A Study on LiDAR Performance Based on Material, Size, and Shape Complexity

Course: AT 419 Unmanned Aerial Systems Capstone
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Content

1. Introduction

Using LiDAR to do a mapping mission is one of the most accurate methods today. As the LiDAR will see more and more things, it will encounter objects with different shapes and materials. This makes people think about the limitations of LiDAR, just like GPS will be affected by multipath between skyscrapers. To investigate the limitations, we need to know what could affect the LiDAR scanning result. The basic theory of LiDAR is to measure the distance to the object based on the time that the laser pulse travels and the speed of light in the air. In practical situations, this process involves several problems.

The DJI L1 uses Livox Avia Lidar as the sensor, and it emits light at the wavelength of 905 nm. Materials can absorb certain wavelengths. But to know which material absorbs the light near 905 nm, it requires plenty of experimentation. Moreover, at this wavelength, the absorptivity may not be a hundred percent, and the sensor can still detect reflected pulses with less energy. This raises a question: what material will absorb most of the light and the sensor can't detect it.

Both GPS and LiDAR require speed of light and time interval to gather data. In some cases, light can travel longer distances because of several reflecting surfaces. This multipath effect extends the time to travel and leads to inaccurate position in GPS. LiDAR could encounter the same situation, but the effect is still unknown.

Another question remains, which is about the penetration capability. What materials can the laser penetrate and be detected correctly? Most common materials include tree leaves, glass, and water. The answer to this question would be very helpful in the forestry industry because in that way people are able to create digital elevation models. It might also be related to the species of the trees. One species could have a better penetration capability than another one. Due to the material and time limitations, only glass will be tested.

In this project, the first objective is to get familiar with LiDAR data collection and data processing. The UAV DJI M300 and D-RTK 2 will be used for the platform, and DJI L1 LiDAR will be used for the payload. A small area with many types of items including control samples will be studied. The data processing will be performed on DJI Terra. The second objective is to find the objects or materials that can provide high quality and low quality data by comparing data processing quality with different items.

2. Methods

2.1 Data Collection Platform

2.1.1 DJI Matrice 300 RTK and DJI Pilot 2

DJI Matrice 300 RTK was used as the UAV platform. It used two 6S Li-po batteries and had a flight time of more than 30 minutes. M300 is able to carry DJI L1, but M210 is not. The mission was created on the DJI Pilot 2 application which was built into the M300 controller. The mission parameter settings can be found in the table below. Maximum flight altitude was set to 100ft, loss of link action was set to return to home, and the return altitude was set to 60ft in general settings.

Figure 2.1.1.1: DJI Matrice 300 RTK

Before the mission started, M300 took off and executed the center of gravity calibration.

When everything was ready, including L1 warm up and RTK connection, PIC entered the mission page, checked “execute all 5 missions”, uploaded the mission, started the mission, and M300I took off from the ground and landed at the home point.

Since the area was very small there was only one flight path showing up on the map with the altitude of 40ft. For DJI L1, one pass was enough for the area. Since the mission type was oblique, there were 5 sub-missions. M300 changed the heading and the L1 heading to 90 degrees facing down, facing north, facing east, facing south, and facing west. During each sub-mission, M300 flew forward and backward several times for the calibration, flew forward slowly to collect the data, and then repeated the forward-backward calibration action.

Table 2.1.1: Flight mission settings in DJI Pilot 2

Flight Mission Settings	Parameters
Mission Type	Oblique
Sensor	Zenmuse L1 LiDAR Mapping
Gimbal Pitch	45
Safe Takeoff Altitude	50 ft
IMU Calibration	On

Terrain Follow	Off
ASL/ALT	Relative to Takeoff Point
Flight Route Altitude	40 ft
Takeoff Speed/Speed/Speed (oblique)	Default
Course Angle	0
Side Overlap (LiDAR)	50%
Forward Overlap (Visible)	70%
Side Overlap (LiDAR/Oblique)	50%
Forward Overlap (LiDAR/Oblique)	70%
Margin	0 ft
Payload Settings Return Mode	Single
Payload Settings Sampling Rate	240 kHz
Payload Settings Scanning Mode	Repetitive
Payload Settings RGB Coloring	On

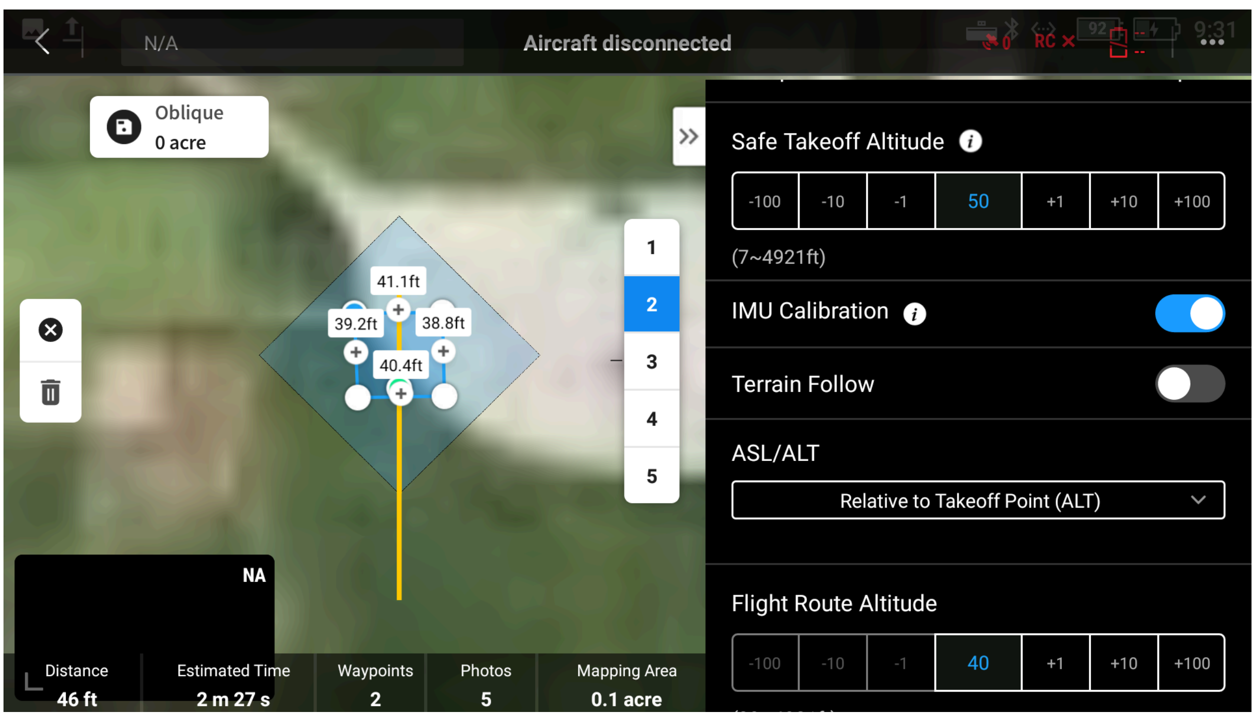

Figure 2.1.1.2: Flight mission setup.

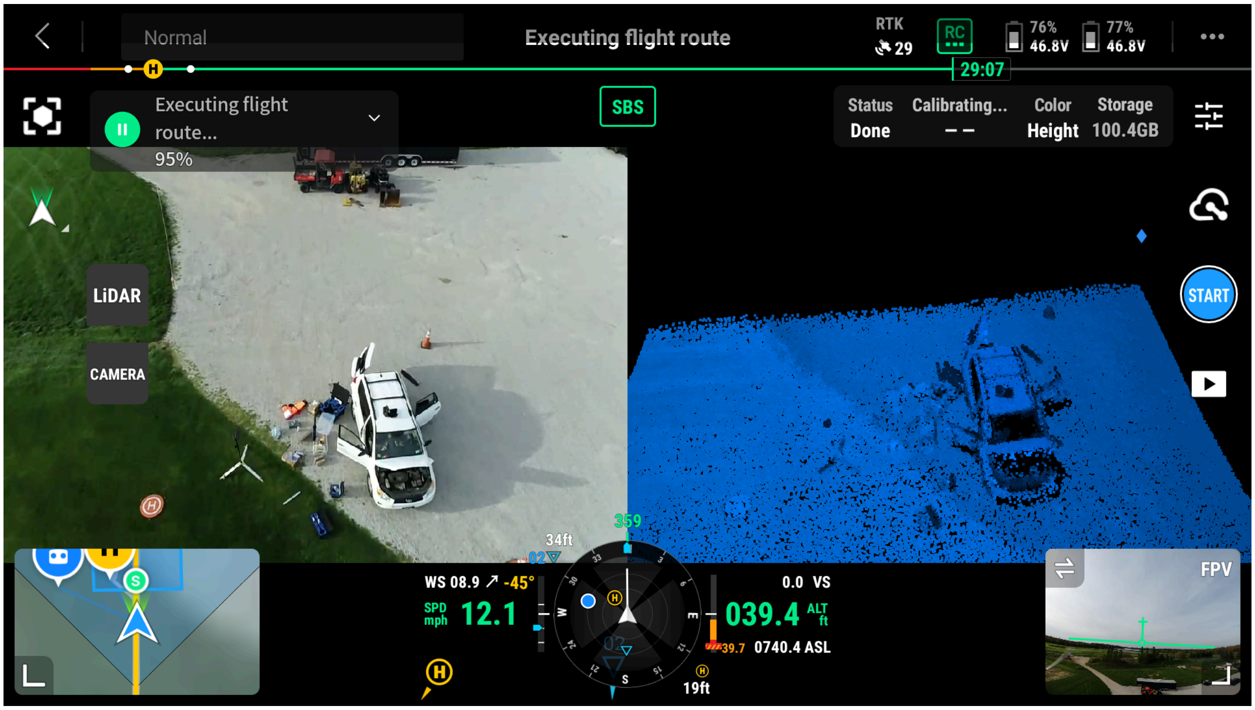

Figure 2.1.1.3: Flight mission in action.

2.1.2 DJI Zenmuse L1

The payload used in this study was DJI L1. Its specifications can be found on the official website. It has one Livox Avia Lidar sensor and one RGB camera. Its ability is far enough for this study since the flight altitude is only 40ft (about 12m). The cap on the gimbal connector on DJI L1 and M300 were removed, and L1 was installed on the gimbal mount. The front rubber cover was removed from L1 and made sure there's no dirt on the "green mirror". Once the M300 was powered on, it took a while to warm up the sensor. While waiting for the warm-up, it's time to set up the RTK.

Figure 2.1.2.1: DJI L1

2.1.3 DJI D-RTK 2 Mobile Station

DJI D-RTK 2 Mobile Station was used for relatively accurate positioning. DJI Terra needed the RTB file which was generated from the RTK station inorder to process the data.

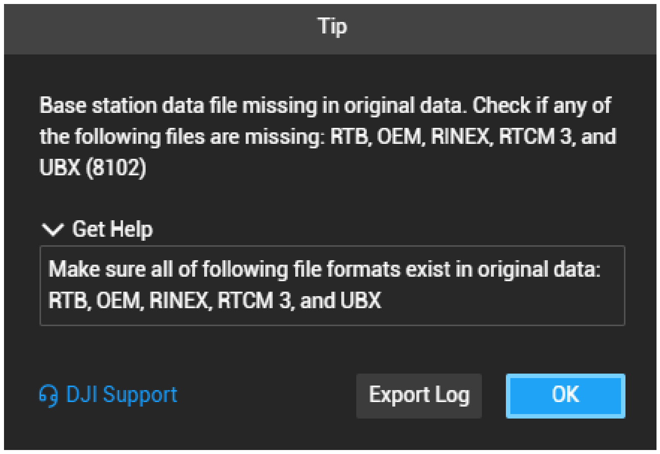

Figure 2.1.3.1: DJI Terra error report

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The RTK antenna was mounted on a carbon fiber tube and a tripod. The tripod was set to level (bubble in the black circle), and the D-RTK 2 was installed level to the carbon fiber tube. After it was powered on, the green LED on the right flashed five times, indicating that it's in the fifth broadcast mode. On the M300 controller, it's set to connect to the station in the RTK settings.

Figure 2.1.3.2: DJI D-RTK 2 set up.

2.2 Study Area

2.2.1 Location

The study area is on the north side of Purdue University - William H. Daniel Turfgrass Research and Diagnostic Center (Turf, 40.441851 N, -86.930971 W). The search format on Google Map of the coordinate is "40.441851, -86.930971". It's at the boundary of grass and the gravel road, so that's two more items in the study field. The tree on the east side was too far to consider a risk.

2.2.2 Study Area Setup

Twenty items were placed in the study area and scanned. Items are placed randomly near the car, and each one has its own purpose. The list of items and their purposes are in the table below. Some complex shape was done through by assigning the items randomly to create concave spaces, such as the lid of a plastic storage box creating a hollow space beneath it. Shape complexity is represented by a scale from 1 (simple shape, can be seen in all 5 directions, top, east, south, west, north) to 5 (complex shape).

Table 2.2.2: Item list

Code	Item	Material	Size	Shape	Purpose
1	Cardboard box	Paper	Edge size range: 15~48 cm	1/5	Dimension comparison
2	Empty Glass Jar	Glass	Diameter: 12 cm Height: 20 cm	2/5	Material and Size Check
3	Steel Tube	Steel	Diameter: 5.6 cm Length: 113 cm	2/5	Material Check
4	Copper Tube	Copper	Diameter: 5.4 cm Length: 77 cm	2/5	Material Shape Check
5	Aluminum Tube	Aluminum alloy	Diameter: 5.1 cm Length: 59 cm	1/5	Material Check
6	Aluminum Rod	Aluminum alloy	Diameter: 1.26 cm Length: 55 cm	1/5	Material and Size Check
7	Tripod base	Aluminum alloy, plastic	Leg size: 2.5cm x 7.5 cm Length: 88 cm	2.5/5	Material and Shape Check
8	Carbon Fiber Tube	Carbon fiber	Diameter: 30 mm Length: 130 cm	1/5	Material and Size Check
9	RTK antenna	Plastic	15 cm x 15 cm x 8 cm	1/5	Material and Size Check
10	Plastic Storage Box	Plastic	78 cm x 46 cm x 32 cm	4/5	Material and Shape Check
11	Plastic Storage Box Lid	Plastic	80 cm x 48 cm x 33 cm	4/5	Material and Shape Check
12	Car	Steel with coating, glass, rubber, plastic	4.6 m x 1.9 m x 1.7 m	5/5	Material and Shape Check

13	Drone Case	Plastic, foam	65 cm x 65 cm x 33 cm (no lid)	3/5	Material and Shape Check
14	Orange Bag	Fabric, rubber	72 cm x 35 cm	2.5/5	Material and Shape Check
15	Ceramic cup	ceramic	Diameter: 11 cm Height: 10 cm	2/5	All
16	Shampoo bottle	Plastic	9 cm x 6 cm x 24 cm	1/5	Size and Shape Check
17	A bag of water bottle	Plastic	35 cm x 35 cm	3.5/5	Material and Shape Check
18	Laminate Flooring Board	High Density Fiber	52 cm x 36 cm	2/5	Shape Check
19	Umbrella	Fabric	Diameter: 4.5 cm Length: 70 cm	1/5	Material and Shape Check

3. Data Collection and Processing

Table 3.1 Metadata

Flight Location	40.441851, -86.930971
Temperature	17 °C
Wind Direction	West
Wind Speed	5.8 m/s
Take off time	18:45
Landing time	18:56
Mission duration	12 minutes
Total data size	365 MB

3.2 DJI Terra Data Processing

Processing steps and screenshots

Data folder was copied to the C drive temp folder on the computer. The Terra version was updated to 4.0.10. The license code was bound with my email and that device.

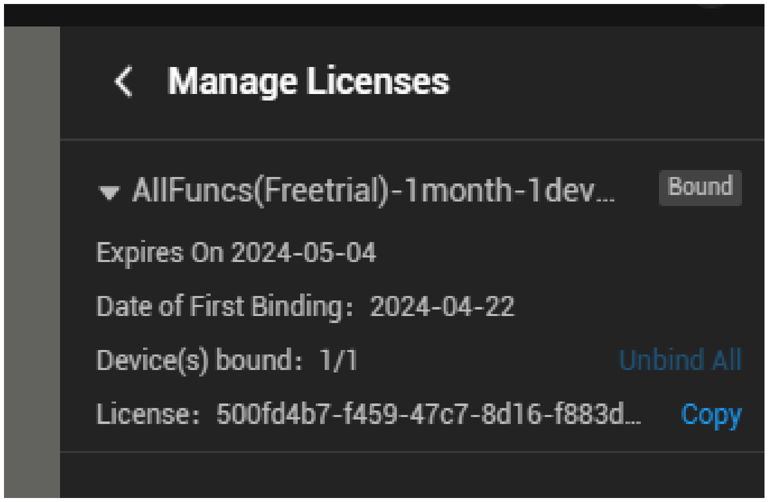

Figure 3.2.1: Activate the license and bind the device.

A new “LiDAR Point Cloud” mission was created, and the folder was chosen to be the project folder that is in the temp folder. The table below is the setting for the processing.

Table 3.2: DJI Terra data processing settings.

Category	Sub-Category	Parameters	Settings	Notes
LiDAR Point Cloud	LiDAR Point Cloud	Point Cloud Density	By Percentage, 100%	The minimum distance in “By Distance” is still very large (5 to 50 cm), so I chose “By Percentage” and 100%. By Distance: “set sample distance to reduce point cloud number and uniform point cloud density”
LiDAR Point Cloud	LiDAR Point Cloud	Scenarios	Point Cloud Processing	“LiDAR Calibration” has fewer settings, but it will generate similar results.
Point Cloud Processing	Point Cloud Effective Distance Range	Point Cloud Effective Distance Range	3-250m	Default
	Optimize Point Cloud Accuracy	Optimize Point Cloud Accuracy	Checked	
	Smooth Point Cloud	Smooth Point Cloud	Unchecked	
	Ground Point Classification	Ground Point Classification	On	“Point cloud output in ground area will be marked as Ground Point”
		Generate DEM	On	
		Ground Type	Flat Ground	

		Building Max Diagonal	20 m	Default
		Iteration Angle	3°	Default
		Iteration Distance	0.3 m	Default
	Generate DEM	Generate DEM	By GSD 0.05 m/pixel	Minimum
	Contour	Contour	On	
		Interval	0.1 m	I didn't find where to show it.
		Datum	0 m	Default
		Elevation Annotation Radius	15 m	It's used to generate elevation points for topographic mapping
		Discard Invalid Contour Lines	Off	Default
Advanced	Advanced	Output Coordinate System	Known Coordinate System	Default
		Horizontal Datum Settings	WGS 84 / UTM zone 16N	Default
		Geoid Settings	Default	Default
		Height Offset	0 m	Default
		Point Cloud	Check PNTS and LAS	Default
		Merged Output	Off	Default

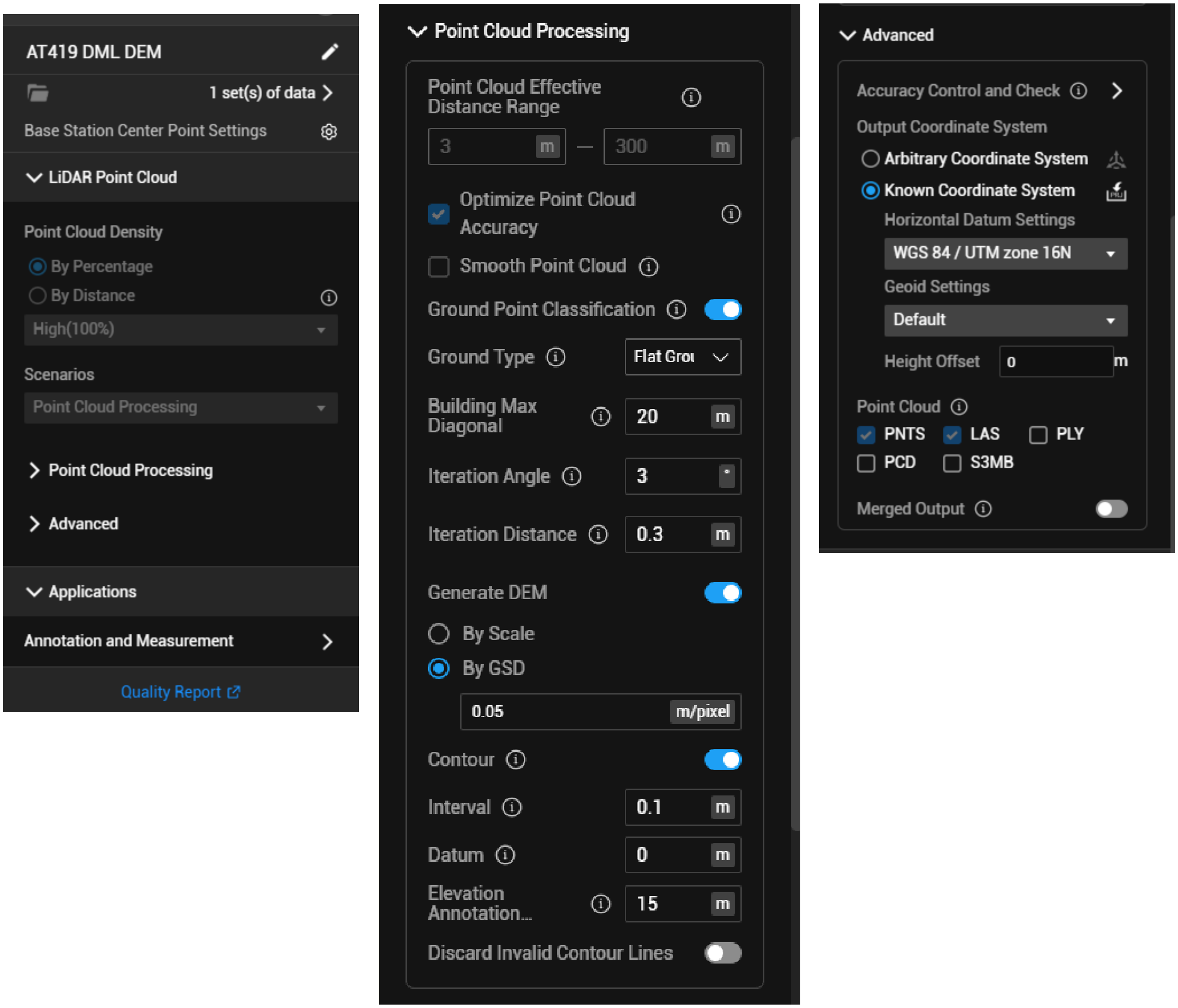

Figure 3.2.2 to Figure 3.2.4: DJI Terra point cloud processing settings.

3.3 Pix4D Mapping and ArcGIS Pro

Another set of data was collected by DJI Mavic 2 Pro. It was flying over the study area and taking pictures for the map. Since the mobile app Pix4D Capture couldn't let Mavic take off, so I flew it manually. The pictures were merged in Pix4D Mapping. New project was created in the C drive temp folder, and the data was processed.

Summary

Project	AT419 Capstone DML Turf Map
Processed	2024-04-22 21:01:21
Camera Model Name(s)	L1D-20c_10.3_5472x3648 (RGB)
Average Ground Sampling Distance (GSD)	0.21 cm / 0.08 in
Area Covered	0.000 km^2 / 0.0348 ha / 0.00 sq. mi. / 0.0861 acres
Time for Initial Processing (without report)	20m:14s

Quality Check

Images	median of 72646 keypoints per image	✔
Dataset	74 out of 74 images calibrated (100%), all images enabled	✔
Camera Optimization	0.47% relative difference between initial and optimized internal camera parameters	✔
Matching	median of 44548.8 matches per calibrated image	✔
Georeferencing	yes, no 3D GCP	⚠

Preview

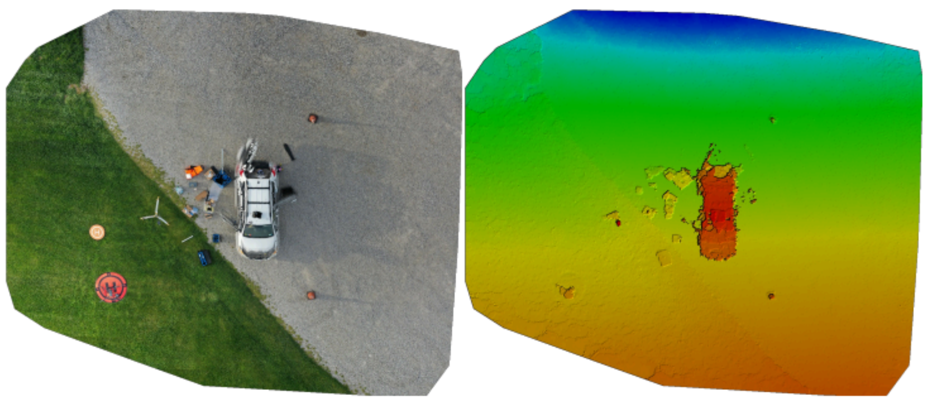

Figure 3.3.1: Pix4D initial processing report

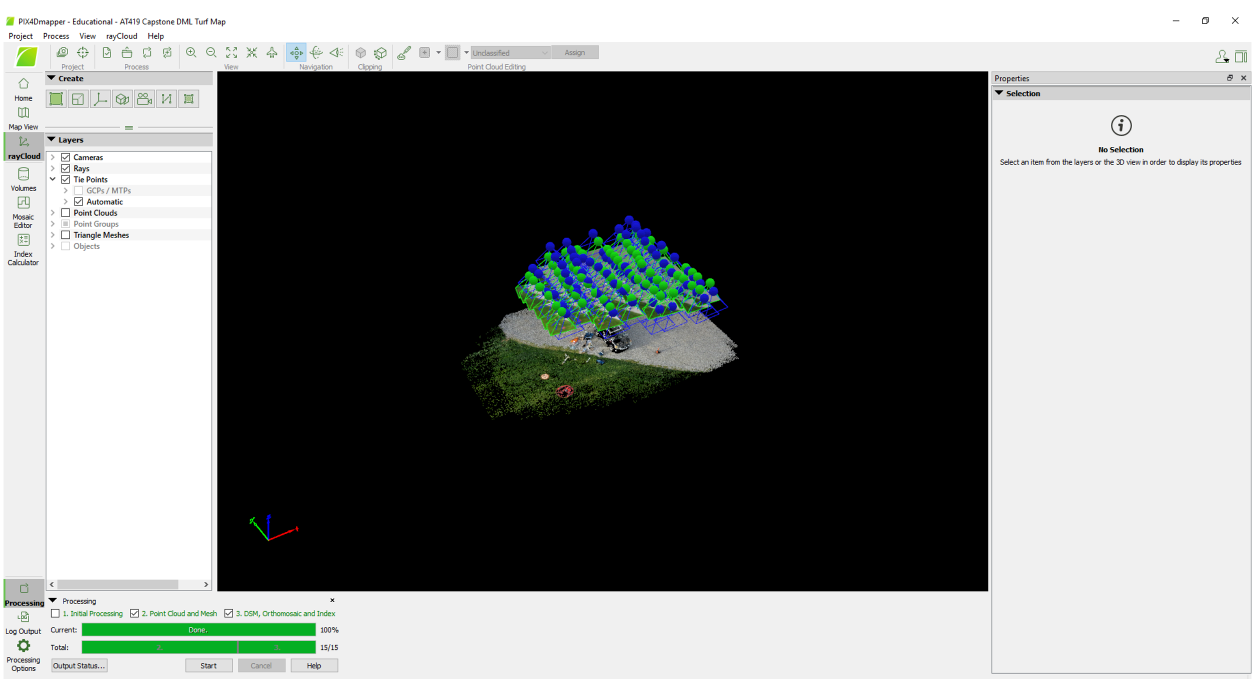

Figure 3.3.2: Pix4D finished Initial Processing, Point Cloud and Mes, and DSM, Orthomosaic and Index processing.

