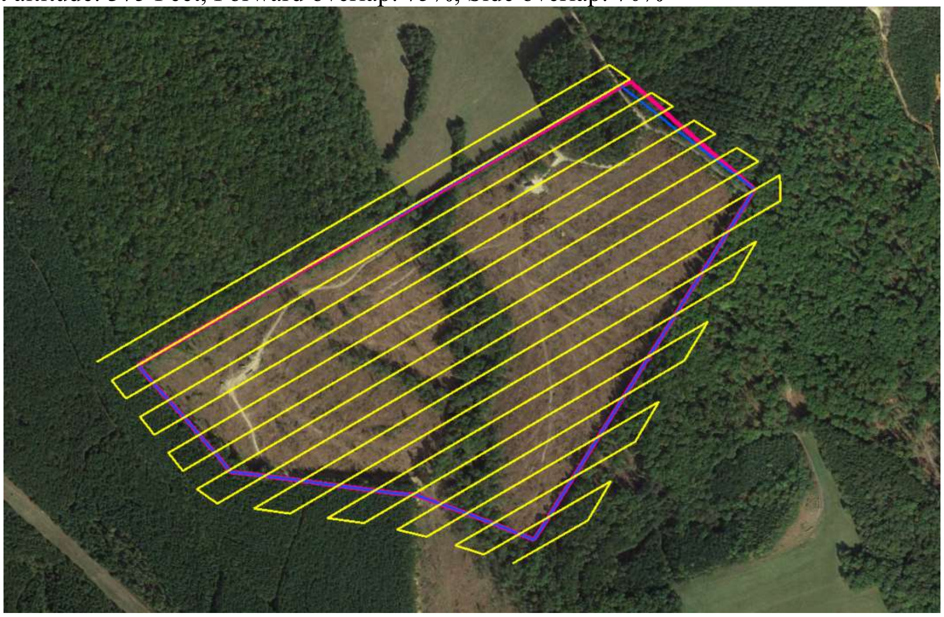


Figure 2. Flight line in yellow

Ground Control

Total of six ground control points and 20 ground check points are selected and surveyed:

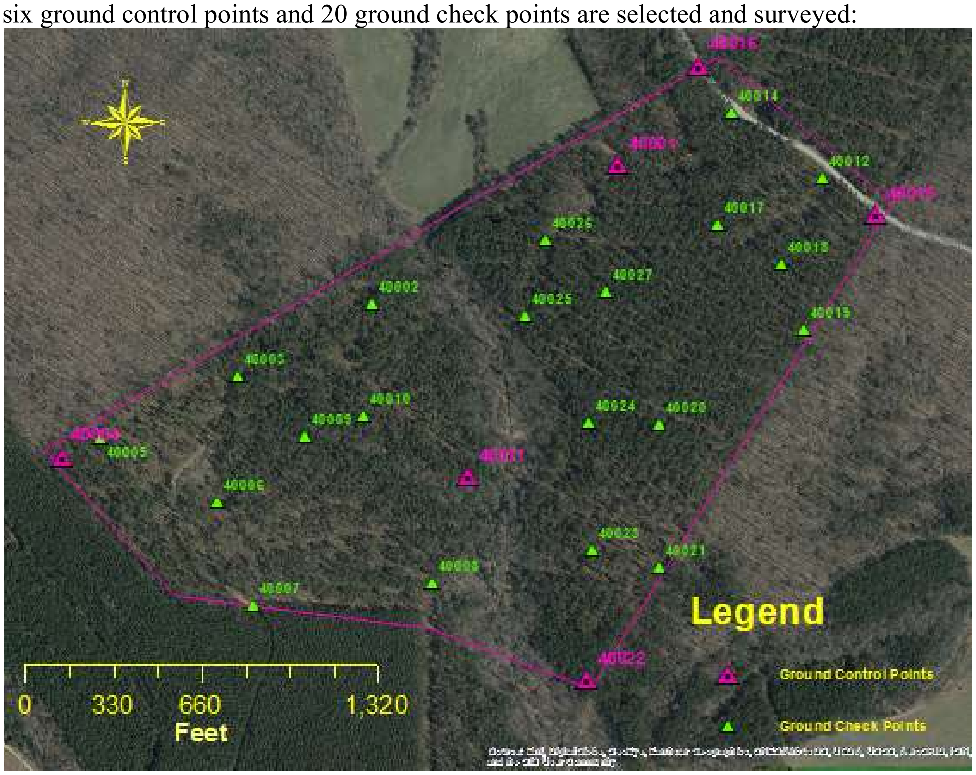


Figure 3. Ground control points in pink, ground check points in green

GPS Post Processing and Image Geotagging

There is a total of three flights with 861 images. The following screenshot shows the camera events in one of flights in the geotagging process with ASPSuite.

