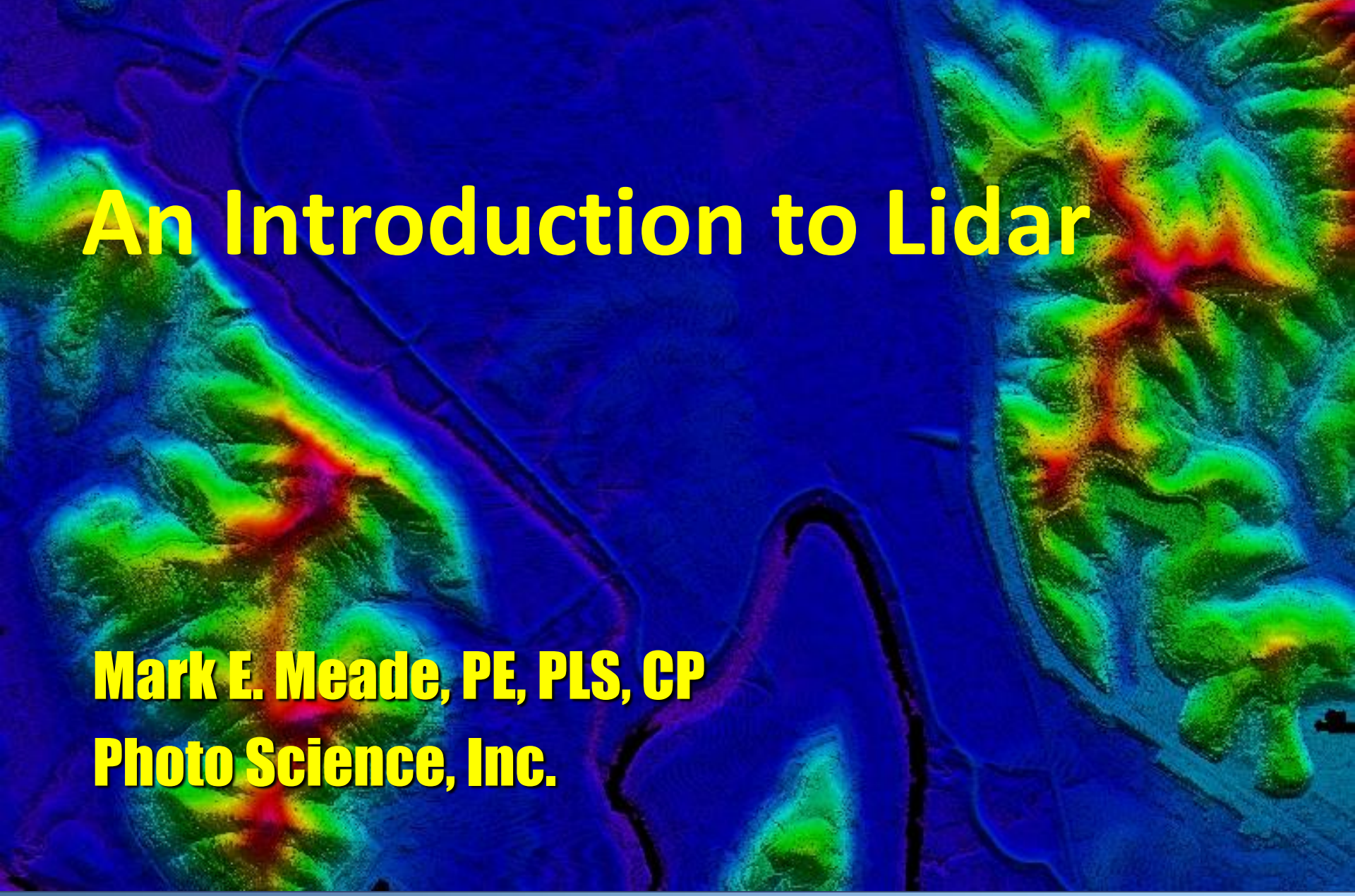

An Introduction to Lidar

Mark E. Meade, PE, PLS, CP
Photo Science, Inc.

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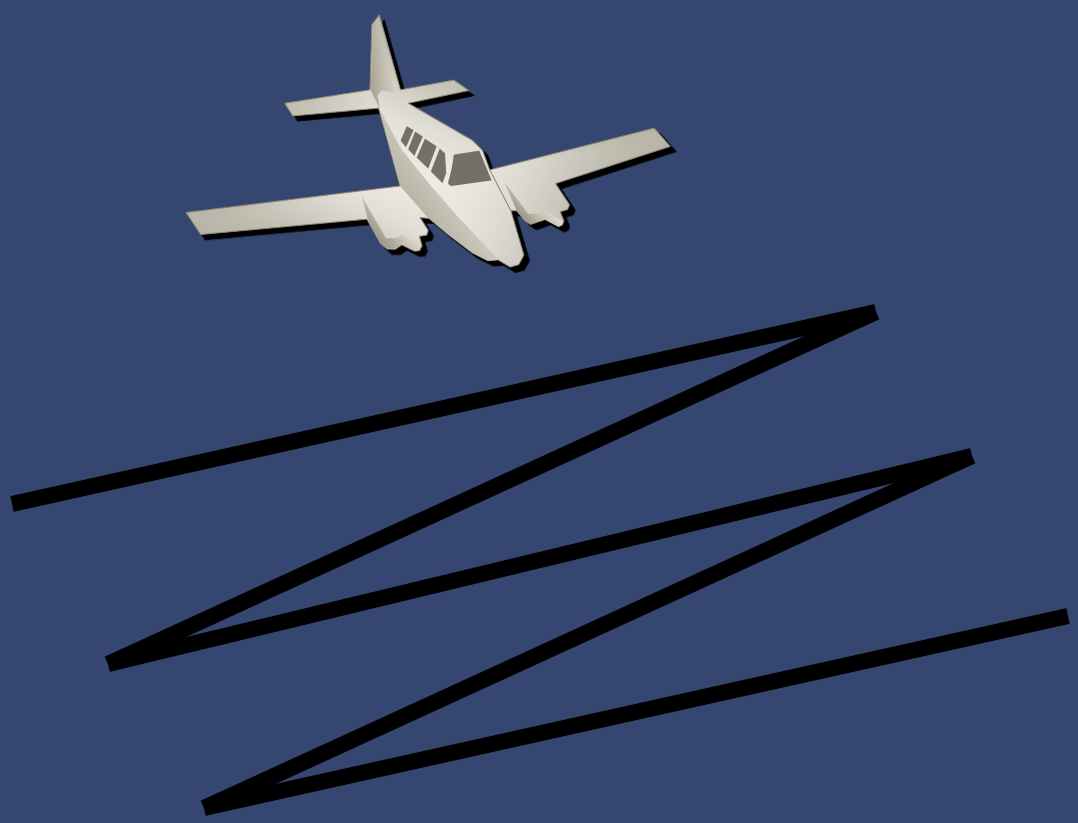
Presentation Outline

- LIDAR Data Capture
  - Advantages of Lidar
  - Technology Basics
  - Intensity and Multiple Returns
  - Lidar Accuracy

Lidar Data Acquisition



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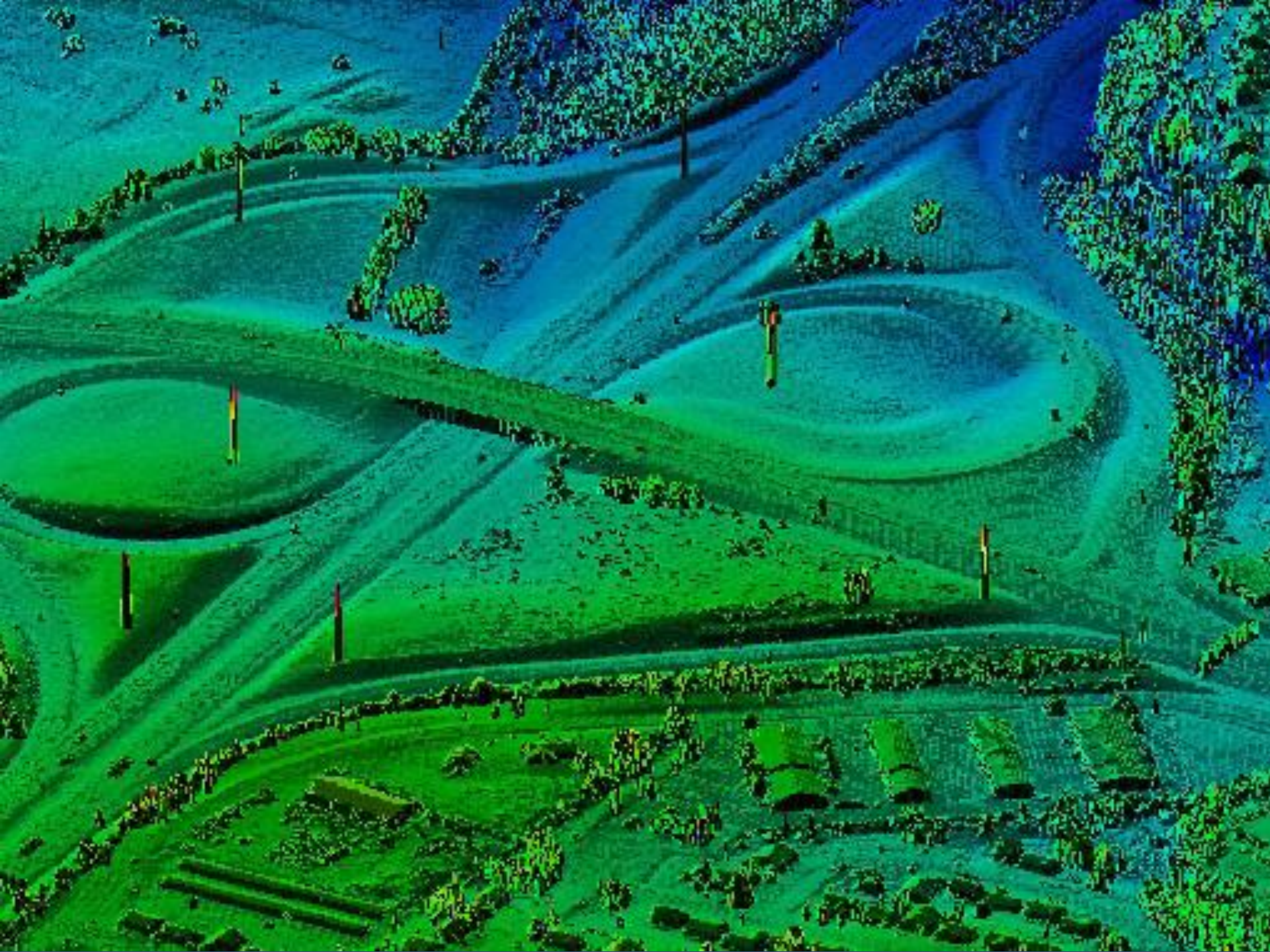

Advantages of LiDAR Technology

- Provides a highly accurate means of elevation model collection for 1’ or 2’ contours
- Acquisition can take place day or night… shadows that are problematic in mountainous areas are not an issue with LiDAR
- Unlike photography, acquisition can take place below cloud cover… cloud shadows no issue
- Very cost effective for larger projects
- Does not provide break lines, nor is it imagery

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Why is This Technology Exciting

Time to Collect 1 Million Points

- Conventional Surveying: 15.5 years
- Photogrammetry: 1.5 years
- Lidar: 6.7 seconds @ 150 kHz

Costs can be significantly less for the right projects…

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Aircraft Requirements

- Flying heights from 3,000 to 6,000 feet
- Speeds ranging from 90 to 130 knots
- Ability to carry equipment, personnel, and full fuel load

