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Aerial Imagery Guidelines

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AERIAL IMAGERY GUIDELINES

FOR THOSE NEEDING TO KNOW BUT AFRAID TO ASK

Updated from Previous Text Published by the Urban and Regional Information Systems Association 1999

*Anyone, but usually public agencies, environmental and community groups, and everyone interested in observing the earth and understanding what they're seeing

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CONTENTS

AERIAL IMAGERY GUIDELINES

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The Purpose of This Publication

Many agencies in the public, private, and nonprofit sectors have a need for aerial and satellite imagery. Since aerial imagery is an expensive and complex commodity, the intent of this publication is to define its basic terms and to discuss and explain the common issues surrounding its acquisition. In addition, minimum standards for imagery are suggested.

Getting the Imagery You Need

In this publication, agencies and companies will be provided with the information and knowledge required to successfully plan and negotiate for imaging and photographic needs. With this and the references cited on the closing page, readers should be able to work more closely with imagery vendors to develop a product tailored to their needs.

While the impetus for generating imagery may vary, in many cases it may be possible for agencies to use the same coverages (i.e., the photographic imagery of the same geographic area). Through cooperation, agencies in a region can share costs and follow minimum standards, enabling the acquisition of imagery of higher resolution, greater accuracy, and greater geographic extent.

Developing Imagery Partnerships

Another intended benefit of these guidelines is to encourage regional data networks and thus prepare regions to respond more quickly to their imaging needs. In the course of emergencies and other natural disasters, it is common for a variety of agencies to express a need for immediate aerial imagery and to scramble to define the product needed and to accumulate funds. For example, intense flooding creates a need for many agencies to have imagery of the affected areas to identify the scope, respond to the crisis, and ultimately plan for future mitigation or prevention. Ideally, the imagery of the flooded areas will be compared to preflood photography. Having a set of minimum standards and guidelines and a strong network between agencies will create planning and funding alliances that can quickly respond to needs born of such emergencies. Through this network, adequate and frequent aerial image updates of the region can be obtained.

What Is Aerial Imagery and How Is It Used?

In general terms, aerial imagery refers to photography or digital pictures taken from the air. Many of the ways to obtain and use this imagery are discussed below. The method chosen to obtain and use imagery will depend on the needs of your organization. Differences in acquiring the imagery include:

- equipment and aircraft;
- photographic versus digital imagery;
- image (color) type;
- pixel size;
- projection coordinates (earth location and registration); and
- uncorrected versus corrected (ortho) photography (the most significant area of difference).

Differences in the use of imagery include:

- hard-copy or paper prints for feature reference or photo-interpretation;
- using a digital form as a computerized photographic backdrop or reference;
- using a digital corrected photograph as the foundation for mapping; and
- using corrected photographs in a hard-copy Mylar form as a basis for generating photographic copies.

Equipment and Aircraft

Photography may be taken from low-altitude small craft, high-altitude airplanes, and satellites. Typically, the lower the altitude, the higher the resolution of the resulting photograph. Special equipment and techniques used before, during, and after the flight are required to produce photography suitable for serving as the basis for mapping. Images are acquired by a variety of specialized cameras, as much as $500,000 or more.

Note: The fact that imagery is taken from an aircraft or satellite does not imply that it is spatially correct (see the section on "Uncorrected versus Corrected (Ortho) Photography").

Photographic versus Digital Imagery

Analog photography is recorded directly onto film whereas digital images can be recorded via film, airborne scanners, digital cameras, or other equipment. Both analog and digital imagery can be stored in digital form (i.e., on computer disks or tape); imagery can also be presented in paper or hard-copy form. For the purpose of this publication, imagery in its digital form will be discussed from this point forward.

Image (Color) Type

Photographs may be taken using black-and-white, color, infrared, or other film. Current developments in technology have allowed for the direct capture of digital images corresponding to a wide range of radiation frequencies including ultraviolet, color, infrared, thermal, and microwave frequencies.

- *Black-and-white* images are generally less expensive and typically require about one-third the digital storage space of color photographs. Properly taken, they can provide excellent resolution and can handle extensive scale enlargement. They will not be as useful for vegetation monitoring or for other analysis where color or heat is of importance. Lastly, more training in photo interpretation is required in the case of black-and-white film than in that of color film.
- *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 three times the digital storage space of black-and-white photography.
- *Color infrared (or false color)* digital photography is sensitive to green, red, and near-infrared radiation. A close inspection will reveal that

vegetated areas appear red. This product is particularly useful for delineating vegetation, since near-infrared radiation captures differences in vegetation type. Infrared film typically produces sharper images than black-and-white or color film. In addition, sharp black-and-white photographs can be produced from infrared film.

