PRODUCT GUIDE

For the
Los Angeles Region
Imagery Acquisition Consortium
(LAR-IAC) Project
2006-07

Product Guide Developed by:

December 2006

Orthophotography Data Acquisition provided by:

Prime Contractor: Infotech Enterprises America, Inc. (formerly VARGIS)
Survey: Stantec
DMC Acquisition and Production: 3001 Inc.; GE Energy; Photo Science Inc.
LiDAR Acquisition and Production: Merrick & Company; Photo Science Inc.

Oblique Imagery Data and Viewer provided by:

Pictometry International Corp.

Quality Assurance, Quality Control and Deliverables provided by:

Dewberry and Davis (prime vendor)
Pinnacle Mapping Technologies, Inc.

Special thanks to two people that were instrumental in the development of the LAR-IAC Program but retired from Los Angeles County service in 2006:

Milan Svitek, AICP, Dept. of Regional Planning, GIS Manager,
Former LAR-IAC Project Manager – retired

John McIntire, Chief Information Office, Associate CIO,
Former LAR-IAC Project Director – retired

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LAR-IAC – The Initiative

Recognizing the growing value of geographic aerial imagery and the often prohibitive cost, the Los Angeles County Chief Information Office, Department of Regional Planning, and County Counsel formulated a program to acquire a set of imagery and digital terrain datasets (i.e., four product types) for a group of agencies willing to share the cost of acquisition. The Los Angeles Region Imagery Acquisition Consortium (LAR-IAC) Program proposed to acquire 4-inch resolution imagery (orthogonal color and CIR, oblique imagery, and digital terrain datasets) for the entire County. The project has successfully gained the participation of 10 County departments, 30 municipalities, and four other public agencies.

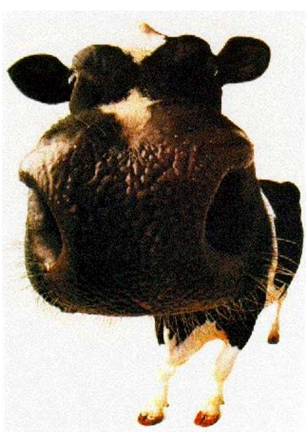
The consortium represents a model in regional cooperation that improves the quality, access, and cost-effectiveness of high resolution digital aerial imagery. Knowledge transfer is increased through consortium program meetings, user groups, and various workshops that have been established in conjunction with the project. The imagery acquired will enable all participating jurisdictions to leverage this key geographic information asset for numerous decision support and business applications, thereby facilitating the effective and efficient delivery of services.

Introduction to Orthophotography

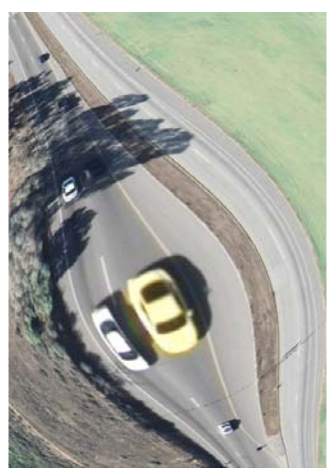
Aerial photography is commonplace in government agencies all across the United States (and beyond). It is among the most important, widely available, and commonly utilized kinds of remotely sensed images.

Aerial photographs record the ever-changing cultural and natural features on the Earth's surface. They capture residential and industrial areas, road and rail networks, and geographical features including mountains, canyons, flatlands, rivers, lakes, forests, and cropland. Aerial photography has many practical applications such as mapmaking, urban and rural planning, environmental impact studies, civil law cases, real estate evaluations, and can even be used as wall art.

Many online sources for aerial photography exist for government agencies and the public, as well as private companies. Online availability varies from searchable map databases, to locality maps, and/or browse images, to Web sites with offline ordering instructions.



By its nature, all photography has some amount of distortion. The process to convert aerial photographs into a geographically accurate map image called digital orthophotography (a.k.a. digital orthos) is a mathematical process of removing distortion in an ordinary photograph caused by hills and valleys, the curvature of the earth, or orientation of the aircraft when it took the photo.



The traditional orthophotography production method used scanned (digitized) film images from cameras combined with digital elevation models produced from the imagery using manual photogrammetric measurement/mapping processes. The state-of-the-art process now includes digital mapping cameras that use either individual frame-based sensors to capture a digital frame image or push broom sensors which scan the terrain with multiple line sensors. The new digital sensor technologies support the simultaneous collection of panchromatic (Black/White), Red/Green/Blue (RGB color) and Color Infrared (CIR) bands. Digital elevation models are now captured using airborne laser-based sensors and through autocorrelation of the digital imagery (pixels) to calculate the terrain surface.

The LAR-IAC 2006-07 data acquisition project utilizes the following state-of-the-art technologies to capture the source data used to create the deliverable products:

- Digital Mapping Camera (DMC) system to capture the 4-inch and 1-foot orthogonal digital imagery.
- Pictometry system to capture the high-resolution community and neighborhood oblique imagery.
- LiDAR (Light Detection and Ranging) laser sensor to capture the digital terrain data in the 4-inch urban areas.
- Autocorrelation of the 1-foot digital imagery to create digital terrain data in the National Forest areas.

This state-of-the-art technology is still based on the underlying mathematical and scientific principles of the professional mapping industry. The technology benefits include faster and more accurate creation of a more diverse set of digital mapping products at a much lower cost. Below we introduce some of the basics of aerial photography, photogrammetry, and orthophotography. Certainly we cannot cover everything that you may need to know, so we have also included a list of useful Web sites and books.

Basics of Photogrammetry

This section presents basic information about the techniques and goals of the science of photogrammetry. Much of the material in this section is summarized from the text *Remote Sensing and Image Interpretation*, by T. Lillesand and W. Kiefer, and the reader is referred to this primary source for more detailed information. In addition, entire texts are devoted to the subject, such as "Elements of Photogrammetry," 3rd edition, by Wolf.

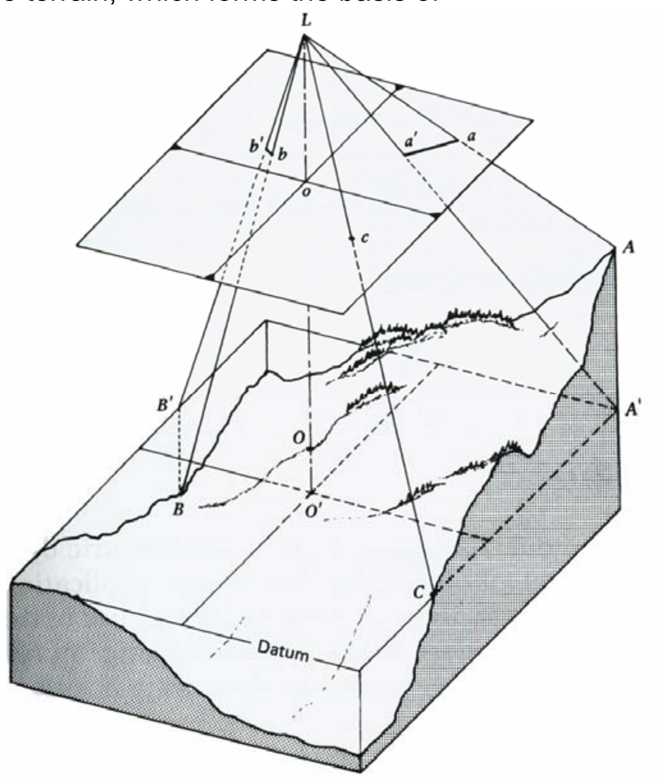
Photogrammetry can be defined as the science of obtaining reliable measurements and producing maps by means of photography. Photogrammetric techniques are required to accurately determine relationships of features on aerial photographs, including ground distances and angles, the heights of objects, and terrain elevations.

The principles of modern day photogrammetry have been developing since 1913, when they were used for reconnaissance missions for World War I. Throughout the following decades, architectural and engineering firms began using photogrammetry for site surveys. It wasn't until the 1980's that government agencies realized how photogrammetry could play an active role in managing a City, County or State. That boom of acceptance coincides with the growing applications of GIS (Geographic Information Systems) in those same government agencies.

When an aerial photo is taken, the exact point on the scene that is directly below the center of the camera is called the ground principal point. Lines drawn to connect marks located along opposite sides of the photo (fiducial marks) intersect precisely at the principal point. This relationship, together with the flying height and the camera, form the basic coordinate system used to quantify various elements of the image.

Identifiable points on the ground (ground control points) are used to determine distances and geometric properties of the image, including camera height above the ground, degree of tilt at the time the photo was taken, distance between photo centers, and to correct for distortions on the image. Distortions that commonly occur on aerial photographs include: relief displacement of vertical features (the top of tall objects appear to lean away from the principal point); and image parallax (the misalignment of the principal point-fiducial axes from image to image based on unavoidable changes in the orientation of the aircraft along its flight axis).

In order to correct (or rectify) these distortions, overlapping photos and ground control points are integrated to produce a stereo model of the terrain, which forms the basis of photogrammetric mapping and orthophotography. Ground control, or accurate geodetic data, is essential for all photogrammetric operations.



Orthophotos are being produced for many parts of the country and combine the constant scale and accuracy of a map with the detail of an aerial photograph. Modern mapping and orthophotography are just two of the products of the science of photogrammetry.

Basics of Orthophotography

Aerial photographs contain distortion – either caused by relief of the Earth being photographed or because of the orientation of the aircraft taking the photo. The process of creating a digital orthophoto involves a couple of steps. The first step is the creation or introduction of a surface model. A surface model is used to define the topography of the Earth's surface over a given geographic area.

The role of a surface model in the orthorectification process is to correct for relief displacement in the photography. The above image (taken from the 5th Edition of *Remote Sensing and Image Interpretation* by Thomas Lillesand, Ralph Kiefer and Jonathan Chipman) illustrates the relief displacement principle.

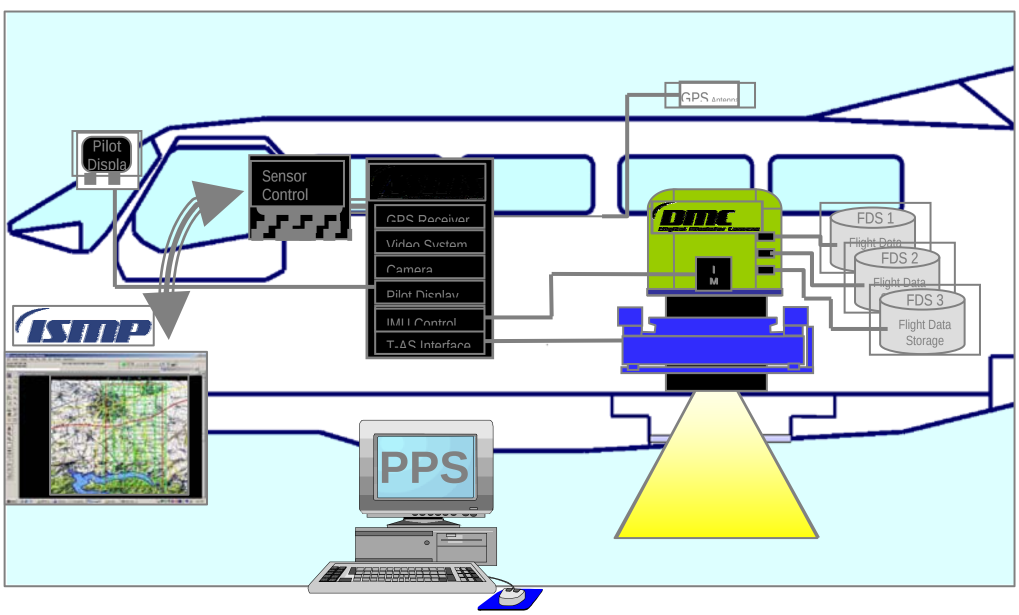
Orthophotos are digital images that are produced by making geometric corrections to digital aerial photographs. The distortion in aerial photographs is removed by un-warping the effects of terrain, removing the perspective projection of the camera, and by fitting the image to a particular map projection to create an "image map" that has a uniform scale and a known accuracy. Hence, orthophotographs can be used as a map whereas aerial photographs cannot. In computer systems, they can be integrated with other geographic information providing a rich visual context.

Due to their properties, orthophotos are more readily used for measurement and spatial analyses because they maintain a constant scale across the image.