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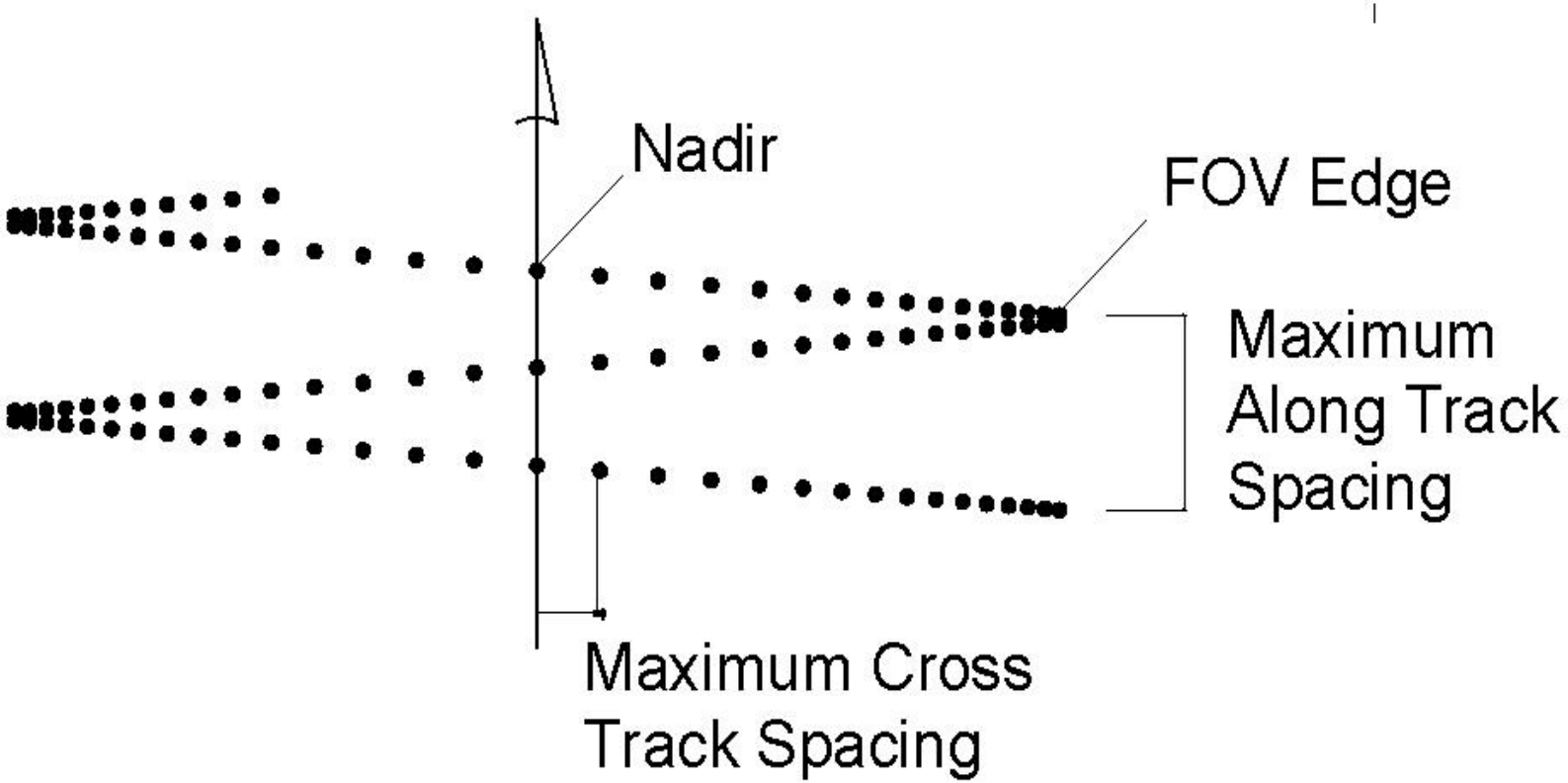
Point Spacing in Lidar



What it is not…

- Photography
  - We can shade the elevation and intensity data to create “imagery”
- Doesn’t capture breaklines
- Doesn’t capture planimetric features
  - Advances in software may allow automatic feature extraction soon

Shading by Elevation

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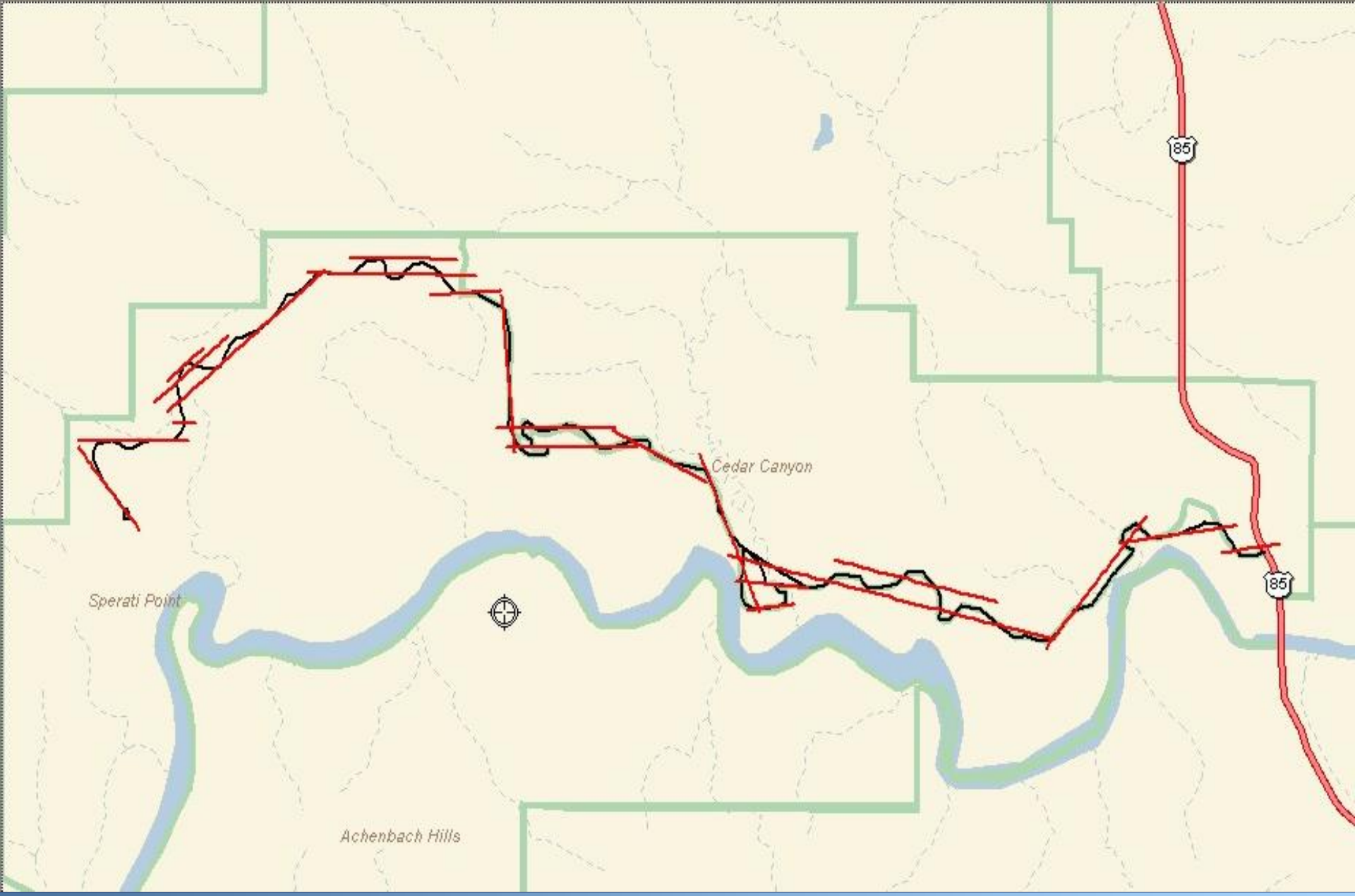

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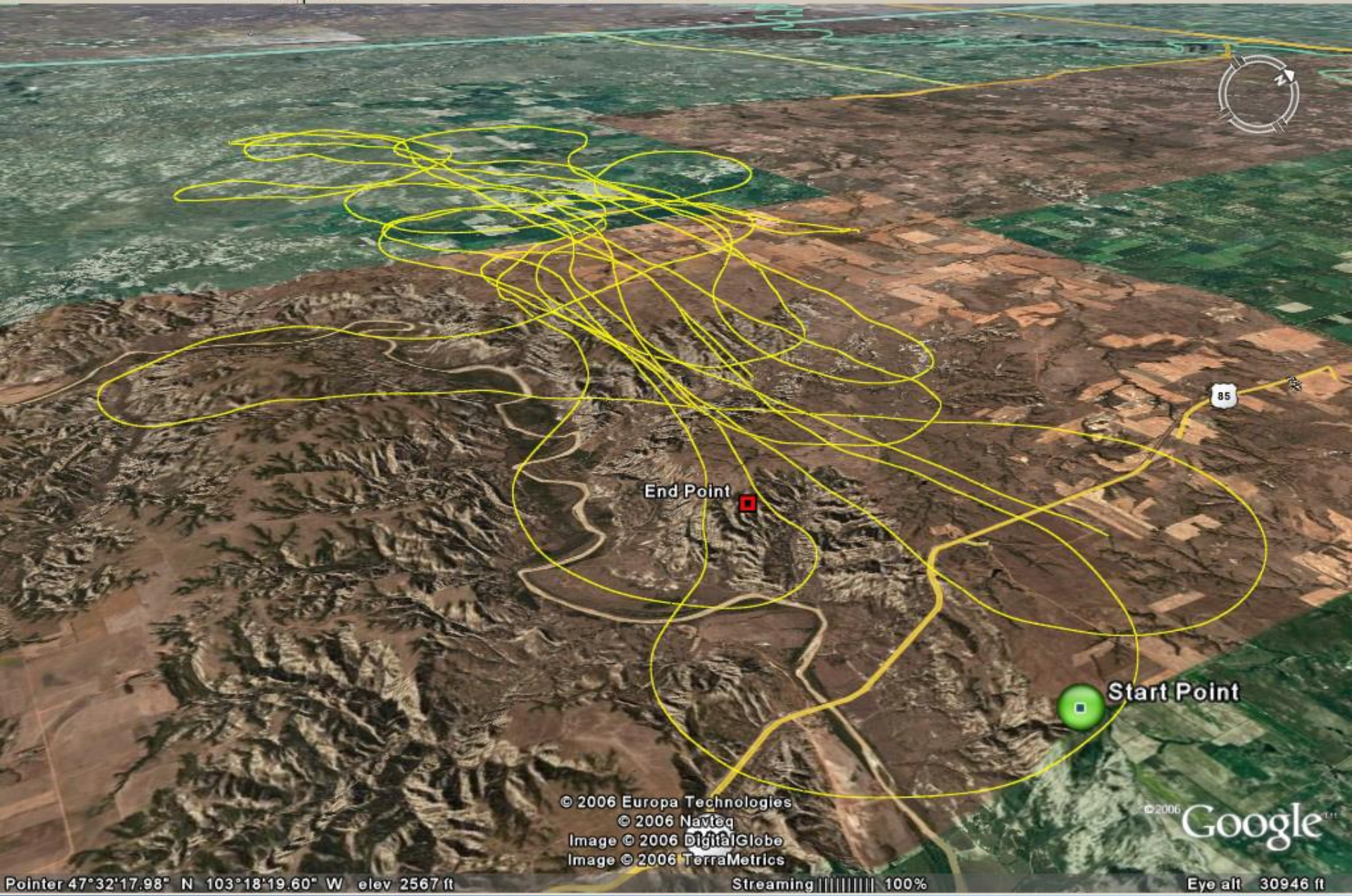

