Guidelines for Acquiring Aerial Imagery

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The information in this publication was compiled from a variety of sources. The following four resources were utilized frequently and excerpts pulled directly into this publication.

> Aerial Imagery Guidelines (for those needing to know but afraid to ask), URISA, 1999 and http://gis.ucsc.edu/Projects/aerial/guidelines.htm
>
> Are All Orthos Created Equal? A Discussion of Orthophoto Accuracy, Scott Cox, Sanborn, http://gis2.esri.com/library/userconf/proc02/pap0265/p0265.htm
>
> SURDEX Mapping FAQ, http://www.surdex.com/html/mapping_faq.html
>
> Draft Digital Orthoimagery Quarter Quadrangle Specification, U.S. Geological Survey, 2007.

Guidelines for Acquiring Aerial Imagery

Purpose of this Publication
Aerial imagery is an expensive and complex product needed by many state and local governments. The intent of this publication is to define the basic terms and explain common issues for acquiring imagery. In addition, minimum standards for imagery are suggested. This document may also help you prepare an RFP for aerial imagery. Finally, as you read through this document you may wish to refer periodically to page 7 for a "Definition of terms frequently used in aerial imaging."

What is Aerial Imagery?
Aerial refers to photography or digital pictures taken from the air. These pictures are normally taken from a vertical perspective looking straight down from the airplane onto the rooftops.

Photographic versus Digital Imagery
Analog photography is imaged directly onto film whereas digital images can be recorded via digital cameras. Both Photographic and Digital require bright sunlight and cloud free conditions for good results.

Uncorrected versus Corrected (Ortho) Photography
Uncorrected images do not allow for accurate measurement of distance between two points. Note: aerial imagery does not include orthorectification (from either photographic or digital) unless that service is requested; either type of imagery can be geo-referenced for use in GIS applications.

Orthophotography (Corrected photography)
If you are planning to measure ground features or to create maps from your photography, orthorectified photography is necessary. The data required for orthorectification include orientation parameters for the source photograph(s) and a digital terrain model of the geographic area to be covered by the orthophoto. Ortho rectification corrects for tip or tilt of the aircraft and displacement in the photograph caused by changes in the ground elevation.

Generally, the development of orthophotos requires the acquisition of stereo photographic coverage (this means overlapping photographs of the same geography) and some combination of surveyed control on the ground and airborne GPS (Global Positioning System) collection at the time of photography. The photogrammetrist will perform aerotriangulation on the resulting block of photographs to establish the orientation parameters of the individual exposures and may need to develop a digital terrain model. These operations make orthophotography more expensive than uncorrected aerial photography, but also make it far more useful.

Good accurate base maps can be derived from orthophotography because the image has been corrected to ensure that horizontal scale is constant. Streets and roads, curbs, manholes, water edge, tree inventories, fire hydrants, and numerous other features can be accurately mapped from the orthophoto.

Defining Your Needs
Local and state governments will have a variety of needs concerning aerial imagery. Since aerial imagery is an expensive and complex product, thoughtful planning is required to accommodate those requirements. Some questions that will assist you in information gathering include:

- How will the imagery be used?
- Who will use the imagery?
- What do I need to see from the imagery?
- Will I be able to interpret what I need from the imagery?

Image (Color) Type
Photographs may be taken using black-and-white, color, infrared, or other film.

- **Black-and White** images are generally less expensive and typically require about one-third the digital storage space of color photographs. More training in photo interpretation is required for black-and-white than in color.
- **Color** photography gives the closest rendition of a scene as viewed by the human eye and thus requires less training in its use. It is a slightly more expensive product and requires about 3 times the digital storage space of black-and-white photography.
- **Infra-Red** images are similar to color, however, trees, crops and things with chlorophyll appear red in color. Infrared is about 3 times the digital storage space of black-and-white photography.

Pixel Size (Resolution)
The pixel is the key to determining the visual resolution of the image. The pixel represents a uniform value of the ground covered within its range, which can be several inches to several meters. Smaller pixels result in higher resolution.