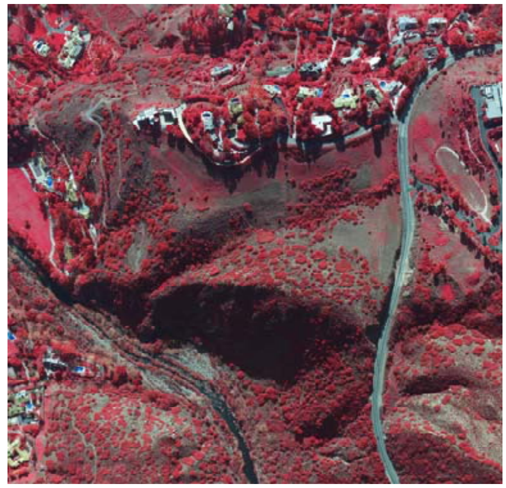
Basics of Digital Mapping Camera (DMC) Imagery

Digital Mapping Camera (DMC) is a turnkey digital aerial camera system designed to support aerial photogrammetric missions demanding high-resolution and high geospatial positional accuracy. Designed from the ground up as a digital replacement for film-based photogrammetric mapping cameras, the DMC features breakthrough technologies enabling successful projects from small-scale mapping operations to precision, high-resolution corridor engineering projects.

The DMC is geared for high resolution, small pixel imagery acquisition.
The DMC is unlike a film camera in that it uses eight individual lenses instead of a single lens. The lenses operate simultaneously and collect color imagery (red, green, and blue bands), color infrared (CIR), and black-and-white (panchromatic) imagery on charged coupled device (CCD) arrays. The panchromatic imagery and the color imagery are then combined to form a single high-resolution image.



The ability to capture infrared imagery has many practical applications. Since active vegetation reflects near-infrared radiation, imagery can be used to study the location, type, and condition of vegetation.

Sample imagery in natural color (RGB) and color infrared (CIR).

Color fusion technology, also commonly referred to as pan sharpening, is another innovative design of the DMC that enables production of full color or color infrared, high-resolution image data. Pan-sharpening is the process by which the color bands collected by the individual color and near infrared sensors on the camera platform are fused with the high-resolution detail found in the panchromatic imagery. No re-sampling of pixels occurs with this approach; therefore, the integrity of the high-quality image resolution is sustained. This technique is automated through post-processing algorithms designed into the DMC system and creates high-resolution, detailed panchromatic, true color, and color infrared imagery from a single aerial pass over the ground, with all imagery combinations perfectly registered with one another. The result is final image quality that is superior to traditional image scans as well as the images produced by push-broom sensors.

Acquisition of Near-Infrared (CIR) Imagery

The DMC is a single pass acquisition system allowing the customer to select one or all three products derived from panchromatic, RGB Color or Infrared sensor collection. For this specific project, the primary deliverable is an RGB Orthophoto product. The option of selecting the Color IR product is a cost savings, not requiring additional aerial collection or aerial triangulation during initial project production. Extra requirements not exclusive to any process are storage, post-processing of raw image data and orthorectification of the IR product. The DMC virtual sensor foot-print of the Infrared image is the same raw interior geometric source as the RGB product source, as opposed to a film solution requiring extra aerial collection, scanning, interior orientation, aerial triangulation effort, results and cost.

A benefit of using the DMC sensor as the source for the infrared product is utilization of a single (or same) aerial triangulation solution derived from the Color RGB source. This can easily be applied to the Infrared post-processed raw imagery as a second product source during the Orthophoto production of the deliverable. If requested during the initial project production phase, additional cost savings are realized (not requiring restoration from the first project production archive, additional project initiation, setup and second level life cycle deliveries).

Introduction to Digital Terrain Datasets

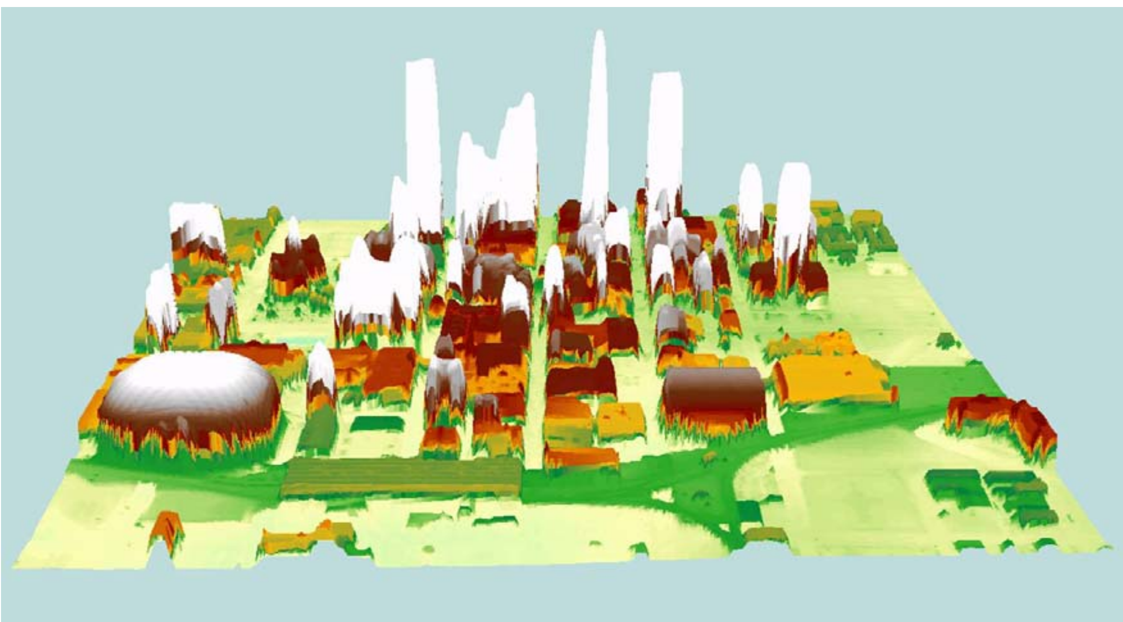
LAR-IAC participants requested Digital Terrain Datasets that included the following:

- A Digital Surface Model (DSM) dataset containing the LiDAR mass points and breaklines used to generate subsequent elevation products.
- A Digital Terrain Model (DTM) representing the bare-earth terrain including all appropriate breaklines.
- A Digital Elevation Model (DEM) dataset representing the bare-earth in grid format.
- Elevation contours at a minimum of 2' (for Area 1 and Area 3) and calculated 4' (for Area 2).

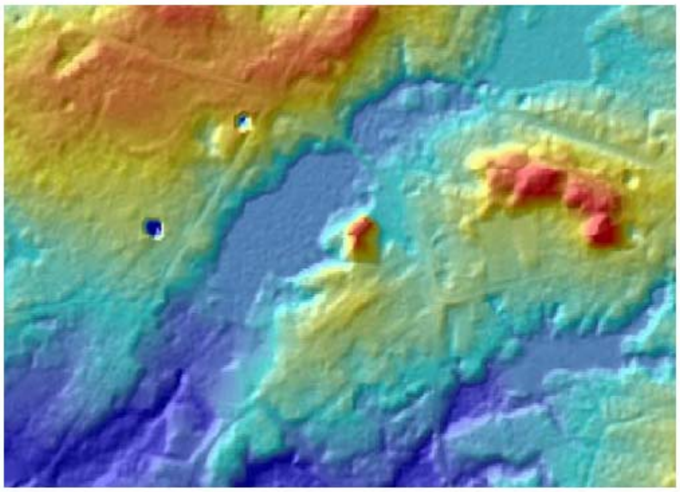
Digital Surface Model (DSM)

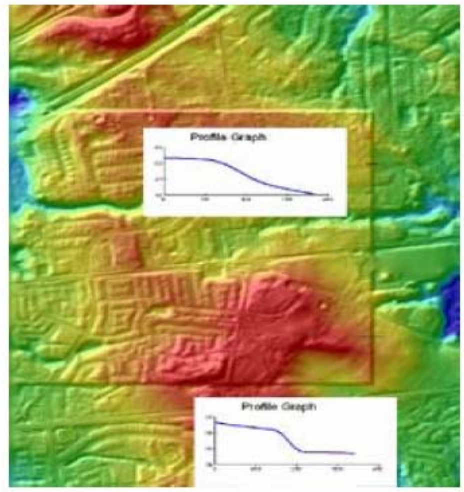
The Digital Surface Model (DSM) represents the top reflective land surface determined by auto-correlation of stereo images, and LIDAR (Light Detection and Ranging). The DSM is used in the orthorectification process for the digital orthophotos, and it need only be accurate enough for orthophoto production.

The DSM is generated through a method known as auto-correlation. This technique involves using complex image matching algorithms to calculate the height displacement in the image and so compute the height of every pixel. This produces a “first return” surface that includes surface features such as buildings and trees.



There may be minor anomalies in the DSM that were not corrected as part of this project (the DSM and DEM are corrected to meet the specifications of orthorectification). For example, when there are long stretches of asphalt highway running parallel to the direction of the airplane flight, the image correlators can get confused by the similar texture and appearance. The same problem can occur with large water bodies, plowed fields, or areas of sand or dark shadows. This can cause the DSM to be distorted which, in turn, will cause waviness in roads and buildings on the digital orthophotos. When correlators get confused, artificial “sinkholes” or “spikes” can form in the DSM. If these artifacts are near the nadir of the flight line, they normally have minimal impact on the horizontal position of imaged features. These distortions are typically removed through additional processing and all LAR-IAC DSMs have been reviewed for these artifacts.





Anomalies can be found with the aid of visualization software and analysis tools.

Using the elevation tool set, we are able to create pseudo 3D visualizations of the different terrain types, and coupled with a statistical analysis, we are able to quickly identify anomalies in the data. Since the source data is an AutoCAD .dwg file, a direct plug-in for ArcMap™ enables us to utilize the data with no conversion at all and is easily incorporated directly into our process flow. To create our 3D pseudo visualizations programmatically, our elevation tool set reads in the data, converts it to a hillshade, combines the grid elevation model and then symbolizes the data with the correct symbology to best identify anomalies. By utilizing a blue to red scheme we can quickly identify high and low points, and elevations that do not fit the norm. The above figures illustrate this technique. The second figure illustrates an edge join issue where one tile is higher than the surrounding tiles (this error was later corrected). Additionally, a histogram may be produced and the statistics reviewed if deemed warranted by the QC analyst. For each DSM tile, Dewberry reviewed the elevation models for completeness of coverage, and to check the model for blunders in a 3D software environment as described to determine suitability for orthorectification.

Digital Terrain Model (DTM)

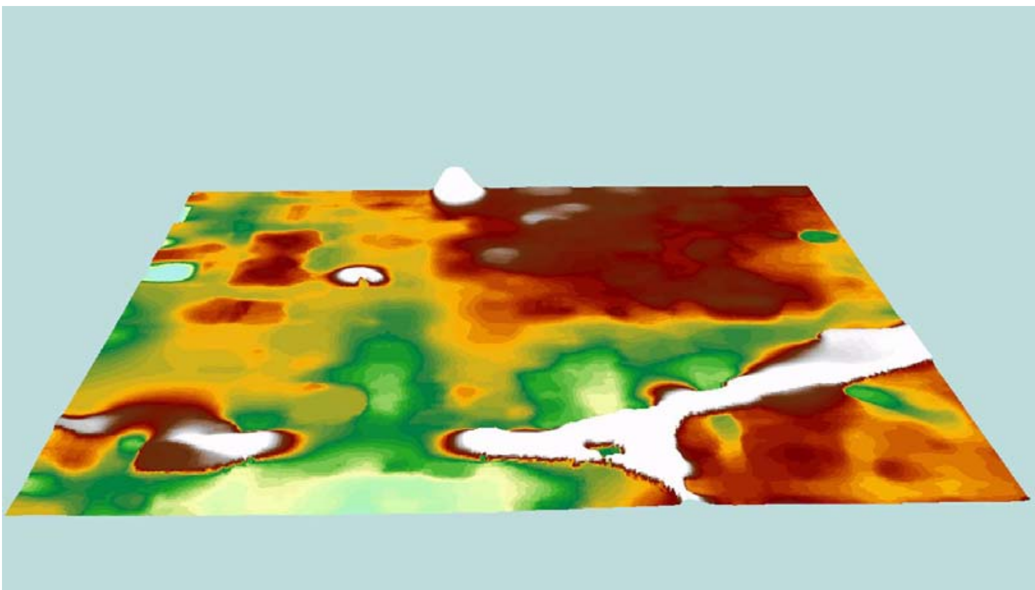
The Digital Terrain Model (DTM) represents the bare earth terrain, from which elevated surface features, such as buildings and trees, have been removed with the addition of breaklines. The removal of the elevated features is executed in a multi-step filtering process, including automated and interactive steps. Breaklines are added using photogrammetric compilation from stereo models. Each stereo model is reviewed and breaklines are interactively collected. Breaklines are compiled at critical locations to enhance the LiDAR mass points to represent the actual terrain and furthermore the generation of the contours.

The DTM also includes the breaklines. The 2’ elevation contours (urban areas) and the 4’ elevation contours (national forests) GIS layers are derived from the DTM.