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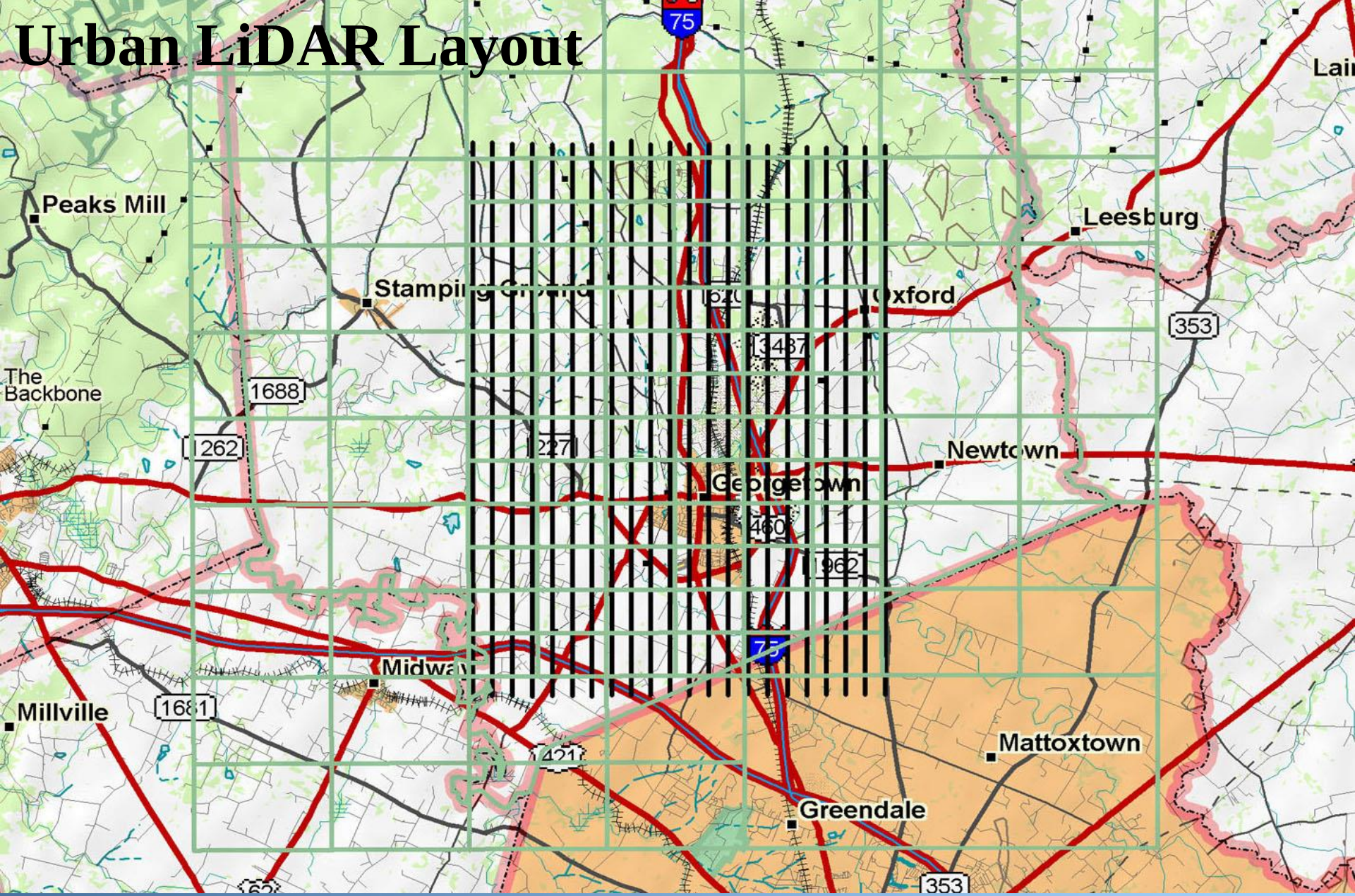
Urban LiDAR Layout



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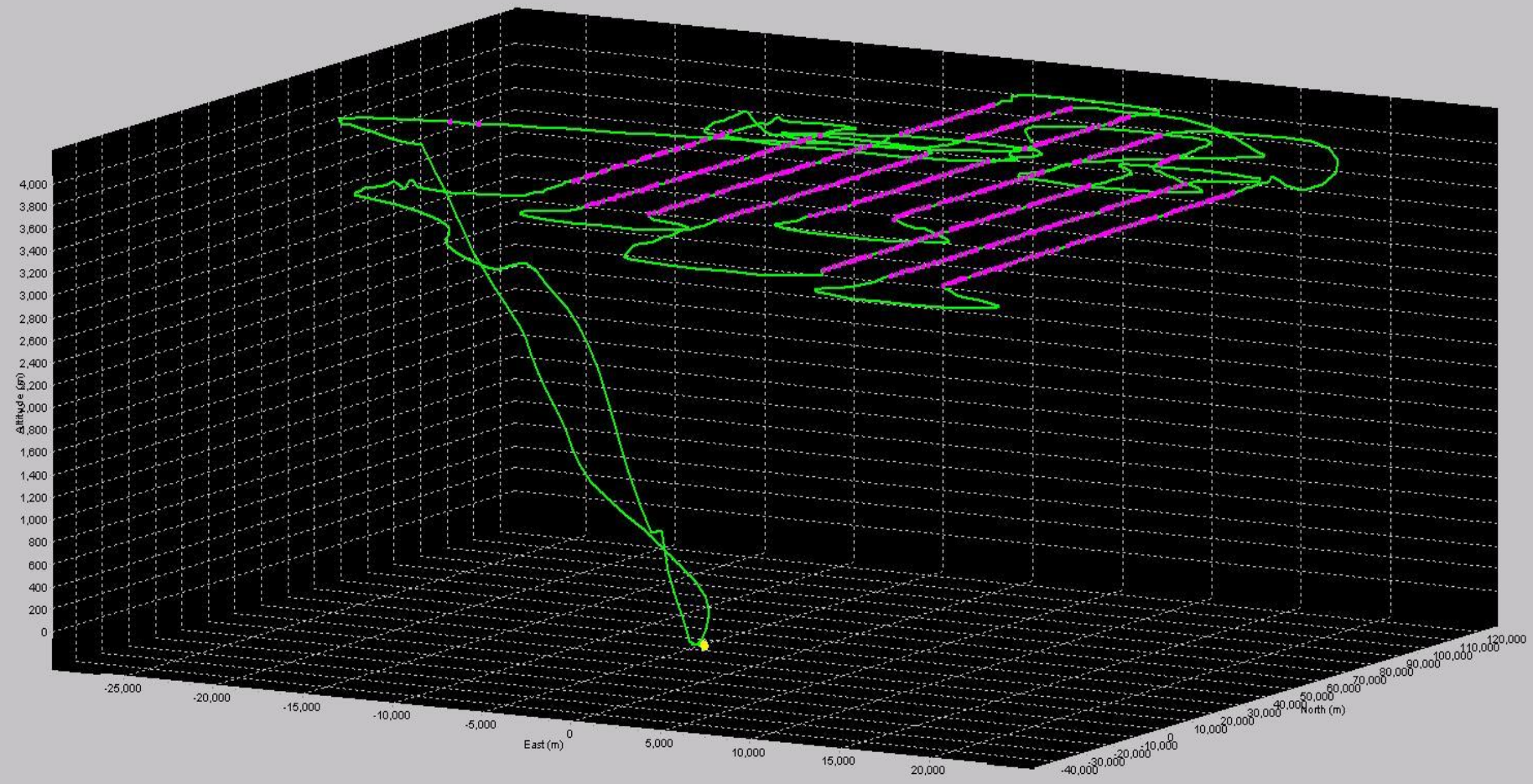
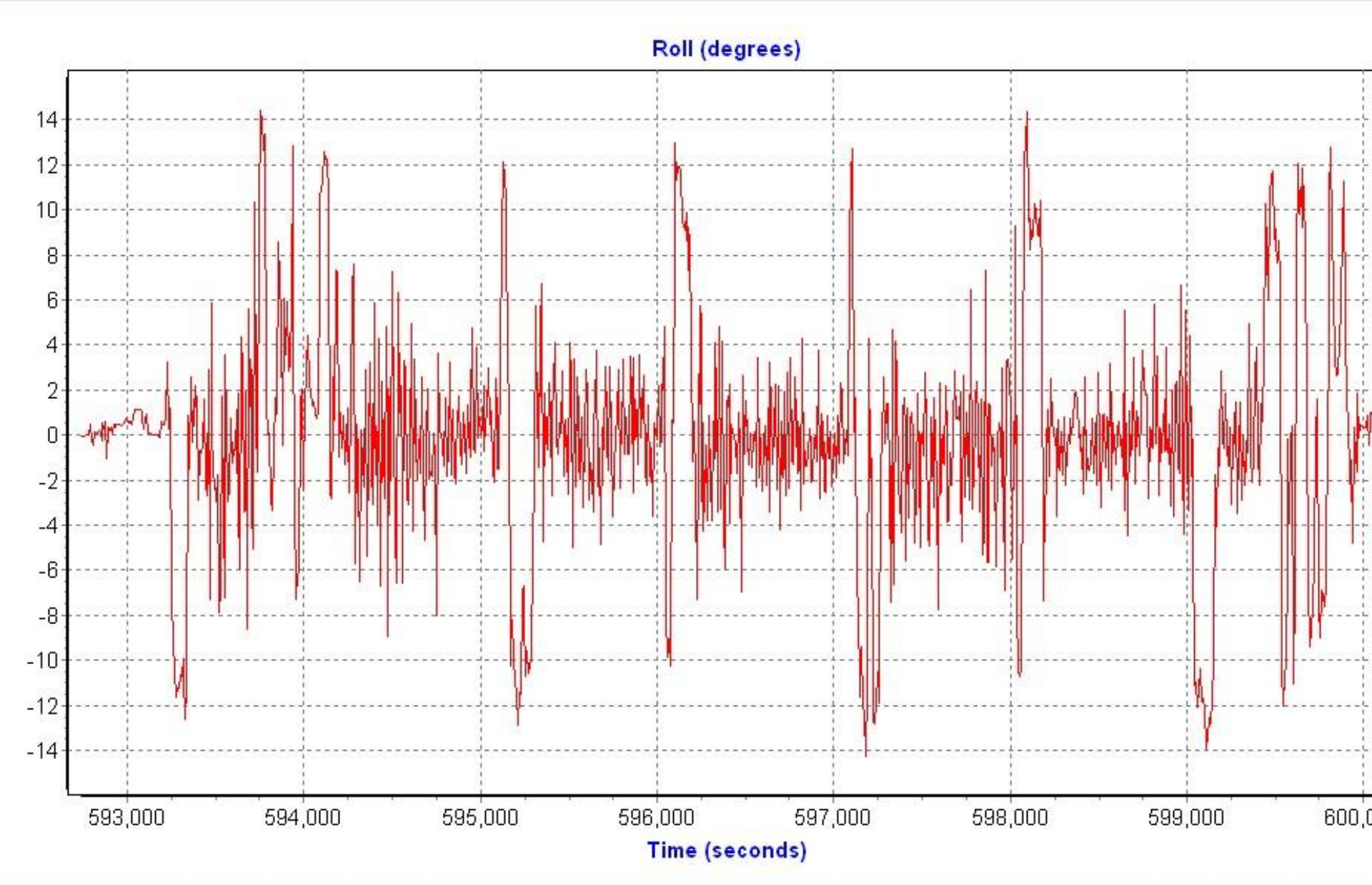

Altitude (m)
4,000
3,800
3,600
3,400
3,200
3,000
2,800
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
East (m)
-25,000
-20,000
-15,000
-10,000
-5,000
0
5,000
10,000
15,000
20,000
North (m)
-40,000
-30,000
-20,000
-10,000
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
110,000
120,000



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Veteran's Boulevard… KTC

- 4 mile long, two lane roadway in Bowling Green, Kentucky
- DMC flight at 2,000 feet for breakline and planimetric mapping, and digital orthophotos
- Lidar flight 3,000 AMT, 90 knots, laser rate of 42.8 kHz, 20 degree FOV
- Total of 31 QA/QC points
- RMSE 8.7 cm or 0.28 feet

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North Dakota Lidar… FHWA

- 64 Lidar flight line miles
- 3 Sites
- Teddy Roosevelt National Park and Des Lacs National Wildlife Refuge
- All surveys and QA/QC points provided by FHWA
- 10 QA/QC points
- RMSE of 4.3 cm or 0.14 feet

