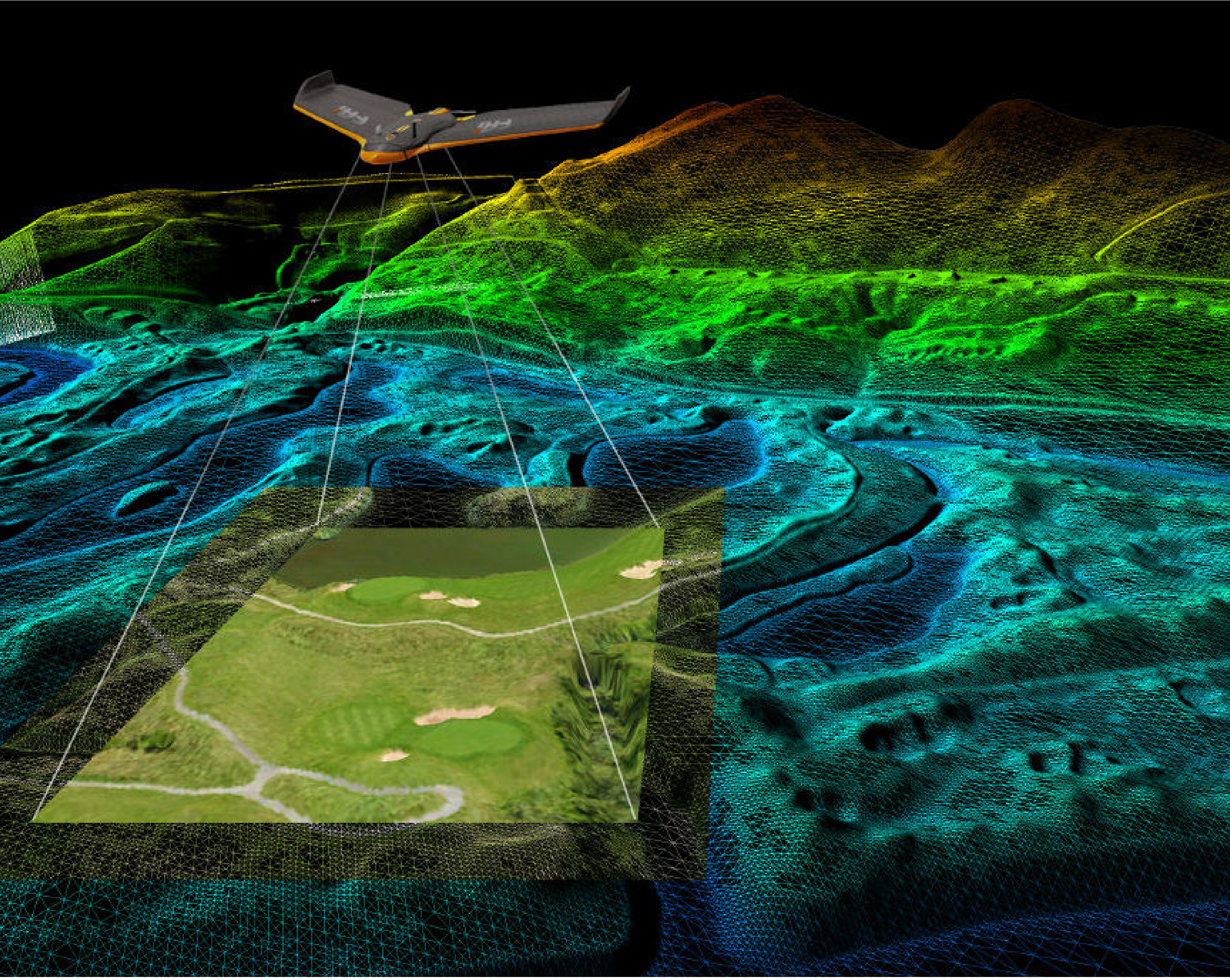


The Truth about Drones in Mapping and Surveying

Surveyors already have access to ground-based, manned flight, and satellite data, so will they embrace this new technology in earnest?