The quality assurance review process for the DTM models is built around multiple software programs. The original LiDAR mass points (ASCII point files) were quality controlled with 3D hillshades using QT Modeler software. The final DTM including breaklines (TIN format) was quality controlled with 3D Analyst software.

Digital Elevation Model (DEM)

The Digital Elevation Model (DEM) is normally presumed to be the same as a bare-earth model from which surface features, such as buildings and trees, have been removed from the DSM. The points are filtered to a DEM "near bare earth" surface through a point classification and filtering algorithm.



Sample DEM with shading for elevation ranges.

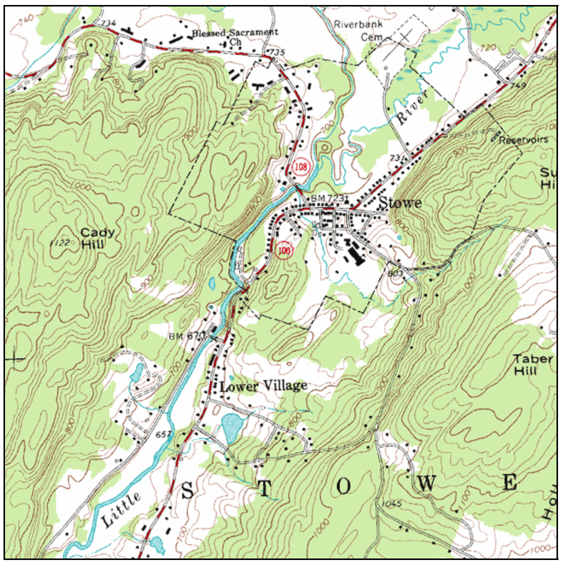
The DEM products for the urban area of the county and Santa Catalina Island (project areas 1 and 3) have been certified to support creation of 2-foot contours or equivalent digital elevation models with no further processing. The DEM products for the rural area of the county (project Area 2) have been certified to support creation of 4-foot contours or equivalent digital elevation models with no further processing. The quality assurance statements provided with the DEMs reads as follows:

"It is recommended that additional ground control points be collected and the AT re-processed before utilizing any given data for generation of elevation data of higher accuracy than 2-foot contours or equivalent digital elevation models (DEMs)."

Elevation Contours

An elevation contour is a line on a map that joins points of equal elevation. In cartography, a contour interval is any space between vertical lines on a topographic map, representing a difference in elevation between the lines. Some definitions related to contours on USGS topographic maps are included below:

- Contour Interval - the distance between each contour line
- Intermediate Contour - a brown line on a topographic map and represents a line of equal elevation
- Index Contour - a bolder/wider brown line that has the elevation value marked at various intervals as a part of the line
- Supplemental Contour - a dotted or dashed line that represents half the interval between the other contour lines
- Depression Contour - a contour that indicates a hole and is represented by a "hachured" brown line

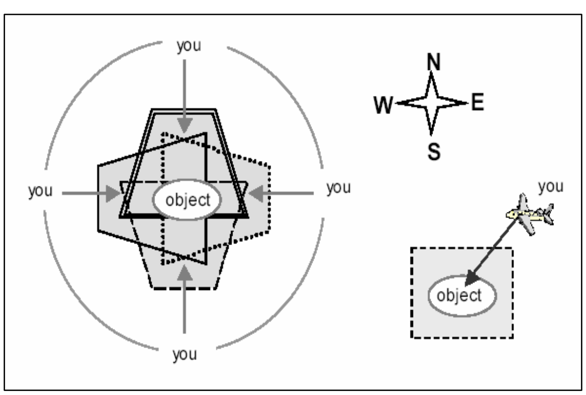


Sample USGS topographic map with contour lines. Screenshot of sample 2'elevation contours.

Elevation contours will be generated at 2' and 4' intervals for the LAR-IAC Project.

Introduction to Oblique Imagery

Oblique aerial imaging is not new. What is new to the world of GIS is taking digital oblique images and providing georeferenced data for each and every pixel contained in the image. For non-traditional GIS users, oblique aerial imagery provides an easier and quicker method to understand image features and location details compared to orthophotos. Oblique imagery is typically taken at a 40-45 degree angle versus the straight down (orthogonal) view, giving it a higher visualization value with a natural perspective, than the latter. Moreover, it is complementary to the ortho imagery.

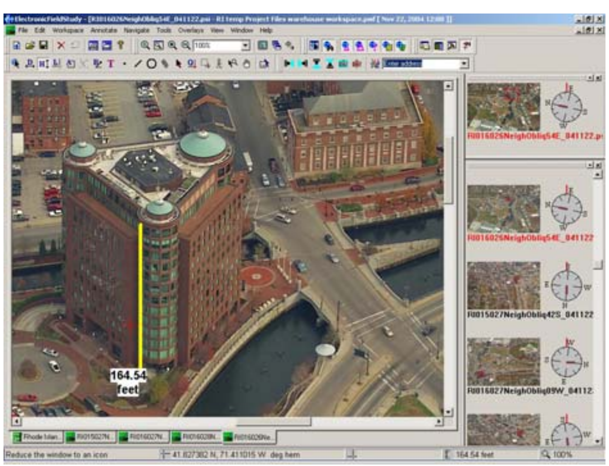


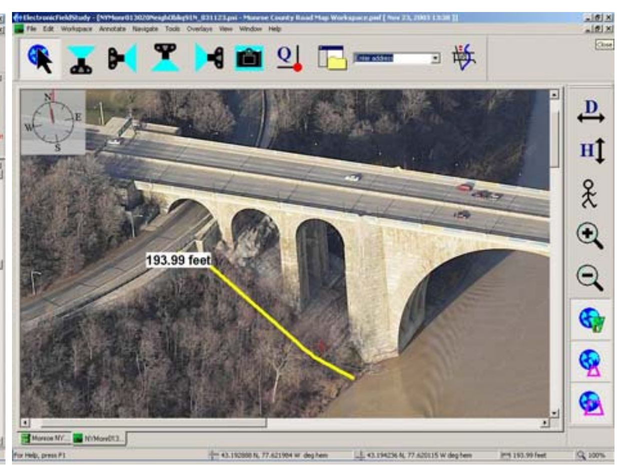
Left: Diagram of oblique views and image trapezoids.

LAR-IAC's oblique imagery shots are taken looking to the North, South, East or West with two different shot types. Community shots are taken from approximately 4,500 feet. There are 26,000 community shots for Los Angeles County at an average resolution (GSD) of 1 foot per pixel. Neighborhood shots are taken at approximately 3,500 feet, resulting in 278,000 neighborhood shots for the County. These shots have an average resolution (GSD) of 5 inches per pixel.

Pictometry International Corp is the provider of LAR-IAC's oblique imaging datasets. The company's patented imaging capture technology provides oblique visual imagery of counties and states that is combined with a direct – georegistration methodology that embeds positional data for each and every pixel in each and every image. Using Pictometry's software (Electronic Field Study) that is included with the imagery, LAR-IAC users can obtain a variety of measurements as well as utilize their GIS data on up to twenty different oblique views of every square foot in LA County. The end result is another resource for gathering GIS and support data for improved decision making capabilities.

Above left: Traditional style orthophoto. Above right: Pictometry oblique aerial photo.

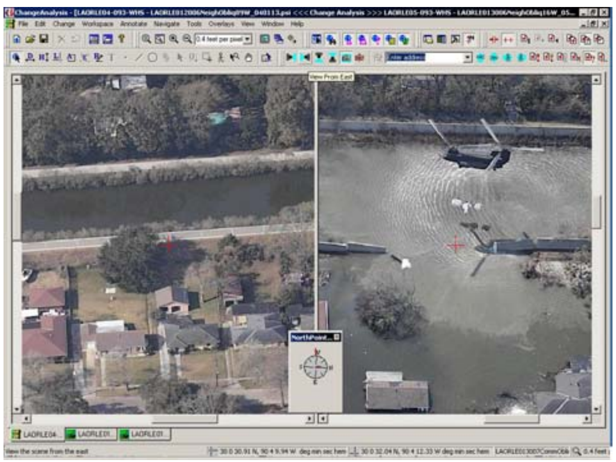


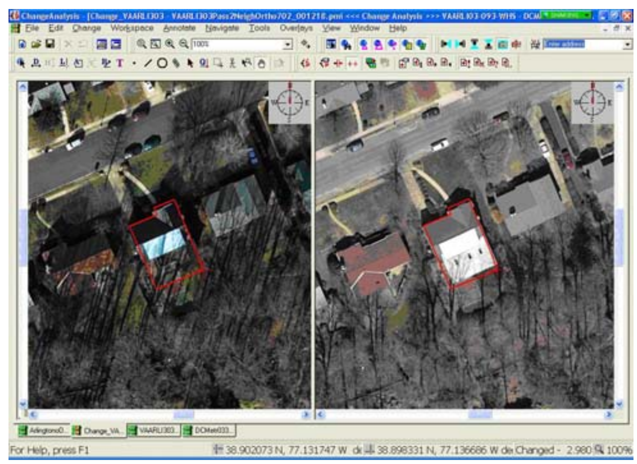


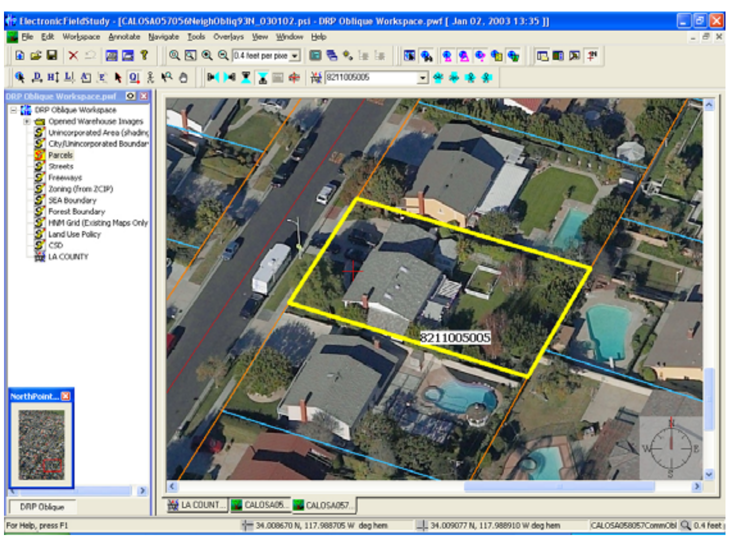
Above left: Pictometry oblique image in EFS software with height measurement tool activated.
Above right: Pictometry oblique image in EFS touch screen software mode with distance measurement with ground following tool activated.

Beyond traditional applications of GIS in land use planning, public works, engineering, transportation, and property assessment, Pictometry® oblique imagery has found significant usage in the areas of homeland security and public safety. The technology has been used in a number of high profile situations that include the Pentagon on September 11 by the Arlington Fire Department, in the capture process of fugitive Brian Nichols (Atlanta Courthouse shooting suspect) by the Gwinnett County (GA) SWAT unit, in the aftermath of natural disasters such as Hurricane Katrina, and is now taught at the United States Fire Academy. The company has partnered with over twenty 9-1-1 dispatching technology providers for improved responses at leading 9-1-1 centers across the county. By using the coordinate data contained in the images, 9-1-1 centers have utilized the high-resolution oblique images to help quickly find calls for service in situations where timing was critical in hard to find locations.

Additional enhancements offered by Pictometry include touch screen software for mobile deployment, a rapid response program for disasters (before and after imagery), Pictometry Change Analysis™, Pictometry ChangeFindr[1], and the Pictometry Extension for ArcGIS®.







Above left: Pictometry Change Analysis software comparing before and after image of levee break in News Orleans from Hurricane Katrina

Above right: Pictometry ChangeFindr image that combines Hitachi HouseDiff service with Pictometry's Change Analysis software for detecting and confirming changes

Left: Screenshot image from Electronic Field Study software showing oblique imagery and GIS shapefiles overlaid.

[1] ChangeFindr is the only product mentioned here that is not part of the LAR-IAC deliverables. If a participant would like this product they would need to contact Pictometry directly.

Project Deliverables

The LAR-IAC Project consists of digital imagery and elevation products in various delivery formats. The LAR-IAC Technical Advisory Group (TAG) made every effort to consider and include as many products and delivery formats as possible. While not every format is included, the final products can be converted to other formats, if necessary. The following is a description of all LAR-IAC Project Deliverables:

Digital Orthophotography, Digital Terrain Datasets, Oblique Imagery and Viewers

After the quality assurance team receives reviews and accepts all of the ortho and terrain data products delivered by Infotech for each delivery area, the data is finalized onto one of the two LAR-IAC Snapservers located on-site at Pinnacle. The full countywide delivery of oblique imagery, software and support data is also delivered to Pinnacle by Pictometry for creation of the Spatially-Limited Dataset (SLDS) deliveries of all project data products to the various LAR-IAC Project participants. The final SLDS datasets will be delivered on USB2/Firewire drives if one is provided by the participant, or the data is delivered on DVD+R media supplied by LAR-IAC. The DVD's are single sided with a data capacity of 4.7 GB (4.0 usable), although each disk delivered may not be completely filled with data.