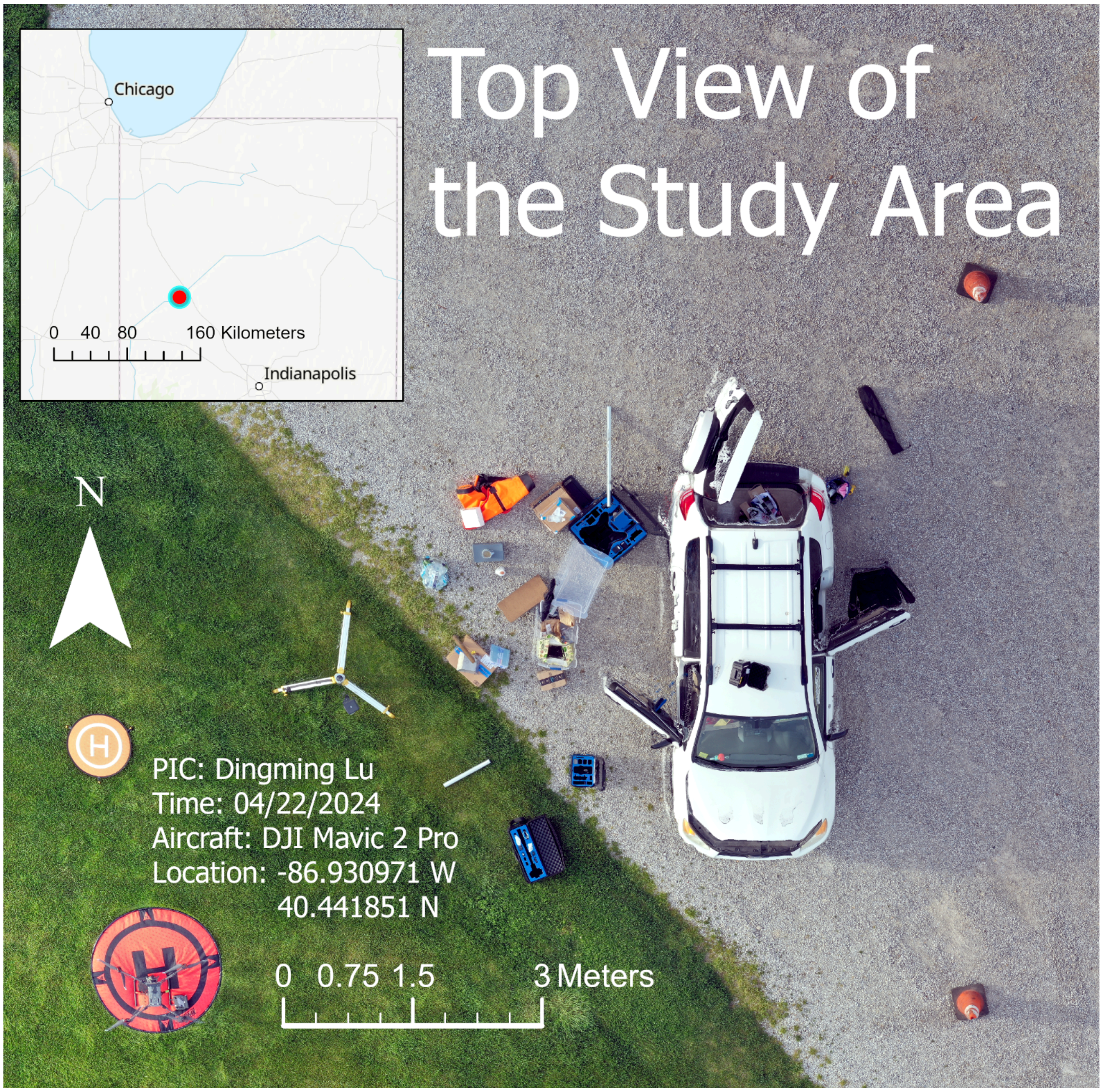

Figure 3.3.3: After putting the merged image into ArcGIS Pro, it's made into this map.

4. Result and Discussion

I need to make an announcement that the result is only for DJI L1 and Terra and may not represent all LiDAR and software on the market. This is just a reference only.

4.1 General Result and Discussion

Since Ground Point Classification and DEM are enabled, DJI Terra generated two more models. The pictures below show the results. In conclusion, DJI L1 and Terra don't like concave shapes that are opening sideways. They are trying to close the gap, such as the engine hood and the base of the tripod. DJI L1 didn't collect any data from glass, including the windshield and the glass jar. Surprisingly, we couldn't see the 30mm diameter carbon fiber tube either. Darker color doesn't mean it has lower reflectivity, the umbrella in the plastic box is the evidence. Also, brighter color doesn't mean it has higher reflectivity, such as the bottom side of the door.

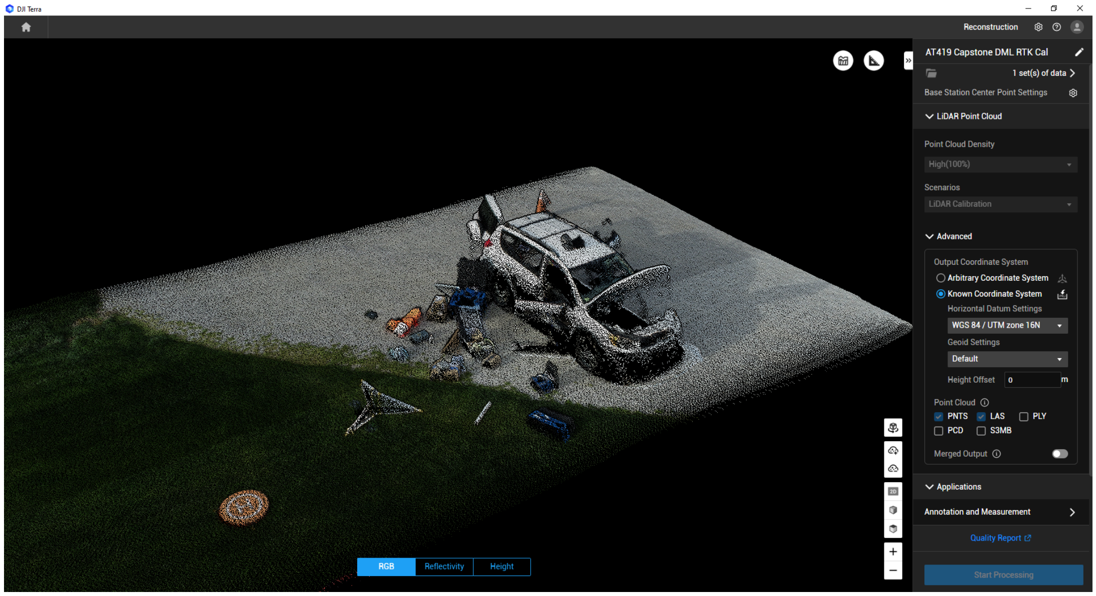

Figure 4.1.1: LiDAR Calibration processing, RGB side view.

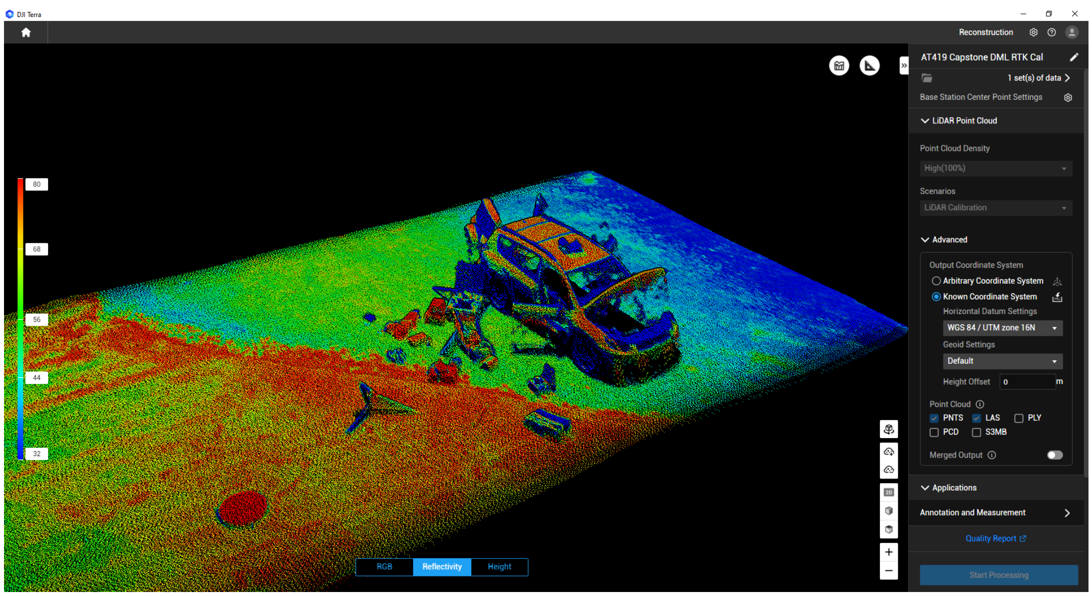

Figure 4.1.2: LiDAR Calibration processing, Reflectivity side view.

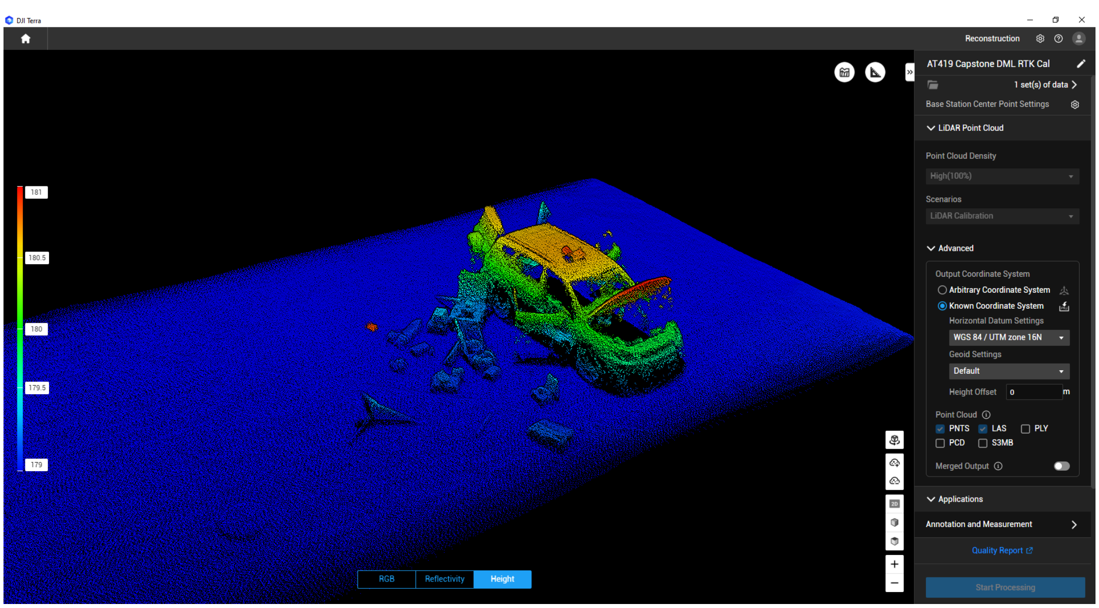

Figure 4.1.3: LiDAR Calibration processing, Height side view.

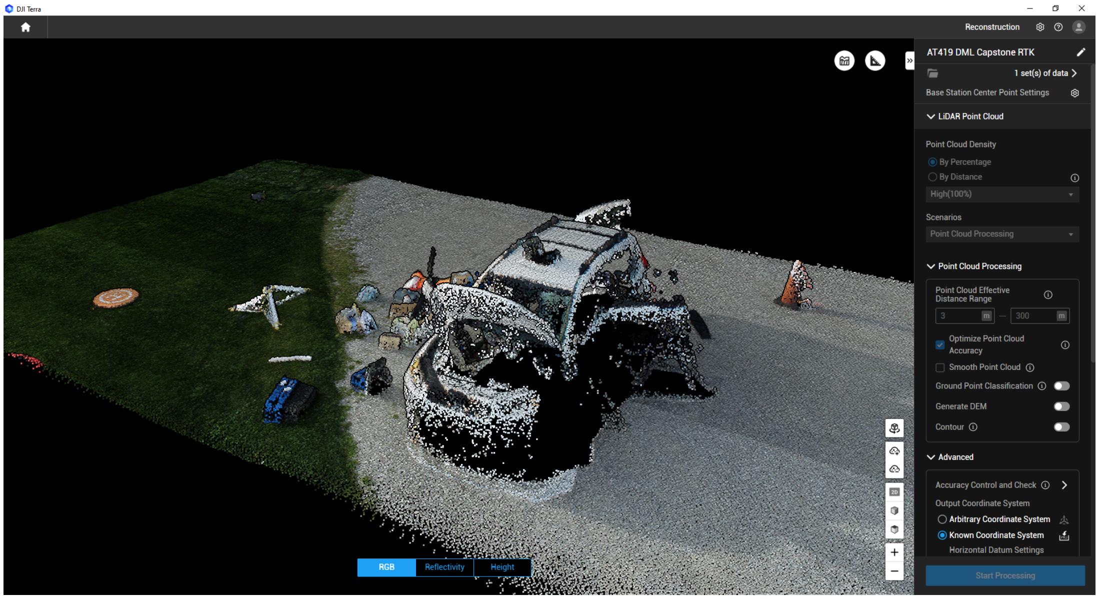

Figure 4.1.4: Point Cloud Processing, RGB side view.

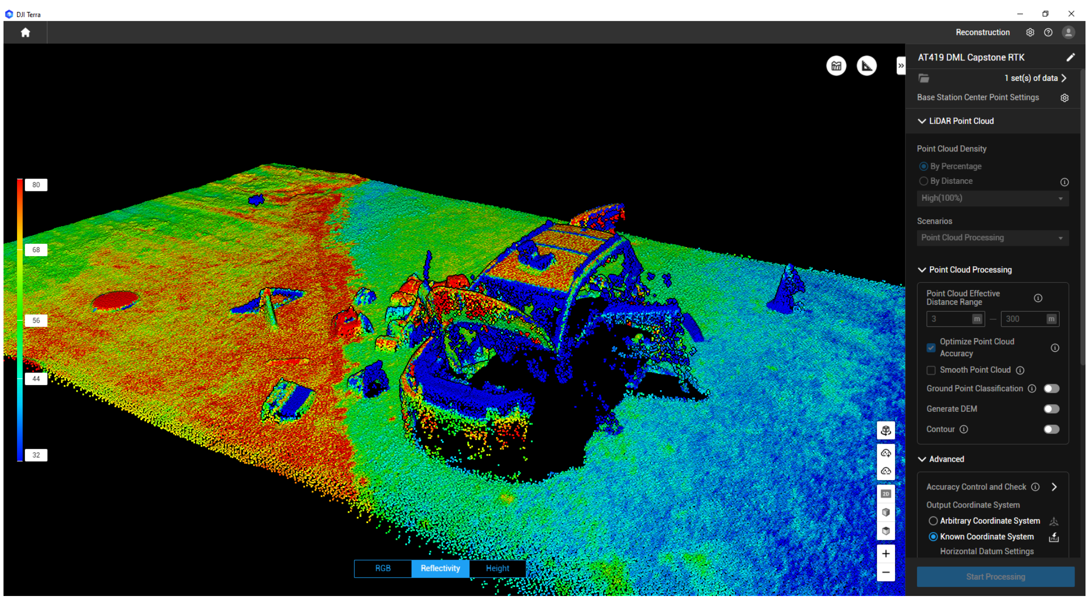

Figure 4.1.5: Point Cloud Processing, Reflectivity side view.

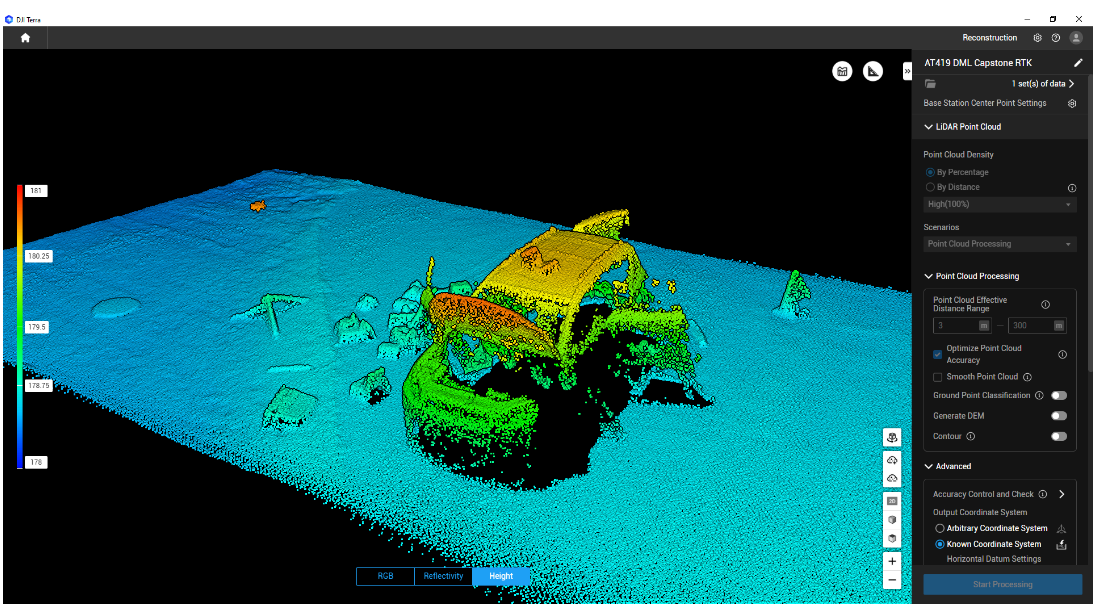

Figure 4.1.6: Point Cloud Processing, Height side view.

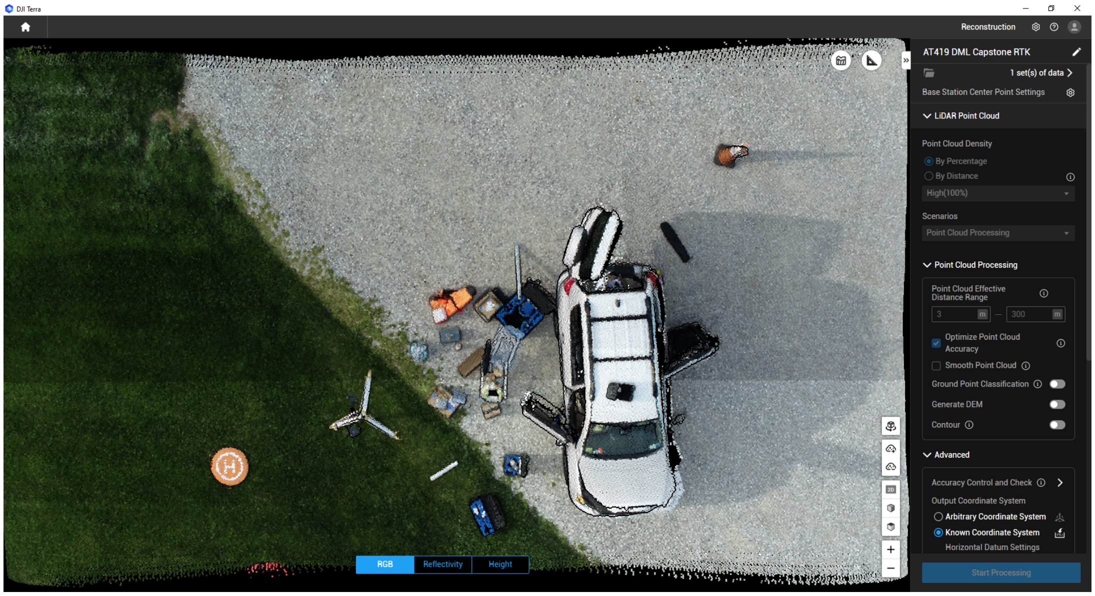

Figure 4.1.7: Point Cloud Processing, RGB top view.

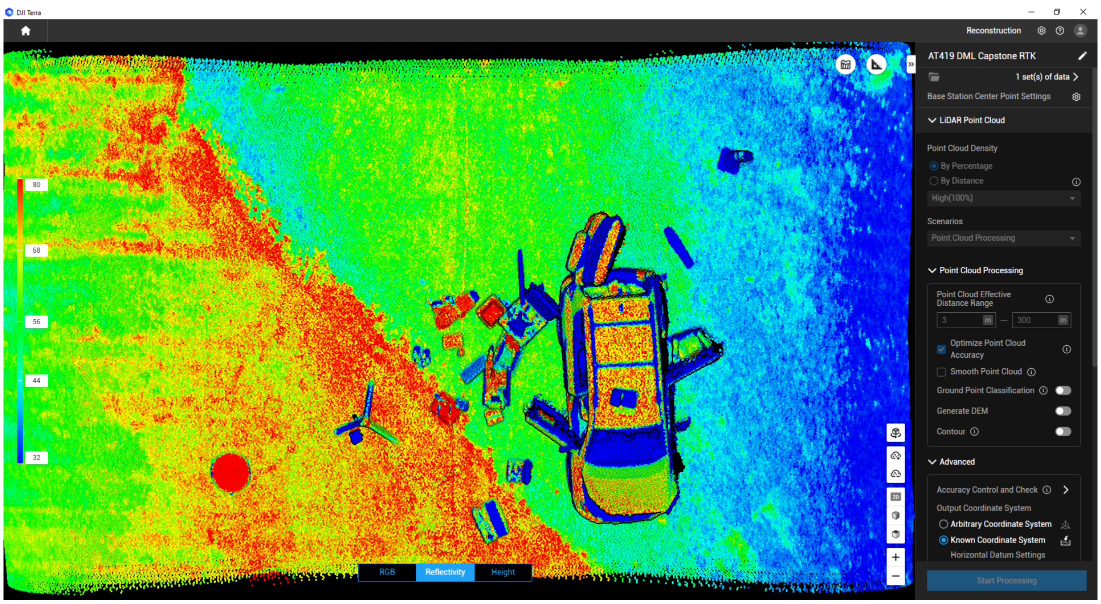

Figure 4.1.8: Point Cloud Processing, Reflectivity top view.

Figure 4.1.9: Point Cloud Processing, Height top view.

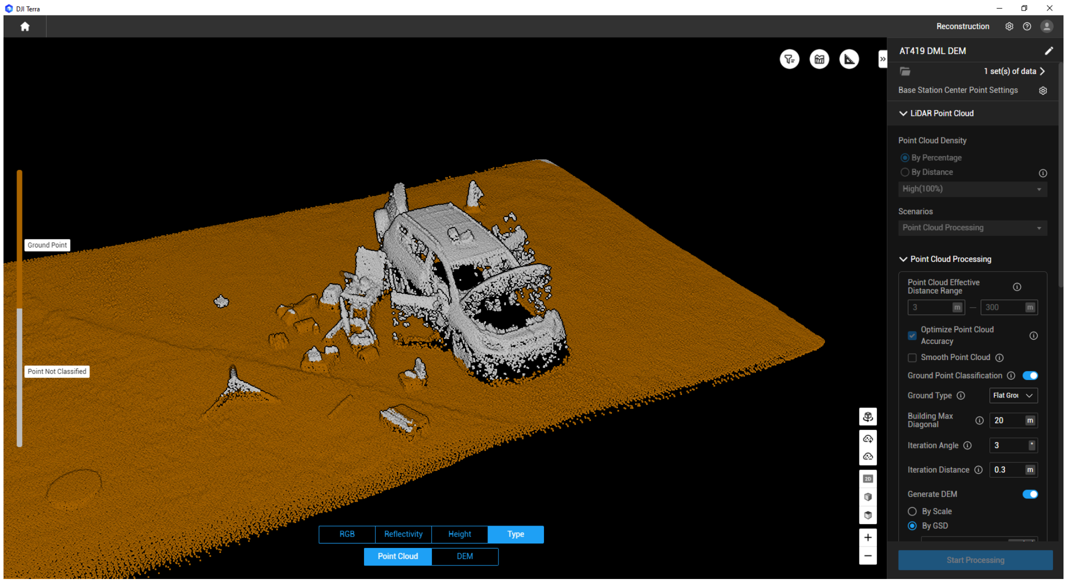

Figure 4.1.10: Point Cloud Processing, Type side view.

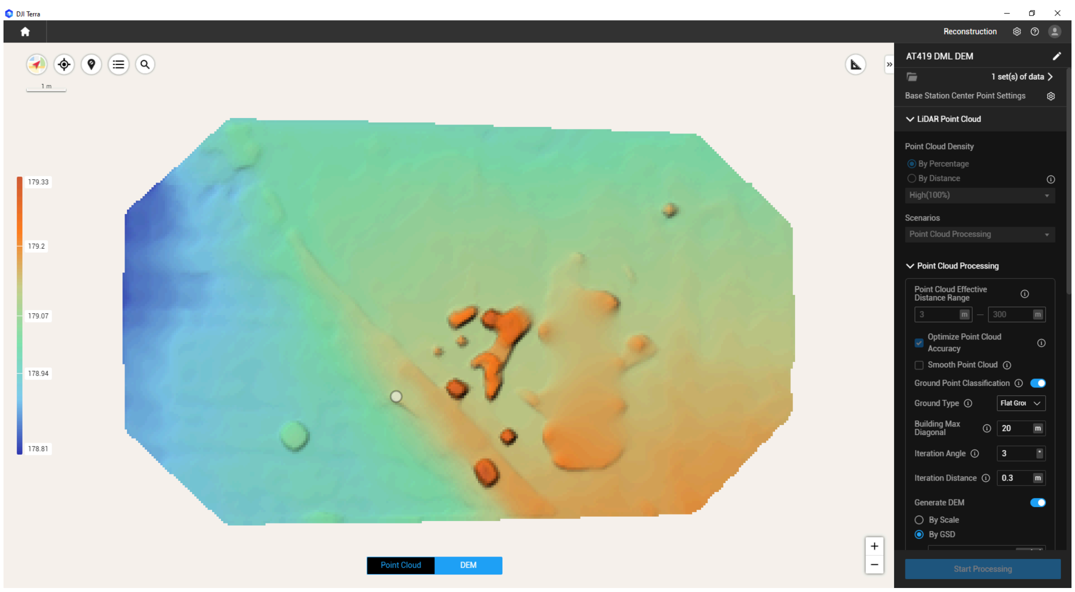

Figure 4.1.11: Point Cloud Processing, DEM.

