EVENT 38

UNMANNED SYSTEMS

PPK surveying with the E400 and Sony RX1R II

April, 2022

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Overview

Aerial surveying using PPK GPS to geotag each photo is the industry standard method when accuracy is a requirement. Using PPK GPS allows a surveyor to create accurate photogrammetry products in remote areas inaccessible on foot where the use of ground control points is not practical. When used in conjunction with ground control, the results of a PPK mapping flight are verifiably accurate. Processing PPK GPS is also less labor intensive than applying GCPs, as GCPs require multiple manual target identifications each.

In cases where time on site is limited or where fewer satellites are typically visible, it is desirable to use a GPS system capable of dual frequency reception. Dual frequency receivers collect information from each satellite over two frequencies. By using the two frequencies together, it is possible to obtain a fix faster than when using a single frequency alone by eliminating atmospheric error. This can reduce time on site and reduce the chance of losing a high quality fix during flight.

Equipment and Setup

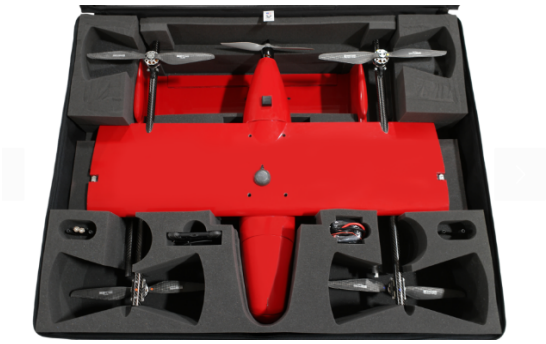
The E400 VTOL mapping drone, the Sony RX1R II, the Emlid Reach M2 L1/L2 PPK GPS, and the Emlid Reach RS2 base station were used to gather the data needed for this test. Full details of each piece of equipment are recorded in the tables at the end of this section.

The E400 was used for its ability to carry the wide bodied RX1R II in landscape mode as well as the PPK GPS receiver. The E400 is flown with a cube orange autopilot and uses a separate, standard GPS module for navigation. By using vertical take off and landing the E400 can fly in the harshest conditions and terrains, accessing areas difficult for surveyors to reach on foot.

The Sony RX1R II was flown with a 35mm lens and collected data at 1.3cm/pixel from 100m AGL flying height. The RX1R II is equipped with a leaf shutter, nearly eliminating rolling shutter effect. The high speed sync port was used to record a precise timestamp at the end of exposure and is corrected to the middle of exposure in post processing.

The air side Emlid Reach M2 module is powered by the U-Blox ZED-F9P gps receiver logging raw satellite data at 10hz with a 20hz update available in the near future. The antenna paired with the M2, the Tallysman 33-8829NM-06-0350, has shown great rejection to multipath, a tight phase center tolerance, as well as a high signal to noise ratio.

The base station used was an Emlid Reach RS2. The RS2 uses the same U-Blox ZED-F9P receiver as the M2 logging raw satellite data at 1hz intervals.



E400 VTOL Aircraft	
All up weight	9kg
Max Flight time	90 minutes
Nominal flight speed	16 m/s

Table 1: Aircraft Configuration

Sony RX1R II	
Lens	Zeiss Sonnar 35mm
Sensor	35.9 x 24 mm; 42.4MP (7952 x 5304 pix)
Image Quality	Fine

Table 2: Sensor Configuration

Emlid reach M2	
Antenna	Tallysman 33-8829NM-06-0350
Satellites	GPS/QZSS L1C/A, L2C GLONASS L1OF, L2OF BeiDou B1I, B2I Galileo E1-B/C, E5b
Logging rate	10Hz

Table 3: PPK GPS Module Configuration

Emlid reach RS2	
Antenna	Internal
Satellites	GPS/QZSS L1C/A, L2C GLONASS L1OF, L2OF BeiDou B1I, B2I Galileo E1-B/C, E5b
Logging rate	1Hz

Table 4: PPK Base Station Configuration

Method

The survey mission was flown in a grid pattern using 60% overlap and 60% sidelap ensuring sufficient overlap to produce an accurate orthomosaic and DSM. Many cameras aren't able to maintain proper image spacing and overlap at 100m AGL while flying at a speed of 16m/s. This is due to the high shutter refresh rate required, but the Sony Rx1R II is able to take photos continuously up to 0.5 second intervals.

Prior to flying the mission, the aircraft and GPS were powered on to obtain a fix and collect satellite information for 8 minutes during ground setup and mission planning. After the mission the Reach RS2 base coordinate was obtained using NTRIP corrections provided by the Ohio CORS network.

Ground control points were collected using an Emlid reach RS2 connected to the Ohio CORS network over NTRIP but were not used for processing. These points were collected and provided by a licensed professional surveyor.

