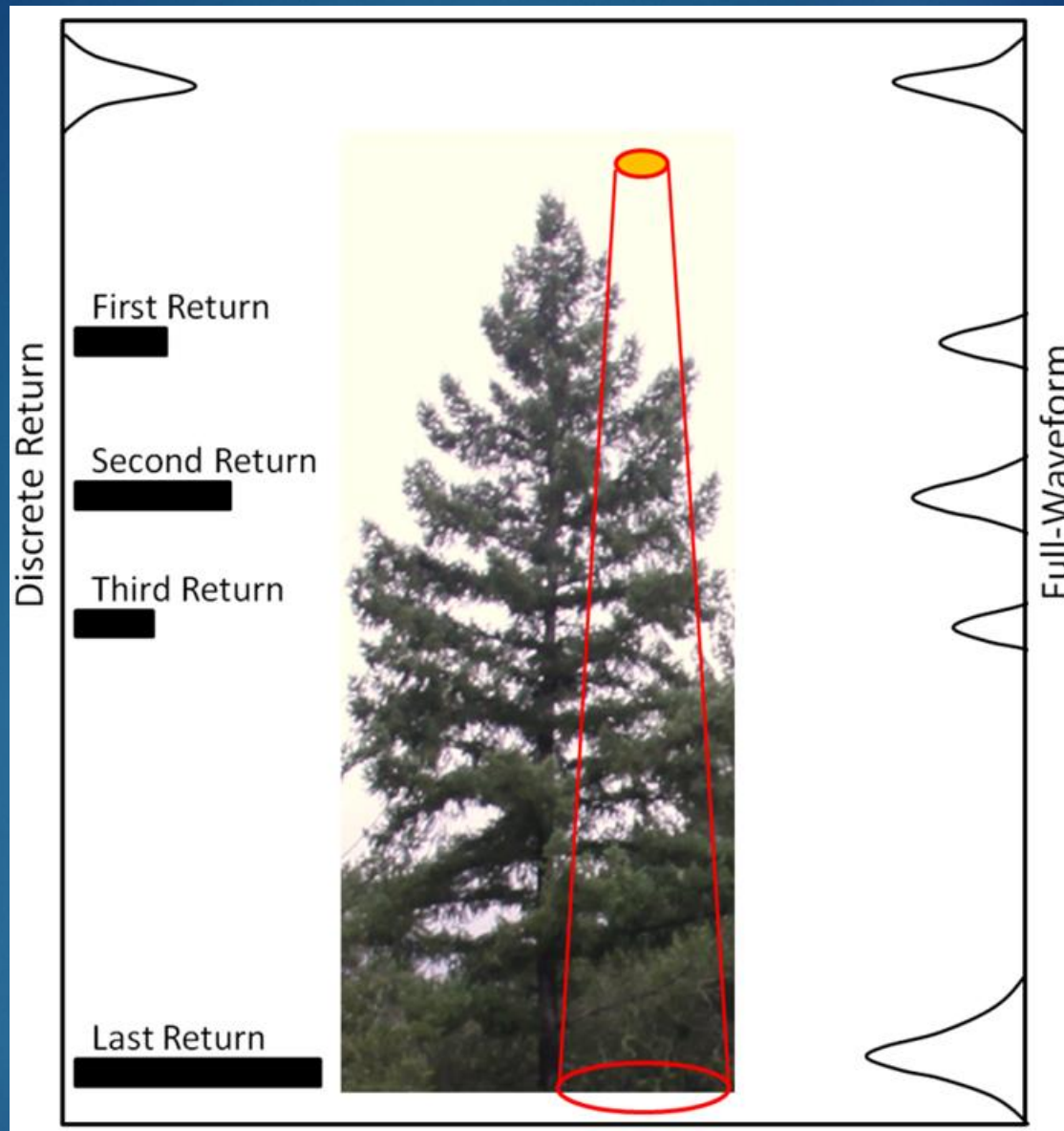




Principles of LiDAR Remote Sensing

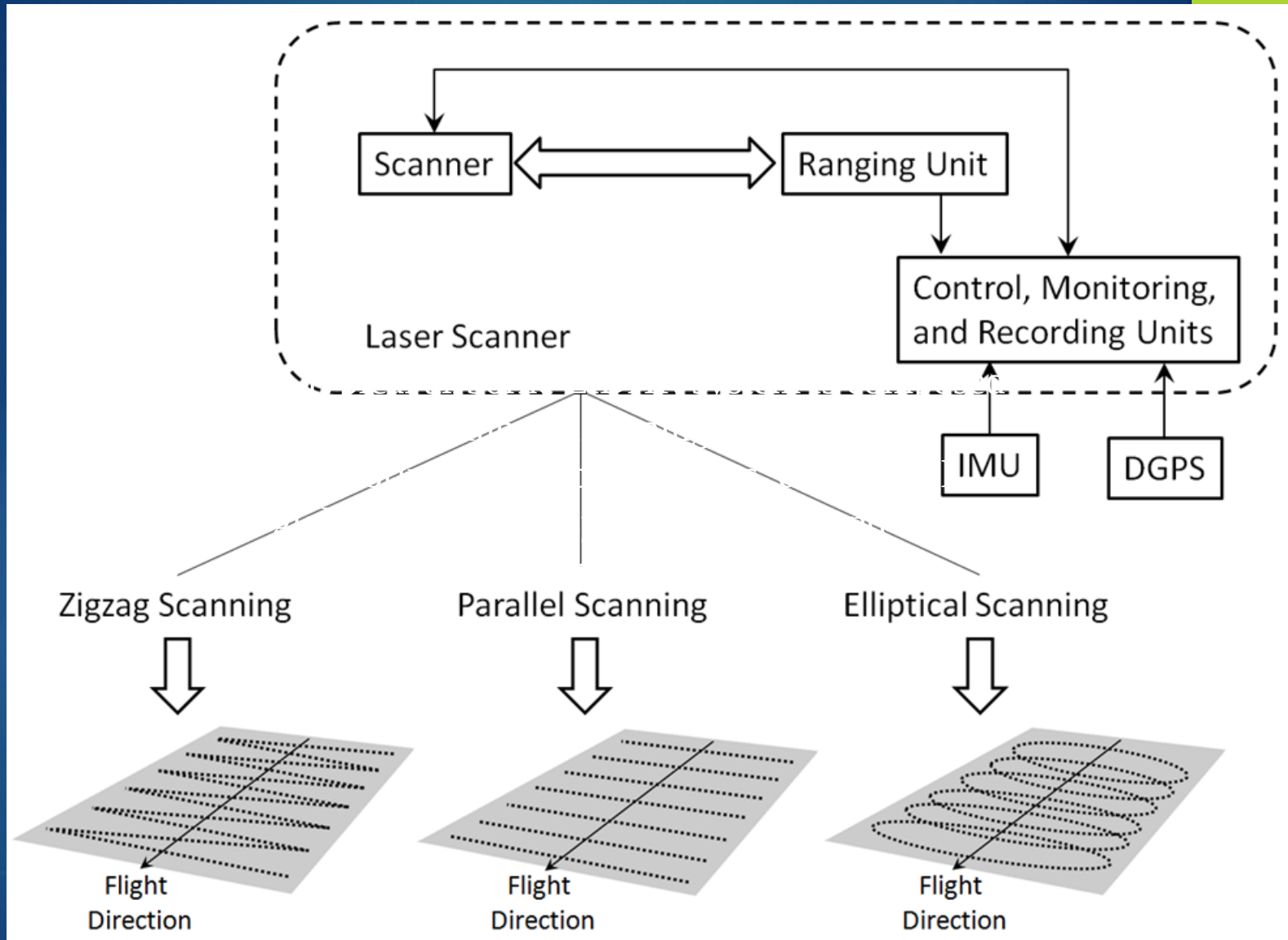
How does LiDAR work?

<https://www.youtube.com/watch?v=EYbhNSUnIdU>



Discrete return and full-waveform measurement using airborne LiDAR

- 
- A typical airborne LiDAR system is composed of a laser scanner, a ranging unit, control, monitoring and recording units, differential global positioning system (DGPS), and an inertial measurement unit (IMU).