By Bill McNeil, Contributor/Advisor, and Colin Snow, CEO and Founder, Skylogic Research, LLC

Image credit: Future Aerial

Introduction

According to 2015 statistics from the US Department of Labor, there are 44,300 surveyors in the United States. But mapping is practiced by a larger population of cartographers, topographers, photogrammetrists, civil engineers, and geographers – it's not exclusive to the surveying industry. The American Society of Civil Engineers lists more than 150,000 members in 177 countries, and the Imaging and Geospatial Society has 7,000 supporters. All of these disciplines can be grouped under a broader category called geographic information systems (GIS). GIS professionals provide a wide variety of land-related services like identifying property boundaries, subdividing land, and surveying construction sites for placement of buildings. They also produce topographic and hydrographic maps, volumetric calculations for stockpiles, and flood insurance maps, among other services.

The number of surveyors is actually projected to decline by two percent from 2014 to 2024 because of improved surveying technology. Even though surveyors are a fraction of the broader population of GIS professionals, how will the improved surveying technology that is affecting them apply to that broader GIS population? And given the downbeat forecast for surveyors compared with the numerous upbeat billion dollar projections of drone use from the FAA and other industry observers, the question becomes, Where do commercial unmanned aircraft systems (UAS) or drones fit into the surveying technology mix?

In this paper, we'll answer that question and show how small drones have been used successfully in surveying and mapping thus far, review competitive and traditional approaches offered by incumbent technology, discuss the opportunities and challenges posed by drone technology itself, outline the lessons learned, and discuss what's next for drones in this sector.

Use Cases

Today, the exact same data collected traditionally by ground-based survey tools can now be gathered faster and more cost effectively by drones. Luke Wijnberg of 3Drone Mapping puts it this way:

> "With quick deployment times and low maintenance costs, we can map pretty much anywhere, at any time. Drones allow us to use all kinds of payloads such as near-infrared cameras to map vegetation chlorophyll levels for agriculture. Not only do drones make things cheaper and faster for a surveyor, but they also make our job safer. We can now survey areas remotely that perhaps have some environmental risks to them, such as quarries, cliff edges, polluted areas, etc."

A June 2016 Wall Street Journal article mentions that surveying and engineering company McKim and Creed plan to have one drone pilot per each of their 21 field offices. According to Christian Stallings, their research and development manager, drones can inexpensively create images with resolutions of features 1 to 2 inches in size when conducting survey plots of a square mile or less.

Drones capture data that can be used in a wide variety of surveying and mapping applications. Some of these include the following:

1. **Automated mapping –** Workflow for automated mapping applications begins by establishing control points. These are either ground features with known coordinates or markers placed at known locations around the area to be mapped. This is a fundamental element of mapping because ground control points establish (1) scale, or the relationship between the map distance to the real world distance, (2) feature height, and (3) north orientation.

   Once control points are in place, the drone's flight path is calculated by using a mission planning application. This solution enables the drone to fly autonomously at a set altitude while taking pictures at two or three-second intervals. Each image taken should overlap the previous picture by 80% to the front and 60% to the side. The screen shot in Figure 1, from Esri's Drone2Map for ArcGIS solution, illustrates the typical lawn mower flight pattern created by a mission planner.

