Results of Camera-Equipped sUAV Testing

(Refer to Chapter 10 of the OC Survey Standards Manual)

Test Scenario 1: Volumetric Survey of a Stockpile

Test Location: Miller Basin

Complications: Stockpile was disturbed after the first flight, thus only one set of data is available

Volume Computations

Topo Volume (cu. yd.):	18812.1	UAS Volume (cu. yd.):	19088.8	Difference (cu. yd.): 276.7
				Difference (%): 1.47

Test Scenario 2: Volumetric Survey of an Earthwork Removal

Test Location: Santa Ana River North of Adams

Complications: Sand contours were disturbed after the first flight, thus only one set of data is available; however hard surface elevation comparisons were made on all three flights

Volume Computations (omitting concrete trapezoidal channel area which was submerged at flight time)

Topo Volume (cu. yd.):	148213.8	UAS Volume (cu. yd.):	148213.5	Difference (cu. yd.): 0.3
				Difference (%): 0.0002

Additional Data Point Analysis: Comparing Topo to Point Cloud (hard surface - elevation only); Data shown is in US Survey Feet

Flight Date	Sample Size	RMSE	Std Dev (95%)
4/16/2019	111 points	0.041	0.046
4/26/2019	102 points	0.031	0.035
4/30/2019	99 points	0.032	0.039
	Averages	0.035	0.040

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Test Scenario 3: Scour Study Survey

~~Test Location: Como Channel~~ Como channel was abandoned as a test area due to presence of a series of negative conditions

Test Location: San Diego Creek Reach 2

Complications: Flight 1 processing using Loki PPK data was not fitting GCPs, check points, or additional QC points. Data was left in the analysis to exemplify the difference when compared to flights with better statistical closures. This flight is identified below with **.

Cross Section Area Computations: Sections on 50 Foot Centers; Average and RMSE are shown as a % difference between individual flights and conventional topo; Areas were computed against a fictitious design template

Comparison	Sample Size	Average	RMSE	Comparison	Sample Size	Average	RMSE
Flight 1 Loki** - 2 Loki	20 sections	0.87	1.03	Flight 1 Loki** - Topo	20 sections	2.94	3.55
Flight 2 Loki - 3 Loki	20 sections	0.24	0.31	Flight 1 GCP - Topo	20 sections	2.89	3.59
Flight 1 GCP - 2 GCP	20 sections	0.32	0.39	Flight 2 Loki - Topo	20 sections	3.00	3.70
Flight 2 GCP - 3 GCP	20 sections	0.33	0.38	Flight 3 Loki - Topo	20 sections	3.08	3.80
Flight 1 GCP - 3 GCP	20 sections	0.30	0.36				
Flight 1 Loki** - 1 GCP	20 sections	1.09	1.23				
Flight 2 Loki - 1 GCP	20 sections	0.34	0.44				
Flight 3 Loki - 1 GCP	20 sections	0.40	0.49				
Flight 2 Loki - 2 GCP	20 sections	0.22	0.30				
Flight 3 Loki - 3 GCP	20 sections	0.45	0.54				

Volume Computations: Shown as a % difference between individual flights and conventional topo; Volumes were computed against a fictitious design template

Comparison	Vol. Diff.	Comparison	Vol. Diff.
Flight 1 Loki** - 2 Loki	0.11	Flight 1 Loki** - Topo	2.77
Flight 2 Loki - 3 Loki	0.04	Flight 1 GCP - Topo	2.90
Flight 1 GCP - 2 GCP	0.16	Flight 2 Loki - Topo	2.66

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Flight 2 GCP - 3 GCP	0.23		Flight 3 Loki - Topo	2.62				
Flight 1 Loki** - 1 GCP	0.29							
Flight 2 Loki - 1 GCP	0.25							
Flight 3 Loki - 1 GCP	0.29							
Flight 2 Loki - 2 GCP	0.09							
Flight 3 Loki - 3 GCP	0.35							

Point of Clarification: Even though all flights analyzed differed from the topo by a seemingly large percentage, this was a result of the rip rap areas being more accurately modeled by the sUAV than by the conventional topo. This was evident when comparing surfaces in CADD, and further justified by the fact that although they varied from the topo surfaces, data from each of the flights agreed with one another.