 - An integrated DGPS/IMU system is also called a position and orientation system (POS) that generates accurate position (longitude, latitude, altitude) and orientation (roll, pitch, heading) information.



A typical airborne LiDAR system

Physical Principles of LiDAR

A_T – Transmitted light signals.

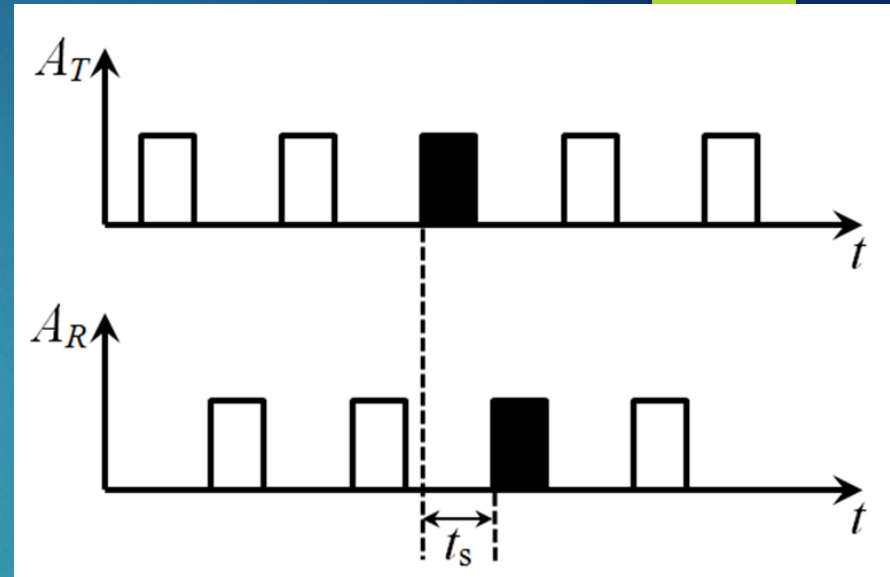
A_R – Received light signal.

c – Speed of light.