Figure 1 - Typical Mission Planner Flight Plan

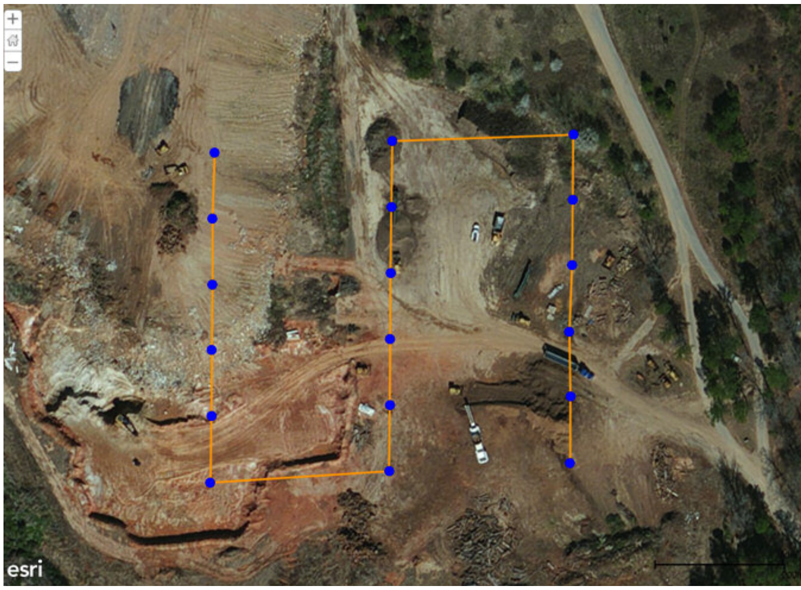


Image: Esri

Terms to Know

An **orthomosaic** — sometimes called orthophoto, orthophotograph, or orthoimage — is an aerial photograph geometrically corrected ("orthorectified") such that the scale is uniform; the photo has the same lack of distortion as a map. Unlike uncorrected aerial photographs, an orthophotograph can be used to measure true distances, because it is an accurate representation of the Earth's surface. It's been adjusted for topographic relief, lens distortion, and camera tilt. Typically, an orthomosaic is a composite of individual photos that have been stitched together to make a larger one.

Photogrammetry is a technique which uses photography to extract measurements of the environment. This is achieved through overlapping imagery, where the same feature can be seen from two perspectives. With photogrammetry, it is possible to calculate distance and volume measurements. Companies use these outputs to create "point clouds" or 3D images used to do things like render a building.

Digital elevation model (DEM) is a digital model or 3D representation of a terrain's surface created from terrain elevation data. A digital surface model (DSM) is the earth's surface including objects like trees and buildings. A digital terrain model (DTM) is the earth's surface without any such objects.

Some mission planners enable data to be streamed real time from the drone to the operator while in flight. However, most data is accessed from the drone after it has landed. The screen shot in Figure 2 illustrates raw data from a flight. From here, different GIS software applications can process the images into 2D, 3D, and point cloud maps.

Figure 2 - Drone Flight Raw Data

Image Information

Enabled	Image	Group	Lat[degree]	Long[degree]	Altitude
✓	DSC01456.JPG	group1	35.709429	-78.67118	236.18
✓	DSC01457.JPG	group1	35.7092	-78.671189	236.11
✓	DSC01458.JPG	group1	35.708972	-78.671189	236.25
✓	DSC01459.JPG	group1	35.708743	-78.671192	236.15
✓	DSC01460.JPG	group1	35.708513	-78.671194	236.47
✓	DSC01461.JPG	group1	35.708282	-78.671198	236.22
✓	DSC01474.JPG	group1	35.708322	-78.670433	236.25
✓	DSC01475.JPG	group1	35.708551	-78.67043	236.23
✓	DSC01476.JPG	group1	35.708782	-78.670428	236.2
✓	DSC01477.JPG	group1	35.709012	-78.670427	236.21
✓	DSC01478.JPG	group1	35.70924	-78.670423	236.19
✓	DSC01479.JPG	group1	35.70947	-78.670419	236.24

Image: Esri

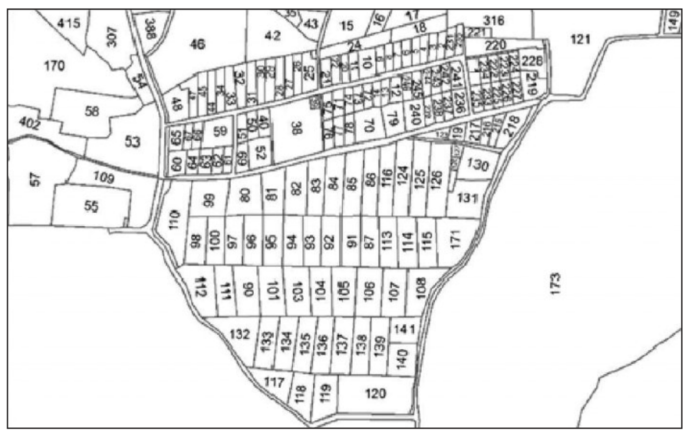
2. **Cadastral surveying –** Cadastral surveying establishes property boundaries consisting of land and buildings on a parcel. In most states, only licensed land surveyors can conduct boundary surveys for the purpose of buying, selling, or renting land, buildings, or housing. This is a valuable service for the real estate market because surveys describe:

- The size and extent of the property being bought or sold
- Utility easements or right-of-ways
- The location of buildings, fences, and driveways
- Potential encroachments

The real estate market has been a significant source of revenue for surveyors, but the 2007 housing meltdown greatly affected their business. Income has largely returned but inexpensive data from drones can further aid the recovery.