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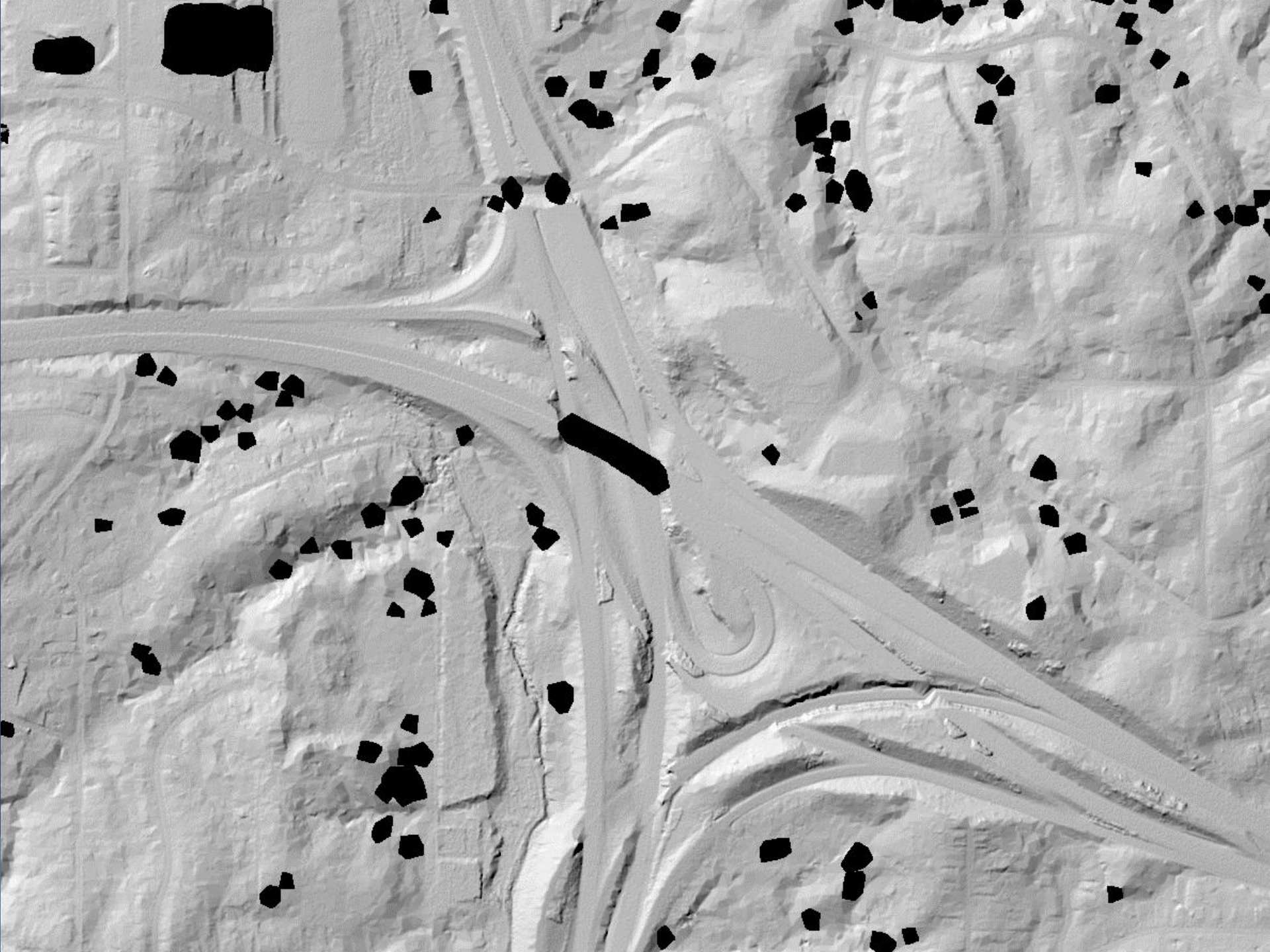
Issues with LIDAR Data

- LIDAR is indiscriminate… it places elevation points on everything. This includes cars, houses, trees, etc.
- LIDAR only places mass points, or random xyz points. It does NOT pick up breaklines, or lines of abrupt change in the ground elevation
- LIDAR is NOT imagery. LIDAR data can be shaded, however, to offer a relief image

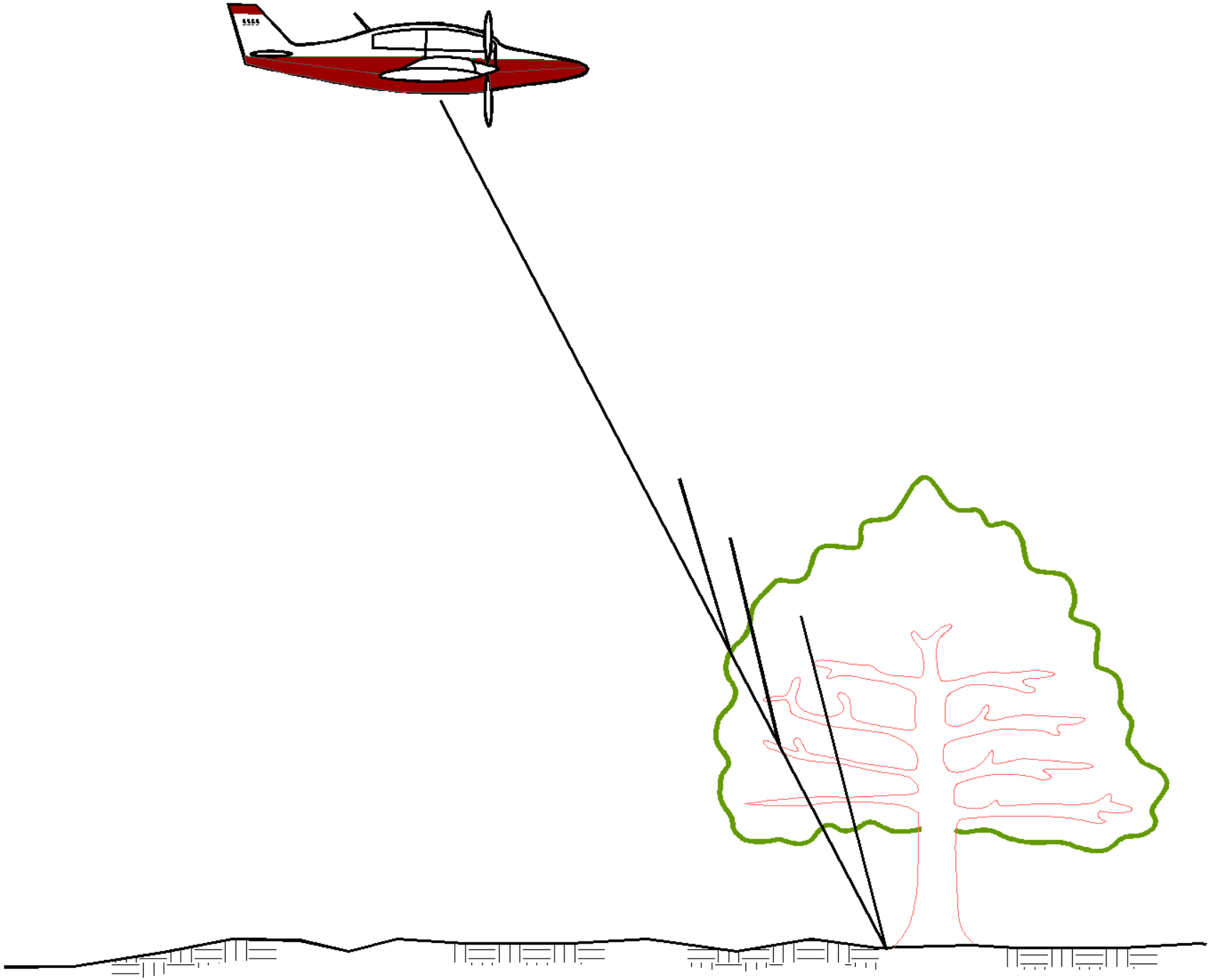
Bare Earth Model

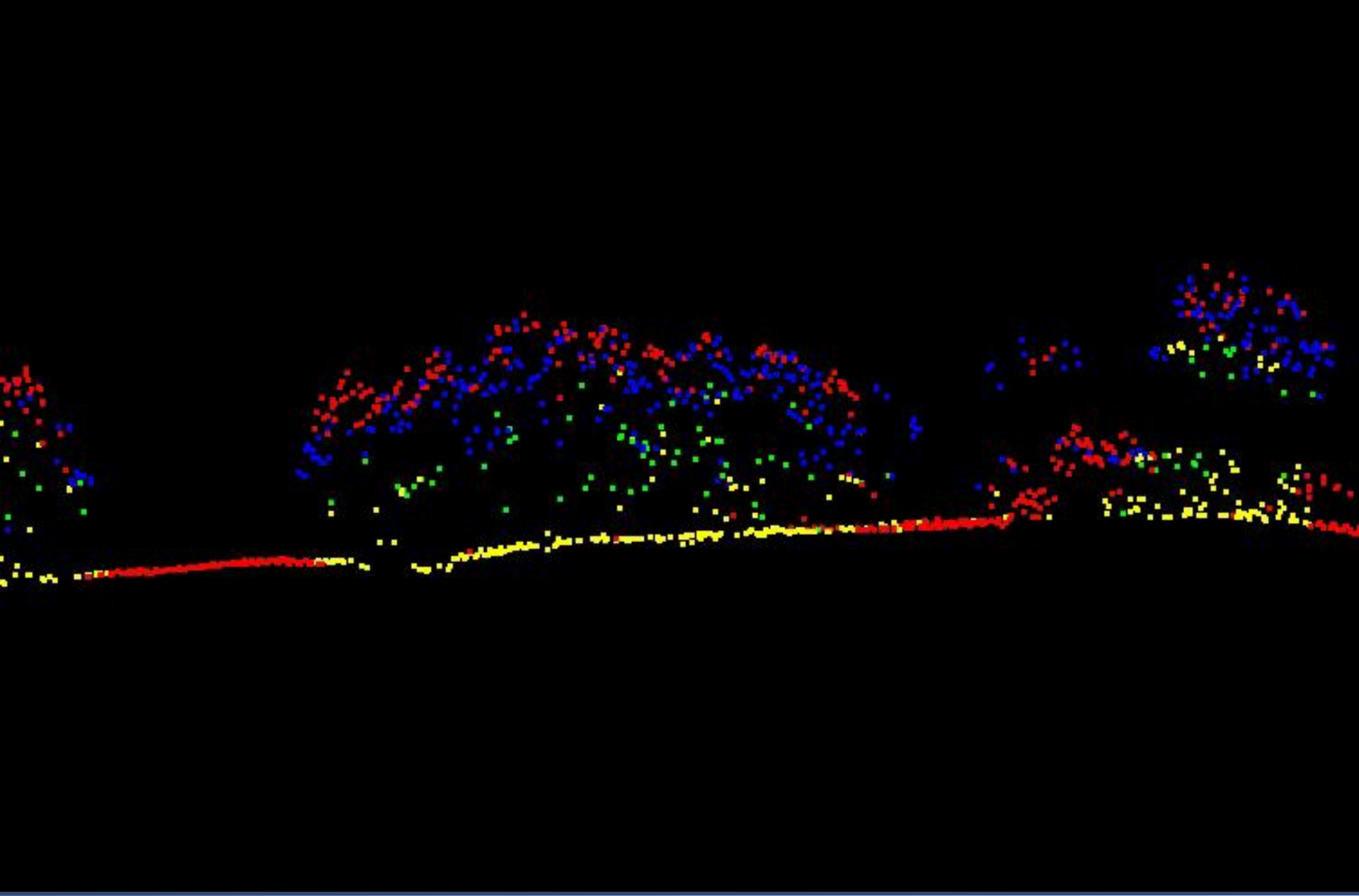
- Significant editing must be employed to create a “Bare Earth Model” which models the natural ground
- Some automated procedures may be used. Imagery backdrop may be necessary
- The 80/20 rule applies here as well
- In some cases, traditional photogrammetry may be necessary to add breaklines



Intensity and Multiple Returns

- Most units today have the ability to measure multiple returns and the intensity of the returned signal for each
- This enables specialized applications using the LIDAR data





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Cincinnati Airport – Aerial Photo

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Cincinnati Airport – Intensity Plot

