**NATIONAL TRANSPORTATION SAFETY BOARD**
Office of Aviation Safety
Washington, D.C. 20594

# UAS Aerial Imagery Report

11/14/2018

## A. ACCIDENT WPR18MA087

Location: Peach Springs, Arizona
Date: February 10, 2018
Time: 1719 Local Time (MST)

## B. PERSONNEL

UAS RPIC[1]: Michael Bauer
National Transportation Safety Board
Washington, D.C.

## C. ACCIDENT SUMMARY

On February 10, 2018, about 1719 mountain standard time (MST), an Airbus Helicopters EC130 B4 helicopter, N155GC, was destroyed when it impacted a canyon wash while on an approach to land at Quartermaster landing zone near Peach Springs, Arizona. The commercial pilot and one passenger sustained serious injuries and five passengers were fatally injured. The air-tour flight was operated by Papillon Airways, Inc. under the provisions of 14 Code of Federal Regulations Part 136. The helicopter departed Boulder City Municipal Airport, Boulder City, Nevada at 1642 MST and had intended to land at Quartermaster landing zone, a group of unimproved landing pads within Quartermaster canyon. Visual meteorological conditions prevailed, and a company flight plan had been filed.

## D. DETAILS OF IMAGERY

### 1.0 Equipment and Procedures

**Equipment**

Mapping and viewpoint flights of the accident site were conducted on May 30th, 2018, using the NTSB DJI Phantom 4 Professional (P4P) small unmanned aircraft system (sUAS, commonly known as a drone).[2]

[1] RPIC – Remote Pilot In Command
[2] Helicopter wreckage was removed from the accident site in February 2018.

The drone was equipped with a dual GPS/GLONASS receiver which provided georeferenced information on all still photos. The drone was equipped with an FC6310 camera using the Sony Exmor 1" CMOS sensor, with a focal length of 8.8 mm and the number of effective pixels of 20 megapixels. Still photos were captured in a JPG format. One video was taken in MP4 format, with 4K resolution at 60 frames per second.

Ground control points were documented with a Trimble GEO7X differential GPS receiver. Due to historical and environmental concerns, five ground control points (GCPs) were positioned and identified using portable, removable targets, in addition to a removable landing pad, Figure 1.

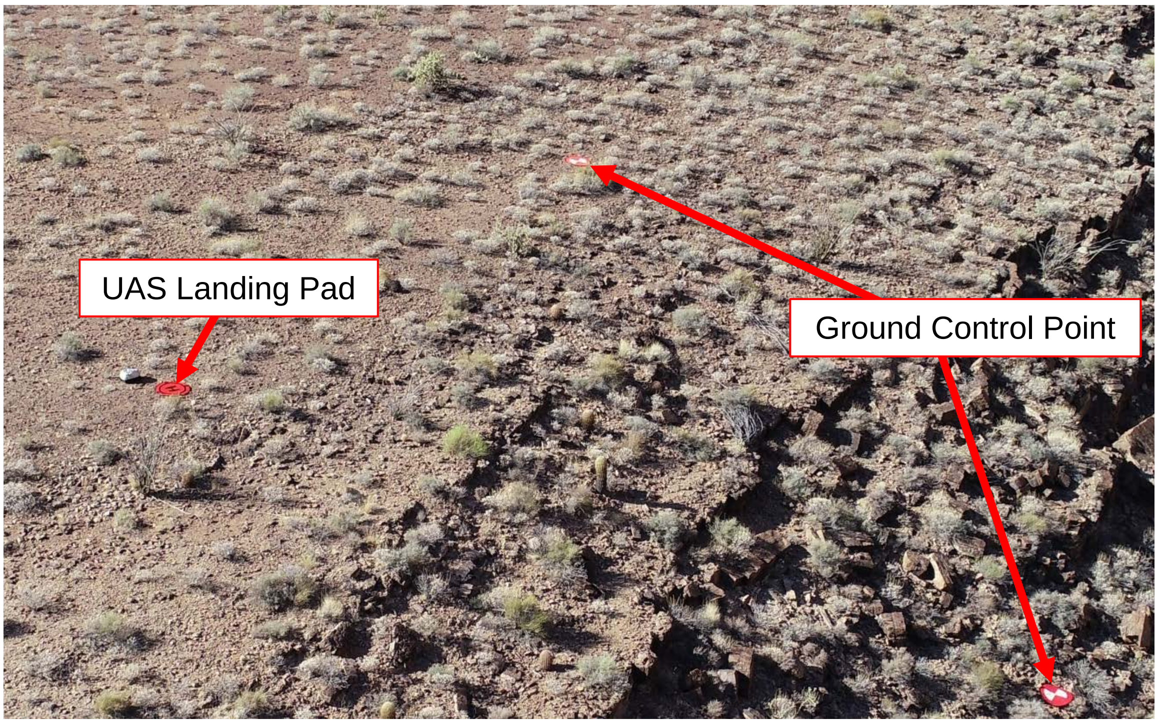


**Figure 1 - Aerial view showing UAS landing pad and removable GCPs (not all GCPs shown)**

Additional tie points were used to compare laser scanner data with the UAS data. The tie points that were common to both sets of data were the laser scanner reference spheres, of which the laser scanning team placed six reference spheres in the scanning area of interest. This allowed for a comparison of the two point cloud data sets, further discussed in section 3.0.

