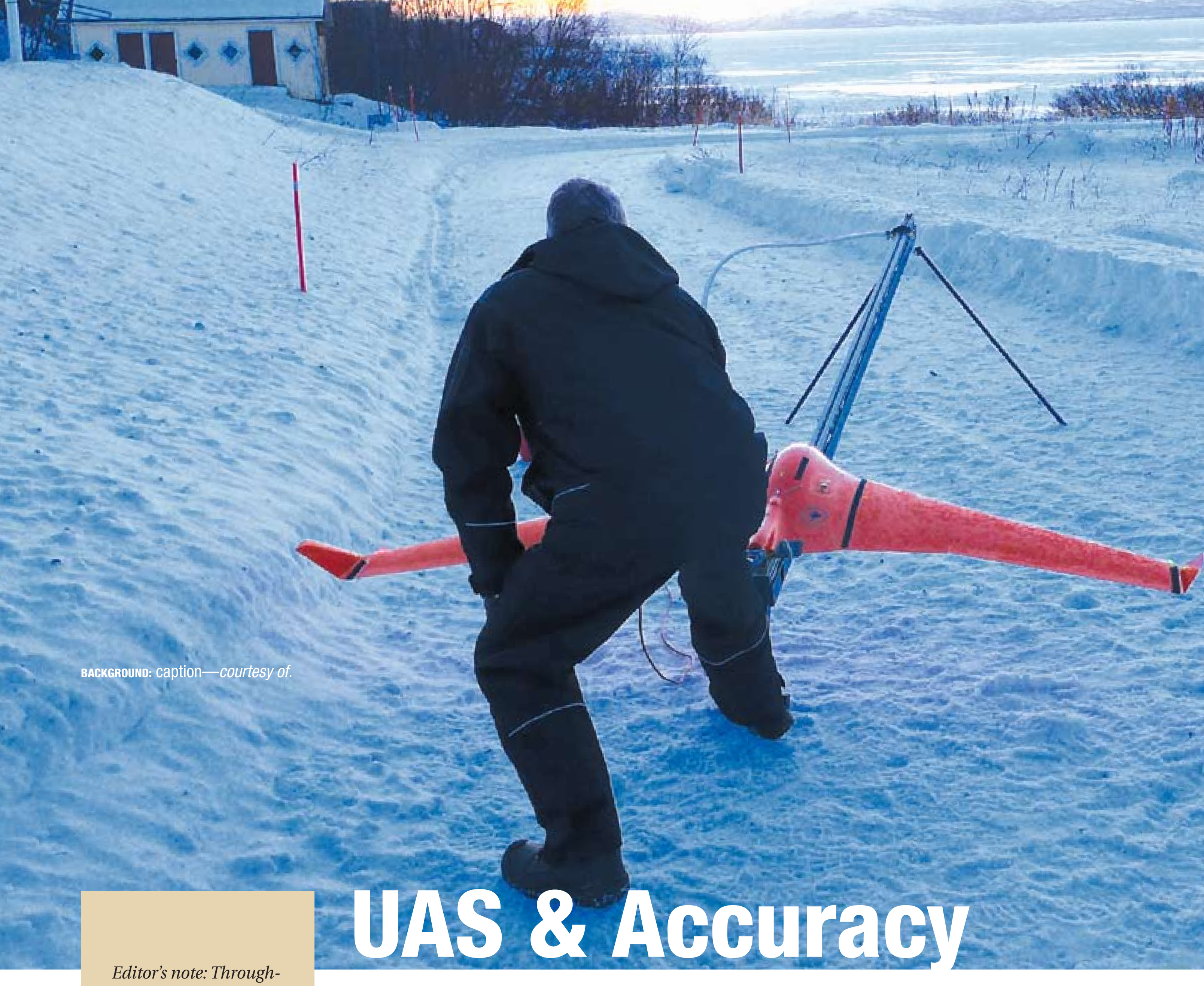


BACKGROUND: caption—*courtesy of.*

UAS & Accuracy

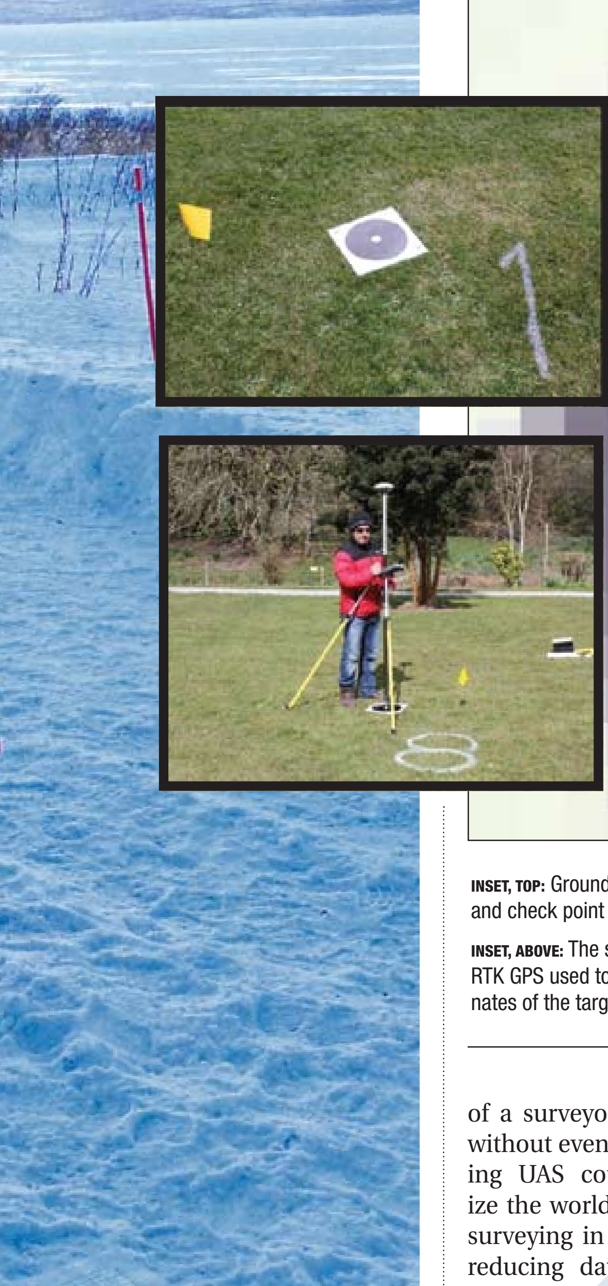
Field tests of UAS photogrammetry reveal verifiably superior results over traditional survey technologies.

