DOES STATE-OF-THE–ART EQUIPMENT SOLVE ALL MAPPING PROBLEMS? A CASE STUDY OF THE LOS ANGELES REGION IMAGERY ACQUISITION CONSORTIUM (LAR-IAC) PROJECT.

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ABSTRACT

The paper describes the specific terrain conditions, the selected methodologies, and solutions to meet the accuracy requirements and delivery schedules for the Los Angeles Region Imagery Acquisition Consortium (LAR-IAC) project under which digital ortho aerial imagery, digital terrain datasets (from LiDAR), and contour data will be provided to all consortium members[1]. This project ranks as one of the most ambitious mapping projects in the US undertaken today. The project specifications called for 4 inch digital ortho coverage with 2 foot contours of 2,898 square miles and 1 foot orthos with 5 foot contours over 1,056 square miles. Image acquisition of over 60,000 images was performed by 3 Z/I DMC systems and LiDAR data was acquired by 2 Leica ALS 50 sensors resulting in a 7 TB data set. The LAR-IAC's data management, storage, and distribution to consortium members are also discussed.

INTRODUCTION

Over the past five years, many Los Angeles County municipalities have independently contracted for medium-quality aerial imagery. Sometimes it was in black and white and sometimes in color. The imagery was developed using inconsistent standards for resolution and accuracy, was captured over different time periods, and because of duplication of efforts, resulted in an inefficient expenditure of public funds.

In 2004 the Los Angeles County started with the development of a conceptual framework to form the Los Angeles Region Imagery Acquisition Consortium (LAR-IAC 2007). Objectives were identified to include the generation of high resolution digital orthophotos and 2 foot contours as well as oblique aerial digital imagery under a different contract. Several meetings were organized to inform the Consortium members of the new image acquisition technology and to obtain digital orthophotos with 4 inch (10 centimeter) pixel size. For most of the Consortium members the proposed pixel resolution would result in new applications and identification of details not available to them before. Under this collaborative effort among County Departments, municipalities and other public agencies established a technical advisory group comprised of key participants to act as the LAR-IAC governance body to research available technologies, product specifications and to devise a cost recovery model. Los Angeles County is divided into 40 departments with 21 separate county-related agencies using digital imagery and mapping data. In addition within the County of Los Angeles there are 88 Cities of which the City of Los Angeles represents the largest city government and has 47 departments and bureaus that will make use of the data. As a result of the information and education effort a wide range of applications were identified and communicated to one of the largest county and city governments in the nation and finally financing was approved and secured.

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[1] Oblique aerial digital imagery will also be included in the LAR-IAC project but was completed by another vendor (Pictometry International Corp.).

From the beginning the Consortium members agreed that only the latest technology shall be used to acquire imagery and elevation data. Under the leadership of the County's Chief Information Officer (CIO) a Request for Proposal (RFP) was issued in 2005 to cover the entire County of Los Angeles with digital orthophotos, digital terrain datasets, and newly generated contours. The County was divided into two major areas; an area of 2,898 square miles of the urban area[2] of the County and 1,056 square miles of National Forest for a total project area of over 4,000 square miles (including Santa Catalina Island), equivalent to over 10,240 square kilometers. This is in comparison twice the size of the State of Delaware. For the urban areas digital orthophotos with 4 inch pixel 2 foot contours were requested, and 5 foot contours for the two distinct National Forest areas within Los Angeles County respectively. As a result of the RFP the Zeiss/Intergraph Digital Mapping Camera (DMC) (Intergraph 2007, Hinz 2003) combined with Leica Geosystem ALS50 LIDAR (Leica, 2007) sensor hardware /software solution and photogrammetric breakline collection was selected by LAR-IAC.

Acquisition Statistics and File Size

The three Zeiss/Intergraph DMC cameras exposed over 60,500 images which were stored, processed, aero-triangulated, adjusted, and processed for one of the final products. The large number of images was necessary to account for the one of the most difficult terrain conditions within one county. Extreme terrain conditions called for frequent flight line breaks to maintain the required pixel size.