4.2.1 ~ 4.2.19 Detailed Result and Discussion on Each Item

This is the overview of the major part of the study area. Most items are already shown in this picture. In the following discussions, this picture will help you to locate where each item is at.

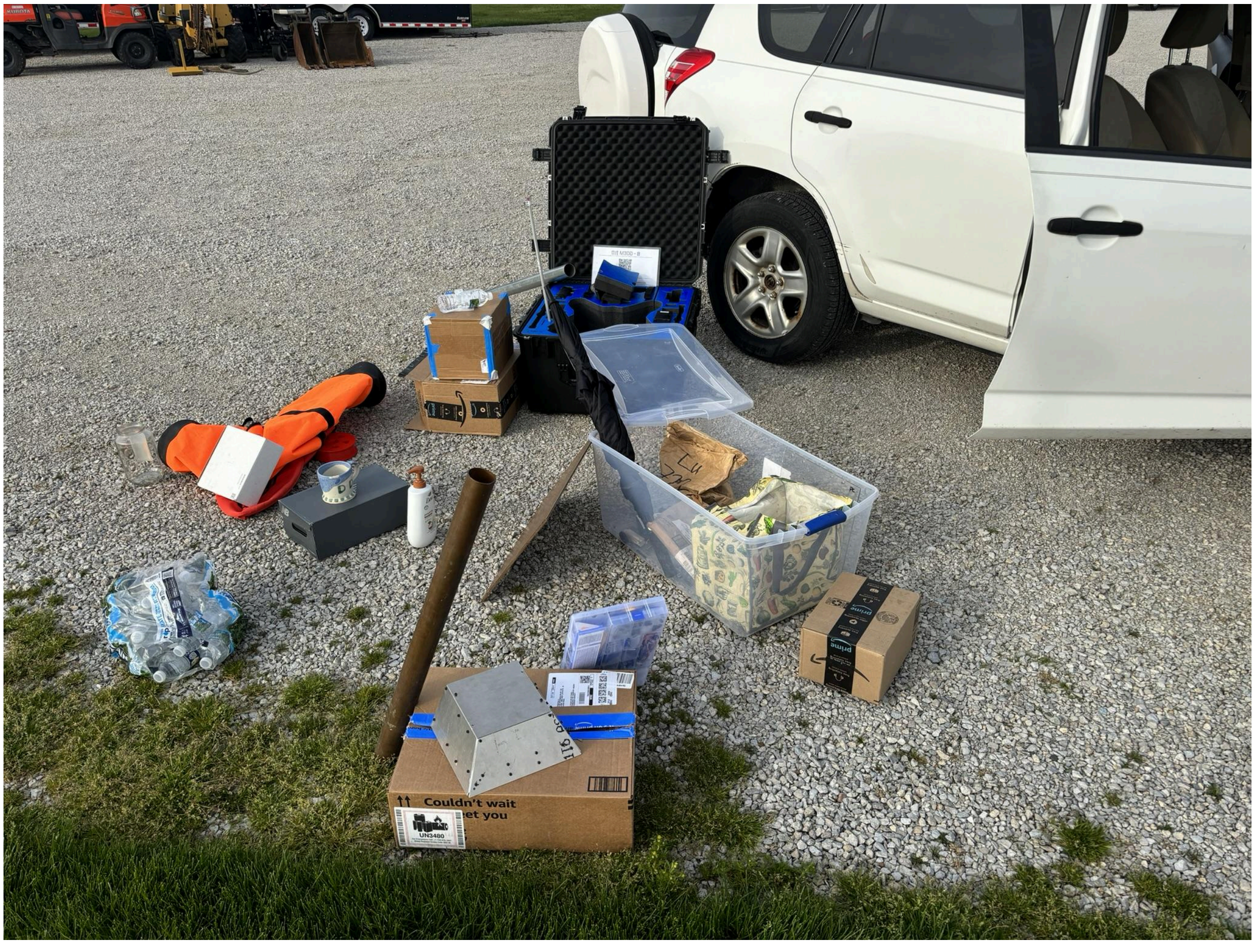

Figure 4.2.1: overview of the major part of the study area.

4.2.1 Cardboard box

Cardboard boxes were used as the dimension comparison. The actual dimensions are labeled in the pictures below. Two measure the distance on any two points of the point cloud, the starting point and the end point must be chosen correctly. It’s kind of hard to do because both points need to verify if it’s at the correct location from three directions. And sometimes, the point doesn’t exist, such as the corner of the box.

Figure 4.2.1.1: The dimensions of the cardboard box.

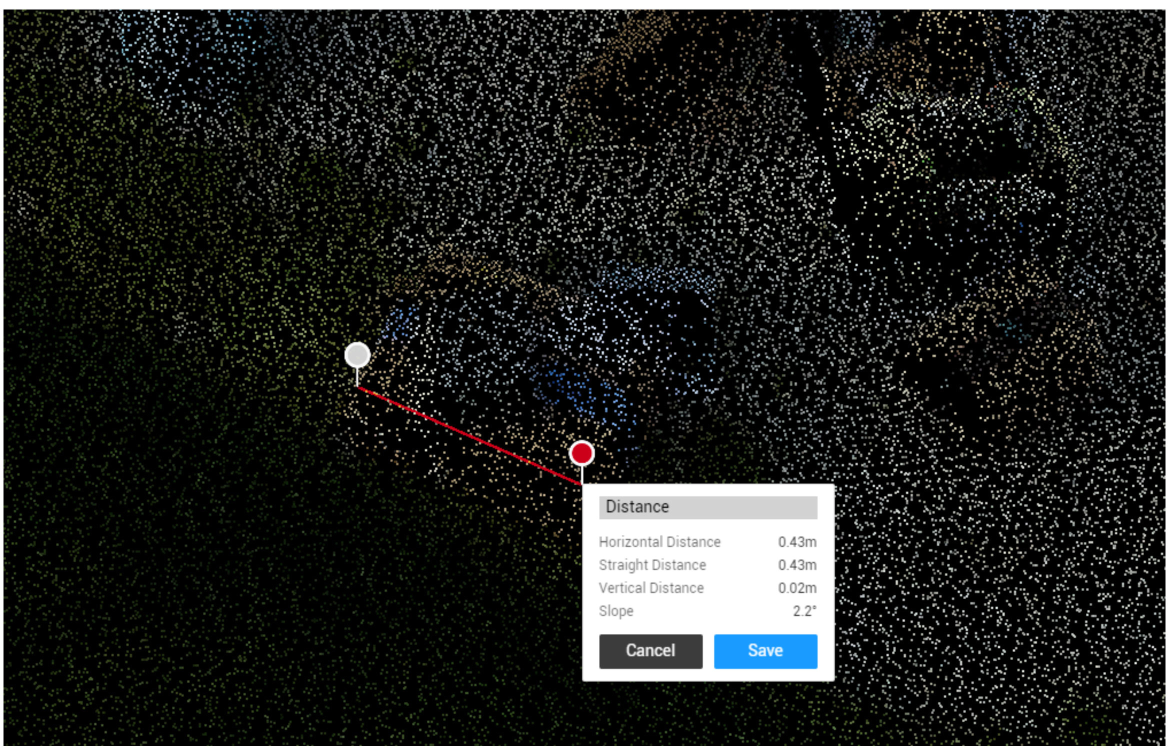

Figure 4.2.1.2: measured length is 43 cm. Actual length is 47.2 cm.

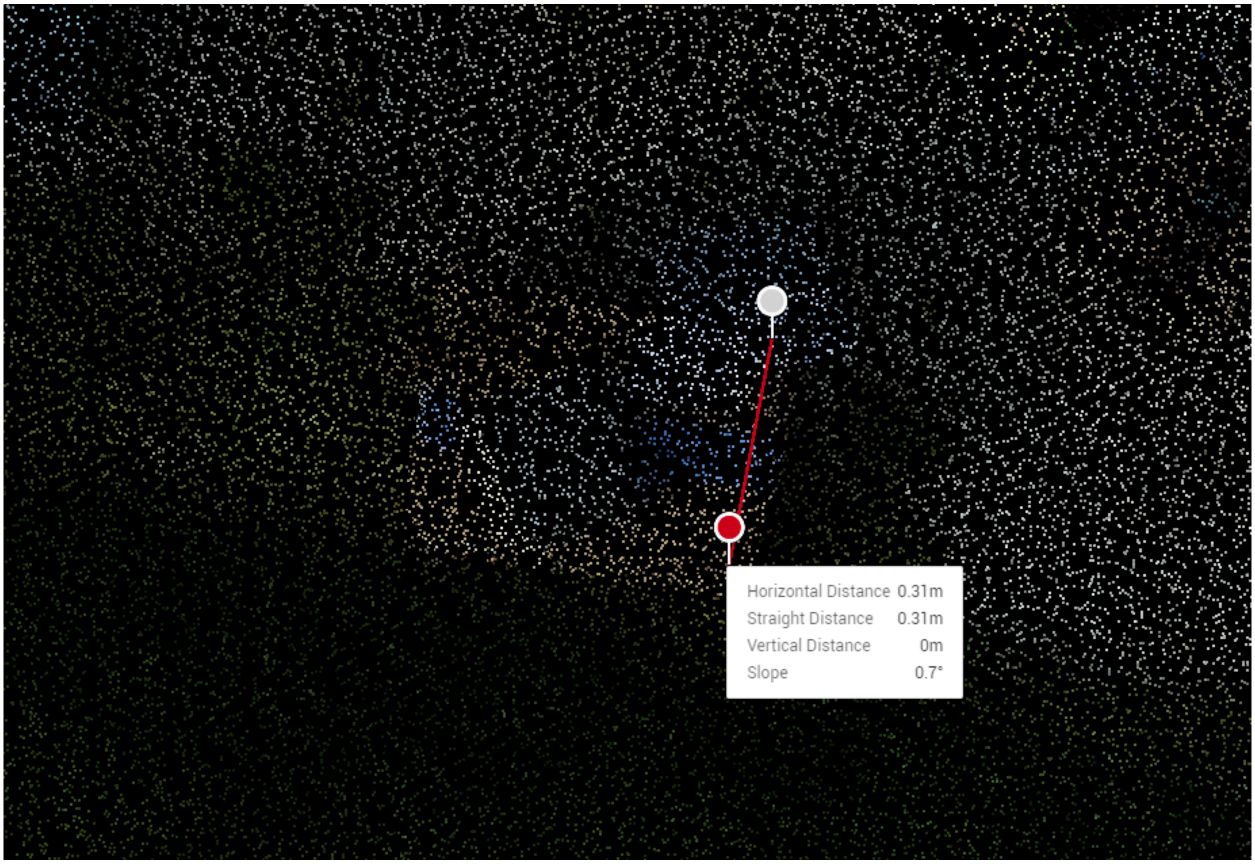

Figure 4.2.1.3: measured length is 36 cm. Actual length is 31 cm.

Figure 4.2.1.4: change the perspective to verify that two points are on the same height.

Figure 4.2.1.5: The dimensions of the cardboard box next to the plastic storage box.

Figure 4.2.1.6: measured length is 16 cm. Actual length is 21 cm. Two sides of the box are not straight up, making its cross section into a trapezoid.

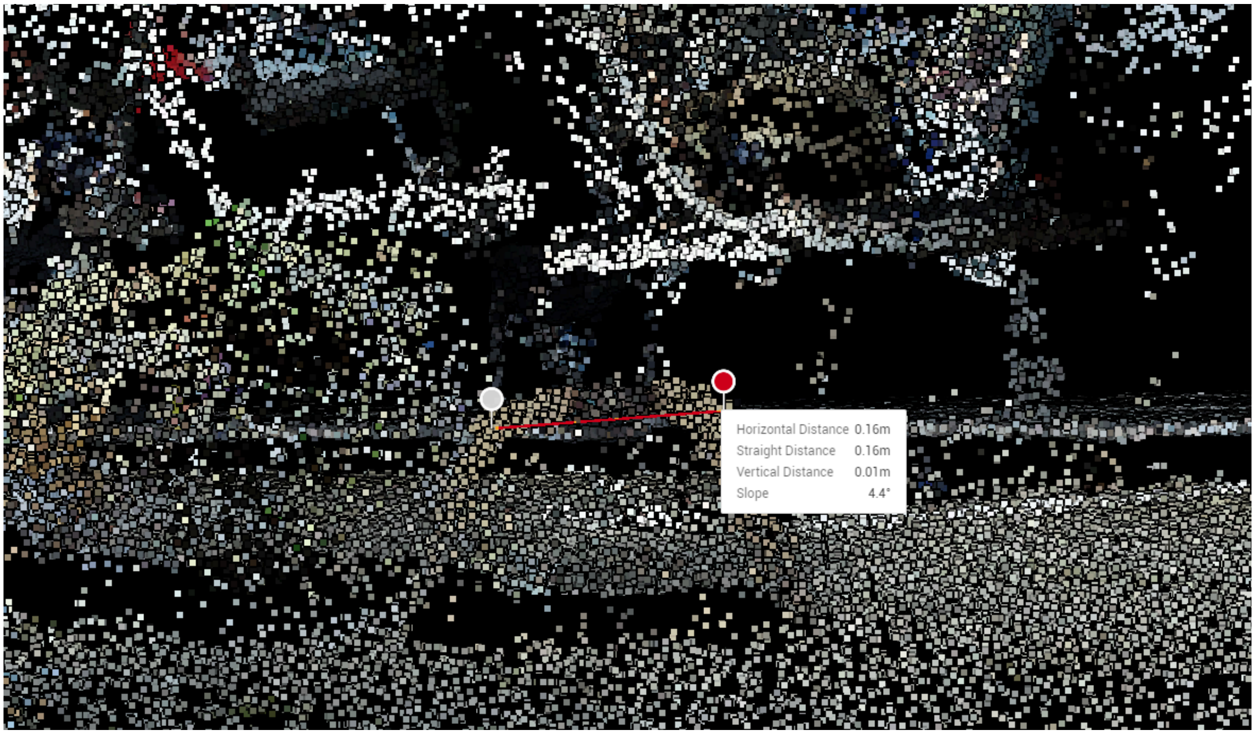

Figure 4.2.1.7: Side view of the box. It's a trapezoid looking from the west.

Figure 4.2.1.8: Top view of the box. Top of the image is east.

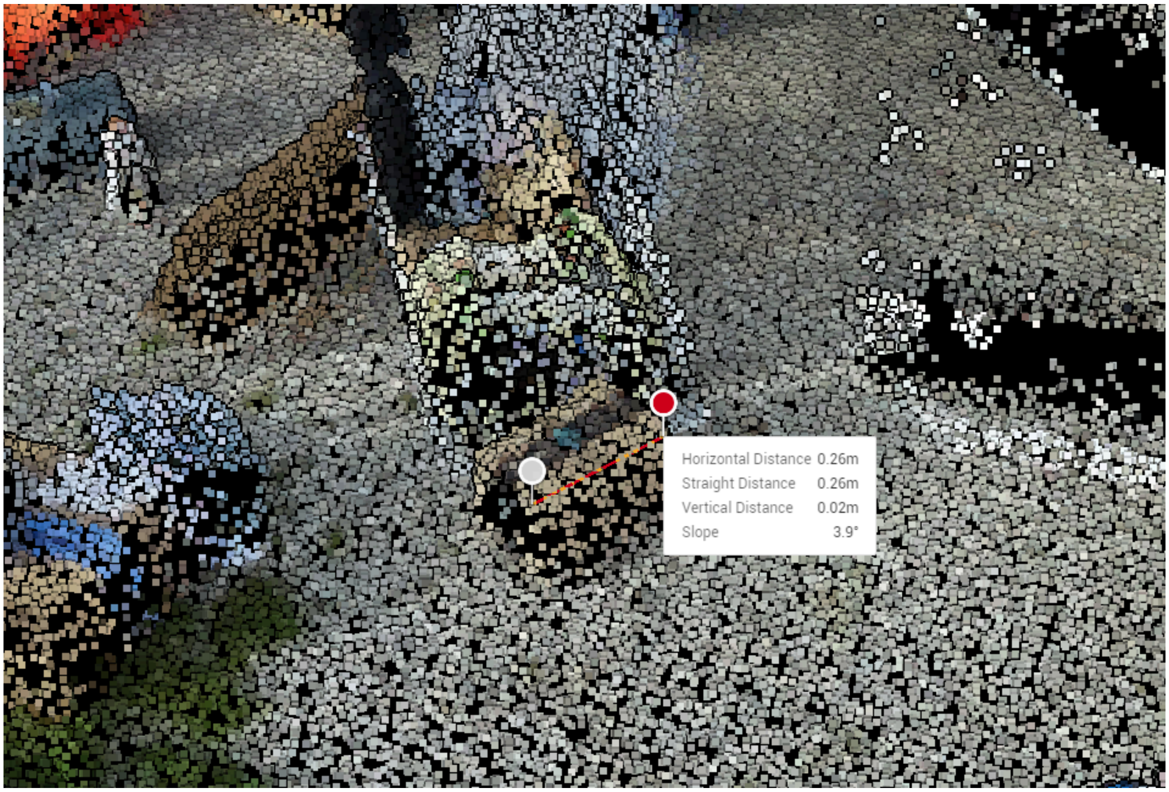

Figure 4.2.1.9: measured length is 26 cm. Actual length is 28 cm.

Figure 4.2.1.10: The dimensions of the cardboard box next to the drone case.

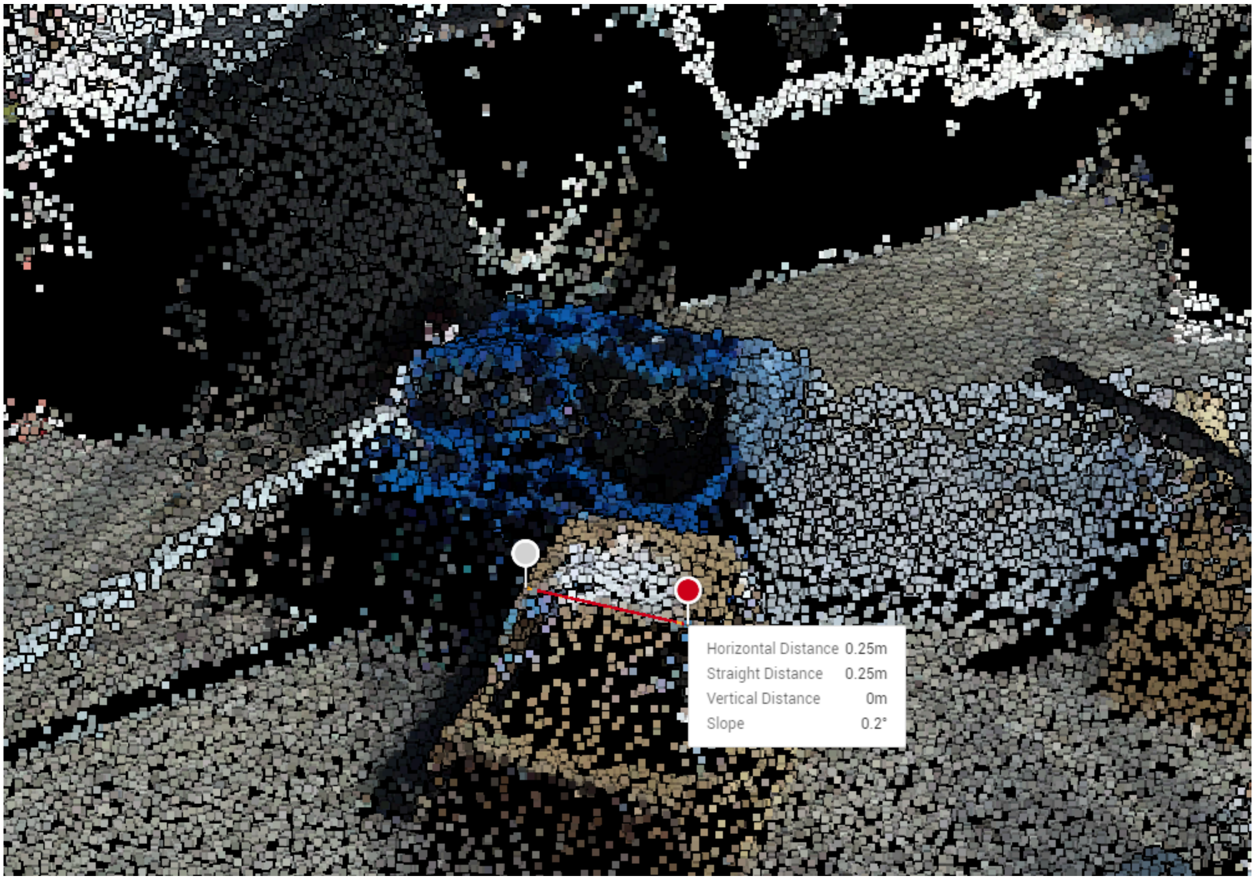

Figure 4.2.1.11: measured length is 25 cm. Actual length is 30.7 cm.

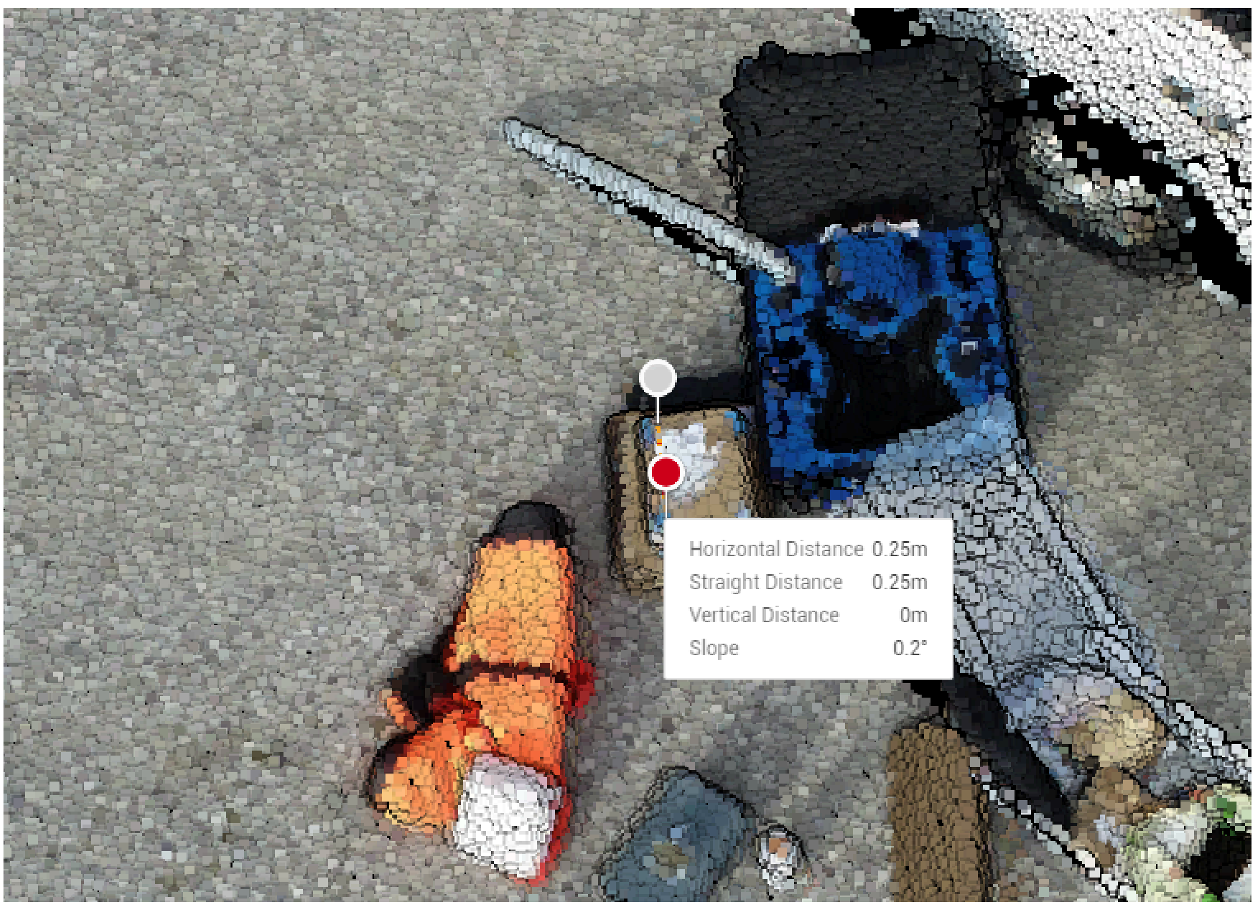

Figure 4.2.1.12: measured length is 25 cm. Actual length is 30.7 cm.

The table below summarized the measurements above. The possible reason for the large percent error might be the size of the object and/or the point cloud density. Some points are lost, such as the point on the corner of the boxes, so the measurement has large errors. Just a few points can reduce 5 cm. One of the settings before the data processing is about the Point Cloud Density. If it is set to “By Distance”, the minimum distance is 5 cm.

Table 4.2.1: Comparison of measured length and actual length

Measured From Terra (cm)	Actual Length (cm)	% error
43	47.2	8.9%
31	36	13.9%
16	21	23.8%
26	28	7.1%
25	30.7	18.6%

4.2.2 Glass Jar

The glass jar that is next to the orange bag has completely vanished in the point cloud.

Figure 4.2.2.1: glass jar next to the orange bag.

Figure 4.2.2.2: There’s only the point cloud of the gravel road.

