Mobile Mapping Technology and Applications

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Presentation Outline

- Mobile Mapping Basics
- Mobile Mapping Applications
- Mobile Mapping Positioning
- Sensor Configuration
- Sensor Capabilities
- System Accuracies
- Feature Extraction
- System Limitations
- Sample Data

Mobile Mapping Basics

Mobile Mapping Basics

- Mobile Mapping is a highly accurate method of spatial data collection
- The Mobile Mapping Sensor is mounted on a mobile platform (SUV, boat, golf cart, ATV, etc.) depending on the specific application
- The mobile platform is driven along a pre-planned route to acquire a spatial model consisting of 3D points (point cloud) of the project area

Mobile Mapping Basics

- The sensor collects the point cloud, and optionally digital imagery from calibrated cameras, of all features within a swath of 250 to 300 feet along the path driven
- Swath width is limited by the relative low power of the eye safe lasers
- Vehicle can be driven at posted road speeds
- To be useful, this 3D model must be both very accurate and very dense

Mobile Mapping Basics

- Primary advantages are high productivity (miles per day, etc.), increased safety (e.g., removing surveyors from traffic on roadways), and high accuracy

Mobile Mapping Basics

- After acquisition, the spatial model collected from the sensor is used in the office environment to extract very accurate feature information from the point cloud
- This information might include topography, utilities, structure locations, cross sections, bridge clearances, signage, etc.
- Semi-automated feature extraction is critically important to any mobile mapping project

Mobile Mapping Basics

- Up to four returns can be measured from each outgoing laser pulse… this allows the sensor to “see” through vegetation
- The intensity (relative reflectivity) of each of the returns is also measured and can be rendered as shown on the next slide

Mobile Mapping Basics

Mobile Mapping Applications

- Any linear or corridor type project that requires considerable accuracy and detail, that also has reasonable access for maneuvering a mobile vehicle
- Ideal applications include roadways, railways, streams, piers, coastal (dunes, etc.), above ground utilities, buildings, etc.
- Access is critical to the project's success

Mobile Mapping Positioning

- GPS provides the 3D positioning of the sensor (XYZ)
- Inertial Navigation Systems (INS) provides the 3D rotation of the sensor (omega, phi, kappa)
- Distance Measurement Indicators (DMI) provides the distance traveled
- The system has the ability to use dead reckoning for brief GPS outages due to tunnels, overhanging vegetation, etc. without significant accuracy degradation

Sensor Configuration

- The typical configuration includes acquisition of LiDAR (providing 3D positional information) from two sensors (200 kHz Each)
- LiDAR uses a rotating laser beam and GPS/INS positioning technology to measure the distance and direction to objects
- Four digital cameras for imagery (5MP Each)

Sensor Configuration

GPS and
Inertial Sensors

LiDAR Sensor

DMI

Calibrated
Digital Cameras

Sensor Configuration

Calibrated
Digital Cameras

GPS and
Inertial Sensors

Calibrated
Digital Cameras

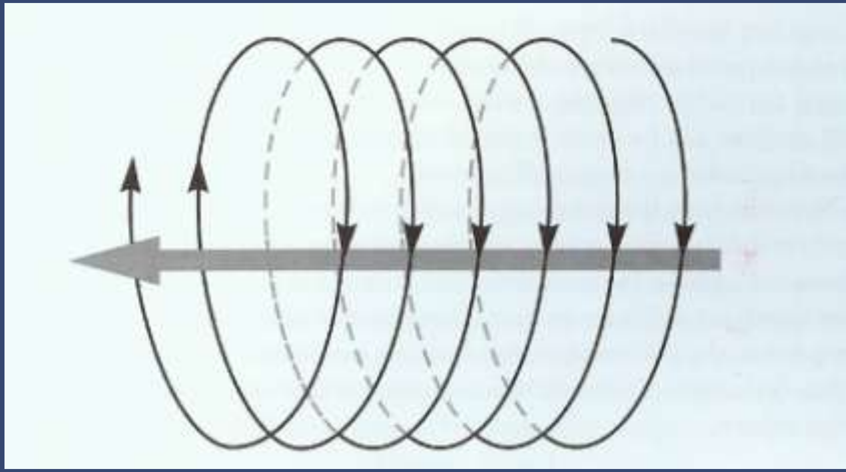
LiDAR Sensors

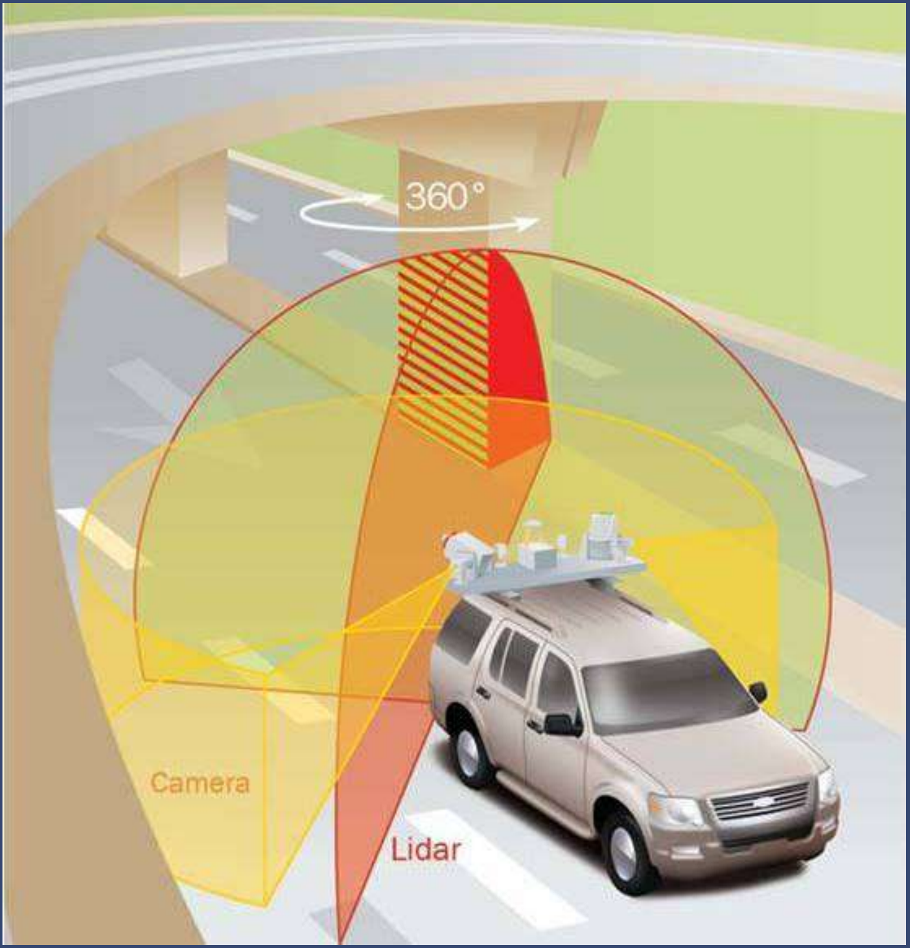
LiDAR Sensors

Calibrated
Digital Cameras

Sensor Configuration

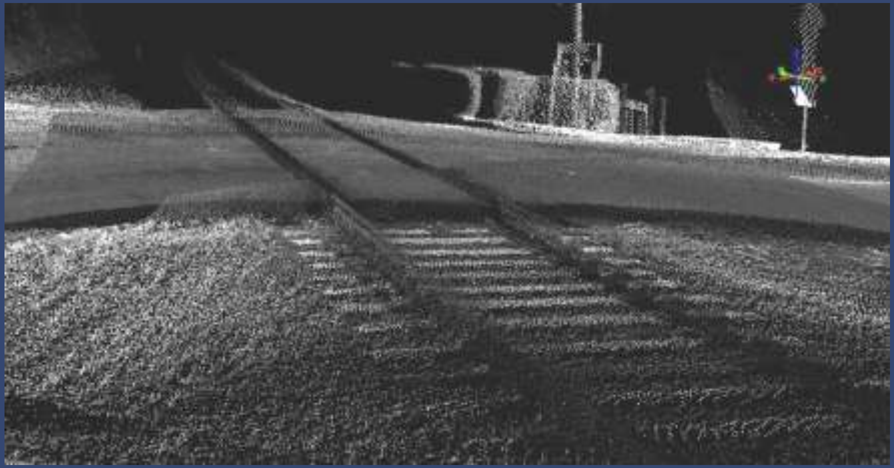
Sensors rotate
in a 360º Arc





Sensor Configuration

- For most applications, the sensor is typically mounted on a van or an SUV… as on our Chevy Suburban
- For rail applications, it is advantageous to mount the sensor on a Hi-Rail Vehicle



Sensor Configuration

- For some applications relating to water bodies, mounting it on a boat is required.