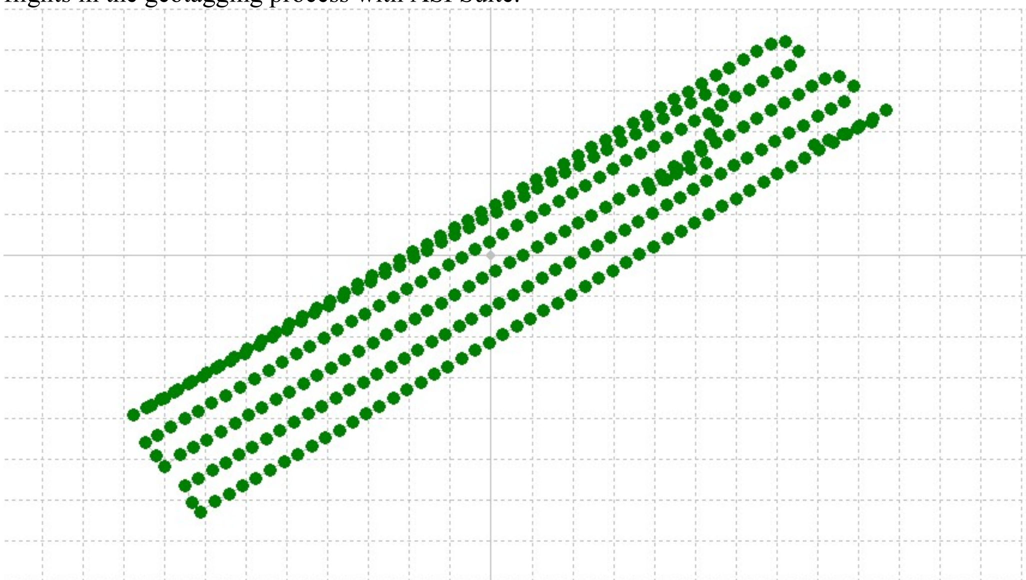


Figure 4. Image center in green

Photogrammetry Processing

Pix4D software is used for the processing that includes bundle adjustment, point cloud and ortho mosaic generating.