- *Multi-spectral imagery* is a rapidly growing field with many experimental applications. Current applications include wetland delineation, vegetation mapping (including vegetation type and stress levels), underwater mapping, and mapping water pollution. Multi-spectral imagery refers to imaging with a large number of layers corresponding to particular electromagnetic radiation frequencies.
- *Radar imagery* is used to actively scan the earth's surface, yielding imagery capable of producing detailed digital elevation models and characterizations of surface texture. This includes synthetic aperture radar (SAR), an enhanced form of radar.

Note: **Digital imagery can create very large files, especially those at higher resolutions. This can affect the computing speed. Various file compression routines are now available that reduce file size while not sacrificing detail. This option should be discussed with a vendor, since many aerial photography companies have the capability to compress files; typically, a small charge is associated with file compression. Some vendors only distribute photography in a compressed mode, some of which is proprietary. If compression is not available, software for file compression can be purchased, although it is relatively expensive. An important consideration is that not all geographic information system (GIS) software can accept all compression routines; check with your GIS software vendor prior to selection.**

Pixel Size (Resolution)

As noted in the Definitions section, the pixel is key to determining the visual resolution of the image. By resolution, we mean the photograph's visual crispness; the lower the resolution, the fuzzier the image. Produced in varying sizes, the pixel presents a uniform value of the ground covered in its range, which can range from several inches to several meters. As the following photographs illustrate, a smaller pixel yields higher resolution. Keep in mind that better resolution does not necessarily result in higher accuracy; rather, the pixel size in combination with survey control, altitude, and focal length is a determinant of image accuracy.

10 meter pixels

1 meter pixels

6 inch pixels

1:3,000 scale images of the same area with 6 inch, 1 meter, and 10 meter pixel sizes.

Uncorrected versus Corrected (Ortho) Photography

Uncorrected images taken from an aircraft or a satellite will not permit accurate orientation to known or surveyed points on the ground. You cannot measure a distance between two points on an uncorrected aerial photograph and get an accurate measure of the distance between any two points. Why? Here's the detailed answer: A photograph is a perspective projection of a three-dimensional space onto a plane and as such it has a particular geometry: one in which the horizontal scale varies and the images of objects are displaced radially from the center of the photograph according to the height of the object. Here's the translation: Imagine the earth as a grapefruit peel lifted intact from the fruit. It is sort of spherical, but bumpy in places. If you break and flatten the peel, parts of the peel get torn and seriously distorted. This is what happens when an image of the earth is flattened into a two-dimensional image. The reasons for this are several: the curvature of the earth, tip and tilt of the camera at the moment of exposure, differences in terrain elevation, and the nature of photography itself.

Negotiating Tip: Quotes for "aerial imagery" do not include orthorectification unless that service is requested. Always specify that the imagery be orthorectified if that is your need, and make certain that the quotation from your vendor states it clearly.

Orthophotography

If you are planning to measure ground features or to create maps from your photography, orthorectified photography is necessary. An orthophoto, from the Greek "ortho" meaning "right, straight or true," is a synthetic image derived by computation from one or more source images. 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. The orthophoto itself is assembled pixel by pixel using algorithms based on photogrammetric principles.

Usually, the development of orthophotos requires the acquisition of stereo photographic coverage (i.e., the overlapping of photographs of the same geography) and some combination of surveyed control on the ground and, increasingly, airborne Global Positioning System (GPS) 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.

In spite of the added expense, many agencies are willing to spend the funds since there are so many benefits from using orthophotography. Good, accurate base maps can be derived from orthophotography because the image has been assembled to ensure that horizontal scale is constant. Streets and roads, centerlines, curbs, manholes, streetlights, traffic signs, water edge, tree inventories, fields, driveways, fire hydrants, and numerous other features can be accurately mapped from the orthophotos. In addition, it is possible to measure the distance between two features on the orthophotograph.

Orthophotography can turn out to be a relatively inexpensive method of acquiring an excellent base or control layer for a GIS. In addition, once the original orthophotography is acquired and maps are enveloped, future photography might be acceptable in its uncorrected mode if the agency is merely looking at change.

Satellite Imagery

Orthophotography is also available from various satellite imaging companies, although this is typically of lower spatial resolution and accuracy than that acquired through aerial photography. Several companies have launched satellites that are designed to deliver better spatial resolution and imagery suitable for urban mapping; however, it will be some months or years before we see these products and determine if the quality of satellite orthoimagery is useful for monitoring change and for mapping large areas of land where the surface is relatively uniform. Forestry and wide-area land use are examples of appropriate uses of satellite imagery.