Sensor Capabilities

- Today's Mobile Mapping LiDAR sensors include the ability to capture 400,000 points per second of travel
- Soon (fall 2011), the LiDAR sensors will move to capture rates up to 1 million points per second – with dual 500 kHz lasers
- Each outgoing laser pulse is captured as an accurate 3D position

Sensor Capabilities

- Very high point densities of 5,000 points per square meter are possible near the driven path
- The point density will decrease somewhat at increased distances from the sensor & speed
- At these very high densities it is possible to recognize and position even very small features along the route
- The lasers provide true 360 degree coverage, allowing the accurate location of both ground-based and aerial (overhead utilities, etc.) features

System Accuracies

- Accuracy depends on a number of factors (max GPS baseline length, GPS configuration, PDOP, etc.)
- GPS positions can vary slightly from epoch-to-epoch, but have no drift over time
- INS has extremely small variations from one epoch to the next, but will drift over longer periods of time

System Accuracies

- Kalman filter brings these two technologies (GPS and IMU) together and uses the strengths of each to compensate for the weaknesses of the other
- Smoothed Best Estimate of Trajectory (SBET) can be extremely accurate with the marriage of the two

System Accuracies

Southbound Lanes I-55
Jackson, Mississippi

Point Number	Easting	Northing	Ground Elevation	LiDAR Elevation	Difference	Difference Squared
201	753,562.66	785,419.70	293.210	293.218	-0.008	0.000
204	753,302.26	785,635.18	302.770	302.787	-0.017	0.000
210	751,619.78	787,948.66	299.460	299.469	-0.009	0.000
213	750,310.12	789,637.89	301.160	301.106	0.054	0.003
216	749,005.72	791,320.16	305.910	305.888	0.022	0.000
222	747,955.80	792,820.00	297.880	298.032	-0.152	0.023
225	747,036.54	793,860.16	314.150	314.120	0.030	0.001
228	745,514.66	795,820.28	305.560	305.562	-0.002	0.000
231	744,185.32	797,537.19	307.180	307.137	0.043	0.002
234	743,323.71	798,648.51	315.520	315.475	0.045	0.002
237	742,079.62	799,941.76	335.550	335.527	0.023	0.001
240	740,353.39	801,721.24	356.390	356.406	-0.016	0.000
243	739,461.19	803,323.15	323.780	323.746	0.034	0.001
246	738,399.31	805,185.06	330.620	330.590	0.030	0.001
249	737,322.15	807,062.50	344.950	344.914	0.036	0.001
252	736,259.64	808,922.06	324.790	324.798	-0.008	0.000
255	735,521.62	810,802.94	332.810	332.865	-0.055	0.003
258	735,069.30	810,922.33	331.180	331.185	-0.005	0.000
264	733,537.13	814,707.48	332.020	332.033	-0.013	0.000
267	732,667.68	816,669.08	334.480	334.494	-0.014	0.000
270	732,083.04	817,762.12	336.960	336.979	-0.019	0.000
273	730,563.12	818,649.39	349.380	349.402	-0.022	0.000
276	730,094.12	818,636.67	363.810	363.816	-0.006	0.000
282	728,202.95	819,631.16	352.050	352.022	0.028	0.001
285	727,710.75	820,025.31	346.220	346.212	0.008	0.000
288	727,319.95	820,252.78	343.520	343.533	-0.013	0.000
291	725,742.88	821,713.76	367.270	367.290	-0.020	0.000
294	725,407.10	822,398.31	384.860	384.851	0.009	0.000
303	722,375.00	825,823.90	380.290	380.300	-0.010	0.000
306	721,640.98	828,123.20	357.190	357.193	-0.003	0.000
309	721,591.94	828,880.99	359.250	359.230	0.020	0.000
312	720,980.82	830,108.62	366.160	366.183	-0.023	0.001
315	720,885.78	830,330.88	361.580	361.585	-0.005	0.000
321	721,818.26	827,146.84	361.620	361.609	0.011	0.000
324	722,166.59	825,335.47	381.930	381.891	0.039	0.002
327	723,855.60	823,492.34	353.250	353.255	-0.005	0.000
330	724,831.22	822,075.97	387.220	387.213	0.007	0.000
333	725,295.26	821,893.04	374.890	374.896	-0.006	0.000
336	727,714.09	819,806.77	349.420	349.452	-0.032	0.001
339	727,561.18	819,534.69	362.360	362.354	0.006	0.000
342	729,546.07	818,750.09	363.070	363.091	-0.021	0.000
345	729,306.01	818,592.43	364.890	364.942	-0.052	0.003
348	730,676.43	818,225.51	357.980	357.996	-0.016	0.000
354	734,113.73	812,957.92	332.640	332.571	0.069	0.005
357	735,781.86	809,427.57	323.110	323.091	0.019	0.000
363	739,746.13	802,491.80	346.800	346.797	0.003	0.000
369	745,129.57	796,048.87	305.610	305.630	-0.020	0.000
372	746,711.72	794,013.49	324.080	324.059	0.021	0.000
375	748,601.52	791,569.59	308.990	308.967	0.023	0.001
378	748,397.38	791,798.90	315.790	315.827	-0.037	0.001
384	752,992.60	785,453.74	303.730	303.679	0.051	0.003

Average of Squared Differences	0.001
RMSE	0.034
NSSDA @95%	0.067
Minimum	-0.152
Maximum	0.069

I-55 – Jackson, MS
Total Check Points = 51
Project Length = 18 Miles
RMSE = 0.034-Feet
NSSDA (95%) = 0.067 Feet

System Accuracies

Point Number	Easting	Northing	Ground Elevation	LIDAR Elevation	Difference	Difference Squared
1053	451,531.25	742,737.44	724.96	724.84	-0.12	0.014
1534	464,953.12	737,713.95	983.94	983.84	-0.09	0.009
1542	458,809.34	737,619.42	795.60	795.53	-0.08	0.006
1548	455,886.95	739,194.85	706.75	706.70	-0.06	0.003
1567	450,524.64	745,392.40	736.77	736.71	-0.06	0.003
1563	450,580.34	744,727.29	735.87	735.81	-0.06	0.003
1531	479,882.40	742,640.52	631.49	631.44	-0.05	0.003
1552	454,022.47	740,711.26	710.92	710.87	-0.05	0.002
1040	464,972.97	737,648.42	983.67	983.63	-0.05	0.002
1561	451,188.74	743,545.37	727.45	727.41	-0.04	0.002
1560	451,746.13	742,991.54	725.68	725.64	-0.04	0.002
1569	476,262.65	740,400.62	820.52	820.48	-0.04	0.001
1568	450,210.72	745,635.20	741.68	741.64	-0.04	0.001
1556	452,309.23	742,426.74	725.84	725.81	-0.04	0.001
1562	450,727.19	744,192.10	731.16	731.13	-0.04	0.001
1521	472,935.23	739,269.90	834.99	834.96	-0.03	0.001
1525	470,487.13	739,009.34	874.51	874.48	-0.03	0.001
1545	457,251.25	738,848.31	711.00	710.98	-0.03	0.001
1553	453,462.02	741,276.54	717.18	717.16	-0.03	0.001
1514	477,993.53	741,139.41	763.55	763.60	0.05	0.003
1058	453,962.60	740,663.41	710.80	710.85	0.05	0.003
1063	450,353.01	745,301.36	735.51	735.56	0.05	0.003
1060	455,114.76	739,537.07	706.99	707.04	0.05	0.003
1003	484,627.38	742,914.48	586.21	586.27	0.06	0.003
1009	482,627.92	742,938.65	553.37	553.43	0.06	0.003
1043	456,614.65	738,852.56	706.19	706.25	0.06	0.004
1028	467,273.19	738,405.06	980.57	980.64	0.07	0.005
1005	486,238.55	742,631.42	644.67	644.74	0.07	0.005
1050	451,722.30	742,897.71	725.55	725.62	0.07	0.005
1055	452,805.00	741,821.73	731.82	731.89	0.07	0.005
1062	450,147.30	745,560.81	738.77	738.84	0.07	0.005
1022	476,037.72	739,704.18	854.14	854.21	0.08	0.006
1044	457,372.39	738,583.35	725.36	725.44	0.08	0.006
1066	450,655.65	744,153.81	730.68	730.77	0.09	0.008
1051	451,448.54	742,982.75	726.43	726.52	0.09	0.008
1011	478,040.85	741,066.83	764.23	764.32	0.09	0.008
1519	474,565.17	739,479.72	869.67	869.77	0.10	0.010
1054	452,296.48	742,326.22	725.99	726.09	0.10	0.011
1057	453,392.01	741,220.39	717.10	717.20	0.11	0.011
1538	461,825.87	736,602.59	932.59	932.70	0.11	0.013
1020	474,584.07	739,400.88	869.49	869.61	0.12	0.014
1036	461,821.22	736,530.83	933.58	933.76	0.18	0.033