6 inch resolution


1 foot resolution


1 meter resolution

Common Map Scales and Applications
The products that are needed by your community as determined in your needs assessment will dictate the map scale to be produced. Many features like street centerlines, edge of pavement and buildings can be captured from many different map scales ranging from 1 inch = 50 feet to 1 inch = 400 feet. Typical map scales for municipal mapping applications are 1" = 100' for urban or developed areas and 1" = 200'

or 1" = 400' for rural and less developed areas. However, should it be determined that features like fire hydrants or manholes are needed by the users, your community should consider an alternative such as 1" = 40' or 1" = 50' which are common engineering scales. It is important to select a mapping scale that ensures you can identify each feature you want to collect. Equally important is not to procure a scale that costs more without any practical benefit. If your community is unsure what types of features can be captured from each output mapping scale, please consult a local aerial photography firm for help.

Accuracy

Horizontal accuracy assessment may be performed both in absolute and relative conditions. Absolute requires the use of ground control points for testing purposes. These points, found in the image and coordinates from the orthorectified image, are compared to the published coordinates. Relative horizontal accuracy assessment involves the visual inspection of adjacent orthophotos for edge matching, and the comparison of the orthophoto to planimetric data. The relative displacement would be quantified.

Accuracy standards vary in complexity and usability. The most commonly used data standard for county and municipal mapping applications are the American Society of Photogrammetry and Remote Sensing (ASPRS) Class I and II. These accuracy standards for large-scale maps (generally 1"=1000' and larger {i.e. 1"=200', 1"=100', etc.}) measure accuracy as Root Mean Squared Error (RMSE). RMSE is a calculation of the average difference between the actual location of something and the location shown on your photograph.

The ASPRS Accuracy Standard varies depending on the scale of the map, and the class of accuracy.

ASPRS Accuracy Standard				
Map Scale	1" = 50'	1" = 100'	1" = 200'	1" = 400'
Pixel Size (typical)	3 inch	6 inch	1 foot	2 feet
Acceptable RMSE Class 1	6 inch	1 foot	2 feet	4 feet
Acceptable RMSE Class 2	1 foot	2 feet	4 feet	8 feet
Acceptable RMSE Class 3	1.5 feet	3 feet	6 feet	12 feet

Minimum number of checks points per orthophoto: 20.

While not necessarily recommended for imagery, the National Map Accuracy Standard (NMAS), developed in 1947, was designed to review data on map sheets. NMAS accuracy is defined as 90% of the measured points being within a certain distance of true ground position. For maps on publication scales larger than 1" = 20,000', not more than 10 percent of well-defined points tested shall be in error by more than 1/30 inch.

NMAS				
Map Scale	1" = 50'	1" = 100'	1" = 200'	1" = 400'
Pixel Size (typical)	3 inch	6 inch	1 foot	2 feet
Acceptable RMSE	1.66 feet	3.33 feet	6.33 feet	13.33 feet

The newest standard developed by the Federal Geographic Data Committee (FGDC) to update the NMAS is the Geospatial Positioning Accuracy Standards, part 3: National

Standard for Spatial Data Accuracy (NSSDA). The NSSDA uses RMSE to estimate positional accuracy. Accuracy is reported in ground distances at the 95% confidence level. Unlike the NMAS and ASPRS standards, NSSDA does not define threshold values. These values are defined by the customer.

Ultimately, the accuracy you define for your project will depend on how you plan to use the imagery. Also consider the other users of the data in other departments when identifying this important imagery specification.

Elevation Data

Elevation data is one of the components required for ortho production. High-resolution ortho imagery typically requires high-resolution elevation data to support the accuracy. The elevation data may come from various sources. Usually the vendor will build a digital terrain model (also called a digital elevation model) by digitizing break lines (features that break the terrain), such as roads, streams, ridges, etc. Alternate sources of high-resolution elevation data include Light Detection and Ranging (LiDAR) data that can be flown at the same time as the aerial imagery. (Some vendors have this capability.) If lesser accuracy is required, the U.S. Geological Survey's National Elevation Dataset (NED)[1] has 1/3 arc-second digital elevation model (DEM) data. The National Agricultural Imagery Program (NAIP)[2] uses the NED DEMs as the elevation source for the 1 and 2 meter resolution imagery products. Unless an area is very flat, the NED should not be used for 6 inch or 1 foot resolution data where higher accuracy is required.

