## Outline for the Particulars for Getting Good Drone Data

## Part I – Key Considerations for Mapping using a Drone system.

I. Drones currently have three key uses in the Construction and Surveying industries.

1. **Mapping**
   a. Terrain mapping of large sites (occasionally with hazardous ground conditions).
   b. Mapping complex structures from a top down prospective.
   c. Volumetric mapping of earth movement or material stockpiles.

2. **Large Volume Data Collection**
   a. Mapping complex areas with limited manpower or field constraints. (i.e.open pit mines).
   b. Highways projects, large construction sites, environmentally hazardous terrain.

3. **Field Data Preservation**
   a. Advanced photographic inspection of structures (buildings, bridges, transmission lines)
   b. Once a site is well photographed it is frozen in time and can be later analyzed for any missing or overlooked data. (Were objects missed during the survey? Did we forget to as-built that pipe? etc.)
   c. Potential future use or incorporation of the data into other projects.

II. The Basics for Integrated Site Mapping (The ability to accurately represent geospatial data on the ground.) The three key attributes of full 3D Integration are:

1. **Planning -** How are we using this data and what are the future uses beyond today? Predicting uses beyond your initial project can benefit you later in the project life cycle. Large data sets can contain information that can reused later without requiring additional field work.

2. **Datums - (**Horizontal & Vertical) - Where are the Fixed Points of Reference for your project? Large datasets can be difficult to correctly reference and integrate into combined datums. Integrating multiple datasets (with various reference frames and units) can be problematic and prone to inducing errors in translation when compiled for a final deliverable.

3. **Control** - What am I leaving behind in the field? Control monuments can provide continuity for any downstream users in connecting their datasets with yours. It's also needed for any future construction of the project site.

Drones become more useful on larger sites and offer significant gains when the site exceeds about five acres in size. Another major consideration is what accuracy of the data is required for it to be actionable? Can you accurately measure to around a tenth of a foot? Is that good enough (and would it be actionable)? Do you require more accurate data? Can you achieve half inch accuracy by modifying your flight parameters? To accomplish this do you need more ground control? These are all questions to take into consideration when selecting your drone system.

## Part II – Key Considerations for selecting a Drone system.

### How to decide on which drone system to choose.

Identify your mission goals & accuracy requirements and payload (i.e., half a foot or half a tenth… photogrameteric or LiDAR or both?) These requirements will drive the resultant aircraft choice.

Common Airframe types and their pros and cons:

1. Fixed Wing Aircraft Pros:
   a. Can map very large areas quickly
   b. Long flight times usually 45 minutes or more.

   Cons:
   c. Requires a large landing area free of obstructions (usually a 150 ft by 300 ft area including a final glide slope).
   d. Do not usually fly with stabilized gimble systems.
2. Multirotor System Pros:
   a. Can take off in small spaces, usually landing in a 400 SF area with a qualified pilot.
   b. Stabilized and vibration isolated camera systems available and typically used.
   c. Can carry various camera systems, and often take both oblique and nadar photos from the same camera. This means you can co-process nadar and oblique photos within the same project, thereby saving time and improving overall quality.
   d. Usually a highly controllable aircraft in complex flight environments.

   Cons:
   a. Can be heavy… gimbles batteries, camera and motors all have weight, making theses systems much heavier than fixed wing systems. Which could be important if you're hiking into a location and carrying your system with you.
   b. Complex… systems with multiple computers, engines and batteries all need software updates and regular maintenance.
   c. Slower speed and shorter flight times (typically 20-40 minutes on a battery).
   d. Louder… the multirotors tend to make more noise while in flight and due to its slower speed, it may be more noticeable to the public.
   e. More dangerous to people on the ground (and aircrew) when landing.

3. Helicopters and VTOL Hybrid Systems (Vertical Take Off and Landing). While not part of this conversation, their benefits and limitations are similar to the Fixed Wind and Multirotor Systems described above, often requiring heavier payloads and longer flight times.

While all four systems have similar attributes, it is important to understand each has a special use, primarily driven by the margin of required accuracy.

### Photogrammetry and LiDAR… The Future of Drone Mapping?

Light Detection And Ranging (LiDAR) is a remote sensing method that is likely to become the future of terrestrial mapping. Under optimal conditions it can see through fairly dense foliage and vegetation. Anywhere that sunlight can penetrate, LiDAR can map. As low-cost units become more available, it represents the next major advancement in drone mapping.