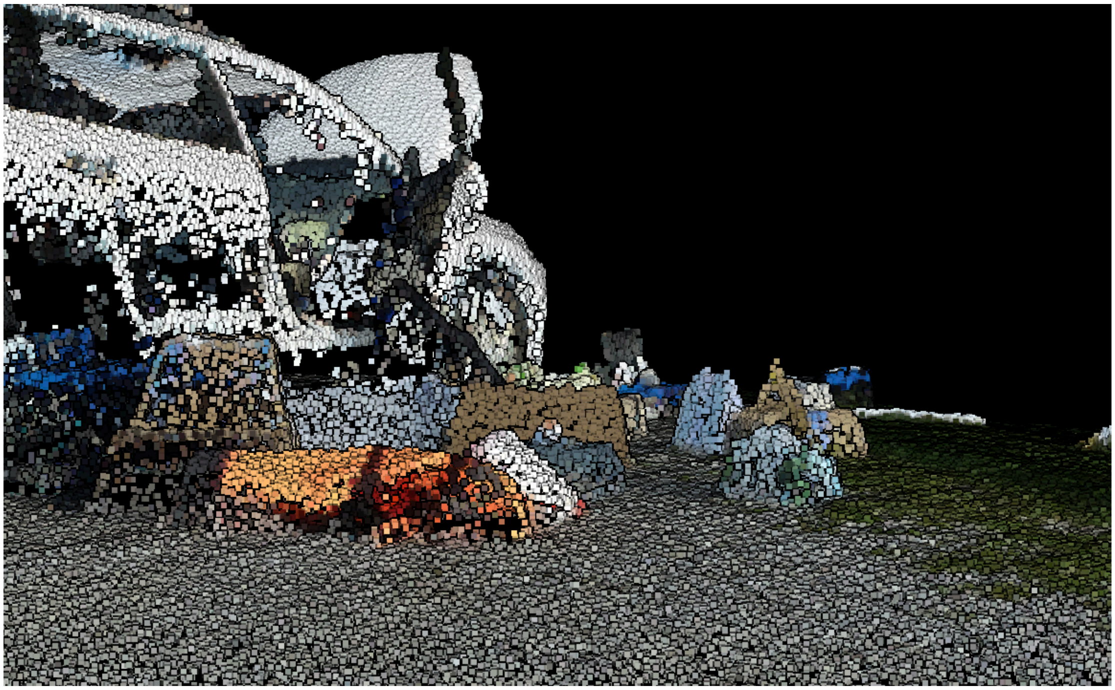

Figure 4.2.2.3: There’s still nothing looking from this angle.

4.2.3 Steel Tube

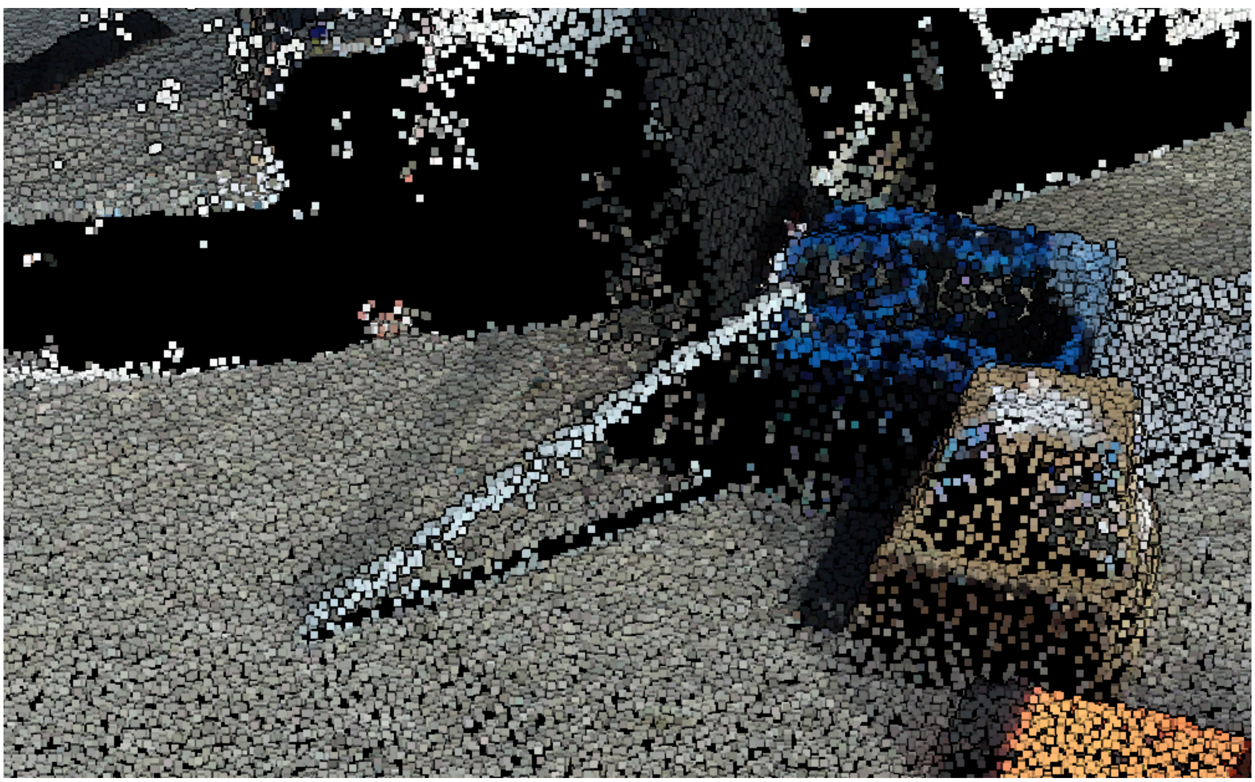

Figure 4.2.3.1: The steel tube is behind the drone case. The area under the steel tube is not covered by the point cloud. There are also point clouds floating above the ground trying to merge the gap.

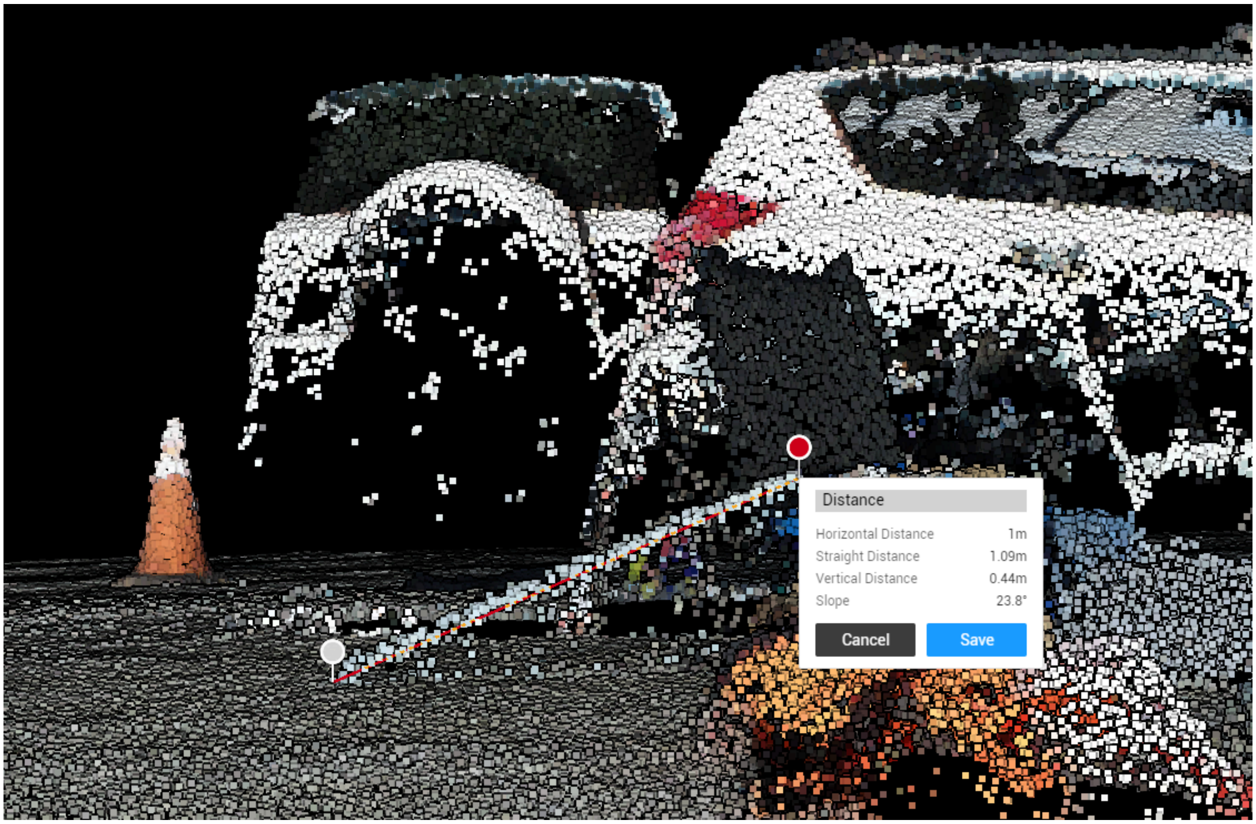

Figure 4.2.3.2: measured length is 109 cm. Actual length is 113 cm. Percent error is 3.5%.

4.2.4 Copper Tube

The copper tube was placed next to the cardboard box. It had a diameter of 5.4 cm and length of 77 cm, but only the lower portion of the tube was scanned.

Figure 4.2.4.1: the copper tube is much higher than the box.

Figure 4.2.4.2: only the small brown area is the copper tube.

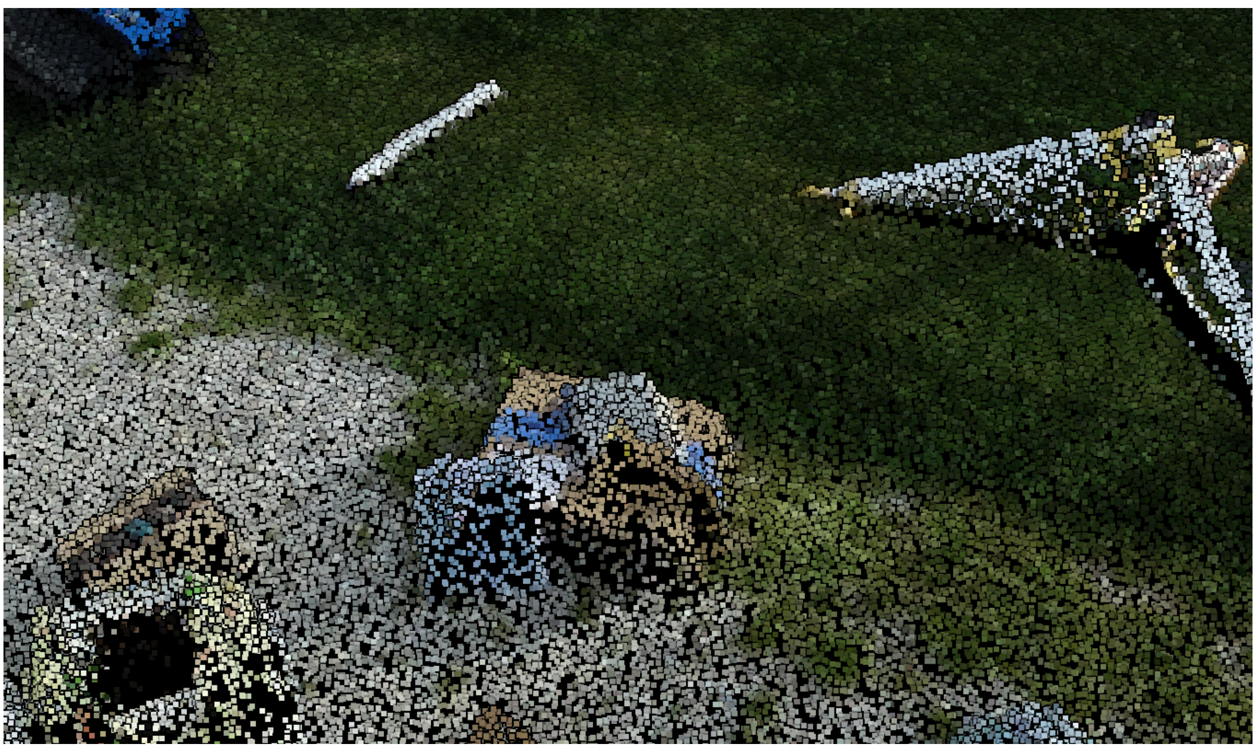

Figure 4.2.4.3: Looking at a different angle.

4.2.5 Aluminum Tube

The aluminum tube has a diameter of 5.1 cm and length of 59 cm. Measured length is 57 cm.

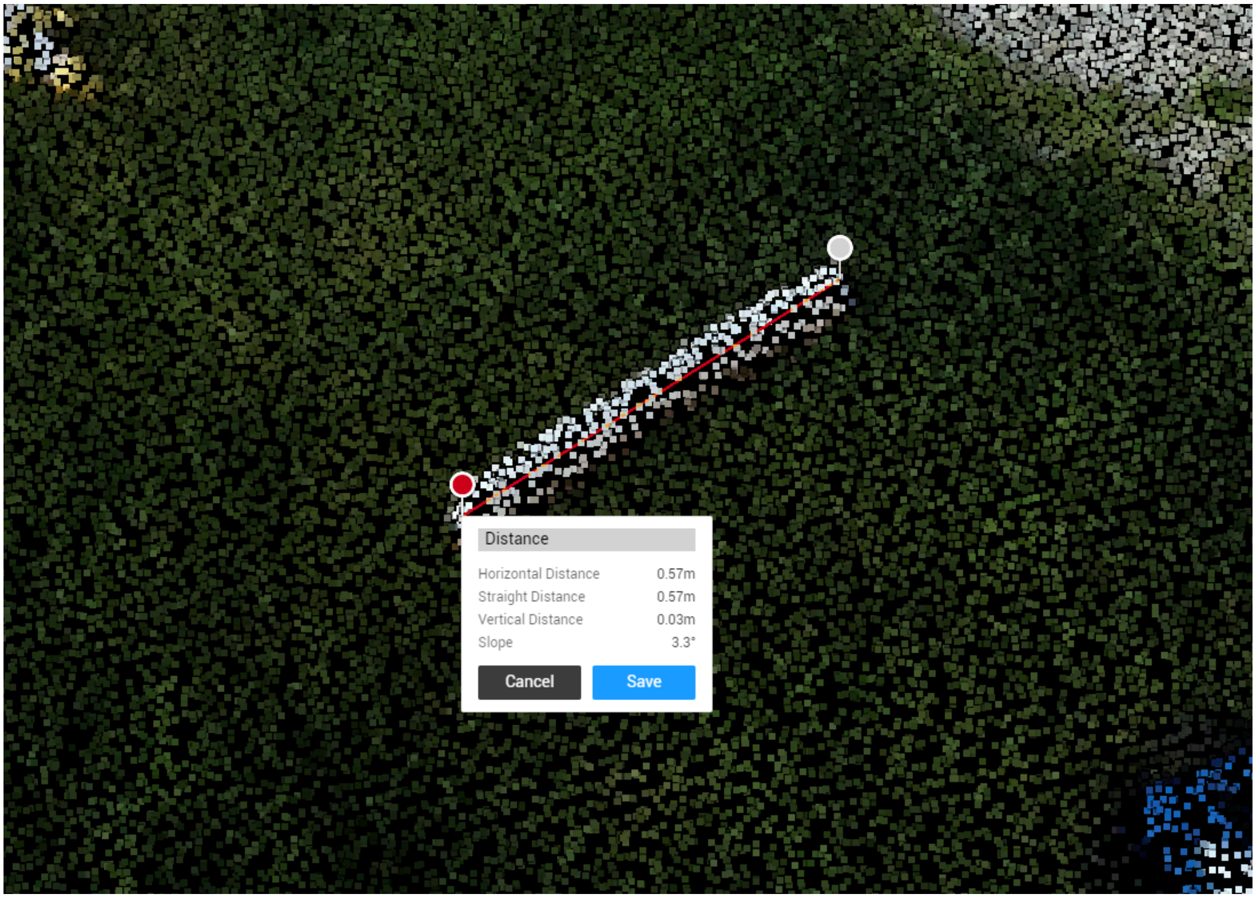

Figure 4.2.5.1: Aluminum tube was placed on the grass.

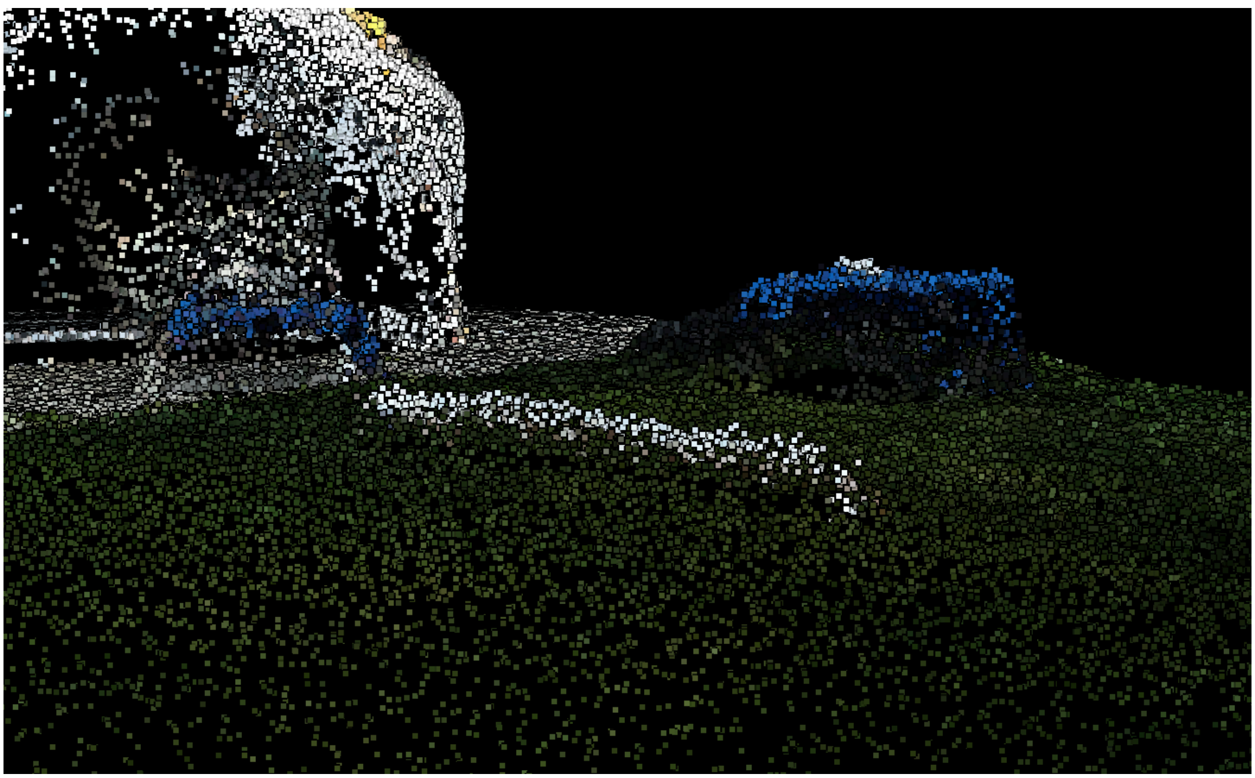

Figure 4.2.5.2: same as the steel tube, it doesn't have a smooth surface.

4.2.6 Aluminum Rod

Figure 4.2.6.1: The aluminum rod was placed on the drone case.

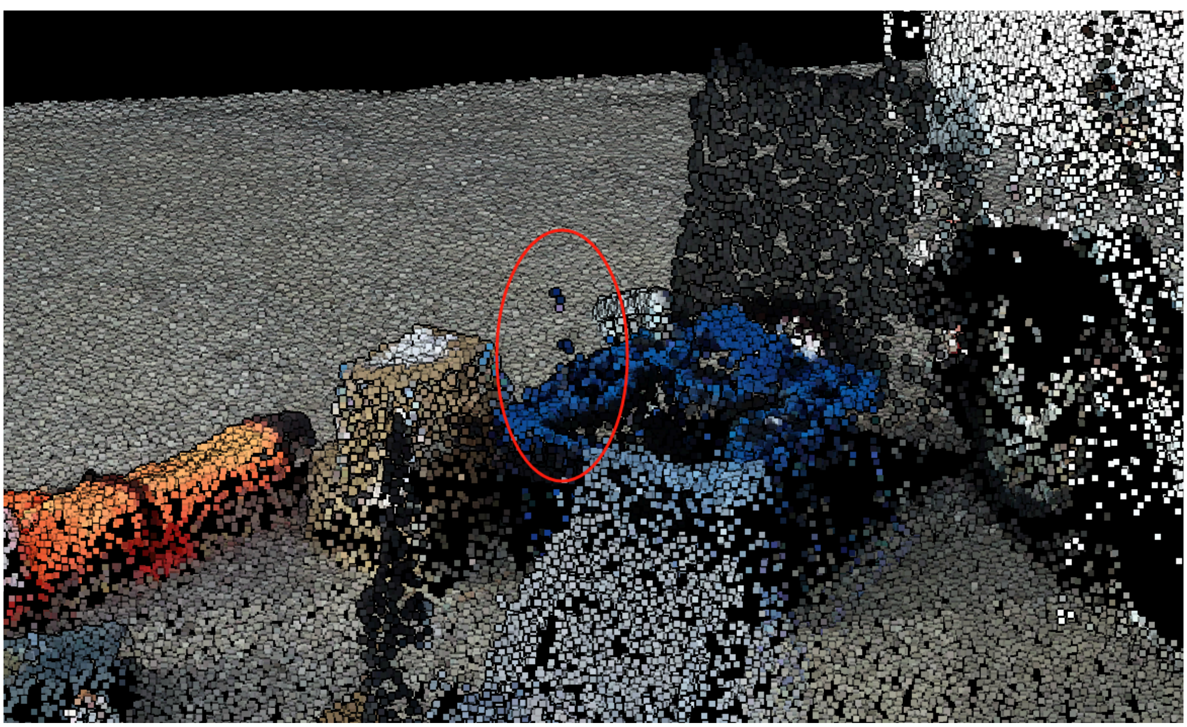

Figure 4.2.6.2: since the diameter is only 1.26 cm (0.5 inches), there's only a few point clouds.

Figure 4.2.6.3: even the color is not silver. It's the color of the top of the drone case.

4.2.7 Tripod Base

The picture shows the RTK setup. It has an antenna (top) and a power module (middle), which are supported by two aligned carbon fiber tubes.


Figure 4.2.7.1: RTK setup

Figure 4.2.7.2:The tripod base formed a concave shape, and the point clouds are trying to merge the gap.


Figure 4.2.7.3: Looking at a different angle.

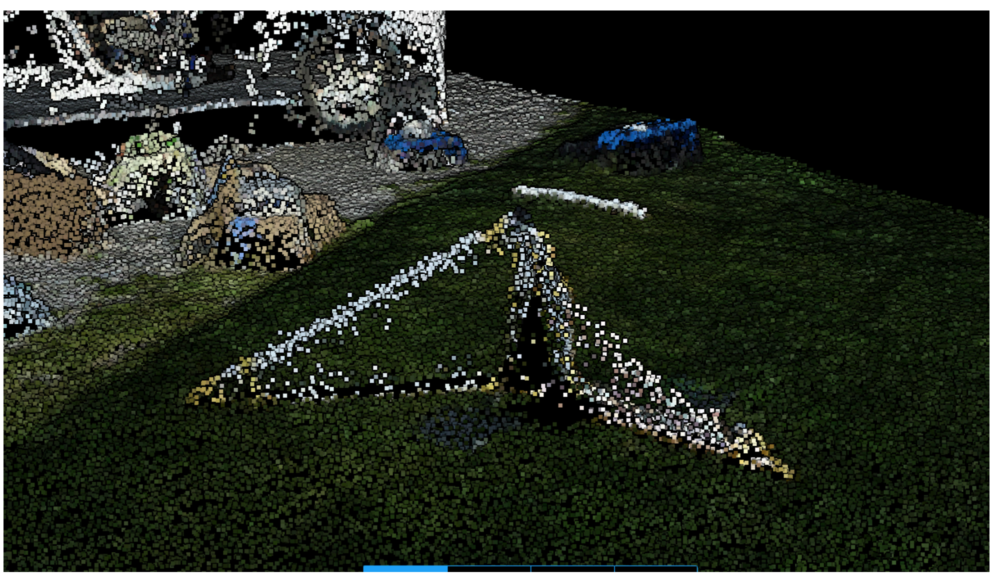
Figure 4.2.7.4: The leg on the north side has less merge effect.

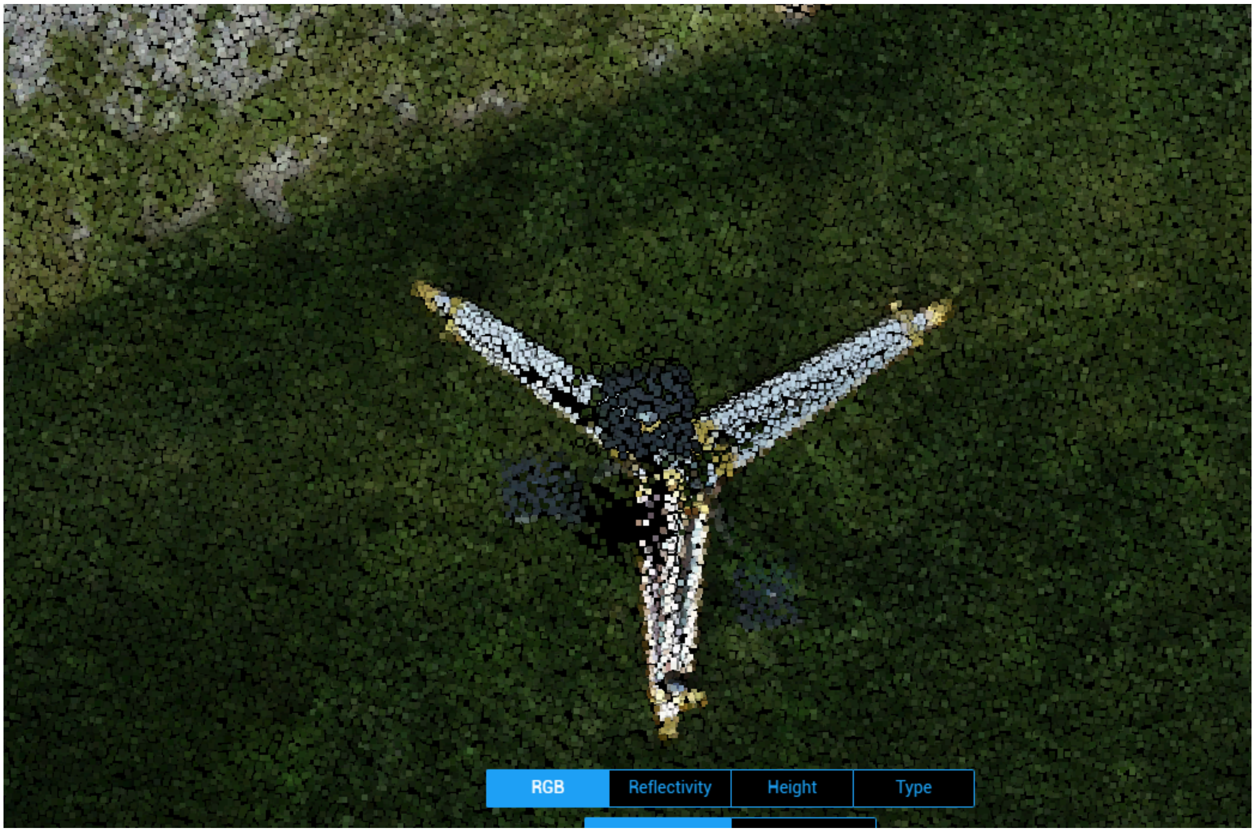

Figure 4.2.7.5: top view of the tripod.

