Aligning Project needs with Geospatial Acquisition Technologies: The New Hybrid Product Approach

WOOLPERT
ARCHITECTURE | ENGINEERING | GEOSPATIAL

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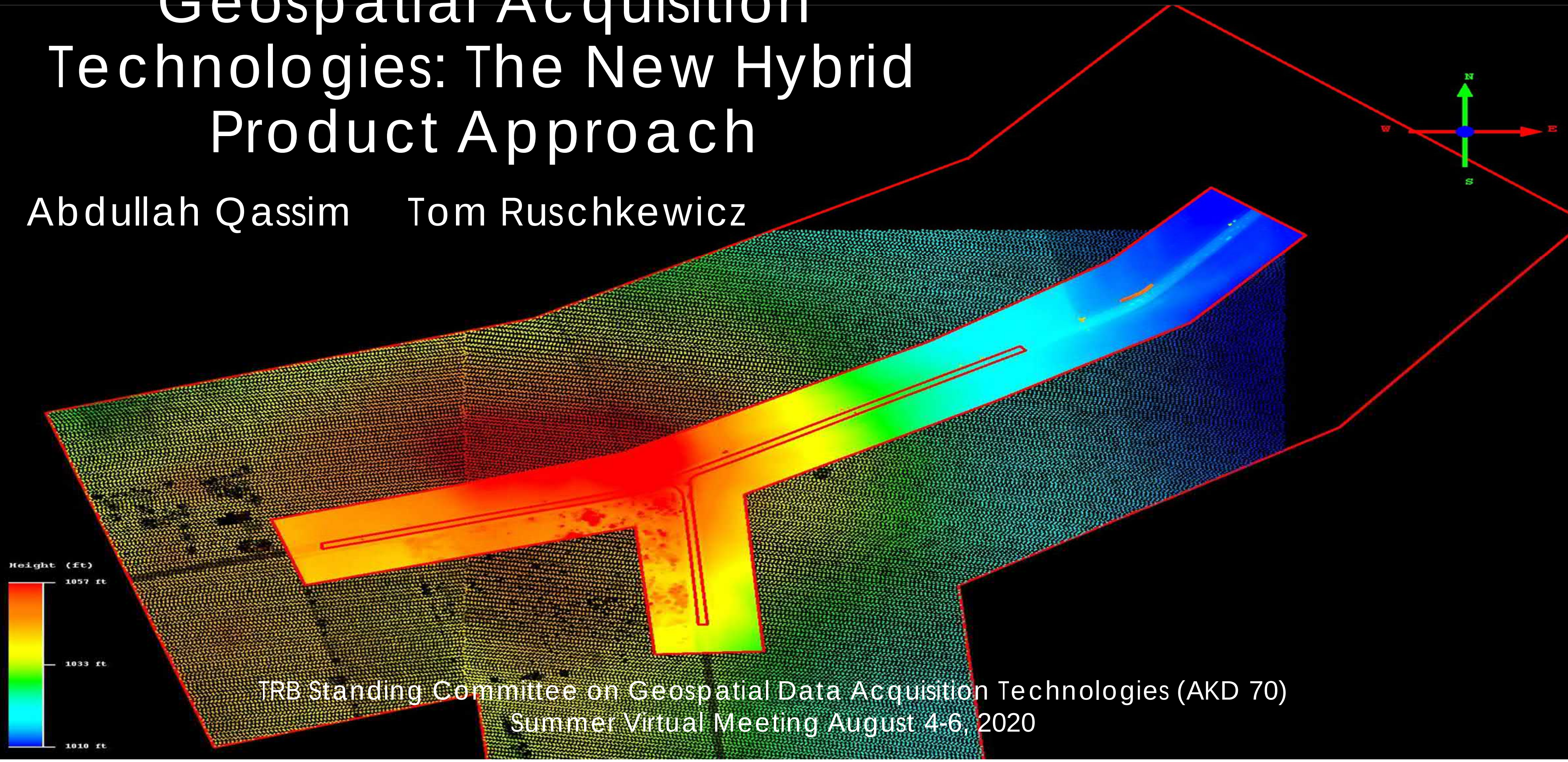


TRB Standing Committee on Geospatial Data Acquisition Technologies (AKD 70)
Summer Virtual Meeting August 4-6, 2020

Agenda

1 Strength and Weakness of Geospatial Technologies

- Aerial Lidar
- Mobile Lidar
- UAS Imagery

2 Hybrid Approach to Project Deliverables – Project I

- Aerial Lidar Quality & Accuracy
- Mobile Lidar Quality & Accuracy
- Imagery-based Points Cloud Quality & Accuracy
- Hybrid DSM/DTM Quality & Accuracy
- Data Preparation
- Products Generations - Contours

3 Hybrid Approach to Project Deliverables – Project II

- PENNDOT Proof of Concept

Woolpert at a Glance

1911

Founded in Dayton, Ohio

30+

Offices across the nation

900+

Global employees

Areas of Expertise

ARCHITECTURE

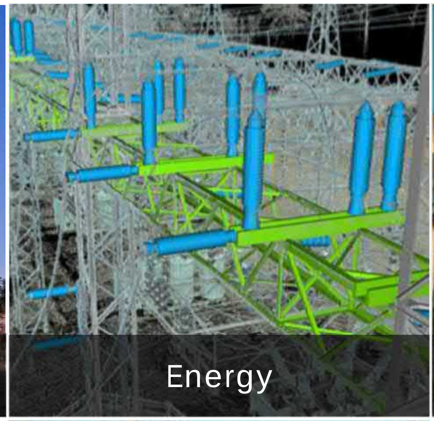
ENGINEERING

GEOSPATIAL

Who We Serve


Aviation


Education

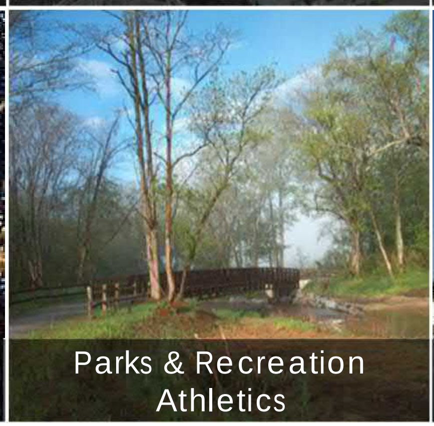

Energy

Facilities


Government


IT Management Consulting


National Security


Parks & Recreation Athletics


Transportation


Water

Statement of the Problem

1. The continuing decline in funds for government agencies, posing a great challenge to these agencies to finance their new projects or maintain existing ones.

2. With funds drying out, many such agencies are looking for creative ways to enable them to move forward with their projects despite the constrained budget.

3. We believe that our client survivability and resilience is important part of our existence and our business growth, so we got our hands dirty looking for such creative ways to enable our clients achieve their goals under strict budget.

Geospatial Acquisition Technologies

Strength & Weakness

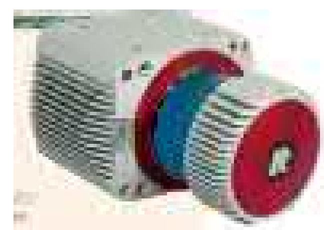

Aerial Lidar

Aerial LiDAR is becoming the workhorse for the Geospatial Industry

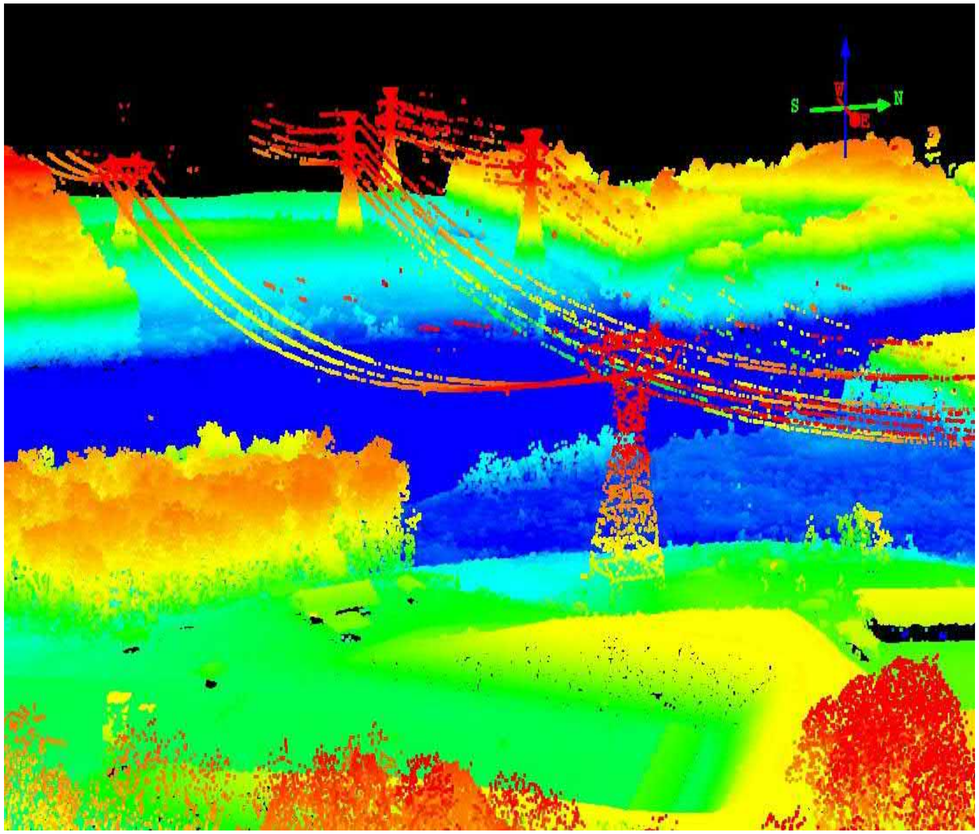
Helicopter

Fixed Wing

Unmanned



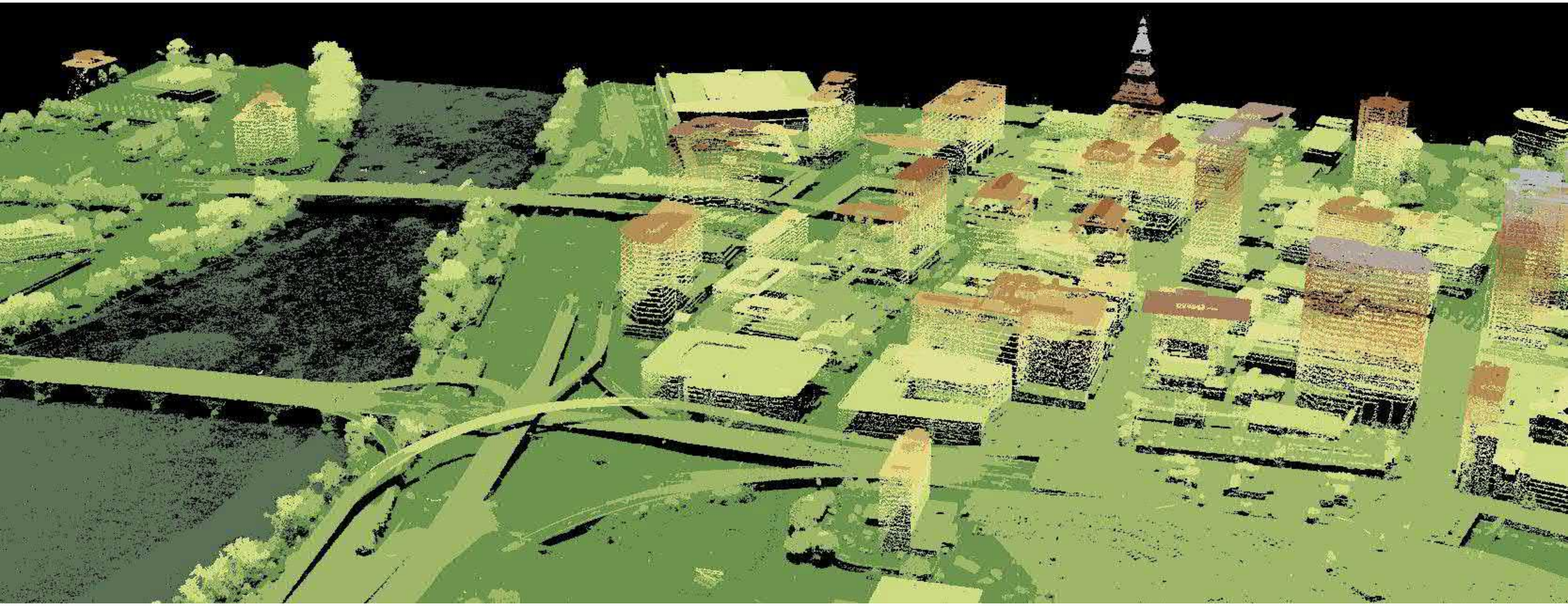
Strength of Aerial Lidar System Technology



1. Best suited for wide area coverage

2. Birds Eye View, i.e. beyond MMS coverage

3. In most cases, it is available for free from local government GIS offices and USGS



Limitations of Aerial Lidar System Technology

- Lower point cloud density as compared to MMS
- Limited positional accuracy design project
- Not suited for small projects

Land-based Lidar:

Mobile Mapping System

Current systems Capabilities

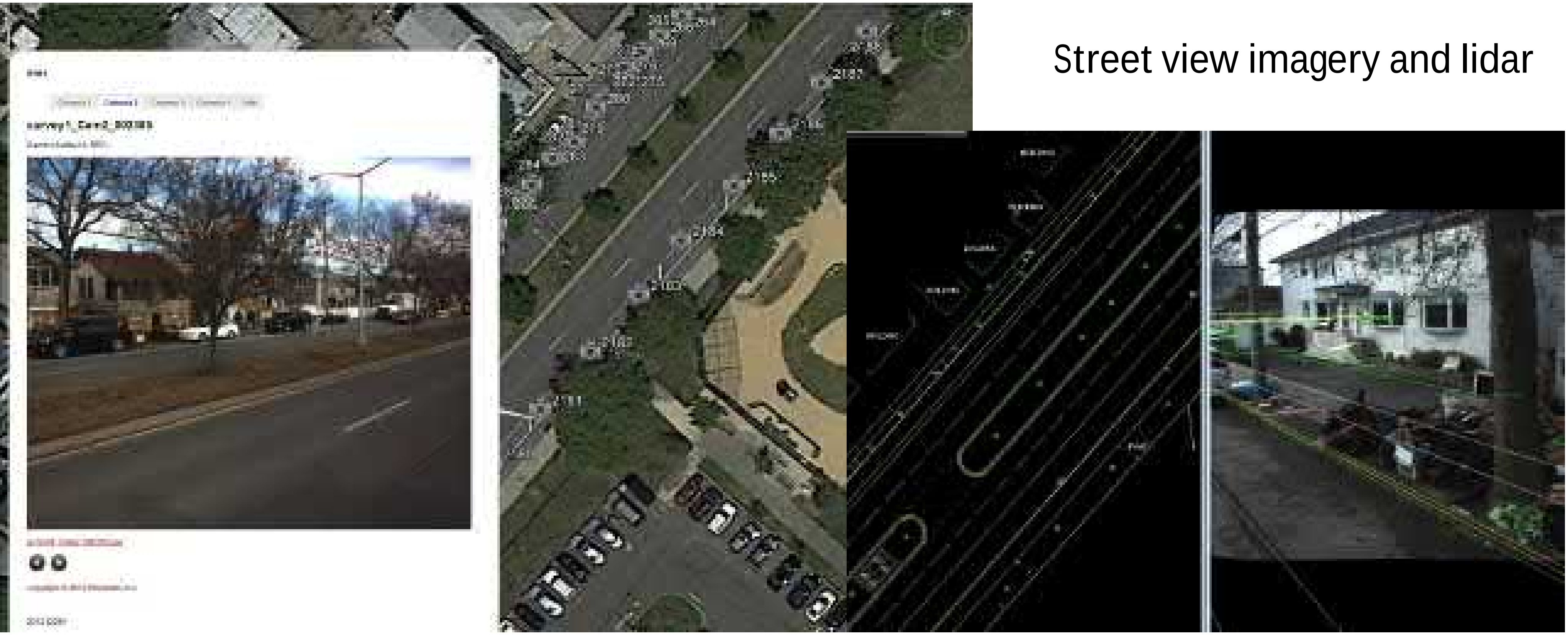
2,000 pts/m^2 to 6,000 pts/m^2

Accuracy≅1.8 cm

Strength of Mobile Mapping System Technology (MMS)

- Best positional accuracy RMSE = 0.05’ or better
- Very dense points cloud 2000 to 6000 points/m2
- Oblique/ground view versus top-down aerial
- Dual Lidar-imagery acquisition

Strength of Mobile Mapping System Technology (MMS)

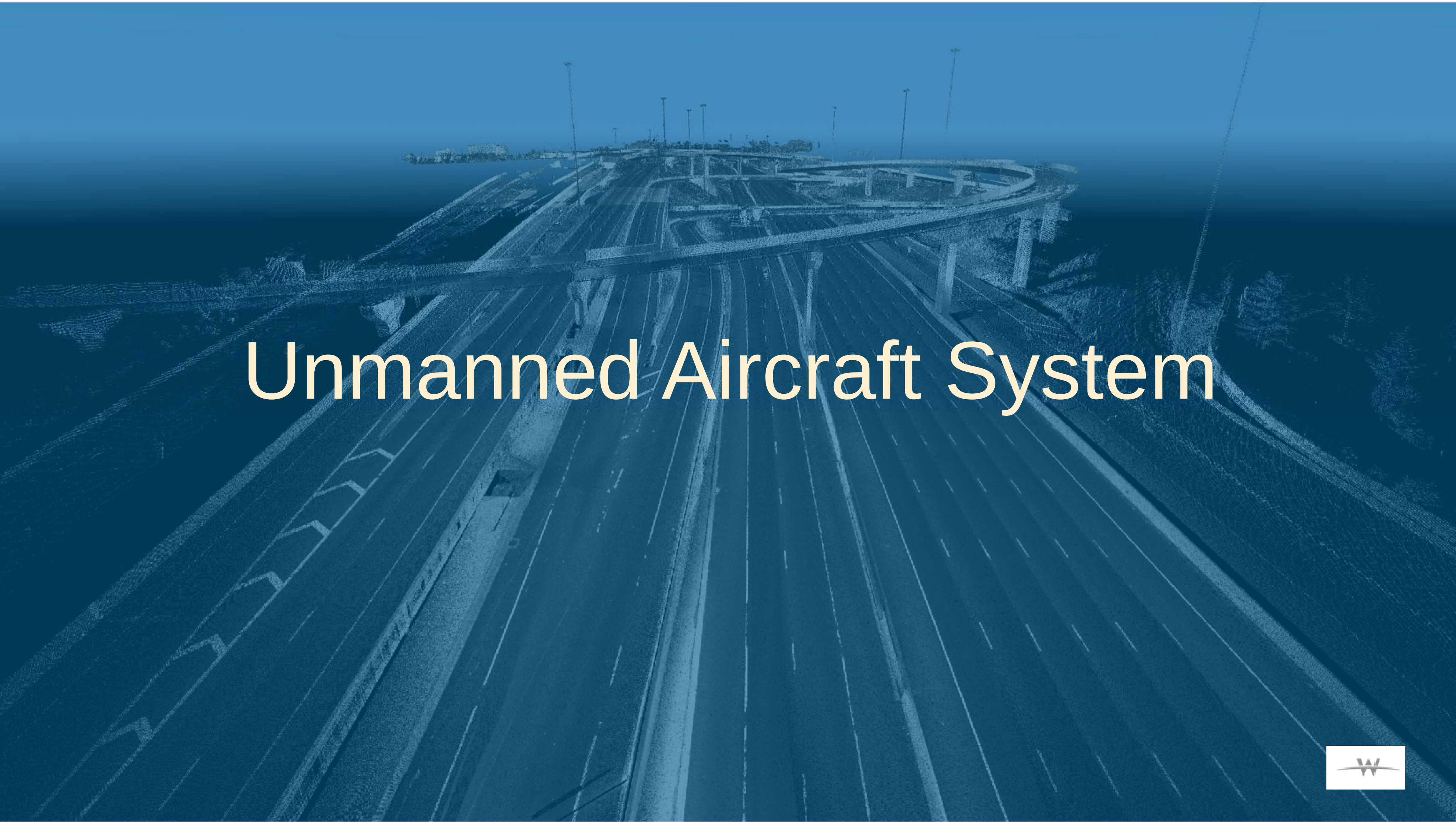


Street view imagery and lidar

Limitations of Mobile Mapping System Technology (MMS)

1. Used only on driven roads
2. Limited range
3. Not suitable for rural environment

Unmanned Aircraft System



UAS-derived Points Cloud

UAS Deliverables

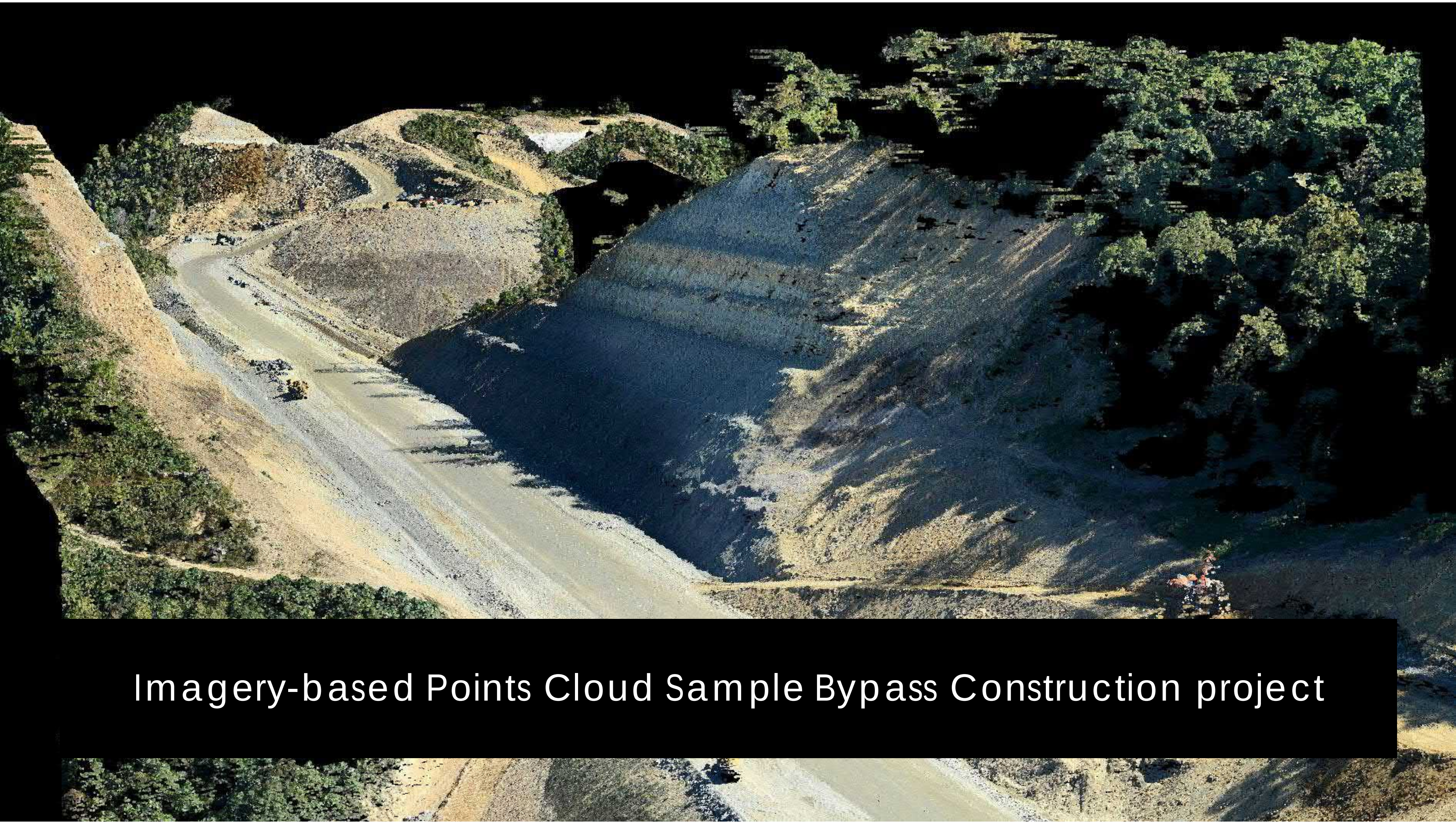
One collect can be used to create multiple datasets

Orthophotography/Video

DSM/DTM/Stereo Compilation

Colorized Point Cloud

Horizontal and Vertical Accuracy*: RMSE= 0.05’ to 0.25 ft
*Absolute accuracy is dependent on quality and amount of control
eBee X can deliver 0.05’ accuracy



