AIR-LAND SURVEYS
A ROWE Company

ARTICLE 1
UAS MAPPING (THE 5W`S AND HOW IT`S DONE)

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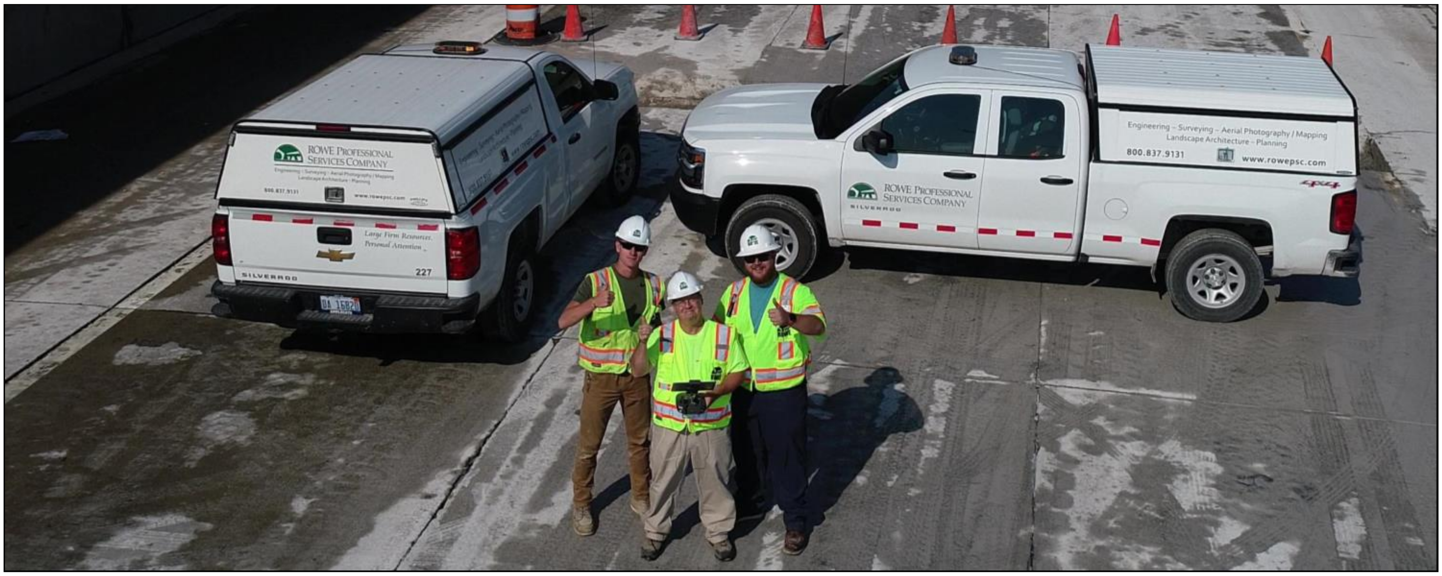

Anyone like me, who is actively involved in the profession of surveying and mapping, has probably heard a lot of talk about the use of Unmanned Aerial Systems (UAS) as a way of providing mapping services to clients. In the past couple years since the FAA and Congress have made large areas of the country available to unrestricted use of UAS technology, many people in our industry have already hired someone to provide these mapping services. Some of us, like me, have become FAA licensed Remote Pilots and are flying UAS and providing mapping services. So how and why is it done and what accuracies can be expected? Who can legally provide these services and what are the rules and restrictions surrounding the use of UAS technology?

For this article, I'll follow the Five W's rule of information gathering "Who, What, Where, Why, When" and will also provide an overview on the HOW. I'm also, going to mix up the order of the W's to better organize the information.

WHAT is UAS?

Unmanned Aerial Systems consist of several hardware and software components. The vehicle or UAV is also commonly called a DRONE (Dynamic Remotely Operated Navigation Equipment). Flight planning software allows the pilot to predefine a flight path for the UAV to follow during autonomous flight mode. The radio controller connects flight plans with the UAV and provides communication between the Remote Pilot and the UAV. The controller allows the Remote Pilot to fly the UAV in manual flight mode where each touch of the controller provides direction to the UAV. Camera systems are a very important consideration when using UAV for mapping applications and are of course the main reason for the use of UAS…photographs. Choosing the correct camera is a key decision to be made when considering the positional accuracy of the products that are required of a UAS flight. Lastly, post processing software is required to turn photographs into imagery that can produce accurately scaled image mosaics (orthophotos), three-dimensional planimetric, and contour topographic mapping.