R – distance between the ranging unit and the object surface.

t_s – Travelling time of a laser pulse

(Wehr and Lohr, 1999)



$$\text{Range: } R = \frac{1}{2}c \cdot t_s \quad (2-1)$$

$$\text{Range Resolution: } \Delta R = \frac{1}{2}c \cdot \Delta t_s \quad (2-2)$$

$$\text{Maximum Range: } R_{max} = \frac{1}{2}c \cdot t_{s_{max}} \quad (2-3)$$

LiDAR Equation

The standard LiDAR equation relates the power of transmitted (P_t) and received (P_r) signals, and can be expressed as (Wagner et al. 2006):

$$P_r(t) = \frac{D^2}{4\pi\lambda^2} \int_0^H \frac{\eta_{sys}\eta_{atm}}{R^4} P_t \left(t - \frac{2R}{v_g} \right) \sigma(R) dR \quad (2-4)$$

where t is the time, D the aperture diameter of the receiver optics, P_r the received power, P_t the emitted power, λ the wavelength, H the flying height, R the distance from the system to the target, η_{sys} and η_{atm} the system and atmospheric transmission factors respectively, v_g the group velocity of the laser pulse, and $\sigma(R)dR$ the apparent effective differential cross-section.

LiDAR Data Formats

Each point data record stores information such as the point's X, Y, Z, intensity, return number, number of returns (of a given pulse), scan direction, classification, GPS time, point source, etc.

X
Y
Z
Intensity
Return Number
Number of Returns
Scan Direction Flag
Edge of Flight Line
Classification
Scan Angle Rank
User Data
Point Source ID
GPS Time
Red
Green
Blue
Wave Packet Descriptor Index
Byte offset to waveform data
Waveform packet size in bytes
Return Point Waveform Location
X(t)
Y(t)
Z(t)

LiDAR Data -- ASCII Format

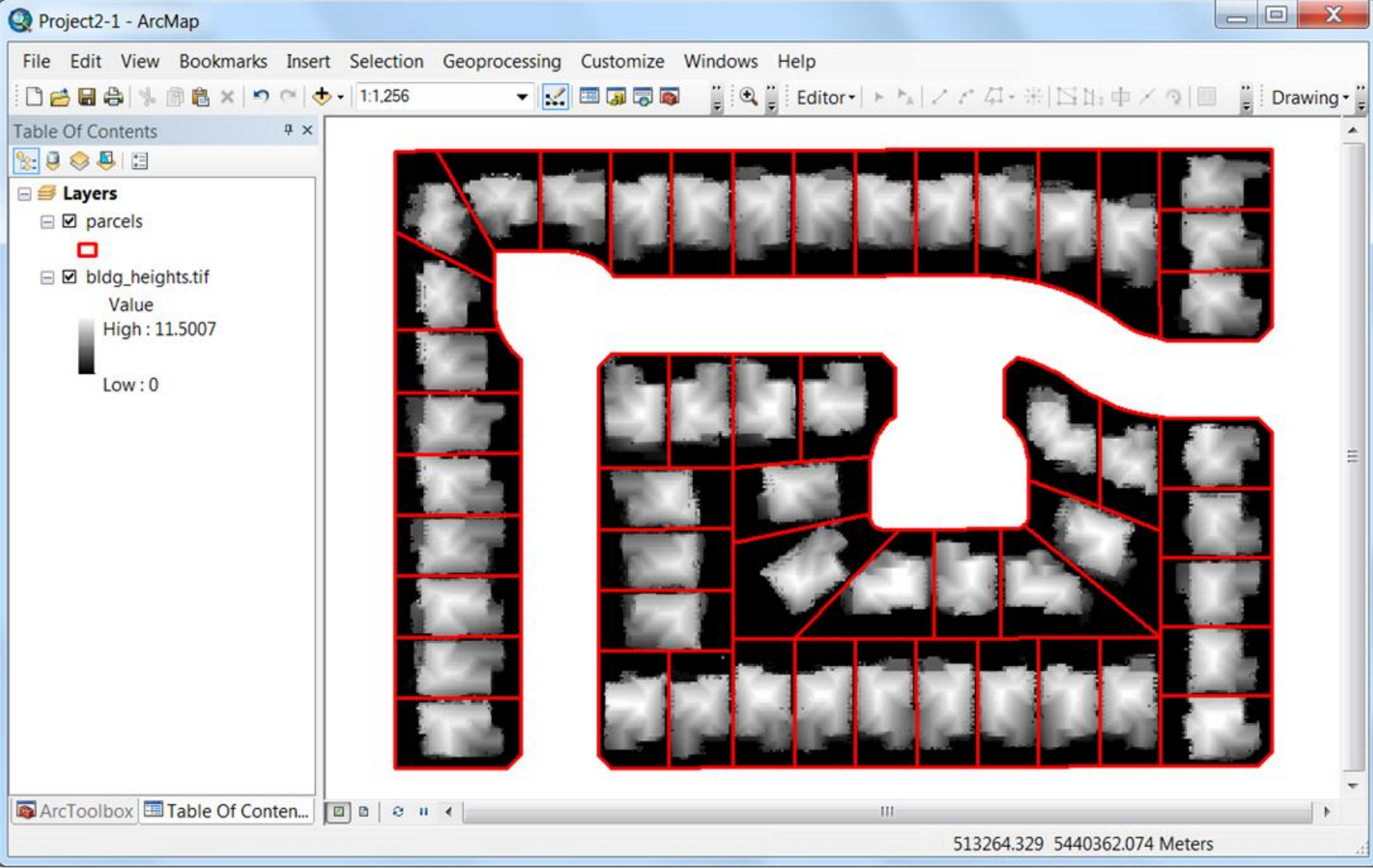
99	358289.210	5973161.180	959.530	24	597546.5670	1770.970	-2482.530	182.670	188.0
99	358290.870	5973162.460	959.290	36	597546.5670	1772.030	-2482.500	182.660	173.0
5	358288.690	5973160.120	978.120	9	597546.5670	1773.080	-2482.490	182.610	188.0
99	358292.470	5973163.670	959.390	19	597546.5870	1774.240	-2483.750	182.560	182.0
5	358290.730	5973161.750	975.930	8	597546.5870	1773.100	-2483.770	182.710	150.0
5	358291.210	5973162.200	973.580	7	597546.5870	1771.930	-2483.810	182.630	176.0
5	358292.310	5973162.940	976.090	9	597546.5870	1770.870	-2483.830	182.630	176.0
5	358293.780	5973162.420	973.610	11	597546.5870	1769.720	-2483.860	182.680	183.0
5	358292.130	5973161.150	973.850	1	597546.5870	1768.560	-2483.880	182.720	172.0
5	358293.180	5973162.130	968.680	9	597546.5870	1767.410	-2483.910	182.810	171.0
5	358291.310	5973160.660	969.960	6	597546.5870	1766.350	-2483.930	182.820	176.0
10	358293.510	5973162.720	959.090	46	597546.5870	1765.200	-2483.960	182.860	195.0
10	358291.870	5973161.450	959.230	37	597546.5870	1763.950	-2483.990	182.930	182.0
5	358289.800	5973159.790	961.540	17	597546.5870	1762.890	-2484.010	182.990	158.0
10	358290.250	5973160.210	959.270	28	597546.5870	1761.740	-2484.040	183.090	166.0

