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

Abdullah Qassim Tom Ruschkewicz

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Agenda

Strength and Weakness of Geospatial Technologies

Aerial Lidar Mobile Lidar UAS Imagery

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

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

14/

Who We Serve



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





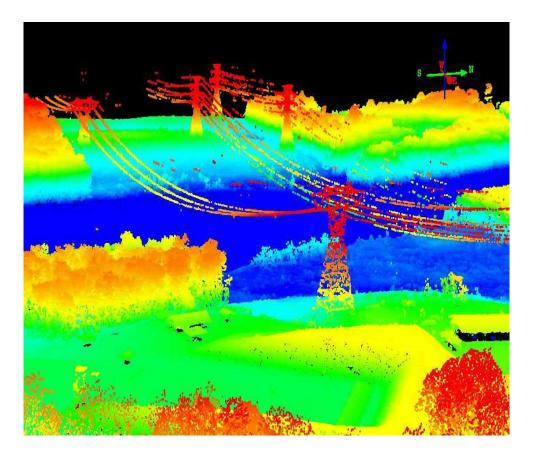
Unmanned

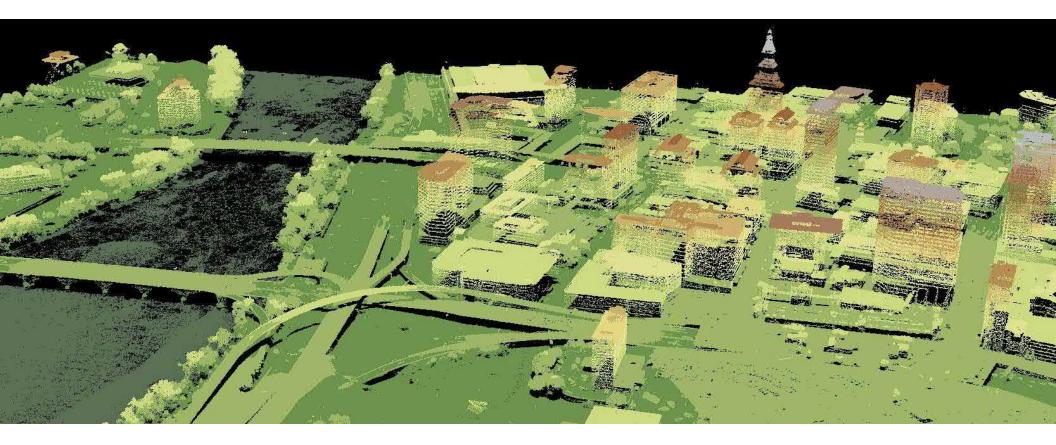


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Strength of Aerial Lidar System Technology

- 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/m² to 6,000 pts/m²

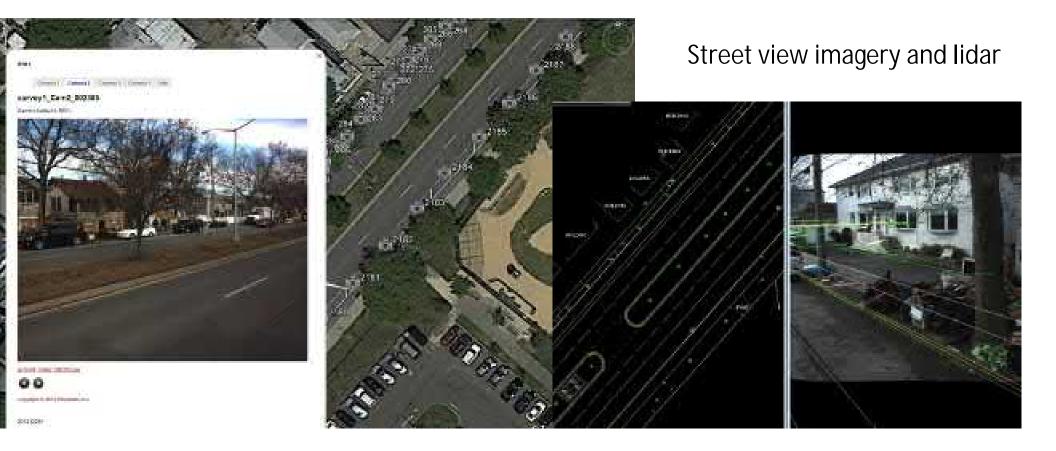
Accuracy≅1.8 cm



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)