WHY use UAS technology?

Why do anything in business? Because it adds value, provides a new way to produce a product, provides a new product that the client can appreciate, it's safer than the other way of doing things, and ~~if~~ it improves profits. UAS is not the answer to all mapping applications, but when it's one of the answers, it should be considered.

WHO can provide the services?

Anyone can fly a UAV as a hobby, but as soon as UAV products and services are acquired for a fee, the UAV operation falls under a commercial designation. It is at this point that the FAA and Federal law require that the pilot be licensed. Licensing requires a background check and passing a knowledge test at an FAA approved facility. The FAA does not require that Remote Pilots carry insurance for their operations. As with any consultant that you work with who carries insurance, your UAS consultant should too. Just because your UAS consultant is licensed and insured does not necessarily mean they are equipped to provide quality mapping services. Do they have experience? Do they have the software to generate all the products that you require? Do they understand the accuracy requirements of your project? Can they be clear about where your site conditions (areas of trees, water, urban canyons etc.) may provide accuracy challenges. Does the consultant process the imagery themselves, or do they send it to the "cloud" for product generation? What checks can they provide that provide confidence in the product accuracy? Can they properly say and spell the word "Photogrammetry"? Just as you would probably not hire an unexperienced company claiming to provide "manned aerial photogrammetry" services, you should consider the qualifications of a UAS consultant just as closely.

WHERE can UAS be used?

Did you know that the FAA considers the airspace from the ground to 60,000 feet above ground to be under their control? That's right…the air that is inside your property line is not yours… It's the federal governments. A whole book could be written about airspace, but the very short version is that the country is broken into several classes. Class B, C and D airspace exist near "major" airports. These are called "controlled airspace" and require approval from the FAA and Air Traffic Control (ATC) to operate UAV's. Approval can take between 30 – 60 days on average, making these difficult areas to operate in under short schedules. In some cases, approval will not be granted. Class G airspace is "uncontrolled" and generally open to unrestricted use by UAV's. With a few exceptions, Class E airspace exists at an altitude above the operational limits of a UAV and Class A airspace is where commercial air traffic takes place above 18,000 feet. Lastly, the FAA requires that UAV activities "cannot be flown higher than 400 feet above ground level (AGL) unless flown within a 400-foot radius of a structure and does not fly higher than 400 feet above the structure's immediate uppermost point". There are other restrictions on where UAV's can and cannot be operated. A licensed Remote Pilot should be able to provide guidance as to where. A great majority of the county is available for UAS use; Where is your project site?

WHEN?

It is possible to get FAA approval for flying a UAV at night, but a restriction waiver is needed. Unless a thermal infrared imagery product that must be collected at night is needed, daytime operations are the preferred time to gather photographs. When manned flight aerial photo missions are needed, it is important that sunny skies and solar angle be closely monitored. This is truer for manned flight than unmanned. Manned flights for mapping projects are usually conducted between 1,000 and 5,000 feet AGL. The large format cameras and downstream processing of the imagery work best with proper illumination and shadows. Also, flight operations are very hard to manage under partly cloudy conditions when the camera is (or could be) higher than the cloud deck. With UAS operations being conducted below 400', partly cloudy to overcast conditions do not pose a problem if there is enough light to properly expose an image. In some cases, overcast conditions are a benefit as there is little chance of the imagery being too overexposed or too hot. Shadows are not as important when UAS imagery is flown because the resolution of the photos is so good, a human or machine operator can much more easily interpret the imagery than can be done from high altitude photos. As a guide, UAS imagery is typically produced with image pixels that are 0.5 to 1.5 inches' square. Manned aircraft image pixels' average between 1.5 to 6 inches' square. Lastly, UAS technology allows for the aerial photographic workflow on project sites that are economically impractical to use a manned aircraft approach. If the end products support the project requirements and provide benefit to the client, UAS technology is a great way to go.

HOW does UAS technology work and how can I get the products I need from a UAS flight?

The answer ~~of course~~ is, it depends.

1. Do you need still photos or a video of a construction site or project area? If so, almost any aerial camera platform will provide these products with very good results.

2. Do you need contour and volumetric analysis on stockpiles, but don't care if the mapping data is tied to a coordinate system? If so, many consultants can take photos, upload the imagery to the cloud and have a third party generate an elevation model from which quantities can be extracted. Bare earth (no vegetation or water) conditions are the easiest areas to map. The resulting point cloud usually represents the ground very well and accurate volumes can be extracted. Of course, if the consultant does not post-process the imagery themselves it may be difficult to get a report showing the accuracy of their point cloud and resulting volumetric quantities.