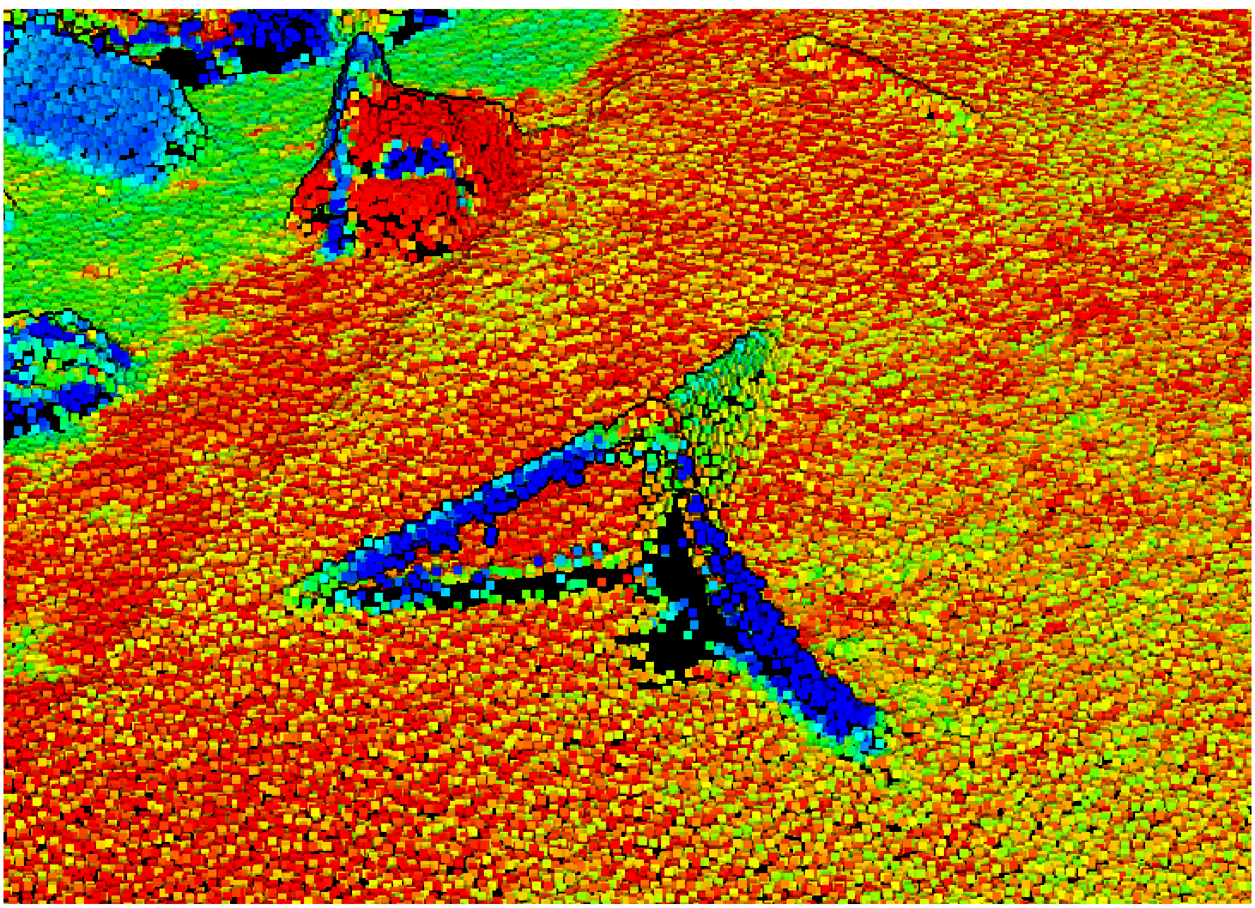
Figure 4.2.7.6: Even it’s the same material, they have different reflectivity.

4.2.8 Carbon Fiber Tube

It's easier to see it in the "Height" mode since the carbon fiber tube is black. The RTK antenna was scanned, but its base and the carbon fiber rod that is connecting to the tripod was not scanned.

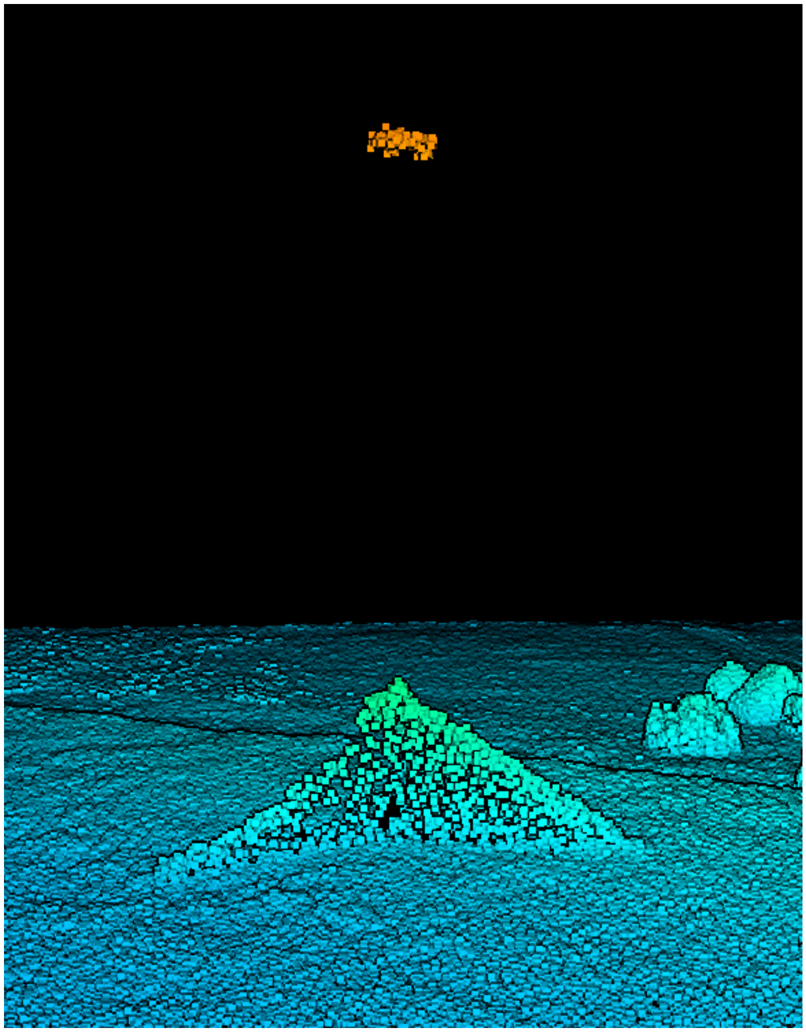

Figure 4.2.8.1: There’s no point cloud between the RTK antenna (orange) and the tripod base (green)

4.2.9 RTK antenna

Figure 4.2.9.1: point cloud of the RTK setup.

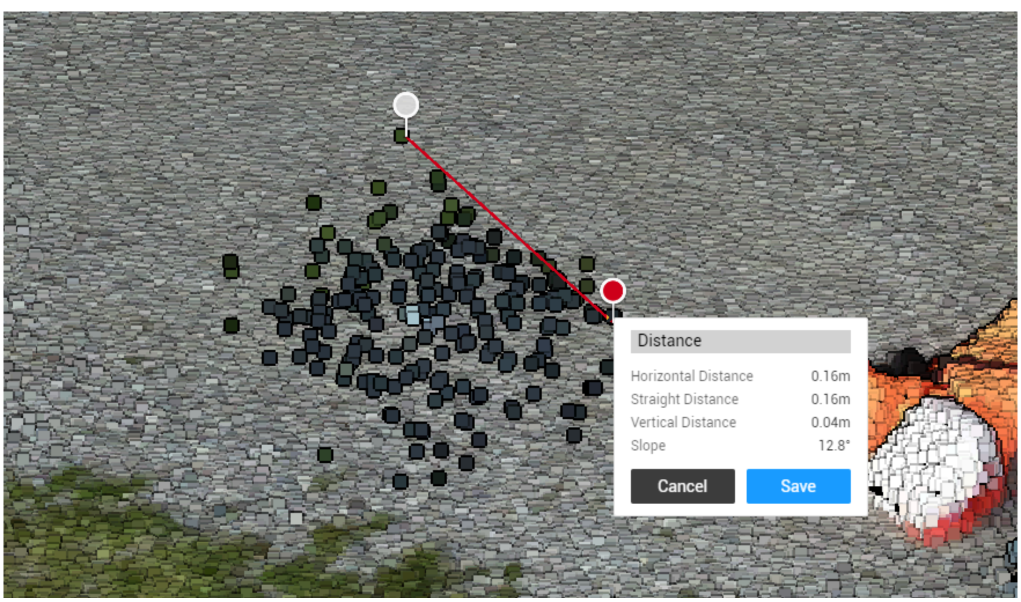

Figure 4.2.9.2: the measured distance 16 cm is very close to the actual length 15 cm. The points on the edge are dark green, I guess that's because it's on the edge and the RGB data merged with the grass.

4.2.10 Plastic Storage Box

Figure 4.2.10.1: The plastic box is in the middle of the area.

Figure 4.2.10.2: Even though the box is a concave shape, the point cloud is still able to generate the shape.

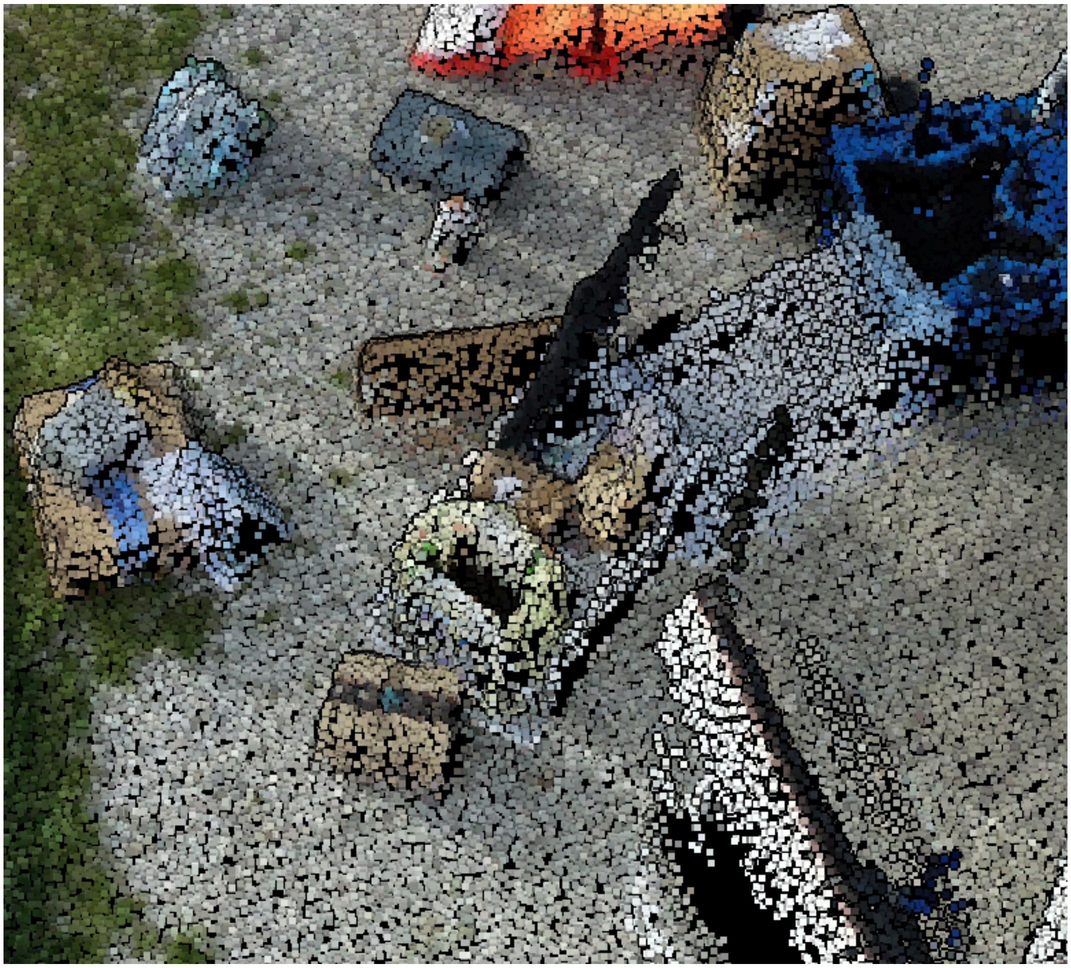

Figure 4.2.10.3: the wall of the box is very clear.

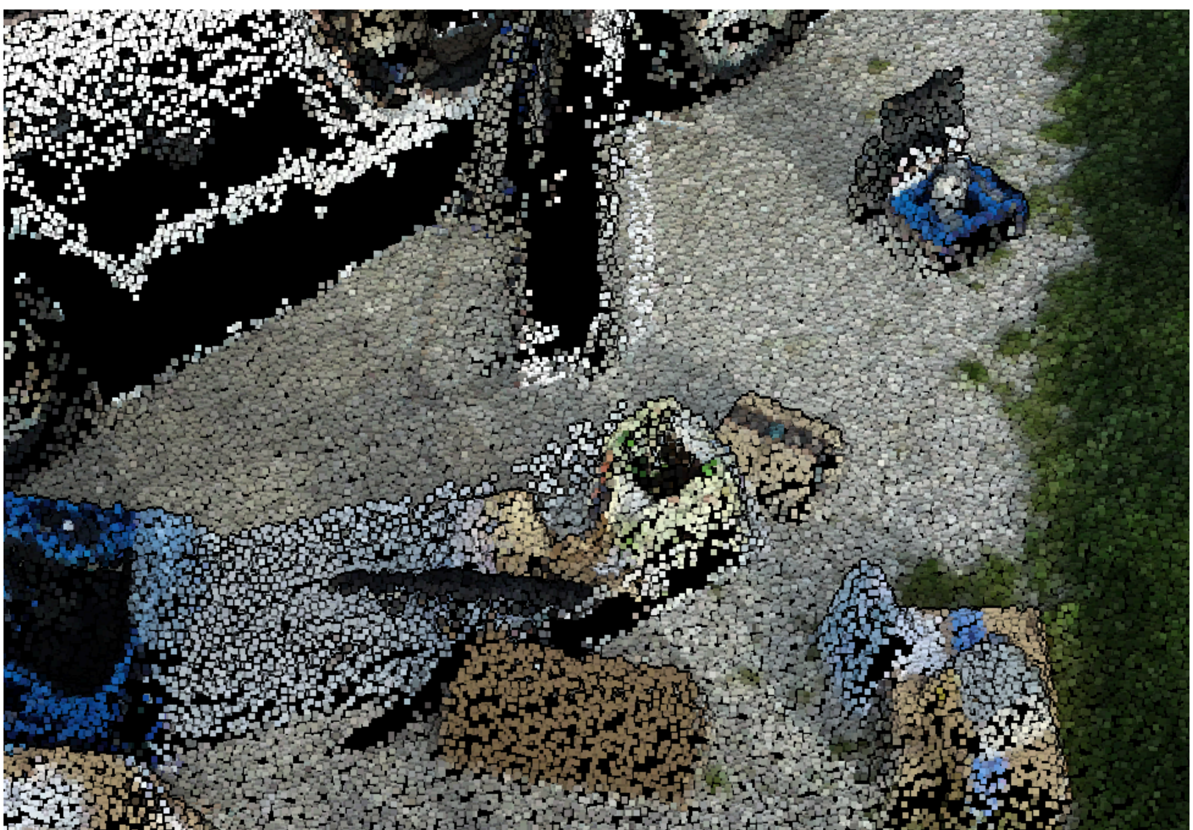

Figure 4.2.10.4: the light yellow bag in the box is also scanned.

4.2.11 Plastic Storage Box Lid

Figure 4.2.11.1: The plastic lid is in the middle of the area, it’s put on top of the plastic box and the drone case.

Figure 4.2.11.2: the lid is regenerated as a box.

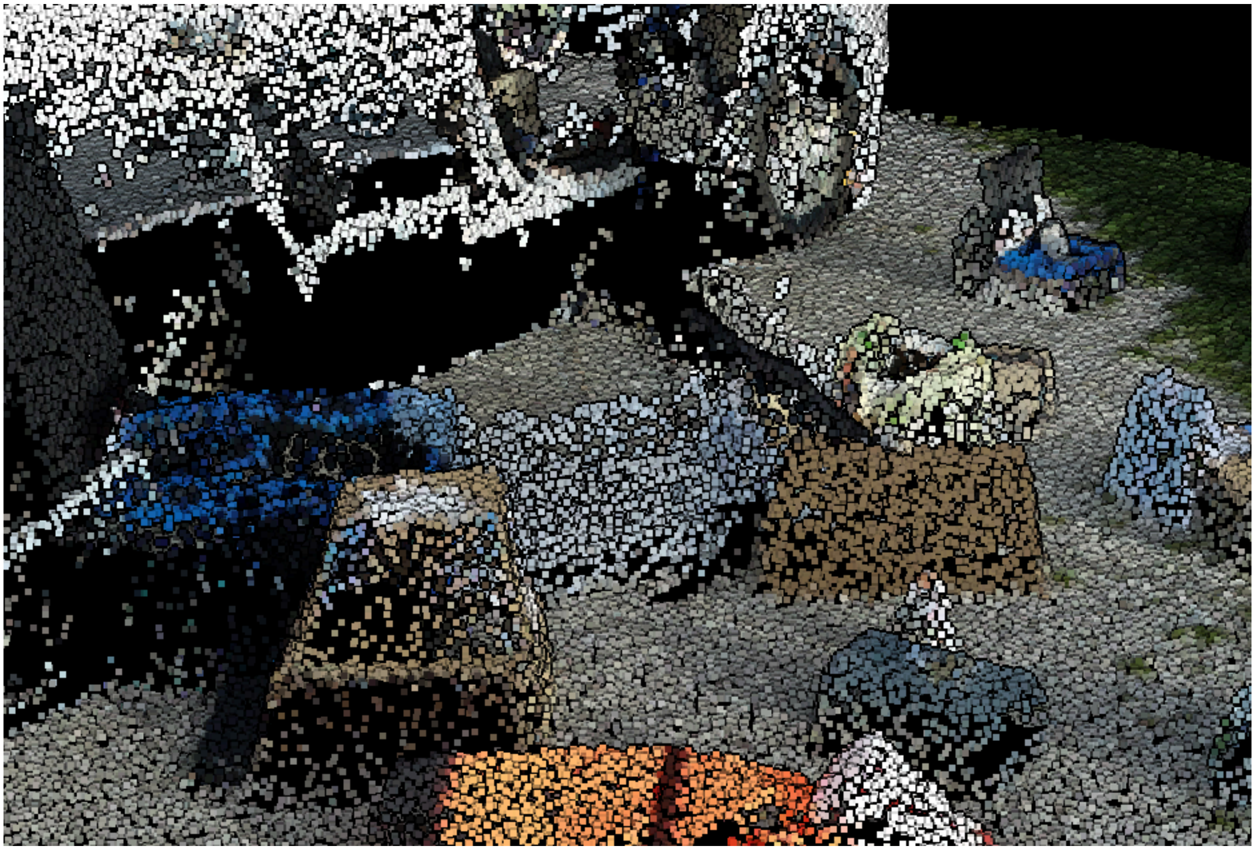

Figure 4.2.11.3: the lid is regenerated as a box. The space under the lid is covered by the wall of point cloud, and the top is opened.

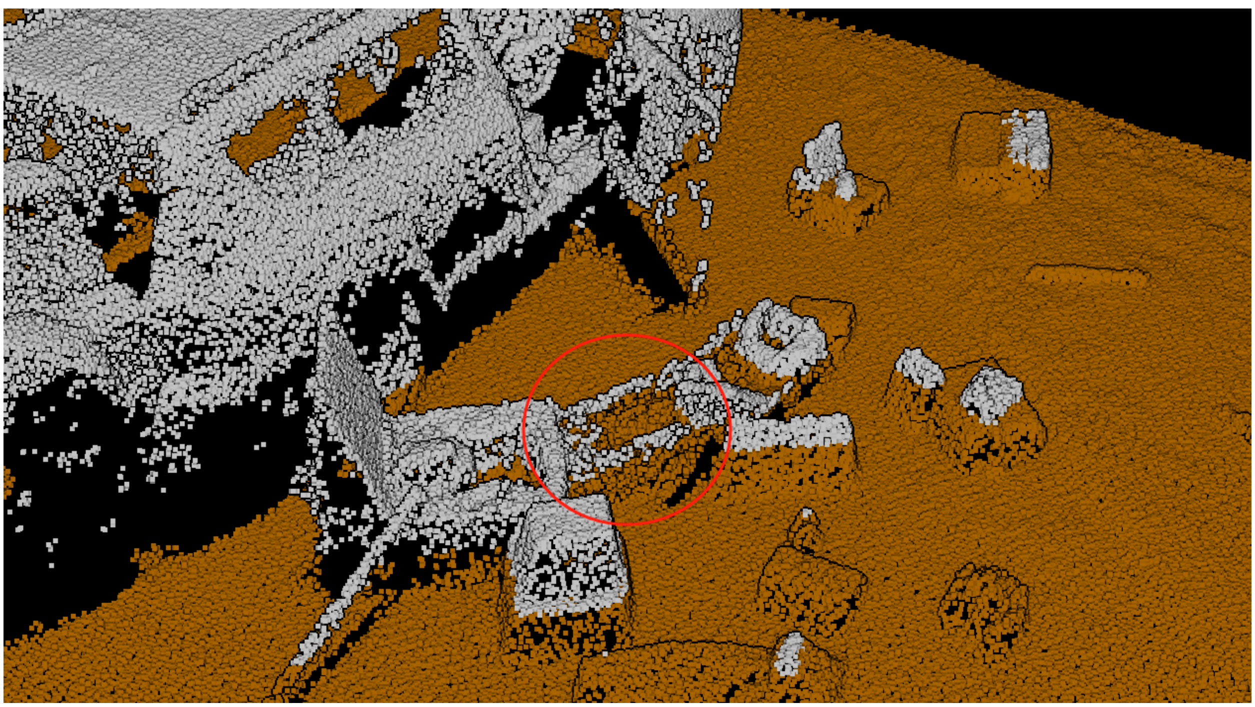

Figure 4.2.11.4: The orange area is classified as ground, and the white area is above the ground. The circled area should be fully covered by the white point cloud.

4.2.12 Car

Figure 4.2.12.1: The car is set up in this way.

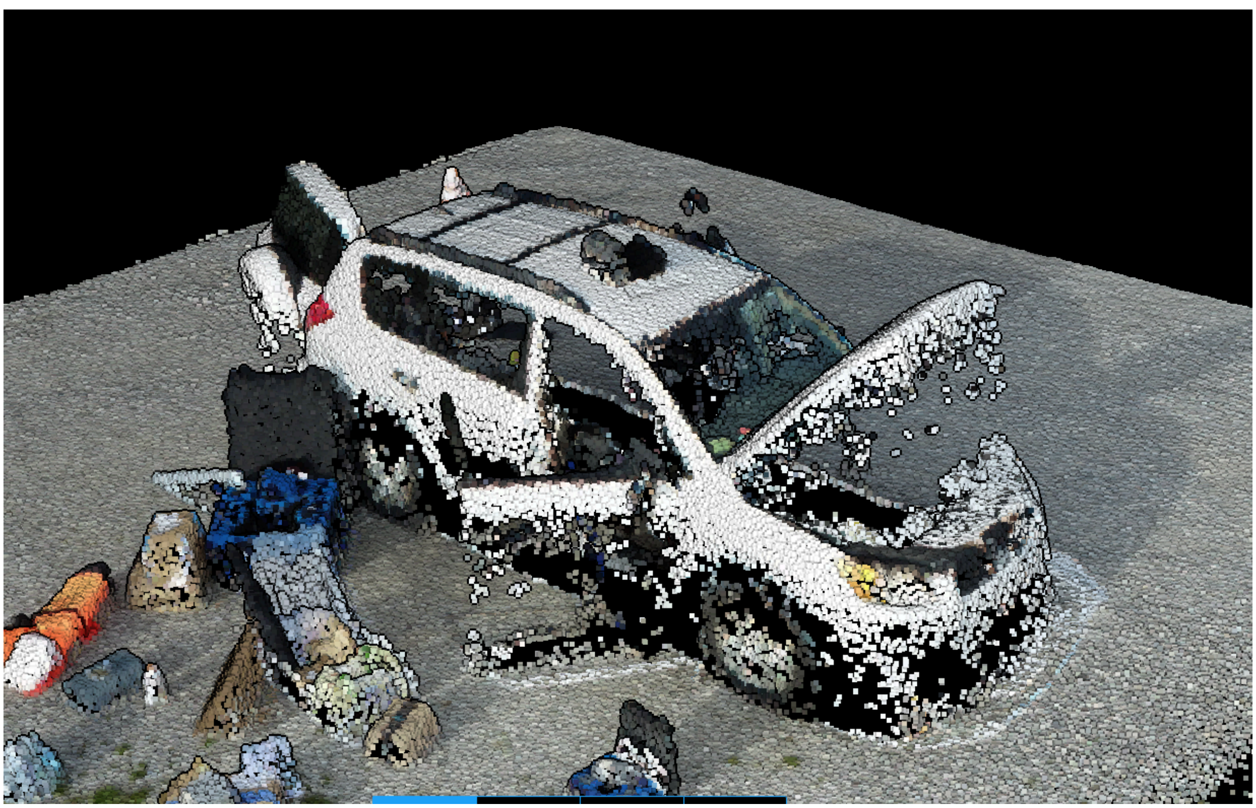

Figure 4.2.12.2: Overview of the point cloud.

Figure 4.2.12.3: the point cloud is trying to merge the gap because the engine hood is a concave shape.

Figure 4.2.12.4: There is no texture or model under the engine hood.