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

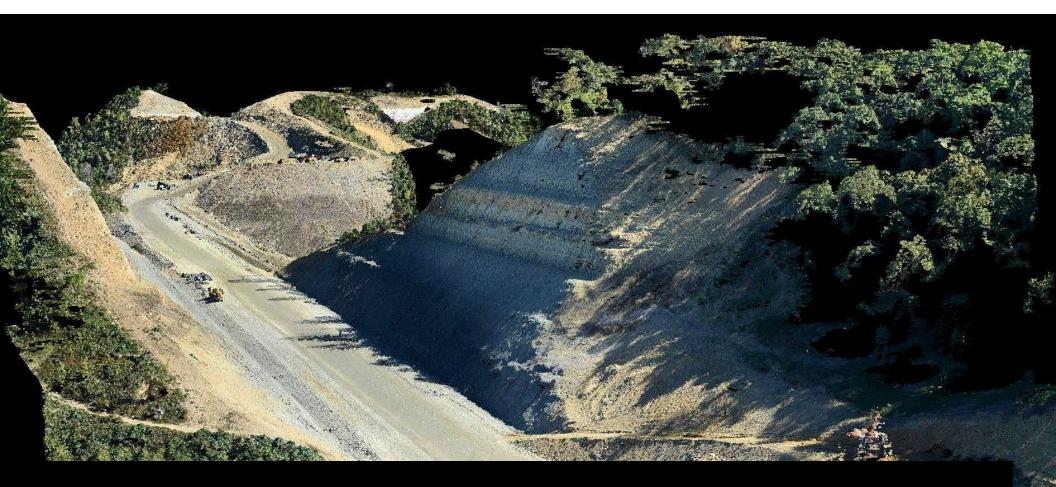


Orthophotography/Video

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/m²

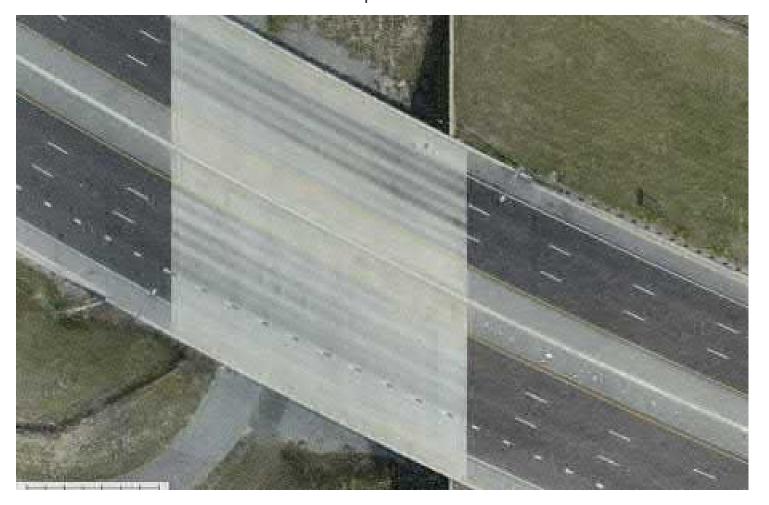


Image Based Points Cloud From Drones

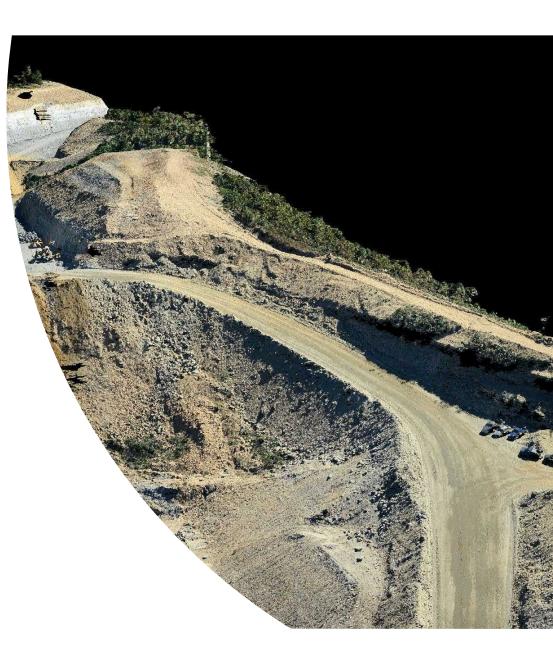
Strength of Points Cloud from UAS Imagery

- 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/m² Accuracy(v) RMSE = 6 to 15 cm



MMS: Points Density: 2,000 to 6,000 pts/m² Accuracy(v) RMSE = 1.5 cm



UAS: Points Density: 40 to 1000 pts/m² 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

