



# **Fireweed Zinc Ltd. LiDAR and Airphoto Data Capture and Processing**

## **2019 LiDAR and Airphoto Report Macmillan Pass Project**

**Our File:  
2611 19449-01**

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## 1. Introduction

McElhanney Ltd performed a LiDAR and aerial photography acquisition for approximately 513 km<sup>2</sup> Macmillan Pass property in eastern Yukon. See figure 1.

The site was flown July and early September, 2019. This report describes the acquisition, post-processing and quality control methodology used to produce the LiDAR deliverables.

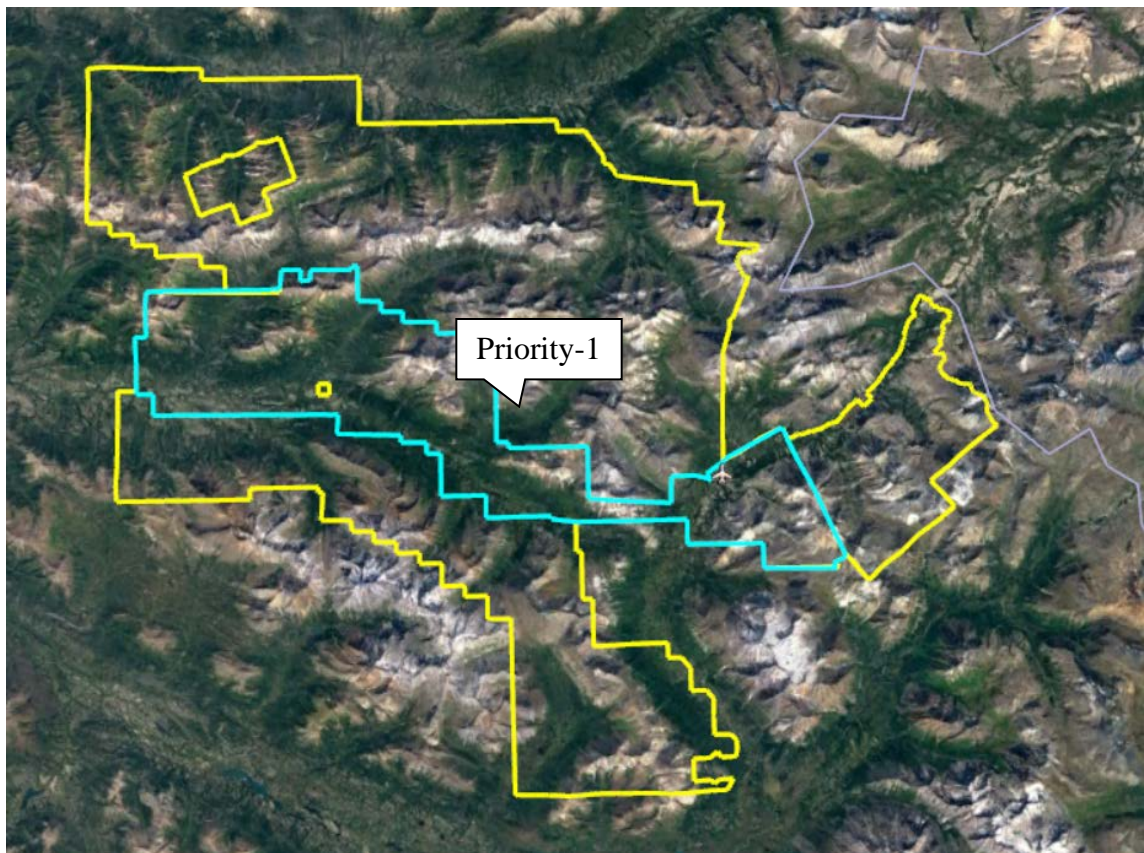
## 2. Mission Plan

**Project:** Fireweed LiDAR and Aerial photo.

**Date:** 2019-07-10, 2019-07-17, 2019-07-18 and 2019-09-07

**Location:** Macmillan Pass Project, Yukon.

**Topography:** Mixed, mountains and low relief.



**Figure 1– LiDAR Survey Site**

### 3. Equipment

McElhanney utilized the Optech Galaxy system for LiDAR Capture (Figure 2).

For Product Specifications of Optech Galaxy please see

<http://www.teledyneoptech.com/index.php/product/optech-altm-galaxy/>

The Galaxy was mounted on Piper Navajo fixed wing Aircraft.