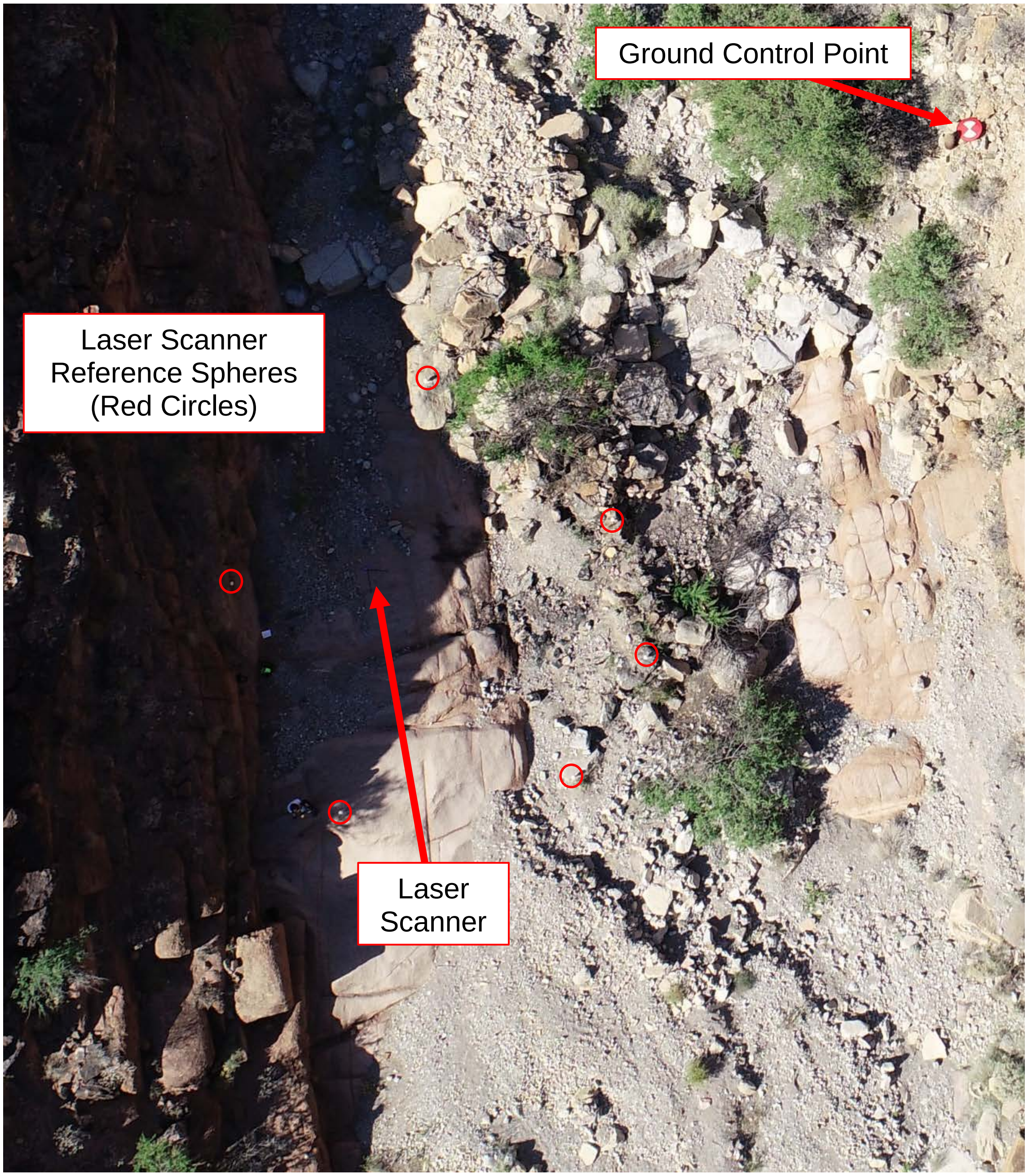


Figure 2 - Aerial view of the accident site showing laser reference spheres and one GCP

## Procedures

The accident site was located in the Grand Canyon National Park on lands controlled by the Hualapai Nation and adjacent to National Park Service lands. A Special Government Interest authorization was obtained from the FAA National Capitol Region Coordination Center and Special Operations Security Center. Flight coordination and approval was also obtained from the Hualapai Nation representatives and the National Park Service. Flights were conducted under the provisions of the SGI and 14 CFR Part 107.

The accident area was down in a small canyon area and the flights remained above the canyon where the accident site was located. Local sightseeing helicopter flights landing in the area adjacent to the accident site were monitored utilizing a visual observer monitoring local VHF frequencies. The UAS would return to the landing zone and remain on the ground during helicopter landing operations in the area.

The sUAS was flown in an overlapping double grid over the region of interest over the wreckage site at two different altitudes, 100 ft AGL from the launch point and 175 ft AGL from the launch site. Additional sets of still images were taken for oblique viewpoints and to make panoramic views of the area for visualization and orientation. Total flight time was approximately 60 minutes.

It should be noted that the wreckage was removed from the scene shortly after the accident in February 2018. The purpose of the sUAS flights were to generate a terrain map of the area where the helicopter came to rest. A laser scan of the local accident area was also performed by the investigation. The sUAS data was collected to be compared with the laser scanner results to understand limitations, advantages and disadvantages of using the sUAS for this application.

## Processing

Geo-referenced still imagery was processed using Pix4D photogrammetry software to produce a 3D point cloud and an orthomosaic map of the wreckage site. Relative accuracy (within the map) was calculated at 1.76 inches, twice the average ground sample distance.

DGPS data was used to correct for any UAS elevation data errors and provide positional data for ground control points and checkpoints. DGPS data was corrected using the continuously operating reference station (CORS) at Dolan Springs, Arizona (AZDS). Horizontal and vertical positional accuracy (when compared to features outside the 3D point cloud) was calculated at 30.0 inches horizontally and 50.0 inches vertically.

## 2.0 Comparison of UAS to Laser Scan Data

As previously mentioned, the NTSB Office of Research and Engineering conducted a laser scan of the immediate accident site using a FARO Focus$^{3D}$ X330 laser scanner. The scanning was done concurrently with the UAS operations at the site. The area was scanned from multiple positions and the resulting data combined and rendered into a three-dimensional (3D) point cloud.

The laser scanned area was approximately 0.16 acres. As previously mentioned, the UAS was flown at two different altitudes (100 ft and 175 ft AGL from takeoff location). The UAS area covered was approximately 9.5 acres for the 100ft altitude and 19.8 acres for the 175 ft altitude. Figure 3 contains a Google Earth image of the extent of the data gathered by the laser scanner and the UAS. The time required to capture the respective datasets is outlined in Table 1. Time to do the post processing of the captured data is not included.

**Table 1 - Approximate time spent collecting datasets**

| Operation | Laser Scanning (hh:mm) | UAS (hh:mm) |
|---|---|---|
| Hiking to launch/scan site | 00:30 | 00:20 |
| Setting high GCPs | N/A[1] | 00:10 |
| Setting low GCPs | N/A[1] | 00:20 |
| Setting up reference spheres | 00:15 | N/A[1] |
| Setting up scanner/UAS | 00:15 | 00:05 |
| UAS low altitude flight | N/A[1] | 00:12 |
| UAS high altitude flight | N/A[1] | 00:10 |
| Laser scans (six scans total) | 01:30 | N/A[1] |
| Teardown/Hike Out | 00:30 | 00:20 |
| Total Time for Data Collection | 03:00 | 01:37 |

Notes:

1 – Operation does not pertain to either scanning or UAS operations

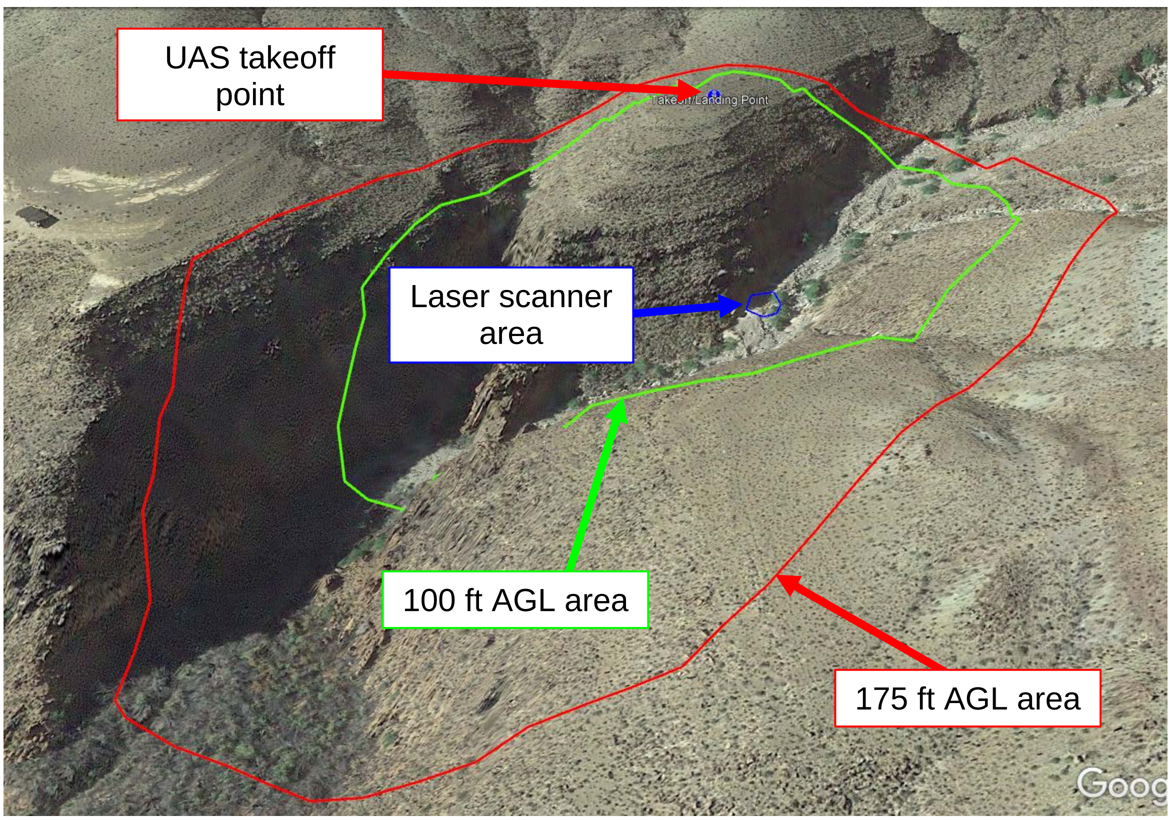


**Figure 3 - Approximate extent of area covered by the FARO scanner and UAS**

Point cloud data from the six laser scans was provided by the NTSB Office of Research and Engineering. The laser scan data and the low altitude (100 ft AGL) UAS mission was compared using CloudCompare, only for the area common to the laser scanned accident site.[3] The laser scanned data set consisted of 17.16 million individual points, ref Figure 4. By comparison the UAS data consisted of 1.02 million individual points, ref Figure 5.

[3] CloudCompare is an open source project which processes both 3D point cloud and meshes created by various

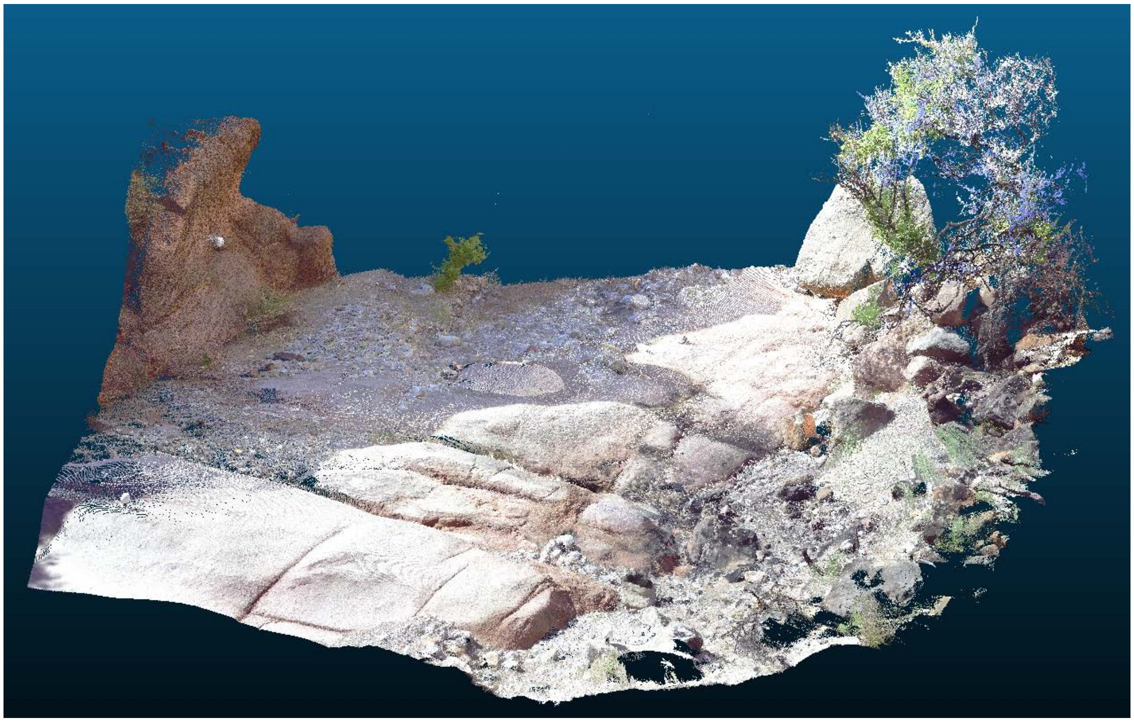

**Figure 4 - Screenshot image of FARO laser scanned point cloud**

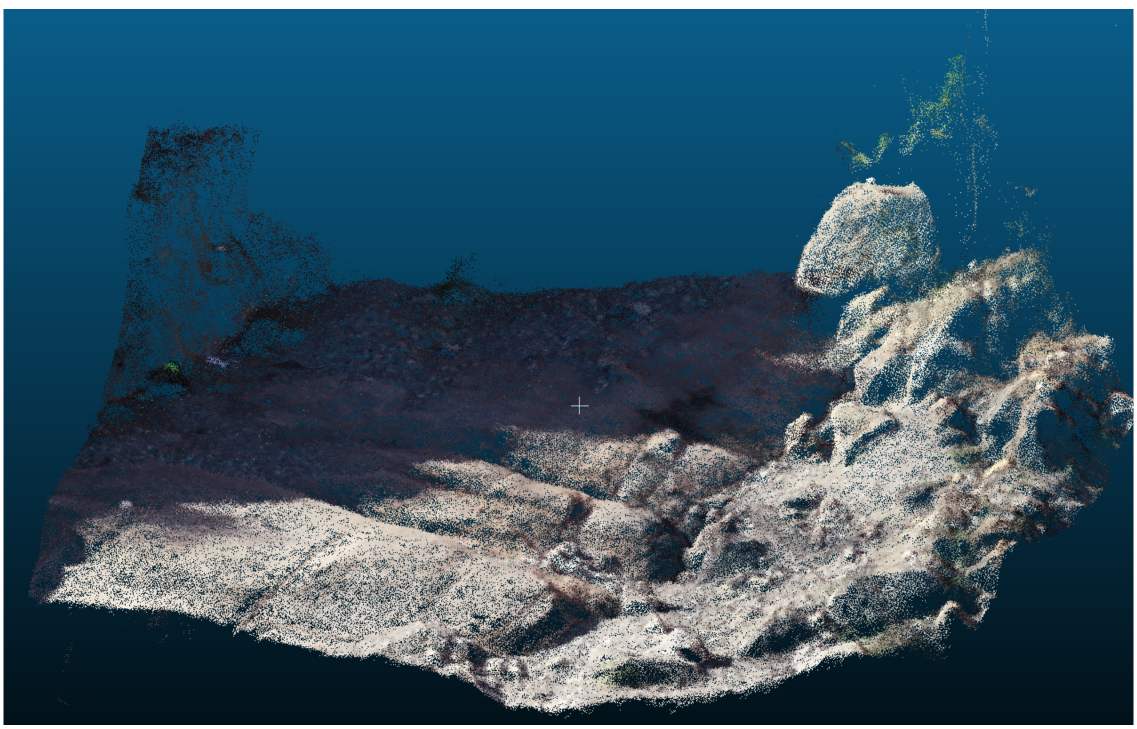

**Figure 5 - Screenshot image of UAS point cloud from low altitude flight**

software products. For further information on CloudCompare refer to www.danielgm.net/cc/ (accessed on 11/15/2018)