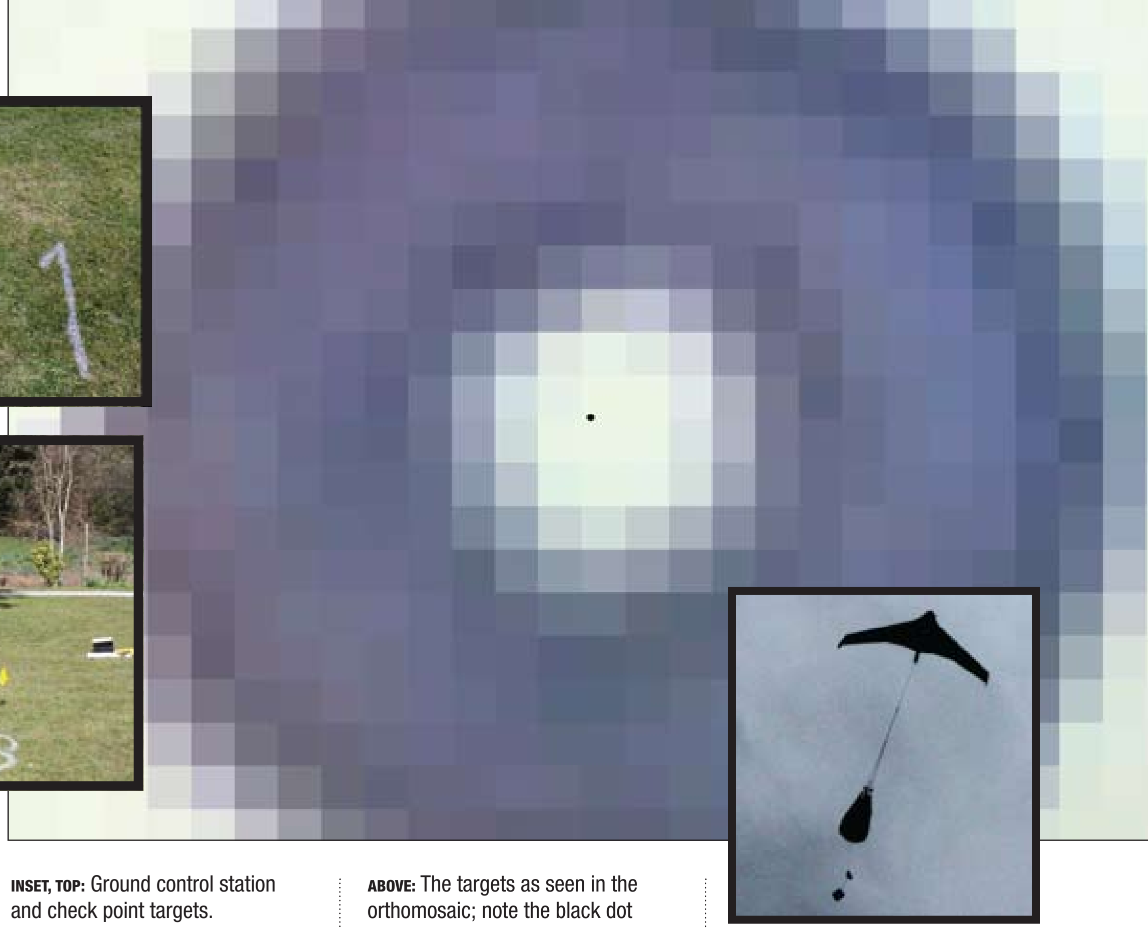
By Paudie Barry and Ross Coakley

Editor's note: Throughout the past year as PSM has been covering UAS, we've been looking for end-user evaluations of the accuracies that can be expected from these promising tools. A forward-thinking surveying firm in Cork, Ireland has done just that: in the following adaptation of their scientific paper, Baseline Surveys Ltd outlines how they evaluated the capabilities of a popular light-weight UAS for digital photogrammetric mapping, with impressive results and thought-provoking conclusions.

Baseline Surveys Ltd specializes in the supply of accurate geospatial data—such as cadastral, topographic, and engineering survey data—to commercial and government organizations. Recently, we invested in unmanned aerial system (UAS) photogrammetric technology and needed to establish the accuracy of the geographic data derived from it before marketing our new service. Having supplied the construction industry with survey data for more than 20 years, we felt that it was crucial for our clients to clearly understand the accuracy of our photogrammetry so they can safely make informed decisions. This information would also inform us on how and where UAS photogrammetry can be used.

Much of current survey work using conventional methods is labor-intensive, it can involve surveyors working in hazardous environments, it's expensive, and the completeness of the data captured often depends on the time allotted to the survey project. No representation of geography is perfect, and certainly the point, text, line, and polygon style of





INSET, TOP: Ground control station and check point targets.

INSET, ABOVE: The stabilized network RTK GPS used to get the coordinates of the target centers.

ABOVE: The targets as seen in the orthomosaic; note the black dot that represents where the center of the target should be according to the network RTK GPS.

INSET, ABOVE: The C-Astral Bramor UAS during the initial deployment of its landing parachute.

21st-century digital mapping is no exception. GPS and total-station geographic data-collection methods are accurate enough to design civil engineering and architectural projects with sufficient practical accuracy (within +/-5cm); however, GPS data completely fails in richness. Each line, point, and polygon must be described by textual means in order to communicate its geographic meaning. So, although it has (traditionally) been accepted as complete, there is an undeniable risk of a surveyor omitting data without even realizing it. Using UAS could revolutionize the world of engineering surveying in terms of vastly reducing data-capture cost while increasing data quality and richness.

Pre-collection Planning

The specific information we required was the actual accuracy that can be reliably achieved using a UAS to collect data under field conditions throughout a typical 2-hectar (Ha, almost 5-acre) site.