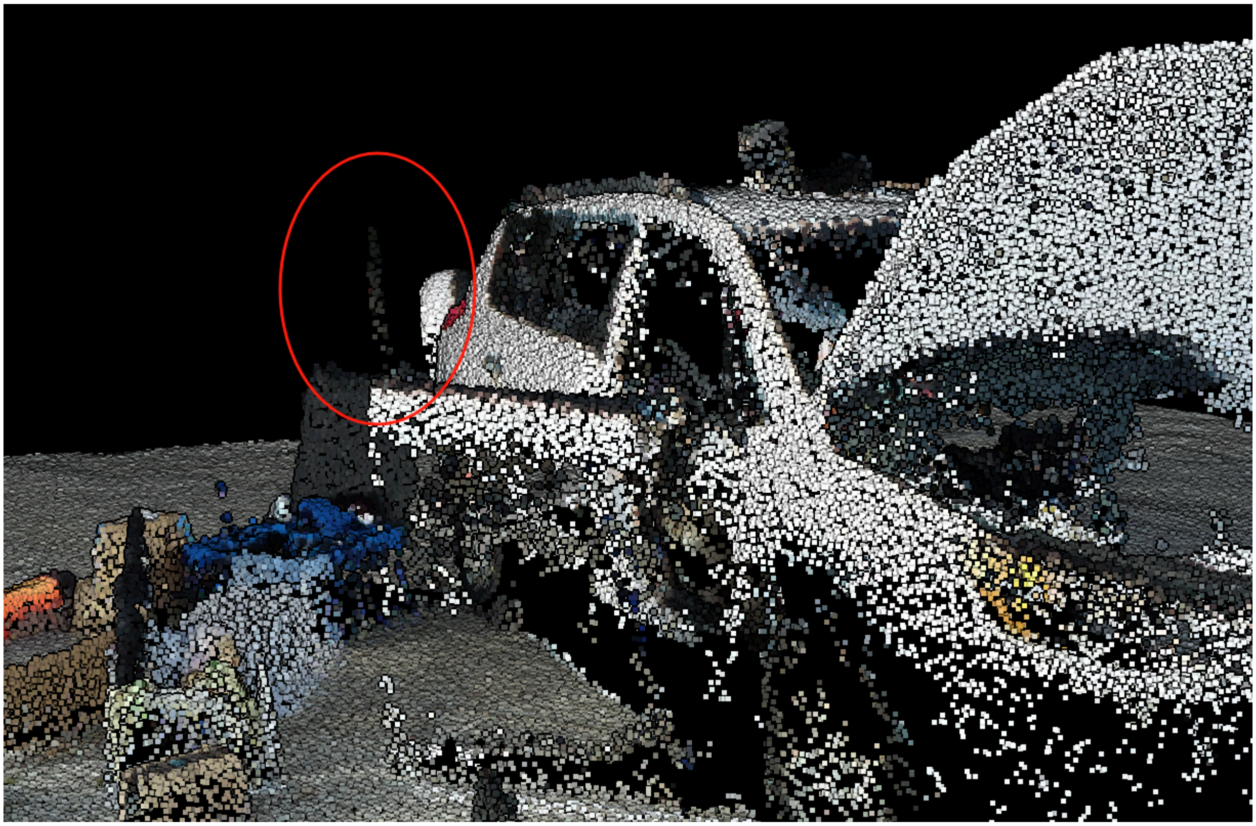
Figure 4.2.12.5: The black points are the window frame of the front door. There is no window, only the part of the frame. The top part of the frame is missing.

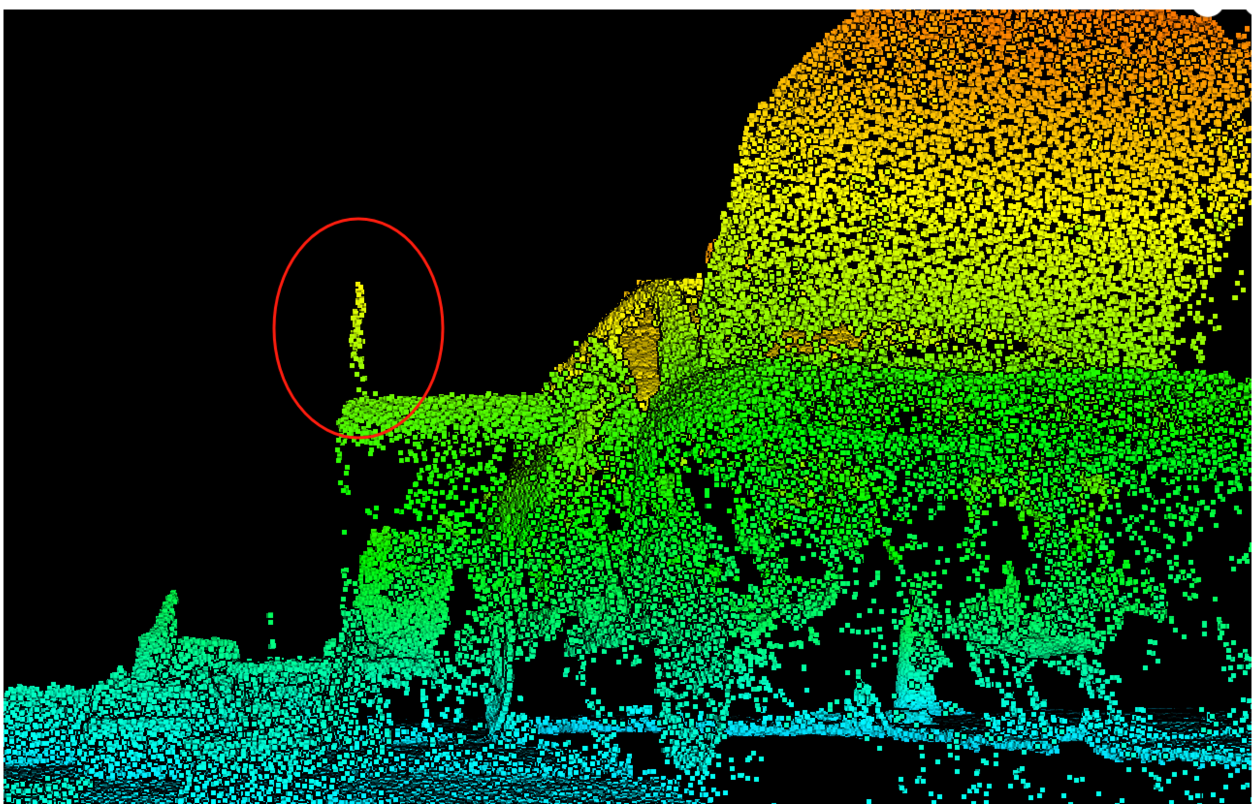
Figure 4.2.12.6: Looking at a lower angle. The highlighted part is the frame.

Figure 4.2.12.7: This is the top view of the front windshield, but the windshield doesn't have any points. The dark gray points are from the dashboard.

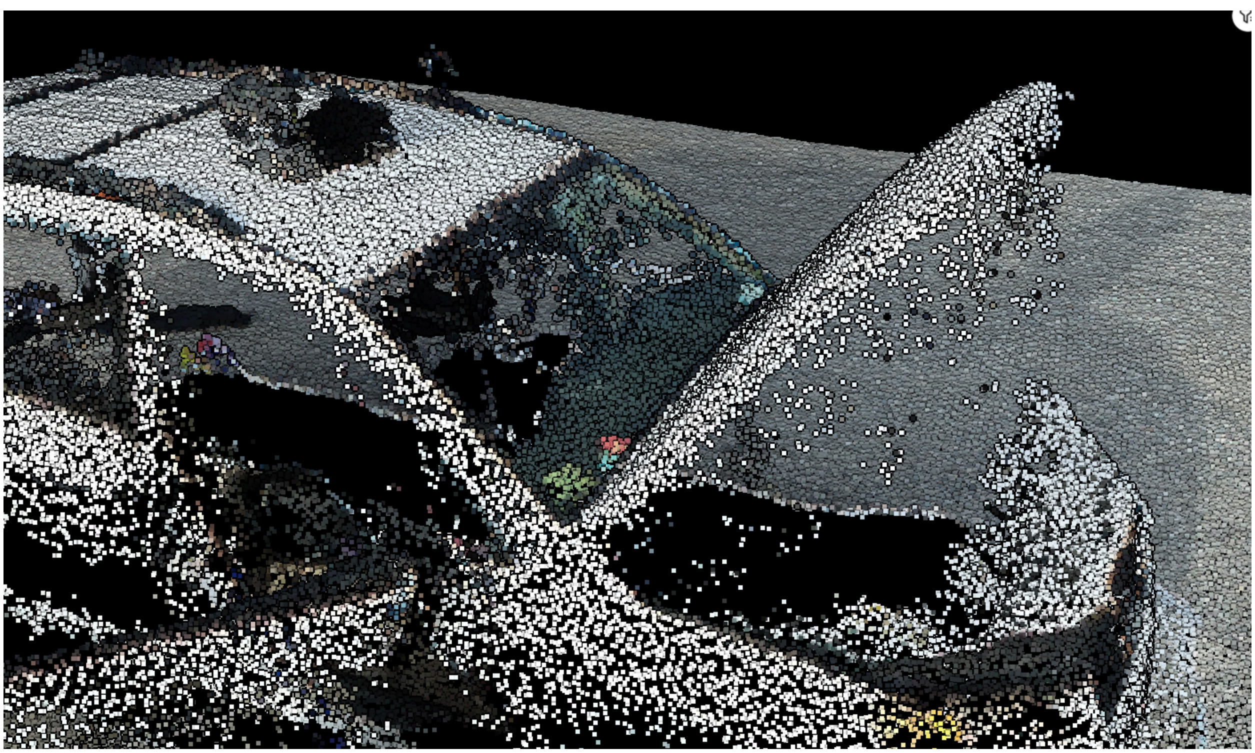

Figure 4.2.12.8: There are only points from the dashboard.

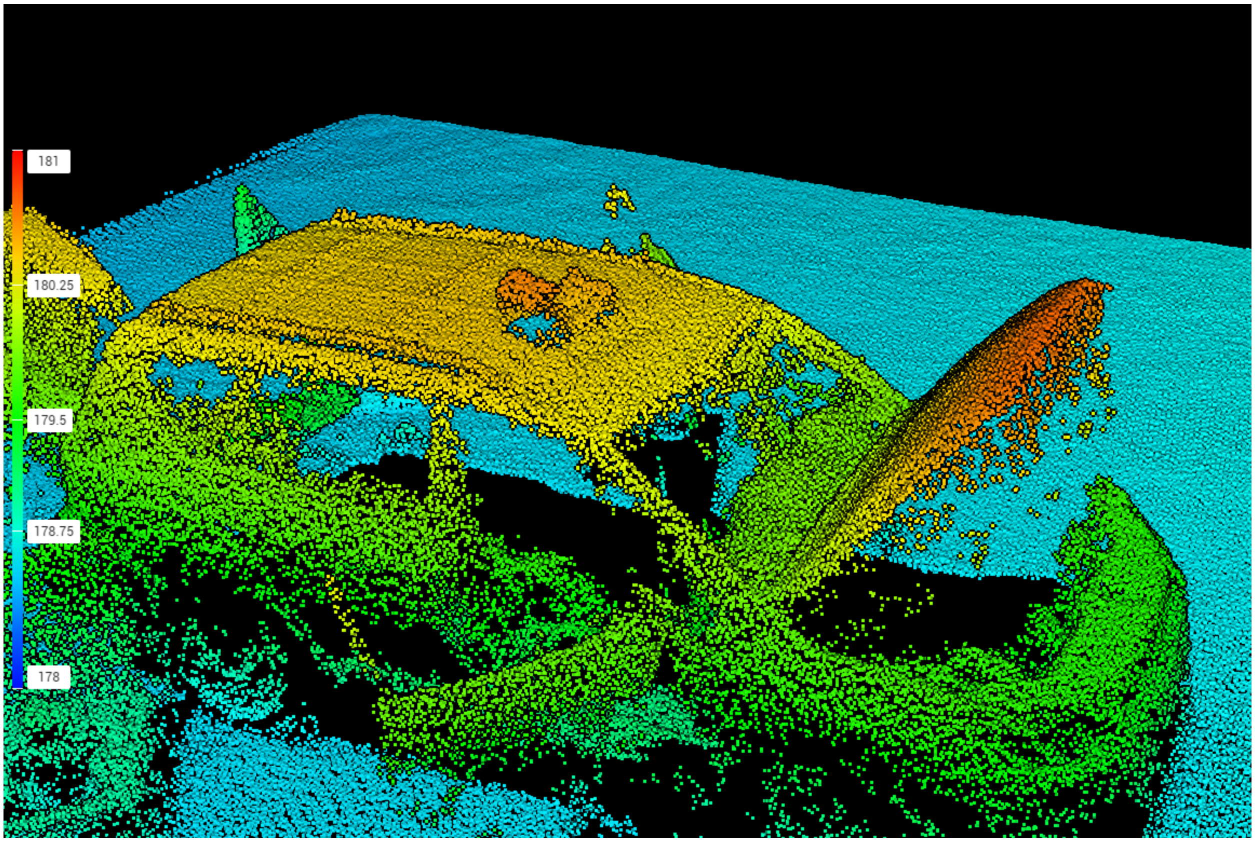

Figure 4.2.12.9: If there's actually windshield, the color should be continuous and become more yellowish.

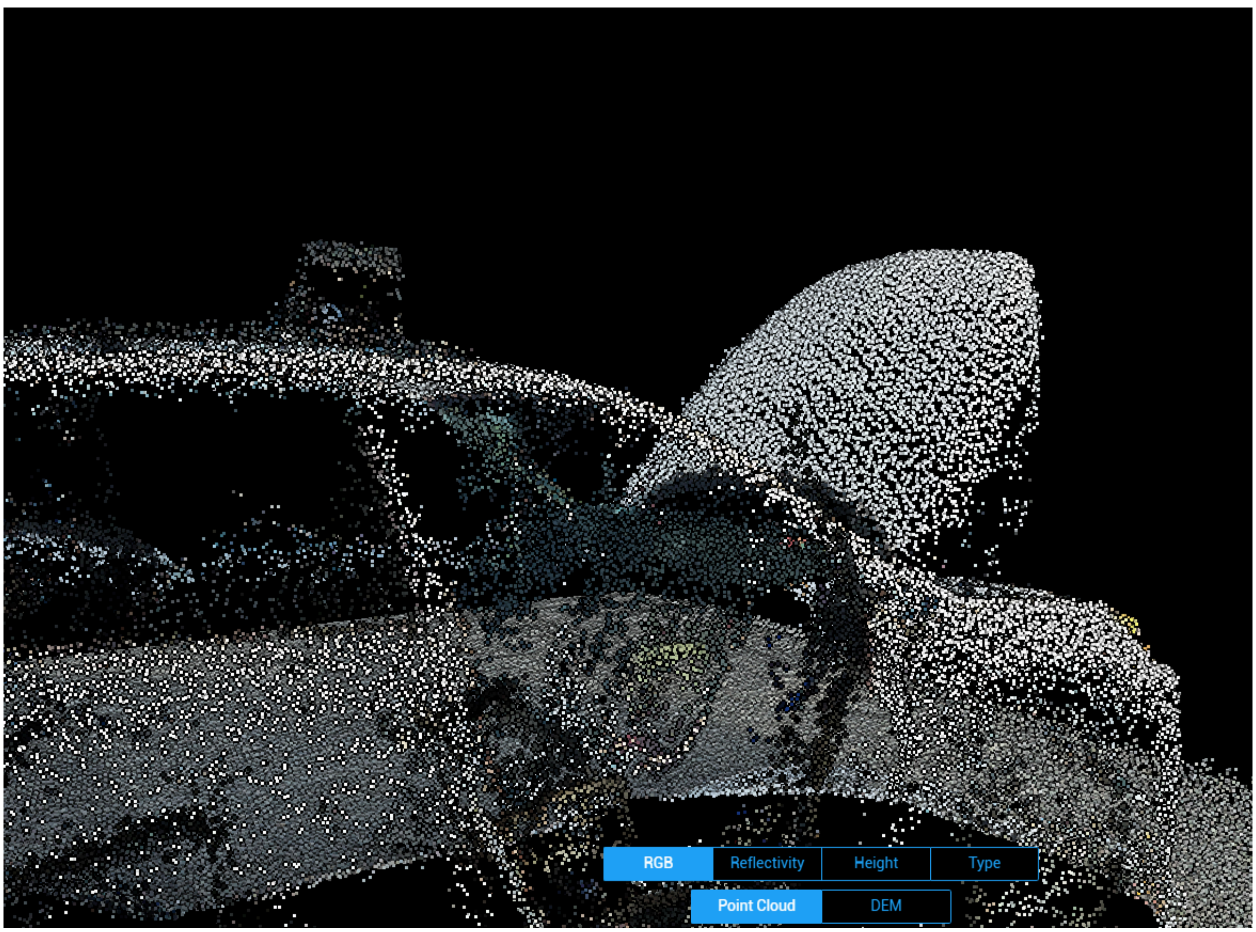

Figure 4.2.12.10: from this height, it's very clear that the dark gray points are the dashboard.

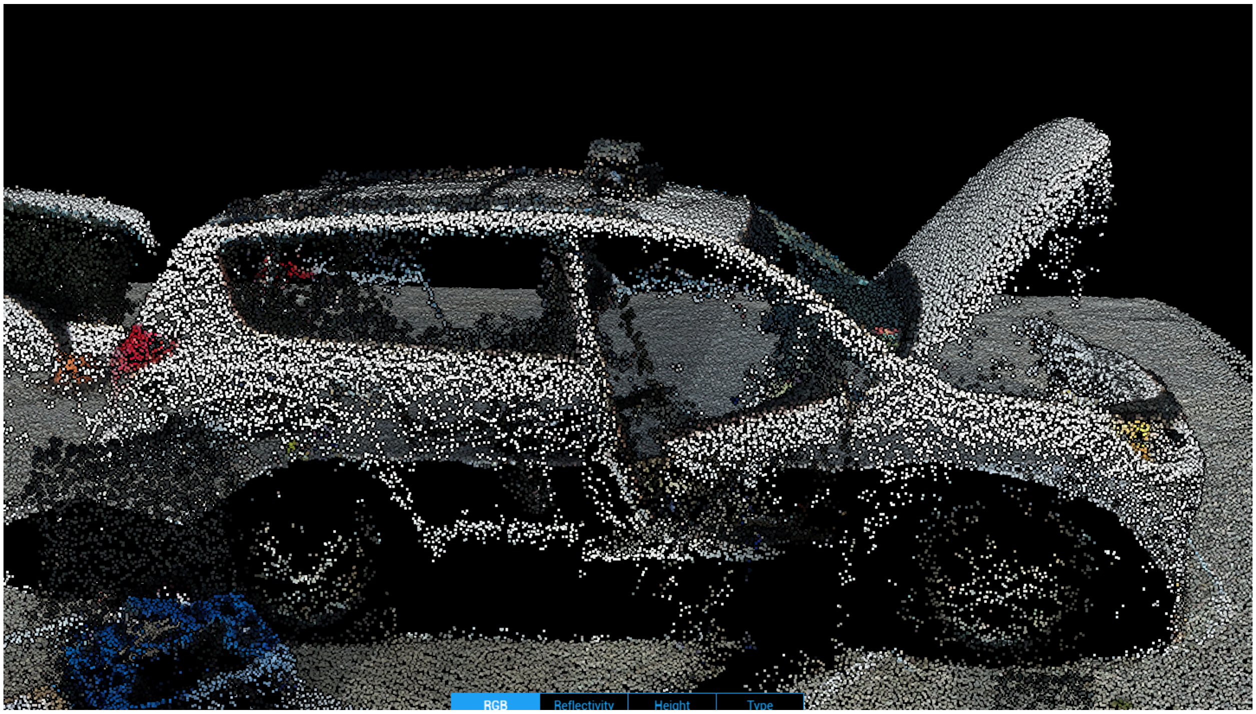

Figure 4.2.12.11: Side view of the car. Even the window next to the back seat was raised, there's nothing.


Figure 4.2.12.12: the lower half of the door has no point cloud. This might be because those surfaces are facing below the horizon.

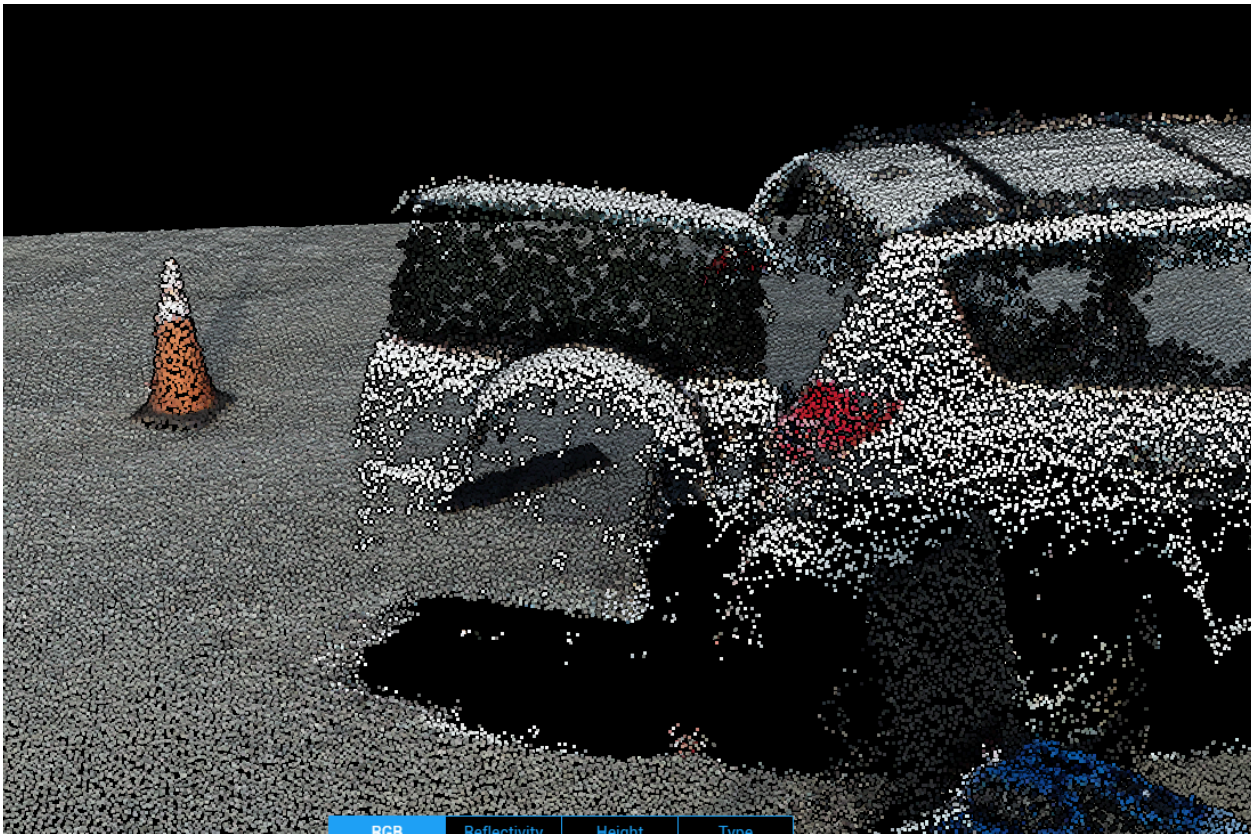

Figure 4.2.12.13: Interestingly the back windshield has a complete scan.

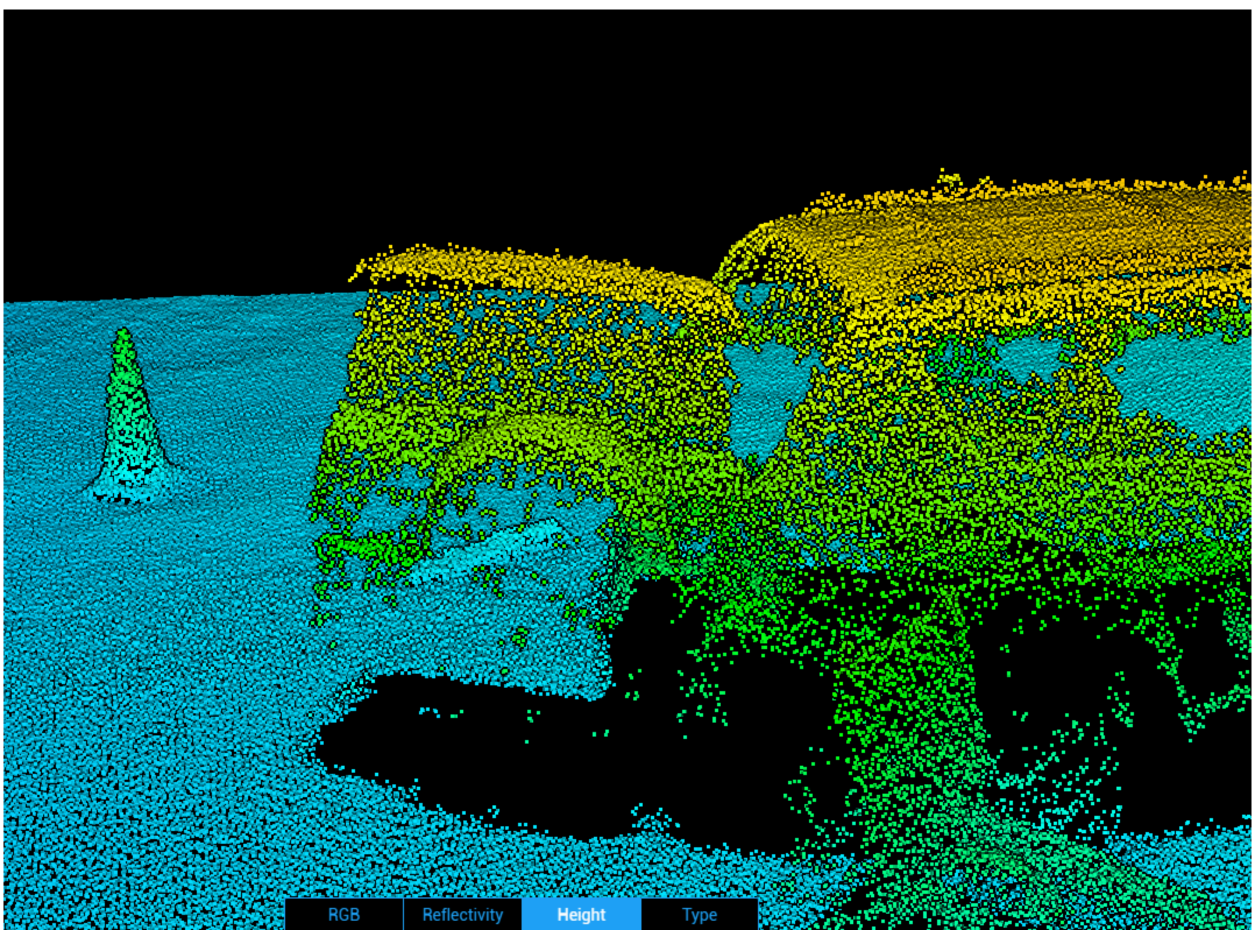

Figure 4.2.12.14: The back windshield is continuous.