Average of Squared Differences	0.002
RMSE	0.045
NSSDA @95%	0.089
Minimum	-0.120
Maximum	0.181

NJ Route 10 – Roxbury, NJ
Total Check Points = 131
Project Length = 7 Miles
RMSE = 0.045-Feet
NSSDA (95%) = 0.089 Feet

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System Accuracies

Used Points

49 known XYZ points

53 known XY points

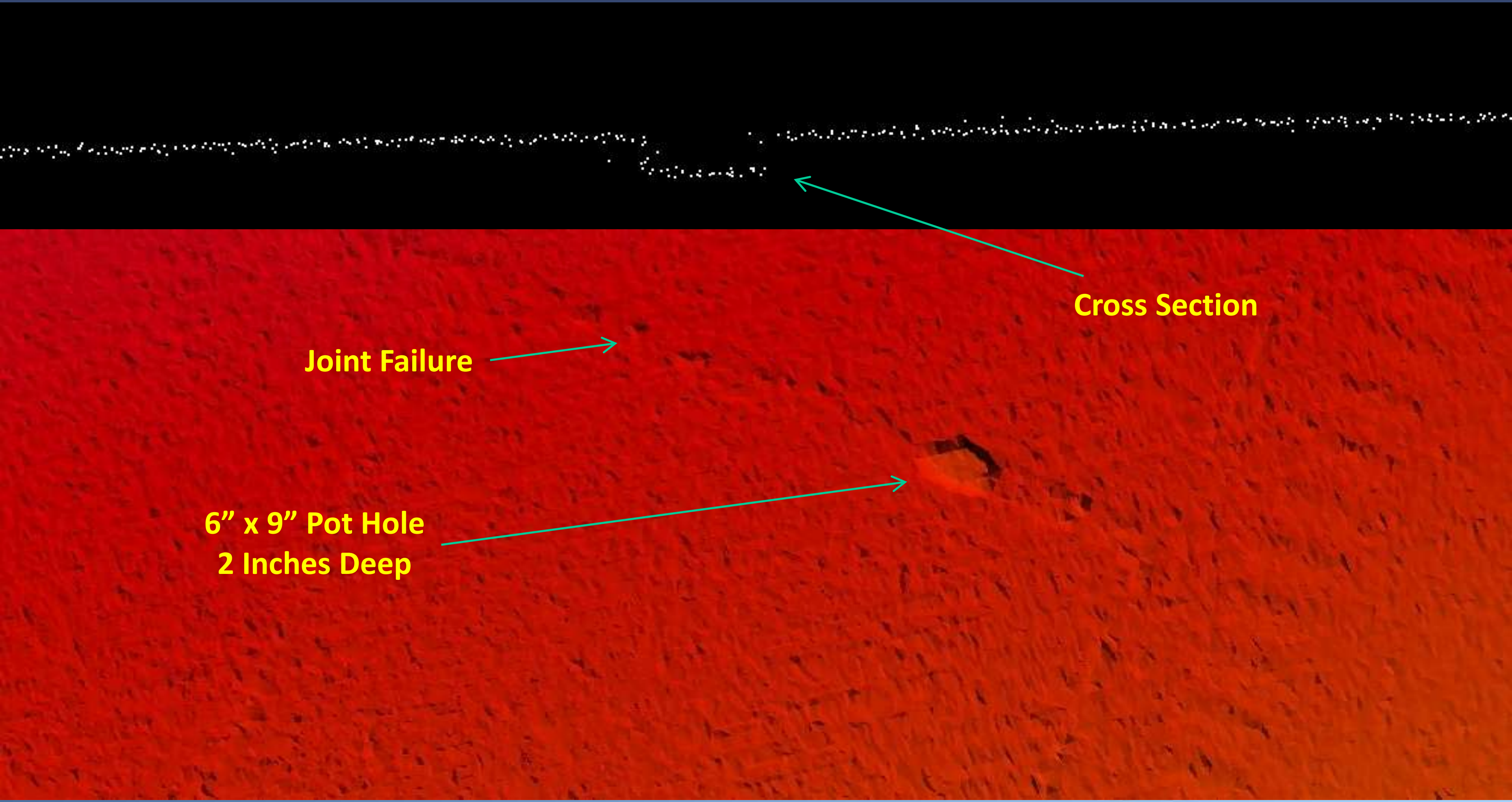
	X	Y
Average magnitude	0.082	0.095
RMS values	0.105	0.119
Maximum values	0.328	0.354