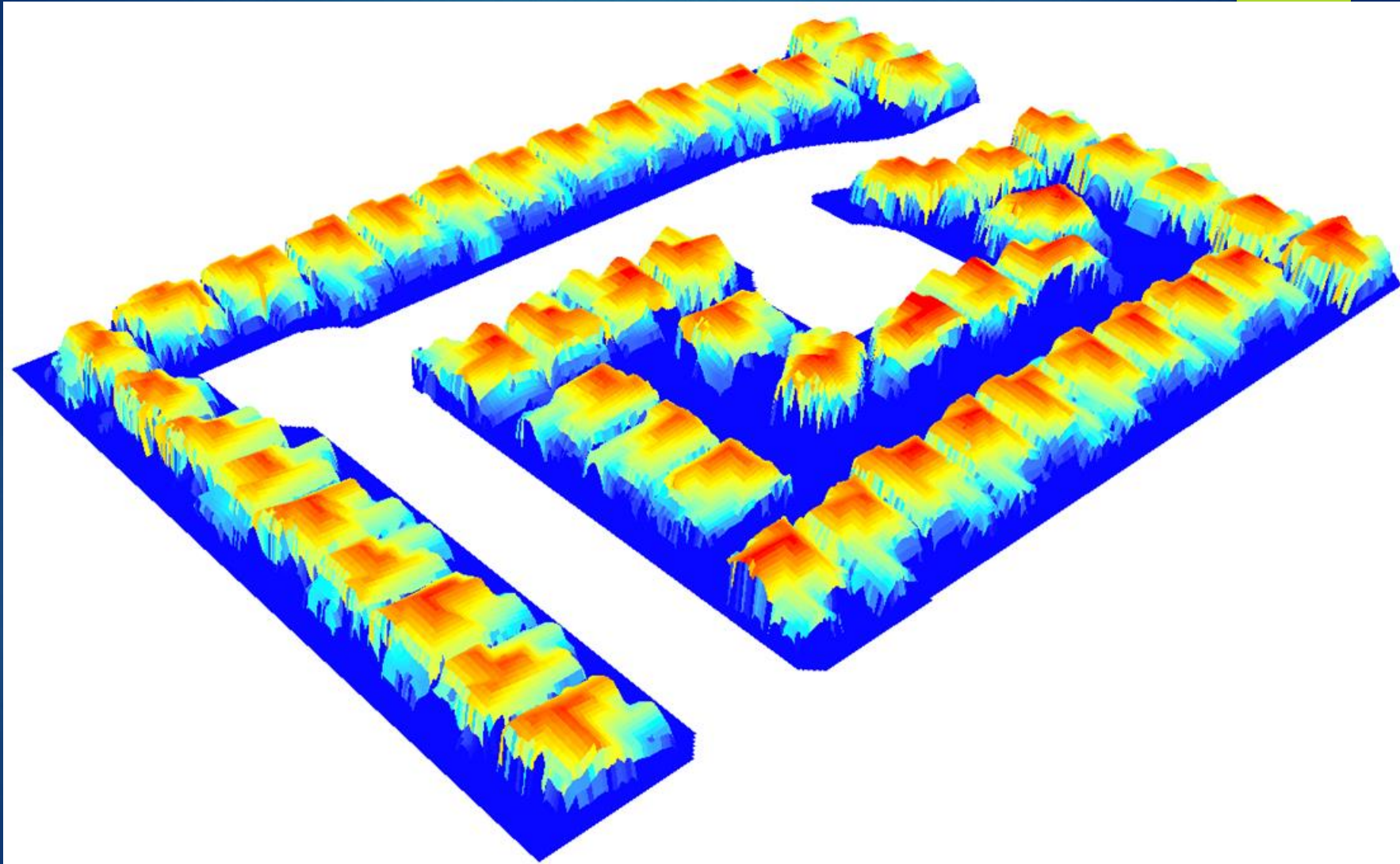
ASPRS standard classes for point data record formats 6-10 in LAS 1.4.