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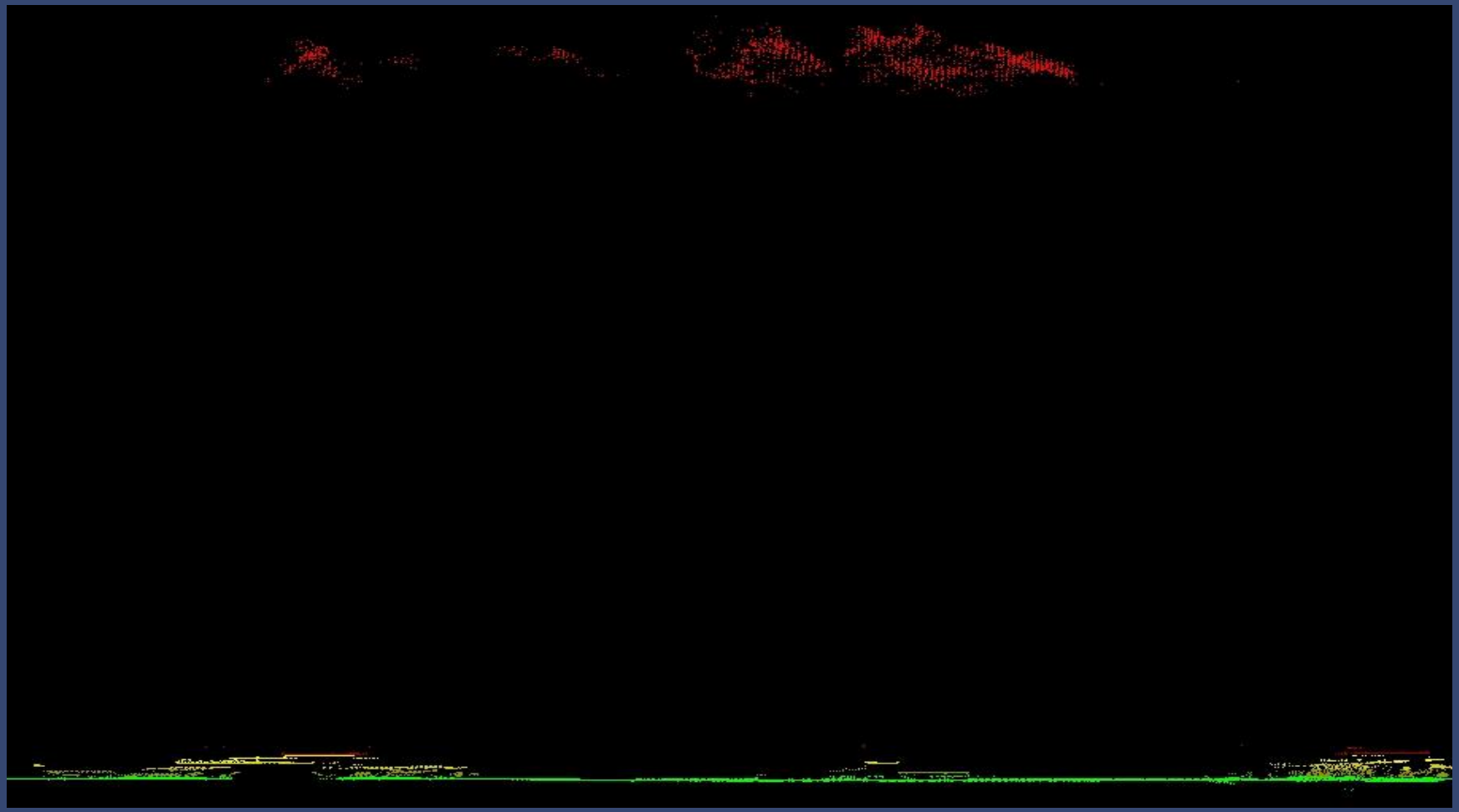
Lidar Returns and Cloud Cover



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LIDAR Applications

- LIDAR has significant fixed cost… but can be very cost effective for large projects
- Appropriate for a wide range of projects including forestry, corridor studies, obstruction mapping, flood studies, city/county mapping, and transportation projects
- Required accuracy must be carefully evaluated

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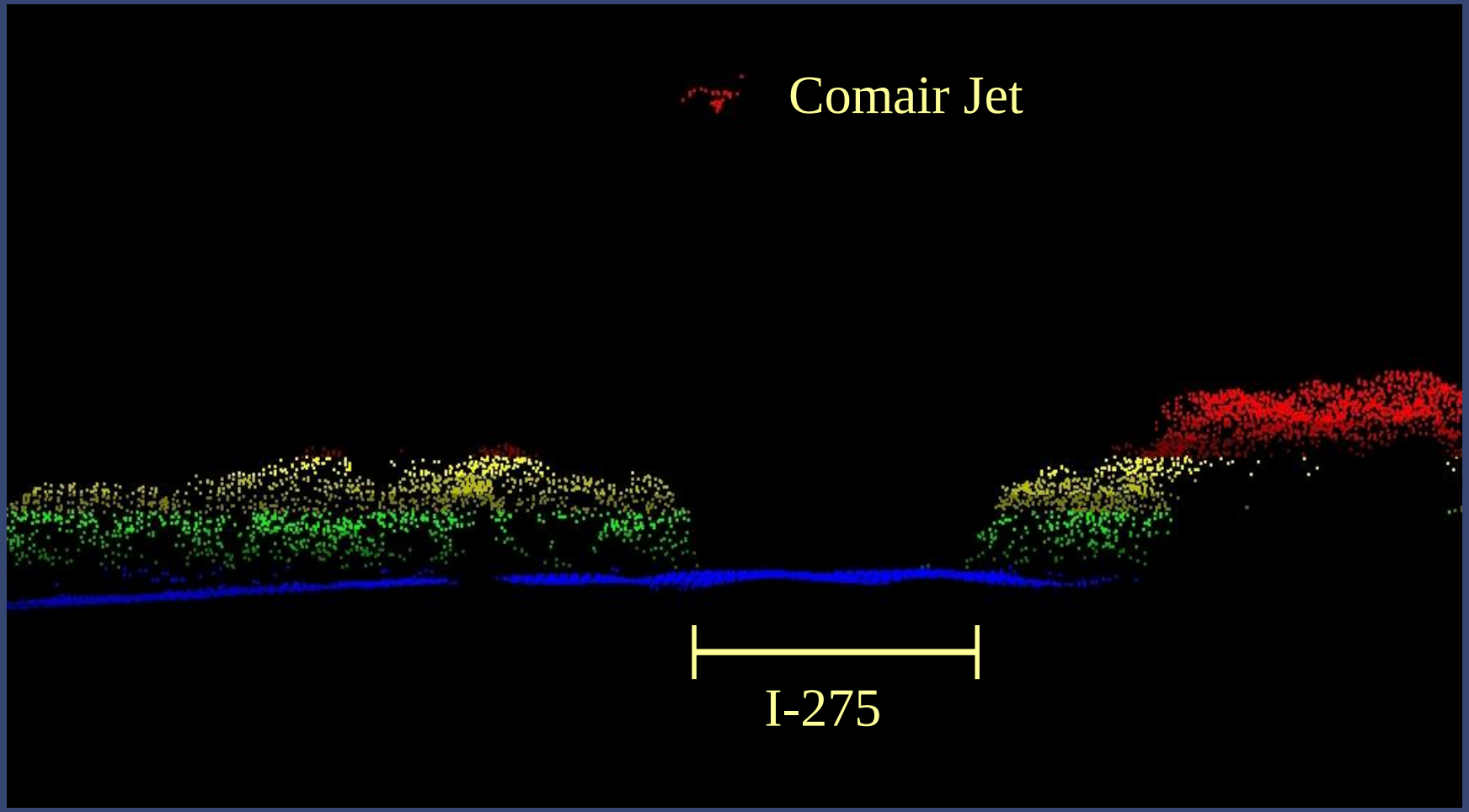
Value of “Noise” in the Data



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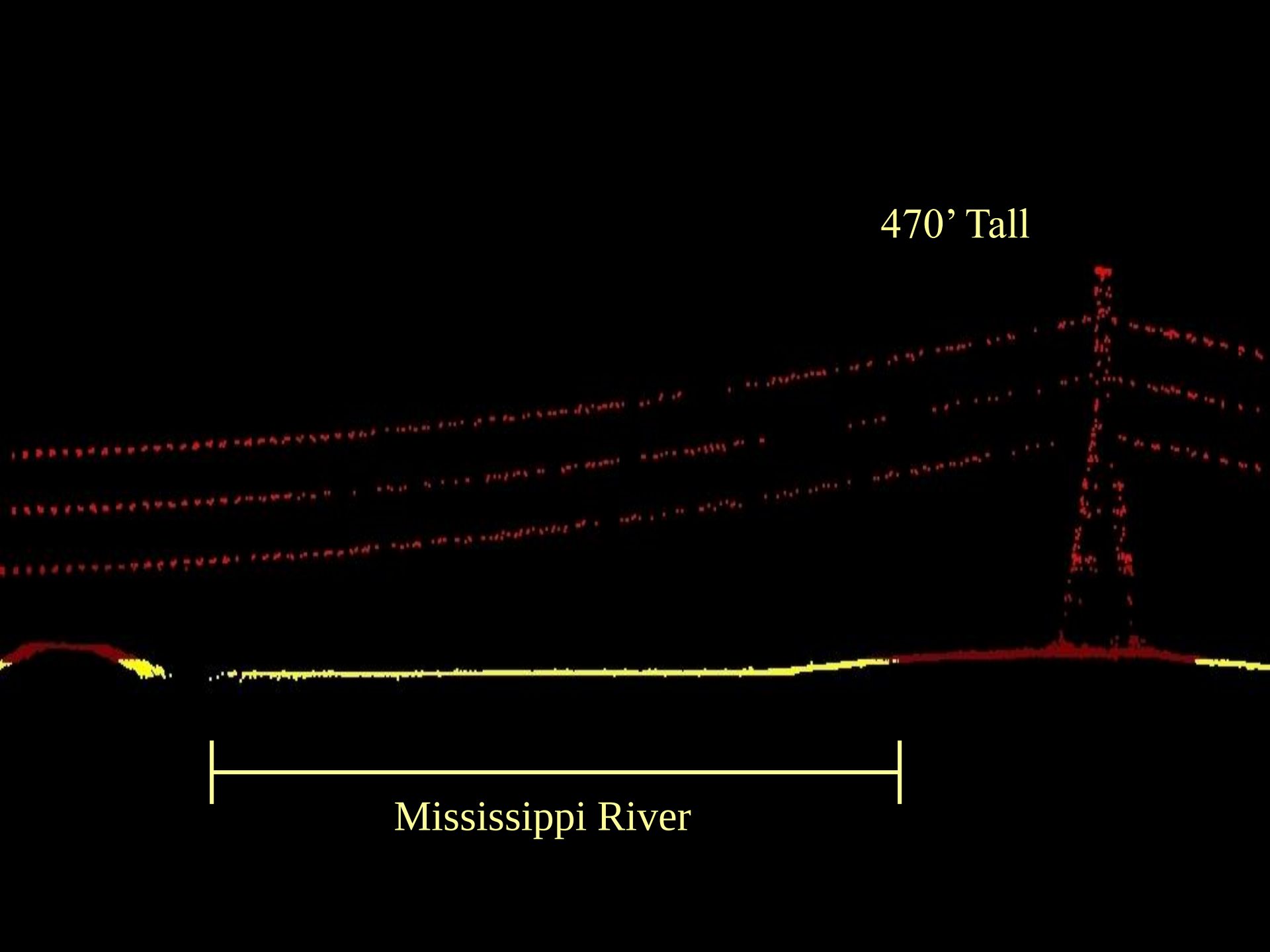
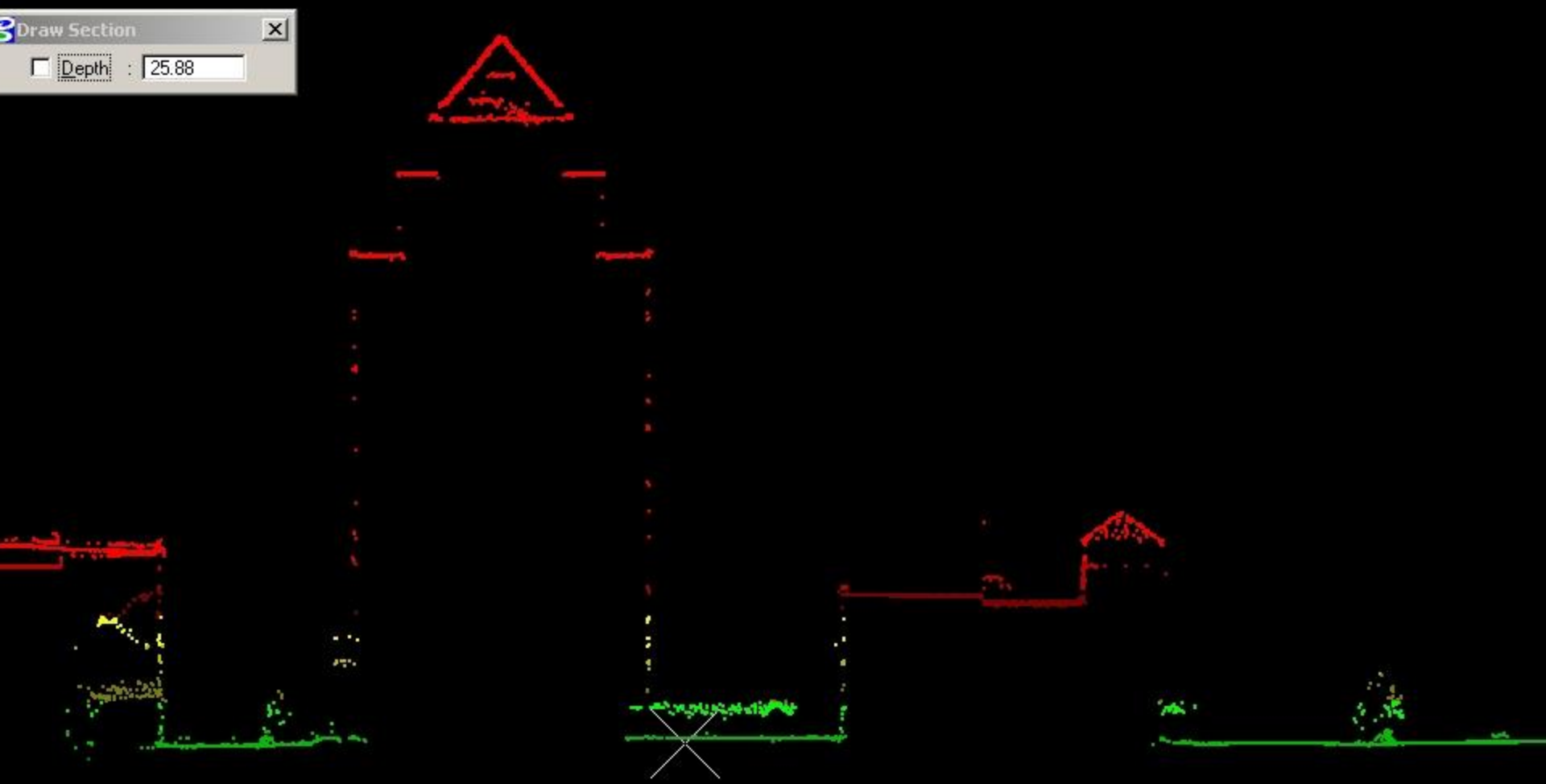