Accuracy Considerations

Typically, greater horizontal accuracy is required in urbanized or developed areas than in rural or undeveloped lands. Again planning agencies typically require less accuracy than engineering agencies. Funding may also play a role in the accuracy required. We strongly urge collaborative programs that are geared to the highest accuracy required by its members; it is futile to acquire imagery at a planning level need when engineers will be using the imagery and resulting maps. Minimum standards are recommended for particular activities and agencies in Appendix B; however, agencies are encouraged to exceed these minimum standards if circumstances permit. If an agency has both urbanized and rural areas, it may wisely choose to acquire high-accuracy imagery for the developed areas and a lesser accuracy for the undeveloped areas.

A Word about Mapping Using Orthophotography

As noted above, many agencies and companies develop maps by tracing over a base of orthophotography (referred to as "vector" maps). A common term for this product is line work. While this procedure works well for ground features, it is inappropriate for mapping structures in the built environment that are elevated above ground level. Orthophotos are usually generated to correct for the relief displacements imparted by differences in terrain elevation — that is, on the ground. The displacements caused by the heights of buildings or other elevated structures may not be corrected in orthorectification. Thus, when buildings appear to lean to one side in an orthophoto, their footprints, when visible, are in the correct location, but their roof lines are not. The lean (sometimes called tilt or urban shadow) occurs because only a small portion of the photograph is directly below the camera lens — the only place that will be captured perfectly. All features to the side of center will show some lean; the taller the structure, the greater the lean. The appearance of offset should not be of great concern; in producing the line work, the mappers will be drawing the structure in its actual location, even if the photograph does not appear to line up exactly.

Flight Planning

Flight planning refers to work done by an imagery vendor prior to the acquisition and development of the photography. To appropriately plan the flight, the vendor will depend on you for information about the intended use of the imagery and the expectations from it. All of these steps are critical to the project's success and your ultimate satisfaction with the product. A list of the information that you can prepare for the vendor is found in Appendix D; the sample information should be replaced with your own requirements.

Setting the Flight Plan

The vendor must know the boundaries of the region for which you wish to acquire imagery, the spatial accuracy expected, and the map scale you anticipate creating. Once that is known, a flight plan will be developed that allows the aircraft to fully cover the area.

Setting the Ground Control (For Orthophotography Only)

Since the generation of orthophotography is a photogrammetric procedure, there must be some surveyed control to which the mapping can be tied. Normally, this will include placing some targeted points on the ground. The vendor will use known control points, such as survey monuments, but may wish to set others; you may be asked if you are aware of known control points. In some cases, you as the client may be able to assist the vendor and perhaps lower the costs somewhat by setting additional control points. Many city and county public works agencies maintain survey monuments and can greatly assist the flight. Traditionally, the higher the specified accuracy of the mapping, the more control points will be required.

Configuring the Aircraft for the Flight
If the vendor offers airborne GPS as part of its orthophotography work, locational readings will be taken on the aircraft and the camera as well as on the GPS receivers on board,. All of these steps are required to ensure the integrity of the locational information that will come from the photography.

Negotiating Tip: Check to see if your vendor (aerial or satellite) or others have existing orthophotography of the area for which you wish to acquire imagery. Some vendors, at regular intervals, prepare orthophotography of certain areas. In some cases, orthophotography may be already available that meets your requirements for current data and horizontal accuracy. If so, the savings could be considerable.

Defining Your Needs

No two agencies or companies are alike. While we are providing guidelines to basic groups that share concerns, enough differences remain that will cause members of those groups to select differing imagery solutions. A sampling of these differing needs are listed below; each category represents a decision you will have to make. Refer to Appendix A for definitions of the technical terms and to Appendix D for a form that will assist in information gathering.