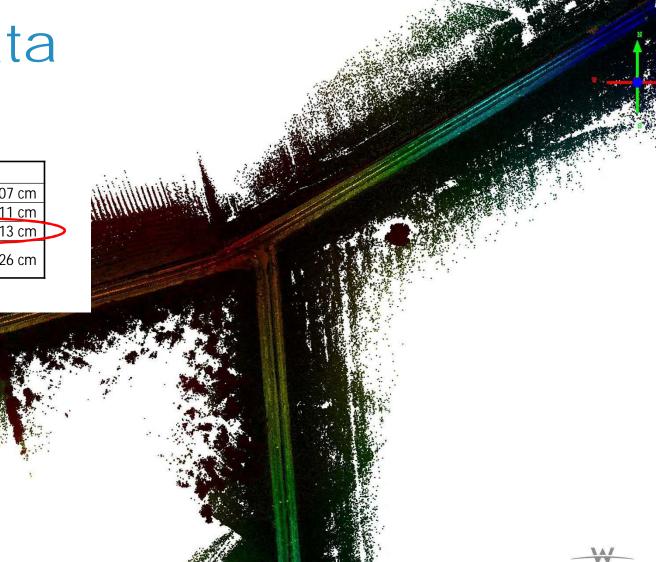
I. Accuracy Verification

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 (RMS	0.043 ft.	0.013 cm	\triangleright
NSSDA Vert Accuracy at 95% Confidence Level	11118511	0.026 cm	



The UAS Data

UAS 100 ft. AGL Altitude

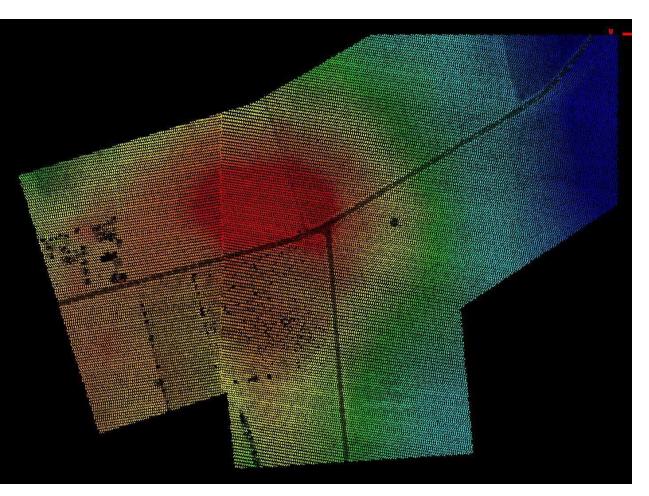
PETERSBURGIRD

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		0.092 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)		15.19 cm
NSSDA Vert Accuracy at 95% Confidence Level		29.79 cm

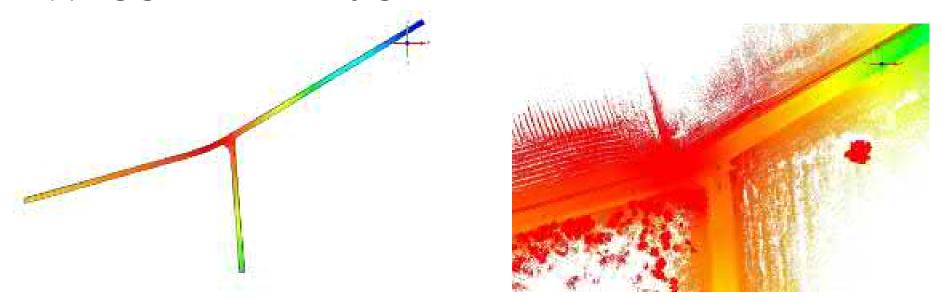
The Aerial Lidar Data

II. Data Preparation

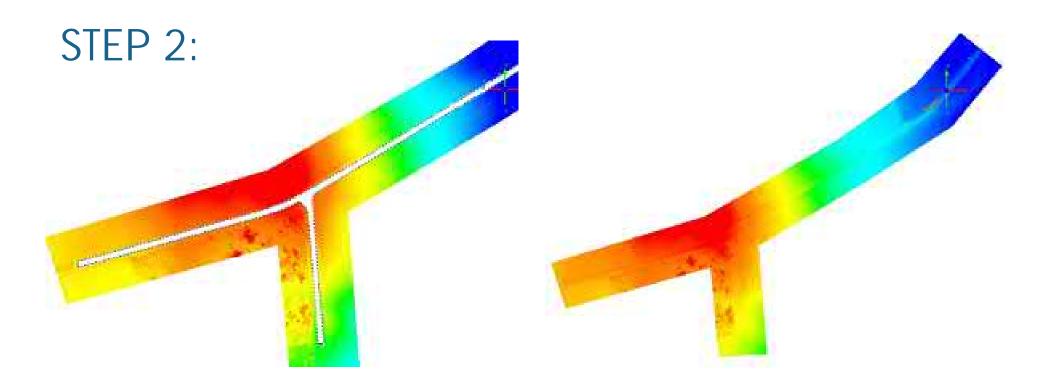
Data need to be prepared for data fusion:Data reformatting necessaryReprojection if necessaryClipping and cropping

STEP 1:

Clipping good data (only good around driven roads)