A standard plugin that is included with the software called "M3C2" was used to perform a distance calculation between two point cloud data sets.[4] Before a comparison of distance between point clouds could be completed, each point cloud needed to be correctly positioned. Both point clouds contained common tie points from the laser reference spheres that could be used to complete the positioning in the cloud compare software. Once the clouds were positioned correctly the "M3C2" plugin was used to generate distance between core points using standard settings. Figure 6 contains the output from the "M3C2" with the computed distances between over 800,000 core points. A majority of core points were within 0.2 ft (2.4 inches) between the two datasets.

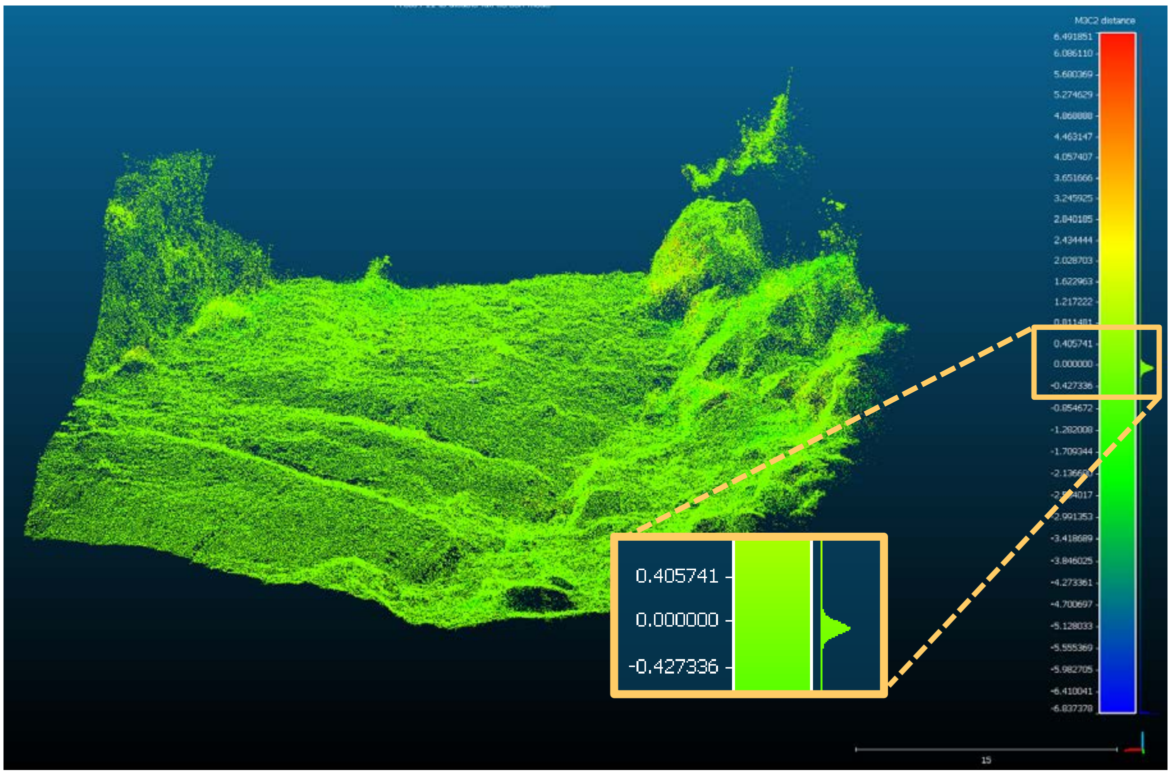


**Figure 6 - Results of M3C2 point cloud comparison**

An additional comparison of distances between the laser reference spheres was also completed. The NTSB Office of Research and Engineering provided the distance data from the FARO data set. Utilizing the tools in Pix4D, measurements between all of the reference spheres were taken. Figure 7 shows the various laser reference sphere locations and Table 2 contains the measurement data from the FARO and the Pix4D outputs. Overall the variation in the distance between the two datasets was less than 1.5 inches.

Additional side by side comparison images of the point cloud are included in section 5.0.

[4] For further information on M3C2 refer to http://www.cloudcompare.org/doc/wiki/index.php?title=M3C2_(plugin) (accessed on 11/15/2018)