Drone-generated photographs that are incorporated into an orthomosaic can identify boundaries and land features from which 2D maps can be created like the one shown in Figure 3. This data for mapping boundaries and property assets will have a major impact on the real estate and appraisal industry because the acquisition cost of data is low.

Figure 3 - Cadastral Survey Example



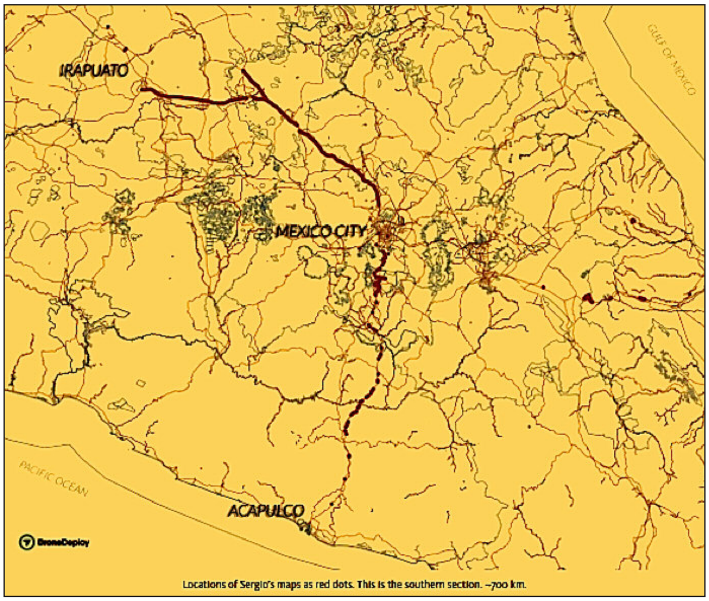
Source: Comparative Study on Cadastral Surveying

3. **Corridor surveying –** Drones are uniquely suited for mapping road, highway, and railway infrastructures because they are extremely cost effective compared with collecting data via manned aircraft, satellites, or road crews. Simple image capture can render photomosaic images of pavement or rail conditions, lane marking, vegetation encroachments, and general road conditions as well as provide planners a digital surface model (DSM).

Two years ago, SkyLab, a Mexican surveying company, teamed up with DroneDeploy to map 620 miles of highways for a government agency (Figure 4). It was a difficult job because of mountainous terrain and locals were less than excited about picture-taking drones flying overhead.

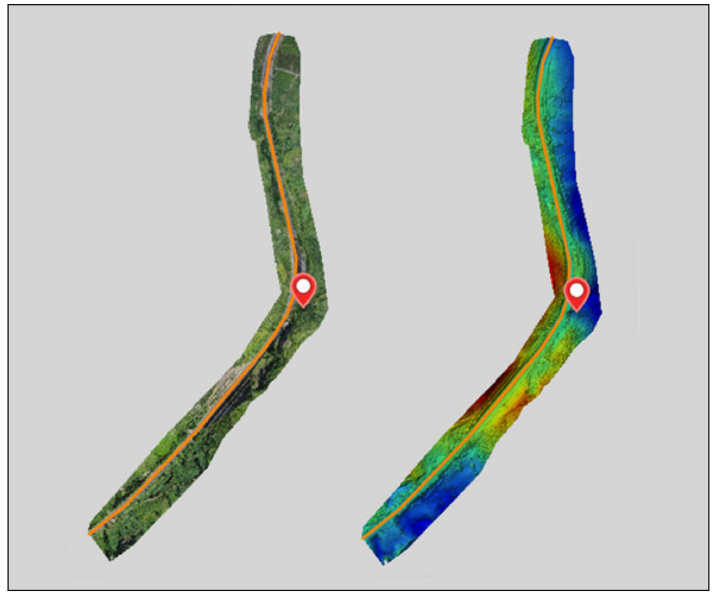
Despite the obstacles, an 8-person team successfully flew five DJI Phantom 3 Professional drones and collected 120,000 images of highways stretching 1,000 kilometers.