470’ Tall
Mississippi River

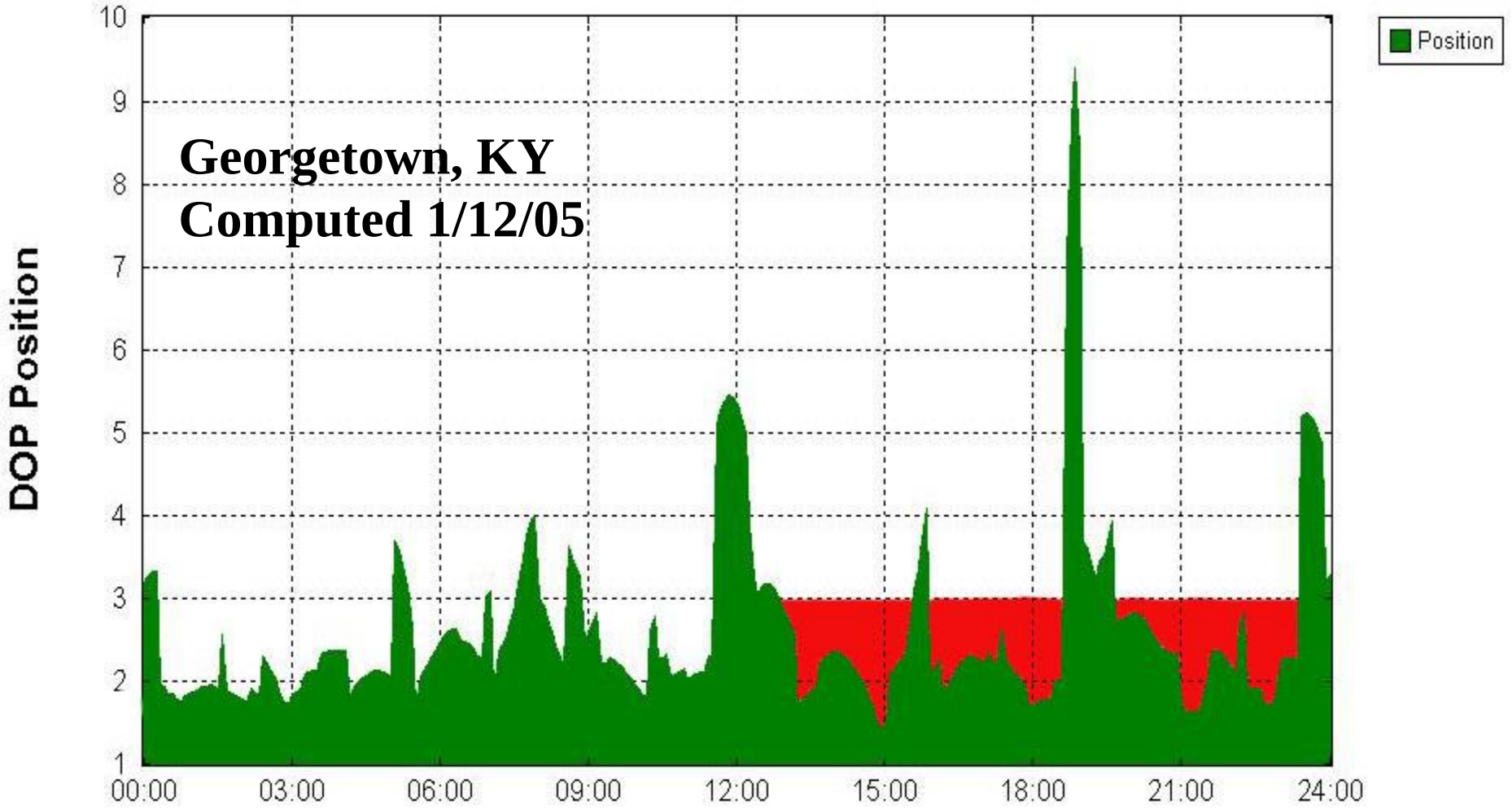
Window 1



LiDAR Accuracy

- Quality of the hardware and software
- Knowledge of the planners, operators, office staff
- Flying height
- Scan angle (also important for vegetation penetration)
- GPS configuration (PDOP and Number of SVs)
- Distance from base station to aerial platform
- Laser power
- Laser rep rate

DOP Position



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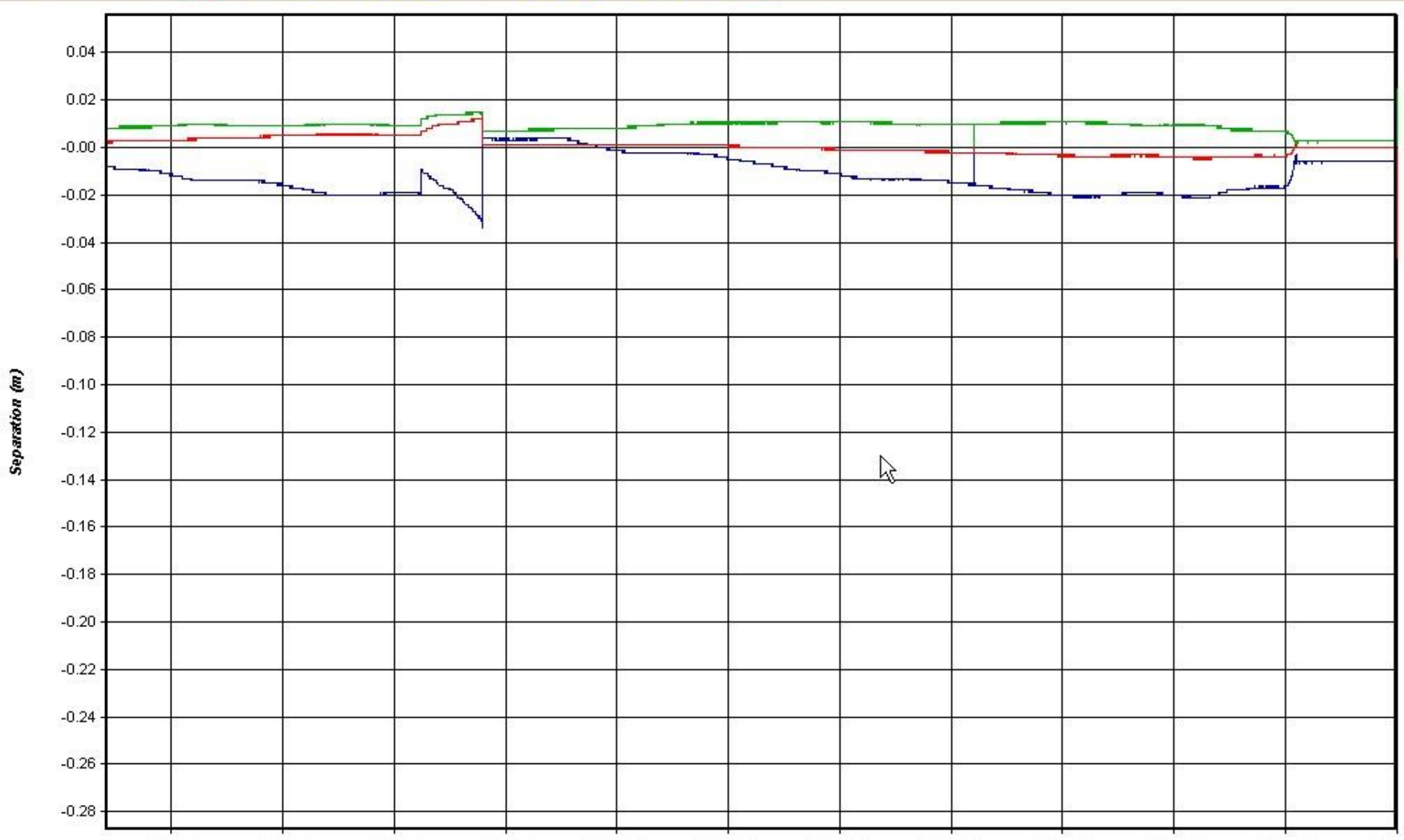
061111b - POSGPS - [061111b [GPS Combined] - Forward/Reverse or Combined Separation Plot]