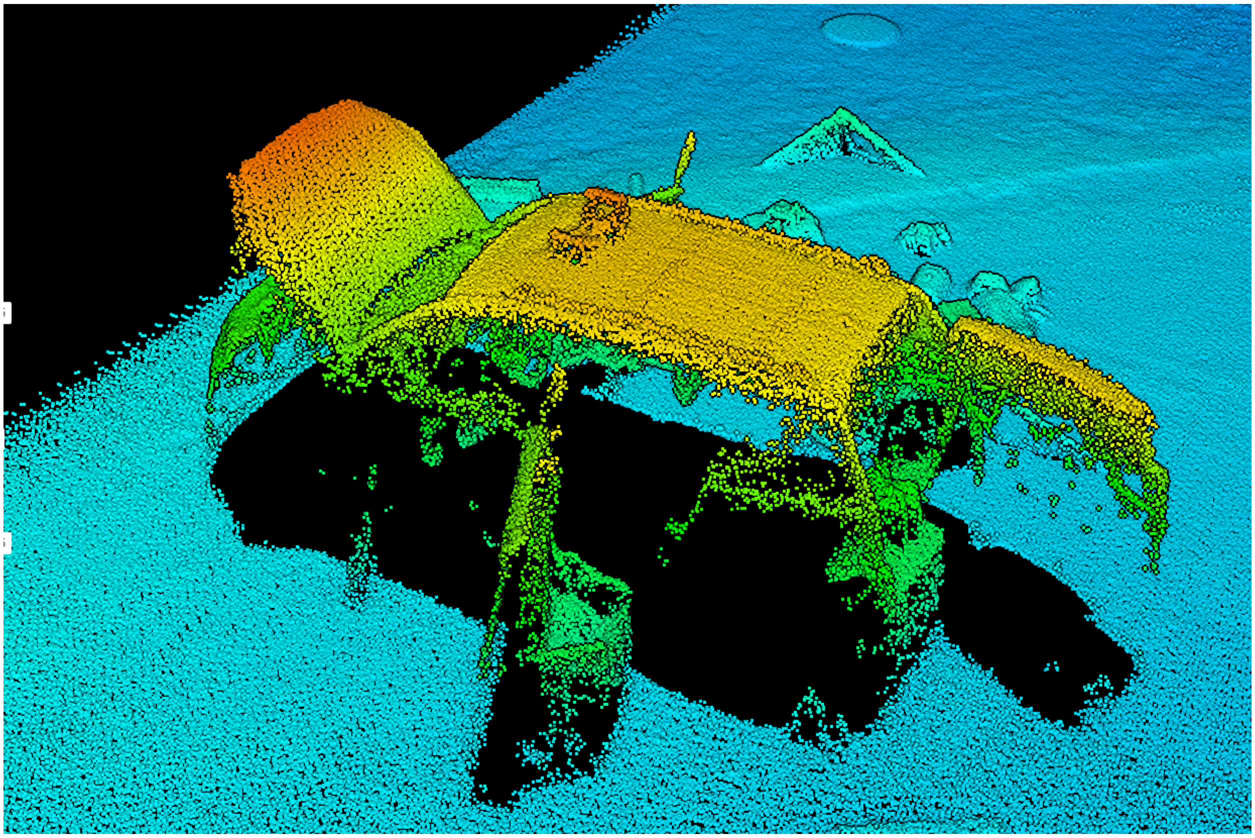

Figure 4.2.12.15: On the east side of the car, the point clouds are missing a lot.

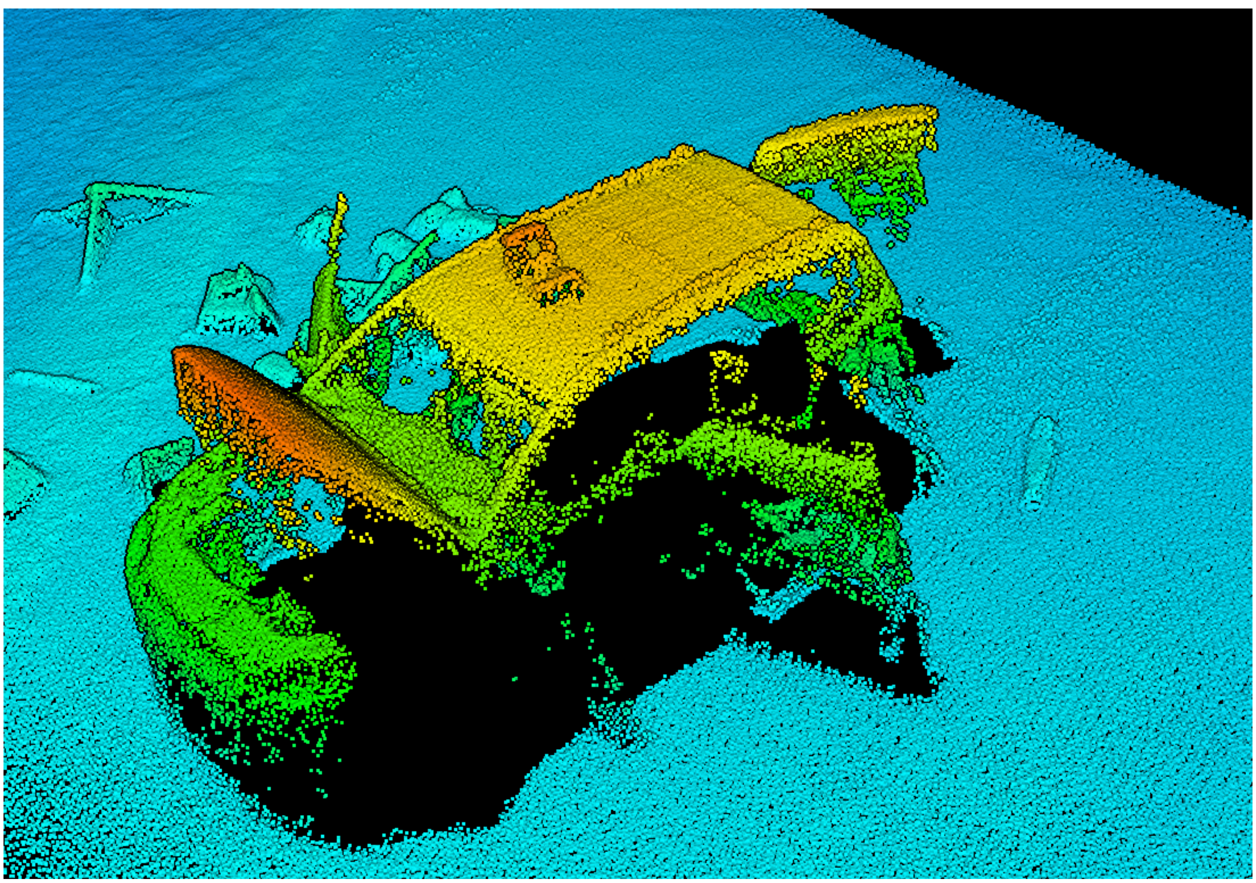

Figure 4.2.12.16: the door was scanned during the mission that were facing north and south.

Figure 4.2.12.17: The missing part in RGB.

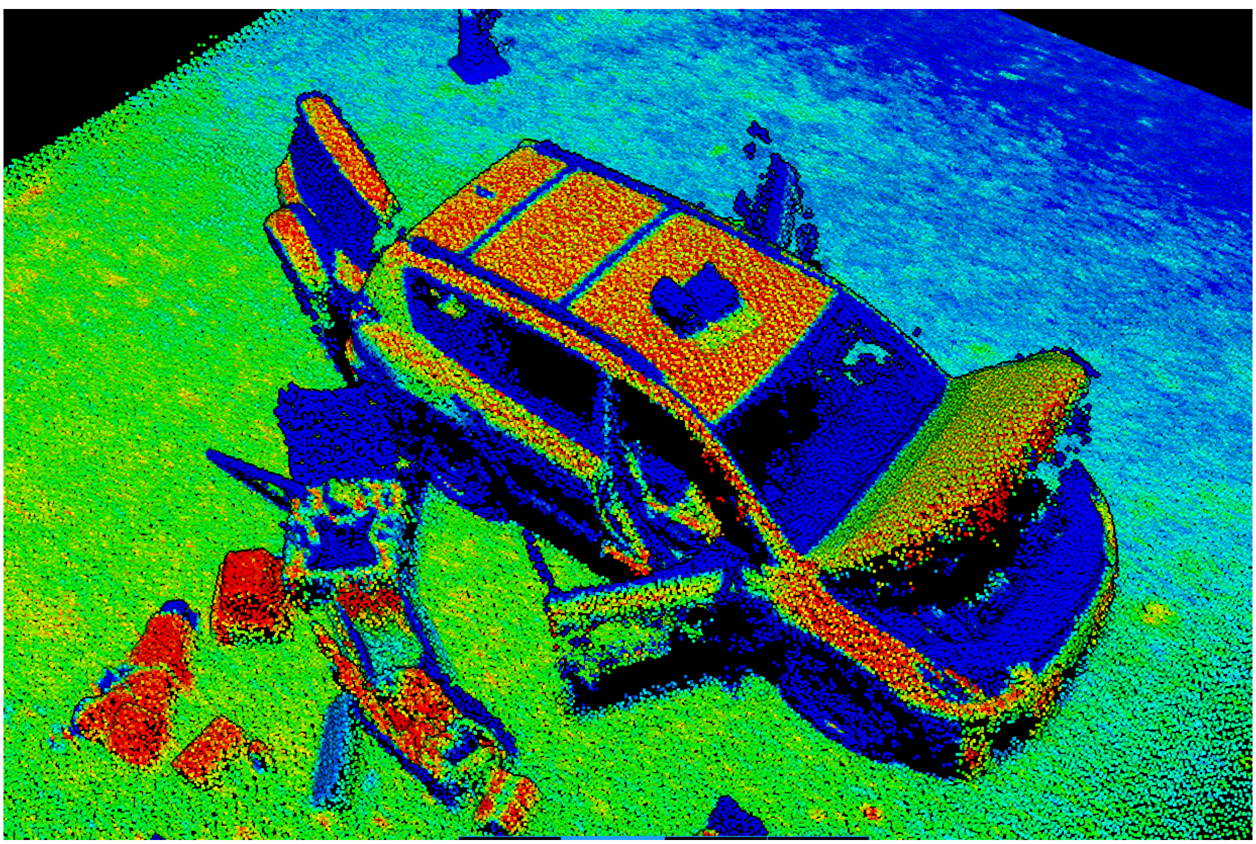

Figure 4.2.12.18: the reflectivity of the car. Red means high reflectivity, and blue means low. It's very clear that only white paint that is facing above the horizon has high reflectivity. For the white paint that's facing below the horizon, LiDAR can hardly detect it. Black car luggage rack, back windshield, wheel and wheel hub, dashboard, and inside of the engine room, black foam in the drone case have low reflectivity.

4.2.13 Drone Case

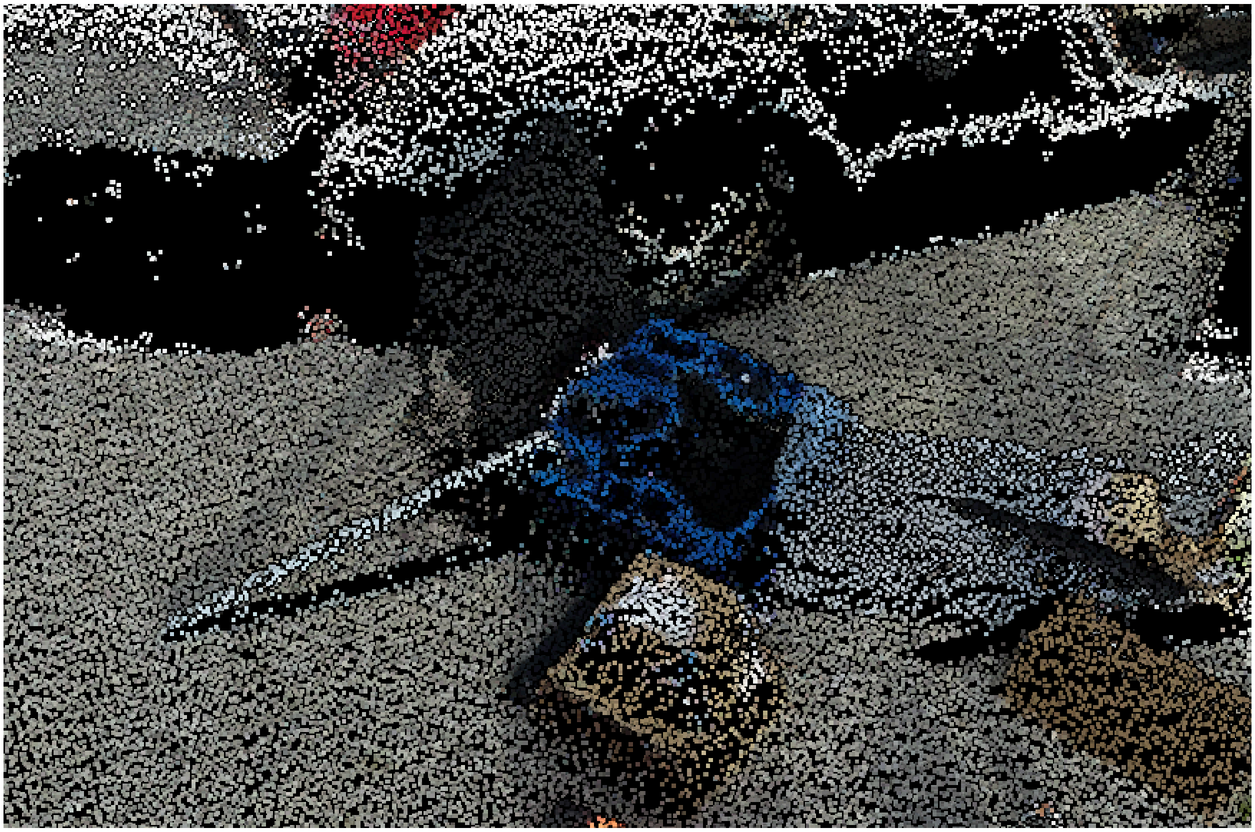

Figure 4.2.13.1: the drone case for DJI M300.

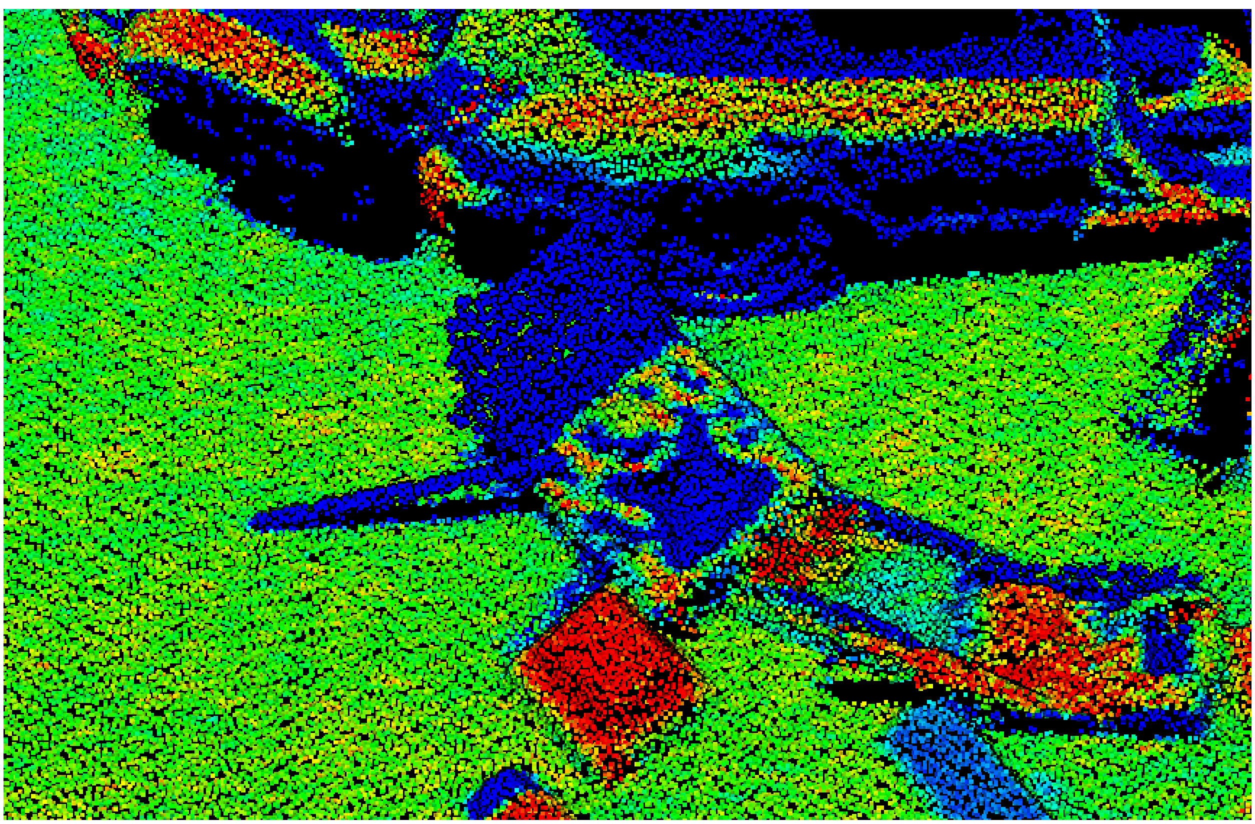

Figure 4.2.13.2: The blue paint has higher reflectivity, and the black foam has much lower reflectivity. (Refer to Figure 2.1.1.1)

4.2.14 Tripod Bag

Figure 4.2.14.1: the tripod bag.

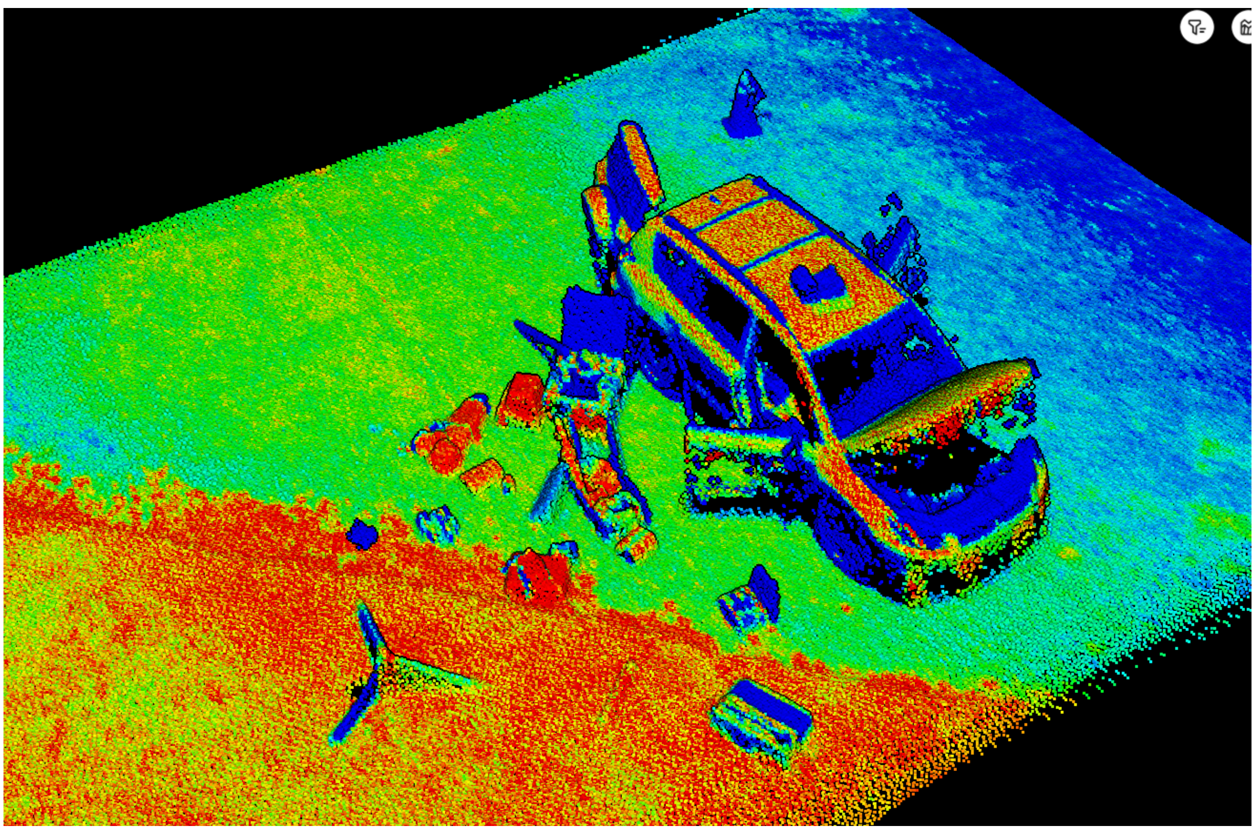

Figure 4.2.14.2: The tripod bag has the highest reflectivity.

4.2.15 Ceramic cup

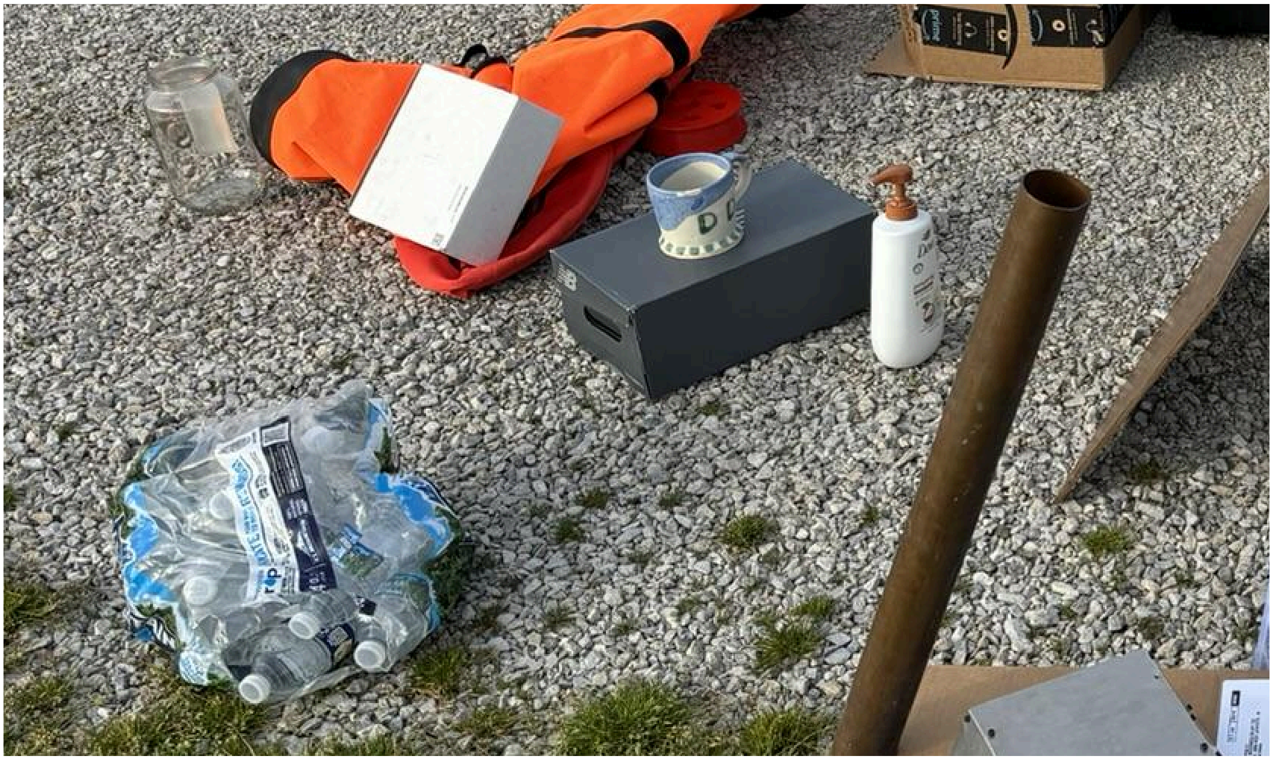

Figure 4.2.15.1: The blue-white ceramic cup is on top of the dark gray box.

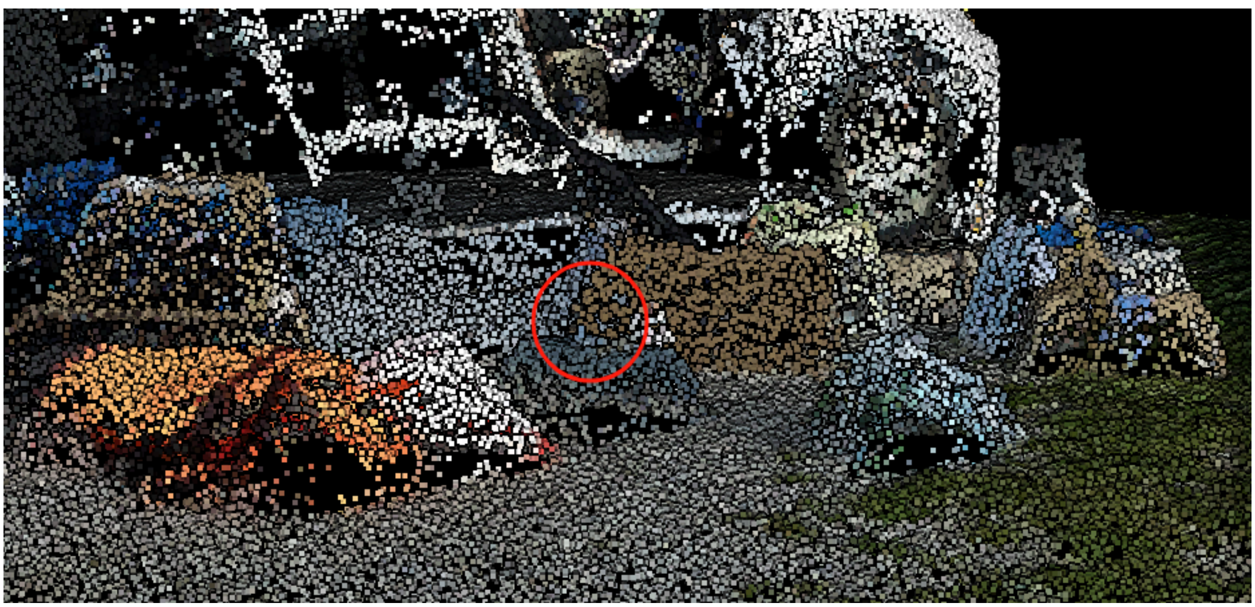

Figure 4.2.15.2: It’s very hard to see the cup because there are not many points.


Figure 4.2.15.3: the point cloud only has the bottom of the cup.