Blind Points

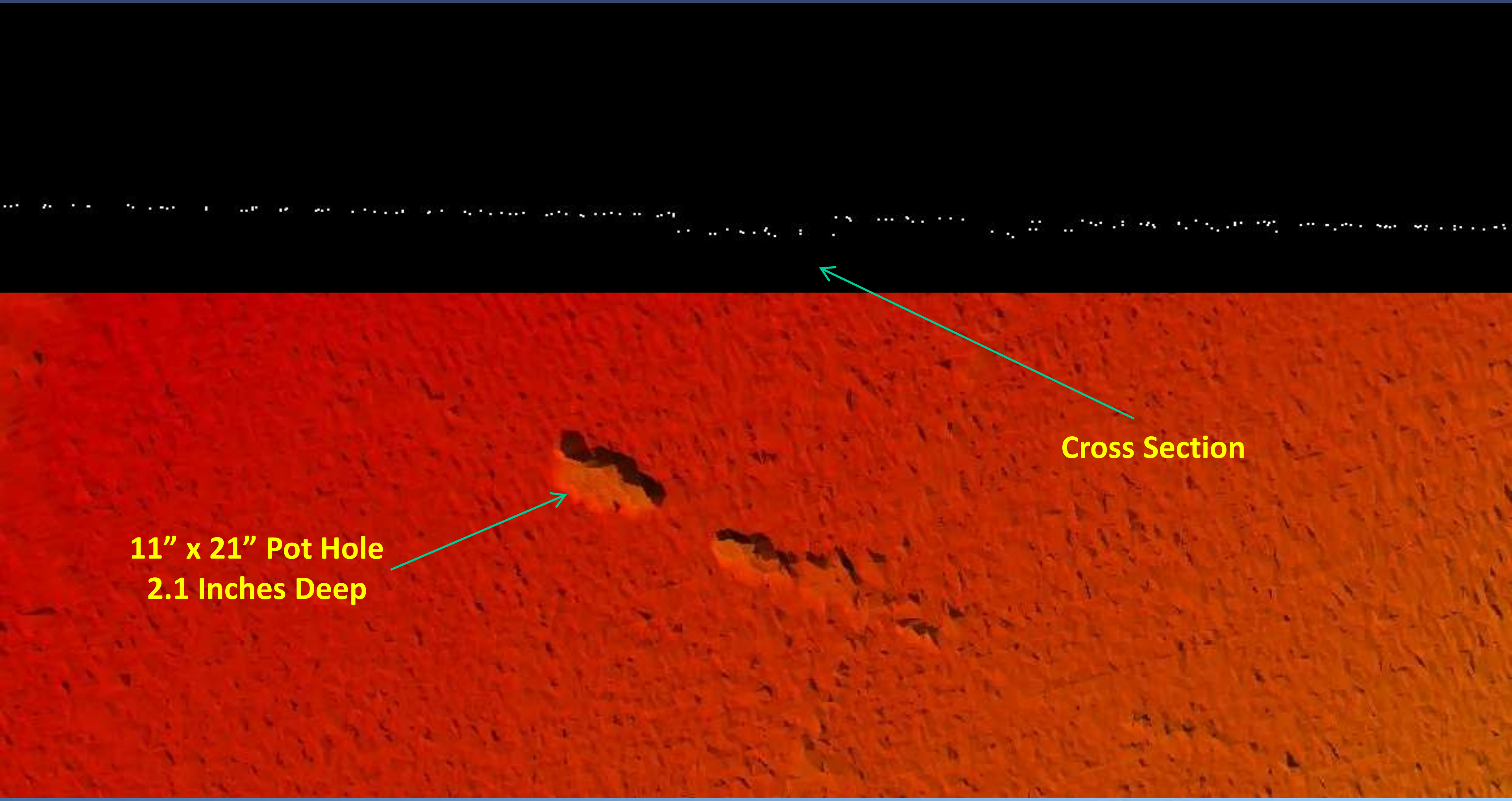
26 known XYZ points

	X	Y	Z
Average magnitude	0.143	0.129	0.056
RMS values	0.194	0.157	0.071
Maximum values	0.611	0.358	0.171

System Accuracies



System Accuracies



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System Accuracies

- Not right for all projects, just another tool
- Software driven
- Requires traditional surveying for control
- Accuracy is dialed to the specific project requirements and end user needs

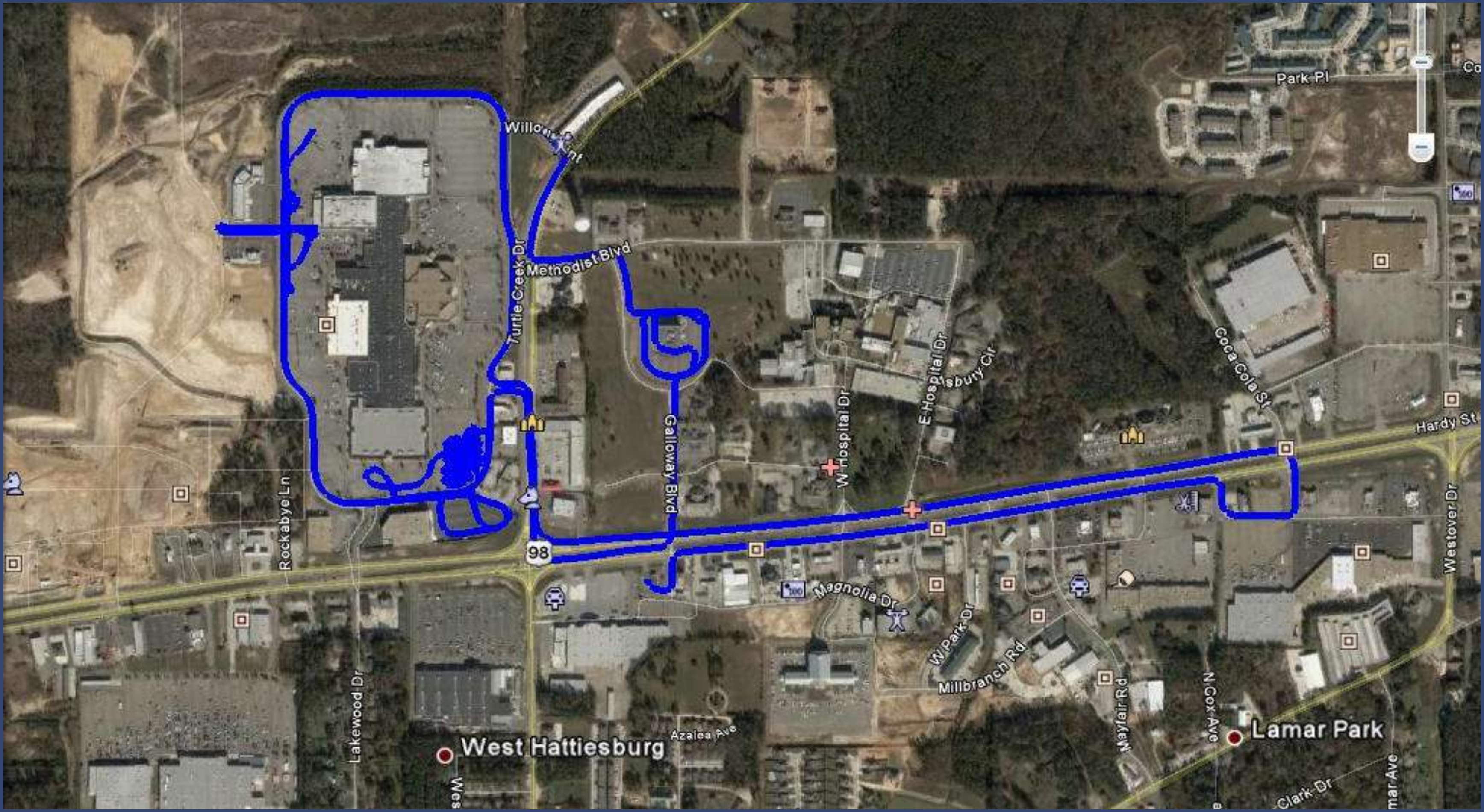
Feature Extraction

- With point clouds often consisting of billions of points, efficiently extracting intelligent vector data from these point clouds is critical to a project's success
- Software has made significant strides in the last year in managing and extracting data from the cloud
- Extraction uses both elevation and intensity models for automated routines

System Limitations

- The sensor is line-of-sight
- It can see through some vegetation, but can not see behind buildings, embankments, etc.
- The system depends on GPS for positioning and therefore tunnels, urban canyons, and overhanging vegetation can pose challenges
- The system generates significant data… up to 90 MB per second currently with dual LiDAR and 4 metric digital cameras

Calibration



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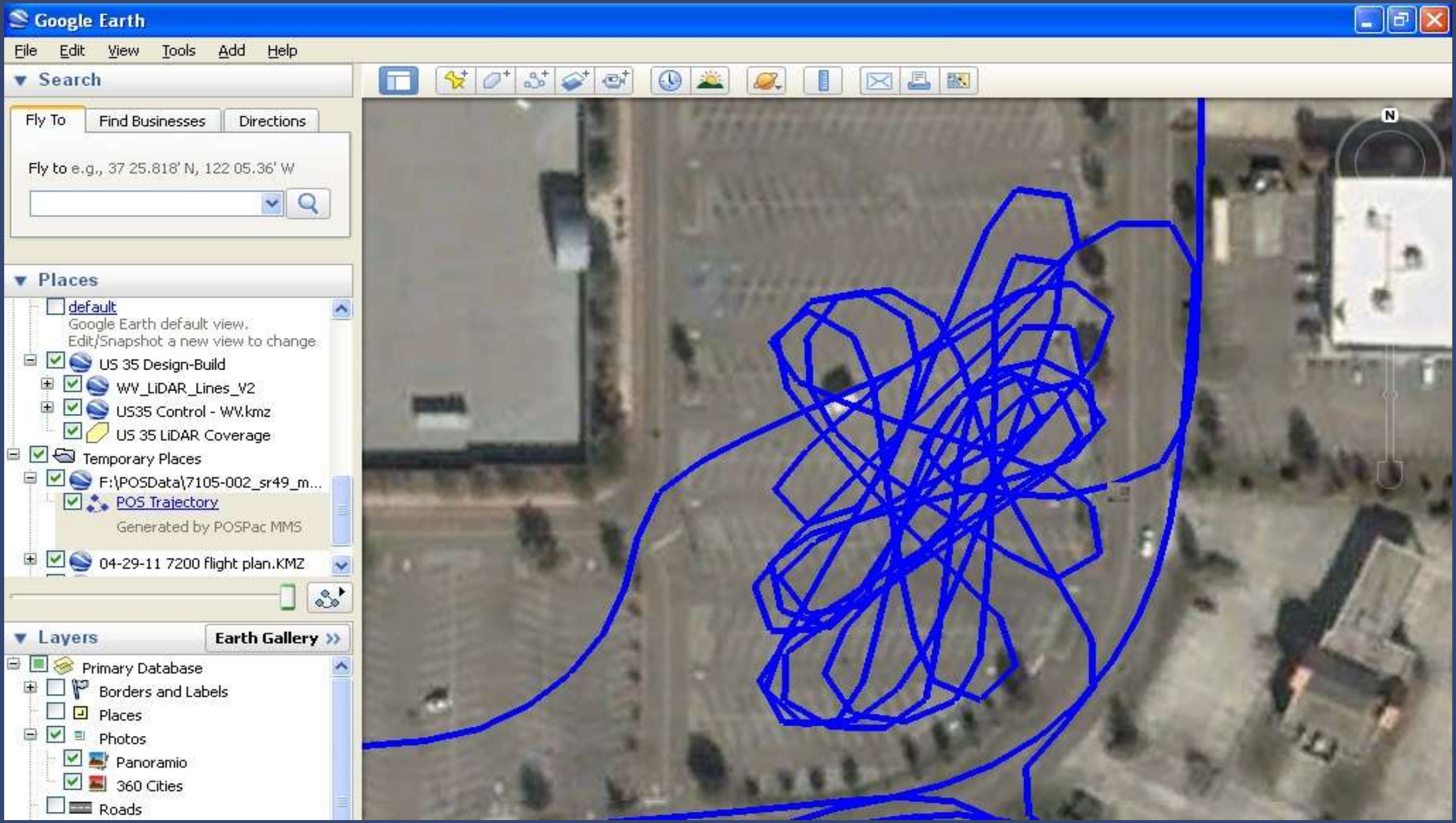
Calibration