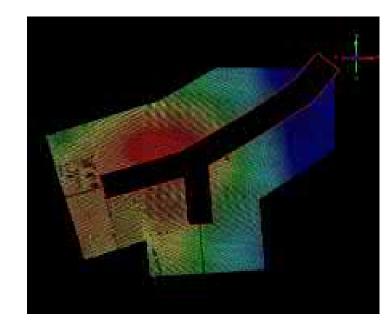


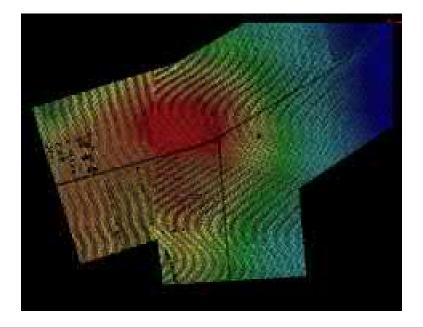
Preparing the MMS Data



Preparing the Drone-based DSM

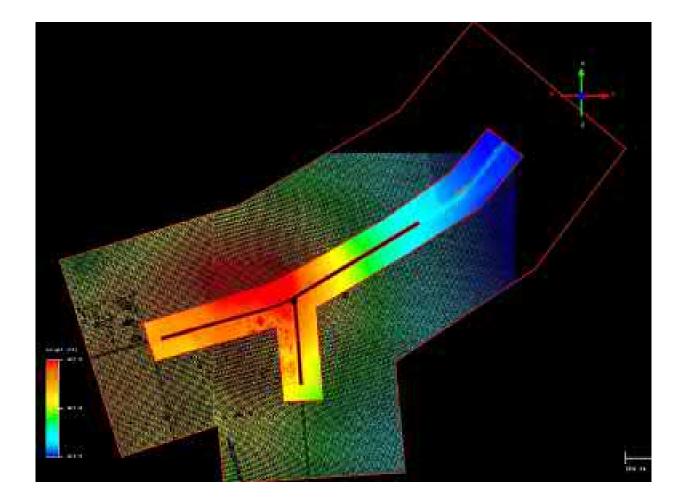
STEP 3:



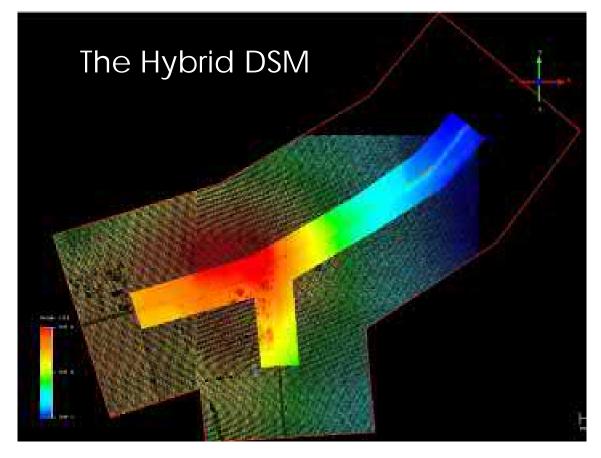


Preparing the Aerial Lidar from Ohio Statewide Project

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

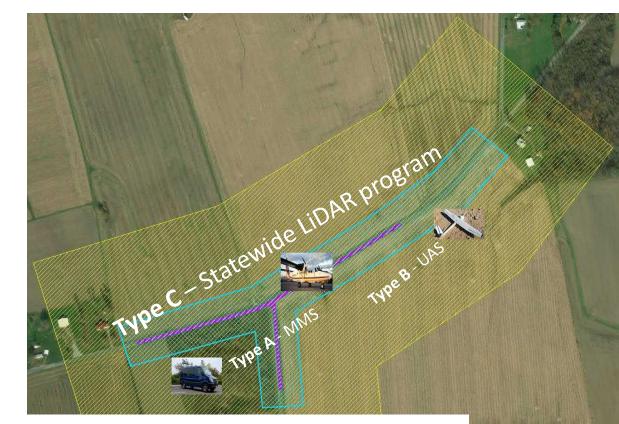
Resulting Products: Seamless Dataset One-foot contours

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**				
FIGURE Specification	Туре А	Туре В	Туре С		
Terrain surface accuracy as verified					
using independent check points $RMSE_v \le 0.06 \text{ ft.} RMSE_v \le 0.10 \text{ ft.} RMSE_v \le 0.50 \text{ ft.}$					
** 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



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



Collected imagery with 2.53-cm GSD (1")

Project Design and Mission Planning

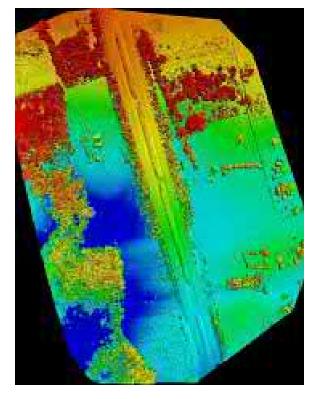
We deployed Sensefly eBee X with RTK/PPK Capability