Although LiDAR lacks the ability to pinpoint field data and Photogrammetry is limited to visible light, the two systems working together allow for a comprehensive, high detail collection strategy and methodology. Used in combination, nearly any detail can be collected on a site.

## **Camera Based Photogrammetric Systems**

### **Camera Payload**

1. Determine your desired accuracy & quality. The camera accuracy is determined by 3 factors
    a. Sensor size
    b. Focal Length
    c. Altitude of drone / distance to target
    d. Mega Pixel Count

    These Four factors drive overall mapping accuracy

2. Areas to also consider about drone mapping are mapping dynamics
    a. I.E. Camera movement
    b. Dynamic range of the camera or how well it will see in over lite or under lite environments
    c. Mapping speed and altitude of each mission
    d. GPS positional accuracy
    e. GCP's layout of GCP's for good results Sensor Size

3. The Larger the sensor the more dynamic range you will have as more light will be exposed to the sensor
4. Also larger sensors tend to yield higher mega pixels counts. Meaning high levels of detail sharper images and more points created more data with more clarity.
5. Mega Pixels do not equal better Quantity for mapping. Mapping requires a large sensor with adequate mega pixels. A proper Focal Length for the required Ground Sampling Distance or GSD and proper exposure time for traveled distance.

### **Camera Sensor Types**

1) Two most common sensors
    a) Rolling Shutter
    b) Global Shutter

### **Common issues with sensor types**

1) Rolling Shutter
    c) Cheaper and usually very small and light weight
    d) Collects bits of an image over time when in motion causing images to blur usually is more compact sensor with less dynamic range and does not perform well in low light conditions
2) Global Shutter – very fast exposure times. The entire sensor is exposed to the scene at one time.
    a) Creates better results as it tends to not blur images while in motion
    b) Larger and heavier sensor
    c) More expensive

3) Performance impact on aircraft
    a) Rolling Shutter requires much slower travel speed
    b) Speed + Distance = Area Mapped
        i) Slow Speed = Smaller mapping area (Per Battery)
    c) Mapping Altitude also effects speed
        i) Higher the Altitude Less Blur faster the speed
    d) Mapping Speed Rolling Shutter - 100-200 ft AGL 3-6 MPH
    e) Mapping Speed Global Shutter 100-200 ft AGL 15-30 MPH (or faster if camera can support it).

## Part III - Key Considerations for the Control Network.

### Why Does Good Control and Monumentation Matter?

Because the geometery involved with fitting the real world to the digital world matters. Beyond just the selection of the reference datums, several other factors come into play for getting the coordinate data on the ground to agree with the digital realm of the scanned point cloud. The conversion from Grid to Ground, the conversion from metric to imperial units, and the translation from (or immersion of) one reference datum to another can all affect the accuracy of the final product.

### The Point of Origin

Sometimes referred to as the Scale Factor Location. This is the Point from which any translation, rotation or scaling of datasets should occur. Depending on the physical location of the Origin point and its relationship to your site, this point can affect how other referenced datasets (i.e. GIS data from other sources such as roadways, utilities, aerial photos, etc.) interacts with your site.

In most cases today new ground control is established using GPS. This is usually accomplished by one of two means. Either by establishing a central Origin Point for the project and processing static observations collected on it through the NGS Online Positioning User Service (OPUS). The other means would be by utilizing a Network VRS. Once established, the Origin Point should be considered the fixed control point for the entire project, and special attention given to it as it ultimately controls many other factors for your localized ground-based coordinate system.

### Why Does This Matter and What does this have to do with Drones?

Drones Are Primarily Using Only WGS 84 Latitude Longitude and Ellipsoid Height as their initial reference frame. As a result, generally they do not automatically scale to the ground and cannot resolve rotation issues caused by reference points existing outside the working area. To resolve this issue can be both complicated and time consuming.

### The effects of Metric Conversion and Grid to Ground Scaling within Software

Since we understand the effects of scaling on a mass Centered Earth, do we understand the effects in the computer environment? Many times the computer environment is based on a Cartesian or Polar coordinate system. This means that the position of the coordinate is projected on a flat plane surface with a relative position based on a defined X,Y,Z (or 0,0,0) value.

### Errors caused by Unit Conversion

Another major source of errors within software is how the software handles unit conversion. As an example, let's look at the conversion from the US Survey Foot to the International Foot. The US Survey Foot is defined as one meter equals 39.37 inches (0.30480061 meters). For the International Foot, one inch is equal to 2.54 centimeter (0.3048 meters). The difference between the two definitions is two parts per million (2PPM).