Root Mean Square Error (RMSE) was calculated using the formula below, where E is the horizontal or vertical error as measured using QGIS and P is the number of points collected.

$$RMSE = \sqrt{\frac{\Sigma(E^2)}{P}}$$

Post-Processing

After the flight RTKConv software was used to convert the raw gps data from the rover and base station into Rinex files. RTKPost software was then used to process the Rinex from the rover against the rinex from the base station resulting in our final geotags.

Agisoft Photoscan Professional version 1.8.3 was used to post-process the imagery and create an orthomosaic and digital elevation model (DEM). Settings used to post-process the imagery are recorded below in Table 5.

Processing Step	Settings
Geotag Accuracy	3cm
Antenna offset	X(m): 0 Y(m): 0 Z(m): 0.1529
Rolling shutter compensation	Off
Alignment	High Accuracy, Reference Preselection
Optimize	f,b1, b2, cx, cy, k1-k4, p1, p2
Dense Cloud Generation	High Quality, Mild, Calculate Colors

Table 5: Agisoft Photoscan PPK Processing Settings

Results

Weather conditions on the day of the flight were overcast, with the flight taking place at approximately 9AM. Winds were out of the east at 5m/s. Groundspeeds during the flight averaged 16 m/s with a maximum of 23 m/s and minimum of 11 m/s.

The mission was purposely planned with a cross wind for optimal image collection conditions.

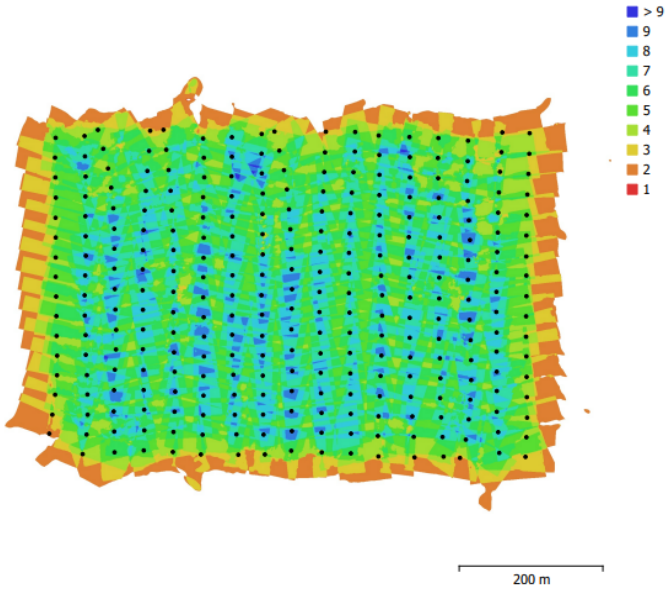


Fig. 1. Camera locations and image overlap.

Number of images:	288	Camera stations:	288
Flying altitude:	99.6 m	Tie points:	664,890
Ground resolution:	1.29 cm/pix	Projections:	1,818,229
Coverage area:	0.375 km²	Reprojection error:	0.601 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
DSC-RX1RM2 (35mm)	7952 x 5304	35 mm	4.53 x 4.53 µm	No

Table 1. Cameras.

The flight resulted in 288 images covering approximately 38 Hectares (93 acres), each automatically geotagged with a Q1 solution.

	Latitude	Longitude	GCP Alt	DEM Alt	X/Y Error (cm)	Z Error (cm)
grid1N	-81.52974094	41.03716776	260.51166	260.50006	1.5	1.2
grid1E	-81.5297328	41.037166	260.52366	260.4927	0.8	2.946
grid1S	-81.52973526	41.03715995	260.52466	260.48306	1	4.151
grid1W	-81.52974307	41.03716173	260.51666	260.49203	1.3	2.27
NEpavement1	-81.52977625	41.03722903	260.62966	260.5982	0.9	2.749
NEpavement2	-81.52977488	41.03722812	260.61966	260.59503	0.8	1.926
NEpavement3	-81.52975979	41.03724061	260.58966	260.60144	1.4	-1.784
NWpavement1	-81.52981441	41.03719649	260.61066	260.58627	0.5	2.411
NWpavement2	-81.52981563	41.03719738	260.55466	260.5791	0.8	-3.582
Spavement1	-81.52972566	41.0370807	260.58866	260.57648	0.8	1.908
NorthWest	-81.5316437	41.03831489	262.32171	262.30737	0.2	-0.149
grid2SE	-81.52839869	41.03523807	261.22659	261.22595	1	-3.418
grid2NE	-81.52839884	41.03524445	261.23659	261.2175	1.3	-2.519
grid2NW	-81.52840723	41.03524435	261.24359	261.2232	1.1	-1.261
grid2SW	-81.52840712	41.0352381	261.24859	261.22775	0.3	-1.633
				RMSE	0.98 cm	2.29 cm