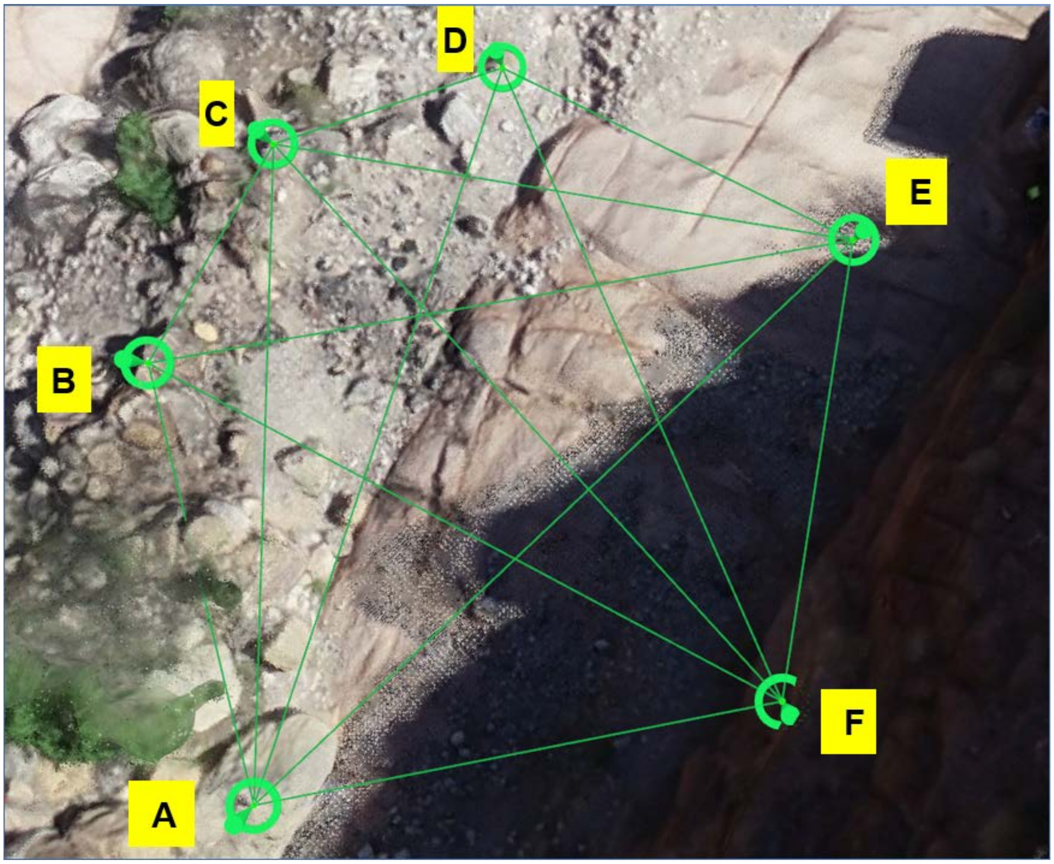


Figure 7 - Location of laser reference spheres used in distance comparison

Table 2 - Distances measured between FARO and UAS point clouds (min and max value highlighted)

| Leg | Measured Distance | | | | | | | Difference in Inches |
|---|---|---|---|---|---|---|---|---|
| | Faro (ft) | Pix4D 3D (m) | Pix4D 3D Error +/- (m) | Pix4D 3D Error +/- (in) | Pix4D 3D min (ft) | Pix4D 3D (nom) (ft) | Pix4D 3D max (ft) | Faro to Pix4D 3D |
| **F-A** | 31.2220 | 9.49 | 0.01 | 0.3937 | 31.1024 | 31.1352 | 31.1680 | 1.0420 |
| **A-B** | 26.8820 | 8.20 | 0.01 | 0.3937 | 26.8701 | 26.9029 | 26.9357 | 0.2506 |
| **B-C** | 16.0703 | 4.90 | 0.02 | 0.7874 | 16.0105 | 16.0761 | 16.1417 | **0.0698** |
| **C-D** | 15.5240 | 4.74 | 0.02 | 0.7874 | 15.4856 | 15.5512 | 15.6168 | 0.3262 |
| **D-E** | 25.7153 | 7.81 | 0.01 | 0.3937 | 25.5906 | 25.6234 | 25.6562 | 1.1033 |
| **E-F** | 28.1997 | 8.63 | 0.04 | 1.5748 | 28.1824 | 28.3136 | 28.4449 | **1.3674** |
| **A-E** | 48.9747 | 14.96 | 0.01 | 0.3937 | 49.0486 | 49.0814 | 49.1142 | 1.2800 |
| **C-E** | 37.3667 | 11.38 | 0.01 | 0.3937 | 37.3031 | 37.3360 | 37.3688 | 0.3689 |
| **B-E** | 43.6967 | 13.33 | 0.01 | 0.3937 | 43.7008 | 43.7336 | 43.7664 | 0.4427 |
| **A-C** | 40.5340 | 12.37 | 0.01 | 0.3937 | 40.5512 | 40.5840 | 40.6168 | 0.5999 |
| **A-D** | 48.1277 | 14.68 | 0.01 | 0.3937 | 48.1299 | 48.1627 | 48.1955 | 0.4204 |

## 3.0 Imagery products

Approximately 690 high resolution photos, including 6 panoramic images and 2 videos were gathered. Select photos and excerpts from the 3D modelling products are included in this report, as described below and are contained in section 5.0. A list of images and select output products attached to this report and contained in the docket are listed in section 4.0.

Figure 8 is an image taken of the general area around the accident site looking towards the Colorado River and the Quartermaster landing zone.

Figure 9 is an overhead image of the accident site.

Figure 10 contains a screenshot of the Pix4D generated point cloud from the low altitude (100 ft AGL) mission. The GCPs and laser reference spheres are annotated by green/blue cones on the image.

Figure 11 contains a screenshot of the orthomosaic map overlaid on Google Earth. The Quartermaster landing zone is noted on the image.

Figure 12 and Figure 13 present panoramic views of the overall accident scene. The images were created using commercially available software which stitched together 34 individual images taken using a programmed sequence from the drone control software. The product is intended to be used with a 360 Panoramic viewer software and it is projected onto 2D for this report, creating various distortions. The original panoramic image is an attachment to this report and located in the accident docket.

Figure 14 and Figure 15 are additional side by side comparisons of the FARO and Pix4D generated point clouds. Figure 14 is a view of a large bolder, upon which one of the laser reference spheres was placed. The increased detail from the FARO data is apparent in the image on the left. Figure 15 is an overhead view comparison of the two point clouds.

## 4.0 Attachments

**Attachment 1 –** Original Photograph used in Figure 8
**Attachment 2 –** Original Photograph used in Figure 9
**Attachment 3 –** Orthomosaic map in Google Earth .kmz format (ref. Figure 11)
**Attachment 4 –** Panoramic Image shown in Figure 12
**Attachment 5 –** Panoramic Image shown in Figure 13