This seemingly small difference when applied from the origin point will represent feet of propagated error. Since most State Plane Coordinate Systems are defined as metric (along with a unit-foot conversion type), means that anyone not defining the Units within there drawing before export to US Survey Feet would have an error when the data is exported to the field for future work. This event is tied not to the Point coordinates them selves but to the actual DXF Line data file. In the case of grading the same event occurs to your 3D model.

**So why Does this occur?**

Most of your software is programed in metric units, as they are easier to define within the software. The typical default conversion setting in most software is to the International Foot. To use the US Survey Foot usually requires you to change that setting. Even though the exported files may be defined in feet, the software usually converts them to a metric system and then rescales the resulting answer.

In some cases, it is easier to leave your projects in metric units and apply this correction at the final step bringing it into AutoCAD as almost all scanners and lidar units natively record their data in metric units. (Once again do to it being easier to calculate from a computing perspective).

Consider for example how Autodesk Recap handles data translation. When a point cloud is brought in it is converted to metric units and AutoCAD Civil 3D will scale the point cloud data to the defined foot conversaion setting. Without manually changing that foot setting, your data may inadvertently be converted to International Feet, perhaps without your knowledge. The critical point to understand is that the computer will apply the scale factor to the metric value from its origin (its defined 0,0,0), which will likely leave your data in a different location than you expected. This translation error is one of the most common horizontal error issues that can occur and represents one of the most vexing issues faced by a new user of Point Cloud data. Additionally, integrating other GIS information into your drawing sets requires paying attention to the smallest difference from Grid as possible, to more accurately represent combined data sets.

**How do we reduce and solve this common Issue and maintain data accuracy?**

Use an Origin Point at the center of your site for scaling or use this centered site point for your starting point of your ground traverse. This Origin Point should exist in both grid and ground coordinates.
Once your data is loaded into AutoCAD or your preferred Cad Software Turn on the Background map and see if it is close to matching the Google Earth Map. This may seem too simple, but you will find that these maps are close enough to detect a scaling issue or other issues that can come up. Keep in mind this check will likely not match well but if your more than 2-3 ft off your likely having an issue.
If you find your thousands of feet off in your position, consider that the software or input did not scale back to your correct units.
You may need to reinsert the data once the units have been corrected.

**<u>What accuracy can really be achieved using photogrammetry and ground control</u>**

1. Your accuracy can only be as good as your control network (i.e. if you want to map accuracy to be tenth of a foot, then your GCP's must be set to an accuracy of one half your requirement or half a tenth. (Your GSD must be set to half of your required accuracy [GSD = 0.05'} to have a reasonable chance of achieving the required accuracy

2. Accuracy of 0.02' or one-quarter inch then your GCP's must be set to an accuracy of one half your requirement or 0.01' and your GSD must be half of your required accuracy or GSD = 0.01' (0.3048 cm) to have a reasonable chance of achieving the required accuracy

**<u>Conclusion</u>**

If you take nothing else from this discussion, understand that the geometry of your site, how it is set up in the field and where your Origin Point is located will affect how your data is placed within the computer environment. This is one of the many reasons the professional surveyor is uniquely qualified to both understand and correctly reference various forms of data into a 3D environment. Our attention to detail, ability to accurately convert between coordinate systems and resolve other legacy issues is one of our most defining qualities. This is where the value of the Professional Surveyor stands above all other geospatial professionals and engineers.

## Part IV – Key Considerations for Data Processing.

**Processing Software**

**Data Processing Control – There are two distinct processing options:**

1 **Cloud Processing** – A limited control method of processing. Computers assume all data is the same. Limited ability to introduce ground control points and tie points.

**Pro** – Reduced need for large, dedicated computer to process drone data the heavy lifting is done by someone else and the final product is delivered to you.

**Con**- Limited Control for data processing and errors in the data. Though it may seem convenient or nice to have a system to process your data remotely the reality of photography is very different. Each photo is not the same. In many cases a single bad photo can cause errors and effect the final product. The ability to control your processing gives you the ability to fix the issue many times without having to reshoot the site.

2 **Desktop Processing** – Best for professional level processing allows the user to control all aspects of their data and retain full ownership of the data.

**Pro** – Full control over the data and the implementation of ground control on a site. Able to analyze and fix issued that could otherwise destroy a data set and determine the causes of the errors. By understanding what caused the issue the root cause can be corrected, and the same issue can be better avoided in the further. A professional level person can be left in control of the data and relied upon to make decisions.