File View Process Settings Output Tools Window Help



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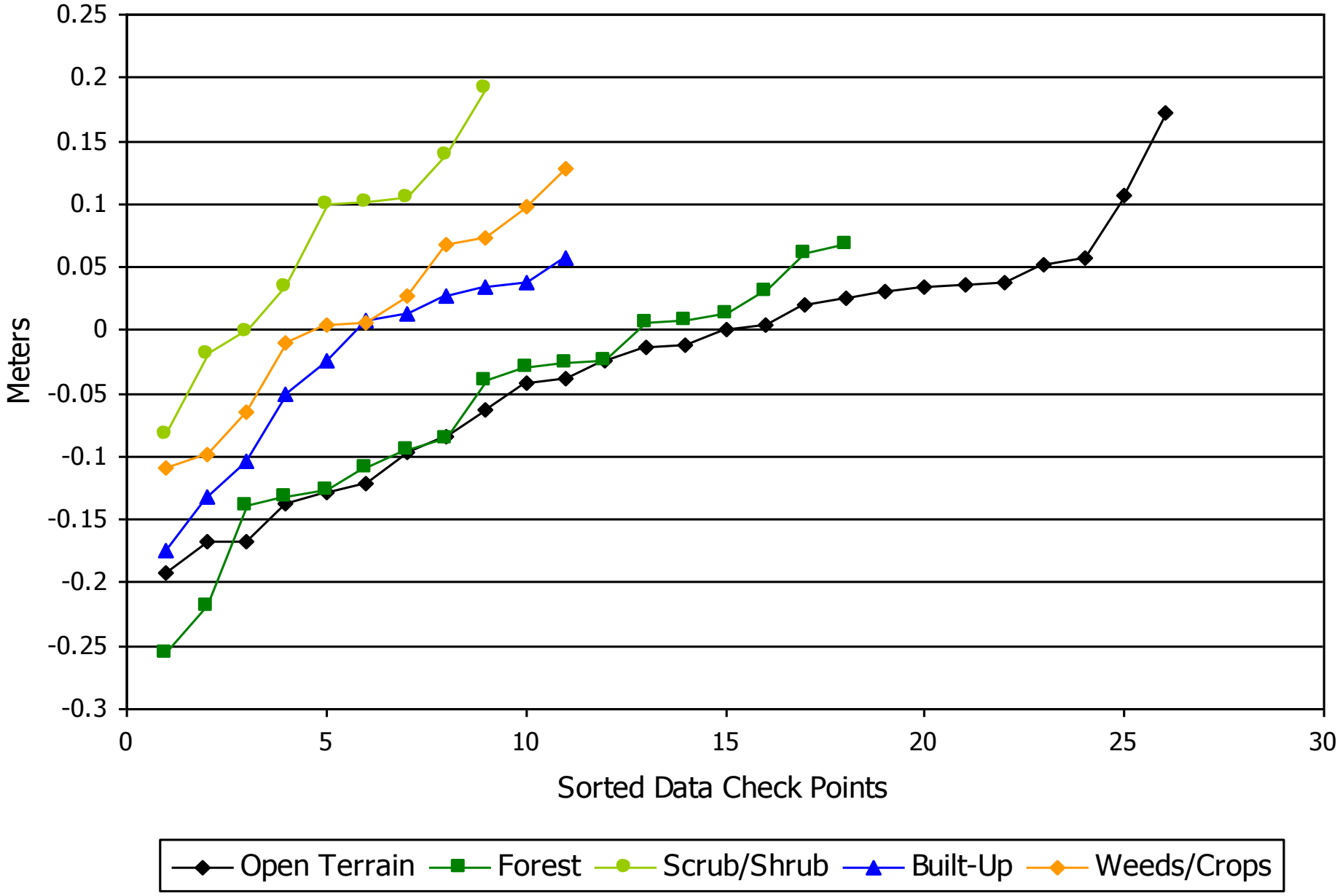
LIDAR Accuracy

- Accuracy of elevation in range of 6 to 30 centimeters (0.20 to 0.98 feet)
- Accuracy of XY position in range of 10 to 46 centimeters (0.33 to 1.51 feet)
- Accuracy depends on pulse rate, flying height, GPS configuration, location of ground stations, and position of the scanner with respect to nadir


0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
Meters
0
5
10
15
20
25
30
Sorted Data Check Points
Open Terrain
Forest
Scrub/Shrub
Built-Up
Weeds/Crops

Microsoft Excel - AEROPLAN_Ver1_27_ALS50-II_temp_060517.xls

File Edit View Insert Format Tools Data Window Help

Type a question for help

Arial 12

Reply with Changes... End Review...

C57

	A	B	C	D	E	S
1	AeroPlan Mission Planning for ALS Airborne Laser Scanners		LEICA GEOSYSTEMS PROPRIETARY			
2	Originator: Roth		do not disclose without written consent of			
3	Filename: AEROPLAN_Ver1_27_ALS50-II_temp_060517.xls		Leica Geosystems			
4			13 Park Drive			
5	***FOR SHAPE / COLOR KEY, SEE BOX AT RIGHT***		Westford, MA 01886			
6			TEL (978) 692-8500 / FAX (978) 692-8510			
7			© 1998-2006			
8	***Scanner Setup***					
9						
10	*Commanded FOV (full angle)*	*degrees*	20.00			
11	Scan FOV (full angle)	radians	0.35			
12	Scan FOV (half angle)	degrees	10.00			
13	Scan FOV (half angle)	radians	0.17			
14	Terrain Elevation AMSL (minimum in survey area)	meters	210.00	688.97	feet	
16	Terrain Elevation AMSL (maximum in survey area)	meters	330.00	1082.66	feet	
18	Nominal Flying Height Above Minimum Terrain Elevation	meters	914.50	3000.29	feet	
20	Nominal Flying Altitude AMSL	meters	1124.50	3689.26	feet	
22	Airspeed	knots	90.00	46.30	meters/sec	151.90 f
24	Range/Intensity Mode (1, 2, 3, 4)		4.00			
25	Max Laser Pulse Rate	Hz	107800.00			
26	Laser Pulse Rate Used	Hz	107800.00	7.89	watts avg	
28	System Controller Firmware (<V2.07, V2.07+)		V2.07+			
29	Laser Power Class (3=3W, 4=4W, LC50, XHR)		LC50			
30	Receiver Aperture Stop (45, 60, 65, 75, LM, ALS50)	degrees	ALS50			
31	Scan Rate	Hz	63.82			
32	Max Scan Rate (ALS50 Phase II only)	Hz	63.82			
37						
38	***Resulting Scan Pattern***					
39						
40	*Full Swath Width (nominal flying height above lowest terrain elevation)*	*meters*	*322.50*	*1058.06*	*feet*	
41	Max Cross Track Spacing (occurs @ nadir)	meters	0.61	2.00	feet	
42	Max Along Track Spacing (occurs @ FOV edge)	meters	0.73	2.38	feet	
43	Cross Track / Along Track Ratio		0.84			
44	Illuminated Footprint Diameter (@ 1.e^2 energy)	meters	0.21	0.70	feet	
45	Point Density (average)	pts/meter^2	7.22	0.67	pts/ft^2	
46	Point Density (@ nadir)	pts/meter^2	4.52			
47	Area / Point (average)	meters^2	0.14	1.49	ft^2	

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Microsoft Excel - AEROPLAN_Ver1_27_ALS50-II_temp_060517.xls

File Edit View Insert Format Tools Data Window Help

Type a question for help

Arial 12

Reply with Changes... End Review...

C85

	A	B	C	D	E	S
80						
81	Roll Allowance (each side of nadir, 1 for roll-stabilized systems)	degrees	1.00			
82	Roll Allowance (each side of nadir)	radians	0.02			
83	Navigation Tolerance (above/below planned elev'n)	meters	50.00	164.04	feet	
84	Swath Width After Roll All, El Nav Tol, Terr Variation	meters	235.83	773.73	feet	
85	Navigation Tolerance (each side of planned line)	meters	50.00	164.04	feet	
86	*Line Spacing (for complete coverage, after roll/nav allowances)*	*meters*	*135.83*	*445.65*	*feet*	
87	*Side Overlap (based on total swath width)*	*percent*	*57.88*			
88	Coverage Rate (based on max line spacing)	km^2 per hr	22.64	8.74	mi^2 per hr	
89						
90	***Resulting Accuracy Estimates (1 sigma)***					
91						
92	Assumed GPS Error	meters	0.05			
93			Nadir	FOV Edge		
94	Estimated Cross-Track Error	meters	0.10	0.10		
95	Estimated Along-Track Error	meters	0.10	0.10		
96	Estimated Height Error	meters	0.05	0.06		
97						
98	Estimated Cross-Track Error	feet	0.33	0.33		
99	Estimated Along-Track Error	feet	0.31	0.32		
100	Estimated Height Error	feet	0.17	0.18		
101						
102	***ALS Data Storage Requirements***					
103						
104	Raw Data - IPAS GPS/IMU	GB/hour	0.10			
105	Raw Data - ALS .scn files	GB/hour	11.36			
106	Post Processed LAS file (max returns @ 20 bytes/return)	GB/hour	28.40			
107	Post Processed LAS file (max returns+GPS time @ 28 bytes/return)	GB/hour	39.77			
108	Allocation for Working Copies (2x factor)	GB/hour	102.46			
109	Total Workstation Disk Space Required (ALS)	GB/hour	153.68			
110						
111						
112	***Camera Setup***					
113						ALS40 Web
114	Array Size (cross-track)	pixels	7216.00	<==========		640.00
115	Array Size (along-track)	pixels	5472.00	<==========		480.00
116	Pixel Pitch	microns	6.80	<==========		5.60

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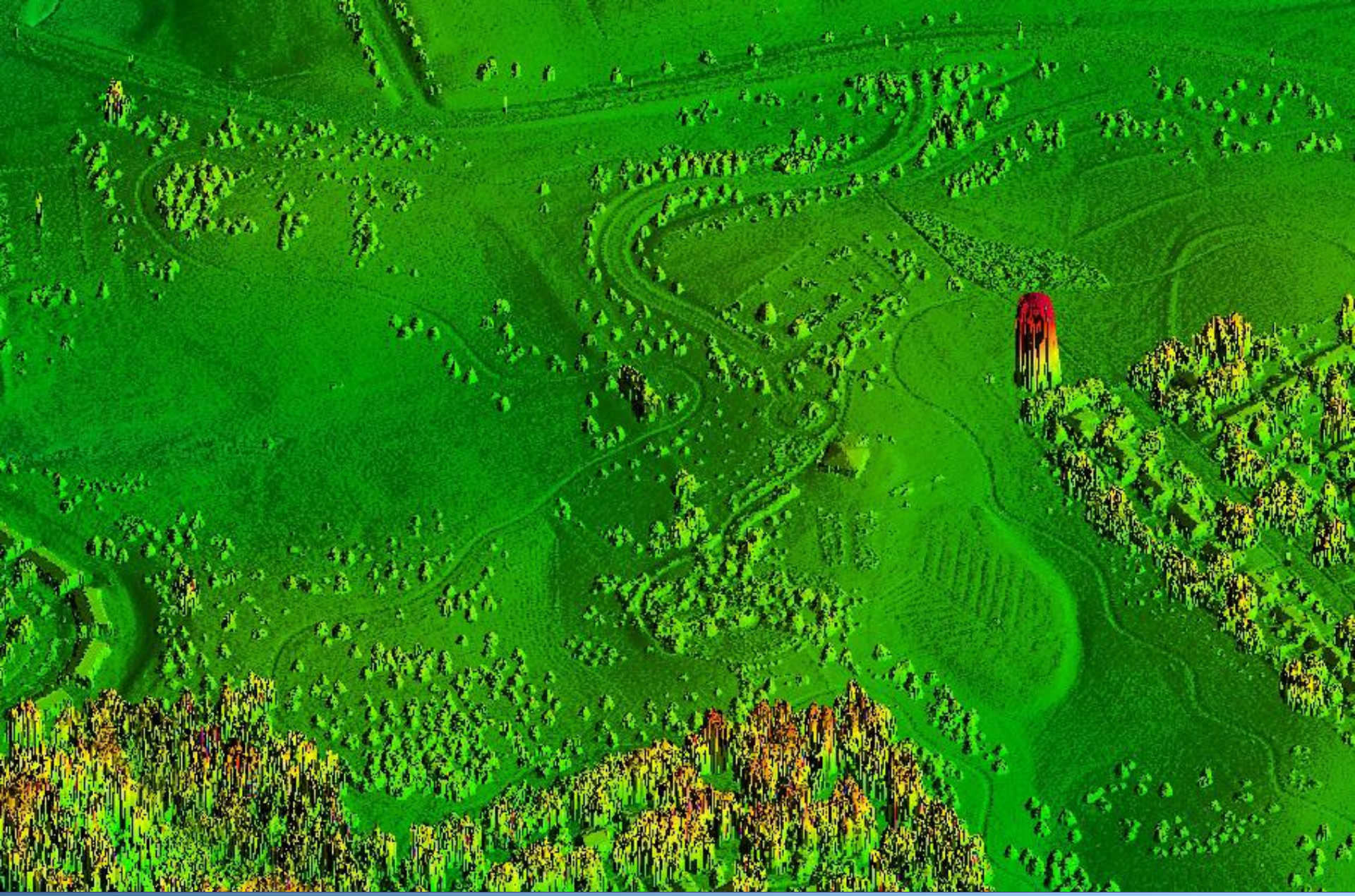