Developing Specifications

There are a variety of imagery solutions and options available when acquiring imagery. Prior to contracting with an imagery vendor, you will need to decide the following:

- The anticipated use of the imagery to be acquired
- Whether you want orthophotography or uncorrected imagery
- The geographic area to be flown (provide a shape file if possible)
- Whether black-and-white or color photography is preferred
- The map scale you wish to create (i.e. 1"=100', 1"-200', 1"=400', etc.)
- The spatial accuracy required of the imagery (recommend using ASPRS or NMAS standard; see Accuracy section below)
- The coordinate and projection system you will typically use (i.e., State Plane, Universal Transverse Mercator (UTM), etc.)
- The resolution of the photograph (i.e., pixel size) i.e. 6 inch, 1 foot, 1 meter
- The tile size or ground coverage of each image (i.e.1 mile x 1 mile; 2,500' x 2,500', etc.)
- The products you want to receive from the vendor

You may also need to decide what season you wish to acquire the imagery. Tree cover can significantly block portions of the ground in summer. In winter the shadows are long and obscure features. Spring and fall seasons are usually optimal for imagery collection.

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[1] For more information on the USGS National Elevation Dataset (NED), visit http://ned.usgs.gov .

[2] NAIP imagery is available at the Kansas Geospatial Community Commons website at http://www.kansasgis.org .

What You Should Get From the Vendor
To say that imagery is provided sounds simple; in reality, imagery can be delivered in a variety of ways. In addition, other products can typically be provided by your vendor, including map work of your choosing and the imagery in a variety of formats. The following are typical products you can receive from your vendor:

- **Orthophotographs** and uncorrected imagery are delivered digitally on a Compact Disc (CD). Orthophotographs are typically broken out into tiles of the size you specify in your project planning; uncorrected imagery is delivered by individual exposure. The vendor should provide you with a grid that identifies each tile in the case of orthophotos, and a flight map with exposure numbers in the case of uncorrected images.
- **Prints (or Contact Prints).** Typically in a 9" x 9" format, the individual tiles of the coverage are frequently useful to agencies wishing to use them on a daily basis for quick reference.
- **Diapositives.** Photographic prints made on a clear film base used by a photogrammetrist in analytical aerotriangulation and traditional stereo compilation.
- **Mylars.** The ortho or uncorrected photographic prints, corresponding to the tiles, can be delivered in mylar form. Some agencies find this useful if they wish to make copies for themselves or clients.
- **Digital Elevation Model (DEM).** Elevation data is both an input to ortho production and an output product. Retaining this data will also be useful for future orthoimagery projects that will require the same data.
- **Flight Plan Map.** Once you and your vendor have decided upon the area to be covered by orthophotographs, you should receive a confirming flight plan map from the company. This will look like an ordinary map, with the flight lines drawn in. You will see a certain amount of overlap in the areas covered by each line; this is required in creating horizontally accurate maps.
- **Triangulation Report.** Aerotriangulation is a photographic procedure that uses relatively few survey control points to create other survey points across a block of photography. The triangulation report shows the survey control points and photogrammetric measurements.

Quality Checking and Quality Assurance
Quality checking and quality assurance are a substantial component of your imagery product. You must be prepared to check the orthophotography against the spatial accuracy your contractual agreement called for. Like any other product, imagery can contain errors, many of which can be corrected.

Metadata. Usually defined as data about data. For full utility of your imagery and the imagery you may acquire from other sources, you must have metadata. This means you must prepare metadata for your own imagery (or require it from your imagery provider) and you must demand it from the producers of imagery you acquire. The national standards for metadata can be found on the Internet at http://www.fgdc.gov/metadata .