We placed 45 ground markers as check points and surveyed them using network RTK GPS; we specifically designed the ground markers to meet our accuracy needs. We established ten separate control points (positioned so that they were equidistantly distributed throughout the site to ensure an even distribution of errors) and put these into our photo modeling software. The rest of the GPS coordinated check marker data were added later in ArcMap to the completed orthomosaic and digital elevation model so we could accurately compare the UAS photogrammetry XYZ data with the RTK GPS XYZ data at highly reliable common points.

For the UAS test, a flight plan was generated so that an 80% front overlap and 80% side overlap as well as an altitude of 90m would provide an expected GSD of 10mm. Flight direction was plotted at 90 degrees to the actual wind direction to maintain a constant ground speed of less than 16m/s during the photographic process. This step helped to reduce ground smear, a phenomenon which blurs the pixels due to the movement of the UAS.

RPAS, UAV, or UAS?

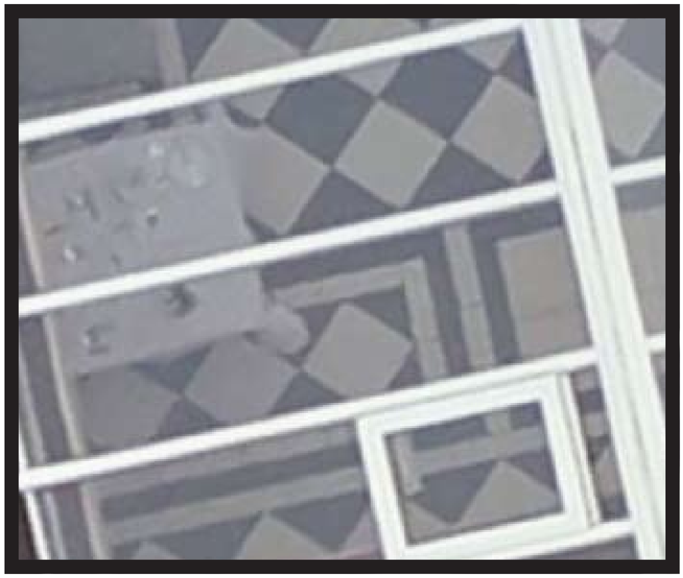
The original academic paper uses the term "remotely piloted aircraft system" (RPAS) to describe the small, unmanned aircraft referenced in this article. PSM has also seen the terms "drone" and "unmanned aerial vehicle" (UAV) and "system" (UAS). We have chosen to use UAS (which are mainly guided along preprogrammed flight paths by autopilot rather than actual remote piloting) in all our publications.

Data Acquisition Systems

We used a hybrid of Trimble GoeXR network RTK GPS and a C-Astral Bramor UAS. We used the RTK GPS to establish Irenet95 (ITM) coordinates on our specifically designed ground markers to provide photo control. The GPS unit has a spatial accuracy in the region of 10-25mm both horizontally and vertically, due to the fact that we used struts to maintain steadiness during network RTK GPS readings.

The C-Astral Bramor UAS platform is a blended wing constructed of Kevlar and carbon fiber and has a 4kg maximum take off mass (MTOM). It is catapult-launched and has extremely steady flight characteristics and advanced safety features afforded by its Lockheed Martin autopilot, including a parachute deployment system for emergency and routine landing procedures. It carries a Sony Nex-7 24MP RGB sensor, which is oriented in portrait to allow for more forward overlap at a slower triggering interval. It also has three-hour endurance and a practical wind tolerance of 20 knots when piloted by an experienced UAS crew.

We decided to use network RTK GPS to establish ITM coordinates on the center positions of the ground control markers; we then carefully designed geometrically patterned ground markers that allowed us to obtain sub-pixel accuracy of the center point location when identifying ground marker positions at the post-data-collection and pre-processing stage. Agisoft Photoscan was the software we used for its stated accuracy of 1-3 pixels and the high quality of the orthophotography and digital elevation model outputs. ArcMap was used for presenting the final fusion of data captured by UAS and GPS.



LEFT: The detail of 1cm orthophotography can be seen in this photo looking down through the atrium over the dining area of the surveyed hotel; note the cutlery on the table.