   You might ask, "aren't point clouds the result of a Light Detection and Ranging (LiDAR) surveys? They ~~are, but~~are but point clouds can also be generated using photogrammetric technologies. Post-processing software uses a technique where all image pixels from one photo are compared with matching pixels in adjacent photos. When common matching features are found in two or more photos, a horizontal and vertical point is calculated for each image pixel. The points can be expressed in the ASCII file format, as well as the binary LASer (LAS) file format that is typically used to distribute LiDAR data. The end result is a file generated with x,y,z coordinates.

3. Do you need 3D contour mapping and orthophoto data that is accurately tied to a specific coordinate system? If so, your UAS survey had better make use of surveyed control points or an airborne GPS survey using an active base station. Alternatively, a UAV that integrates very accurate Inertial Measuring Units (IMU) and GPS systems to allow for the reduction or elimination of physical control points on the ground. The post-processed photos will need to undergo the pixel image "matching" procedure mentioned above, as well as combining measurements at physical control points, or the adoption of GPS and IMU inputs from the UAV, so the x,y,z point cloud can be accurately positioned to a known coordinate system. All measurements derived from the processed photos and point cloud will then be tied to the desired coordinate system. If your UAS consultant cannot provide surveying services, an additional consultant may be needed to provide the ground control points.

4. Do you need 3D contours, orthophotos and planimetric (feature) mapping data that is accurately tied to a specific coordinate system? If so, see points 2 and 3 above and now ask yourself, "How will a UAS consultant accurately provide the locations of such things as road, building, hydrology, vegetation, and other linear features? What about the point features such as utilities, trees, and poles? They will need to be digitized somewhere into a CAD file of some sort (ACAD, MIcroStation). Unlike terrain mapping, there are no practical ways to automate the extraction of lines and points from photos. They need to be manually digitized and placed on a CAD layer. There are two ways to do this. One is to insert an orthophoto into a CAD file and trace all features on a 2D monitor using "heads up digitizing". Try it some time. Add a photo to a CAD file and trace everything you see with a 2D mouse. Make sure you snap all the end points and properly code all the objects. Do you need parallel strings on the curbs? Do it. It's not fun. The second way is to insert all the aerial photos into the same 3D stereo collection (softcopy) software that is used to compile maps from manned flights. Using this approach, you can compile the features directly into a CAD file without the need to look at an orthophoto. Also, consider that while the orthophoto is horizontally accurate, there is no way to digitize accurate 3D line work or point features from them.

   Only from a stereo environment can breaklines and point elevations be digitized exactly where they are needed to further support the surface that was generated through the "matching" routine. **It is possible to compile 2D lines from an orthophoto and then compute the elevations on the line from the elevations found in the point cloud (draping). Exact placement of a line that represents an**

important breakline feature will be hard to do and might support the 3D terrain very well. However, without the ability to inspect the automatically generated surface or 3D elevated lines computed from that surface in a stereo mode, how can we be sure any of the point cloud features are accurate? Just because a piece of software generates a surface doesn't mean that it's perfect. It needs to be edited for erroneous points that fall near vegetation, water, and all other obscuring features.

The great thing about UAS mapping is the very ~~high resolution~~high-resolution imagery and the relative simplicity of processing the imagery into surface models and orthophotos. The real weakness in UAS mapping is the difficulty checking the accuracy of the surface model and digitizing the planimetric features. The great thing about traditional stereo softcopy software is its ability to use stereo photographs to compile new data and to check the accuracy of existing data. Using proper camera systems, ground control, softcopy mapping, and QA/QC technology, it is possible to generate elevation data that is accurate within hundredths of a foot on hard surfaces and planimetric mapping data to within tenths of a foot horizontally. If a project site is not too heavily vegetated, the expectation for receiving accurate 6" or ~~1 foot~~1-foot contours is a reasonable one.

As with all new technology, it's a good idea to look for creative ways to adopt it. Become familiar with the good, the bad, and the ugly. Compare the new technology to the old and learn how to make the most of it moving forward.

Greg Lemke is an ASPRS, Certified Photogrammetrist with 30 years of experience producing aerial imagery and mapping products from manned and unmanned systems. He is a FAA licensed Remote Pilot and leads the UAS program at Rowe Professional Services Company headquartered in Flint Michigan.