The delivery extents for each SLDS are defined by two (and sometimes three) shapefiles developed and provided by LAR-IAC for each of the project participants. One shapefile defines the 4-inch (urban) ortho and terrain product delivery boundary, and the other defines the Pictometry (oblique product) delivery boundary. The third shapefile defines the 1-foot (national forest) ortho and terrain product boundary (when applicable).

LAR-IAC Project Deliverables (each described below):

There are five (5) main products (now called deliverables) for the LAR-IAC and over sixteen (16) data formats. The main products include:

Deliverable 1 - Color Orthogonal Imagery, 4" resolution (urban areas) and 1' resolution (national forests), 1' resolution for urban areas (for Web/public consumption).

Deliverable 2 - Color Infrared Imagery (CIR), 4" resolution (urban areas) and 1' resolution (national forests).

Deliverable 3 - Digital Terrain Datasets (DTM, DSM and DEM) – based on LiDAR (for urban areas) and from stereo compilation for national forest areas.

Deliverable 4 - 2' Elevation Contours GIS layer derived from the DTM (urban areas) and 4' contours (national forests).

Deliverable 5 - Color Oblique Aerial Digital Imagery (with viewer application and other integration software).

Data Formats

Infotech will translate or transfer the digital data from the original system specific format to the final and required output format. The softcopy photogrammetric data collection software of choice is Bentley Microstation which allows direct translation to Autodesk AutoCAD Map 5 (ACAD2000) dwg format and ESRI ArcGIS format. Pictometry will provide their oblique imagery library, software and supporting materials. Their oblique imagery format is a propriety JPEG format. The formats listed below for the listed deliverables are for graphic display only and do not contain any written reports.

Delivery Product	Format 1	Format 2	Format 3
Orthophoto - RGB Orthophoto – CIR	GeoTIFF GeoTIFF	JPEG 2000 JPEG 2000	
Digital Surface Model *	ASCII - points	ArcGIS shapefile - points	Microstation (dgn) - points , lines
Digital Terrain Model **	ArcGIS shapefile - points, 3D lines	AutoCAD (dwg) – points , lines	Microstation (dgn) – points , lines
Digital Elevation Model ***	ArcGIS raster	AutoCAD (dwg)	
2' and 4' Elevation Contours	ArcGIS shapefile	AutoCAD (dwg)	
Oblique images	Proprietary JPEG		

* *Digital Surface Model- contains the mass points (from LIDAR or photogrammetric compilation) and breaklines to generate subsequent elevation products*
** *Digital Terrain Model represents the bare earth terrain including the breaklines*
*** *Digital Elevation Model represents the bare earth in grid format*

Reports and support data:

Ground Control:	ESRI ArcGIS shapefile with attributes ASCII point file listing Report
Tile Grid	ESRI ArcGIS shapefile
Block Adjustment	ESRI ArcGIS shapefile Report

Each participant will receive all delivery formats for the area agreed upon prior to joining the LAR-IAC (provided in their letter of support with the County). For most entities this is their jurisdiction or coverage area along with a buffer area. All products are delivered in the State Plane Coordinate System, NAD83, California, Zone V, U.S. Survey Feet (0405).

Deliverable 1 – Natural Color Orthophotos

1. Four-inch pixel resolution natural color ortho imagery coverage of the urban project area and Catalina Island (Area 1 and Area 3) at a 1" = 100' map scale.
2. One-foot pixel resolution ortho imagery coverage of National Forest area (Area 2) at a 1" = 200' map scale.
3. One-foot pixel resolution ortho imagery coverage of the urban project area and Catalina Island (Area 1 and Area 3) at a 1"=200' map scale (reprocessed from 4" pixel resolution imagery).
4. Imagery to be delivered as GeoTIFF files (uncompressed) corresponding to each ortho tile in the supplied tile grid. Imagery also to be delivered as JPEG2000 (compressed) format for each tile (except for the reprocessed imagery listed in item 3 above which will only be delivered as GeoTIFF files).

Deliverable 2 - Color Infrared Imagery (CIR)

1. Four-inch pixel resolution color infrared (CIR) ortho imagery coverage of the urban project area and Catalina Island (Area 1 and Area 3) at a 1" = 100' map scale.
2. One-foot pixel resolution color infrared (CIR) ortho imagery coverage of the national forest areas (Area 2) at a 1" = 200' map scale.
3. Imagery to be delivered as GeoTIFF files (uncompressed) corresponding to each ortho tile in the supplied tile grid. Imagery also to be delivered as JPEG2000 (compressed) format for each tile.

Deliverable 3 - Digital Terrain Datasets (DTM, DSM and DEM)

1. Digital Terrain Datasets from LiDAR (DSM, DTM and DEM[2]) to support contour generation for the urban project area and Catalina Island (Area 1 and Area 3).
2. Digital Terrain Datasets from stereo compilation to support contour generation for the national forest areas (Area 2)

Deliverable 4 - Elevation Contours

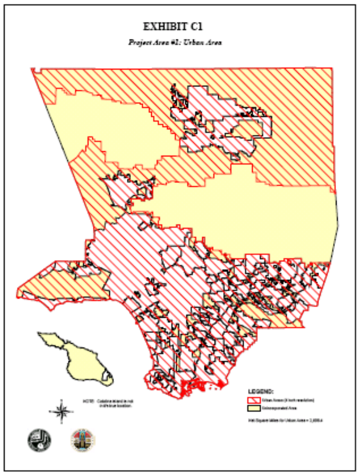
1. 2-foot elevation contours derived from DTM for urban project areas and Catalina Island (Area 1 and Area 3)
2. 4-foot elevation contours (at 5-foot accuracy) derived from DTM for the national forest areas (Area 2).

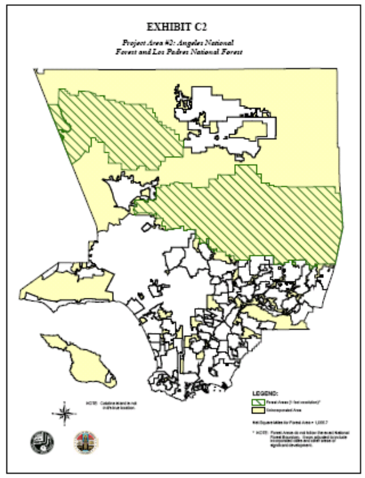
Deliverable 5 - Color Oblique Aerial Digital Imagery

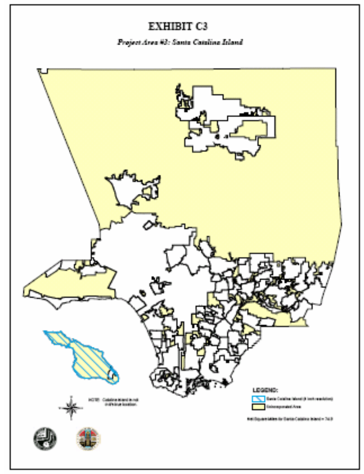
1. 946 Sectors of Community 2-Way Images covering 946 square miles of the County (roughly Area 2)
2. 3,162 Sectors of Neighborhood 4-Way Images covering (Area 1 and Area 3)
3. 3,162 Sectors of Community 4-Way covering the 3,162 square miles of the County (Area 1 and Area 3). Each sector will have four Oblique Images collected, one from each direction (N, S, E & W).
4. Shapefiles representing the oblique footprint of each image trapezoid in California State Plane Coordinate System, Zone V, NAD 83, and U.S. Survey Feet.
5. Oblique imagery is a proprietary image trailer tacked onto industry standard image format. May be exported to a number of formats. County DTM with up to 1.7m spacing will be included in image trailer.

[2] *DSM – Digital Surface Model; DTM – Digital Terrain Model; DEM – Digital Elevation Model.*

Maps of Project Areas







Area 1 – urban areas, Area 2 – national forests, Area 3 – Catalina Island.

Other Deliverables

1. Federal Geographic Data Committee (FGDC) compliant metadata.
2. Geodetic control network for ground control points used for AT solution.
3. Oblique imagery software from Pictometry
   - Electronic Field Study (EFS)
   - Configuration Editor
   - ArcGIS Extension
   - Change Analysis
   - ActiveX control for integrating with other applications (upon request)

Deliverable Review & Acceptance Criteria

All products from the LAR-IAC Project underwent rigorous quality assurance and quality control (QA/QC) procedures. The following documents the review and acceptance criteria:

Acceptance Criteria for the Los Angeles Region Image Acquisition Consortium (LAR-IAC) - Prepared: December 2005

	Tested Characteristic	Measure of Acceptability
A	**All Scales Natural Color and Near Infrared Digital Orthoimagery (100-Scale, 200-Scale)**	
A.1.	Media: DVD 2.0, 4.7 GB single sided (4.3 GB usable), snap server with 2 TB	Media is readable, all files accessible, no files corrupted
A.2.	Media label	As specified by L.A. County
A.3.	File organization	Files written in tile sheet order
A.4.	File name	Conforms to required convention- based on CA SPCS Zone 5 xxxx_yyyya for 4 inch and xxxx_yyyy for 1 foot orthos

A.5.	GeoTIFF format	File reads in ESRI (see sample of Geotiff header)
A.6.	Files must open in correct location	Files must open with ESRI software
A.7.	Pixel definition	File must reference to the center of the pixel located in the upper left hand corner of the tile as the point of origin.
A.8.	Georeferencing	for correct pixel size 0.33 ft (4 inch) and 1 ft.
A.9.	Vertical Datum	NAVD88
A.10.	Projection	NAD 1983 State Plane – California Zone V
A.11.	Datum	NAD 83 reference datum
A.12.	Units	U.S. Survey Feet
A.13.	24 bit natural color	256 levels of value for each band, 0=black, 255=white
A.14.	Tonal quality	< 2 percent of values at 0 or 255, to the extent possible per client's radiometry choices
A.15	DMC sensor anomalies	N/A
A.16.	Conformance of tile index grid	tile matches grid, no gaps between tiles at 1:1 view.
A.17.	Image Appearance	The difference in average pixel values on either side of a mosaic seam-line should generally not exceed 70 (30 preferred), when measured on a homogeneous surface with similar characteristics (water surfaces are exempt from this requirement). Greater differences may be allowed if the correction will cause significant degradation of the image content on either side. No image will be rejected for such radiometry inconsistencies without prior approval of L.A. County. Image acquisition should be obtained with acceptable weather conditions per ASPRS standards.
A.18.	Radiometry	Radiometry should be consistent throughout the imagery, on large and small scales. Mosaic seamlines should not produce great visual (tonal, brightness) differences in imagery on either side (water being exempt from this requirement). In some instances, greater differences may be allowed if the correction will cause significant degradation of the image content on either side. Color balancing between tiles should be as consistent as possible. Radiometry target chips will be reviewed and approved by the LAR-IAC prior to orthoimagery production. The chips will provide a guide and expectation of final imagery appearance.
A.19.	Smears	Normally corrected by adding mass points or breaklines to DEM/DSM as necessary to reflect actual terrain or by image processing where appropriate. Where DSM/DEM corrections or image processing will result in reduced horizontal accuracy or misrepresentation of the location or appearance of important features (buildings, roads, etc.), the smear will remain untreated. No image will be rejected for smears without prior approval of L.A. County.
A.20.	Wavy features	Distinct linear ground features (such as road markings, and curbs) should not deviate from their

		apparent path by more than 3 feet measured perpendicular to the feature within any 100 foot distance measured along the feature length.
A.21.	Mosaic lines	No mosaic lines through buildings. No mosaic lines through above ground transportation structures carrying automobiles or trains unless unavoidable.
A.22.	Metadata	Complies with standard (to be determined by L.A. County). Meets minimum FGDC Content Standard.
A.23.	Building lean within Downtown areas (polygons provided by LA County)	The maximum displacement of a 10 story building at the edge of a model will be 16 feet (approximately 1.6 feet per story)
A.24.	Bridges	Accuracy of multi-layered bridge decks identified by L.A. County. 3D breaklines required to ensure continuity of deck surfaces
A.25.	Coverage	At least 500’ beyond LAR-IAC boundary
A.26.	Tile grid layout	At least 500’ buffer around LAR-IAC boundary

B	**1-foot GSD, equivalent to 1”=200’-scale (1:2400)**	
B.1.	Ground Resolution	1 foot
B.2.	Tile size	5280’ x 5280’
B.3.	RMSE of QA/QC points measured on the image *See ASPRS Class I Standards Page 8, Table 16, and NSSDA Part 3, Appendices 3-A and 3-D for explanation of formulas.*	$RMSE_x = RMSE_y = 2'$ (2 pixels) or $RMSE_r = 1.4142 * RMSE_x = 2.83'$
B.4.	NSSDA radial accuracy	NSSDA accuracy (95% confidence level) such that $1.7308 * RMSE_r < 5$ft
B.5.	Mismatch of features along mosaic lines and production block boundaries of equal scale	Equal to or less than 3 pixels on well defined ground features (roads, sidewalks, curbs).
C	**4 inch GSD, equivalent to 1”=100’-scale (1:1200)**	
C.1.	Ground Resolution	0.33 U.S. survey foot (2 decimals)
C.2.	Tile size	2640’ x 2640’ (8000 pixels x 8000 pixels)
C.3.	RMSE of known ground points measured on the image *See ASPRS Class I Standards Page 8, Table 16, and NSSDA Part 3, Appendices 3-A and 3-D for explanation of formulas.*	$RMSE_x = RMSE_y = 1.0$-ft $RMSE_{r=} = 1.4142 * RMSE_x = 1.4142 * RMSE_y = 1.41$-ft
C.4.	NSSDA radial accuracy	NSSDA accuracy (20+ points) such that $1.73 * RMSE_r < 2.5'$
C.5.	Mismatch of features along mosaic lines between pixel resolution blocks of equal scale	Equal to or less than 4 pixels on well defined ground features (roads, sidewalks, curbs).
C.6.	Mismatch of features between 1-foot and 4-inch images	Equal to or less than 3 pixels (1 ft) on well defined ground features (roads, sidewalks, curbs).