Figure 4 - Highways Mapped with DroneDeploy



Source: DroneDeploy

Figure 5 - Orthomosaic and Digital Surface Model



Source: DroneDeploy

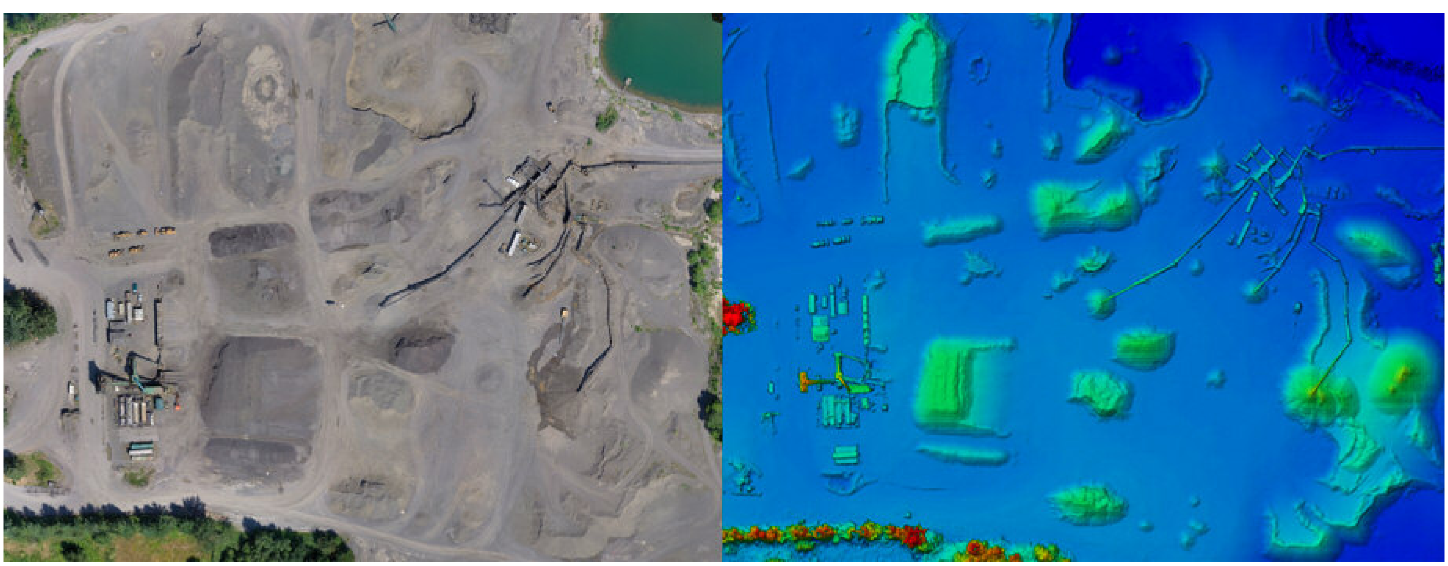
Drone Deploy then processed these images with its new map engine and resultant orthomosaic and DSM (Figure 5) was delivered on time to the client. According to Michael Winn, DroneDeploy's CEO, the images were detailed enough to see a dime on the ground.

4. **Volumetric calculations –** As we have noted in The Truth About Drones in Construction and Infrastructure Inspection, mining and construction sites frequently need to measure the volume of stockpiles and material extraction pits. Drones are proving to be an excellent tool for this application because, once mapped, DSMs can be created of the area and ground features measured.

   Dallas VanZanten, owner of SkyMedia Northwest, an aerial mapping company, explained that if traditional mapping methods were used to calculate stockpile volume, a ground-based surveyor would need to measure the stockpile elevation every 5 or 10 feet. This would be time consuming and, depending on the type of material, it could be dangerous. The process would also generate fewer reference points than a DSM of the same area created with data from a drone flight. VanZanten further indicated it would take a whole day for a man to cover the 30-acre site, but his DJI Phantom 3 did it in 30 minutes. After the drone flew over the site, data was processed into the DSM (see the right half of the image in Figure 6). From here, it was just a matter of drawing polygons around each stockpile to get the associated volume.