Imagery-based Points Cloud Sample Bypass Construction project

Points cloud from imagery

210 points/m^2

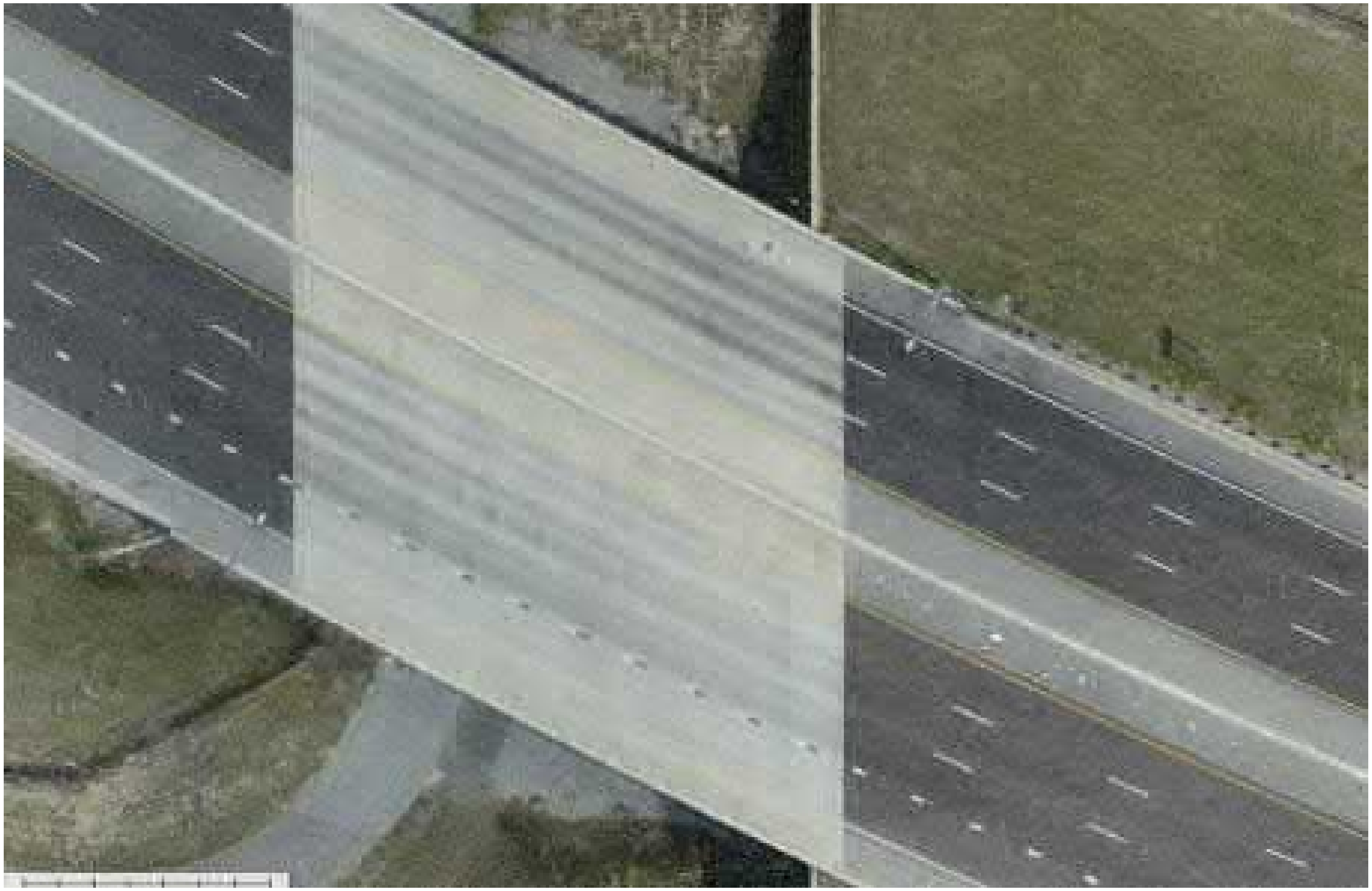


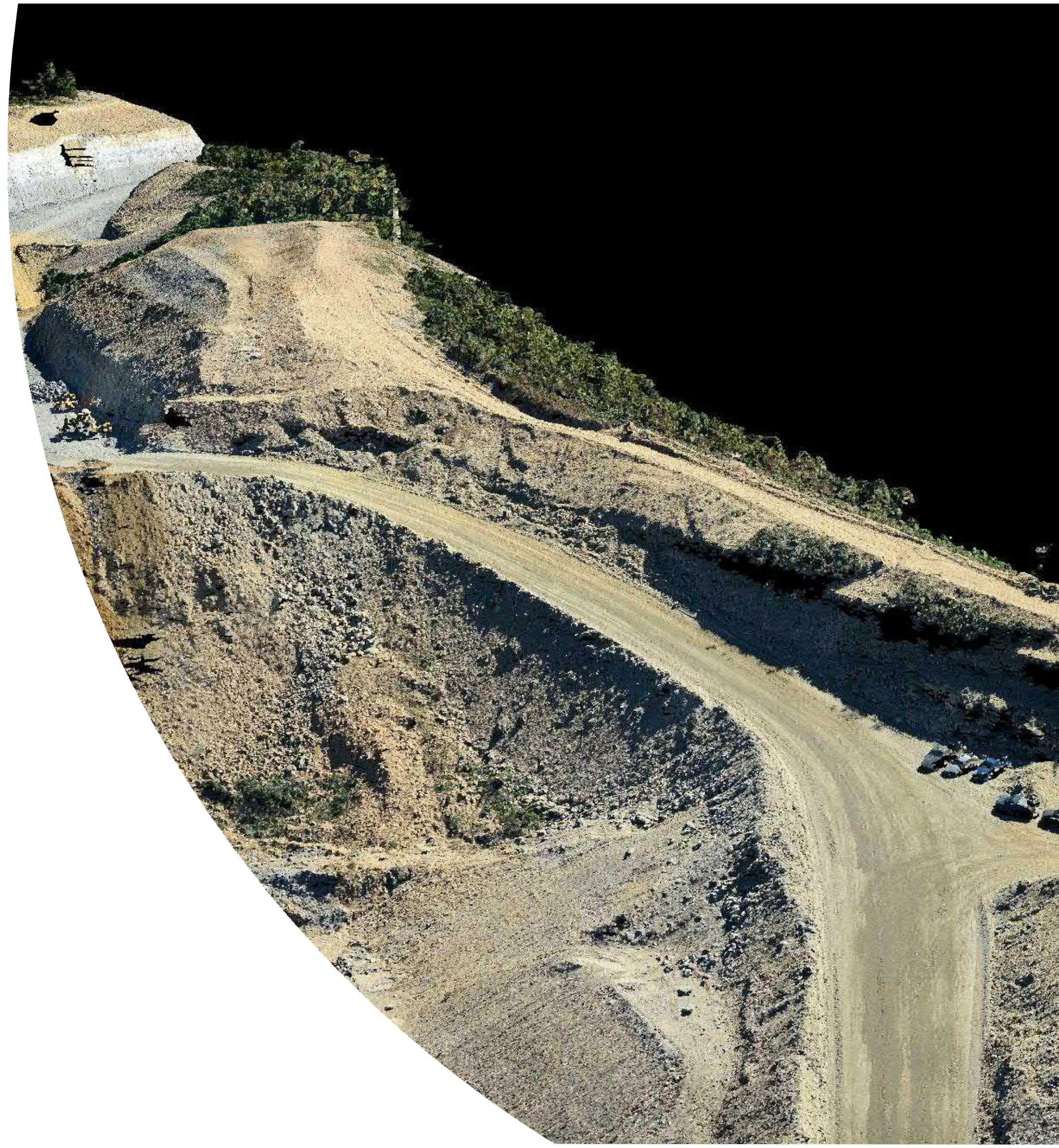
Image Based Points Cloud From Drones

Strength of Points Cloud from UAS Imagery

- Birds Eye View, i.e. beyond MMS coverage
- Affordable approach
- Easy to deploy
- Easy to process
- Excessive Overlap

Limitations of Points Cloud From Imagery

- Less accurate than Lidar
- No trees penetration
- FAA Regulations



The Hybrid Product Approach

The Best of All Worlds:

The Hybrid DSM

Aerial Lidar + MMS + UAS

Aerial Lidar:

Points Density: up to 30 pts/m^2

Accuracy(v) RMSE = 6 to 15 cm

MMS:

Points Density: 2,000 to 6,000 pts/m^2

Accuracy(v) RMSE = 1.5 cm

UAS:

Points Density: 40 to 1000 pts/m^2

Accuracy(v) RMSE = 5 to 15 cm

Project 1:

The Petersburg/Overman Roads Intersection Improvement, Ohio

Project Case:

The Petersburg/Overman Roads Intersection Improvement, Ohio

Data Used:

- Mobile Mapping Lidar
- Existing Ohio State Wide Lidar Program
- Drone-based imagery and point clouds

The Hybrid DSM Approach

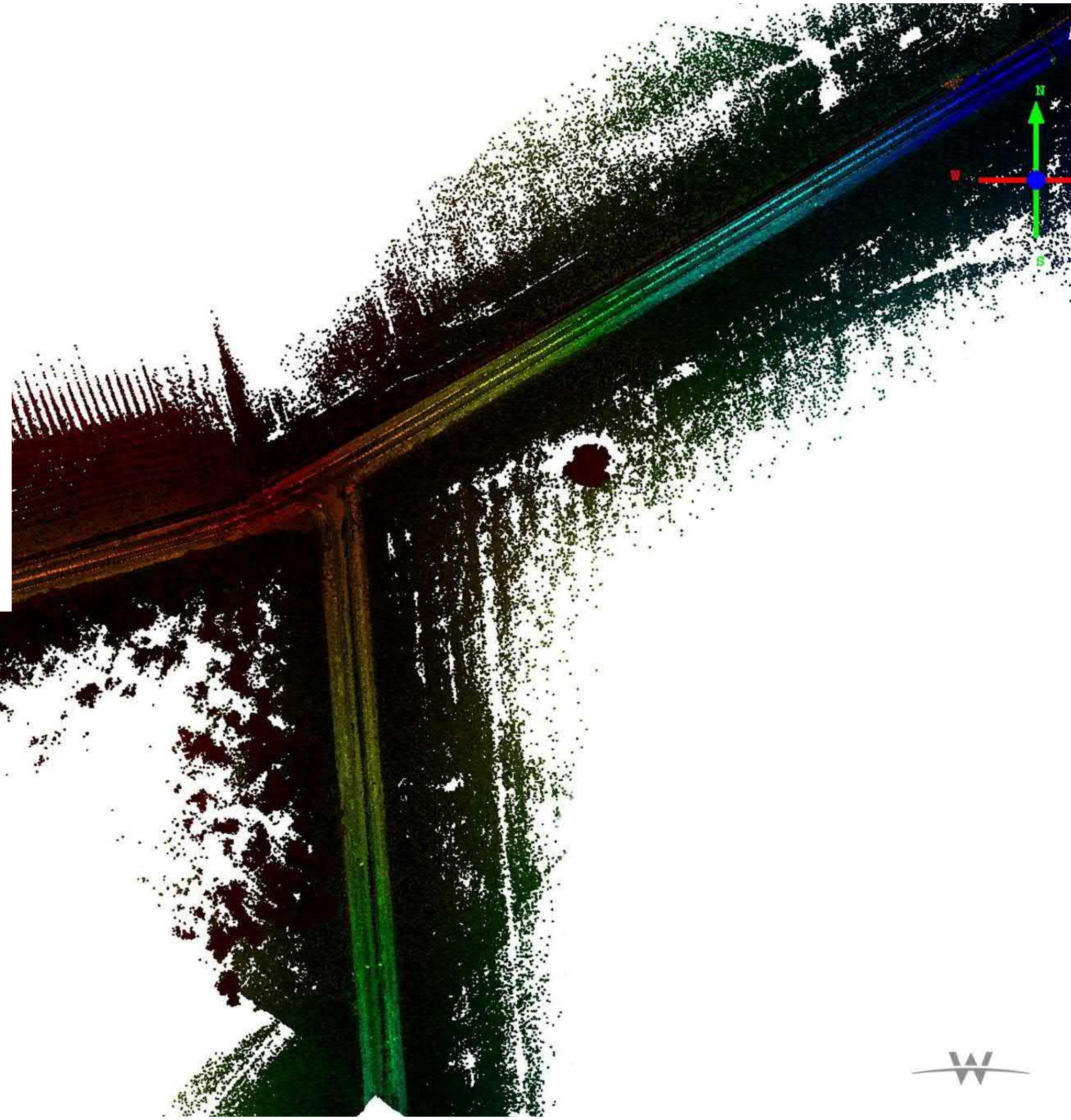
Step-by-step instructions


I. Accuracy Verification
All products used in data fusion need to be analyzed and verified

The MMS Data

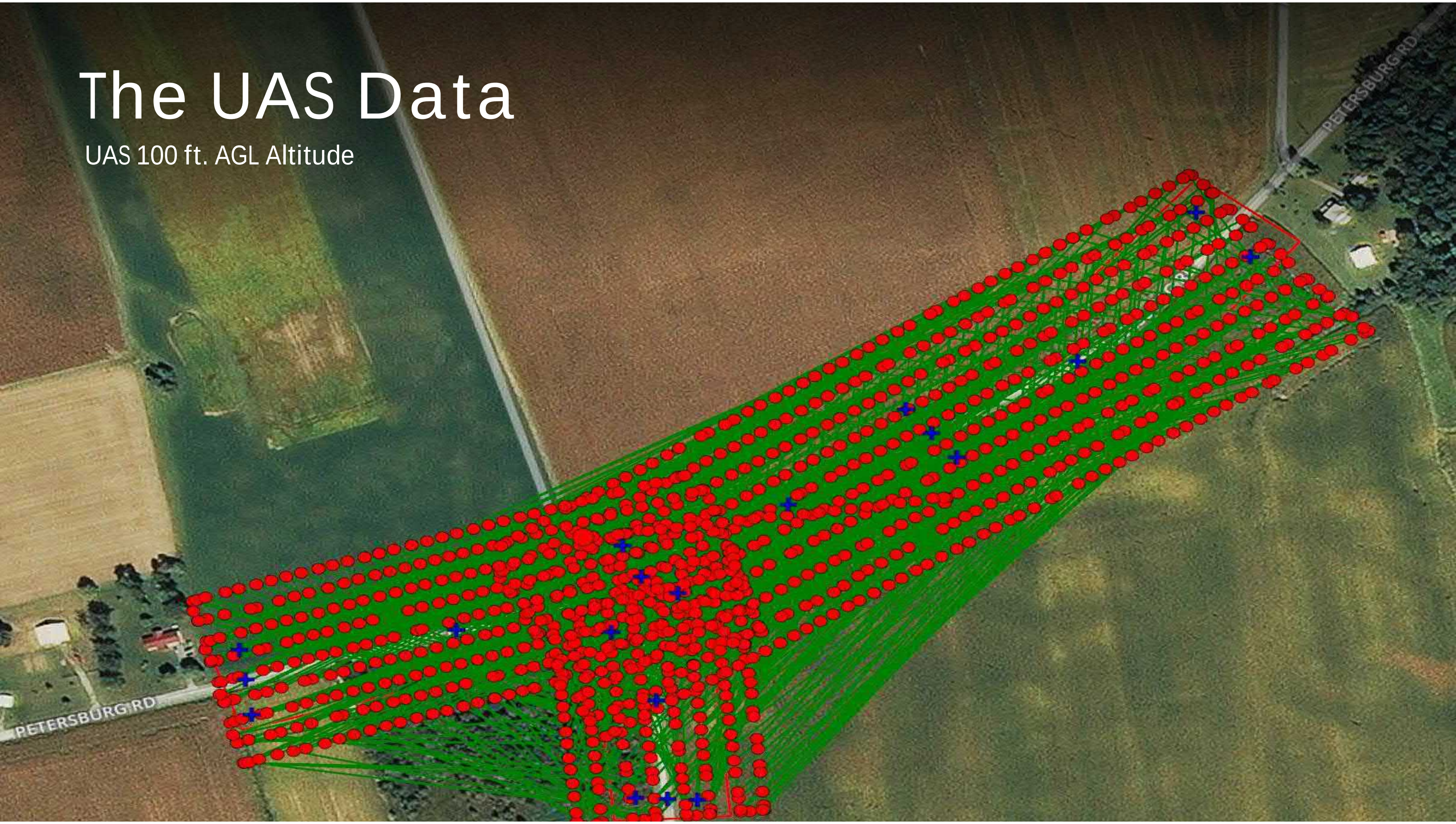
Accuracy Validation

Number of Check Points	79	
Mean Error	0.023 ft.	0.007 cm
Standard Deviation (StDEV)	0.037 ft.	0.011 cm
Root Mean Squares Error (RMSEz)	0.043 ft.	0.013 cm
NSSDA Vert Accuracy at 95% Confidence Level	0.085 ft.	0.026 cm