Aerotriangulation (AT) Acceptance Criteria

D	Tested Characteristic	Measure of Acceptability
D.1.	Report Format	Conforms to required convention
D.2.	Report Completeness	All information complete and readable
D.3.	PATB readable	Conforms to PATB output file for model setting.
D.4.	1"=100' map scale AT Horizontal accuracy against ground control	For 100' AT blocks, $RMSE_x$ and $RMSE_y$ values are acceptable up to 0.35'. $RMSE_r$ is acceptable up to 0.5'. Higher RMSE values are subject to review.
D.5.	1'=200' map scale AT Horizontal accuracy against ground control	For 200' AT blocks, $RMSE_x$ and $RMSE_y$ values are acceptable up to 0.6'. $RMSE_r$ is acceptable up to 0.84'. Higher RMSE values are subject to review.
D.6.	RMSE of control and tie points.	<10 micron. Higher RMSE values are subject to review.
D.7.	RMSE of survey check points	Not to exceed 12 micron
D.8	NSSDA analysis [E, N] of 20+ QA points	95% within 1.73 * RMSE for corresponding scale

Ground Control Acceptance Criteria

E	Tested Characteristic	Measure of Acceptability
E.1.	Report Format	Conforms to required convention
E.2.	Report Completeness	All information complete and readable
E.3.	Approval	CA Licensed Surveyor Signature and Seal
E.4.	Monument Record Form	Sufficient information to revisit point, description and picture
E.5.	Network	Meet NOAA specifications for Order and Class
E.6.	Geodetic Survey: Horizontal Accuracy	Second Order Class 1 tied to NGS monuments.
E.7.	Geodetic Survey: Vertical Accuracy	Third Order.
E.8.	Coordinate System	California Coordinate System of 1983, Zone 5,
E.9	Epoch	Epoch date: 2004.0

Digital Surface Model QA Acceptance Criteria (suitable only for orthorectification)

F	Tested Characteristic All Scales	Measure of Acceptability
F.1.	Media: DVD 2.0, 4.7 GB single sided (4.3 GB usable), snap server with 2 TB	Media is readable, all files accessible, no files corrupted
F.2.	File organization	Files written one per ortho tile delivered. Size TBD
F.3.	File name	Conforms to required convention
F.4.	Format	ArcGIS raster
F.5.	Format	Microstation .dgn Version V8.
F.6.	Georeferencing	Locates in proper tile grid cell
F.7.	Mass point locations	Mass points sufficient to accurately build terrain to support orthophotos;
F.8.	Breakline locations	Breaklines as needed to control bridges, edge of pavement, hydrographic features, ridgelines, retaining walls as needed for orthorectification, none in open water.
F.9.	Continuity	No spikes, holes or blunders; no gaps of sufficient

		size to affect orthorectification, regardless of perspective center.
F.10.	Breakline Format	Microstation .dgn V8

Horizontal QA/QC Point Acceptance Criteria

G	Tested Characteristic All Scales	Measure of Acceptability
G.1.	Visibility on digital imagery	QA/QC checkpoints must be clearly photo-identifiable on images at map scales evaluated (4-inch and 1-foot orthos)
G.2.	Well defined	Points must be clearly visible and not elevated (no fence posts, fire hydrants, etc.) that cast shadows
G.3.	Documentation	Each point is documented to describe the photo-identifiable feature surveyed
G.4.	Terrestrial images	Each point is photographed from the ground to help in photo-identification
G.5.	Survey accuracy and description of survey procedure used	Accuracy estimate, to include description of survey procedures used to achieve such accuracy

Coordinate System and Datum for LAR-IAC Project Data

All LAR-IAC Project deliverables (except oblique aerial digital imagery) are projected in the State Plane Coordinate System, NAD 83, CA Zone V, US Survey Feet (0405).

Horizontal and Vertical Positional Accuracy

Horizontal Accuracy – For Orthophotos

LAR-IAC's 4" digital orthophotos were tested in accordance with the 4 inch GSD Acceptance Criteria listed above. The "georeferenced ground positions of higher accuracy," referred to generically as "QA/QC checkpoints," were provided by LAR-IAC from multiple sources. The National Standard for Spatial Data Accuracy (NSSDA) absolute accuracy statistic ($Accuracy_r$) is computed as $RMSE_r$ x 1.7308 in order to report the tested horizontal accuracy at the 95% confidence level as required by FGDC Geospatial Positioning Accuracy Standards, Part 3: NSSDA. The 4" digital orthophotos were tested with **1.500 feet horizontal accuracy at 95% confidence level.**

Vertical Accuracy – For LiDAR

The accuracy assessment for LAR-IAC was performed in accordance with the two methods now used by the LiDAR industry. The original method based on the NSSDA and the Federal Emergency Management Agency (FEMA) assumes all errors follow a normal error distribution, and the newer method based on the National Digital Elevation Program (NDEP) and the American Society for Photogrammetry and Remote Sensing (ASPRS) assumes that LiDAR errors in some land cover categories may not follow a normal error distribution. Based on NSSDA and FEMA methodology LiDAR was tested with 0.82 ft vertical accuracy at 95% confidence level (Consolidated $RMSE_z$ x 1.9600). Based on NDEP and ASPRS methodology, LiDAR was tested with **0.91 ft vertical accuracy at 95% confidence level** (Consolidated Vertical Accuracy). These values easily satisfy the 1.19 ft vertical accuracy standard required for digital elevation data to support the generation of 2 ft contours.

Bare-Earth LiDAR Acceptance Criteria

H	Tested Characteristic All Scales	Measure of Acceptability
H.1.	Point spacing	Max. 11 feet on all raw random collected points,
H.2.	Vertical accuracy	Lidar mass points equivalent to 2 ft contours: $RMSE_z$ = 18.5 cm (0.607 ft) $Accuracy_z$ = 36.3 cm (1.190 ft) at 95% confidence level
H.3.	Satisfy FEMA testing requirements in land cover categories: • Open terrain (sand, rock, dirt) • Tall weeds and crops • Scrub and bushes • Forested • Build-up areas	• Fundamental Vertical Accuracy must equal 1.190 ft or better at the 95% confidence level, based on $RMSE_z$ x 1.9600 for checkpoints in open terrain only • Supplemental Vertical Accuracy in each land cover category should equal 1.190 ft at the 95% confidence level based on the 95th percentile errors for each category. This is desirable but not mandatory. • Consolidated Vertical Accuracy in all land cover categories combined must equal 1.190 ft at the 95% confidence level based on the 95th percentile errors for all categories combined.
H.4.	Qualitative criteria	Post-processed to remove structures and vegetation with minimum residual artifacts (this is somewhat subjective)
H.5.	QC Checkpoints	Minimum of 20 QC points for each of the five land cover categories, i.e., 100 total minimum
H.6.	QC checkpoint survey accuracy and description of survey procedure used	Surveyed to NGS-58 procedures for 5-cm. Checkpoints located per guidance specified by FEMA and ASPRS.
H.7.	Data type and datum	NAVD88 orthometric heights
H.8.	Coordinate System	California Coordinate System of 1983, Zone 5,
H.9.	Epoch	Epoch 2004
H.10.	File format	ArcGIS raster, Microstation dgn V8
H.11.	File organization	Files written one per ortho tile delivered
H.12.	File name	Conforms to required tile naming convention

2 foot Contours QA Acceptance Criteria

I	Tested Characteristic	Measure of Acceptability
I.1.	Media: DVD 2.0, 4.7 GB single sided (4.3 GB usable), snap server with 2 TB	Media is readable, all files accessible, no files corrupted
I.2.	File organization	Files written one per ortho tile delivered
I.3.	File name	Conforms to required convention
I.4.	File size	2640’ x 2640’
I.5.	Format	ESRI ArcGIS shapefile
I.6.	Format	ACAD 2000
I.7.	Georeferencing	Locates in proper tile grid cell
I.8.	Appearance / smoothing	Contour lines should be “smooth enough” to avoid confusion. Contours should not cross other contours, touch them, or be within 0.003” of adjoining contours.
I.9	Continuity	Continuous, no voids or gaps
I.10	Roads	Edge of pavement breaklines should be used to generate road surface polygons and remove LiDAR points on paved roads so contours cross generally straight across roads. Contours can curve slightly when crossing roads but should not reverse directions because of LiDAR “noise.”
I.11	Bridges and overpasses	“Cut” bridges and overpasses to depict narrowly-spaced contours near abutments
I.12	Drainage	Breaklines should define center of single-line drains; shorelines of double-line drains with LiDAR points removed within so contours cross generally straight across rivers. Lakes/reservoirs should be flat.
I.13	Buildings	Contours should represent topographic surface as though buildings are not there.
I.14	Temporary Conditions	Depression contours should not be captured for temporary holes caused by ongoing construction. Similarly, contours should not be captured for temporary piles of sand, construction materials, coal at electrical power plants, etc. Depression contours are appropriate for permanent depressions such as quarries.
I.15	Accuracy	Meet ASPRS accuracy for 2 foot contours for which RMSEz = 0.6 ft (18.5 cm). Testing will be based on LiDAR data used for contours.

4 foot Contours QA Acceptance Criteria

J	Tested Characteristic All Scales	Measure of Acceptability
J.1.	Media: DVD 2.0, 4.7 GB single sided (4.3 GB usable), snap server with 2 TB	Media is readable, all files accessible, no files corrupted
J.2.	File organization	Files written one per ortho tile delivered
J.3	Tile name	Conforms to required convention
J.4.	Tile size	5280' x 5280'
J.5.	Format	ESRI ArcGIS shapefile
J.6.	Format	ACAD 2000 .dwg
J.7.	Georeferencing	Locates in proper tile grid cell
J.8.	Appearance / smoothing	Contour lines should be "smooth enough" to avoid confusion. Contours should not cross other contours, touch them, or be within 0.003" of adjoining contours.
J.9	Continuity	Continuous, no voids or gaps
J.10	Roads	Edge of pavement breaklines should be used to generate road surface polygons and remove LiDAR points on paved roads so contours cross generally straight across roads. Contours can curve slightly when crossing roads but should not reverse directions because of LiDAR "noise."
J.11	Bridges and overpasses	"Cut" bridges and overpasses to depict narrowly-spaced contours near abutments
J.12	Drainage	Breaklines should define center of single-line drains; shorelines of double-line drains with LiDAR points removed within so contours cross generally straight across rivers. Lakes/reservoirs should be flat.
J.13	Buildings	Contours should represent topographic surface as though buildings are not there.
J.14	Temporary Conditions	Depression contours should not be captured for temporary holes caused by ongoing construction. Similarly, contours should not be captured for temporary piles of sand, construction materials, coal at electrical power plants, etc. Depression contours are appropriate for permanent depressions such as quarries.
J.15	Accuracy	Meet ASPRS accuracy for 2 foot contours for which RMSEz = 0.6 ft (18.5 cm). Testing will be based on LiDAR data used for contours.