Site Conditions

As surveyors we wanted to carry out our accuracy test in everyday conditions, which are often sub-optimal. The prevailing weather conditions on the day of our flight test were cloudy with intermittent sunny spells, with a wind speed at our flying altitude of 90m above ground level (AGL) a maximum of 7m/s. The wind direction at altitude diverged from that used in our pre-flight planning by 20 degrees. This had the effect on the UAS of getting a 10m/s variation in its ground speed when travelling with and against the wind.

The topography of the site had a 5m variation in level, was surrounded by mature woodland up to 25m high, and had numerous buildings that would all contribute to turbulence at our flying altitude.

Processing the Data

First, the 10 ground control points and 45 check points, which were surveyed by network RTK GPS in ITM coordinates, were downloaded into Geosite Office 5.1 and exported to AutoCADlt 2013 as two separate files.

We downloaded 1,601 photographs from the Bramor UAS along with the log file, which contains photo to GPS position, barometric height, roll, pitch, and yaw. We imported the photos and the log file into Agisoft Photoscan and, using the software, we eliminated superfluous photographs by deleting photos with high roll values, which occurred at turns. The refined 728 photographs were then used for the photo alignment stage; we used an oversized area because we felt that the additional photographs would contribute to alignment accuracy of the target area. We then imported the 10 ground control points into Photoscan and identified the center of each control point marker on each photo and attached it with its appropriate coordinate value.

Of the 728 photographs, we then used 168 photographs to further process the data into a 3D model for subsequent orthophoto and DEM output. The orthophoto was output at a resolution of 10.2mm pixel size, and the DEM was output at 20mm pixel size.

The resulting geo-referenced orthophoto and DEM were imported into ArcGIS along with the GPS CAD data. Distances were measured from the center of the target as they appeared on the orthophoto to the center of the target as measured by GPS by using the ArcGIS measure tool to attain the distance between both readings. GPS level point data were compared with DEM readings at the same point. Results were then recorded.

The resulting geo-referenced orthophoto and DEM were imported into ArcMap

Figure 1

Point No.	XY Error m	Z Error m	Point No.	XY Error m	Z Error m
1	0.025	0.06	24	0.008	0.02
2	0.023	0.02	25	0.000	0.03
3	0.014	0.01	26	0.004	-0.02
4	0.014	-0.04	27	0.012	0.03
5	0.018	-0.05	28	0.011	0.00
6	0.020	-0.02	29	0.029	0.02
7	0.035	-0.02	30	0.023	-0.05
8	0.019	-0.01	31	0.021	-0.04
9	0.010	0.04	32	0.010	-0.02
10	0.043	0.01	33	0.031	-0.07
11	0.041	0.04	34	0.007	-0.01
12	0.015	-0.01	35	0.026	-0.02
13	0.040	-0.01	36	0.040	-0.07
14	0.016	-0.02	37	0.007	-0.04
15	0.016	-0.02	38	0.012	-0.03
16	0.017	-0.03	39	0.007	-0.03
17	0.006	-0.02	40	0.025	0.02
18	0.047	-0.04	41	0.012	0.03
19	0.023	-0.02	42	0.033	0.03
20	0.008	0.05	43	0.024	0.07
21	0.010	0.00	44	0.015	0.01
22	0.013	-0.01	45	0.011	0.03
23	0.016	0.00			

along with the coordinated data from the RTK GPS. The measure tool was used to measure the horizontal distance between the GPS-derived center of each check point and the center of each corresponding check point derived from the orthophotography. The Z error was calculated by subtracting the GPS-derived Z value from the DEM value at the same point. The difference between the two data sets is shown in **Figure 1**. From these figures results were obtained as shown in **Figures 2** through **5**.