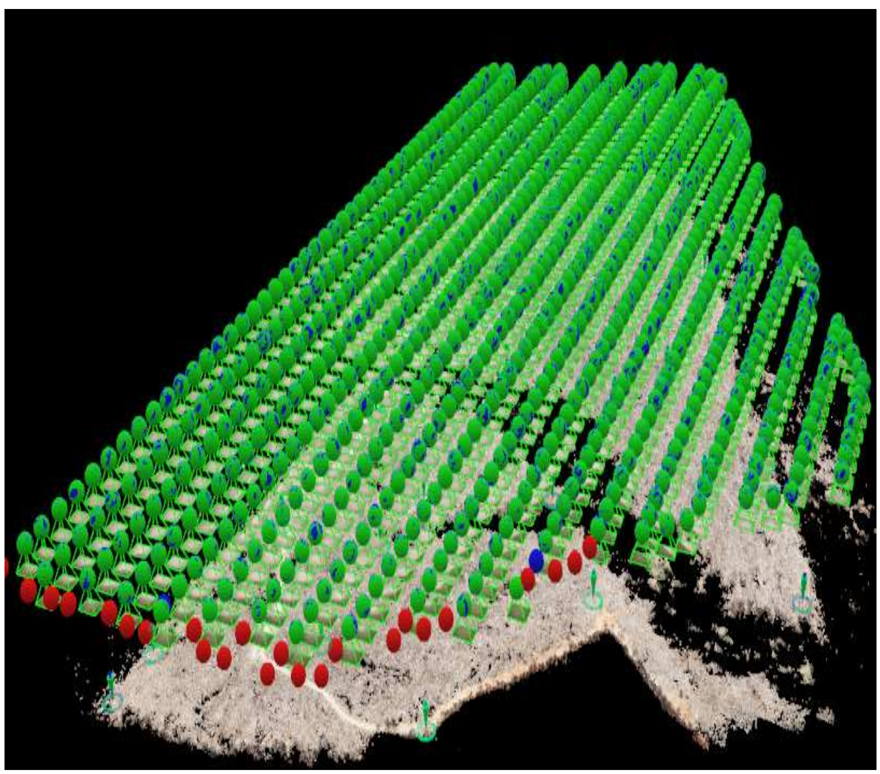


Figure 5. Imager center in green, point cloud in gray

Point cloud QC and Editing

LP360 sUAS by AirGon is used in the processing:

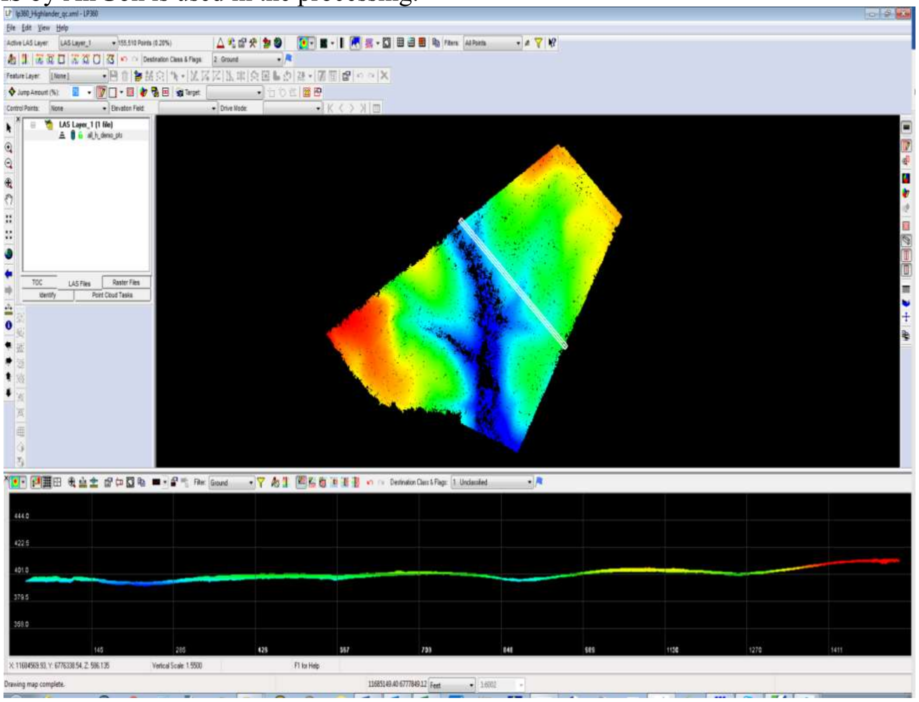


Figure 6. bottom part of window shows the profile of point cloud

Compilation

The task is performed with the photogrammetry software Summit by DAT/EM.