5. **LiDAR mapping –** LiDAR allows mapping and surveying professionals to capture minute details that photos can't — and with those details create precise digital representation of objects, buildings, and the ground. LiDAR is based on the same concept as RADAR, but it uses laser light instead of radio waves. By sending out laser beams in all directions,

Figure 6 – Stockpile Orthomosaic and DSM Example



Source: DroneDeploy

collecting the reflected energy, and performing some nifty high-speed computer processing, a scanner can create a real-time, virtual map of the surrounding area. These representations have many uses.

But most LiDAR units are heavy and — up to now — had to be mounted on trucks or manned aircraft. So over the past couple of years manufacturers like Riegl, Routescene, Velodyne, and YellowScan have reduced the size and weight of their units such that it's now possible to mount them on large multicopter drones. By coupling novel drone-mounted LiDAR systems with vision cameras, advanced computer processing, and GPS, it has become possible to create a remotely piloted flying LiDAR scanner. Vendors like Phoenix Aerial Systems and XactSense offer integrated solutions.

LiDAR drone solutions cost significantly less than vehicle-based mobile mapping systems. Photogrammetry-based solutions may be a low-cost purchase, but results are time-consuming to produce and thus expensive to undertake. Also, when compared with photogrammetry, LiDAR is a much better mapping technology when the potential for strong shadows, areas of poor contrast, or featureless surfaces exist. Photogrammetry also requires you have access to the site to survey your ground control points, which is a time-consuming task. LiDAR eliminates this task altogether.

Competitive Traditional Approaches

Today, surveyors have access to a variety of terrestrial data. Satellite data from companies like DigitalGlobe, Airbus Defense & Space, TerraBella, and PlanetLabs offers extensive coverage with wide spectral capabilities, but at times resolution can be relatively poor and clouds may provide inconsistence coverage. Higher resolution data with the same wide spectral capabilities can be acquired from manned aircraft, but it can be expensive and is also subject to weather conditions. Drone data, suited for smaller jobs, can be acquired on demand, is of very high resolution, and is the least expensive. Ground-based data acquisition using GPS receivers and total stations (an electronic transit and distance meter for reading slope distances) also collects high-resolution data but the process can be time consuming and expensive.

Satellite, manned aircraft, and ground-based data sources have been trusted and reliable resources that surveyors have been using for years. Many mapmakers will need to see real cost savings and operational benefits before they consider adding UAS to collect data. Unlike some of the firms referenced in this paper, most surveyors will not be early adaptors.

Opportunities

Drones are going to have a major impact on the surveying and mapping industry, but perhaps to a lesser degree on traditional surveyors. As mentioned earlier, the Department of Labor is forecasting a 2% drop in the number of surveyors from 2014 to 2024. On the other hand, the Labor Department is projecting 29% growth for the photogrammetry category. This means more and more photogrammetrists will do surveying work and more surveyors will use photogrammetry tools for mapping. In other words, inexpensive data collected from drones has and will continue to blur the lines between photogrammetry and mapping.

There is another issue at play here. The process of physically flying a drone is not unique to map making. The type of data collected is determined by the instrument payload — not by the drone operator. In other words, it really doesn't make any difference if the application is precision agriculture or mapping a pipeline, the deliverables are the information extracted and processed by the crop consultant, the photogrammetrist, or the surveyor.

Drone technology is moving extremely fast. It's very possible many surveyors would rather hire a service provider to collect data than invest in a tool that can be obsolete is as little as six months. They may also consider short-term leases to ensure their technology is relatively current or just rent a drone when needed. Regardless of how small drones fit into the workflow, they will not only affect the industry, but they will also create new opportunities for independent contractors who, based on their experience, may be able to fly and collect data less expensively than surveyors. The value add is the knowledge and data processing skills of the surveyor and photogrammetrist, not their drone-flying skills.

The real industry growth may come not from the surveying and mapping community using drones but rather from the surveying and mapping community using drone data purchased from independent UAS contractors or service providers. If you think about it, how many survey companies own satellites?