The UAS Data

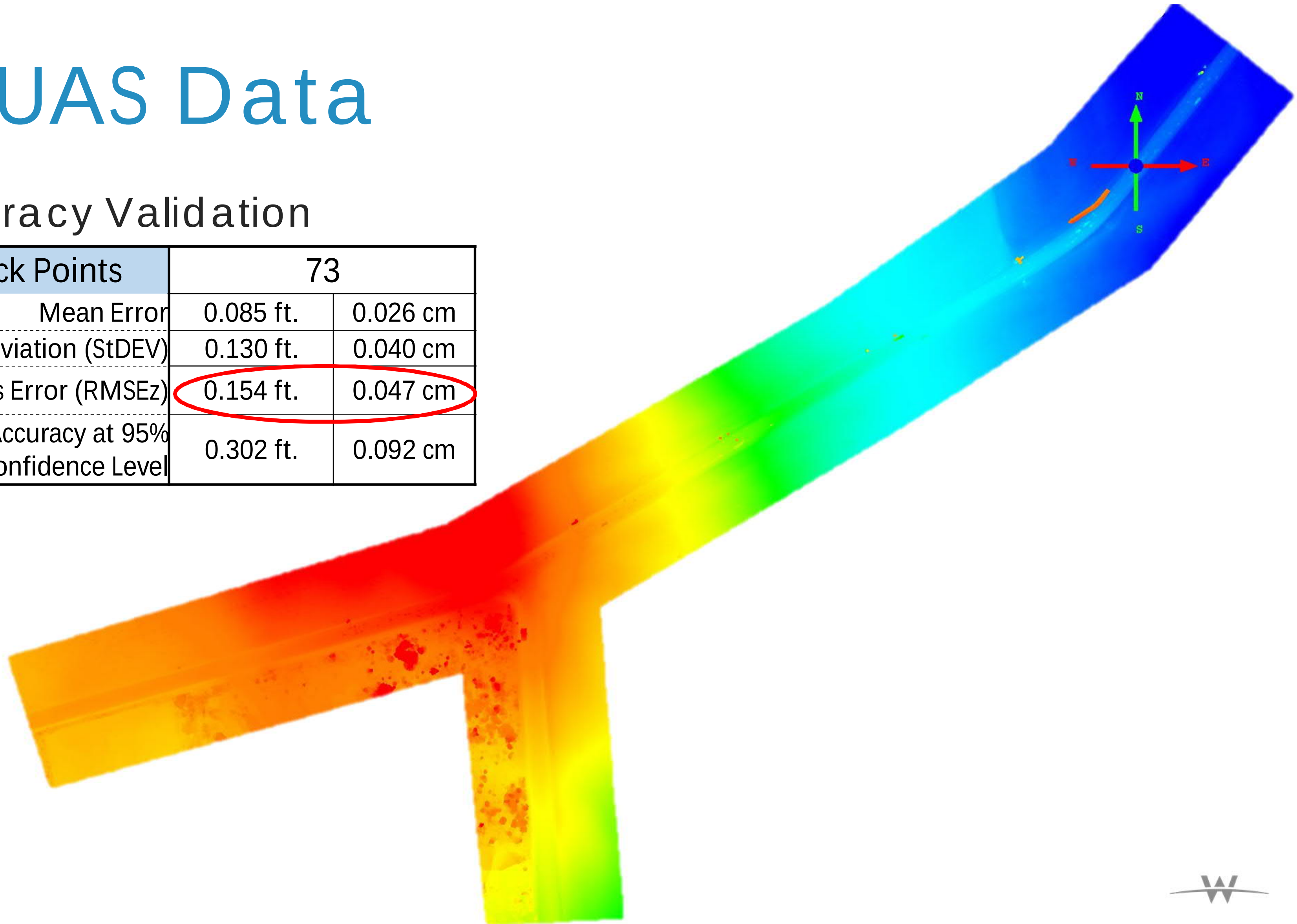
UAS 100 ft. AGL Altitude



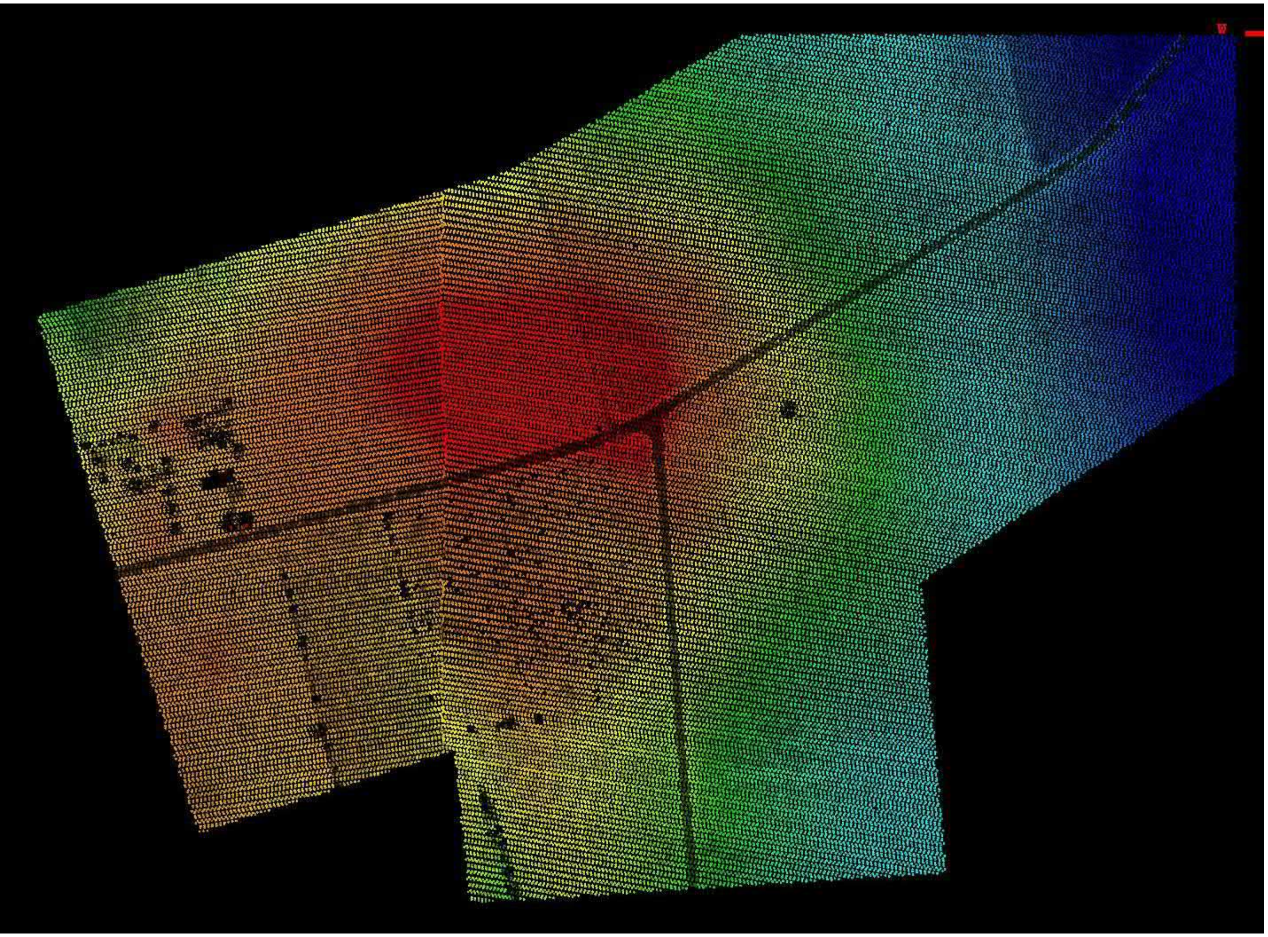
The UAS Data

Accuracy Validation

Number of Check Points	73	
Mean Error	0.085 ft.	0.026 cm
Standard Deviation (StDEV)	0.130 ft.	0.040 cm
Root Mean Squares Error (RMSEz)	0.154 ft.	0.047 cm
NSSDA Vert Accuracy at 95% Confidence Level	0.302 ft.	0.092 cm



The Aerial Lidar: Existing OSIP (State wide program)



Accuracy Validation

Number of Check Points	197	
Mean Error	0.47 ft.	14.39 cm
Standard Deviation (StDEV)	0.16 ft.	4.90 cm
Root Mean Squares Error (RMSEz)	0.50 ft.	15.19 cm
NSSDA Vert Accuracy at 95% Confidence Level	0.98 ft.	29.79 cm

The Aerial Lidar Data

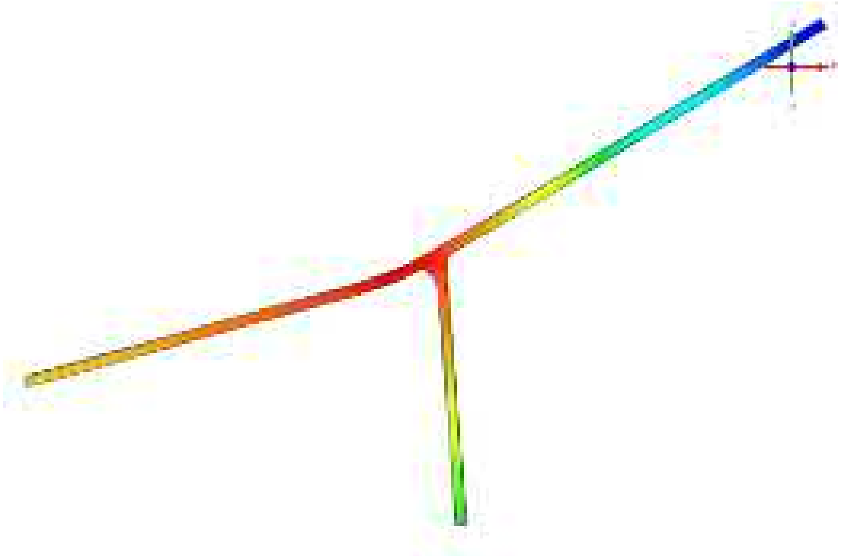
II. Data Preparation

Data need to be prepared for data fusion:

- Data reformatting necessary
- Reprojection if necessary
- Clipping and cropping

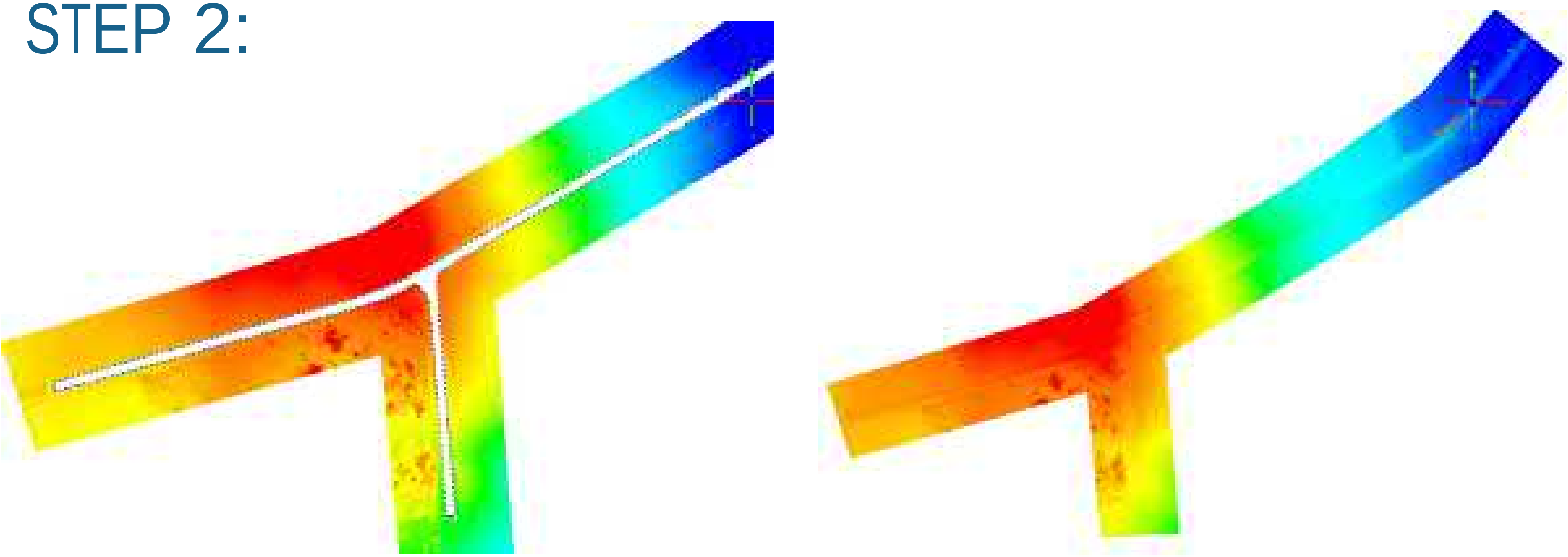
STEP 1:

Clipping good data (only good around driven roads)



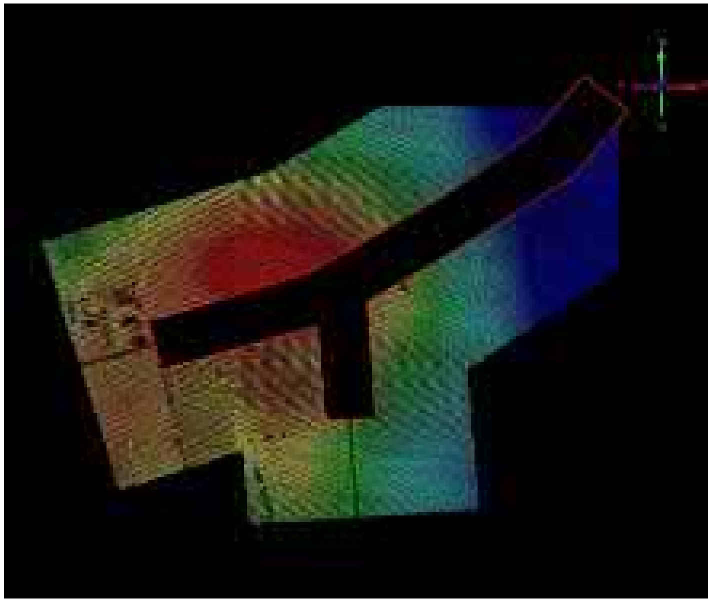
Preparing the MMS Data

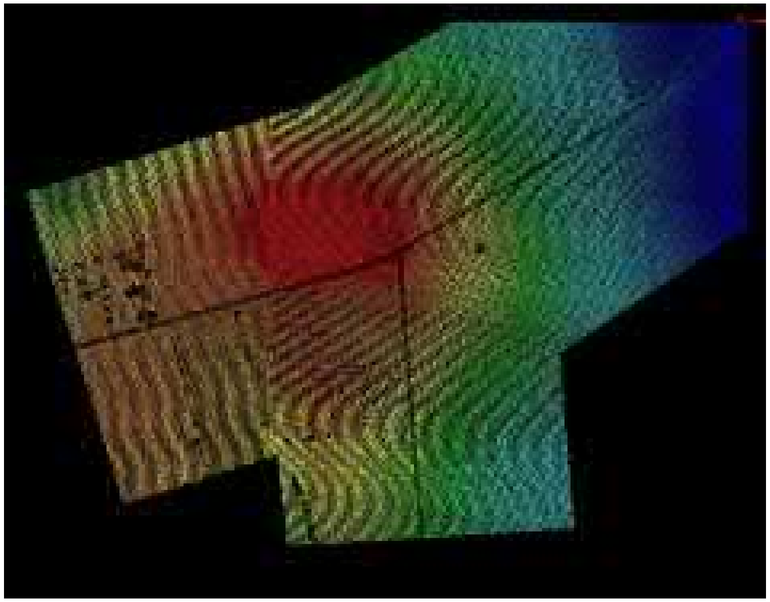
STEP 2:



Preparing the Drone-based DSM

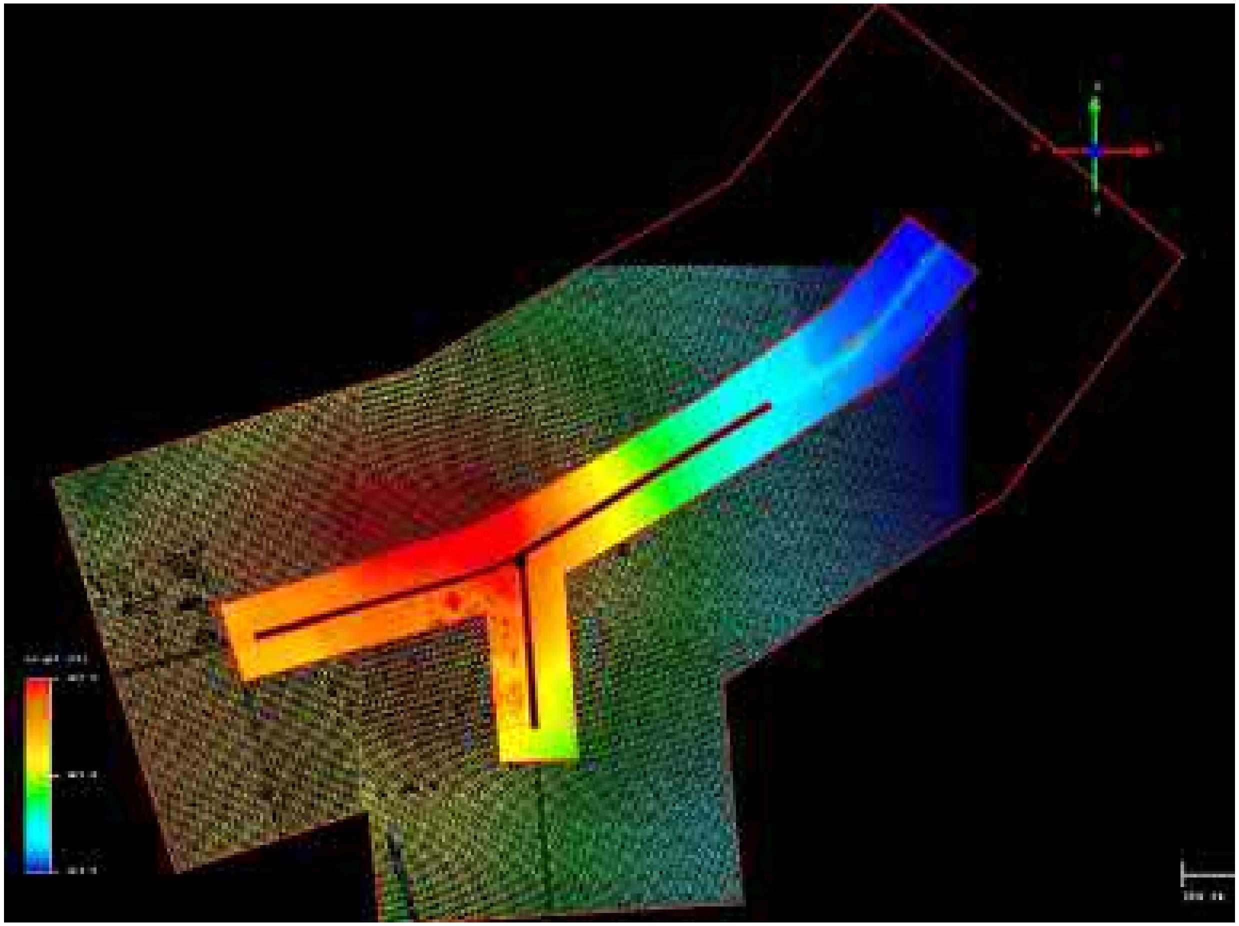
STEP 3:



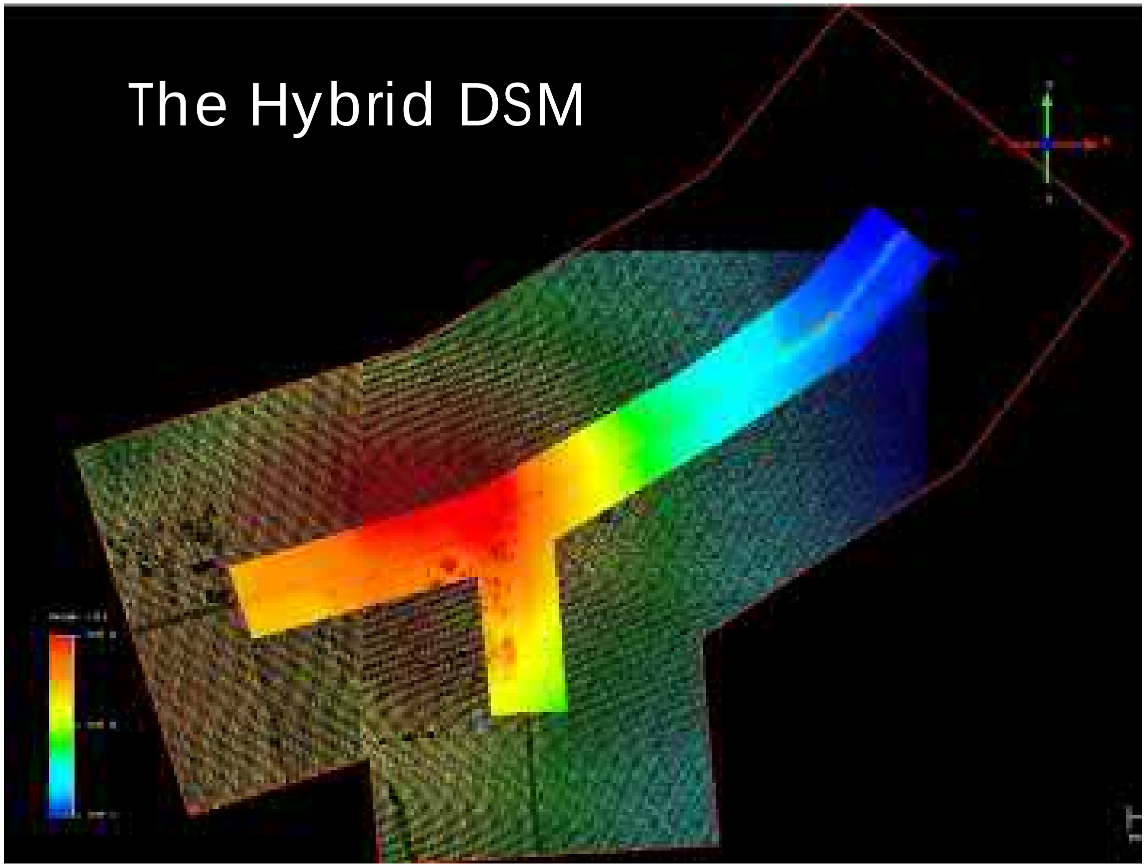


Preparing the Aerial Lidar from Ohio Statewide Project

STEP 4: Merging Aerial Lidar + UAS DSM



STEP 5: Merging Aerial Lidar + UAS DSM + MMS DSM (The Hybrid DSM)



III. Products Development and Final Deliverables

Resulting Products:

Seamless Dataset

One-foot contours

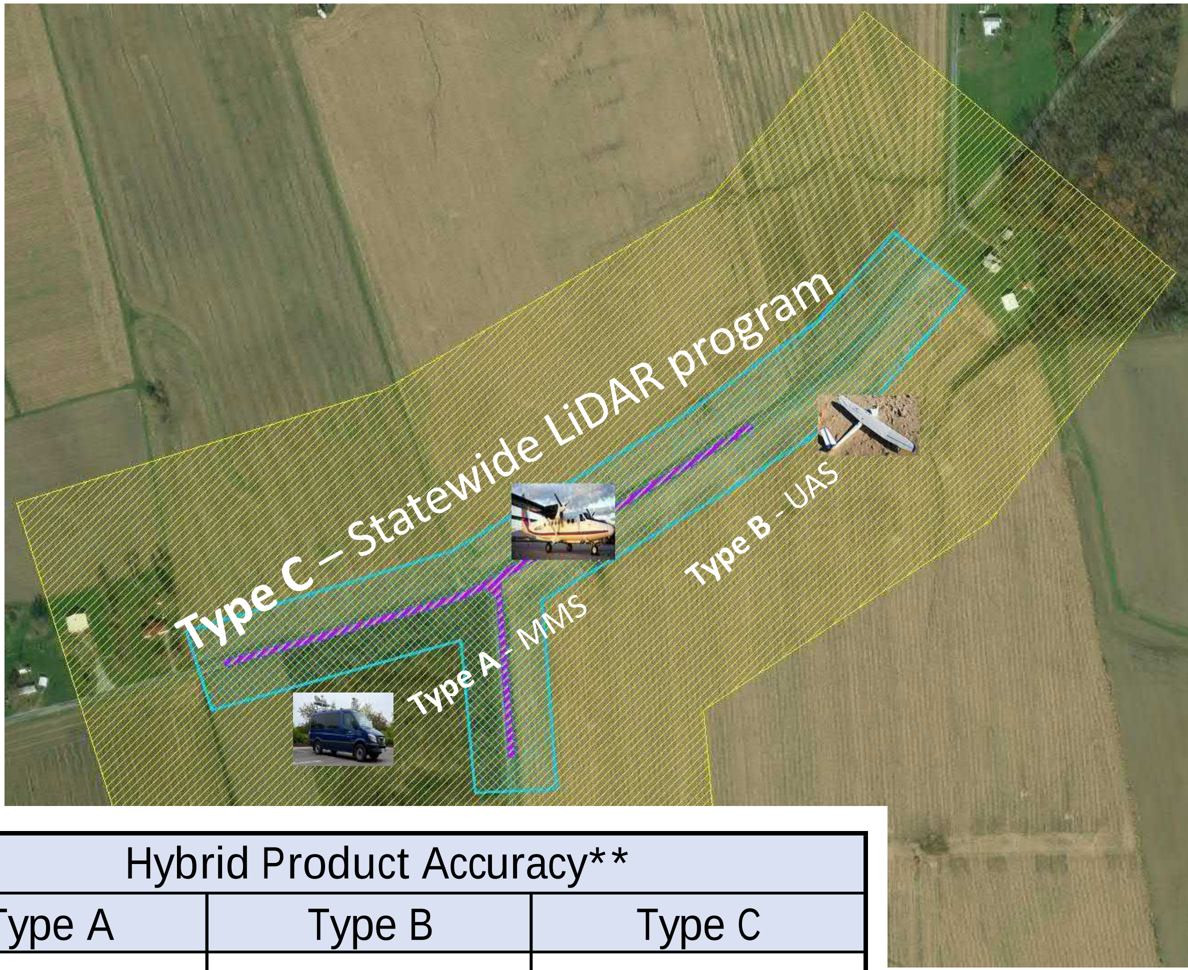
Hybrid Approach to Project Data

Final Outcome: Accuracy on Demand

The Results:

- Hybrid DSM that is more affordable and more suitable for site planning and project design

- Data Fusion provides accuracy where you need it most!



Product Specification	Hybrid Product Accuracy**		
	Type A	Type B	Type C
Terrain surface accuracy as verified using independent check points	$RMSE_v \leq 0.06$ ft.	$RMSE_v \leq 0.10$ ft.	$RMSE_v \leq 0.50$ ft.

** Type A = MMS lidar , Type B = UAS imagery-based points cloud, Type C = State wide lidar program

Project #2

Mapping Products Generation from UAS: Proof of Concept for PennDOT

Project Objectives

BACKGROUND

Woolpert acquired and delivered Mobile Mapping Lidar System (MMS) data and 3” natural colors imagery for PennDOT for section 35 of SR80

OBJECTIVES

Woolpert pursued a proof of concept study to investigate the feasibility of using Unmanned Aircraft System (UAS) for the following PennDOT activities:

- Whether stereo compiled DTM from UAS can augment or replace the need for MMS to model edge-to-edge pavement modeling
- To evaluate the quality and suitability of the high resolution ortho-rectified imagery and points cloud generated from UAS within and outside ROW for other roads planning and design activities by PennDOT

The Project Procedure

Project Design and Mission Planning

We deployed Sensefly eBee X with RTK/PPK Capability

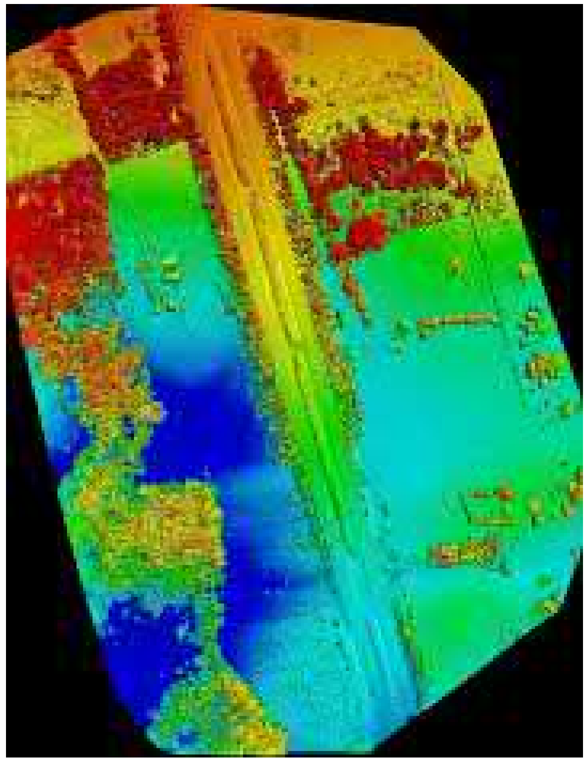
eBee X
Fixed-Wing Drone

senseFly S.O.D.A. 3D
Mapping Camera

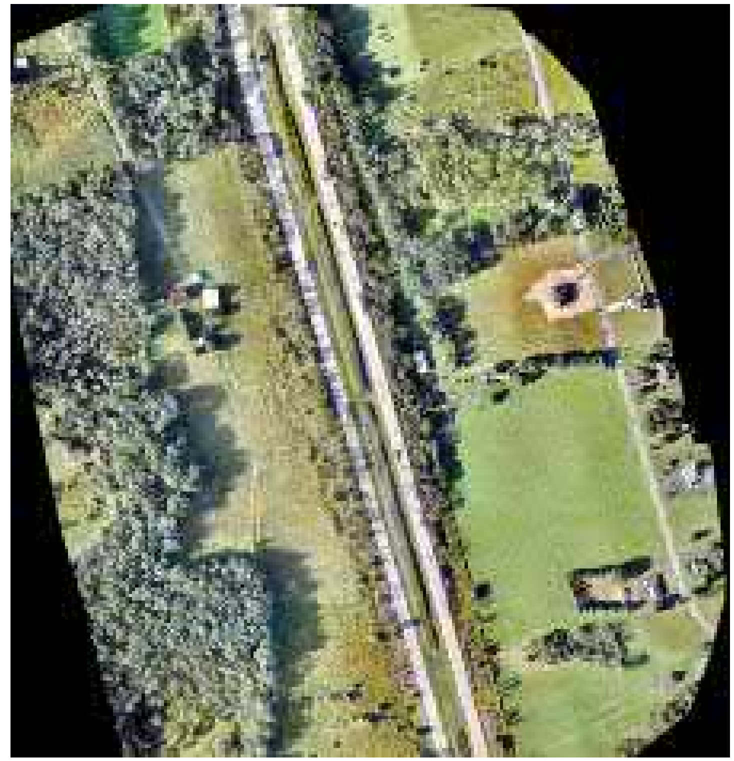
Collected imagery with
2.53-cm GSD (1”)