- *One-time versus periodic photographic coverage.* Some imagery need only be obtained once, at a particular time. Other photography for an area must be repeated over a period of days, seasons, or years. This variation depends on the agency and the intended function of the imagery.
- *Image type.* See above descriptions.
- *Standard versus ortho-rectified photography.* If an agency wishes to map from the photography, orthorectification is necessary. If change detection or resource monitoring is needed, uncorrected photography may be suitable.
- *Datums.* There are horizontal and vertical datums. As you might guess, the horizontal datums control horizontal measurements, while the vertical datums help control the vertical. Contour lines would be an example of a map feature controlled by vertical datum. Many counties have existing maps using as horizontal datum the North American Datum of 1927 (NAD27). Most new mapping is being done on NAD83. NAD83 is the currently recognized standard and is based on the same ellipsoid employed by the GPS technology. Similarly, there are two widely used vertical datums, the National Geodetic Vertical Datum of 1929 (NGVD29) and the North American Vertical Datum of 1988 (NAVD88), and a multitude of local vertical datums. Often, individual cities or agencies will have their own vertical datum. Generally speaking, there is more reluctance to move to the newer vertical datum than encountered in the shift from NAD27 to NAD83. This may be due to the fact that drainage engineering is so intimately tied to elevation, and the elevations of existing features are related to whatever datum was in use before 1988.
- *Projection.* This should match whatever your agency or company is using at present for its mapping. Check with your surveyors, Public Works staff, or other agencies with which you share data before settling this with the vendor. You should also determine whether the projection should be made in feet or meters.
- *Accuracy.* As noted earlier, some agencies may require a very generalized map or imagery product, while others may require engineering-scale accuracy. Always map to the highest level of accuracy your use will require. A typical agency discussion of accuracy involves the terms

"planning scale accuracy" and "engineering scale accuracy." These reflect the varying needs well: planners usually do not have a need for precise ground measurement, whereas engineers in the public works arena do have a need for precision. Planners may be well served by mapping that is accurate within 30 feet, whereas an engineer will usually require sub-meter accuracy. When specifying accuracy, aerial imagery companies typically refer to accuracy as "plus or minus 3 to 9 feet" or some other range.

- *Resolution.* Many agencies intend to use orthophotography to print images of a particular area and thus want a very clear picture. As noted elsewhere, a clear picture is not necessarily an accurate picture, but clarity can often be a useful tool. If you expect your product to provide a crisp image, be certain to tell the vendor that this is a requirement.

Negotiating Tip: If you are planning to have aerial imagery flown, search for adjacent agencies or companies with a similar interest or need for the product. (State and federal agencies frequently have imaging needs that could be obtained by a partnership endeavor.) Identify the highest level of accuracy and resolution required and pursue the project as a joint venture. Most vendors will work with you in this partnership effort. The price will likely be lower than if each entity pursues the imagery on its own. An initial expense is involved in flight planning, setting the control points; getting the craft into the air; once in the air, the greater flight area is typically of less concern and expense.

Getting Ready To Fly — Developing Specifications

Prior to contracting with an imagery vendor, you will need to decide the following:

- Whether you want orthophotography or uncorrected imagery
- The geographic scope of the area to be flown
- The tile size required: the ground coverage of each image, typically 2000 x 3000 feet
- The map scale you wish to create
- The coordinate and projection system you will typically use.
- The anticipated use of the imagery to be acquired
- The spatial accuracy required of the imagery
- The resolution of the photograph (i.e., pixel size)
- Whether black-and-white or color photography is preferred
- Whether you will use the imagery in a GIS
- If you have any partners to the project
- The products you want to receive from the vendor (See "What You Should Get from the Vendor" (below) and refer to Appendix D).

You may also have some subsidiary decisions to make. For example, you will need to decide in what season you wish to acquire the imagery. In some areas, tree cover is significant and blocks substantial portions of the terrain. If the trees are deciduous, a flight in winter would acquire imagery of terrain that would be obscured in the summer; however, the window of opportunity for winter flights is small and you risk having a lot of shadow in the photographs. Other seasonal issues such as fog and other cloud cover may have a significant bearing on the timing of your flight.

Related to this issue is the decision of how to handle features that are obscured. These include features hidden by trees, as noted above, and also a variety of other obstructions. Examples would include automobiles (which might obscure features on the curb or pavement; roof lines, and vertical obstructions such as tall buildings, signs, towers, etc.). Once the imagery is received and the obstructions identified, many agencies field-check the features obstructed and obtain precise locations using GPS or other surveying techniques.

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 the vendor, including map work of your choosing and the imagery in a variety of formats. The following are typical products you can receive from a vendor; you should be very clear about the products expected in your negotiations with the vendor. See Appendix D for a sample listing.