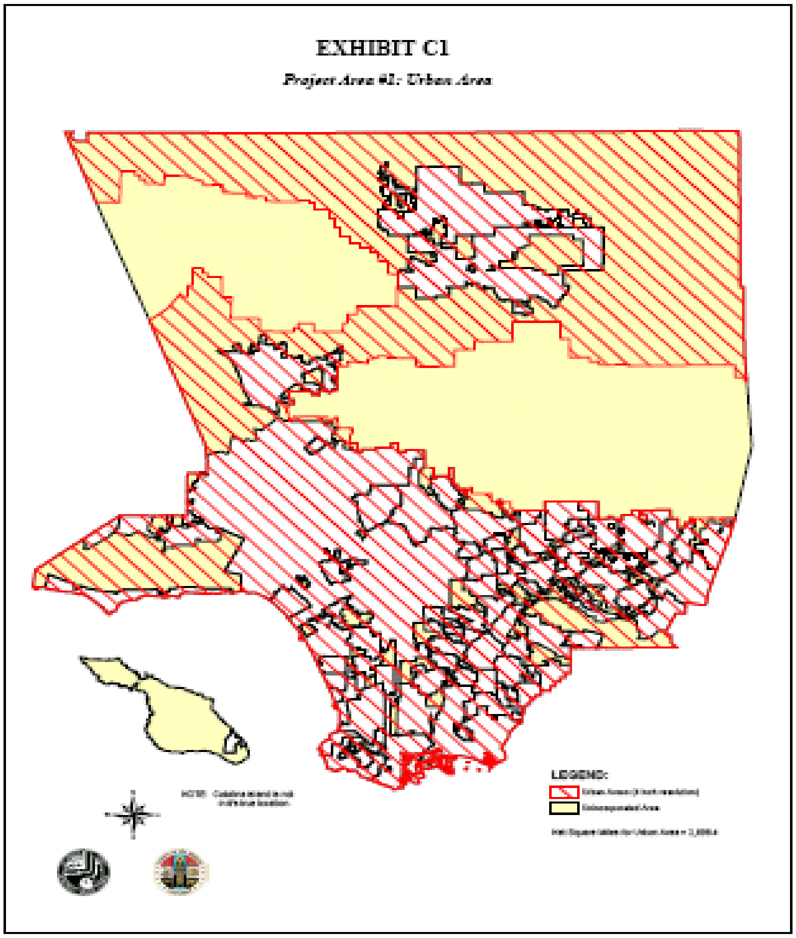
Two Leica Geosystem ALS50 LIDAR sensors were dispatched to acquire data over the urban project area for the generation of 2 foot contours (bare earth) and a surface model. The two aircraft flew over 6,200 miles during approximately 280 hours of actual data acquisition. After pre-processing the digital surface model accounted for over 1 TB.

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.)

With the project potentially providing terabyte of original data a new approach was required for managing, availability and distribution of the digital data. It was decided that the existing infrastructure of hard drives would not manage the extra data. Therefore a new countywide storage system was implemented which would enable all users to be integrated in accessing the digital orthophotos, LiDAR data, and contours. Of course, some county departments and agencies will have their set of the data, but they will also be able to access for this centralized location.

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. The graphic below outlines the project area – urban area is hatched and national Forest areas are solid.

[2] Urban area refers to all land in the County not in the national forest areas. This land could be urban or rural in nature; it was how the County was divided for this project.



From the very beginning all participants and the producer were fully aware of the large size of spatial data. Los Angeles County as the administrator of the data opted for the acquisition of new hardware to hold the estimated 8 TB of data. SAN devices needed with fiber channel and RAID arrays for storage and fast retrieval of data. Data warehousing protocol and image processing for managing large quantities of digital orthophotos required the purchase of sophisticated spatial imagery processing and GIS software. The County Enterprise GIS data repository will also be hosting the data and several other county departments having an interest in their own copies of this extensive dataset. Table 1 below provides information for most of the image data products and deliverables.

Table 1. Imagery Data Product and Deliverables

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

Data Formats

With LAR-IAC members wanting the highest quality data and multiple image formats data storage became an issue. This was more prevalent for agencies getting the entire county dataset (7 TB) versus some member cities getting their city and a two mile buffer (80 GB maybe). Infotech transferred 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. Formats included GeoTiff and JPEG2000 for the natural color and CIR imagery. For the Digital Terrain Model (DEM) the formats were ASCII points, ArcGIS shapefile – points, and Microstation (dgn) – points, lines. These are just some of the total product delivery formats.