We produced

Stereo compiled break lines



Digital Surface Model



Ortho-rectified Mosaic GSD = 2.5 cm (1")

Products Quality

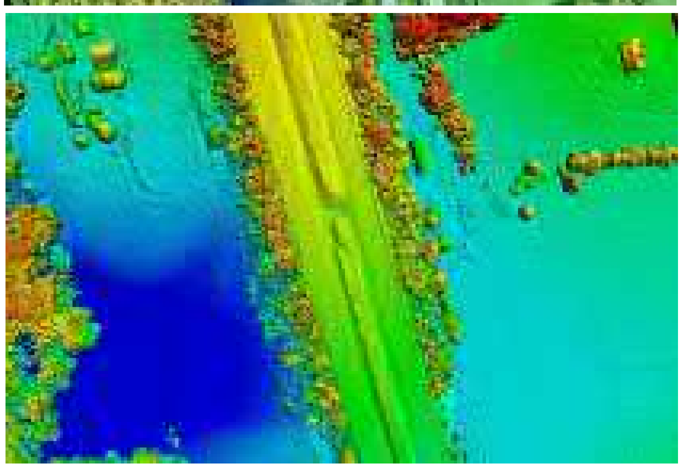
UAS Imagery Quality

GSD = 1”
(2.54-cm)