We produced



Stereo compiled break lines

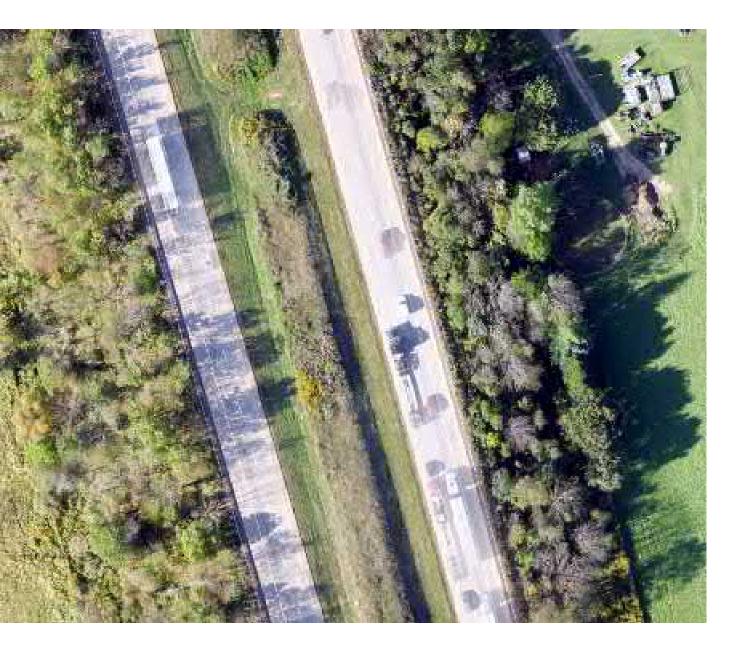


Digital Surface Model



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

Products Quality



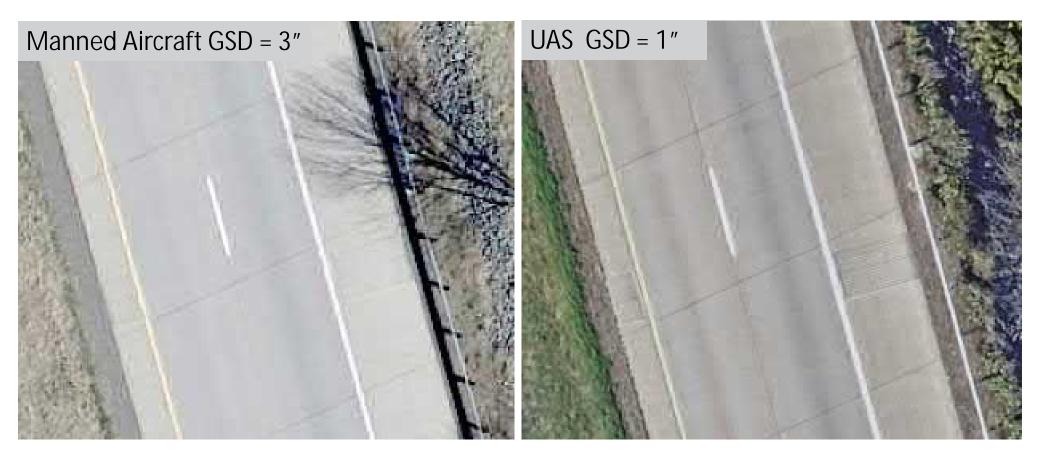
UAS Imagery Quality

> GSD = 1" (2.54-cm)