Additional Data Point Analysis: Comparing Topo to Point Cloud (hard surface - xyz); Data shown is in US Survey Feet; Note that RMSE and Std Dev denoted "XY" reflects combined X and Y components; Flight 1 Loki was not used to compute averages shown below

Flight	Sample Size	RMSE - XY	Std Dev - XY (95%)	RMSE - Z	Std Dev - Z (95%)			
Flight 1 Loki**	12 points	0.226**	0.162**	0.203**	0.231**			
Flight 2 Loki	12 points	0.070	0.078	0.088	0.092			
Flight 3 Loki	12 points	0.088	0.053	0.076	0.096			
Flight 1 GCP	12 points	0.078	0.078	0.070	0.052			
Flight 2 GCP	12 points	0.084	0.080	0.081	0.067			
Flight 3 GCP	12 points	0.087	0.057	0.074	0.057			
Averages		0.081	0.069	0.078	0.073			

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Test Scenario 4: Engineering Topographic Survey

Test Location: Glassell Yard

Additional Comparison: Comparison was made using Potree software instead of Trimble Business Center for one of the flights (5/1/2019) - see below for results of the comparison

Data Point Analysis: Comparing Topo to Point Cloud (hard surface - elevation only); Data shown is in US Survey Feet

Flight Date	Sample Size	RMSE - Z	Std Dev - Z (95%)						
2/28/2019	73 points	0.019	0.016						
4/18/2019	72 points	0.030	0.035						
5/1/2019	73 points	0.022	0.027						
	Averages	0.024	0.026						

Data Point Analysis: Comparing Topo to Point Cloud (hard surface - xyz); Data shown is in US Survey Feet; Note that RMSE and Std Dev denoted "XY" reflects combined X and Y components

Flight Date	Sample Size	RMSE - XY	Std Dev - XY (95%)	RMSE - Z	Std Dev - Z (95%)			
2/28/2019	25 points	0.114	0.097	0.027	0.028			
4/18/2019	25 points	0.113	0.115	0.044	0.059			
5/1/2019	25 points	0.119	0.129	0.030	0.039			
	Averages	0.115	0.114	0.034	0.042			

Data Point Analysis: Comparing TBC to Potree Point Cloud (hard surface - xyz); Data shown is in US Survey Feet; Note that RMSE and Std Dev denoted "XY" reflects combined X and Y components

Flight Date	Sample Size	RMSE - XY	Std Dev - XY (95%)	RMSE - Z	Std Dev - Z (95%)			
5/1/2019	24 points	0.132	0.130	0.026	0.034			

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General Conclusions - Applicable to All Scenarios of Camera-Equipped sUAV Testing

Precise horizontal location of topographic features could not be made with certainty unless there was clear color contrast with adjacent features. Horizontal data points used for comparisons which were clearly discernable were a small percentage of the overall project. In addition, grade breaks (top of curb, flowline, top of wall, etc.) were not discernable, even using specific "picker" tools within TBC.

Imagery was unable to penetrate vegetation or water, thus objects even partially obscured could not be reliably located.

Approved Uses of Camera-Equipped sUAV:

General Purpose Surveys: Camera-equipped sUAV may be used on surveys which require horizontal accuracies of ≥ 0.15 feet and vertical accuracies of ≥ 0.10 feet, provided that limiting conditions described above are not present or are appropriately mitigated.

Engineering Design Surveys: The inability to accurately locate breaklines, such as top of curb, flowline, etc. and the inability to consistently segregate adjacent features which lack significant color contrast precludes the use of camera-equipped sUAV on topographic surveys for engineering design purposes at this time. sUAV may however be used to collect supplemental topographic data, for example features and terrain falling within private property adjacent to a roadway or flood control facility.

Scour Study Surveys: Scour study surveys may be conducted using camera-equipped sUAV, provided features which are submerged or obscured by foliage are captured conventionally and merged with the data collected by the sUAV.

Volumetric Surveys: Surveys made for the purpose of computing volumes of stockpiles or earthwork removals may be conducted using camera-equipped sUAV.

Additional Note: When conducting a survey which presents field personnel with a one-time access (e.g. an earthwork removal on an active construction site), additional measures shall be undertaken to ensure successful processing of the flight data. The measures taken will be at the discretion of the flight PIC, and may include on-site post-processing of GNSS data (for data validation), setting additional GCPs and check-points, etc.