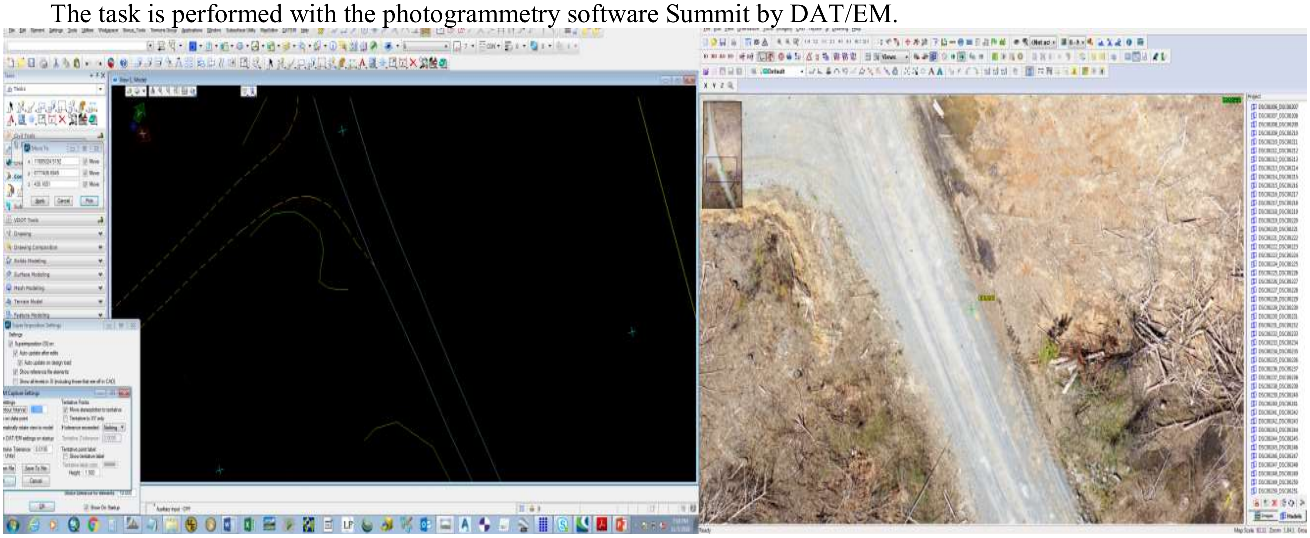
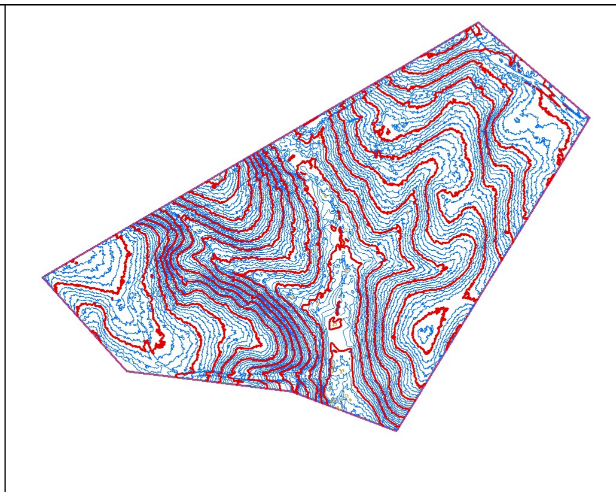


Figure 7. Left is MicroStation window, right Summit window

Deliverables
The following three screenshots demonstrate the deliverables for the project.