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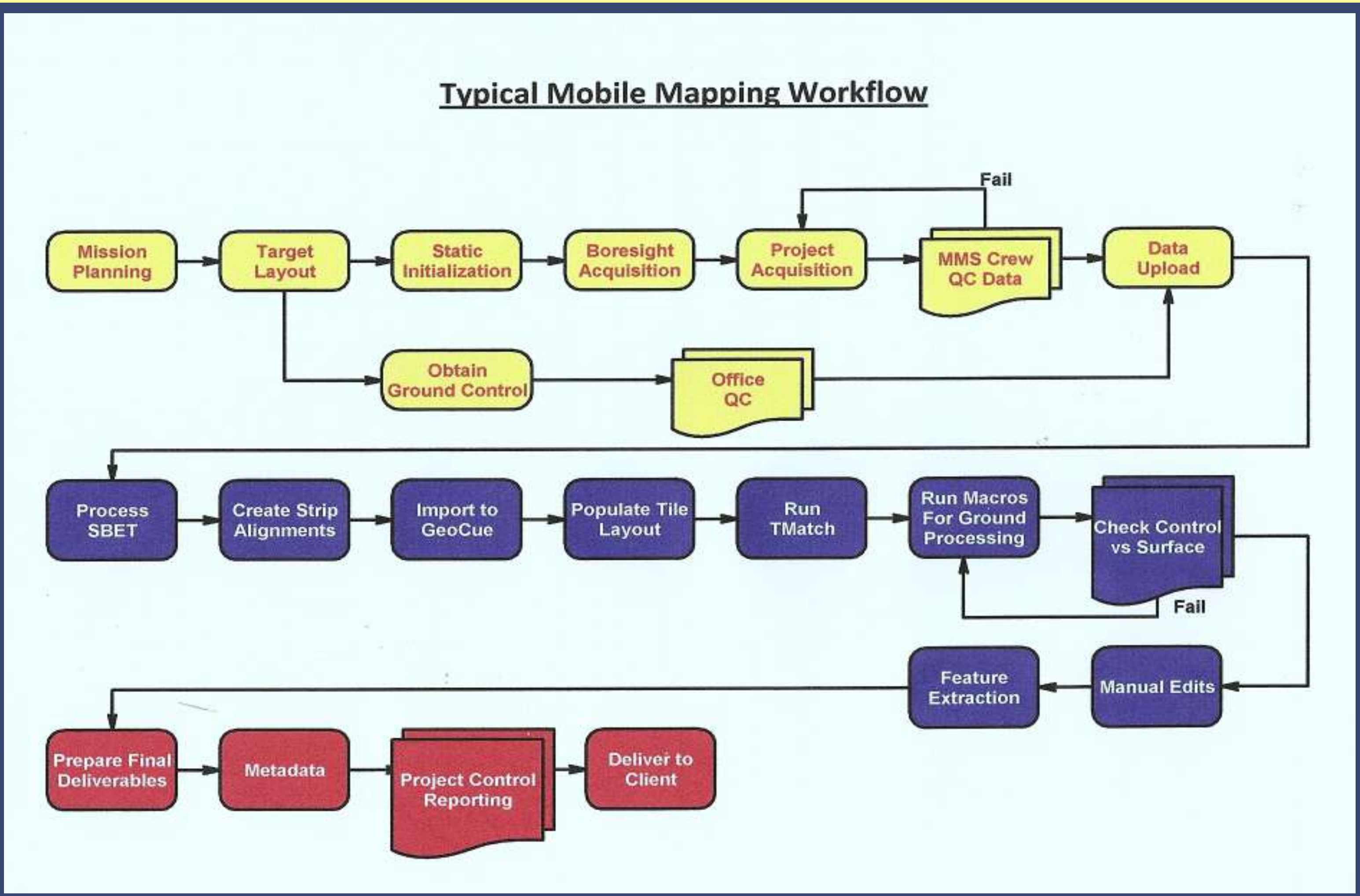
Workflow



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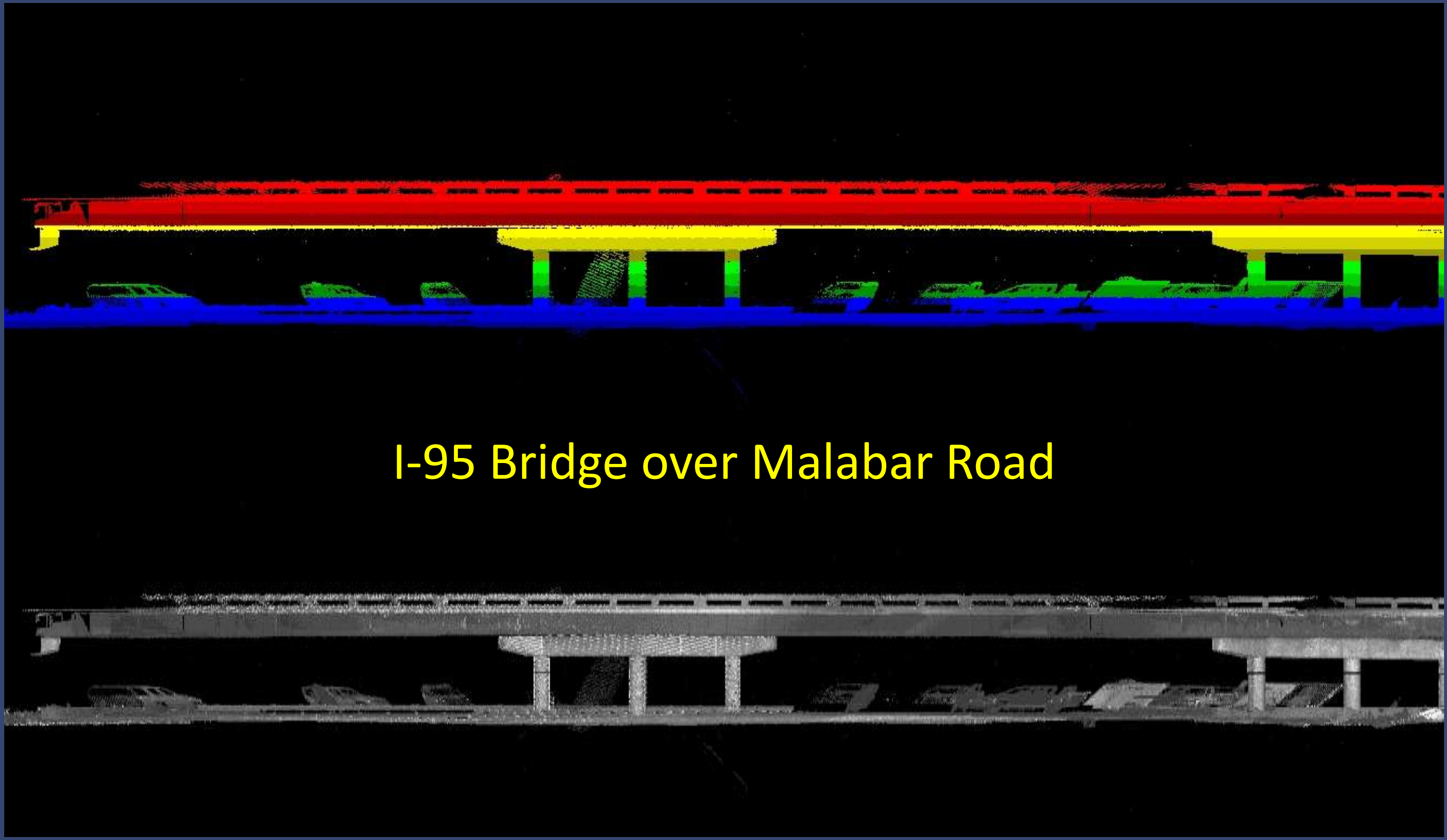
Sample Data