> ***Why bother with metadata?*** Think of it as a prescription. You probably don't want to use a medication unless you know what its intended use is, who produced it, how old it is, and any particular problems that are known about it. Similarly, with any data, but particularly with imagery, you need to know where it

came from, what its intended use is, its scale, its format, whether or not it has been orthorectified and so on.

Metadata helps people find the data they need and determine how to best use it. Metadata also benefits your organization when there is a personnel change and that institutional knowledge leaves the organization. Subsequent users may have little understanding of the contents and may find they can't trust the results generated from the data. It may seem burdensome to add the cost of generating metadata to the cost of data collection, but in the long run metadata is worth it.

Definition of Terms Frequently Used in Aerial Imaging

Accuracy, Horizontal: A measure of the horizontal distance on a photograph within defined tolerances.

Accuracy, Vertical: Vertical (elevation) accuracy of a rectified image and associated digital elevation models. Vertical measurements are usually expressed as contour lines or spot heights.

Band: A range of wavelengths of electromagnetic radiation.

Datum: The description of the shape of the earth as defined by the National Geodetic Survey; usually referred to as NAD27 or NAD83 for the horizontal datums and NAVD29 or NAVD88 for the vertical datums. NAD27 uses surface reference points, whereas NAD83 uses the center of the earth as the reference point.

Forward Lap or End Lap: The extent to which sequential exposures in a flight line overlap, typical end lap for stereo photography is 60%.

Ground Sample Distance (GSD): The area of ground represented in each pixel in x and y components.

Side Lap: The extent to which the exposures of adjacent flight lines overlap, typical side lap for a block of stereo photography is 30%.

Pixel: The smallest cell size with a uniform value of an image. This digital image cell is produced in varying sizes, usually referred to in ground units such as 6 inches, 1 foot, 3 meters, etc. Pixels are created during the scanning of the aerial imagery and are key to establishing the resolution of the orthophotograph.

Map or Cartographic Scale: The relationship between a given distance on the ground and the corresponding distance on a photograph or image. Scale is expressed in at least two different ways. Both are ratios. In the first, commonly used measuring systems are compared; for example 1" = 100' (one inch on the map equals 100 feet on the earth). In the second, the map unit is arbitrary; for example, 1:100 means that one of anything (an inch, a foot, a centimeter, etc.) on the map equals 100 of that same unit on the earth. (1"=100' is the same scale as 1:1200). Scale is presented in several ways: as a bar at the bottom of the map, as a ratio (1:100), or as an equation (1"=100').

Projection: Methods of presenting the earth (a three-dimensional object) on a plane, (a two-dimensional object) with as little distortion as possible.

Root-mean-square error (RMSE): Square root of average squared error.

Scanning: The process of converting analog photographs or hard copy maps into a digital form.

Spatial Accuracy: Distance from true ground location.

Spatial Resolution: Pixel size.

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Aerial Imagery Guidelines (for those needing to know but afraid to ask), URISA, 1999 and http://gis.ucsc.edu/Projects/aerial/guidelines.htm

Are All Orthos Created Equal? A Discussion of Orthophoto Accuracy, Scott Cox, Sanborn, http://gis2.esri.com/library/userconf/proc02/pap0265/p0265.htm

Draft Digital Orthoimagery Quarter Quadrangle Specification, U.S. Geological Survey, 2007.

SURDEX Mapping FAQ, http://www.surdex.com/html/mapping_faq.html

Additional References

ASPRS Interim Accuracy Standards for Large-Scale Maps, American Society for Photogrammetry and Remote Sensing, 1988.

United States National Map Accuracy Standards (NMAS), U.S. Bureau of the Budget, 1947.

Final Note

Questions concerning aerial imagery or the content of this document may be directed to:

Ivan Weichert, State GIS Director
Kansas Information Technology Office
Landon State Office Building
900 SW Jackson St., Rm 751-S
Topeka, KS 66612-1275
Ph: 785-296-0257 Fax: 785-296-1168
Email: ivan.weichert@da.ks.gov