Horizontal and Vertical Positional Accuracy - For Oblique Imagery

The *georeferenced ground positions of higher accuracy*, referred to generically as *QA/QC checkpoints*, were provided by LAR-IAC from multiple sources. Most checkpoints were X's painted on asphalt and accurately surveyed as control points, used as *target points* by photogrammetric firms for aerial triangulation. Because these checkpoints are accurate, well-defined and photo-identifiable on the airborne oblique imagery, Dewberry measured the x-, y- and z-coordinates on these checkpoints on each of the 4-view Pictometry images, where visible, to compute errors in Eastings (Δx), errors in Northings (Δy), and errors in elevations (Δz). For each checkpoint, Dewberry also averaged the Eastings, Northings and elevations for all views that were visible; for many, the average resulted from four views, but some points were obscured by buildings, trees, cars, etc., so the average resulted from the mean of three, two, and (in a few cases) only one view.

When coordinates were averaged from north-view, south-view, east-view, and west-view images, the averaged coordinates were normally more accurate than coordinates from individual views, as summarized with the following accuracy statements:

Accuracy of clearly-defined surveyed targets on Pictometry 4-view images with coordinates averaged from all views in which targets were visible and could be measured:

> **All-view averaged coordinates tested 5.04 ft horizontal accuracy at 95% confidence level**
>
> **All-view averaged coordinates tested 2.47 ft vertical accuracy at 95% confidence level.**

These results are well within contract specifications for oblique imagery for the LAR-IAC Project.

Operating Options

The LAR-IAC Project is mainly about data products but it is important to note how the data can be viewed and what special software is included or can be used.

Hardware

System requirements for use of the LAR-IAC Project data will generally be the same as required by the software used to view or access the data.

All data for each county deliverable are provided on external hard drives or DVD's (snap servers for full countywide participants). The data can be loaded on hard disk or accessed from the DVD using a DVD+R reader. The DVD's are single sided with a data capacity of 4.7 GB (4.3 usable), although each disk delivered may not be completely filled with data. The orthophotography files are large and the amounts of time required to access or copy these files from the media depends on the speed of the DVD reader, the faster the reader the better.

Additional hard disk space (internal or external hard drive) may be required to store or back-up the LAR-IAC Project data. This will depend on the capacity of the system on which the data is being loaded and user preferences. External hard disks, which use one of the new fast "firewire" or USB 2.0" connectors may require an adapter card to work with the existing system.

Software

Orthophotography from the LAR-IAC Project can be viewed using any software that can read and display the TIFF or JPEG2000 file format. The TIFF v6 format is widely used and software that supports this file format can generally be grouped into two categories; image viewers and GIS software.

Raster Image Viewing Software
Image viewing software will display raster images like the LAR-IAC Project deliverables. The images can generally only be viewed one tile at a time. With viewer software images do not have any geo-referencing. Therefore, any measurements made on the photo are reported in photo units rather than in ground units.

"Imaging for Windows" by Kodak which comes by default with the Windows2000 operating system is an example of image viewing software. Additional information on TIFF viewers can be found at http://hazmat.dot.fov/ntsb/ntsb_viewer_help.htm.

Oblique Imagery Viewer Software
This software is provided from the vendor that produced the oblique aerial digital imagery, Pictometry International, Corp. The software is called EFS (Electronic Field Study) and can be integrated with GIS data layers.

Electronic Field Study™ (EFS) –
EFS maps each pixel in each image to its actual geographic coordinates. Then using the *Intelligent Images*® tool set, the following can be done:

Measuring tools for distance, height, areas, location, elevation and bearings
Other tools for selection, drawing, annotation, navigation, search and zoom

EFS can display shapefiles on top of oblique imagery. In addition, EFS can export locations and measurements into a tab delineated text file or shapefile that can then be imported into GIS. EFS can also export orthogonal images with corresponding coordinate mapping files for use with GIS.

ArcGIS Extension –
Pictometry's Extension for ArcGIS allows digital oblique imagery to be viewed and used inside a variety of ESRI products. The power of Pictometry oblique imagery combined with the power of GIS all within the ESRI operating environment opens many doors for GIS professionals. The Pictometry Extension is available for ArcGIS/ArcMap 9.X and ArcIMS.

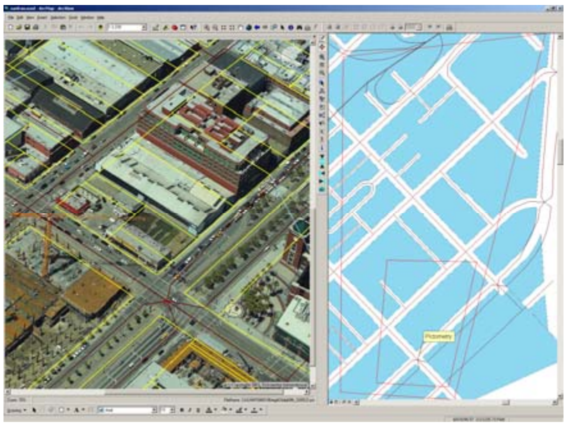
There are three primary Pictometry functions within the extension; View, Navigate, and Measure as well as ESRI-like GIS functions. Within those functions the following features exist:

View Controls: Image Tool, Zoom Control and Directional View Select (N, S, E, W, orthos and filters)
Navigate Controls: Pictometry Navigation Tool, Display Compass on Image, Display Location on Map, Location Tool, Rotate Map to Image and View Window on Map.

Pictometry's Measurement Capabilities (in ESRI software viewer):

Distance – straight line, perimeter, poly-line.
Area – Polygon, Freeform Area.
Height – measures heights of buildings and other vertical structures.
Façade – measures sides of buildings, windows, or entries/egresses.
Bearing – allows user to visualize directionality from true north.
Elevation – displays the ground elevation data of selected point.

GIS: Overlay GIS Features, Info Tool, Zoom Map to Image Footprint and Display Image Footprint on Map.



Above image: Screen capture of ArcMap software embedded with Pictometry software and oblique image with GIS layers

Pictometry Change Analysis™ –

Pictometry Change Analysis is an additional software feature from Pictometry that enables LAR-IAC users to simultaneously view and compare two sets of imagery; either ortho to ortho or oblique to oblique, and navigate in the images where both images will move together to view new areas for further inspection. Applications are many, as in comparing land use over time, reviewing impact of natural or other types of disasters, or monitoring individual parcel changes from one point in time to a newer image.

The above images illustrate a set of orthophotos (old image on the left, new image is in center) and both images together in Pictometry Change Analysis (right). The slider bar in the middle of the screen allows the user to scroll over each image to reveal changes.

ActiveX Control[3] - Integration allows for the connection of ArcIMS Web mapping sites to the oblique imagery library. This integration also allows for some basic tools such as measuring distances and areas, location, height and elevation. This tool will also allow for the draping of GIS vector data onto oblique imagery (similar to the EFS application).

CADD/GIS Applications
The orthophotography and DTM data from the LAR-IAC Project, can be readily opened and used by CADD (Computer Aided Design and Drafting) and almost all GIS software. One advantage of GIS software is that multiple files can be viewed at one time allowing for the assemblage and viewing of large areas.

This software also uses the geo-referencing embedded in the file header or an alternate world file (.tfw) to display orthophotography in its proper geographic location. TIFF world files are included on the orthoimagery DVD's for software that require separate world files. All locations and measurements on the photo or tile are therefore reported relative to their absolute location on the surface of the earth and measurements are reported in ground units.

Examples of software that can be used to work with the LAR-IAC Project data include:

- ArcGIS by ESRI (ArcView, ArcEditor or ArcInfo)
- ArcExplorer by ESRI, which can be downloaded free from its Web site at http://www.esri.com/software/arcexplorer/index.html
- AccuGlobe by DDTI, which can be downloaded free from their Web site at http://www.ddti.net
- Many other free and commercial GIS software applications exist; for more information on free GIS software, see http://software.geocomm.com/viewers/

LAR-IAC product deliverable Index Files (identifying the tile grid, etc.) are provided in ESRI shapefile format. ArcView, or the free ArcExplorer and AccuGlobe applications, and most other GIS software can read the index shapefiles included with the data.

Other LAR-IAC Project reports (Horizontal and Vertical Accuracy, Aerial Triangulation, Geodetic Control, etc.) are provided in Adobe Acrobat (.pdf) file format. Other miscellaneous data tables can be opened and used with a word processing and/or spreadsheet application like Microsoft Word or Microsoft Excel.

Accessing or Loading Data

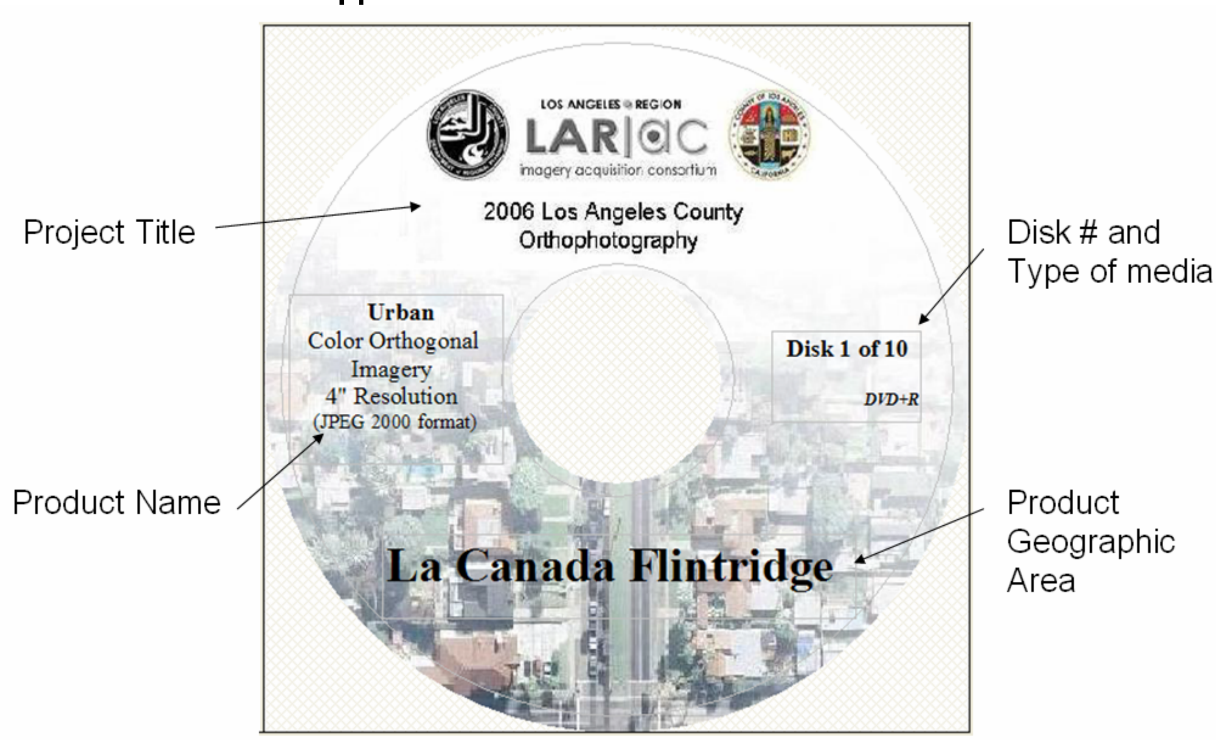
The following section refers to accessing and/or loading the LAR-IAC data. Most agencies are receiving their data on an external hard drive; there are directions from loading from DVDs as well.

[3] The ActiveX control is available for all LAR-IAC participants but the code will be provided by Pictometry directly. Please contact your Pictometry customer service representative if/when you decide to deploy the ActiveX control with your application.

Data Loading

The delivered LAR-IAC product data can be used directly from the delivered hard drives, but we strongly recommend that if the data is delivered on DVD+R media, you should load (copy) the data to a hard drive before using. We recommend you use the Windows XCOPY command or the ROBOCOPY software provided to load the data onto a hard drive. The directory structure of the data on the drive/disk is intended to help organize the data. It is strongly recommended (but not mandatory) that this directory structure be maintained.