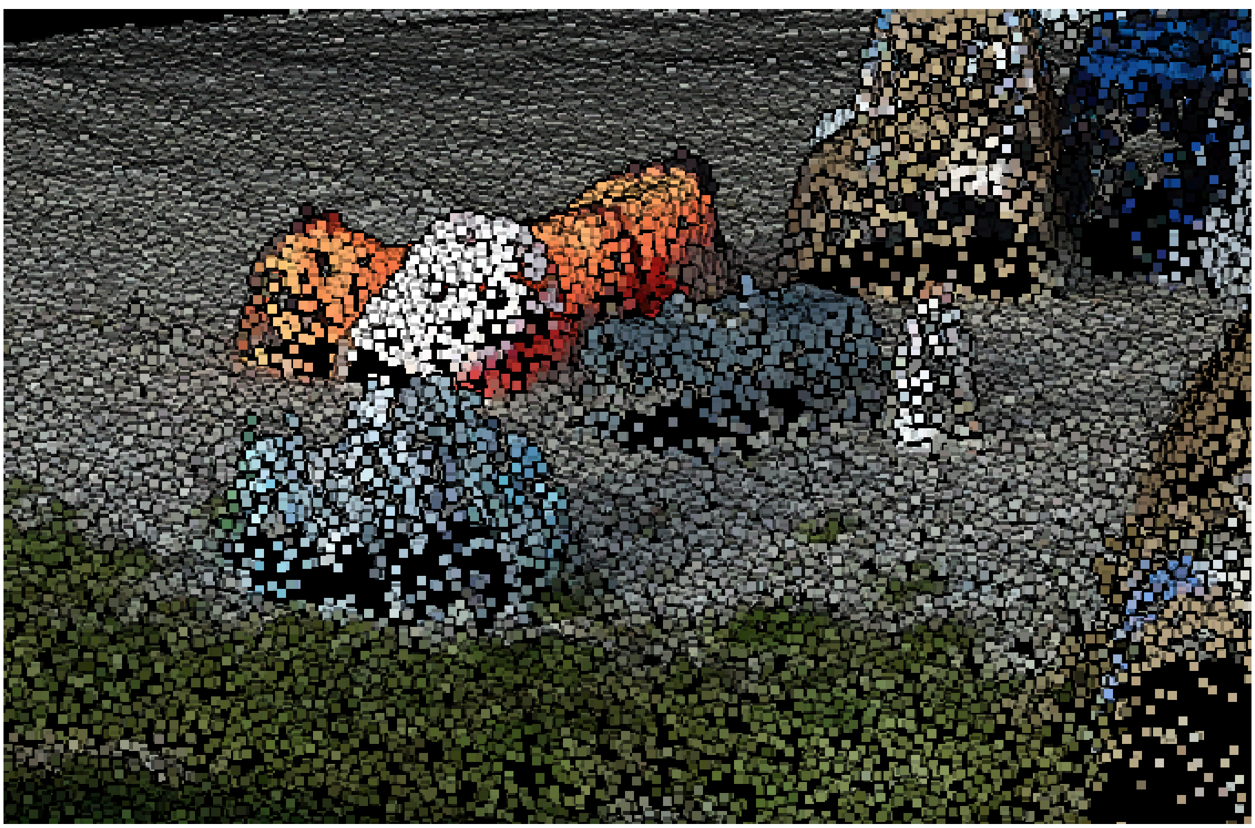
Figure 4.2.15.4: the point cloud for the shampoo and the bag of water are easy to see, but the cup only has the lower part.

4.2.16 Shampoo bottle

Figure 4.2.15.1 to Figure 4.2.15.4 show the results. The point cloud for the shampoo is recognizable with proper shape and the size.

4.2.17 A bag of water bottle

Figure 4.2.15.1 to Figure 4.2.15.4 show the results. It's hard to tell the actual model from the point cloud.

4.2.18 Laminate Flooring Board

Figure 4.2.18.1: the laminate flooring board was leaning next to the plastic storage box. The side with floor texture is facing down, and the back smooth side is facing outside.

Figure 4.2.18.2: the right side of the laminate flooring board formed a concave shape and the point cloud merged it.

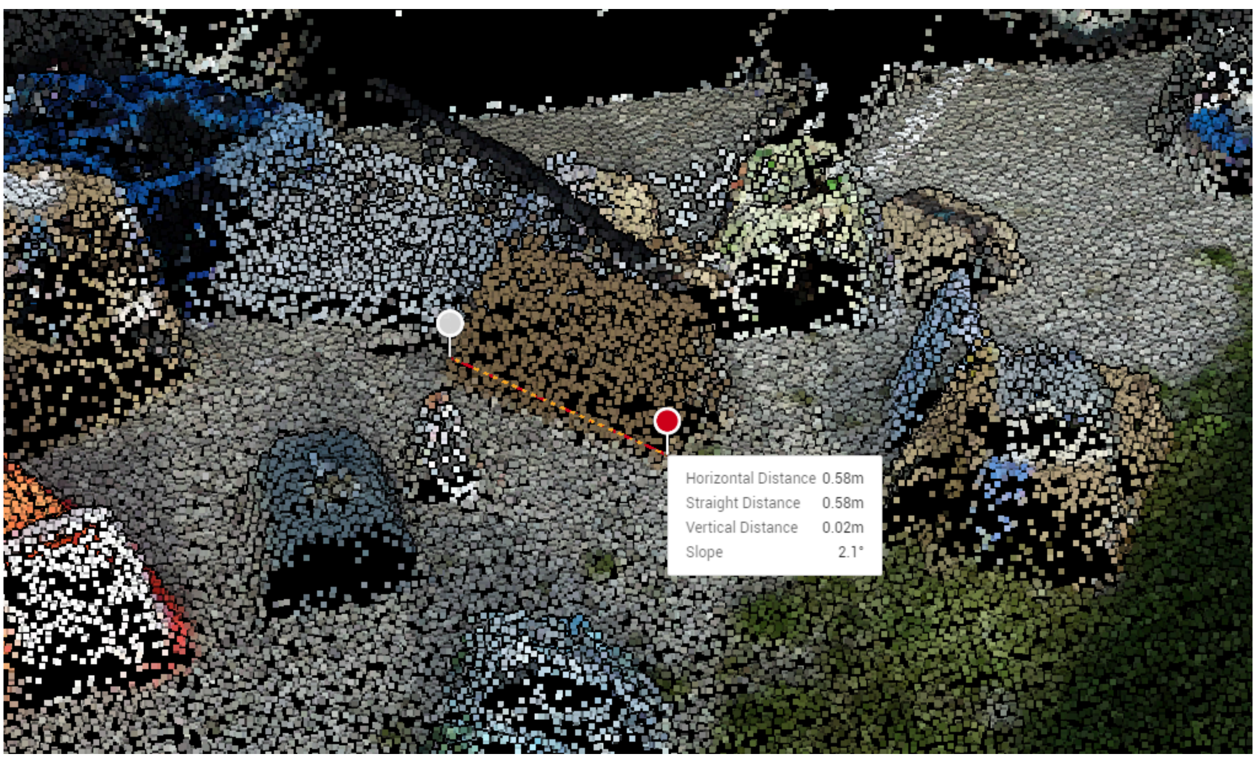

Figure 4.2.18.3: measured length is 58 cm. Actual length is 52 cm.

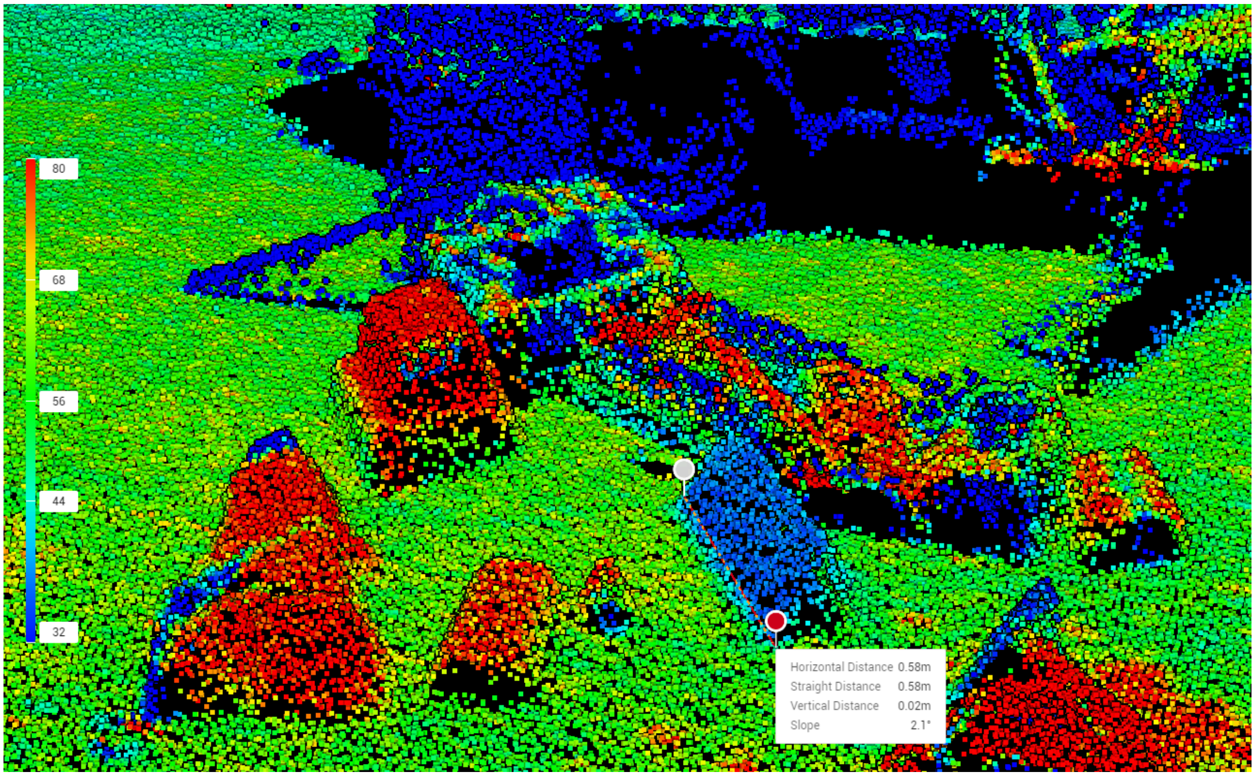

Figure 4.2.18.4: the surface has a very low reflectivity.

4.2.19 Umbrella

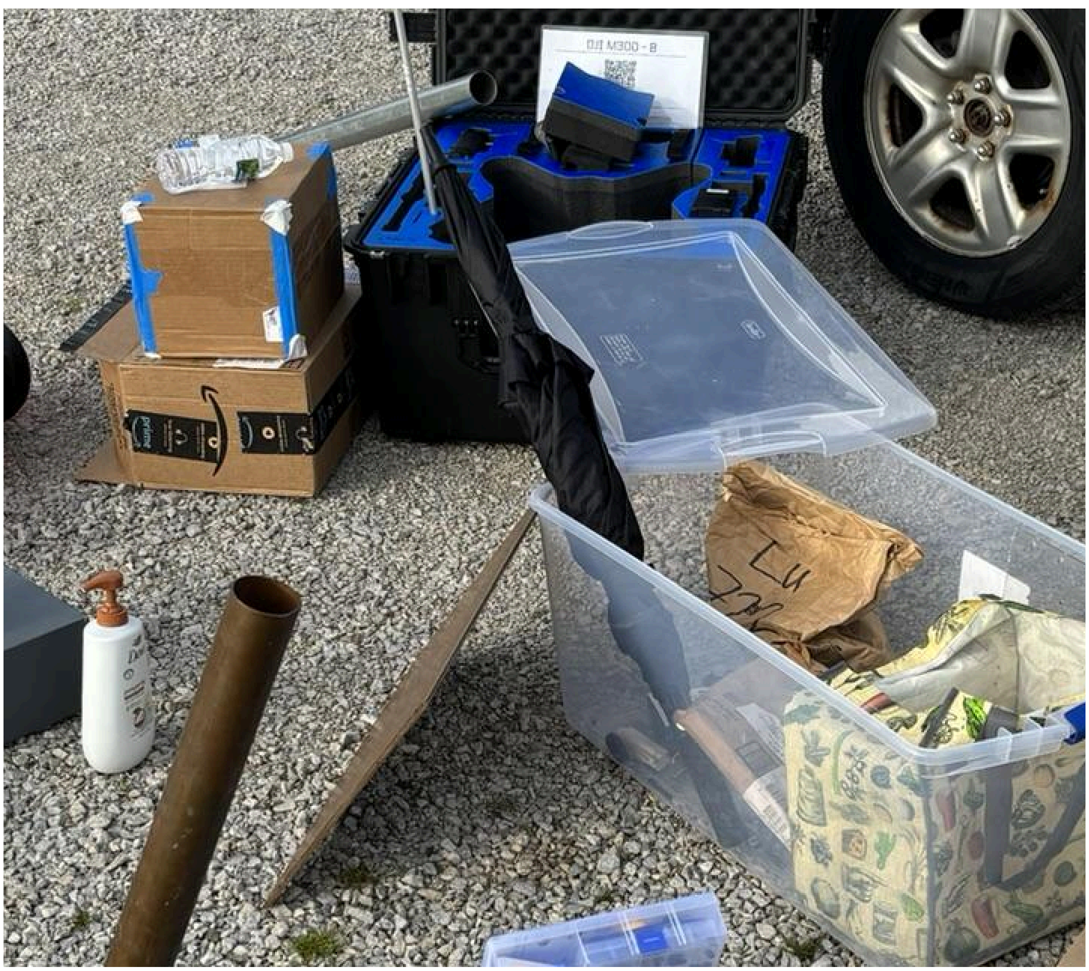

Figure 4.2.19.1: the umbrella was placed inside the plastic box.

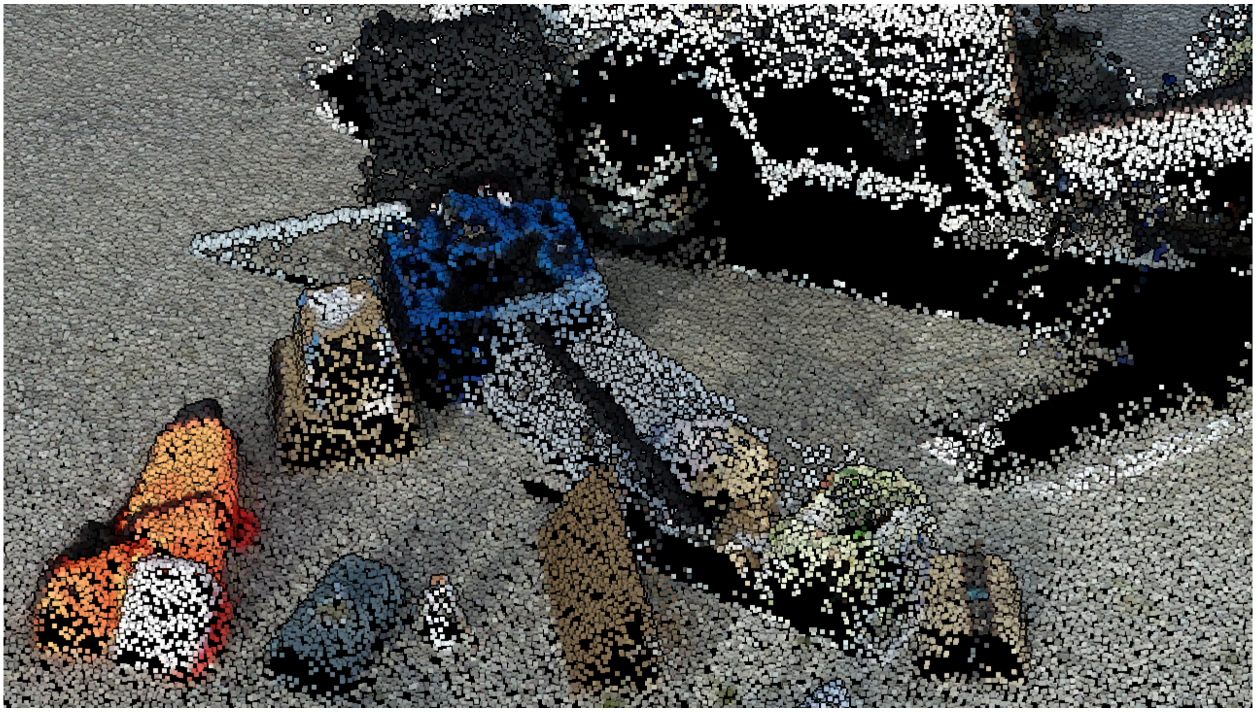

Figure 4.2.19.2: The point cloud for the umbrella formed a decent model.

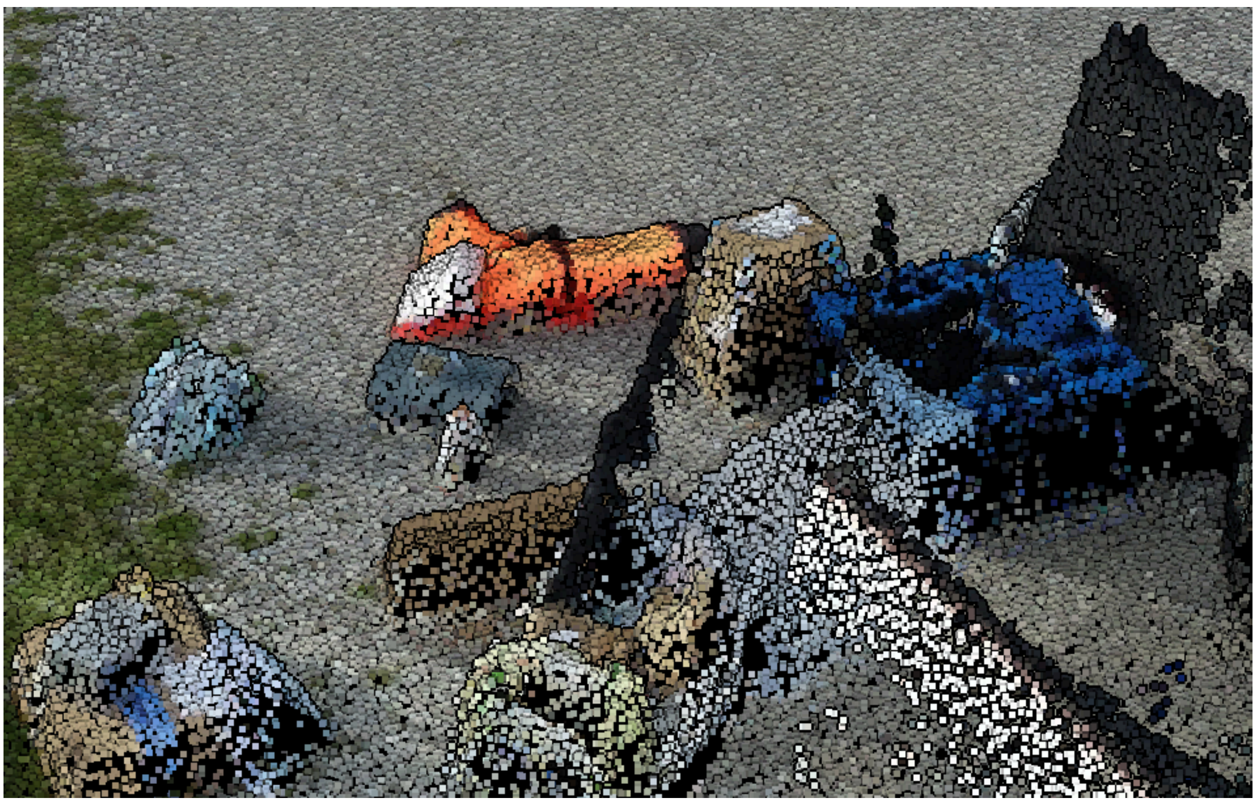

Figure 4.2.19.3: Looking from another angle.

Figure 4.2.19.4: Looking from another angle.

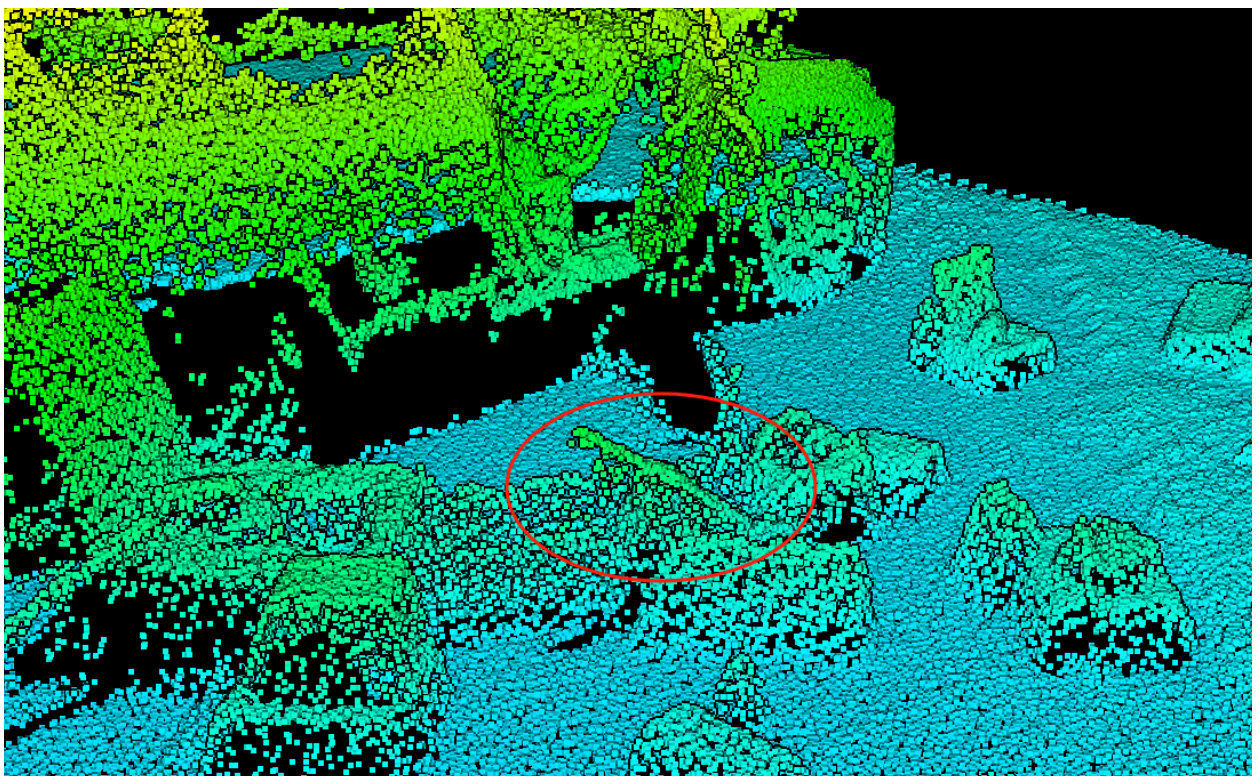

Figure 4.2.19.5: the color on the umbrella is turning to green from bottom to top.

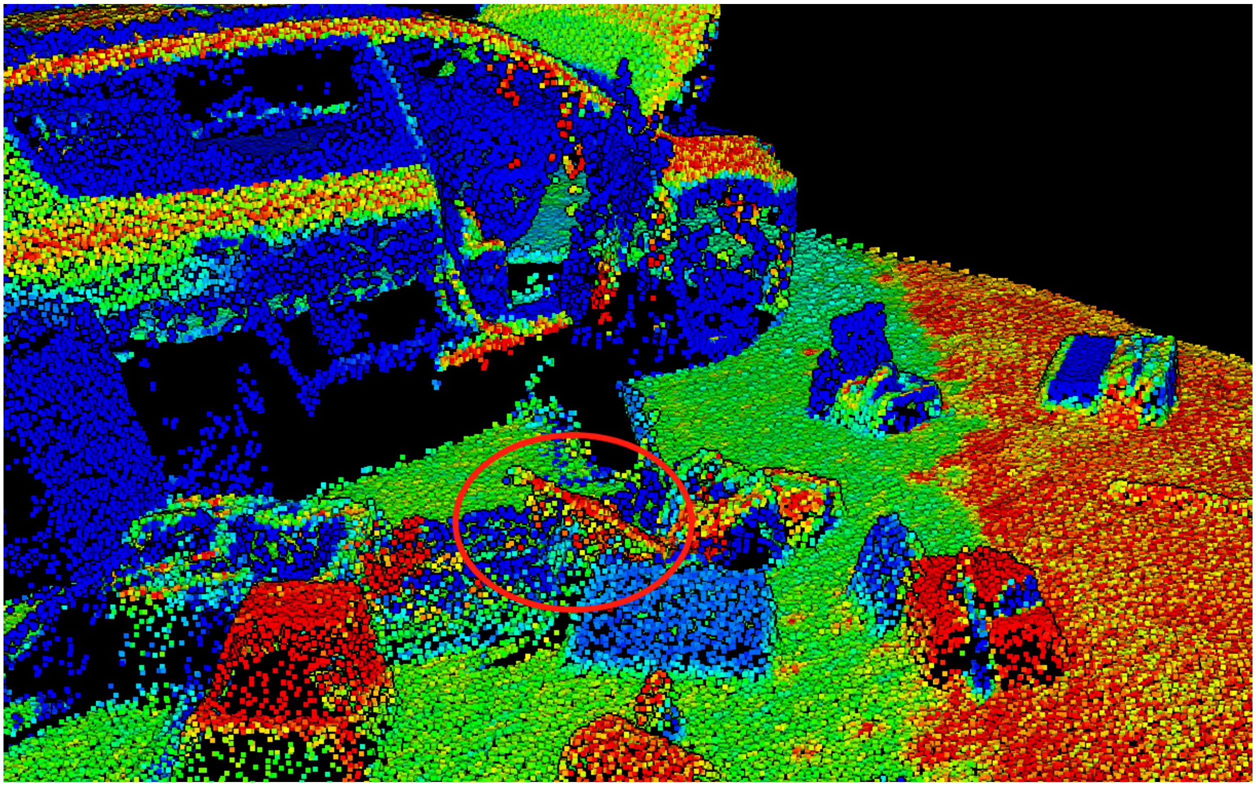

Figure 4.2.19.6: even the surface is black, but it doesn't mean it has a low reflectivity. The light emitted from LiDAR has a wavelength of 905 nm. It's outside of the visible light (400 - 700 nm). Absorbing most of the visible light doesn't mean it also absorbs the light at the wavelength of 905 nm.

5. Improvement

5.1 Copper tube

The copper tube should stand out alone. Copper is used to check if the material worked with the LiDAR. Putting it next to other object and creating the concave shape largely affect the result. In future experiment, each item should only has one purpose.

5.2 Larger area

The study area is not in the center of the scanned area. The study area doesn't have any obvious landmarks, so it's very hard to match the study area and the mission area on DJI Pilot 2. One way to solve this is to gather the precise coordinates on the field, and use that coordinate on the software to generate the missing area. Another solution is to fly it manually so LiDAR can scan the blind spots.

5.3 Fly on a cloudy day

It is said that strong sunlight can affect the LiDAR result, and the best result is from a cloudy day.

5.4 Use GCPs

DJI Terra supports the use of GCPs. It can largely increase the precision of the result.

6. Reference

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