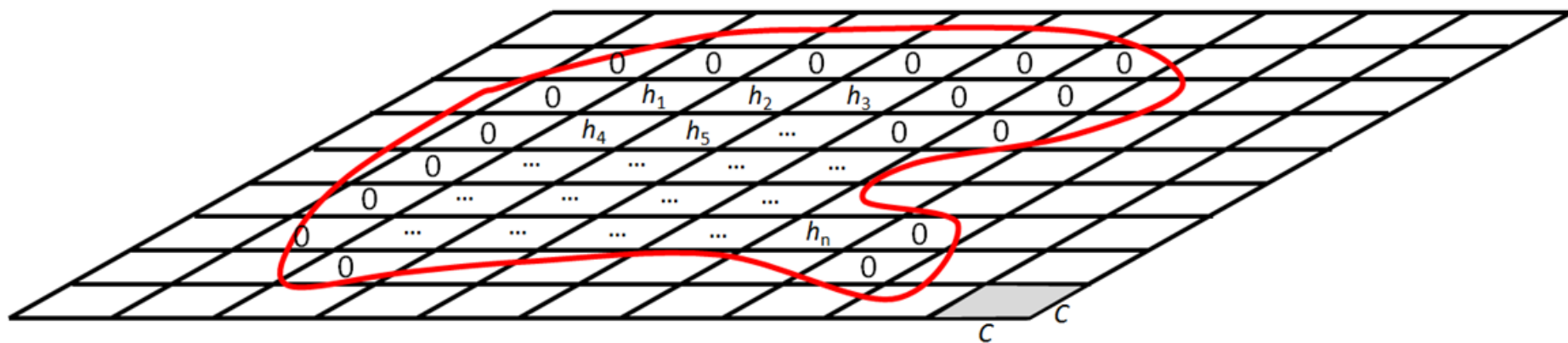
Classification Value	Meaning
0	Created, never classified
1	Unclassified
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Reserved
9	Water
10	Rail
11	Road Surface
12	Reserved
13	Wire – Guard (Shield)
14	Wire – Conductor (Phase)
15	Transmission Tower
16	Wire – Structure Connector (e.g. Insulator)
17	Bridge Deck
18	Nigh Noise
19-63	Reserved
64-255	User definable

LiDAR data sources:

- (1) Open Topography (<http://www.opentopography.org>)
- (2) USGS Earth Explorer (<http://earthexplorer.usgs.gov>)
- (3) United States Interagency Elevation Inventory
(<https://coast.noaa.gov/inventory/>)
- (4) NOAA Digital Coast (<https://www.coast.noaa.gov/dataviewer/#>)
- (5) Wikipedia LiDAR
[https://en.wikipedia.org/wiki/National_Lidar_Dataset_\(United_States\)](https://en.wikipedia.org/wiki/National_Lidar_Dataset_(United_States))
- (6) LiDAR Online (<http://www.lidar-online.com>)
- (7) National Ecological Observatory Network – NEON
(<http://www.neonscience.org/data-resources/get-data/airborne-data>)
- (8) LiDAR Data for Northern Spain
(http://b5m.gipuzkoa.net/url5000/en/G_22485/PUBLI&consulta=HAZLIDAR)
- (9) LiDAR Data for the United Kingdom
(http://catalogue.ceda.ac.uk/list/?return_obj=obj&id=8049,8042,8051,8053)









Zonal Statistics as Table

Input raster or feature zone data

parcels



Zone field

FID

Input value raster

bldg_heights.tif



Output table

H:\Book\Chapter2\Project2-1\Zonal_Statistics



☒ Ignore NoData in calculations (optional)

Statistics type (optional)

ALL

Zonal Statistics as Table

Summarizes the values of a raster within the zones of another dataset and reports the results to a table.

OK

Cancel

Environments...

<< Hide Help

Tool Help

Table



Zonal_Statistics



	Rowid	FID	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	BLDG_VOLUME
▶	1	0	1430	357.5	0	10.114115	10.114115	4.269443	3.852909	6105.30312	1526.326
	2	1	1497	374.25	0	10.165668	10.165668	4.213391	3.698037	6307.445782	1576.861
	3	2	1456	364	0	10.785145	10.785145	4.466122	3.907755	6502.67432	1625.669
	4	3	1845	461.25	0	11.500671	11.500671	3.858065	4.171799	7118.12915	1779.532
	5	4	1439	359.75	0	9.920364	9.920364	3.589593	3.829357	5165.424841	1291.356
	6	5	1485	371.25	0	10.694481	10.694481	4.82669	3.613788	7167.634064	1791.909
	7	6	1563	390.75	0	9.974758	9.974758	3.891149	3.598547	6081.866226	1520.467
	8	7	1512	378	0	10.470276	10.470276	4.682991	3.779658	7080.682598	1770.171
	9	8	1460	365	0	10.02475	10.02475	4.47508	3.512831	6533.616856	1633.404
	10	9	1512	378	0	10.4016	10.4016	4.700264	3.818521	7106.79916	1776.7
	11	10	1512	378	0	9.976505	9.976505	4.510839	3.595289	6820.388119	1705.097
	12	11	1484	371	0	10.291059	10.291059	4.285593	3.759957	6359.820326	1589.955
	13	12	1512	378	0	10.270721	10.270721	4.120725	3.910178	6230.536018	1557.634
	14	13	2095	523.75	0	10.372648	10.372648	3.292861	3.730723	6898.544329	1724.636