PROJECT EXECUTION

During the RFP phase it was clear that only with an increase in the number of digital cameras the project could be completed within the limited time frame and account for all terrain conditions and possible delays. The most concern was the outbreak of wild fires, flight restrictions from LAX, and other high volume airports in the area as well as general climate conditions. Most favorable climate conditions were predicted for the time period between December 2005 and February 2006.

LAR-IAC selection committee recommended the DMC approach. Direct digital airborne camera systems are complex systems, the DMC is more than the simple exchange of film for silicone. The DMC system concept, introduced by Hinz, Heier and Dörstel (Hinz 2001, Heier 2002), is based on matrix sensor technology and thus the DMC provides very high radiometric and geometric stability (Madani 2004, Dörstel 2003). The DMC system is a total solution designed to be a modular system. The modular system design concept means that during development a considerable effort was spent to make sure that components which are expected to have fast innovation cycles are easy to exchange. Disk drives would be a good example of the always changing technology.

From the onset three (3) DMC were mobilized to counter any unforeseen problems and difficulties. For a project of this size challenges are plentiful. First and foremost was the challenge to meet the specifications for the 4 inch pixel resolution due to the often extreme and diverse topographic conditions. The topographic conditions within one half of mile change so drastically that many flight line breaks were necessary. In addition steep hill sides (recall the famous Hollywood sign) could not be ignored because these sites have buildings constructed into the slope. The challenges for this project can be separated into topographic, flight administrative, and general. Most importantly the County's topographic range extended from sea level to mountain ranges around 9,200 feet, with the highest point at 10,064 ft at Mt. San Antonio making the flight planning even more challenging. After all parameters were assessed and considered the three DMC collected over 60,500 images over the project area

In regard to the practicality of the production workflow, considerations include the efficient processing, management, and distribution of the image data. Post processing of the digital imagery is very fast; especially utilizing the DMC Distributed Processing system (Doerstel, 2005) where processing of 2000 images can be reduced to less than 24 hours. DMC images can be processed with all existing photogrammetric workstation without modification or software upgrade and the color stereo model data are usable in any standard softcopy system on the market.

Due to the large project area for the 4 inch GSD imagery and low flying height of 4100 ft Infotech employed three (3) DMCs. Use of three cameras with similar lens and color characteristic allowed a more homogeneous final product and aided in the pre-processing stage. Geometric and radiometric calibration of the three cameras was assumed equal. The LAR-IAC technical advisory group and Infotech generated 3D LUTs (Look-Up Table) to be used to match the final output to the pre-processed 12 bit imagery by considering atmosphere, lightening direction which changes the resulting colors from lift to lift.

Two Leica Geosystem LIDAR ALS50 systems were mobilized and captured during 17 days and over 250 hours of flying the required data. Similar problems as in the imagery acquisition were encountered and actions were taken to comply with the proposed specifications.

Data Distribution

Distribution of this data was an issue for participants receiving the entire county dataset. For this the County purchased two snap servers (8 TB total storage) and shipped them to the QA/QC and distribution vendor. The entire data will be placed on these servers and shipped to Los Angeles County. There are eight (8) participants that will take delivery of these servers and a rotation plan was devised.

The servers will first go to the LAR-IAC Project Manager at the Department of Regional Planning. There they will load the data onto their server. This has been estimated to take 4 days. When this is complete they will take the two machines to the next participant. They will do the same. When they are completed they'll pass to the next participant; and so on. This alone will take more than a month to deliver.

Those cities and agencies participating will get their LAR-IAC delivery either on external hard drives they provided or DVD media. For those agencies receiving excess of 100 GB of data the County recommended an external hard drive delivery. This has proved very successful as they have received their data more timely and do not need to load from hundreds of DVDs.

Achievements

Horizontal Accuracy – For Orthophotos. LAR-IAC's 4" digital orthophotos were tested in accordance with the 4 inch GSD Acceptance Criteria. 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.

CONCLUSION

From the experience gained during the execution of the project a conclusion can be derived that a state-of-the-art approach to county mapping provides the user with high-quality data. It is the user who has to make the most of the data by developing new applications and service new customer within their own organization. Advanced processing capabilities result in shorter delivery times providing the user with up-to-date data.

Overall the project has been very successful. The sheer volume of data, because of the resolution and number of formats, did present challenges; but the benefits were far greater and the Consortium pushed forward. Discussions are underway for the next re-fly to acquire new imagery datasets with plans to undertake this every two years.

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