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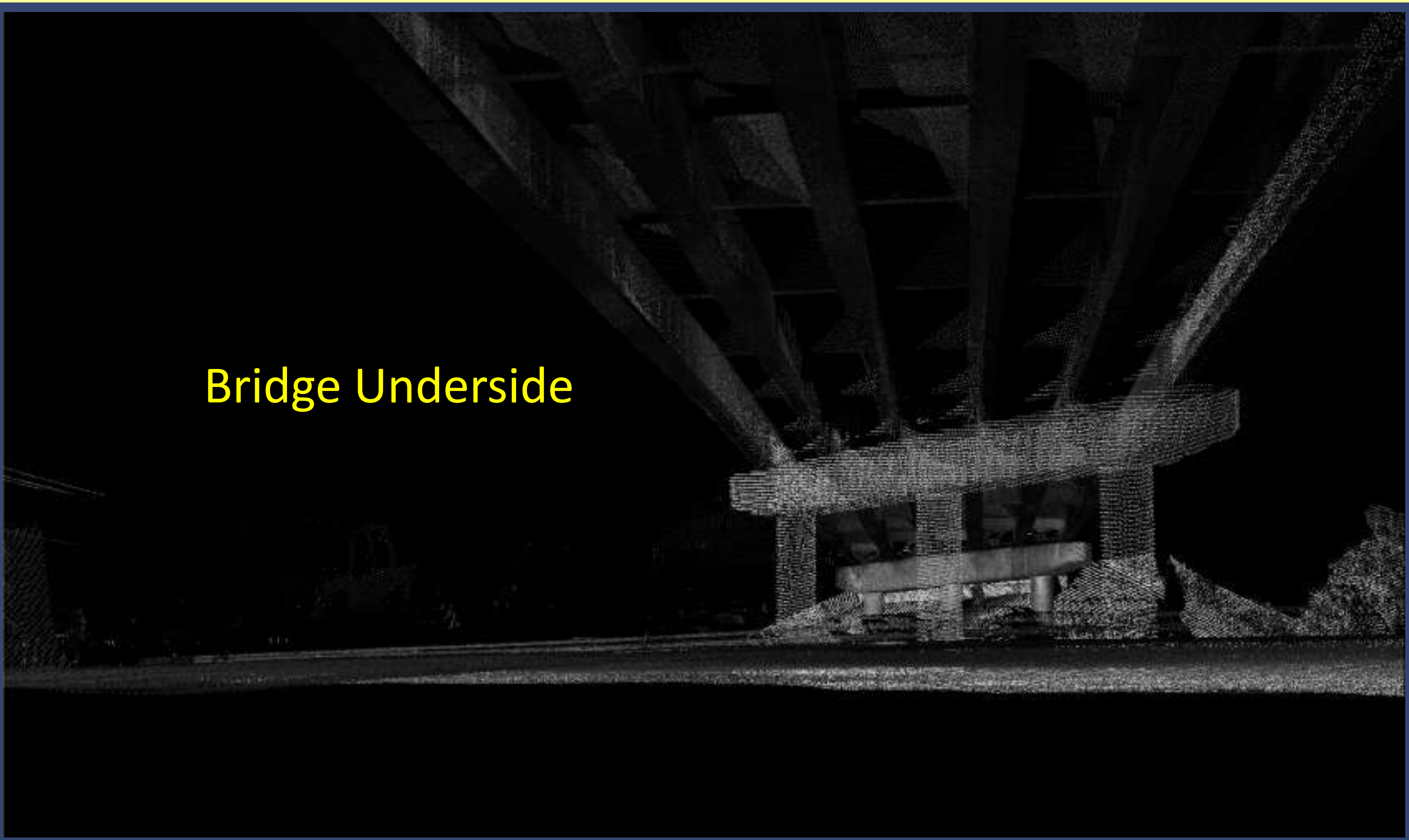

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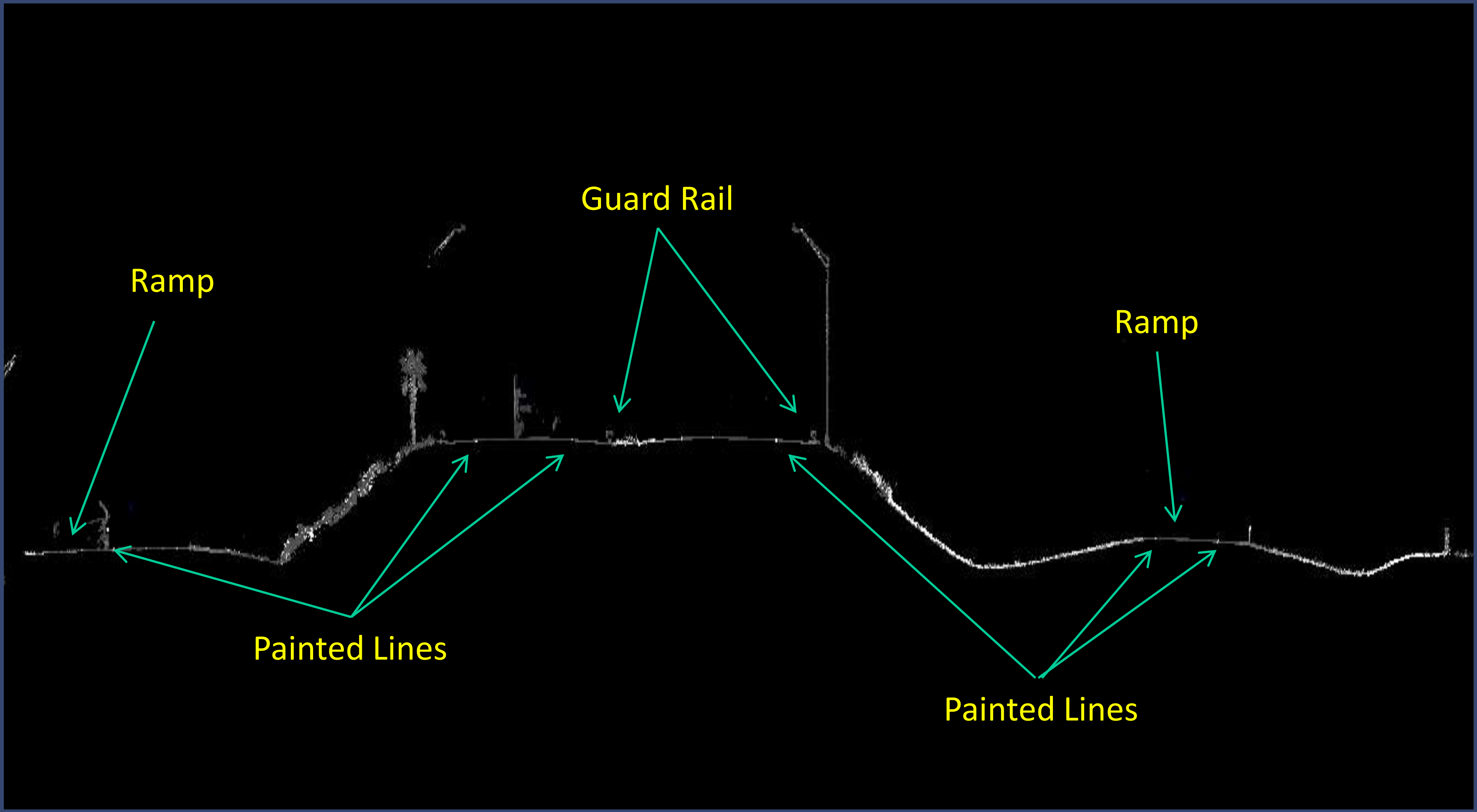