**Con** – Requires a large computer to handle processing and a trained technician or professional to operate the system. Processing time could be longer if the computer is not up to the task.

**General Workflow for High Density Point Cloud Data Processing.**

1. Field Data Collection
   a. Drone Photogrammetry Lidar or Scanning of data
2. Initial processing of data
   a. Pix4D, Leica Cyclone, Trimble Business Center
3. Introduction of Ground control and Adjustment
   a. Usually Controlled within the Processing Software
4. Completed Processed data correctly georeferenced, Scaled, and tied to ground control.
   a. Typically, a Point Cloud and orthomosaic photo (a photo without perspective dimensionally free from perspective errors)
5. Secondary Processing to Clean the point cloud data classify the data and usually prepare for a Ground Surface Map.
   a. This can be done through various software usually general tools and classification is done within the processing software as well as removal of vehicles and ground data not wanted for a surface map of an area.
   b. Noise Filters to further reduce the point cloud and improve accuracy. I typically use the Cloud Compare tool to do this step using the Noise Filter and The SOR Tools in that order to remove noise from the point cloud and create a weighted average of points to increase overall accuracy of the point cloud in a 2 step method.
6. Point Cloud Data Merging to a Larger Project within Autocad Civil 3D Using Autocad Recap
   c. Load refined and processed Point Cloud data into Autocad Recap

i Select the Correct coordinate System the data is in and where the Data is intended to go to. IE if the data needs to be translated to a new coordinate system for use in a GIS or other systems.

ii Once loaded review that data make sure the point cloud fully loaded and appears correct.

6. Load the Point Cloud into Autocad Civil 3D using the insert Recap tool
   a. Before importing data make sure the drawing has the correct coordinate system selected.
   b. Set the correct units to be used. Note that the data will be scaled from point X=0 Y=0 Z=0. If you have the wrong or no units selected the drawing will not insert your point cloud and orthomosaic photo in the same / correct location. In the case of US Survey Feet Verse International Feet in MO83 East you will see 2'-3' horizontal shift.
   c. A common issue with loading data using Autocad Recap is an error where recap incorrectly translates the point cloud and hold the point cloud in meters even if its is told to use feet.
      i. The advantage of using recap is it significantly reduces the weight of the point cloud while in Autocad Civil 3D and allows Autocad to load more and stay relatively responsive even when working with larger data sets and viewing them in 3D.
7. Decimating the point cloud for surface creation.
   a. Select the point cloud in Civil 3D the tool ribbon will change.
   b. Select create Surface
   c. Set the Layer to be used
   d. Set the decimation to be less than 1 million points for the surface. If Higher detail is required break up the surface into multiple surfaces of less that 1 million points and a smaller sampling distance.
   i) If you do not decimate the surface to less than 1 million points auto cad will have a difficult time dealing with the data and significantly reduce overall performance.
   ii) ii. When decimating the point cloud understand you will reduce the accuracy and create chipping of the surface as triangles attempt to connect to points that may be spaced improperly to represent the detail your attempting to render.
   iii. Typically I use a decimation by distance and set the value to between 1 and 2 linear feet. This usually avoids major errors, however, detailed inspection of the surface in a 3D view will usually give an indication as to the validity of your surface.
8. Congratulations you have built your surface. Simple right?
   a. Hardly! But you have a powerful tool to do work with.
   b. Keep in mind you are now dealing with about 1% or less of the available data.
   c. All of that decimation and data manipulation can create a variety of issues from accuracy and precision to errors from bad or misused points while decimating.

**<u>The deliverable</u>** – Ultimately the final product is all that matters in the traditional boundary survey and topo the final product is a set of lines with contours showing the expected gradings on the ground usually expressed in 1' minor and 5' major contour lines. The Boundary Lines are 2D lines displaying only the bare essential information of Bearing and Distance with symbols showing the property corners.

**<u>During Design</u>** -The line work in many cases is converted to 2D lines to support proper displaying of line colors weights and text information. The contours created by building a tin surface model are extracted as polylines with elevations and the true tin surface is removed or no longer referenced. In many cases this is done as the designer's computer systems lack the horsepower to deal with the complex data that begins to rapidly accumulate. In almost all cases the 3D information originally created by the surveyor is destroyed or lost in this process. An unfortunate side effect of decimation of data that eventually leads the designer to a final product with only the bare essential information present on the final plan sets and PDF drawings.