- *Diapositives.* Photographic prints made on a clear film base used by a photogrammetrist in analytical aerotriangulation and traditional stereocompilation. Most vendors consider the diapositives to be the property of the client who commissioned the project and will willingly deliver them. A few vendors, however, hold on to the diapositives as a means of retaining the business of orthorectification. Specify your wishes in your preflight contract.
- *Digital elevation model (DEM).* Elevation data produced from overlapping stereo orthophotos. DEMs can usually be delivered at little or no additional cost, as they are a required component of producing the orthophoto. DEMs can be used to derive slope, aspect and shaded relief images.
- *Flight plan map.* Once the area to be covered by orthophotographs has been decided, a confirming flight plan map should be prepared by 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 to create horizontally accurate maps.
- *Line work.* Many vendors have the capability to develop the initial map base. They will do the necessary interpretation required to develop map layers derived from physical features shown on the imagery. Examples might include streets and roads, centerlines, curb lines, manhole covers, streetlights, roof lines, waterlines, hydrants, and signs. (You will want line work only if you are contracting for orthophotography.) Keep in mind that line work can only be developed for physical features that can be seen in the photograph; line work cannot be developed for features that are conceptual, such as parcel lines, district or city boundaries, etc. In addition, a certain amount of interpretation is involved in creating the line work, so you should plan to include serious review in the quality-checking process.
- *Delivery format.* You must specify how you wish to receive the data, particularly if the data are going to be used as part of a GIS. If it is delivered in a computer aided design (CAD) format, you or someone else must work with the data to create topology, and polygonize and tag the data, thus rendering it useful to the GIS. Incidentally, many vendors work in the CAD environment, while relatively few work in a full GIS environment. Nonetheless, the CAD-format delivery is extremely useful and makes the final GIS work much easier.
- *Mylar.* The orthophotographs or the 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, since Mylar is a very stable plastic medium that distorts very little in the copying process.
- *Compact disk.* The orthophotographs and uncorrected imagery are delivered digitally on a compact disk. Orthophotographs are typically broken out into tiles of the size you specify in the project planning; uncorrected imagery is delivered by individual exposure. The vendor should provide you with a grid or index 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-inch format, the individual tiles of the coverage are frequently useful to agencies wishing to use them on a daily basis for quick reference. These are uncorrected photographs, and you will see the same geography covered by several photographs. The apparent duplication is necessary for good aerial photography. The photographs are sequenced by flight line and photograph number; these are to be found in the upper margin of the photograph.
- *Triangulation report.* Aerotriangulation is a photogrammetric procedure that uses relatively few surveyed control points to derive coordinates for other points within a block of photography. When the process is complete, each pair of overlapping photographs in a block can be set in a stereoplotting instrument and mapping can proceed. The procedure involves the precise measurement of stereo conjugate points and surveyed control targets on diapositives. Aerotriangulation is the mathematical adjustment of this set of redundant measurements to reach a unique solution. It means that points on the ground are measured several times in several ways to reach the most precise description of their location.

One of the first and probably most confusing products you will receive from the vendor is the triangulation report. This usually takes the form of a paper report with lists of mysterious numbers, letters, and abbreviations. What the vendor is trying to do is to report on the adjustments made to the survey measurements. This is meant to reassure you of the quality of the measurements and to indicate that the orthorectification process is proceeding from a sound basis.

The triangulation report should state the RMS (root mean square) error for the surveyed control points and the RMS error for the image measurements made on the diapositives. The first of these values is a measure of the control survey quality, the second is a measure of the photogrammetric measurement's quality. While the RMS for the surveyed control points will be influenced by the scale of the photography, the quality of the photogrammetric measurements is independent of scale. A good adjustment will have an RMS of 0.010 mm (10 microns) or less on the image measurements.

Negotiating Tip: Some companies or agencies write requests that attempt to tell the vendor how to complete their work. Given the complexity of orthoimagery processing and the rapid change in associated technologies, it is better to tell the vendor what you need and want and to give them the responsibility to select the means to produce it.

Quality Checking And Quality Assurance

Quality checking and quality assurance are a substantial component of the imagery product. You must be prepared to check the photography against the contractual agreement. Like any other product, imagery can contain errors, many of which can be corrected. Line work in particular may contain errors, since a great deal of interpretation is involved in its development.

Examples of interpretation errors may include simple misidentification of a feature, such as a stop light or manhole cover, or faulty presentation of the feature.

APPENDIX A:

DEFINITIONS OF TERMS FREQUENTLY USED IN AERIAL IMAGING

Accuracy, horizontal: This is usually expressed as "plus or minus 10 feet" or "±15 feet." A more formal definition has been written:

"...a measure of the confidence that a particular location on an orthophoto can be located to within a specified distance. For instance, the accuracy standards for a 1:24,000 scale digital orthoquad state that 90% of well-defined point features must fall within 40 feet of the actual ground coordinates. Areas of high terrain relief, and which fall on the edge of a photo will experience greater horizontal inaccuracies."