Figure 2 – Optech Galaxy components

On Board Camera Phase One iXU-RS1000 RGB simultaneous capture (Figure 3.)

#### Phase One Industrial – Cameras iXU-RS1000 series



iXU-RS1000 series

Camera Type	iXU-RS1000
Camera Specifications	
Lens type	Rodenstock / Schneider-Kreuznach
Focal length F (mm)	RS lenses: 32, 40, 50, 70, 90, 110, 150 SK lenses: 28, 55, 80, 110, 150, 240
FOV (across line, deg)	86.5 (28mm) – 12.9 (240mm)
FOV (along flight line, deg)	70.3 (28mm) – 9.7 (240mm)
Aperture	f/5.6
Exposure principle	Leaf shutter
Exposure (sec)	1/2000 to 1/125
Image capture rate	1 frame every 0.6 sec
Light Sensitivity (ISO)	50-6400
Dynamic Range (db)	>84
Spectral characteristics	R,G,B
Sensor Specifications	
CMOS pixel size (µm)	4.6
CMOS array (pix)	11,608 x 8,708
Analog-to-digital-conversion (bit)	14
Frame / Image Specifications	
Frame geometry	Central projection
Image size (pixel)	11,608 x 8,708
Image volume (MP)	100
Color	RGB or NIR
Typical image size (MB)	300
Image format	Phase One RAW, TIFF, JPEG
Operational Specifications	
Power Consumption	< 10W
Dimensions (depends on lens)	97.4 x 93 x <218 mm
Weight (depends on lens)	< 2 kg

PHASEONE  
Specialty Imaging Solutions

Figure 3 – Phase One Camera Series

#### 4. Flight Plan

**Table 1:** Flight Parameters- 2019-07-10a

Strip ID	Start [s]	Stop [s]	PRF [kHz]	Scan Frequency [Hz]	Scan Swath [deg]	Speed Avg [m/s]	Height Avg [m]
1	323061.2	323464	402.8	400	73	42	81
2	323574.5	324055.7	481.2	400	73	42	69.6
3	324155.1	324598	442.9	400	73	42	75.4
4	324702	325203.7	501.7	400	73	42	72.3
5	325308.7	325764.7	456	400	73	42	79.9
6	325886.4	326390	503.6	400	73	42	72.2
7	326492.8	326943.5	450.7	400	73	42	79.8
8	327057.8	327545.5	487.7	400	73	42	73.9
9	327658.8	328097.1	438.3	400	73	42	81.2
10	328279.5	328733.6	454.1	400	73	42	75
11	328860.1	329287.1	427	400	73	42	78.6
12	329502.2	329947	444.8	400	73	42	75.5
13	330058.4	330478	419.6	400	73	42	80.7
14	330761.3	331197.7	436.4	400	73	42	76.6
15	331327.8	331782.9	455.1	400	73	42	76.1
16	331917.7	332357.8	440.1	400	73	42	78.1
17	332488.9	332942.1	453.2	400	73	42	76.2
18	333051.7	333510.5	458.8	400	73	42	76.6
19	333642.5	334137.7	495.2	400	73	42	71.8
20	334253.8	334740.6	486.8	400	73	42	74.1
21	334914.6	335161.6	246.9	400	73	42	79.6

**Table 2:** Flight Parameters- 2019-07-10b

Strip ID	Start [s]	Stop [s]	PRF [kHz]	Scan Frequency [Hz]	Scan Swath [deg]	Speed Avg [m/s]	Height Avg [m]
1	347778.5	347897.5	119.1	400	73	42	82.2
2	348068.8	348196.2	127.4	400	73	42	71.9
3	348257.3	348379.2	121.8	400	73	42	79.4
4	348462.6	348590.1	127.5	400	73	42	71.6
5	348656.8	348779.6	122.8	400	73	42	81.2
6	348862.1	348923.8	61.7	400	73	42	78.4

**Table 3:** Flight Parameters- 2019-07-10c

Strip ID	Start [s]	Stop [s]	PRF [kHz]	Scan Frequency [Hz]	Scan Swath [deg]	Speed Avg [m/s]	Height Avg [m]
1	350870.7	350994.4	123.7	400	73	42	79.7
2	351073.2	351187.6	114.4	400	73	42	77.4
3	351251.5	351378.9	127.5	400	73	42	77.4
4	351473.6	351578.7	105	400	73	42	78.6
5	351665.9	351792.4	126.5	400	73	42	75
6	351890.8	351991.2	100.4	400	73	42	81.6
7	352097.1	352195.6	98.5	400	73	42	74.5
8	352298.7	352375.7	77	400	73	42	68.8
9	352497.5	352567.1	69.6	400	73	42	74.7
10	352700	352781.7	81.7	400	73	42	74.7