## 5.0 Oversized Imagery

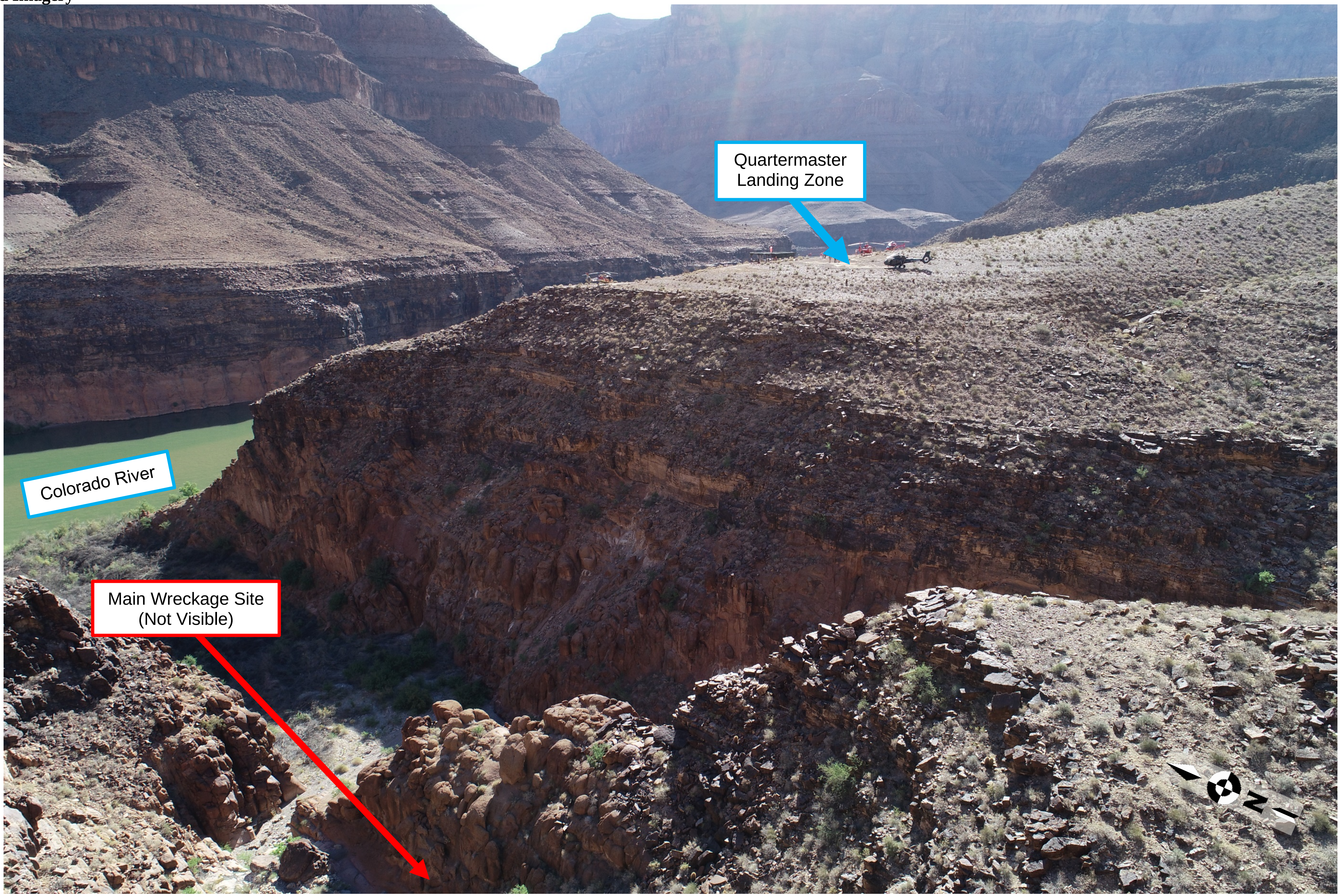


Figure 8 – Photo – Aerial view of accident site looking towards the Quartermaster Landing Zone (directional arrow approximated)


Figure 9 – Photo - Aerial overhead view of accident site (directional arrow approximated)

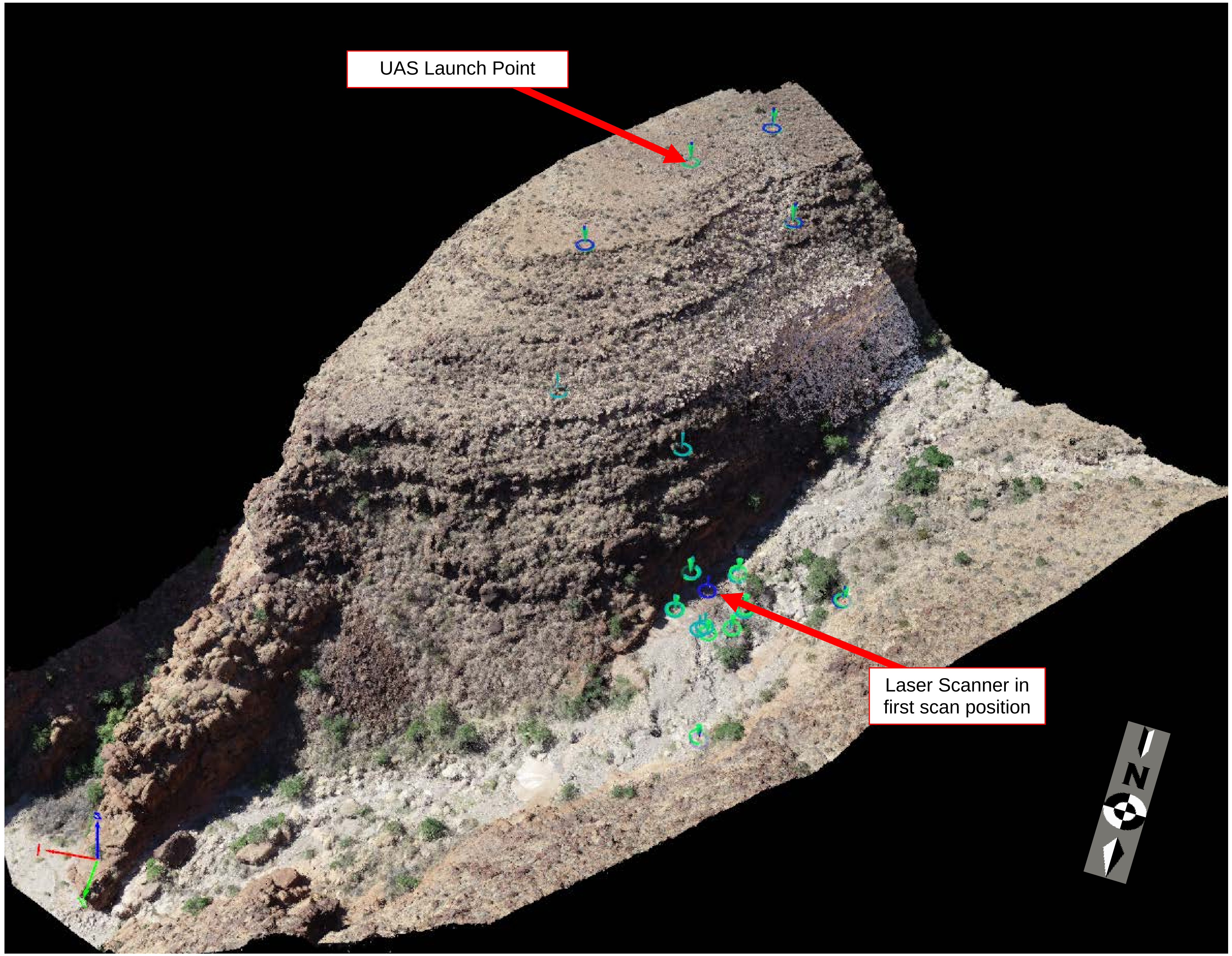


Figure 10 – Screenshot – Pix4D point cloud of low altitude dataset, GCPs and laser reference spheres shown as blue/green markers (directional arrow approximated)