	
Figure 8. Ortho mosaic	**Figure 9.** Contours

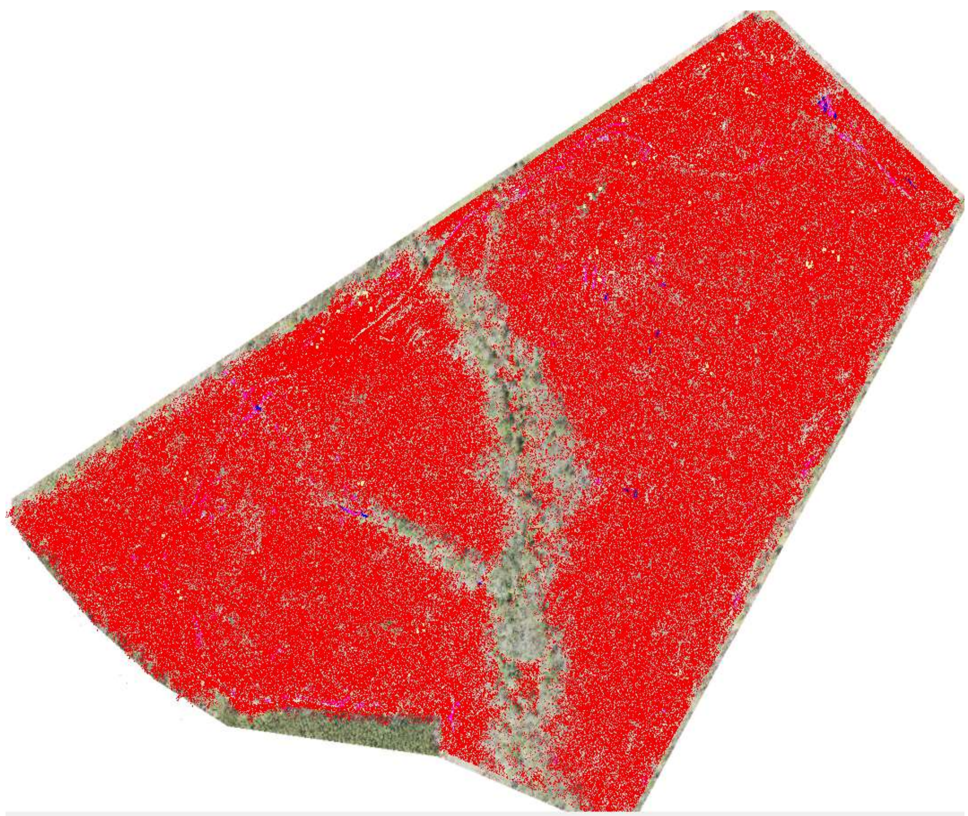


Figure 10. DTM data with break-lines, auto point cloud with only ground points

ACCURACY ASSESSMENT

Table 1. Accuracy assessment calculation in which 20 check points are evaluated on a photogrammetry softcopy work station

Point ID	Ground Survey Check Point Values			Map-derived Values			Residuals (Errors)		
	x	**y**	**z**	**x_ph**	**y_ph**	**z_ph**	**dx**	**dy**	**dz**
40002	11683574	6776725.5	417.0999	11683574	6776725.3	417.146	0.003	0.129	-0.046
40003	11683071	6776456	424.2075	11683071	6776455.8	424.361	-0.034	0.165	-0.154
40005	11682556	6776228.1	443.0751	11682556	6776228.2	443.19	0.04	-0.068	-0.115
40006	11682995	6775985.8	434.0549	11682995	6775985.9	434.198	-0.043	-0.079	-0.143
40007	11683135	6775599.3	429.7379	11683135	6775599.4	429.388	-0.151	-0.091	0.35
40008	11683804	6775681.5	402.5472	11683804	6775681.6	402.548	-0.02	-0.073	-0.001
40009	11683326	6776229	402.5282	11683326	6776229	402.755	0.011	0.06	-0.227
40010	11683544	6776312	401.5807	11683544	6776311.9	401.747	0.026	0.059	-0.166
40012	11685266	6777195.5	430.347	11685266	6777195.3	430.236	-0.005	0.214	0.111
40013	11684927	6777444.2	426.6849	11684927	6777444.1	426.799	-0.02	0.112	-0.114
40014	11684927	6777444.2	426.7097	11684927	6777444.1	426.799	-0.02	0.12	-0.089
40017	11684869	6777023.9	414.4667	11684869	6777023.9	414.569	-0.004	0.025	-0.102
40018	11685111	6776873.6	423.523	11685111	6776873.5	423.579	-0.005	0.007	-0.056
40019	11685195	6776630.2	426.946	11685195	6776630.2	426.999	-0.056	-0.022	-0.053
40020	11684654	6776279.6	401.463	11684654	6776279.7	401.44	-0.122	-0.084	0.023
40021	11684652	6775744.5	407.048	11684652	6775744.4	406.854	-0.18	0.064	0.194
40023	11684404	6775806.2	406.0302	11684404	6775806.1	405.999	-0.131	0.069	0.031
40024	11684387	6776284.9	392.2766	11684387	6776284.9	392.467	-0.184	-0.022	-0.19
40025	11684152	6776685.3	395.3047	11684152	6776685.1	395.392	-0.032	0.136	-0.087
40026	11684226	6776965.6	411.1795	11684226	6776965.6	411.096	0.004	0	0.084
40027	11684452	6776776.1	405.7189	11684452	6776776.1	405.626	-0.016	0.006	0.093
Number of Points							**20**	**20**	**20**
Mean Error							**0.055**	**0.080**	**0.121**
RMSE(ft)							**0.081**	**0.096**	**0.143**
RMSEr(ft)							**0.368**		
NSSDA Horizontal Accuracy (ACCr) at 95 % Confidence Level							**0.637**	**RMSEr x 1.7308**	
NSSDA Vertical Accuracy (ACCz) at 95 % Confidence Level							**0.280**	**RMSEz x 1.9600**	

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