Figure 2

Label	X error (m)	Y error (m)	Z error (m)	Error (m)	Projections	Error (pix)
point 1	0.001958	0.001193	-0.000491	0.002344	33	1.277433
point 10	0.009328	-0.026748	-0.012029	0.030776	9	0.863605
point 2	0.000012	-0.003082	-0.024623	0.024815	35	1.419103
point 3	-0.004135	0.010068	0.006149	0.012501	21	1.063595
point 4	0.007812	0.009205	0.012708	0.017529	20	1.610777
point 5	-0.000001	0.003609	0.007510	0.008332	18	0.551958
point 6	-0.004106	-0.003277	0.012169	0.013255	19	0.574836
point 7	-0.000441	-0.002176	-0.010497	0.010729	20	0.752000
point 8	-0.002598	-0.004642	-0.006060	0.008064	16	0.845599
point 9	-0.006739	0.000893	-0.016638	0.017973	18	0.610214

Figure 3

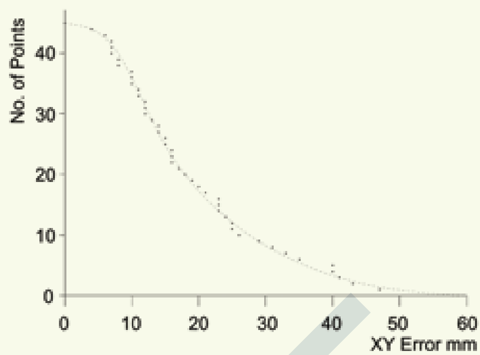


Figure 4

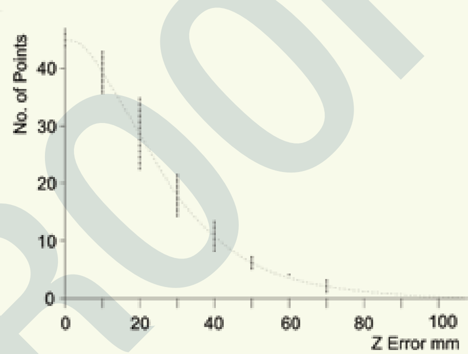


Figure 5

	XY m	Z m
Mean	0.021	0.031
RSME	0.023	0.035
Accurancy 95%	0.041	0.068

The accuracy we achieved throughout the 45 check points was 95% reliable

Results

The accuracy we achieved throughout the 45 check points was 95% reliable within 41mm horizontally and 68mm vertically and with a 11.7mm ground sample distance taken from a flight altitude above ground level of 90m. The area covered by one image was 70.2m x 46.4m, which equals 0.325Ha (288 square yards). The accuracy that can be achieved by UAS photogrammetry is within 1:200 scale, according to NSDI & FGDC mapping accuracy standards during sub-optimal data collection conditions.

I believe that UAS will mostly overtake the work of GPS and total-station ground-based survey systems as the main survey-grade data-collection method used. Although RTK GPS still remains indispensable for accurately geo-referencing of ground markers to spatially control the UAS aerial data, UAS are far more efficient at capturing mass geographic data than either GPS or tacheometry, particularly over larger areas. Total stations and laser scanners, unlike GPS and UAS, are very good at collecting data under tree and building canopies, so will be mostly used to ground survey what cannot be seen from above.

In addition to an enormous time savings on data collection without an appreciable loss in accuracy, UAS aerial photogrammetry offers far richer data than conventional survey vector data consisting of points, text, and lines. UAS photogrammetry offers the user a bird's eye view of the site without any need for text or any fear of data being omitted, except for features not visible from the air such as under trees. The accuracy to which levels are generated by the photogrammetry allows for contouring at 0.2m intervals, which is very encouraging; GPS readings would still be required for manhole covers, finished floor levels etc., but even so, this represents a huge leap forward in terms of surveying efficiency.

In terms of representing the landscape, the orthophoto generated from a UAS can be combined with its DEM to produce very accurate photorealistic 3D modeling in programs such as ArcScene and can be analyzed to yield highly accurate earthmoving volumetric calculations.

These findings mean that UAS photogrammetry can replace GPS surveying as the main method of data capture for engineering projects, boundary mapping, and topographical surveying.

Paudie Barry worked as an engineering surveyor on the London Water Ring main project, returning to his native Ireland in 1990 to set up Baseline Surveys Ltd at the age of 22. He is a committee member of Unmanned Vehicle Systems International.

Ross Coakley, BE, MIEI worked in England as an engineer before establishing an engineering consultancy in Cork, Ireland in 1996. In 2012 he teamed with Baseline Surveys to develop a UAV aerial photogrammetry and GIS data-capture service.