DVD+R Media Appearance:



DVD+R Media Product Name (Labels):

Urban (Area 1 and Area 3)

1. Color Orthogonal Imagery
   - Color Orthogonal Imagery 4” resolution (GeoTIFF format)
   - Color Orthogonal Imagery 4” resolution (JPEG 2000 format)
   - Color Orthogonal Imagery 1’ resolution (GeoTIFF format)

2. Color Infrared Imagery
   - Color Infrared Imagery 4” resolution (GeoTIFF format)
   - Color Infrared Imagery 4” resolution (JPEG 2000 format)

3. Digital Terrain Datasets
   - Digital Terrain Data - Digital Surface Model (DSM)
   - Digital Terrain Data - Digital Terrain Model (DTM)
   - Digital Terrain Data - Digital Elevation Model (DEM)

4. Elevation Contours
   2' Elevation Contours

National Forest (Area 2)

1. Color Orthogonal Imagery
   Color Orthogonal Imagery 1' resolution (GeoTIFF format)
   Color Orthogonal Imagery 1' resolution (JPEG 2000 format)

2. Color Infrared Imagery
   Color Infrared Imagery (CIR) 1' resolution (GeoTIFF format)
   Color Infrared Imagery (CIR) 1' resolution (JPEG 2000 format)

3. Digital Terrain Datasets
   Digital Terrain Data - Digital Terrain Model (DTM)
   Digital Terrain Data - Digital Elevation Model (DEM)

4. Elevation Contours
   4' Elevation Contours

Pictometry

5. Color Oblique Aerial Digital Imagery
   Color Oblique Aerial Digital Imagery

Data Storage

The orthophotography was developed at one resolution and scale for the Los Angeles County urban areas, and a different resolution and scale for the national forest areas. All imagery of the same scale is organized and delivered as seamless tiles (files). There is 500' overlap (buffer area) between the 4" (urban) and 1' (national forest) imagery products. The size of the different imagery files are dependant on the resolution and format of the imagery product:

Area	Image Resolution	Imagery Map Scale	Tile Size (Feet / Pixels)	Approximate File Size
Urban	4-inch (GeoTIFF)	1" = 100'	2640' x 2640' 8000 x 8000	190 MB
Urban	4-inch (JPEG 2000)	1" = 100'	2640' x 2640' 8000 x 8000	9 MB
Urban	4-inch resampled to1-foot (GeoTIFF)	1" = 100'	2640' x 2640' 2640 x 2640	20 MB
National Forest	1-foot (GeoTIFF)	1" = 200'	5280' x 5280' 5280 x 5280	80 MB
National Forest	1-foot (JPEG 2000)	1" = 200'	5280' x 5280' 5280 x 5280	4 MB

2006 LAR-IAC Data Products Folder Structure

The following folder hierarchy details the folder structure for the LAR-IAC Project "2006 Imagery Products".

Folder Structure:

```
Drive:\
└───LAR-IAC_2006*
    ├───NAME OF GEOGRAPHIC AREA**
    │   ├───Contours
    │   │   ├───DWG
    │   │   └───SHP
    │   ├───Elevation
    │   │   ├───DEM
    │   │   │   ├───GRD
    │   │   │   └───DWG
    │   │   ├───DSM
    │   │   │   ├───DGN
    │   │   │   ├───ASCII
    │   │   │   └───SHP
    │   │   └───DTM
    │   │       ├───DWG
    │   │       ├───DGN
    │   │       └───SHP
    │   ├───Ortho_1foot
    │   │   ├───RGB_TIF
    │   │   ├───RGB_JP2***
    │   │   ├───CIR_TIF***
    │   │   └───CIR_JP2***
    │   ├───Ortho_4inch
    │   │   ├───RGB_TIF
    │   │   ├───RGB_JP2
    │   │   ├───CIR_TIF
    │   │   └───CIR_JP2
    ├───Documentation
    │   ├───AT_Reports
    │   ├───Directory_Listings
    │   ├───Geodetic_Control_Data
    │   ├───Metadata
    │   ├───Shapefiles
    │   └───Software
    └───Pictometry****
        ├───Additional Materials
        │   ├───Handouts
        │   ├───HowTos
        │   └───Presentations
        ├───CALOSA06-093-LIB
        │   ├───CALOSA06-AREANAME-WHS
        │   │   └───See Pictometry Section
        │   ├───Image Polygons
        │   └───Maps and GIS
        │       └───Shapefiles
        └───Software
            ├───ArcGIS Pictometry Viewer 1.2
            ├───Change_Analysis
            ├───EFS 2.6 R4.8
            ├───RoboCopy
            └───EFS Config Editor
```

NOTE:

***LAR-IAC_2006 –** The top most folder, LAR-IAC_2006 is located in the root directory of the hard drive or DVD media that is delivered.

****Name of Geographic Area –** This name will be the name of the LAR-IAC participant for each of the spatially-limited dataset deliveries e.g. Long Beach); or for the countywide dataset delivery it will be the Infotech delivery area/block designation (e.g. For the 4-inch product delivery areas: Area_1 through Area_24, and Catalina_Island. For the 1-foot product delivery areas: Block_1 and Block_2).

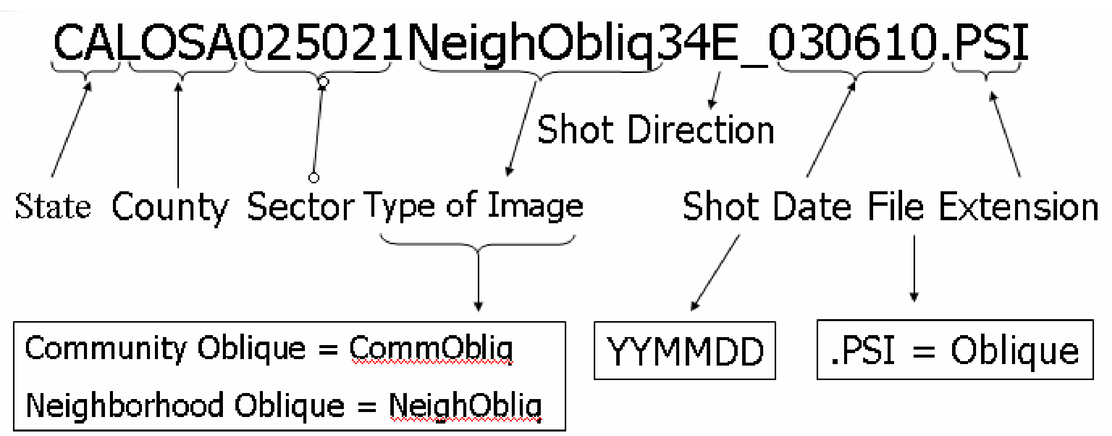
*****Ortho_1foot Products –** The `RGB_TIF` folder will exist in all 4-inch areas regardless whether the area includes part of the National Forest area. All 1-foot pixel resampled 4-inch tiles will be located here. The remaining three folders (`RGB_JP2, CIR_TIF`, `RGB, CIR_JP2`) will only exist in delivery areas that include part of the National Forest area.

******Pictometry –** This subfolder shown above is included in the delivery of the spatially-limited Pictometry datasets. (See the Oblique Imagery File Structure section below for additional details regarding the Pictometry folder and data structure).

Oblique Imagery File Structure

Pictometry Warehouse Naming Scheme

An Image warehouse consists of a series of folders that contain additional directories and/or geo-referenced images. These folders and directories are required to access the Electronic Field Study (EFS) program. Cluster folders and sector folders are the primary directories that make up the image warehouse structure. A Cluster represents a 25 square mile area of imagery. A Sector represents a one square mile area of imagery within the Cluster. In the physical structure of folders within the warehouse, sector folders are the lowest level of folders and consist of a single square mile of images.



Components to the Pictometry oblique imagery naming scheme.

Localityname Folder

The localityname folder is named after the state and county. This is the main folder that contains all the images of the area. The images of a sector are stored within each individual sectors folder. Sector folders are stored within each individual clusters folder (*see figure above*). Pictometry names this localityname folder according to the state or county name, the year imagery was initially captured, image size capacity followed by the warehouse abbreviation, WHS. Your warehouse name would be identified **similar to "CALOSA06-093-WHS".**

Cluster Folder

The next folder level down from the localityname folder are cluster folders. Each cluster folder contains up to 25 sector folders, for a total of 25 square miles. Each cluster folder is named after the NorthWest sector number of that cluster. The naming convention for Cluster folders use the two letter state abbreviation plus the first four-letters of the county name, followed by the sector number of the NorthWest (upper-left) sector of that specific cluster, followed by the word "cluster".
In your library, Northwest sector number 011016 (row 011, column 016) would be named as "CALOSA**011016 cluster".**

Sector Folder

Sector folders are the lowest level of folders. Each folder represents a single square mile of coverage and contains the imagery for that sector. These folders are the basic building blocks for any image warehouse. The sector folder naming convention uses the sector's number. Sectors are numbered by combining together a sectors row and a column number, both starting with 001 and starting with the Northwest sector of your area of coverage, 001001 (row 001, column 001). In addition to the row and column numeric format, the folder name also includes the two-letter state abbreviation plus the first four letters of the county name. A sector folder name for Los Angeles: row 035, and column 005 would be "CALOSA**035005".**

Maps and GIS Folder

This folder contains base maps, Pictometry workspace files and optional GIS data. Included in the LAR-IAC delivery are the following shapefiles:

City/unincorporated boundary (gplan_index_all.shp)
National forest boundary (gplan_forest.shp)
[[participant]] parcel boundary ([[participant]]_parcels.shp)
[[participant]] area boundary ([[participant]]_area_bdy.shp)

Pictometry Workspace Files

Workspace files consist of starter base maps (or GIS Image) of the county or state and layers of GIS data. Users use Workspace files as an initial point of access to EFS and the Image Warehouse. Users also use Workspace files to record notations (annotations) and specific images that are desired.

Typical File Extensions within Pictometry Software

Pictometry Map Image (.pmi) - represents a base map of the state/county or village provided by Pictometry as well as all the orthogonal (straight-down) images.

Pictometry Shot Image (.psi) - represents all oblique (side angle) images.

Pictometry Workspace File (.pwf) - contains the base map, GIS Images and Layers, saved images and created annotations. These files may be saved and re-accessed for future use.

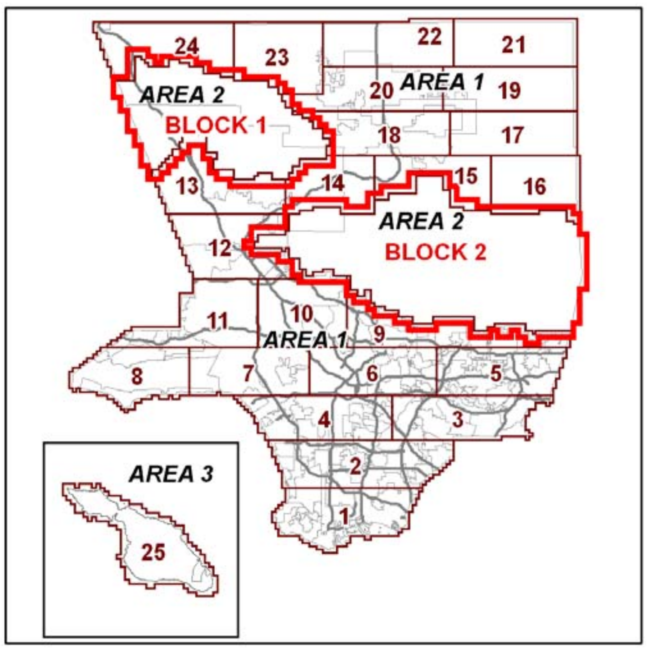
Pictometry Image Warehouse (.piw) - allows all the locational data to link to an image and is found in each cluster and sector folder.

Pictometry License File (.plf) - is a file stored onto the installation disc and is necessary for viewing and using all tools within EFS.

Orthophotography – Delivery Blocks, Tile Counts, Tile Grid and Tile Naming Convention

Delivery Blocks:

The LAR-IAC Project area is divided into delivery area blocks and each block is divided into delivery tiles (files). Each tile represents an orthophoto, contour file, or elevation data file. The size of the grid is as follows:



Map of Project Delivery blocks (Infotech products)

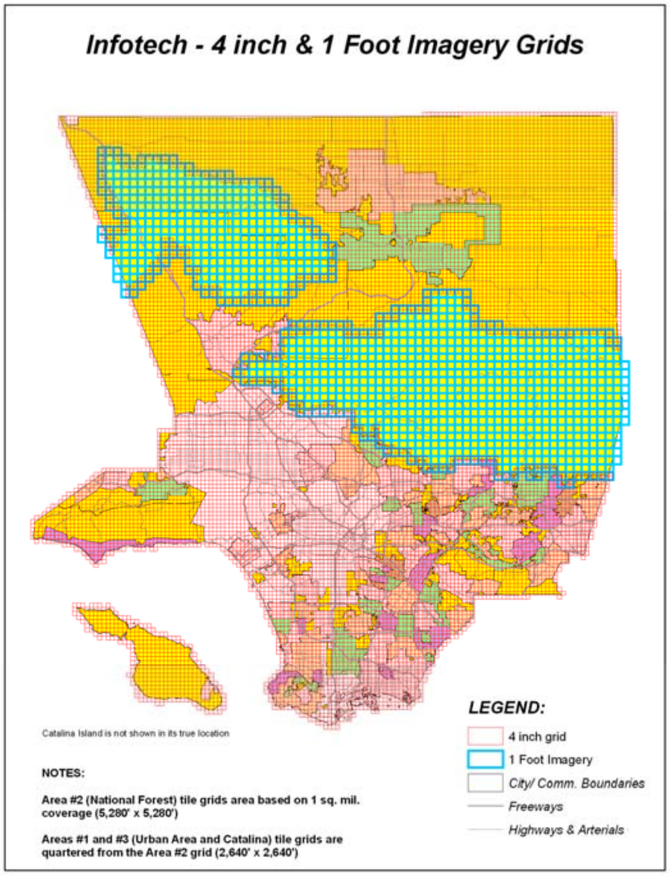
Tile Counts:

12,412 tiles for 4” orthos and digital terrain datasets (Area 1 – Urban)
1,197 tiles for 1’ orthos and digital terrain datasets (Area 2 – National Forests)
373 tiles for 4” orthos and digital terrain datasets (Area 3 – Santa Catalina Island)

Tile Grid:

Tiles for Area 1 and Area 3 – 0.25 sq. mile area, 0.5 mile length and width
(2,640 ft. x 2,640 ft.)