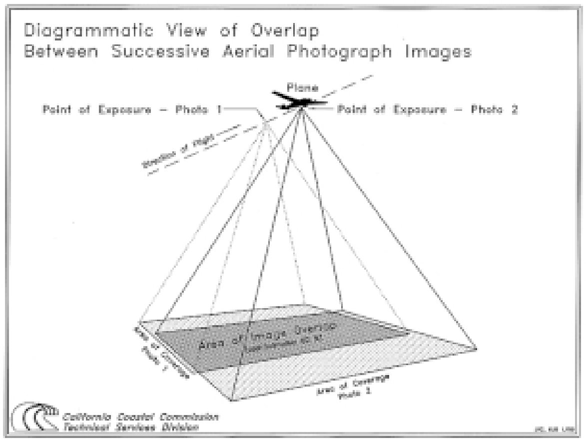
National Mapping Program Geospatial Standards, Digital Orthophoto Standards. Part 2: Specifications, Standards for Digital Orthophotos. 1996.

When the final digital orthophotograph is viewed, it is possible to accurately measure horizontal distances on the photograph within the tolerances expressed. The accuracy tolerances are affected by a range of factors but are generally correlated with pixel size; usually, the smaller the pixel, the better spatial resolution or horizontal accuracy of the photograph.

Accuracy, vertical: vertical (elevation) accuracy of a rectified image and associated digital elevation models. This may also include accuracy assessments of vertical measurements using soft or hard-copy photogrammetric methods. Vertical measurements are usually expressed as contour lines or spot heights. They are more easily obtained in areas of steep terrain; it is considerably more difficult and expensive to accurately measure vertical distances in relatively flat terrain. Recent technological advances may change this constraint; for example, light intensity detection and ranging (LiDAR) and SAR are now being used experimentally to map terrain at great detail. Vertical standards are yet to be developed.

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 as NGVD29 or NAVD88 for the vertical datums. NAD27 uses surface reference points, whereas NAD83 uses the center of the earth as the reference point.

Diapositives: photographic prints made on a clear film base used by a photogrammetrist in analytical aerotriangulation and traditional stereocompilation.



Forward lap or end lap: the extent to which sequential exposures in a flight line overlap; the typical end lap for stereo photography is 60%.

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

H/V: shorthand for horizontal/vertical.

NAD27, NAD83, NGVD29, or NAVD88: See "Datum," above.

Pixel: developed from the "picture element." The smallest cell size with a uniform value of an image. This digital image grain is produced in varying sizes, usually referred to in ground units such as 6 inches, 1 foot, 3 meters, etc. Incidentally, the mixing of inches, feet, and meters is intentional. While it is desirable to stick with one measurement system, vendors typically refer to pixel size in inches and feet in the smaller range (3 inches to 2 feet), and in meters in the larger pixel sizes. Pixels are created during scanning of the aerial imagery and are key to establishing the resolution of the orthophotograph. Generally, the smaller the pixel size, the higher the resolution of the resulting image.

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

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 inch = 100 feet (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 inch = 100 feet 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 inch = 100 feet). The ratio is referred to as a representative fraction, and the equation as an equivalent scale.

Large- versus small-scale mapping: A small-scale map covers a large area in less detail than a large-scale map (1/1000000 is a smaller number than 1/100).

Scanning: the process of converting analog photographs or live scenes or hard-copy maps into a digital form. The scanning process results in the creation of pixels (see above for definition), which ultimately determine the spatial resolution of the image.

Spatial resolution: the density of pixels in an image per unit length. Resolution may also be described as the relative clarity (crispness or fuzziness) of an image.

Spectral resolution: the width and number of bands in the electromagnetic spectrum to produce an image. The smaller the bandwidth and the greater the number of bands result in a finer spectral resolution, and will yield more information and detail to the user.

APPENDIX B:

RECOMMENDATIONS FOR PHOTOGRAPHY BY AGENCY TYPE

Guidelines for agencies and agencies with varying applications are described in this section. First, a table is presented that summarizes the relationship of scale to scanning to pixel size and the resulting accuracy. As noted in the table below, scanning and pixel size have a direct correlation to map scale. It is thus imperative that, in planning orthophotography, you have a firm idea of the mapping scale needs of your agency or company.

Cities. Of all imagery users, cities typically require the largest scale and the highest level of resolution, due to the more intensive land use and the density of the population and the built environment. Still, the imagery needs of different cities and different city departments will vary. For example, it is not unusual for the City Engineer to map at 1 inch = 40 feet, whereas other city departments may map at 1 inch = 100 feet or 1 inch = 500 feet. As noted earlier, plan the photography to the highest level required by any department who may use it. Most cities can function very well with black-and-white photography; however, if vegetation patterns or plant inventory is important, a city might opt for color photography.