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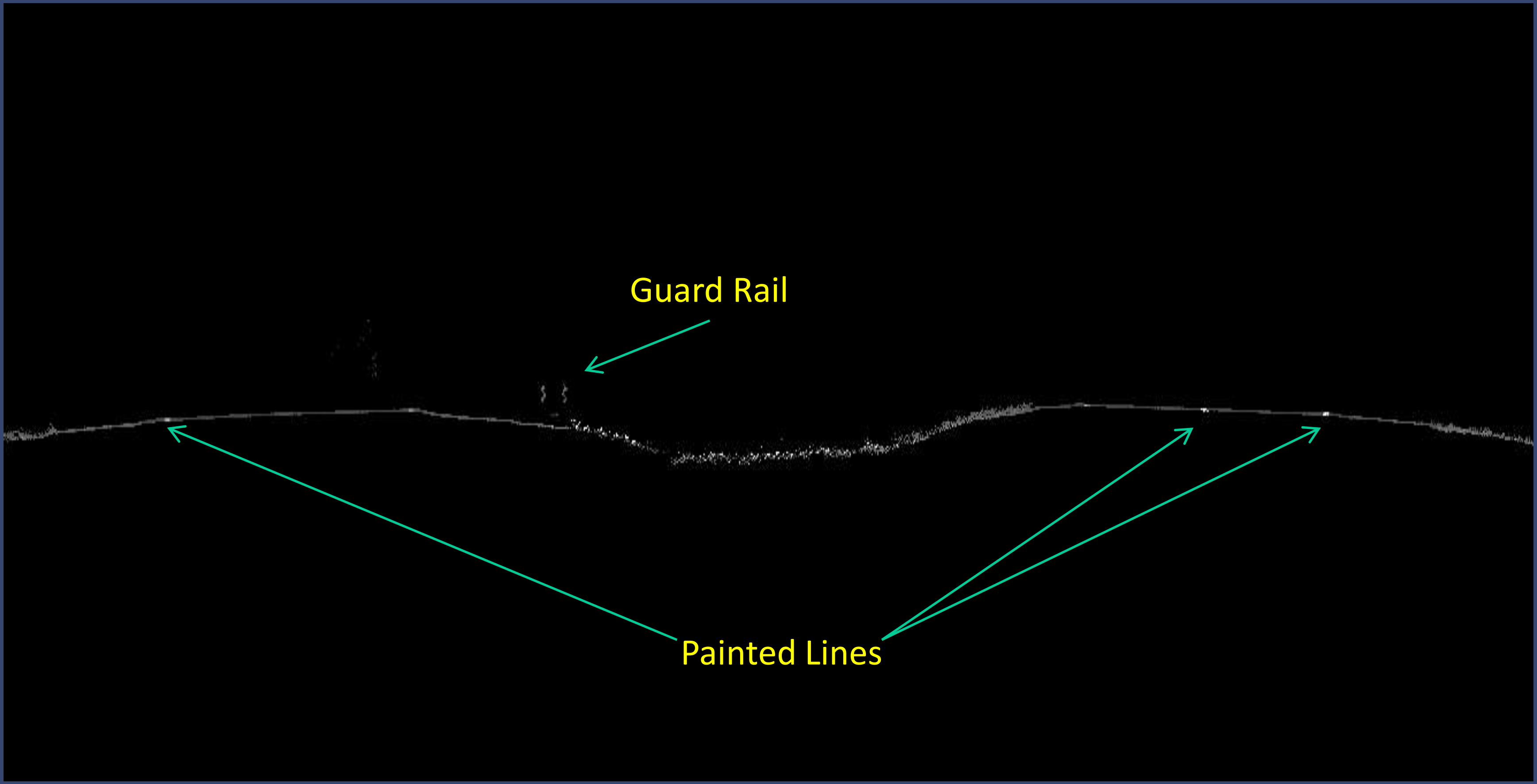

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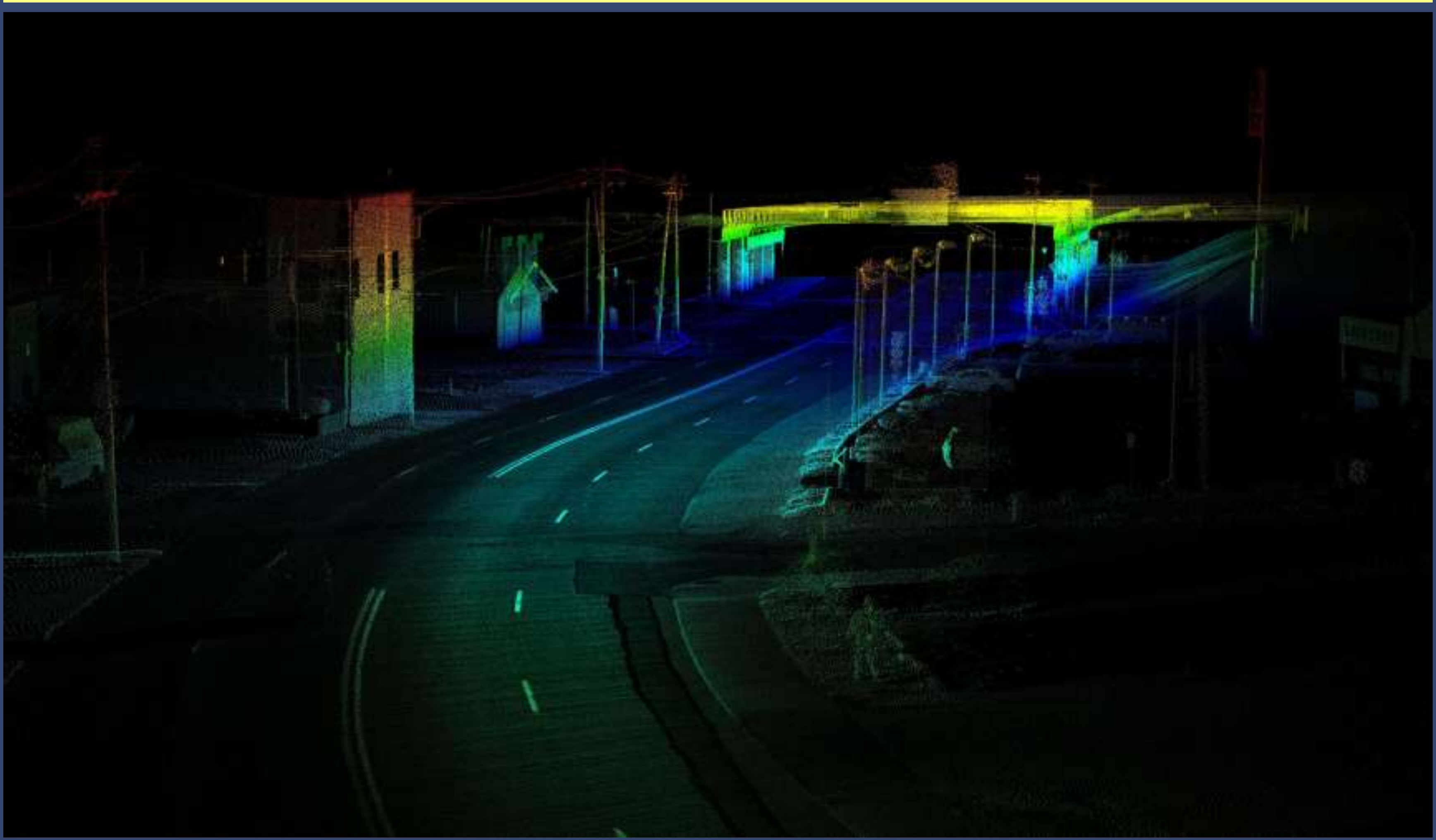