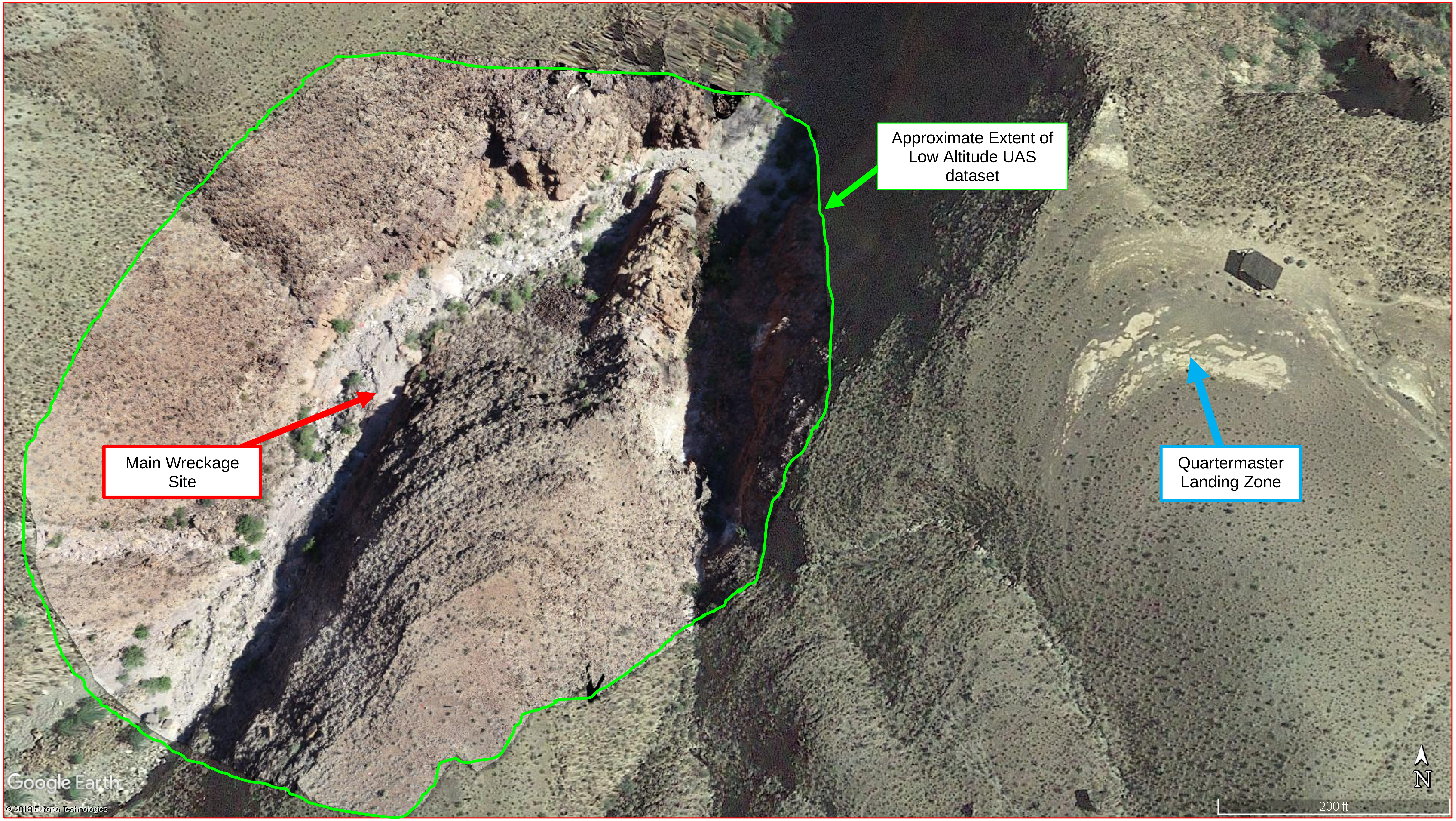


Figure 11 – Orthomosaic image overlaid on Google Earth of accident site.

Figure 12 - Panoramic image of scene taken from above the accident site (light blue strip at top of image added during panoramic creation, and the 2D image contains distortions)[5]

[5] The image is intended to be viewed with 360 Panoramic viewer software and it is projected onto 2D for this report, creating various distortions (i.e. terrain curvature)

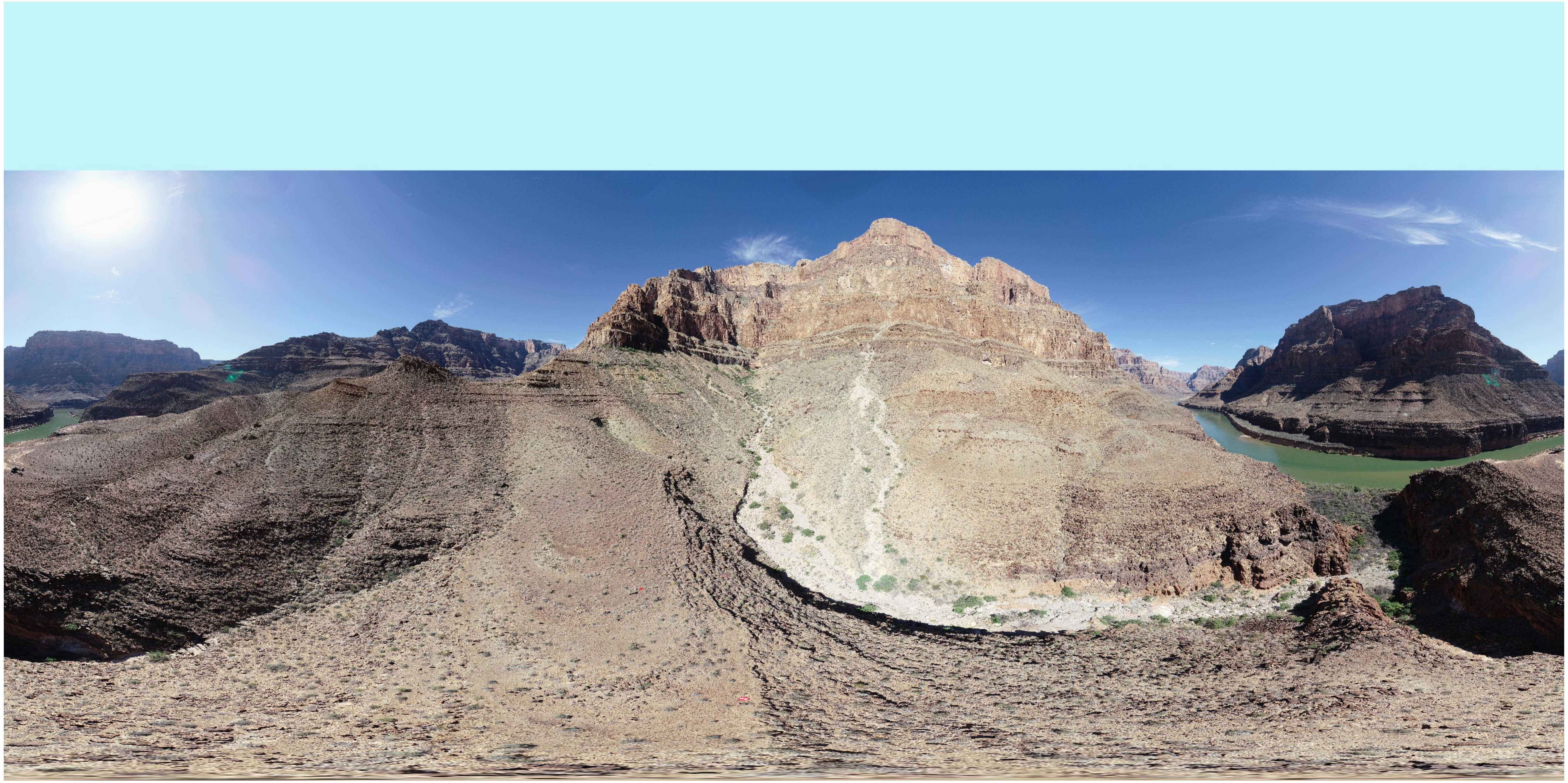

Figure 13 - Panoramic image of scene taken from above mesa near the accident site (light blue strip at top of image added during panoramic creation, and the 2D image contains distortions)[6]