Imagery Quality: UAS versus Manned



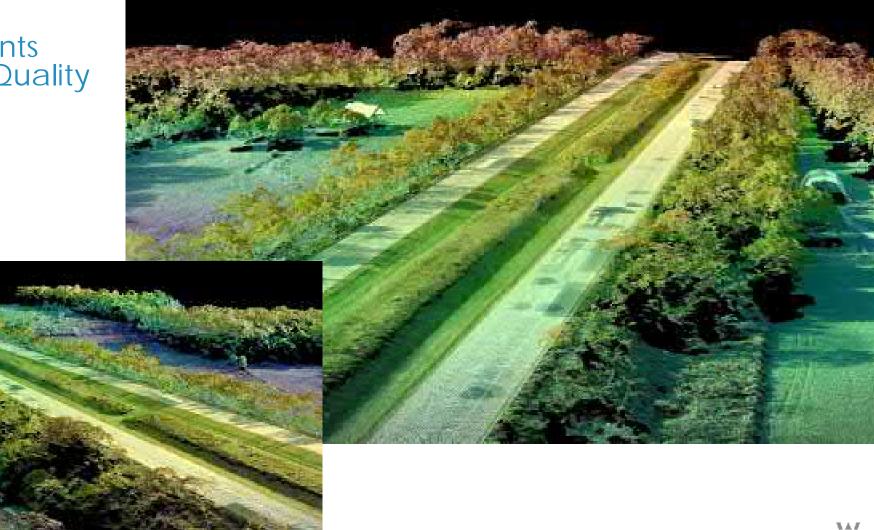
Imagery Quality: UAS versus Manned



Points Cloud Quality

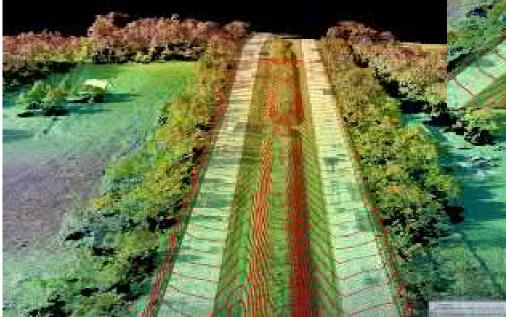


UAS Points Cloud Quality

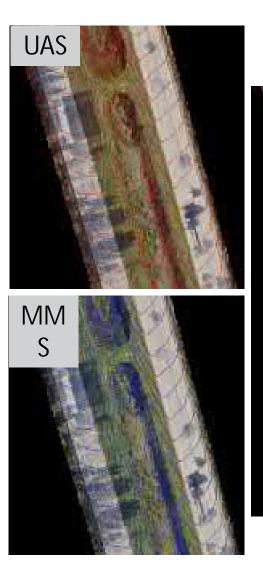




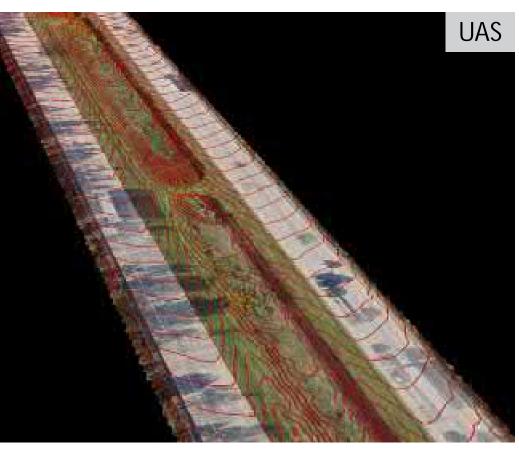
UAS Contours Quality





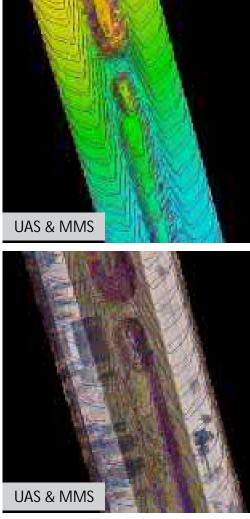


Contours Quality





MMS: Mobile Mapping System



Positional Accuracy

DTM and Contours Analysis



Contours from UAS

Contours from UAS & MMS



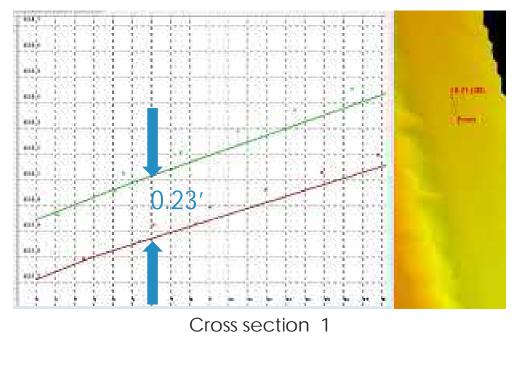


Green: UAS

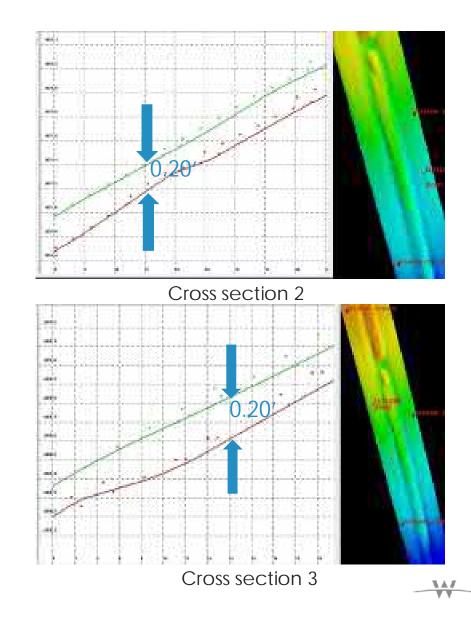
Blue: MMS

UAS Accuracy as Compared to Mobile Lidar (MMS)