Table 6: GCP coordinates, horizontal and vertical errors

Comparison of standard accuracy tags

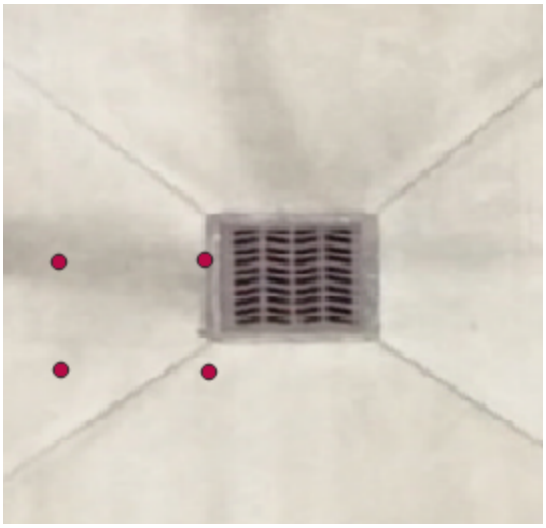
The E400 Sony RX1RII hot swap payload bay includes the Event 38 Companion Computer system. The Companion Computer controls the camera during flight and records geotags for the images with standard accuracy geotags. Standard accuracy geotags have an accuracy of about 5 meters depending on environmental factors.

Sony RX1RII with companion computer

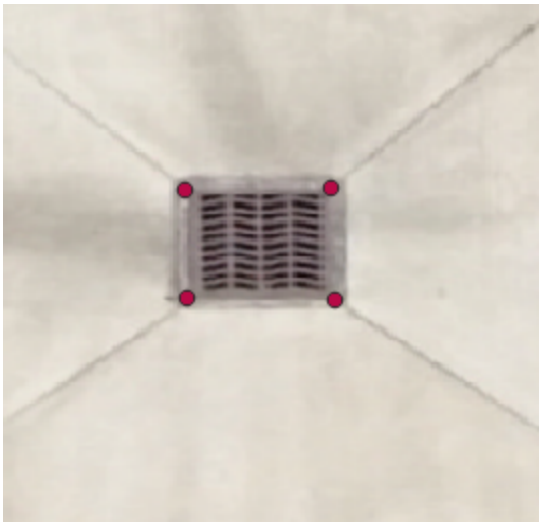
A standard accuracy mosaic was created with the following settings in agisoft. Notably the settings changed are the antenna offset and the geotag accuracy.

Processing Step	Settings
Geotag Accuracy	5m
Antenna offset	X(m): 0 Y(m): 0 Z(m): 0
Rolling shutter compensation	off
Alignment	High Accuracy, Reference Preselection
Optimize	f,b1, b2, cx, cy, k1-k4, p1, p2
Dense Cloud Generation	High Quality, Mild, Calculate Colors

Table 7: Agisoft Photoscan Standard GPS Processing Settings



Standard GPS Mosaic without GCPS



PPK GPS Mosaic without GCPS

	Latitude	Longitude	X/Y Error standard GPS (m)	X/Y Error PPK GPS (m)
grid1N	-81.52974094	41.03716776	0.735	1.5
grid1E	-81.5297328	41.037166	0.717	0.8
grid1S	-81.52973526	41.03715995	0.723	1
grid1W	-81.52974307	41.03716173	0.701	1.3
NEpavement1	-81.52977625	41.03722903	0.707	0.9
NEpavement2	-81.52977488	41.03722812	0.712	0.8
NEpavement3	-81.52975979	41.03724061	0.695	1.4
NWpavement1	-81.52981441	41.03719649	0.709	0.5
NWpavement2	-81.52981563	41.03719738	0.720	0.8
Spavement1	-81.52972566	41.0370807	0.720	0.8
NorthWest	-81.5316437	41.03831489	0.636	0.2
grid2SE	-81.52839869	41.03523807	0.785	1
grid2NE	-81.52839884	41.03524445	0.785	1.3
grid2NW	-81.52840723	41.03524435	0.951	1.1
grid2SW	-81.52840712	41.0352381	0.813	0.3
		RMSE	Standard GPS: 0.744 m	PPK GPS: 0.0098 m

Conclusion

Using the Emlid Reach M2 system with the Sony RX1R II camera flying at 100m AGL resulted in 0.98 cm horizontal and 2.47cm vertical RMSE. Neither base nor receiver required an excessive warmup time or additional calibration steps. Weather conditions were not optimal but not particularly demanding. By producing 93 acres of surveyed area in the 15 minute flight, the E400 surveyed land at 6.2 acres/minute despite high sidelap and windy conditions.