Counties. Although not requiring as fine a scale as cities, counties require a larger scale than states or federal agencies. Counties also have an option to mix

Map Scale	*Scanning Dots per inch*	*Pixel Size*	*Approximate Horizontal Accuracy**
1:1,200	300	4 inches	3-9 feet
1:3,600	300	1 foot	6-12 feet
1:7,200	300	2 feet	9-18 feet
1:12,000	300	1 meter	6-12 meters
1:20,000	300	1.7 meters	8-15 meters
1:30,000	300	2.5 meters	10-20 meters

** Horizontal Accuracy can only be determined by the company that produces the imagery. It is dependent on a number of factors, including the type of camera, terrain relief, atmospheric distortion, what is being imaged, and processing routines.*

scales of photography. For example, a county with expanses of undeveloped remote areas may acquire photography at a smaller scale in those regions and at a larger scale in urbanized areas. As development occurs, they will want increasingly accurate maps and will need to acquire finer orthophotography.

Coastal zone. Coastal areas are prone to rapid erosion rates that can change the morphology significantly over the course of a human life span. With increasing urbanization pressure in coastal areas, it is easy to see the need for repeated measurements of coastal bluff erosion, along with the need to protect sensitive marshlands, dunes, mud flats, and intertidal areas. While black-and-white photography is the minimum standard (see below), color is preferred in order to identify and monitor marshlands, mud flats, other vegetation, and wildlife habitat.

Areas of special interest. Areas of special interest are usually of an environmental nature, but could be an area of any sort of special study. Photography of these areas should be at a larger scale that that of the general coastline, since more detail is typically required.

Regional land use. Regional land-use studies attempt to quantify the location and type of land use over large areas (usually covering several counties). While past land-use studies have utilized Landsat(tm) data with 30-meter pixels, we advocate a smaller pixel size for these studies in order to more accurately quantify areas and delineate land-use types that can be missed with 30-meter pixels (e.g., small riparian corridors, small-cluster residential development, and forest fragmentation).The following are the minimum guidelines for each of the photographic subjects listed above. You may want to acquire imagery at an even higher standard.

	Map Scale*	Horizontal Accuracy	Pixel Size or Ground Resolution	Film Type
Cities	1 inch = 100 feet	±5 feet	6 inches	Black & white
Counties	1 inch = 600 feet 1 inch = 100 feet	±20 feet ±5 feet	2 feet (rural areas) 6 inches (urbanized areas)	Black & white
Areas of special interest	1 inch = 600 feet	±15—20 feet	2 feet	Color; near infrared
Coastal zone	1 inch = 1000 feet	±6 meters	0.5 meter	Black & white
Regional land use	1 inch = 5000 feet	±25 meters (75 feet)	4—5 meters	Corresponds to bands 1-4 of Landsat sensor

** These are approximate scale recommendations developed in consultation with subject experts. The appearance of offset should not be of great concern; in producing the line work, the mappers will be drawing the structure in its actual location, even if the photograph does not appear to line up exactly.*

APPENDIX C:

METADATA

Metadata

Usually defined as data about data. For full utility of the imagery and any imagery acquired 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 must demand it from the producers of imagery you acquire.

The United States Geological Survey (USGS) has led the efforts of the Federal Geographic Data Committee (FGDC) to create standards for metadata development and tools for its acquisition. The national standards for metadata can be found on the Internet at the USGS site (http://www.usgs.gov/). Many states have metadata coordinating councils that participate in the national program and adhere to the national standard. The USGS Website also has a complete listing of these agencies, along with contact information.

Why Bother with Metadata?

Think of it as a prescription. You probably do not 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. At a minimum, the description of data or metadata for imagery should include the following:

Scale	The map scale used, whether ratio or equation, expressed in common mapping units, such as feet, miles, centimeters, or kilometers
Date and time	The date the imagery was taken and the time of day
Bands	The number of frequencies of the electromagnetic spectrum that are included
Lat/long centroid of photograph	Real-world coordinates of the center of each photograph
Geographic bounding box	The geographic extent of the photography, expressed in north, south, east, and west latitude/longitude
H/V accuracies	Horizontal or vertical tolerances of the photograph's accuracy; usually expressed as "±5 feet" or other tolerance
Sensor information, if applicable	Specifications of the type of camera acquiring the imagery
Medium of photograph	The material in which the photograph exists: hard copy (print or Mylar), raw film, digital, etc.
DPI of digital images	Dots per inch, as an indicator of the photograph's resolution or level of detail
Azimuth	Angle of the sun
Altitude	The height at which the aerials were flown
Source of photo and frame reference number	The company or agency that took the photograph and their reference number
Purpose of imagery	A narrative description of the use intended for the imagery
Contact information for photo acquisition	The person or agency to be contacted for information about or acquisition of the photographic materials
Stereo	Whether or not photographic overlap is provided