[6] The image is intended to be viewed with 360 Panoramic viewer software and it is projected onto 2D for this report, creating various distortions (i.e. terrain curvature, riverway)

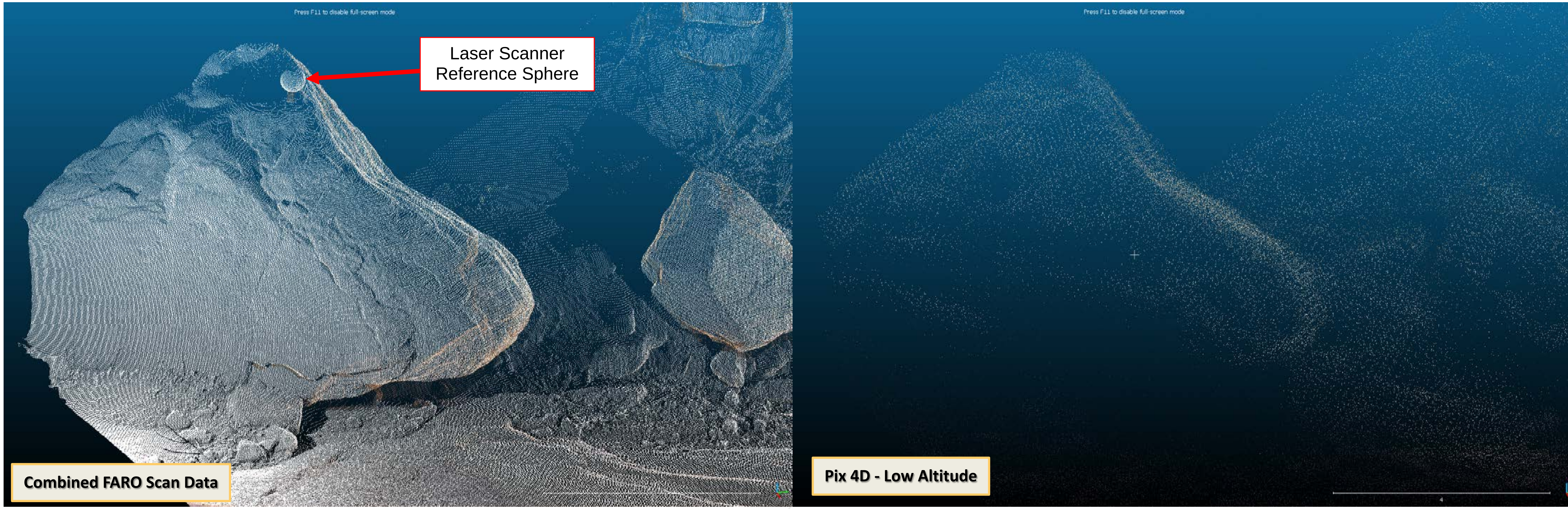


Figure 14 - Side by Side comparison of FARO and UAS point clouds

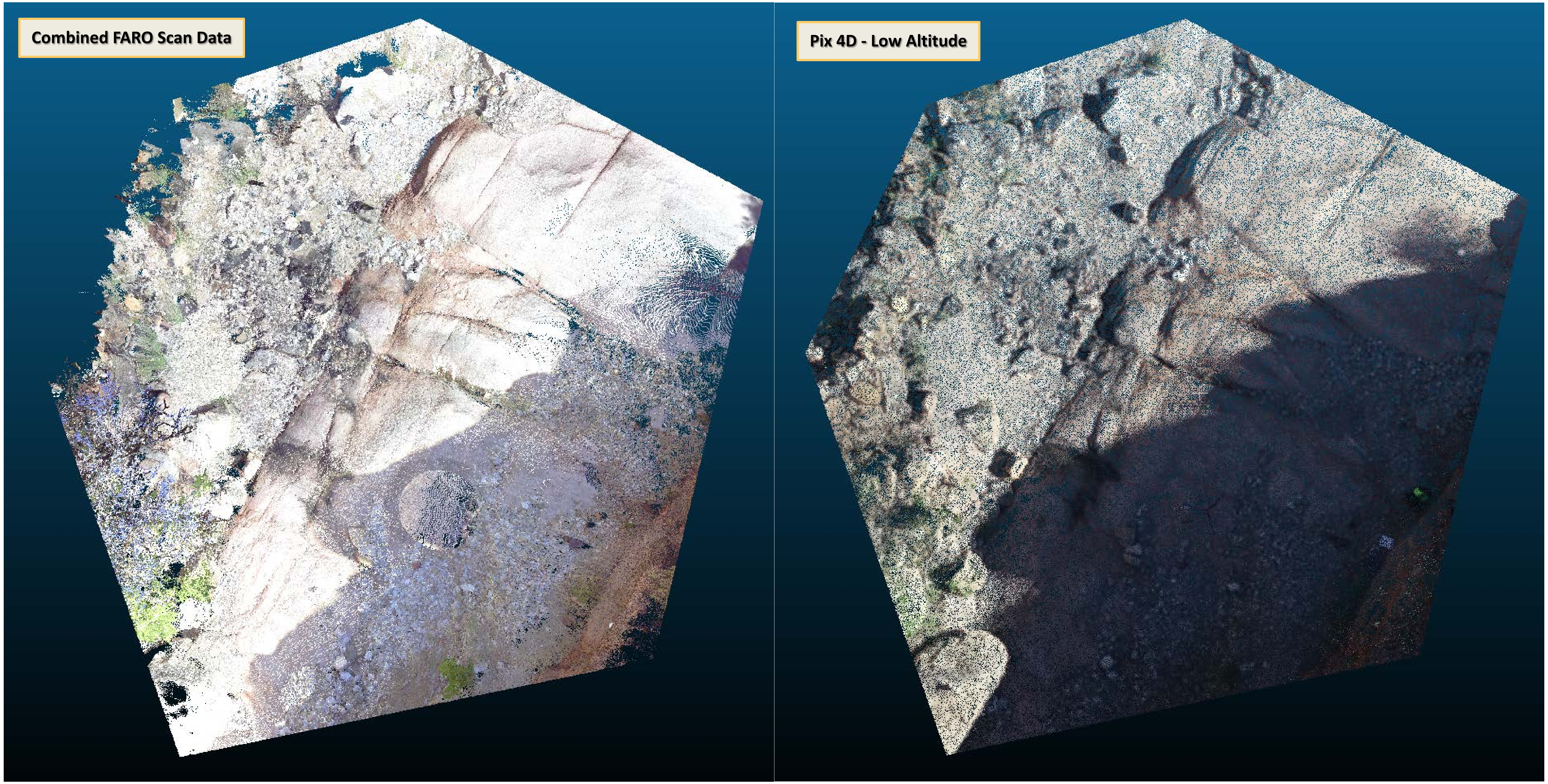


**Figure 15 - Side by Side comparison of overhead view of FARO and UAS point clouds**