Finding 0.2 ft. bias







Positional Accuracy

DTM and GCPs Analysis



MMS DTM Accuracy As Compared to 5 GCPs

	PennDOT	JAS Proof	of Concept	t - Accuracy Analy	ysis (Comparing MMS DTM to GCPs)		
Point	Surve	eyed Eleva	tion	MMS Elevation	Residual Values (ft.)	Delta Z after Z-bias	
ID	Easting (ft.)	Northing (ft.)	Elevation (ft.)	Elevation (ft.)	Error in Elevation (ft.)	Removed (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	
			Nu	mber of Check Points	5	5	
				Mean Error	-0.038	0.000	
			Standa	ard Deviation (StDEV)	0.046	0.046	
		Root	Mean Square	es Error (RMSE _{x or y or z})	0.056	0.041	
		NSSDA V	ert Accuracy	at 95% accuracy Level	0.110		
	NSSDA	Vert Accuracy	y at 95% accur	racy Level after z-bias	0.081		

UAS-derived DTM Accuracy As Compared to 6 GCPs

	PennDOT	UAS Proot	f of Concep	ot - Accuracy Ana	lysis (Comparing UAS DTM to GCPs)	
Point	Surve	eyed Eleva	tion	UAS Elevation	Residual Values (ft.)	Delta Z after Z-bias
ID	Easting (ft.)	Northing (ft.)	Elevation (ft.)	Elevation (ft.)	Error in Elevation (ft.)	Removed (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
			Nu	mber of Check Points	6	6
				Mean Error	0.291	0.000
			Standa	ard Deviation (StDEV)	0.137	0.137
		Root	Mean Square	es Error (RMSE _{x or y or z})	0.317	0.125
		NSSDA V	ert Accuracy	at 95% accuracy Level	0.621	
	NSSDA	Vert Accuracy	y at 95% accur	racy Level after z-bias	0.244	



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

	PennD	OT UAS Pro	of of Conce	lysis (Comparing UAS DSM to GCPs)		
Point	Surv	eyed Eleva	tion	UAS Elevation	Residual Values (ft.)	Delta Z after Z-bias
ID	Easting (ft.)	Northing (ft.)	Elevation (ft.)	Elevation (ft.)	Error in Elevation (ft.)	Removed (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
			Ni	umber of Check Points	14	14
				Mean Error	0.073	0.000
			Stand	lard Deviation (StDEV)	0.107	0.107
		Roc	t Mean Squar	res Error (RMSE _{x or y or z})	0.126	0.103
		NSSDA	Vert Accuracy	at 95% accuracy Level	0.247	
	NSSDA Vert Ad	ccuracy at 95%	accuracy Lev	el after z-bias removal	0.201	