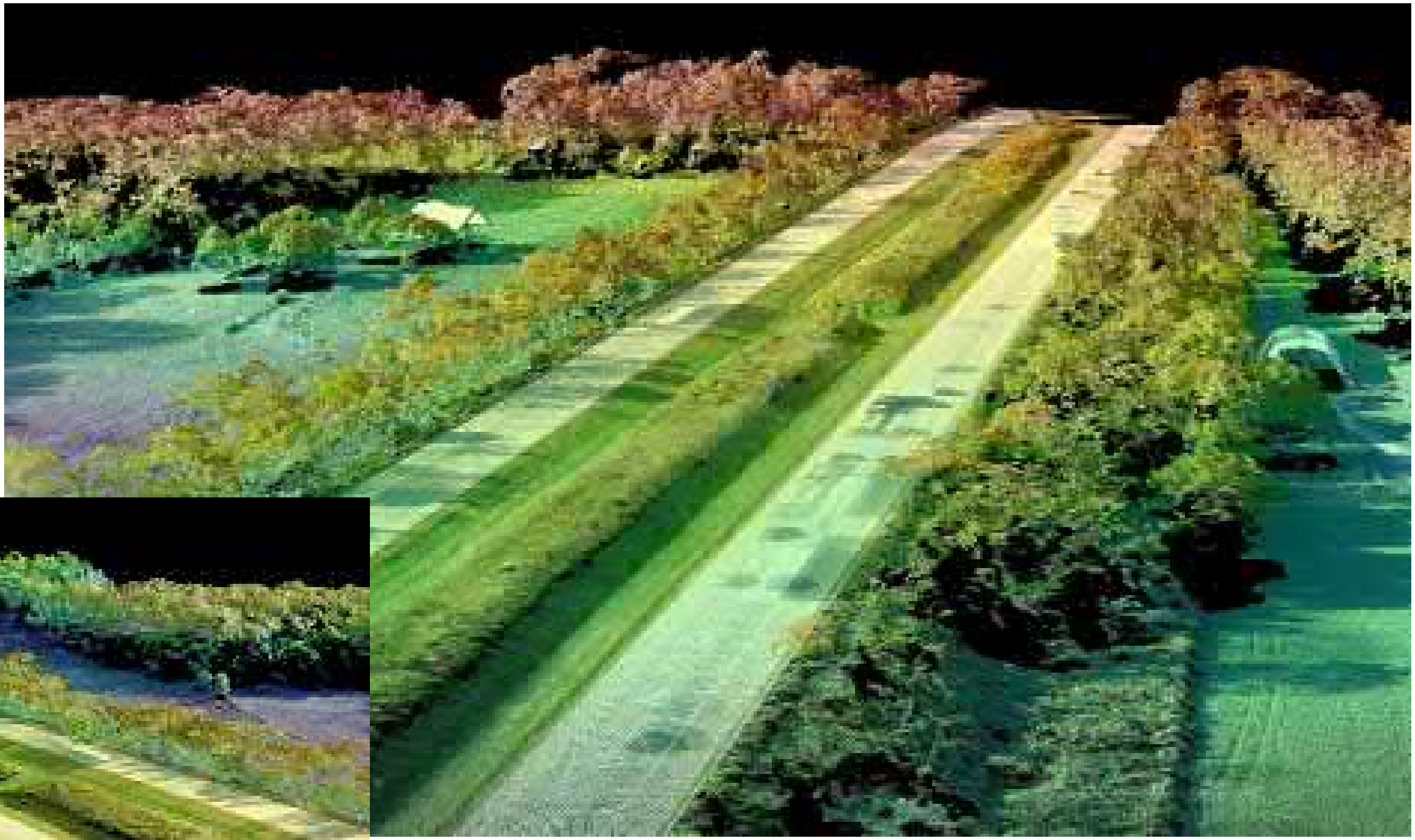
Imagery Quality: UAS versus Manned

Imagery Quality: UAS versus Manned

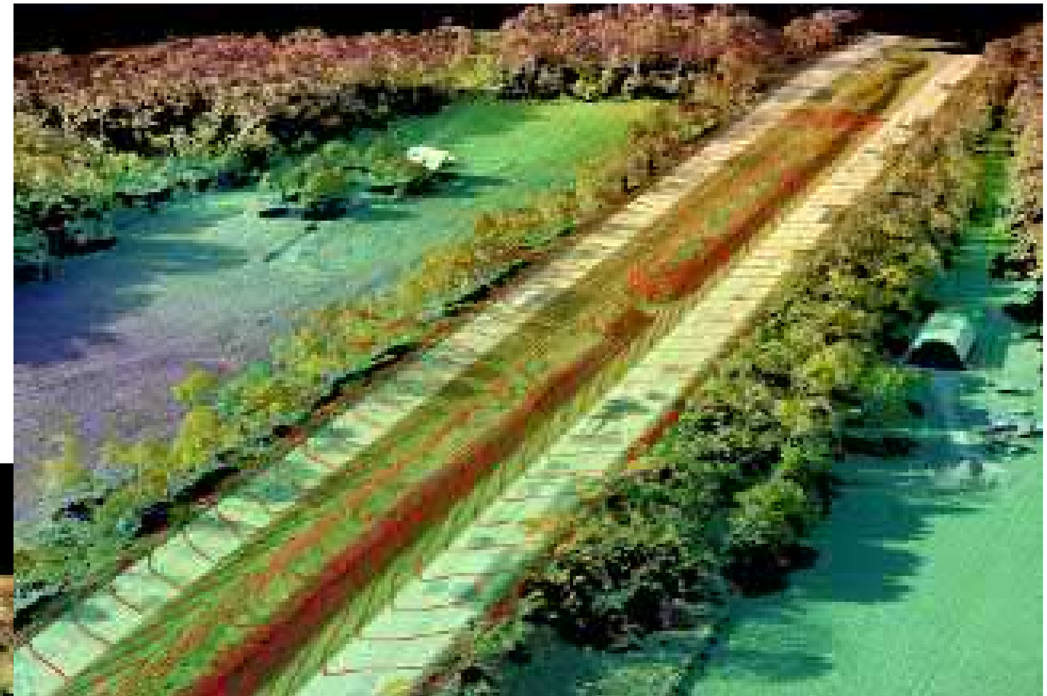
Points Cloud Quality

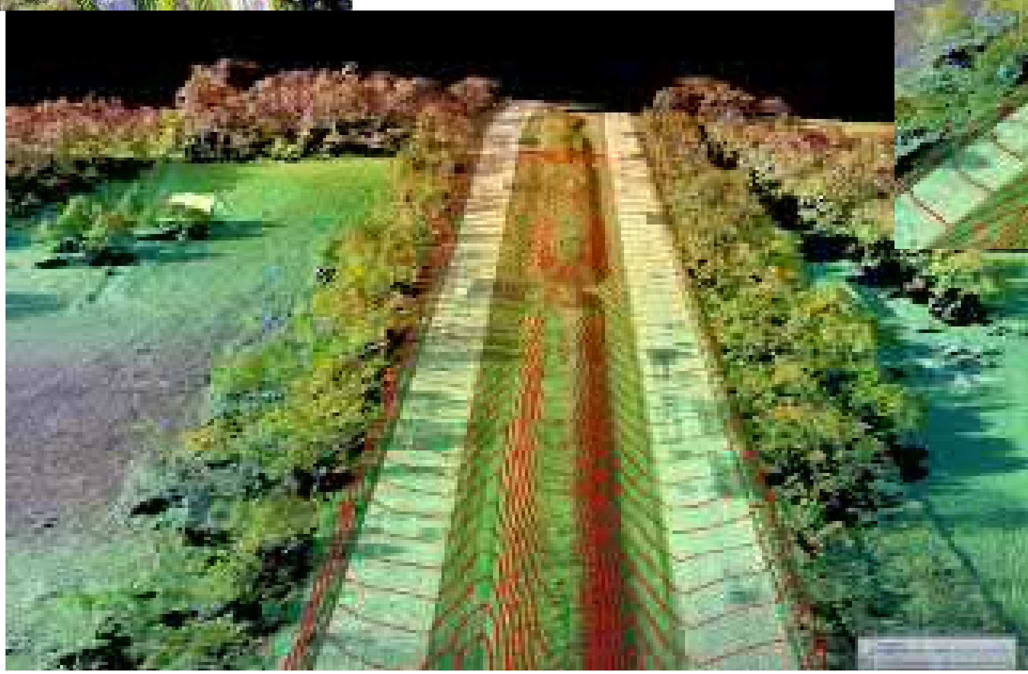


UAS Points Cloud Quality

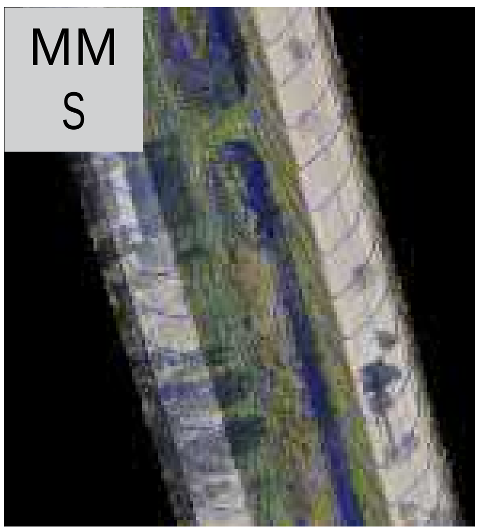


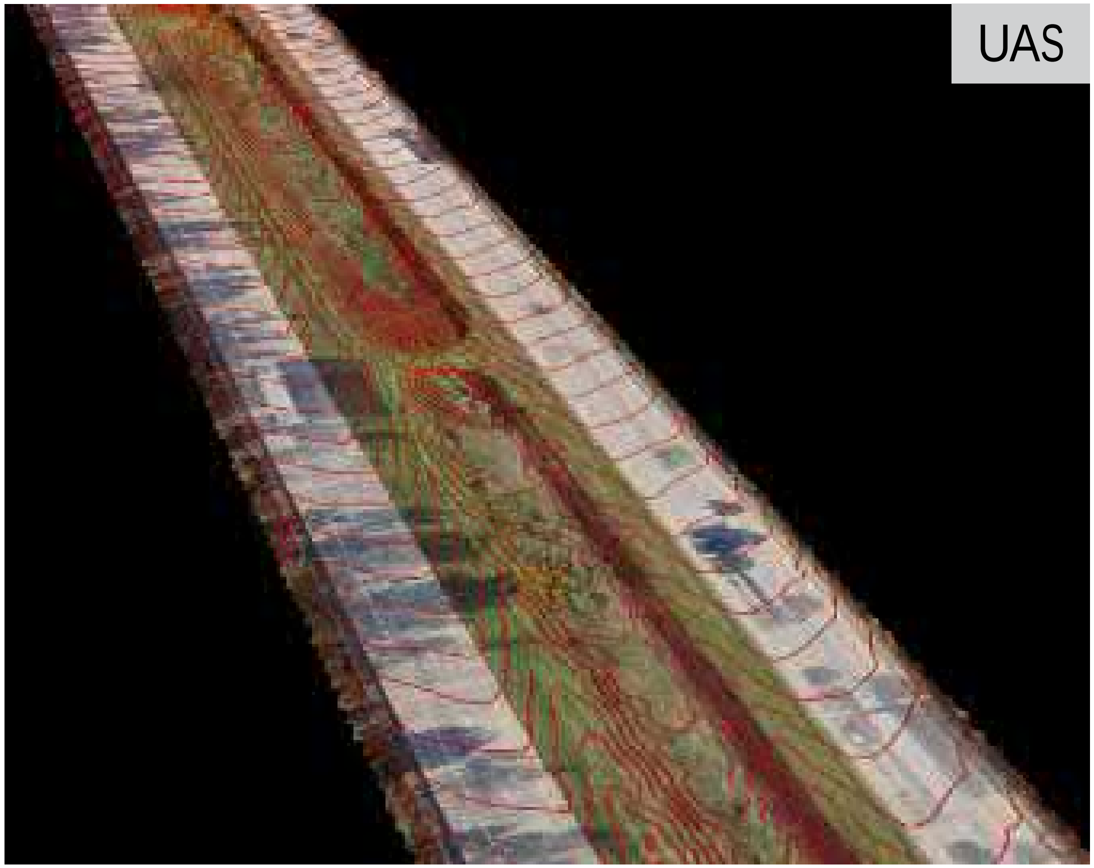
UAS Contours Quality

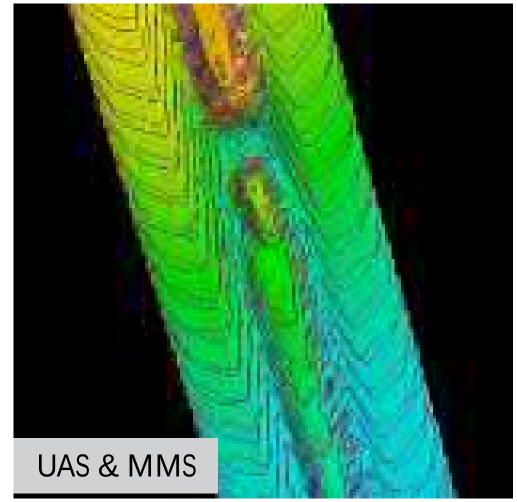


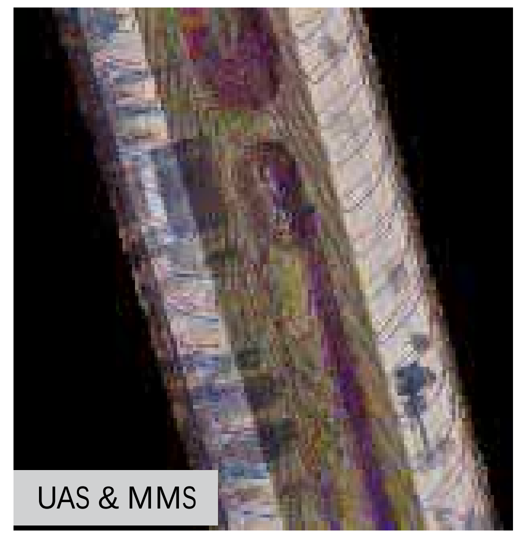


Contours Quality









Red: UAS Blue: MMS

MMS: Mobile Mapping System

Positional Accuracy

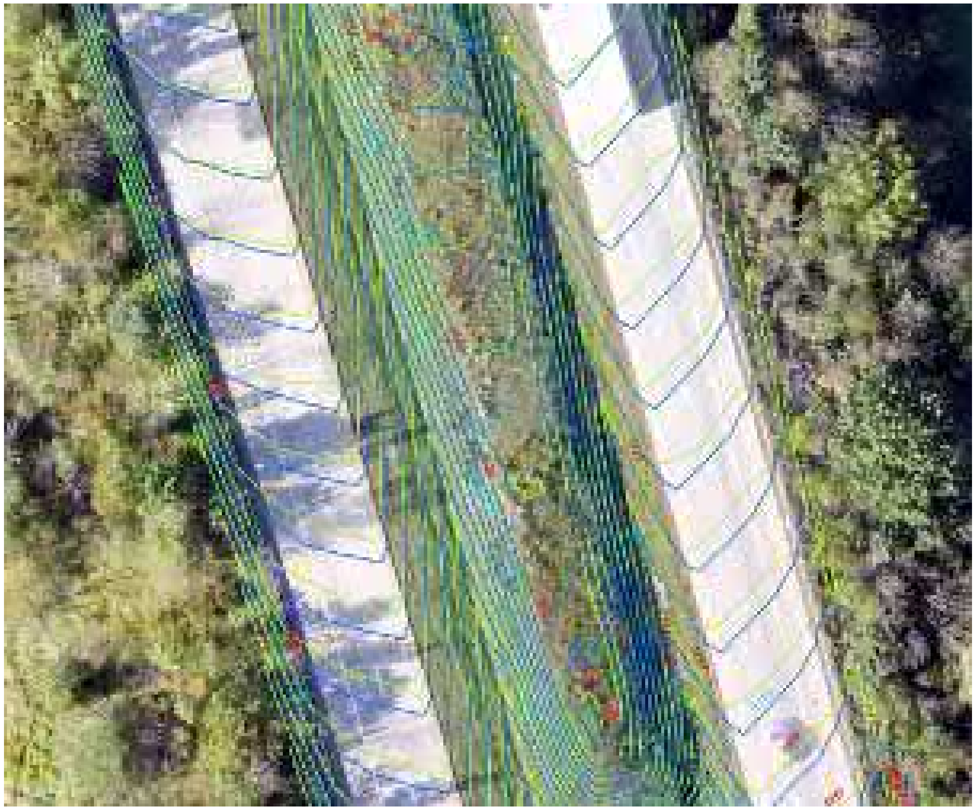
DTM and Contours Analysis

Contours Quality

Vertical Accuracy

Contours from UAS

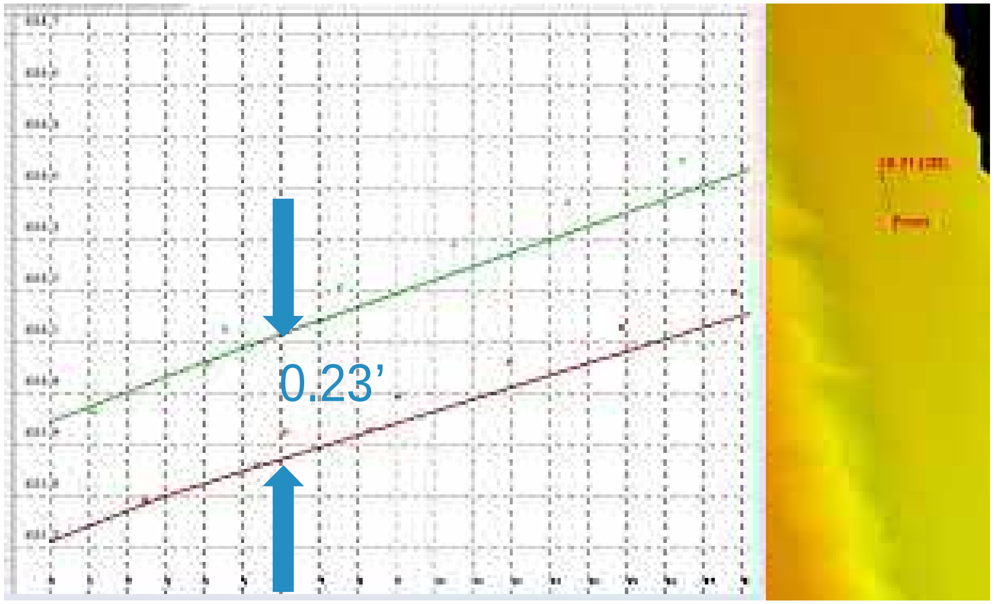
Contours from UAS & MMS



Green: UAS Blue: MMS

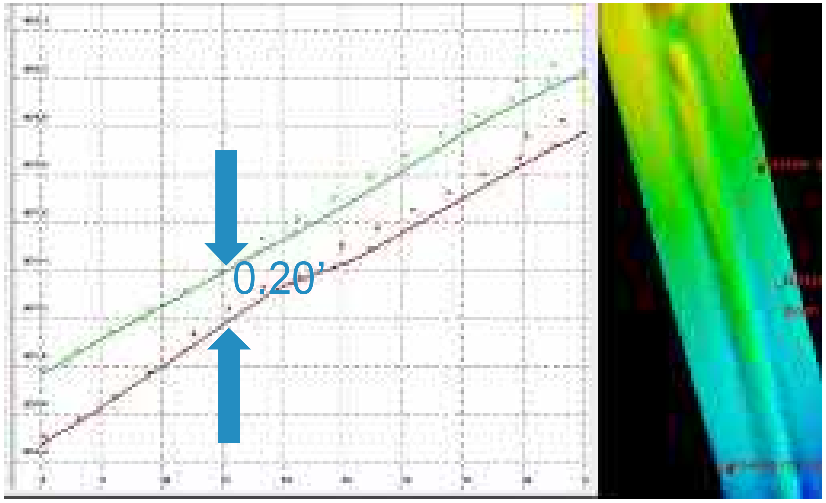
UAS Accuracy as Compared to Mobile Lidar (MMS)