**Table 4: Flight Parameters- 2019-07-17**

Strip ID	Start [s]	Stop [s]	PRF [kHz]	Scan Frequency [Hz]	Scan Swath [deg]	Speed Avg [m/s]	Height Avg [m]
1	321074.4	321419.4	344.9	400	73	42	72.3
2	321523.4	321797.4	274	400	73	42	83.8
3	321898.6	322242.6	344	400	73	42	72.4
4	322349.4	322674.7	325.3	400	73	42	80.2
5	322796.5	323173.1	376.6	400	73	42	71.8
6	323285.5	323616.4	330.9	400	73	42	81.2
7	323890.3	324138.2	247.8	400	73	42	78.2
8	324357.9	324407	49	400	73	42	75.4
9	324643.5	324771	127.5	400	73	42	71.5
10	324849.8	325019.3	169.5	400	73	42	77.7
11	325189.6	325308.6	119	400	73	42	71.7
12	325439.7	325566.2	126.5	400	73	42	67.6
13	325966.1	326126.2	160.1	400	73	42	74.3
14	326265.7	326439.8	174.1	400	73	42	68.7
15	326564.4	326709.5	145.2	400	73	42	82.6
16	326838.8	327005.4	166.6	400	73	42	72
17	327150.5	327488	337.4	400	73	42	81.6

**Table 5: Flight Parameters- 2019-07-18**

Strip ID	Start [s]	Stop [s]	PRF [kHz]	Scan Frequency [Hz]	Scan Swath [deg]	Speed Avg [m/s]	Height Avg [m]
1	403635.4	403971.9	336.5	400	66	50	77
2	404084.3	404408.7	324.4	400	66	50	81.5
3	404576.2	404909.9	333.7	400	66	50	79.5

Strip ID	Start [s]	Stop [s]	PRF [kHz]	Scan Frequency [Hz]	Scan Swath [deg]	Speed Avg [m/s]	Height Avg [m]
4	405025.1	405349.5	324.4	400	66	50	80.8
5	405463.8	405790.1	326.3	400	66	50	77.9
6	405927.7	406225.9	298.2	400	66	50	79.9
7	406341.2	406619.8	278.6	400	66	50	78.2
8	406748.1	407005.3	257.2	400	66	50	80.6
9	407139.1	407379.5	240.4	400	66	50	78.7
10	407609.6	407936.8	327.2	400	66	50	82.1
11	408033.3	408298.9	265.6	400	66	50	80.6
12	410265.8	410289.7	23.9	450	66	50	94.7
13	410502	410563.2	61.2	450	66	50	78.7
14	410824.9	411077.4	252.5	500	66	50	75
15	411178.7	411421.9	243.2	500	66	50	80
16	411540.8	411813.9	273.1	500	66	50	72.4
17	411939.3	412194.7	255.3	500	66	50	77.2
18	412315.5	412582.9	267.4	500	66	50	74
19	412704.7	412960.9	256.2	500	66	50	74.5
20	413082.7	413339.9	257.2	500	66	50	73.2
21	413450.4	413698.3	247.9	500	66	50	73.5
22	413813.5	414061.3	247.8	500	66	50	72
23	414170	414406.7	236.6	500	66	50	71.8
24	414522.8	414750.2	227.3	500	66	50	74.7
25	414859.8	415086.2	226.4	500	66	50	74.8
26	415202.3	415433.4	231	500	66	50	73.7
27	415557.9	415781.5	223.6	500	66	50	75.8
28	415892	416121.2	229.2	500	66	50	74.3
29	416257	416495.5	238.5	500	66	50	71.3
30	416606.1	416838	232	500	66	50	73.6