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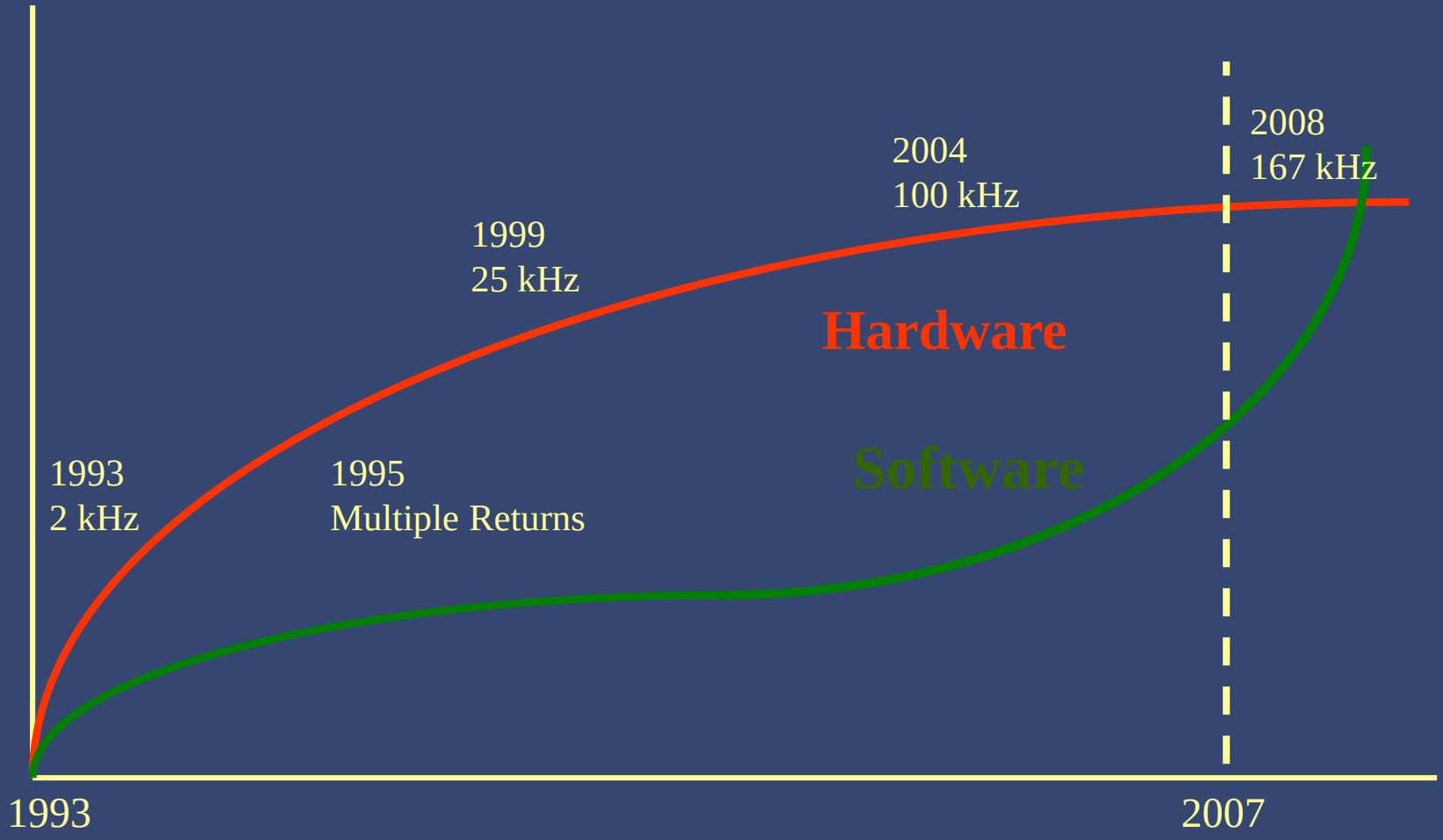
Hardware & Software Capabilities



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Where Do We Go from Here?

- Accuracy
- Software Processing
- Automated Feature Classification
  - Building Footprints
  - Roof Types
  - Pervious/Impervious
  - Vegetation
- Data Fusion

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LIDAR Summary

- Simply another tool in our toolbox
- It is not right for every project, but it can provide substantial cost savings for the right project
- Large-scale, high-accuracy projects still require conventional mapping solution
- LIDAR and the software we use in processing will continue to improve with time

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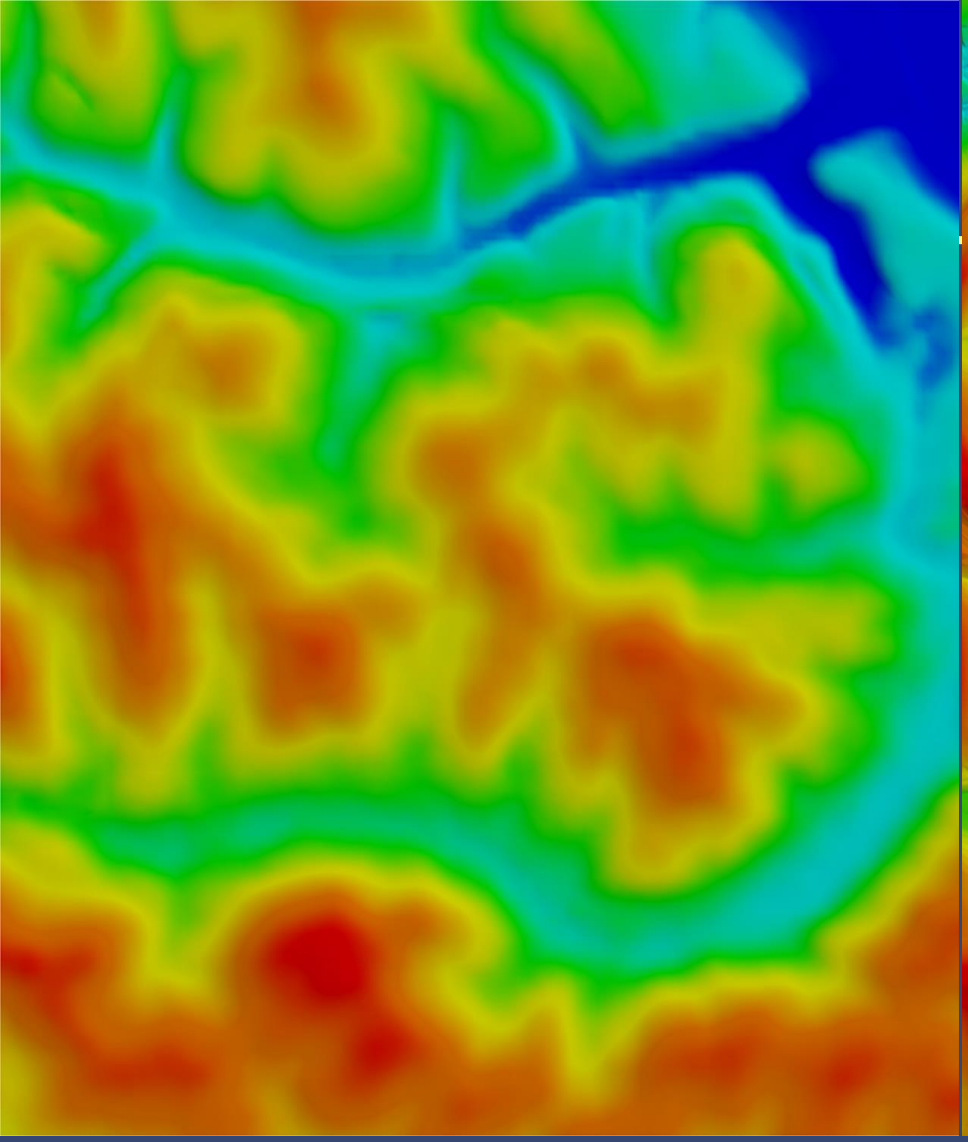
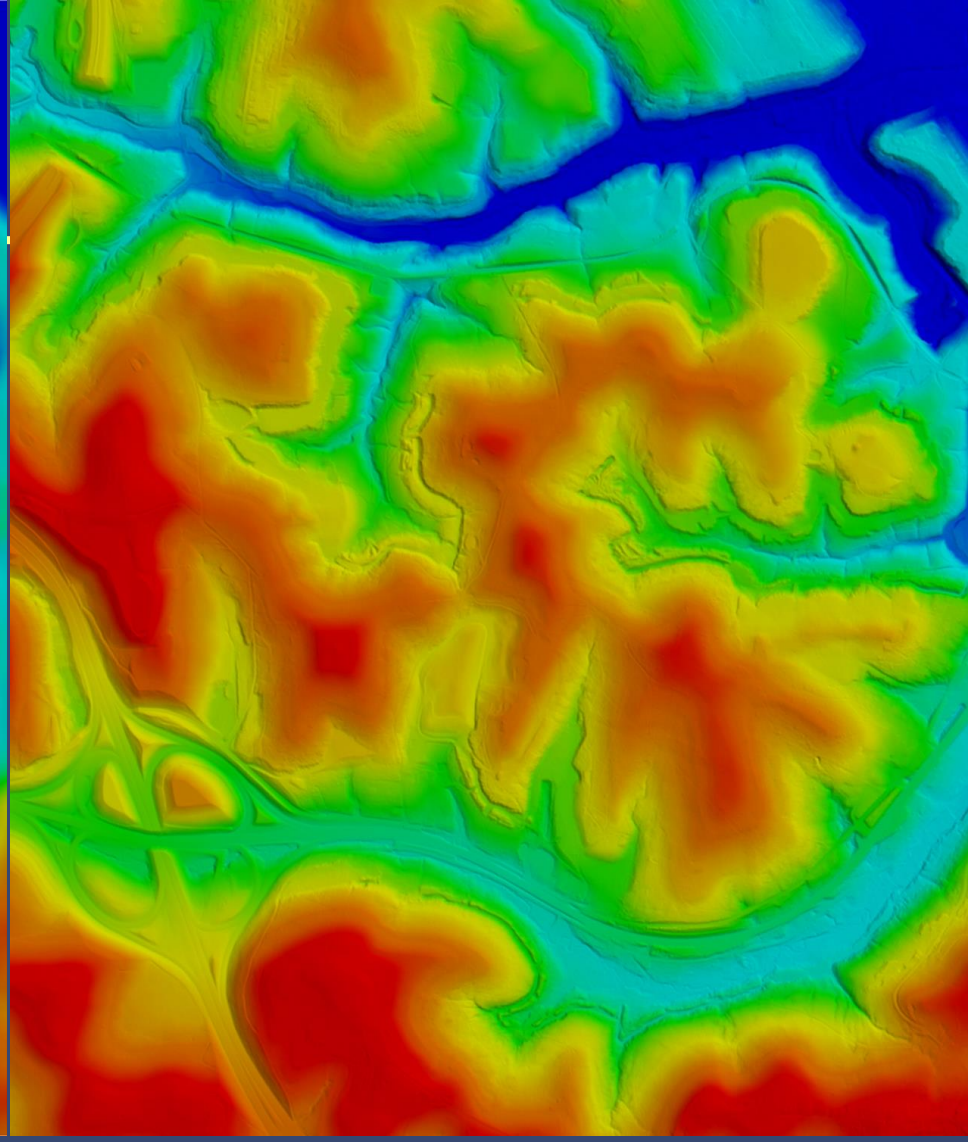


USGS DEM



Lidar DEM

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