Tiles for Area 2 – 1 sq. mile area, 1 mile length and width
(5,280 ft. x 5,280 ft.)

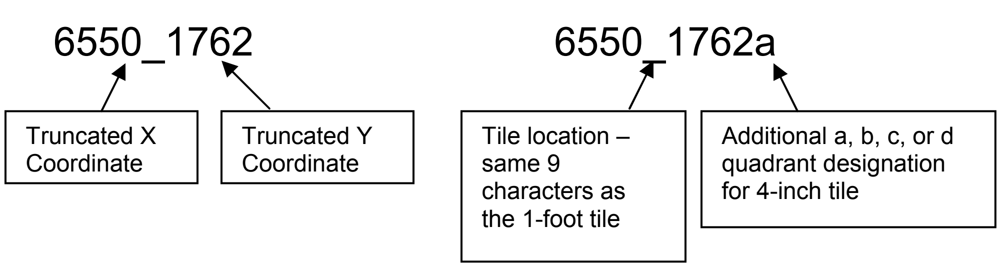


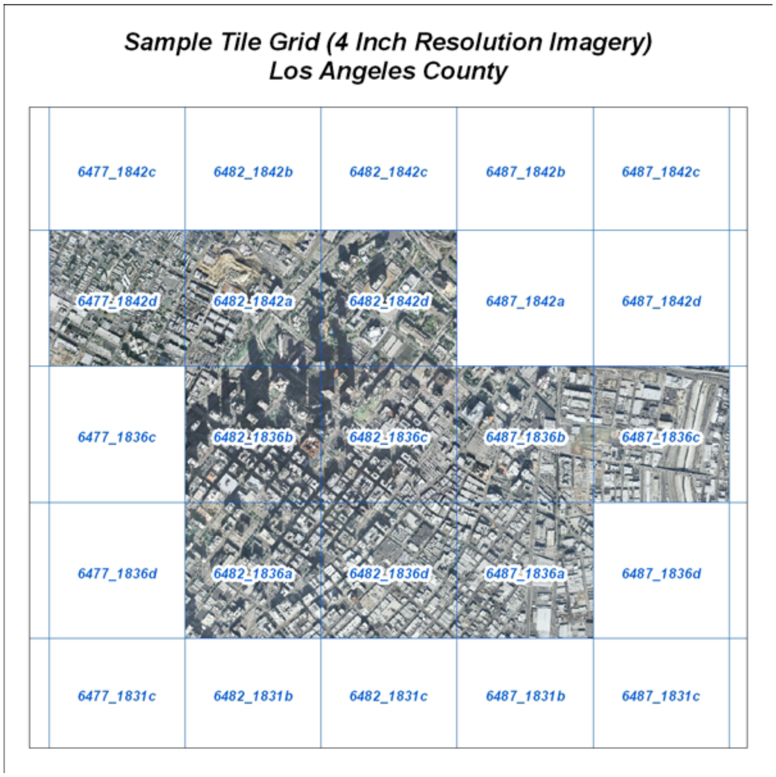
Map of tile grids for Infotech delivery products.

Tile Naming Convention – Tile ID:

In order to be able to work with the tiles it is necessary to give each tile a unique name that uses a deterministic process to define both a unique name (that defines the geographic location of each tile), as well as identifies the type of data product and format. Each tile name starts with a 9-character ID number to uniquely identify it. The first part is a truncated X coordinate (first 4 digits) in thousands of feet, separated with an underscore from a truncated Y coordinate in thousands (last 4 digits).

Examples: **1-foot tile** **4-inch tile**





Downtown Los Angeles sample tiles with tile grid and naming convention.

All of the core orthophotography files are identified by this tile number and a file extension that designates the files data file format (e.g. .tif, or .jp2). For all of the other LAR-IAC data products, the 9-characted ID number is followed by a product type identifier (suffix). The file type (product) suffix starts with an underscore and is followed by a 2 or 3 character product type designation, consisting of:

_1.	1-foot resampled ortho tile
_ct.	contour data
_dem.	digital elevation model data
_dsm.	digital surface model data
_dtm.	digital terrain model data

NOTE:
For the ESRI shapefiles delivered, an additional suffix is added to define the type of features stored in each file (e.g. _polyline. and _point.)

Following each file name is the file extension. The extension begins with a period and then a 3 (or more) character string designation of the files data format (e.g. .dwg, .dgn, .shp, .xyz, etc…).

Credits - How You Should Cite the Data

The mapping products provided under the LAR-IAC consortium are an important operative component to all consortium members and have significant value. This value must be protected by all consortium members and parties affiliated with LAR-IAC and its contractors. When using the LAR-IAC datasets for public viewing, media or third party applications the LAR-IAC consortium strongly encourages its members to properly cite the source of the data. **Please Note: Third party or "derived datasets" created from the LAR-IAC data are not subject to citation requirements.**

Citing Infotech Data

When citing the source of the Infotech data please use one of the two following options:

Option 1 - Short Version:

"This is a proprietary dataset provided courtesy of the Los Angeles Region Imagery Acquisition Consortium (LAR-IAC) and Infotech Enterprises America Inc."

Option 2 - Long Version:

This is a proprietary dataset provided courtesy of the Los Angeles Region Imagery Acquisition Consortium (LAR-IAC) and Infotech Enterprises America Inc. Use other than what is allowable under license or by written permission by Infotech Enterprises America, Inc. will be considered unauthorized and may be punishable by law. Permission for external use may be given with written permission from Infotech Enterprises America, Inc.

Citing Pictometry Imagery

When citing the Pictometry oblique imagery please use the following:

"© Copyright 2006, Pictometry International"

Let Us Know How You Are Using the LAR-IAC Data

We want to know about your successes! The LAR-IAC Technical Advisory Group will be documenting how people are using the LAR-IAC products. This valuable information will help Los Angeles County present a strong business case to decision-makers for maintaining the county's geographic information systems (GIS) infrastructure. You can send us a few sentences about how you are using it to gis@planning.lacounty.gov.

LAR-IAC Project Help

We want to do everything in our power to ensure that all our participating entities (cities, county departments and other public agencies) can take full advantage of the LAR-IAC products. In order to provide help as expeditiously as possible we have set up the following information for users:

- Half day and/or two hour data delivery/training seminars will be held at key locations around the County (TBD).

- A LAR-IAC User Group will be established to meet regularly to discuss and promote efficiencies in support and maintenance of the products.

- As another option for help in using the LAR-IAC product, users can contact:

Los Angeles County Department of Regional Planning – GIS Section
Project Manager – Nick Franchino, GIS Manager
gis@planning.lacounty.gov (213) 893-0881

Los Angeles County Chief Information Office
Project Director – Mark Greninger, Associate CIO (County GIO)
mgreninger@cio.lacounty.gov (213) 974-2154

Project information, including plans for the next re-fly (LAR-IAC^2), can be found at the project Web site:
http://planning.lacounty.gov/lariac

For Technical Assistance with hard drive/DVD deliveries, please contact:
Phil Worrall
Pinnacle Mapping Technologies, Inc.
8021 Knue Road, Suite 113
Indianapolis, IN 46250
Phone: (317) 585-2011
Fax: (317) 585-2014
pworrall@pinnaclemapping.com

Data Acquisition and Data Production by:
Infotech Enterprises America
100 Carpenter Drive; Suite 200
Sterling, VA 20164
Phone: (703) 834-0225
Fax: (703) 318-7224
IEA-Info@infotechsw.com

Pictometry International Corp.
100 Town Centre Drive, Suite A
Rochester, NY 14623
Phone: (888) 771-9714
customersupport@pictometry.com

Revised in December 2009

Data Quality Assurance and Distribution by:
Dewberry & Davis LLC
8401 Arlington Boulevard
Fairfax, VA 22031-4666

Citations

The following books are useful for introductions to the basics of aerial photography.

American Society for Photogrammetry and Remote Sensing, American Congress on Surveying and Mapping and American Society of Civil Engineers, 1994. Glossary of the Mapping Sciences

> Everything you need to know about the mapping sciences from A to Z. The Glossary contains more than 11,000 definitions that encompass every aspect of the mapping sciences. Definitions are included in the areas of Photogrammetry, Remote Sensing, Cartography, Mapping, Land Surveying, Construction Surveying, Engineering Surveying, Geodesy, Hydrography, LIS/GIS/LIM, Surveying Law, and Metrology.

Avery, Thomas E. and Graydon L. Berlin, 1985. *Remote Sensing and Image Interpretation, 5th Edition,* Burgess Publishing Company.

> This book discusses the basics of aerial photography, and a wide range of uses for aerial photography from land-use mapping for GIS to soils mapping to studying urban development.

Branch, M.C., 1971. *City Planning and Aerial Information*, Harvard University Press.

> This book provides a good description of aerial photography and its use in city planning, although much of the technical information in the text is dated.

Lillesand, Thomas M. and Ralph W. Kiefer, 1994. Remote Sensing and Image Interpretation, John Wiley & Sons.

> This book provides a good all around look at the current field of Remote Sensing, with focus on discussing methods of processing multi-band satellite imagery.

Mikhail, Edward M., Bethel, James S. and McGlone, J. Chris, 2001. Introduction to Modern Photogrammetry, John Wiley & Sons

> Dr. Mikhail and Dr. Bethel are both professors at Purdue University. In this edition, they team up with Dr. McGlone from Carnegie Melon University, to provide a mathematical look at the science of photogrammetry. They also take aim at a photogrammetric correlation of related fields, such as GIS and Remote Sensing.

Paine, David P., 1981. Aerial Photography and Image Interpretation for Resource Management, John Wiley & Sons

> Geared towards the use of aerial photography in forestry and other natural resource disciplines. Emphasis is on photo interpretation, although other forms of remote sensing, as well as some photogrammetry are covered.

Robinson, Arthur H., et al, 1995. Elements of Cartography, John Wiley & Sons.

Primarily concerned with cartography; many of the fundamentals of aerial photography are covered in Chapter 10.

Slama, Chester C. (editor), 1980. Manual of Photogrammetry, American Society of Photogrammetry and Remote Sensing.

Provides detailed descriptions of all aspects of aerial photography, ranging from a discussion of film types to explanations of photogrammetric equipment.

Smith, John T. (editor), 1968. Manual of Color Aerial Photography, American Society of Photogrammetry and Remote Sensing.

Covers all aspects of planning, taking and using color photography.

Taylor, Charles E. and Richard E. Spurr, 1973. Aerial Photographs in the National Archives, National Archives and Records Service (Special List No. 25).

A listing of the aerial photography held at the National Archives in Washington D.C. The photography is from before 1950, and is organized by state.

Wolf, Paul R., DeWitt, Bon A., 2000. Elements of Photogrammetry,2nd Edition, McGraw Hill..

This book gives a full explanation and history to the science of photogrammetry. It discusses its many uses and advances in the field of study and gives a new focus to photogrammetric applications in GIS.

Pictometry International Corporation, Understanding the Structure of the Client Image Warehouse, Electronic Field Study (EFS) Software v2.6, Pictometry International Corp., 2006.

Provides the structure of the Pictometry data files (includes folders and file naming convention).

"Topographic Maps: An Overview of the Basics," <http://www2.una.edu/geography/topo_maps/overview.htm>.

Provides a basic overview of topographic maps, including scale and symbology.

The following book is useful for introductions to the basics of LiDAR, DSMs, DTMs, DEMs, Accuracy Standards, Accuracy Testing and Reporting.

American Society for Photogrammetry and Remote Sensing, *Digital Elevation Model Technologies and Applications: The DEM Users Manual*, 2nd edition, 2007, edited by Dr. David Maune.

Provides an overview of terminology (DEMs, DTMs, DSM, TINs, mass points, breaklines), Vertical Datums, Accuracy Standards, Photogrammetry, IFSAR, Topographic LiDAR, Bathymetric LiDAR, Sonar, Enabling Technologies, DEM User Applications, DEM Quality Assessment, DEM User Requirements, LiDAR Data Processing, and Sample Elevation Datasets.