Strip ID	Start [s]	Stop [s]	PRF [kHz]	Scan Frequency [Hz]	Scan Swath [deg]	Speed Avg [m/s]	Height Avg [m]
31	416969.1	417215.1	246	500	66	50	69.3
32	417325.7	417557.7	232	500	66	50	73.4
33	417662.6	417890.9	228.2	500	66	50	74.5
34	418018.2	418251.1	232.9	500	66	50	73.2
35	418354.2	418574.1	219.9	500	66	50	77.7
36	418690.2	418920.3	230.1	500	66	50	74.3
37	419018.7	419239.5	220.8	500	66	50	77.2
38	419343.5	419579.3	235.7	500	66	50	72.6
39	419676.8	419891	214.2	500	66	50	79.4
40	420077.2	420225.2	148	500	66	50	76.7

**Table 6: Flight Parameters- 2019-09-07a**

Strip ID	Start [s]	Stop [s]	PRF [kHz]	Scan Frequency [Hz]	Scan Swath [deg]	Speed Avg [m/s]	Height Avg [m]
1	581500.1	581653.7	153.6	400	66	50	76
2	581755.8	582174.5	418.7	400	66	50	72.6
3	582262.6	582642.1	379.4	400	66	50	80.6
4	582769.4	583186.2	416.8	400	66	50	73.5
5	583242.7	583634.2	391.6	400	66	50	77.7
6	583714.9	584136.4	421.4	400	66	50	72.6
7	584225.4	584623.6	398.1	400	66	50	76.5
8	584762.1	585109.8	347.7	400	66	50	77.8
9	585258.7	585311.5	52.8	400	66	50	70.6
10	585398.7	585473.9	75.2	400	66	50	75.9
11	585670.3	585706.3	36	400	66	50	73.2
12	585818.7	585858.4	39.7	400	66	50	80.6

Strip ID	Start [s]	Stop [s]	PRF [kHz]	Scan Frequency [Hz]	Scan Swath [deg]	Speed Avg [m/s]	Height Avg [m]
13	585993.2	586035.7	42.5	400	66	50	73.4
14	586165.9	586206.5	40.7	400	66	50	78.4
15	586283.5	586323.2	39.7	400	66	50	74.8
16	586387.1	586410.9	23.8	400	66	50	83.4
17	586712.8	586751.6	38.8	400	66	50	77.6
18	586891.1	587183.7	292.7	400	66	50	74.3
19	587264.4	587530	265.6	400	66	50	80.4
20	587615.3	587896.8	281.5	400	66	50	74.1
21	588000.8	588075.1	74.3	400	66	50	77.9
22	588156.7	588257.1	100.4	400	66	50	71.9
23	589242.2	589326.7	84.5	400	66	50	71.4
24	589414.8	589470.4	55.6	400	66	50	76.2
25	589553	589652.4	99.4	400	66	50	70.8
26	589763.9	589863.4	99.4	400	66	50	77
27	590003.8	590131.2	127.4	400	66	50	71.5
28	590226.9	590295.5	68.6	400	66	50	69.8
29	590368.7	590475.6	106.9	400	66	50	74.9
30	590541.4	590631.5	90.1	400	66	50	70
31	590703.8	590817.2	113.5	400	66	50	74.4
32	590905.4	591009.5	104.1	400	66	50	70.2
33	591066.9	591184	117.2	400	66	50	74.3
34	591239.5	591367	127.5	400	66	50	69.3
35	591416.9	591535.9	119	400	66	50	74.1
36	591595.1	591717.9	122.8	400	66	50	69.8
37	591773.4	591892.4	119.1	400	66	50	75.3
38	591953.5	592069.8	116.3	400	66	50	70.5
39	592127.1	592242.5	115.3	400	66	50	74.8

Strip ID	Start [s]	Stop [s]	PRF [kHz]	Scan Frequency [Hz]	Scan Swath [deg]	Speed Avg [m/s]	Height Avg [m]
40	593642.9	593743.3	100.4	400	66	50	73.9
41	593820.2	593890.7	70.5	400	66	50	72.7
42	593981.7	594071.8	90.1	400	66	50	72.4
43	594167.4	594196.9	29.4	400	66	50	74.4
44	594277.6	594415.3	137.7	400	66	50	69.3
45	594558.5	594605.7	47.2	400	66	50	74.7
46	594692.9	594799.8	106.9	400	66	50	64.7
47	594896.4	594973.4	77.1	400	66	50	74.4
48	595049.4	595169.4	120	400	66	50	64.1
49	595228.6	595348.6	120	400	66	50	70.3
50	595402.2	595529.7	127.5	400	66	50	64.6
51	595600.1	595723.8	123.7	400	66	50	70.2
52	595794.2	595924.5	130.2	400	66	50	66.5
53	595986.5	596103.7	117.2	400	66	50	74.6
54	596164.8	596294.1	129.3	400	66	50	68.2
55	596358	596478	120	400	66	50	71.1
56	596587.6	596700.1	112.5	400	66	50	71.5

## 5. Data Processing

All GPS and IMU data were processed using PosPac MMS 8.4 software. The laser data was extracted using Teledyne Optech LMS software. The GPS antenna position in the airplane was calculated by post-processing the raw data at 1 second intervals for the entire flight.