APPENDIX D:

REQUIREMENTS CHECKLIST

As you develop the specifications for the orthoimagery, it will be useful to document the decisions and use that documentation in the Request for Proposal (RFP) or other tools used to obtain bids from qualified companies. The aerial-imagery companies will benefit from the information and be able to more easily provide the level of imagery required for your needs. In addition, when the flight is complete and the products delivered, the document will serve as a good checklist to help determine whether you received everything requested of the vendor. The form below is a list of basic items to be included in an RFP. For illustration, sample requirements have been entered in the right column; these should be changed to meet the requirements of your organization.

If you have been able to craft a partnership with other agencies or companies to develop imagery, the participants may have differing needs; thus each partner should fill out a separate form.

Orthoimagery Specifications

Factor	Type
Image	Color or black and white
Pixel size	6 inches. Second set scanned at 5 or 10 feet for use in presentation background.
Flight area	Refer to attached map
Line work	Contours as described below
Delivery media	Compact disk: color or black and white Contact prints: 9- x 9-inch analog prints of the aerial imagery Compressed files: color or black and white Mylars: black and white for the full area
Compression	Mr. Sid or other compression software to be approved by city
Contours	2 feet for areas within CITY limits; 10 feet for remaining areas in the flight plan except 20 feet for hilly areas within the flight boundary
Triangulation report	Required in digital and hard-copy formats
Survey report	Required in digital and hard-copy formats.
Digital elevation model / triangulated irregular network (TIN)	Required to be at a density that will support ortho production and generate the appropriate 2- and 10-feet contours.
Diapositives	To be owned by the city
Control	Ground control Airborne GPS City-wide vertical control City has 25 pt. Net use for triangular control
Horizontal accuracy	Mapping within the city limits: 1 inch = 100 feet (1:1200); for areas outside city limits and within planning area boundaries: 1 inch = 200 feet (1:2400)
Vertical accuracy	Sufficient to support 2-feet contours
Map scale	100 scale
NAD	NAD83
NAVD	NAVD88
Coordinate system	State plane, zone _:‘ feet
Match grid	City grid
Flight date	March 2001

Who Produced This Publication?

The Central Coast Joint Data Committee is a consortium of public, private, academic, and nonprofit entities agreeing to share spatial data in the Monterey Bay region of California. It has taken on the task of building a metadata clearinghouse on the Internet, so that the community and its agencies can search for existing information about the region. It is also helping to fill in the gaps of spatial data, providing spatial data on streets and roads, parcels, and census tracts.

The Imagery Special Interest Group's interest is in identifying regional imagery needs. Its efforts will be reflected both in the metadata clearinghouse and in the data building efforts. It is therefore setting forth desirable standards for the acquisition of aerial imagery (both digital and nondigital) for California's Central Coast; in addition, it is providing guidelines to agencies that are pursuing the acquisition of imagery. Please visit our Website (http://www.centralcoastdata.org/).

These standards have arisen from a series of discussions among area researchers, government representatives, and GIS professionals regarding the types of imagery that are most useful to them. Special thanks to Peter Ashley, LSIT, of Hammon, Jensen, Wallen and Associates in Oakland, California, for providing technical review, and to Jonathan Van Coops of the California Coastal Commission for providing graphics.

More Information And Further Reading

A variety of resources exist for learning more about imagery and its uses. The following is a small sampling of those resources:

Websites

American Society for Photogrammetry and Remote Sensing (ASPRS) = http://www.asprs.org/

NASA = http://www.nasa.gov

US Geological Survey = http://www.usgs.gov

Books

Avery, T. E., and Berlin, G. L., 1992, Fundamentals of Remote Sensing and Airphoto Interpretation, 5th Ed. (Upper Saddle River, NJ: Prentice-Hall).

Graham, R., 1997, Digital Imaging (Whittles Publishing).

Greve, C. W. (Ed.), 1996, Digital Photogrammetry: An Addendum to the Manual of Photogrammetry (ASPRS).

Maclean, A., 1994, Remote Sensing and GIS: An Integration of Technologies for Resource Management (ASPRS).