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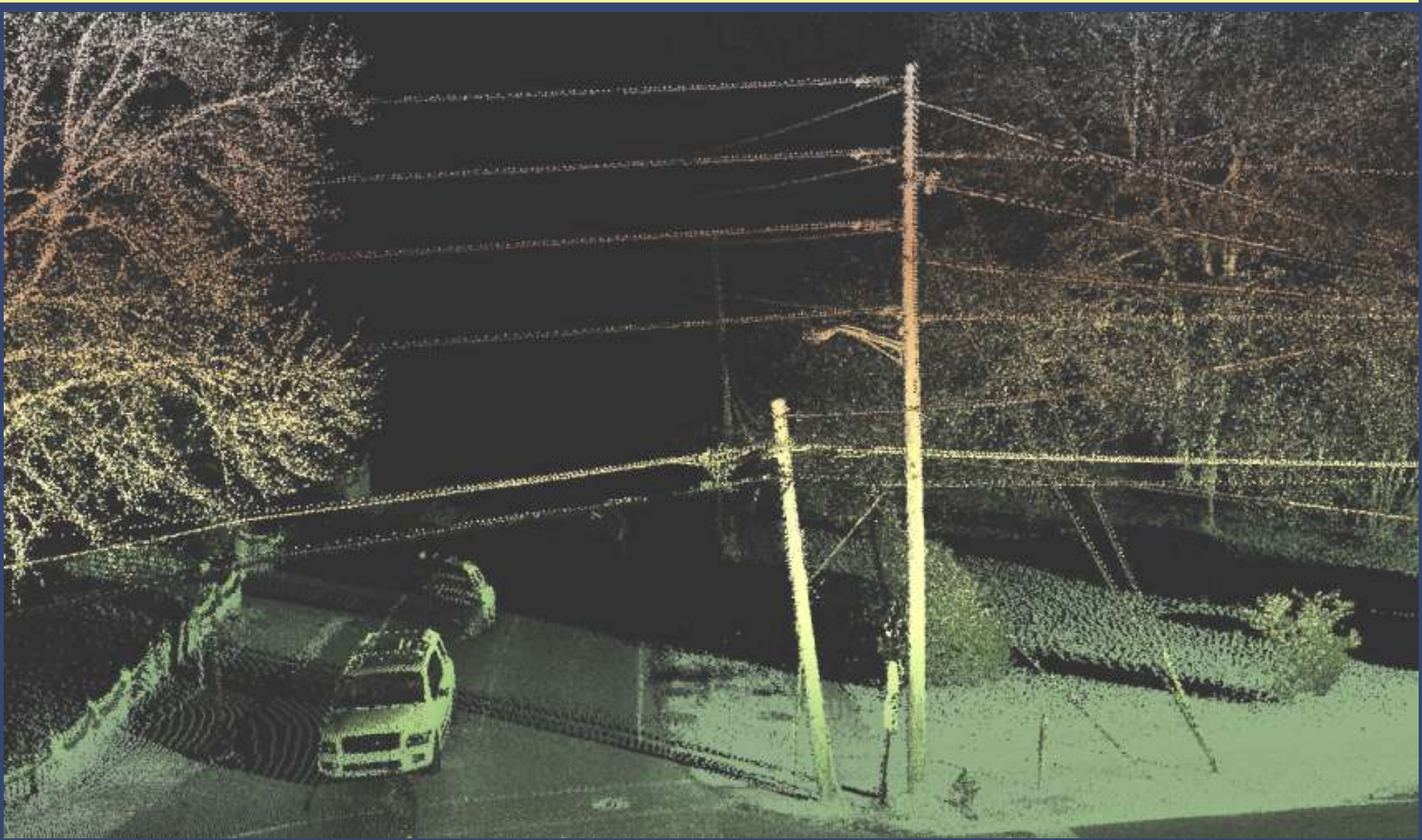
Sample Data

Sample Data



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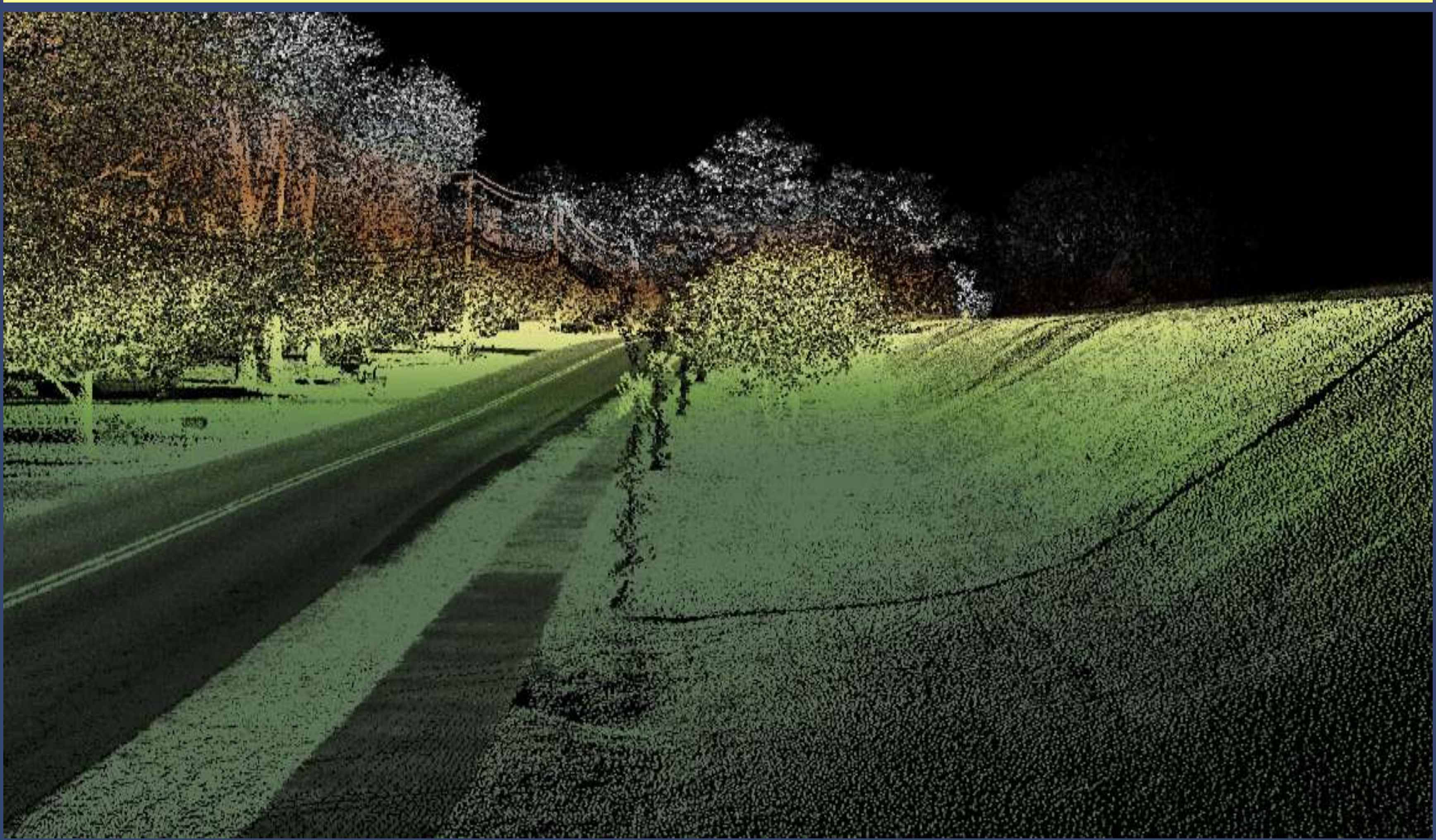

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Sample Data

Questions?

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