We have used both DGPS and Precise Point Positioning (PPP) data for the airborne GPS processing, and the coordinates were calculated in NAD83-CSRCS. As Underhill Geomatics staff reported that there were interruptions in DGPS data collection, we used available DGPS data to corroborate data processed using PPP.

The airborne positions were combined with the post-processed platform (aircraft) attitude information to generate a time tagged position and orientation solution.

The standard deviation of the airborne GPS solution for using KAR (Kinematics Ambiguity Resolution) was estimated to be 0.03, 0.04 and 0.05m in East, North and height directions, respectively.

The estimated values for the GPS antenna position were used with the laser ranges and platform angles to compute all the individual X, Y, and Z coordinates for each laser return in each flight line. The result is a processed point cloud containing all measured points.

## **6. Point Density**

Bare earth point density varies with canopy closure, understory density and topographic features. For the priority-1 area, the mean density of the point cloud was measured at nominal 15.76 pts/m<sup>2</sup> and the Bare earth point density was measured at nominal 3.26 pts/m<sup>2</sup>. For areas outside the priority-1 area, the mean density of the point cloud was measured at nominal 13.35 pts/m<sup>2</sup> and the Bare earth point density was measured at nominal 3.53 pts/m<sup>2</sup>.

## **7. Calibration**

**System: Optech ALTM Galaxy S/N 5060392**

**LiDAR Calibration flight:**

Calibration Date: June 14, 2019 Location: Whitehorse, Yukon

The LiDAR system calibration was flown over calibration site. The lever arms (offset between GPS antenna IMU and Laser Mirror), were measured as:

Lever Arms

GPS Lever arms in (m):

x: 0.28 y: -0.445 z: -1.196

IMU Lever arms in (m):

x: 0 y: 0 z: 0

There were a total number of 10 flight lines for calibration: 9 basic orthogonal lines for LMS software analysis and 1 redundant line for better accuracy. The lines were planned as follow:

Flight line direction: 3 lines north – south and 3 lines east – west and 1-line NW-SE  
All GPS with IMU data was processed using PosPac Applanix software v.8.3. and the laser data was extracted using LMS v.4.3 The GPS antenna position in the airplane was calculated by post-processing the raw data at 1 second intervals for the entire flight.

The calibration values used for this project are as follows:

imu\_ex: 0.049404867 arcsec

imu\_ey: -0.062994531 arcsec

imu\_ez: -0.131591982 arcsec

## 8. Quality Control

The LiDAR data consistencies have been checked between the flight lines using Terrascan software. As per the work authorization all survey control data was provide by the client. Survey control was established by Underhill Geomatics Ltd.

### Comparison of Bare Earth LiDAR data with Ground Survey Values

According to ASPRS guidelines, the vertical accuracy of LiDAR is as follows:

$$RMSE_z = Sqrt[\sum (Z_{Lidar(i)} - Z_{check(i)})^2 / n] = 0.03 \text{ m}$$

Where the "Check" refers to the ground truth ( In this project, we used survey points which are at least three times more accurate than the individual LiDAR points) and  $n$  is

the number of check points. LiDAR 2019 was checked vs ground survey points. A total of 801 ground check points were used for this analysis.

Average dz	+0.003 m
Minimum dz	-0.094 m
Maximum dz	+0.098 m
Average magnitude	0.025 m
Root mean square	0.032 m
Std deviation	0.032 m

## **9. Deliverables**

Final output data is provided in NAD83CSRS UTM 9 and the elevations are based on CGVD28 HT2 geoid model. The deliverables include:

- LiDAR data: Bare-Earth, Full-Feature and Model Key Points in LAS format.
- 1m pixel, bare-earth DEM
- LiDAR hillshade imagery in ECW format
- 5m contours in ESRI Shapefile format
- 20 cm orthophoto in TIF (1km tiles) and ECW (overview mosaic) format.
- LiDAR and Airphoto report