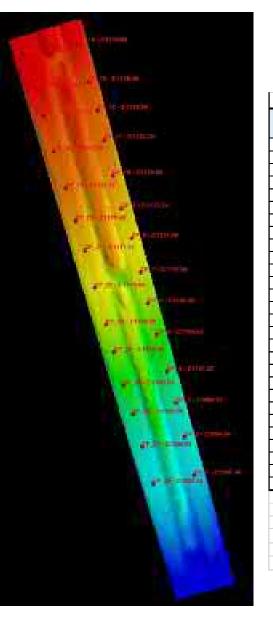


Positional Accuracy

DTM and 2nd Gen Check Points from MMS Analysis

Derived 28 2nd Gen Check Points from MMS DTM

W



UAS Accuracy as Compared to Mobile Lidar using 28 Locations

Point ID MMS Elevation UAS Elevation Residual Values (ft.) Delta Z after Z-bias Removed (ft.) F0 1 244783.6668 303999.273 1091.0005 0.2942 0.0033 CP_2 244783.5668 32015.792 1098.378 1095.155 1094.9447 0.2078 -0.0381 CP_3 2447783.170 32118.792 1098.378 1098.1479 0.2079 -0.0381 CP_4 2447781.5663 32119.0748 1108.2950 1101.233 0.2707 0.0428 CP_5 2447708.1566 32118.2708 1108.2950 1108.2041 0.2909 0.0450 CP_7 244765.4364 32151.8570 1108.2950 1108.0041 0.3903 0.0934 CP_9 244756.43632 32170.59385 1104.640 1113.304 0.3933 0.0934 CP_10 24757.44631 32189.3933 1172.289 1124.417 0.0175 CP 11 244756.566 32179 1124.412 1124.4178 0.2466 0.0394 CP_112 244756.566		PennDOT						
Leasting (II) Northing (II) Elevation (II) Error in Elevation (II) Removed (It.) Removed (It.) CP_1 2447183.6688 32099 277.1 1091.2095 1091.4095 0.0333 CP_2 2447783.3707 32113.7985 1098.1525 1094.1497 0.2026 -0.0381 CP_3 2447783.3073 32136.6243 1101.533 0.2707 0.0248 CP_5 2447703.0766 321417.00.7566 321419.0448 1106.940 1.02909 0.0450 CP_5 2447706.3566 321419.0448 1108.094 0.2909 0.0450 CP_7 2447563.632 32118.5870 108.094 0.2909 0.0551 CP_8 244756.3632 321905.3981 112.0917 1113.500 0.0256 0.0107 CP_11 244756.6611 32195 9759 1124.4512 1124.1878 0.2634 0.0175 CP_11 244756.6611 321965 9759 1124.4512 1124.1878 0.2634 0.0175 CP_13 244750.2614 322086 9043 1132.9055	Point ID	MMS Elevation UAS E			UAS Elevation	Residual Values (ft.)	Delta Z after Z-bias	
CP_2 2447783 307 32113 7985 1098 1525 1094 9447 0.2078 -0.0381 CP_3 2447759 1650 321215 2972 1098 3978 1098 1479 0.2499 0.0040 CP_4 2447733 1073 321308 6243 1015 1032 0.2707 0.0248 CP_5 2447700 7556 321410 0448 1105 108 2949 0.2715 0.0256 CP_6 244763 6438 321118 507 1108 2949 0.2909 0.0460 CP_7 244763 6432 321195 3985 1114 640 1114 3570 0.2909 0.0611 CP_9 244756 6411 32196 5795 1124 4512 1117 6797 1124 4512 0.0528 -0.1931 CP_11 244756 6411 32196 5795 1124 4512 1124 1878 0.2634 0.0107 CP_13 244756 6411 32196 5791 1124 592 1124 1878 0.2634 0.0107 CP_14 244736 4274 32281 5251 1138 353 0.1980 -0.0179 0.0484 CP_15 244738 4717 133 4333 0.2065 -0.0394 0.219 CP_16 244738 1787 <td>FUILT</td> <td>Easting (ft.)</td> <td>Northing (ft.)</td> <td>Elevation (ft.)</td> <td>Elevation (ft.)</td> <td>Error in Elevation (ft.)</td> <td>Removed (ft.)</td> <td></td>	FUILT	Easting (ft.)	Northing (ft.)	Elevation (ft.)	Elevation (ft.)	Error in Elevation (ft.)	Removed (ft.)	
CP_3 2447759.1660 321215.2972 1098.3978 1099.1479 0.2499 0.0040 CP_5 2447730.756 32138.623 1011.232 0.2715 0.0256 CP_6 244763.163 32138.623 1101.523 0.2715 0.0266 CP_7 244763.1632 32160.4381 1105.1964 1104.9249 0.2715 0.0256 CP_7 244763.1632 32160.4481 1115.2901 1110.6818 0.3993 0.0511 CP_8 244765.3652 321793.1444 111.4560 1111.28170 0.2970 0.0511 CP_10 244754.64611 32199.0739 1124.4512 1124.878 0.2646 0.0175 CP_11 244756.5666 32149.9759 1124.4512 1124.878 0.2646 0.0175 CP_12 2447785.5766 32199.9759 1124.4512 1124.878 0.2646 0.0175 CP_13 244756.561 32199.2728 1138.071 0.1951 -0.0598 0.0179 CP_14 2447785.370 32248.871 1138.2702 1138.0751 0.1224 0.0216 0.0219 <th< td=""><td>CP_1</td><td>2447813.6658</td><td>320999.2773</td><td>1091.2897</td><td>1091.0405</td><td>0.2492</td><td>0.0033</td><td></td></th<>	CP_1	2447813.6658	320999.2773	1091.2897	1091.0405	0.2492	0.0033	
CP_4 244730793 321308.6243 1101.900 1101.222 0.2707 0.0248 CP_5 2447700.7566 321419.0448 1106.1964 1104.9249 0.2715 0.0256 CP_6 244763.8168 321511.8570 1108.2590 0.0450 0.0450 CP_7 2447654.8168 321793.514 1114.570 0.2970 0.0511 CP_9 244754.8168 321793.91424 1117.677 1117.3404 0.3933 0.0934 CP_11 244756.5566 32080.3338 1124.9712 1124.876 0.2634 0.0175 CP_11 244756.6611 321690.3793 1124.9791 0.2656 0.0107 CP_13 244750.2643 322064.011 1134.370 0.2943 0.0484 CP_14 244736.6649 322484.5215 1138.2702 1138.0751 0.1951 -0.0568 CP_15 2447361.411.32795 1134.5498 1134.3433 0.2065 -0.0394 CP_17 2447362.492 322185.2648 1124.0704 0.0946 -0.1513 0.219 CP_28 24474781.6963 32189.13441 1127.	CP_2	2447783.7307	321113.7985	1095.1525	1094.9447	0.2078	-0.0381	
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Concluding Remarks

Emerging geospatial technologies such as UAS are effective in serving transportation projects to help reduce costs and expedite delivery schedule

Utilizing different technologies to serve a project with diverse specifications and requirements is the most efficient way to execute projects

The hybrid approach contributes to better efficiency and resources utilization

Accuracy on demand within a project is a logical outcome of the hybrid approach. It helps project budget and timeline.

Concluding Remarks

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

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

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

Thank you!

Qassim Abdullah qassim.abdullah@woolpert.com

Tom Ruschkewicz Tom.Ruschkewicz@Woolpert.com

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