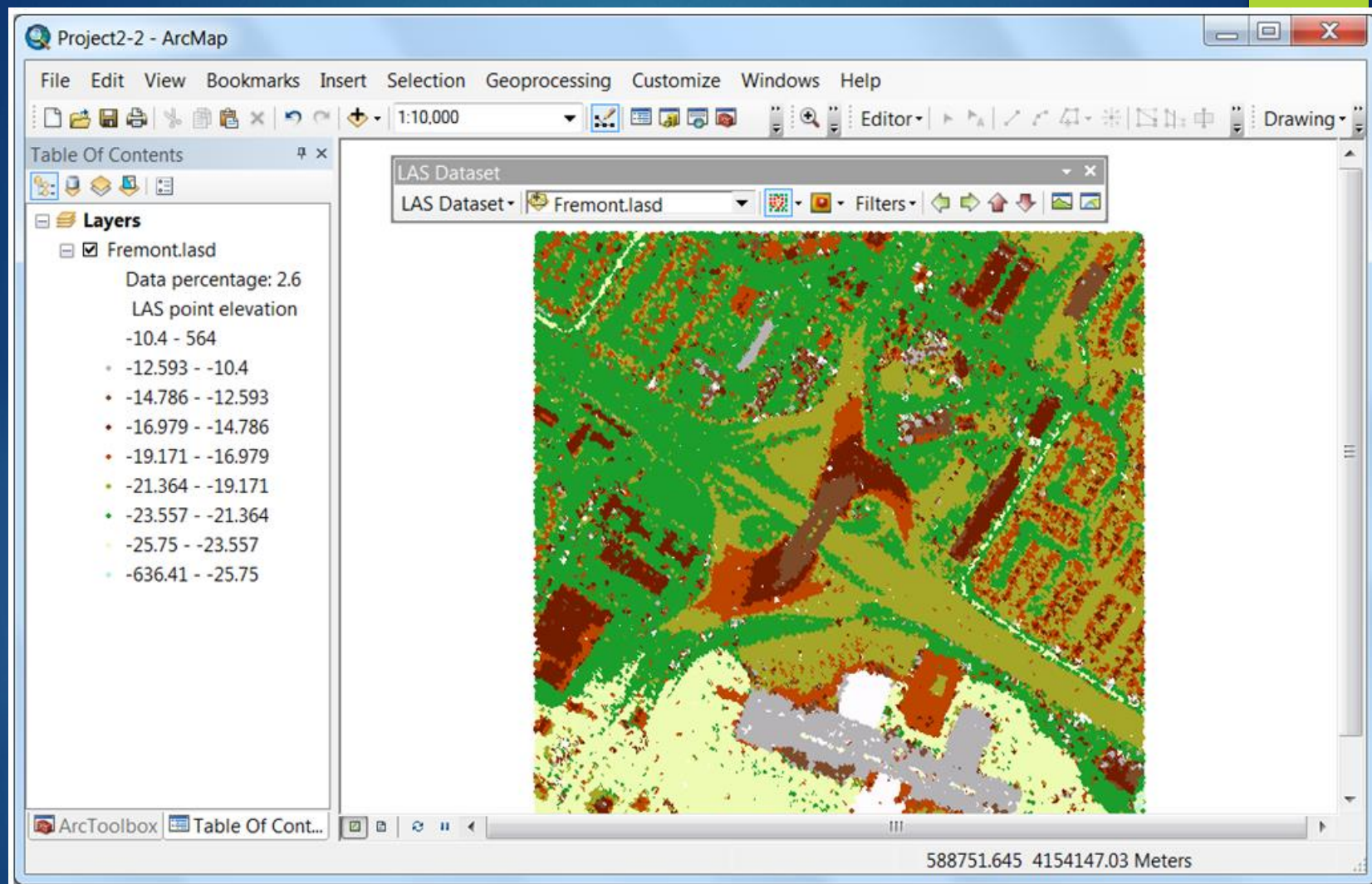


1



(0 out of 52 Selected)

Zonal_Statistics





LAS Dataset Statistics

Input LAS Dataset

Fremont.lasd



☒ Skip Existing (optional)

Output Statistics Report Text File (optional)

H:\Book\Chapter2\Project2-2\FremontLSD.txt



Summary Level (optional)

DATASET

Decimal Separator (optional)

DECIMAL_POINT

Delimiter (optional)

COMMA

LAS Dataset Statistics

Calculates or updates statistics for a LAS dataset and generates an optional statistics report.

OK

Cancel

Environments...