Finding 0.2 ft. bias

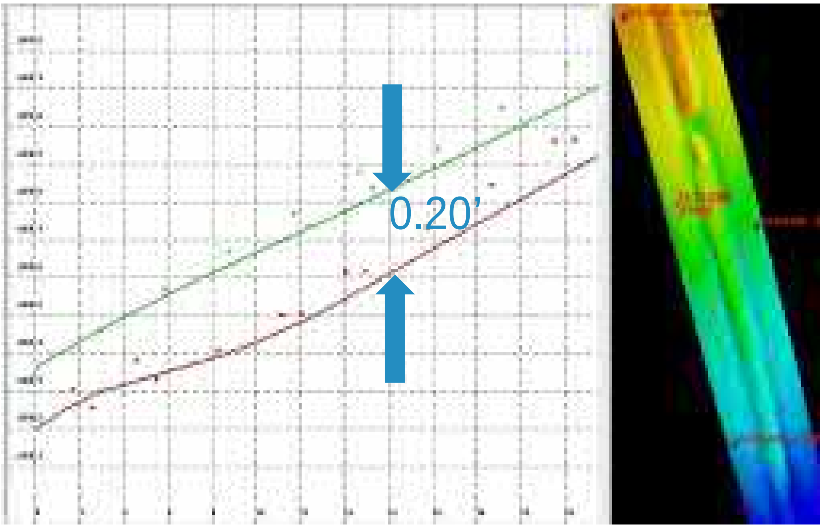


Cross section 1

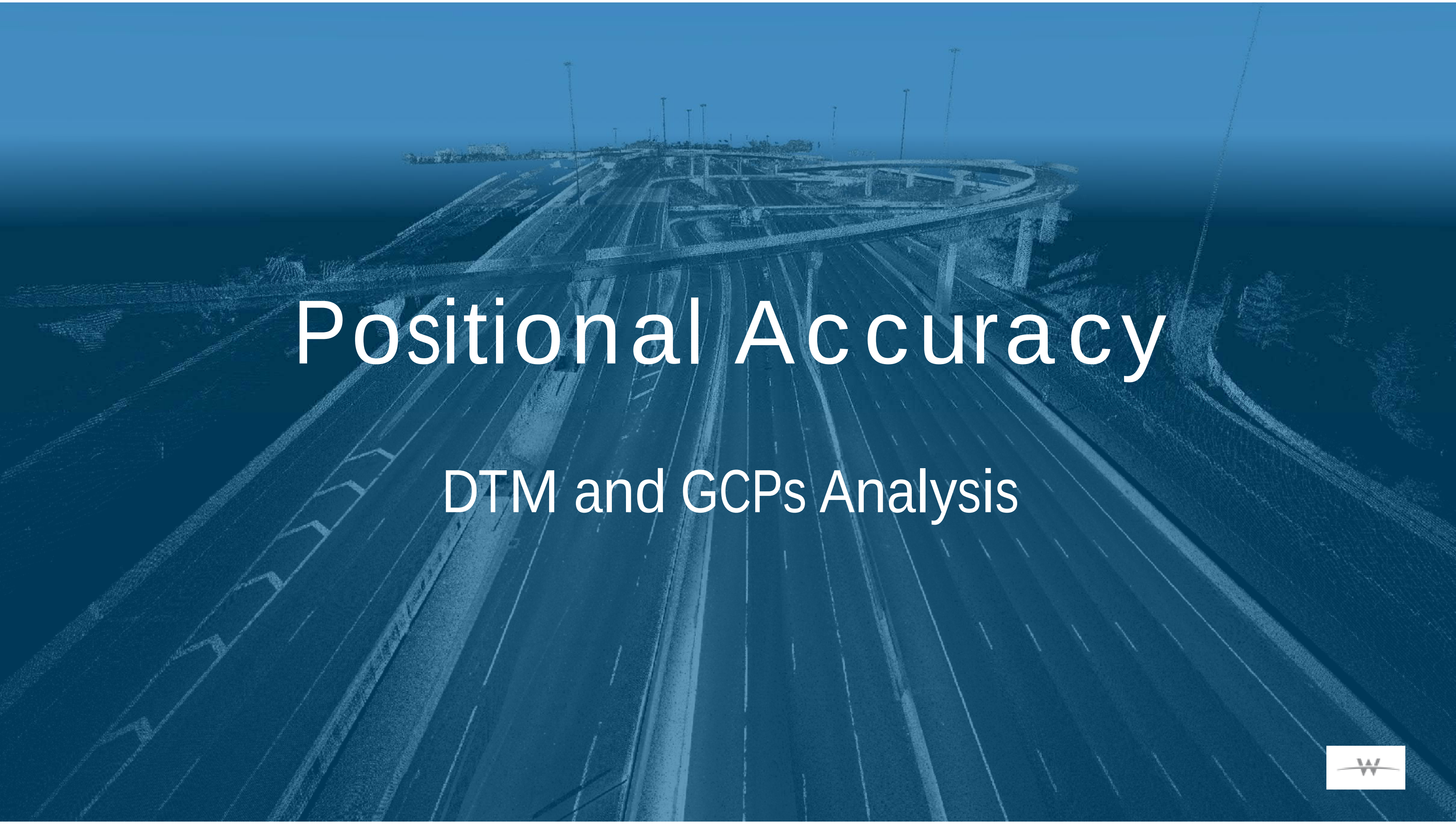
RED: UAS GREEN: MMS

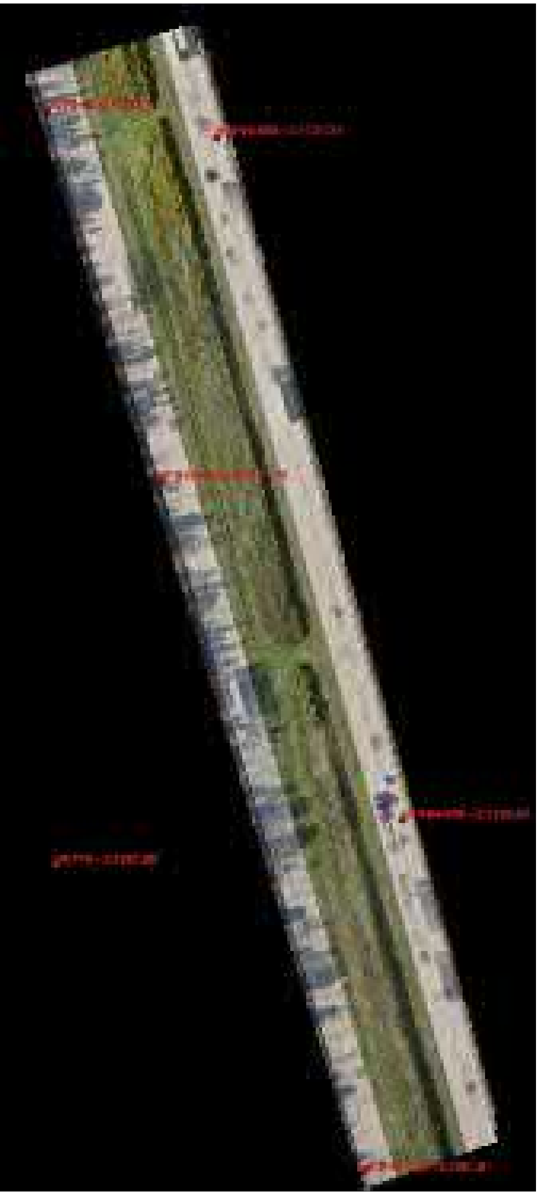


Cross section 2



Cross section 3


Positional Accuracy
DTM and GCPs Analysis

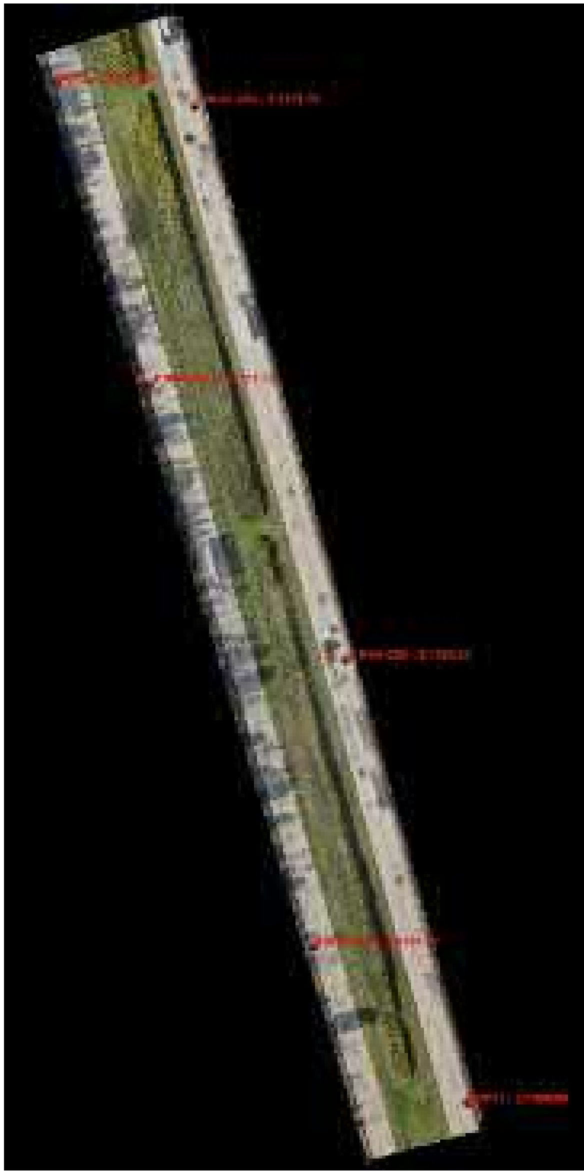


MMS DTM Accuracy As Compared to 5 GCPs

PennDOT UAS Proof of Concept - Accuracy Analysis (Comparing MMS DTM to GCPs)						
Point ID	Surveyed Elevation			MMS Elevation	Residual Values (ft.)	Delta Z after Z-bias Removed (ft.)
	Easting (ft.)	Northing (ft.)	Elevation (ft.)	Elevation (ft.)	Error in Elevation (ft.)	
GCP2	2447293.2930	322244.4390	1137.8010	1137.8695	-0.0685	-0.0302
9-04-029	2447677.8720	320950.1000	1091.9690	1092.0690	-0.1000	-0.0617
9-04-030	2447724.3770	321383.5380	1103.5330	1103.5639	-0.0309	0.0074
9-04-031	2447430.5130	321797.2720	1121.9360	1121.9407	-0.0047	0.0336
9-04-032	2447498.4030	322213.3580	1131.3380	1131.3255	0.0125	0.0508
	Number of Check Points				5	5
	Mean Error				-0.038	0.000
	Standard Deviation (StDEV)				0.046	0.046
	Root Mean Squares Error ($RMSE_{x\ or\ y\ or\ z}$)				0.056	0.041
	NSSDA Vert Accuracy at 95% accuracy Level				0.110	
	NSSDA Vert Accuracy at 95% accuracy Level after z-bias				0.081	

UAS-derived DTM Accuracy As Compared to 6 GCPs

PennDOT UAS Proof of Concept - Accuracy Analysis (Comparing UAS DTM to GCPs)						
Point ID	Surveyed Elevation			UAS Elevation	Residual Values (ft.)	Delta Z after Z-bias Removed (ft.)
	Easting (ft.)	Northing (ft.)	Elevation (ft.)	Elevation (ft.)	Error in Elevation (ft.)	
GCP2	2447293.2930	322244.4390	1137.8010	1137.6909	0.1101	-0.1810
CP11	2447910.4270	320711.2340	1081.3250	1080.8039	0.5211	0.2300
9-04-029	2447677.8720	320950.1000	1091.9690	1091.6676	0.3014	0.0103
9-04-030	2447724.3770	321383.5380	1103.5330	1103.2408	0.2922	0.0011
9-04-031	2447430.5130	321797.2720	1121.9360	1121.7284	0.2076	-0.0835
9-04-032	2447498.4030	322213.3580	1131.3380	1131.0238	0.3142	0.0231
	Number of Check Points				6	6
	Mean Error				0.291	0.000
	Standard Deviation (StDEV)				0.137	0.137
	Root Mean Squares Error ($RMSE_{x\ or\ y\ or\ z}$)				0.317	0.125
	NSSDA Vert Accuracy at 95% accuracy Level				0.621	
	NSSDA Vert Accuracy at 95% accuracy Level after z-bias				0.244	



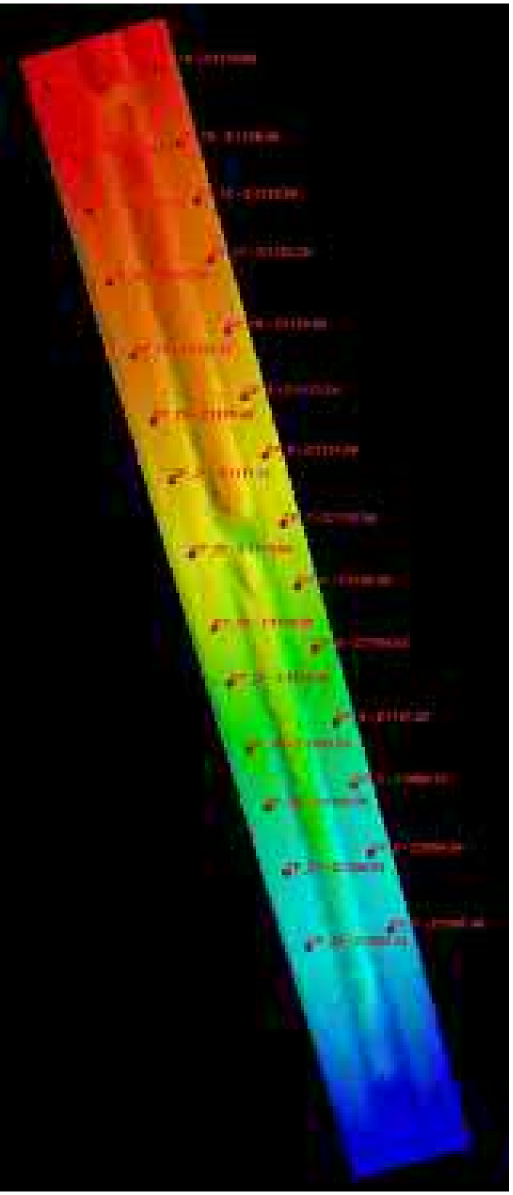
UAS-derived DSM (points cloud) Accuracy as Compared to 14 GCPs

PennDOT UAS Proof of Concept - Accuracy Analysis (Comparing UAS DSM to GCPs)						
Point ID	Surveyed Elevation			UAS Elevation	Residual Values (ft.)	Delta Z after Z-bias Removed (ft.)
	Easting (ft.)	Northing (ft.)	Elevation (ft.)	Elevation (ft.)	Error in Elevation (ft.)	
GCP1	2446871.7270	322224.0520	1101.1950	1101.0107	0.1843	0.1117
CP2	2447293.2930	322244.4390	1137.8010	1137.8131	-0.0121	-0.0847
CP4	2448031.2750	322011.6600	1096.2910	1096.1981	0.0929	0.0203
CP5	2447080.0510	321196.4780	1034.2650	1034.3458	-0.0808	-0.1534
CP8	2448247.4430	321624.7970	1087.3320	1087.2327	0.0993	0.0267
CP9	2447355.3560	320639.6540	1039.8630	1039.8103	0.0527	-0.0199
CP11	2447910.4270	320711.2340	1081.3250	1081.1639	0.1611	0.0885
CP12	2448461.6570	320839.7850	1092.5790	1092.5704	0.0086	-0.0640
CP13	2447297.0920	321326.6270	1044.9120	1045.0738	-0.1618	-0.2344
CP14	2448060.2810	321507.2270	1081.7280	1081.6222	0.1058	0.0332
9-04-029	2447677.8720	320950.1000	1091.9690	1091.9281	0.0409	-0.0317
9-04-030	2447724.3770	321383.5380	1103.5330	1103.3168	0.2162	0.1436
9-04-031	2447430.5130	321797.2720	1121.9360	1121.7878	0.1482	0.0756
9-04-032	2447498.4030	322213.3580	1131.3380	1131.1766	0.1614	0.0888
	Number of Check Points				14	14
	Mean Error				0.073	0.000
	Standard Deviation (StDEV)				0.107	0.107
	Root Mean Squares Error ($RMSE_{x\ or\ y\ or\ z}$)				0.126	0.103
	NSSDA Vert Accuracy at 95% accuracy Level				0.247	
	NSSDA Vert Accuracy at 95% accuracy Level after z-bias removal				0.201	

Positional Accuracy

DTM and 2nd Gen Check Points from MMS Analysis

Derived 28 2nd Gen Check Points from MMS DTM



UAS Accuracy as Compared to Mobile Lidar using 28 Locations

PennDOT UAS Proof of Concept - Accuracy Analysis (Comparing UAS DTM to MMS DTM)

Point ID	MMS Elevation			UAS Elevation	Residual Values (ft.)	Delta Z after Z-bias Removed (ft.)
	Easting (ft.)	Northing (ft.)	Elevation (ft.)	Elevation (ft.)	Error in Elevation (ft.)	
CP_1	2447813.6658	320999.2773	1091.2897	1091.0405	0.2492	0.0033
CP_2	2447783.7307	321113.7985	1095.1525	1094.9447	0.2078	-0.0381
CP_3	2447759.1650	321215.2972	1098.3978	1098.1479	0.2499	0.0040
CP_4	2447733.0793	321308.6243	1101.5030	1101.2323	0.2707	0.0248
CP_5	2447700.7566	321419.0448	1105.1964	1104.9249	0.2715	0.0256
CP_6	2447674.8168	321511.8570	1108.2950	1108.0041	0.2909	0.0450
CP_7	2447653.6632	321604.4581	1111.2501	1110.8518	0.3983	0.1524
CP_8	2447626.2922	321705.3985	1114.6540	1114.3570	0.2970	0.0511
CP_9	2447596.3534	321793.1424	1117.6797	1117.3404	0.3393	0.0934
CP_10	2447571.4603	321890.3933	1120.9124	1120.8596	0.0528	-0.1931
CP_11	2447546.6611	321995.9759	1124.4512	1124.1878	0.2634	0.0175
CP_12	2447526.5566	322083.3588	1127.2359	1126.9793	0.2566	0.0107
CP_13	2447500.2614	322166.6011	1130.1904	1129.8961	0.2943	0.0484
CP_14	2447466.4229	322281.2289	1134.0343	1133.8363	0.1980	-0.0479
CP_15	2447308.6649	322248.5215	1138.2702	1138.0751	0.1951	-0.0508
CP_16	2447344.7171	322148.4501	1134.5498	1134.3433	0.2065	-0.0394
CP_17	2447365.3790	322069.0943	1131.7290	1131.6055	0.1235	-0.1224
CP_18	2447397.6980	321961.4341	1127.9513	1127.8022	0.1491	-0.0968
CP_19	2447432.4695	321852.6548	1124.1650	1124.0704	0.0946	-0.1513
CP_20	2447461.1104	321756.1124	1120.7587	1120.4909	0.2678	0.0219
CP_21	2447488.2891	321668.7552	1117.6552	1117.3064	0.3488	0.10[illegible]
CP_22	2447517.8379	321559.0553	1113.8186	1113.5437	0.2749	0.[illegible]
CP_23	2447551.4267	321449.0224	1110.0430	1109.8008	0.2422	[illegible]037
CP_24	2447574.2564	321367.1508	1107.0800	1106.8535	0.2265	-0.0194
CP_25	2447603.1840	321268.4371	1103.5923	1103.2865	0.3058	0.0599
CP_26	2447630.6428	321182.1303	1100.5619	1100.2992	0.2627	0.0168
CP_27	2447658.1476	321084.4832	1097.1436	1096.9267	0.2169	-0.0290
CP_28	2447691.2635	320973.0090	1093.2373	1092.9071	0.3302	0.0843
	Number of Check Points				28	28
	Mean Error				0.246	0.000
	Standard Deviation (StDEV)				0.076	0.076
	Root Mean Squares Error ($RMSE_{x\ or\ y\ or\ z}$)				0.257	0.075
	NSSDA Vert Accuracy at 95% accuracy Level				0.504	
	NSSDA Vert Accuracy at 95% accuracy Level after z-bias removal				0.147	

Bias of 0.246 ft.

RMSEz = 0.075 ft. after bias removal

Concluding Remarks

1. Emerging geospatial technologies such as UAS are effective in serving transportation projects to help reduce costs and expedite delivery schedule
2. Utilizing different technologies to serve a project with diverse specifications and requirements is the most efficient way to execute projects
3. The hybrid approach contributes to better efficiency and resources utilization
4. Accuracy on demand within a project is a logical outcome of the hybrid approach. It helps project budget and timeline.

Concluding Remarks

5 The hybrid approach is most effective when used during the project planning phases.

6 Users of the resulting hybrid product need to be aware of the different data quality and accuracy of the integrated products.

7 Metadata is the best approach to communicate quality and accuracy variation.

Thank you!

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