Inexpensive drone data has created opportunities for those people or companies that want to provide drone flights for hire, and it's also spawned new GIS software applications to process the data.

Challenges

Drones are not just another tool in the surveyor's toolbox — there are strings attached. Under newly released Federal Aviation Administration (FAA) Part 107 regulations, small commercial drones must remain within visual line-of-sight (VLOS) of the remote pilot. This may not be too much of a hardship when surveying a real estate parcel, but it could be a significant impediment when mapping a long narrow highway.

The range of small drones continues to be a problem. Most quadcopter drones have a flight time of less than 30 minutes. It is certainly possible to land, change batteries, and continue the mission, but this interruption can affect the flow of data and introduce a manual process that adds labor cost.

Package cost is another consideration. Quadcopters that have good cameras are available from vendors like 3D Robotics, DJI, and Yuneec and are priced under $2,000. However, this only buys the drone -- and maybe a couple batteries. If you want to be in the mapping business, you will need more. The "system" part of a UAS part includes things like the mission planning and data processing software needed to convert raw drone data into orthomosaics, 2D, 3D, and point cloud maps – and that does not come cheap. GIS data solutions have quite a disparity in price. For instance, 3DR's Site Scan UAS can cost over $10,000; Esri's Drone2Map desktop solution costs $3,500 plus data storage fees; and Pix4Dmapper can be licensed for $5,000 per year. The point being, many surveyors and other mapmakers may not want to invest in expensive technology that could be obsolete in 18 months.

Lessons Learned

One of the things we're learning is fast-moving technology often outpaces the market it is supposed to serve. Many surveyors will be more than content to sit on the sideline and purchase data from licensed drone pilots, just as they now do with manned aircraft and satellite vendors. We expect we will witness a greater adoption rate when UAS technology becomes less fluid and less expensive.

But others are not sitting on sidelines; they are innovating and finding new ways to use drones. Cemetery mapping probably wouldn't be near the top of the list when thinking about mapping applications, but it's a simple example that illustrates the power of what small drones can do. According to AARP, there are 115,000 cemeteries in the US. Many still use old paper records to map out new property. This antiquated system can lead to burying people in the wrong grave plot. PlotBox, an Irish startup, has developed a cloud-based application that uses drones to identify and map available plots on cemetery grounds. The founders, Sean and Leona McAllister, indicated they could fly a 50-acre cemetery that would normally take up to 100 hours, in 30 minutes. Plotbox has been called the Google of cemeteries and has already sold $280,000 worth of services.

What's Next for Drones in Surveying and Mapping?

In this paper, we selected examples of prosumer drones and cloud-based software because they are inexpensive, ubiquitous tools that hold the promise of collecting and processing data at an affordable price. On the surface, these prosumer drones look like pretty much alike. And even at second glance, it's hard to differentiate their current technology from that offered by the major survey equipment vendors. But these vendors — like Leica Geosystems, Riegl, Trimble, and Topcon — which now sell their own drones costing $25,000 or more, are much better known brands among surveying and mapping firms. That's their advantage. At this time, there is simply too much of a disparity between the $2,000 cost of a prosumer drone and the $25,000 or $50,000 cost of a well-known brand.

The same is true for mapping and surveying software. As the demand for drone-sourced data grows, the pressure to provide lower cost data processing solutions will mount. We expect established companies like Esri will be able to maintain a higher price for their applications because they are selling to their installed base – at least for a while. As the 800-pound gorilla in the GIS industry, Esri can sell 1,000 copies of Drone2Map without acquiring one new customer. Other solutions like 3DR's Site Scan, DroneDeploy, PrecisionHawk's Datamaper, and Pix4Dmapper may be forced to lower the cost of their applications or see less expensive solutions enter the market.

On the horizon we see that DroneDeploy is working closely with DJI to make thermal mapping a reality now that the Zenmuse XT camera is widely available for the DJI Inspire and Matrice drones. The company reports in their newsletter that processing is currently in the beta test phase, with automated flight for the XT coming soon.

Keep your eye on this space for more innovation. We believe there will be more technological advances as the resolution of camera sensors goes up and the cost, size, and weight of LiDAR comes down. We also expect GIS professionals will continue to find new ways to use drones beyond the ones mentioned here.

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