<< Hide Help

Tool Help



Table

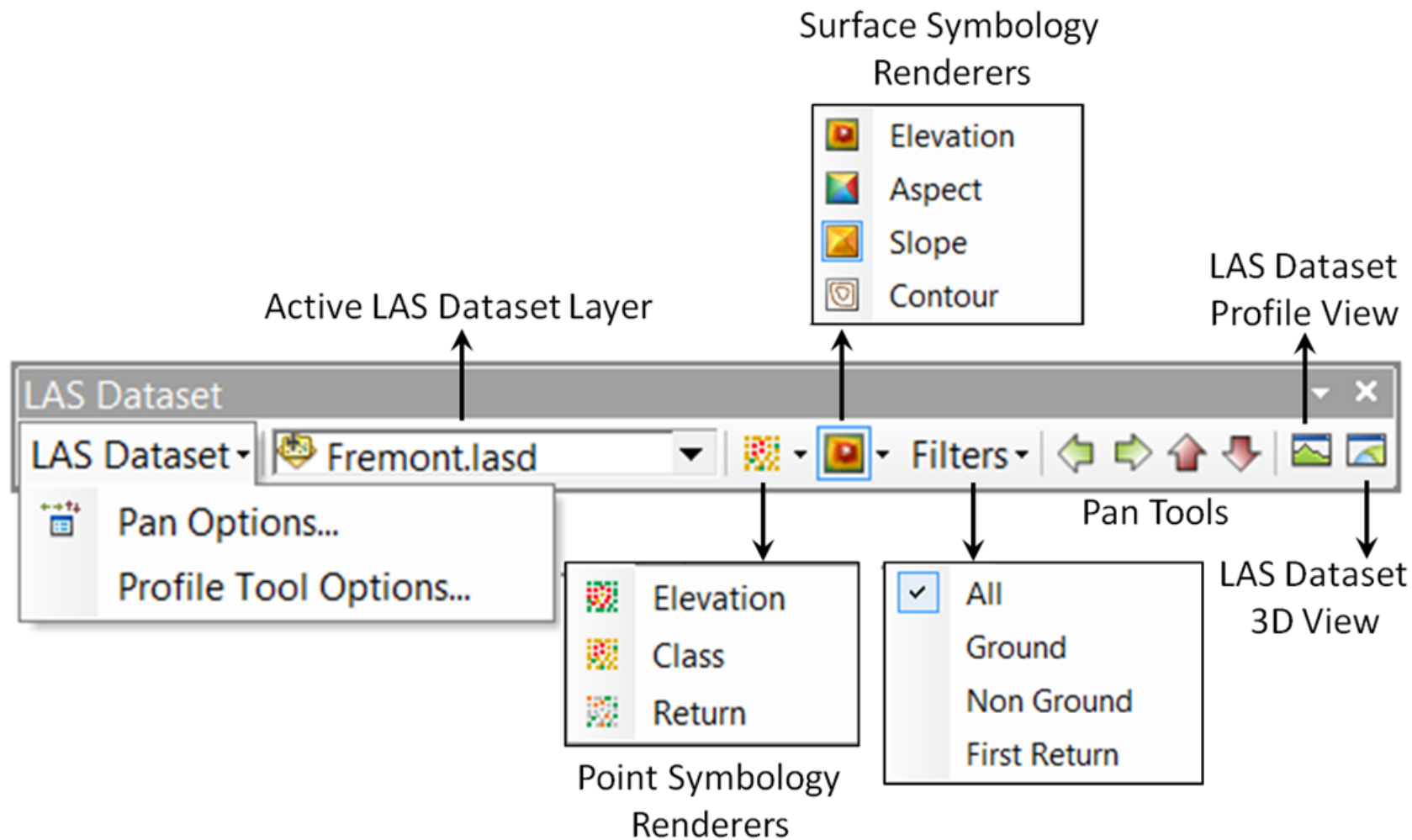
FremontLSD

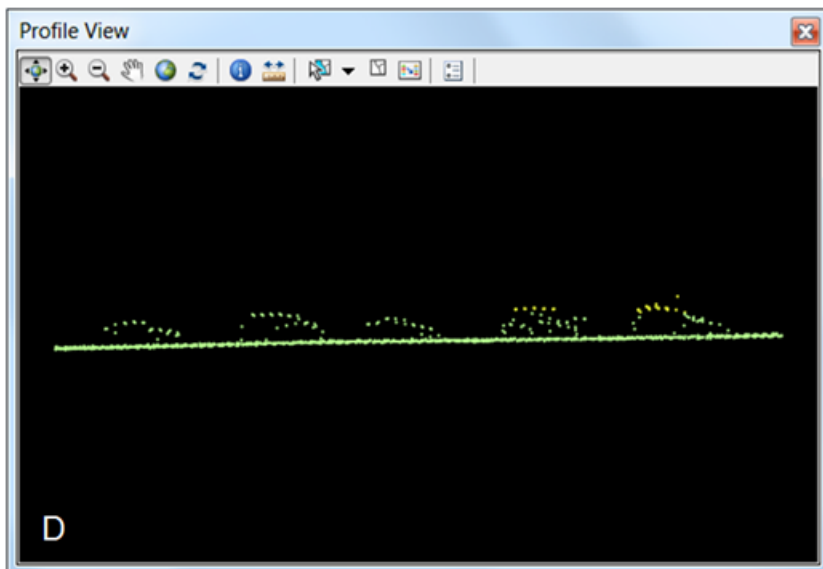
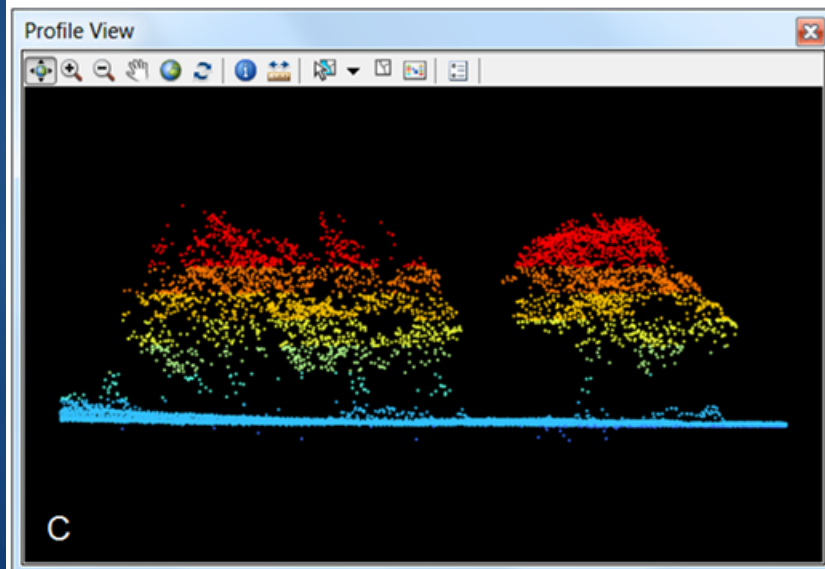
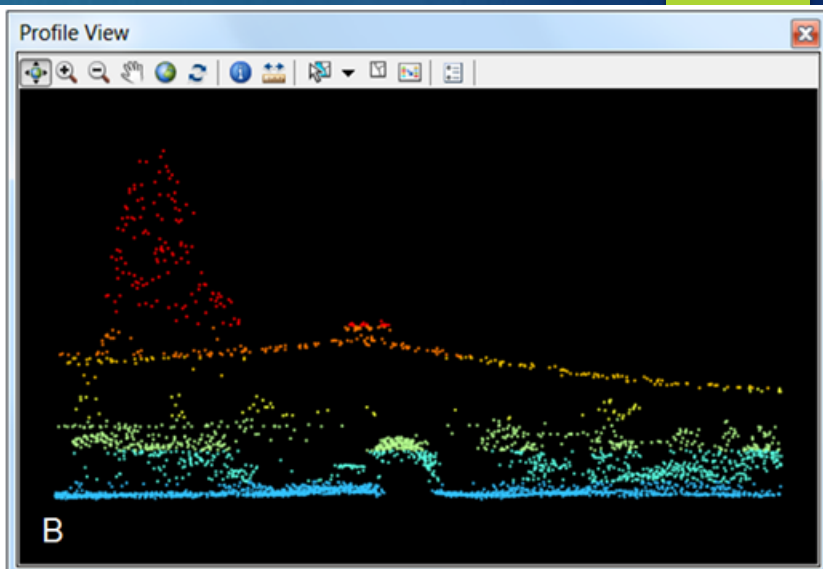
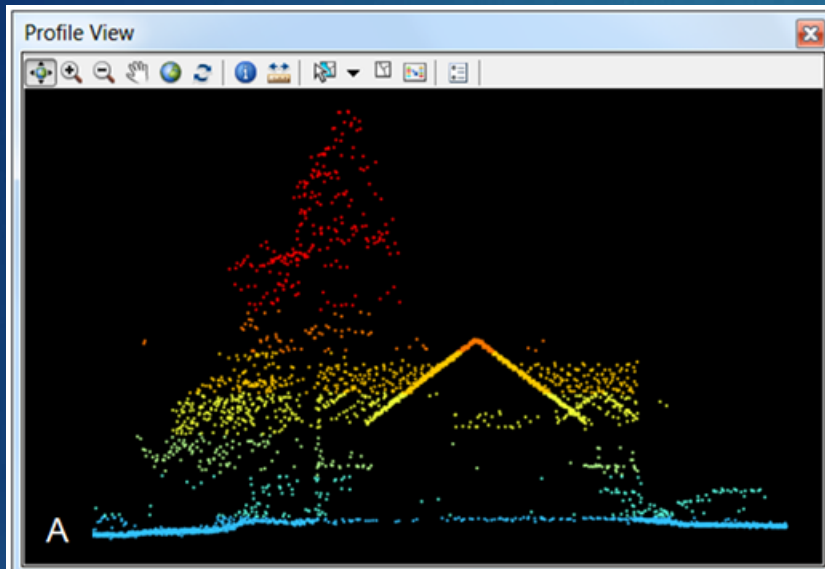
Item	Category	Pt_Cnt	Percent	Z_Min	Z_Max	Intensity_Min	Intensity_Max	Synthetic_Pt_Cnt	Range_Min	Range_Max
Unknown	Returns	5265284	100	-636.41	564	<Null>	<Null>	<Null>	<Null>	<Null>
Last	Returns	5265284	100	-636.41	564	<Null>	<Null>	<Null>	<Null>	<Null>
All	Returns	5265284	100	-636.41	564	<Null>	<Null>	<Null>	<Null>	<Null>
1_Unclassified	ClassCodes	2809746	53.36	-26.5	6	0	284	0	<Null>	<Null>
2_Ground	ClassCodes	2411009	45.79	-26.54	-13.02	0	263	0	<Null>	<Null>
5_High_Vegetation	ClassCodes	9649	0.18	-636.41	564	0	230	0	<Null>	<Null>
7_Low_Point(noise)	ClassCodes	34880	0.66	-211.96	-6.98	0	71	0	<Null>	<Null>
Return_No	Attributes	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	0	0
Intensity	Attributes	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	0	284
Class_Code	Attributes	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	1	7
Scan_Angle	Attributes	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	0	0
User_Data	Attributes	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	0	0
Point_Source	Attributes	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	8	14
Model_Key	ClassFlags	0	0	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
Synthetic	ClassFlags	0	0	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
WithHeld	ClassFlags	0	0	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>

◀ ◀ 0 ▶ ▶

(0 out of 16 Selected)

FremontLSD





3D View

