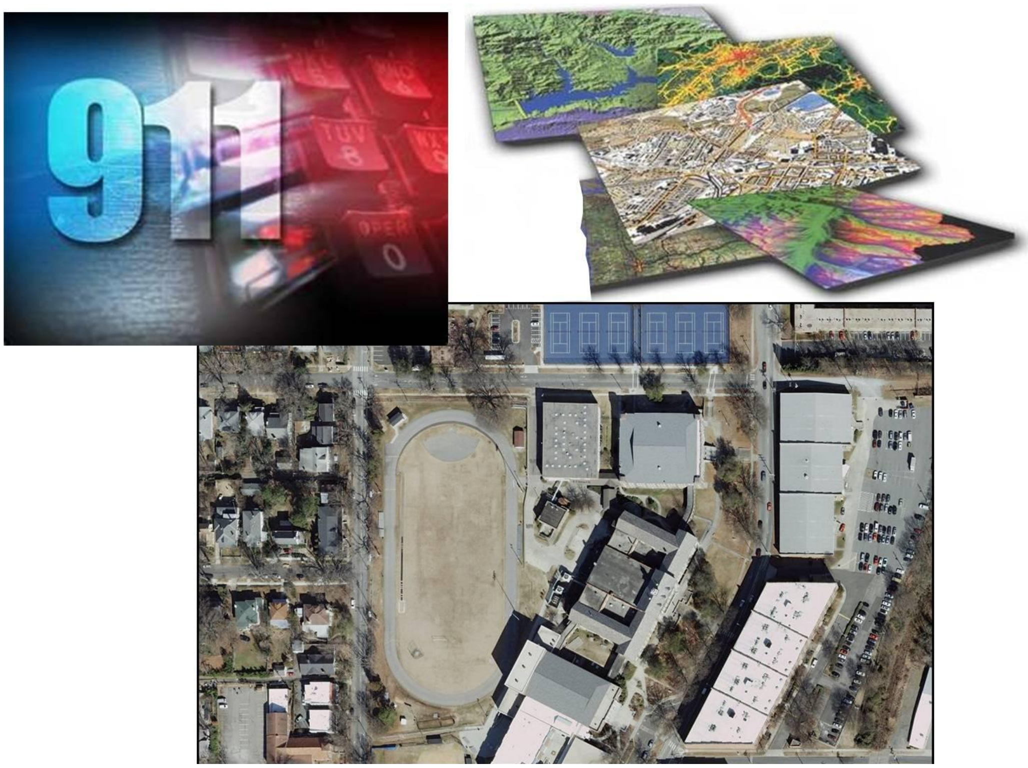
North Carolina Statewide Orthoimagery 2010
Final Report



Prepared for:

The City of Durham

and

The North Carolina 911 Board

Prepared by:

North Carolina Center for Geographic Information and Analysis

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1. Project Background

Digital aerial imagery is the most fundamental dataset for use with geographic information systems in local, state, and federal government and in numerous private and non-profit organizations. The 2010 Statewide Orthoimagery project confirmed that imagery is used by Public Safety Answering Points (PSAP) for visual reference and for accurate street mapping, by counties to map property boundaries and infrastructure, and by a range of users to display land use and impervious surfaces.

Orthoimagery is used in search and rescue operations, by the state emergency management office for emergency response planning and development of hazard mitigation plans, and by the floodplain program to develop flood insurance maps; it is used by the NC Department of Agriculture and Consumers Services for bio-emergency planning operations; it is used by NC Department of Transportation (NCDOT) for highway mapping and planning; and by numerous other state and federal organizations to get a clear, current, and accurate picture of the landscape. In addition, other groups, such as, the timber industry, utilities, and conservation organizations use aerial imagery to meet their information needs. The North Carolina Geographic Information Coordinating Council recognizes orthoimagery as a priority dataset, and the GIS Study conducted by the NC Office of State Budget and Management recommended funding of orthoimagery as a key dataset for multiple benefits.

Orthoimagery is a set of pictures of the earth captured by aircraft equipped with digital or film cameras and processed to fit the earth with high precision. Before this project, orthoimagery was available for all counties in North Carolina, but in a patchwork of different dates and resolutions (i.e., visible detail). As shown in Figure 1, the year of the most recent orthoimagery ranged from 2003 to 2009. The resolution (pixel size, the smaller the more detail) varies within counties to match tax mapping conventions (more detail in densely settled areas) and across county boundaries. That pattern revealed that many of the lower tax-base counties (western and northern) had imagery more than four years old, and some of the most urbanized counties had images last captured in 2005.

Orthoimagery provides a visual base map that is highly accurate for measuring distances and has enough clarity to represent roads, structures, vegetation, and other features on the ground to support 911 communications centers and the many other uses. Orthoimagery is not oblique (where sides of buildings are visible), but it is the most accurate way to represent what is on the surface of the earth.

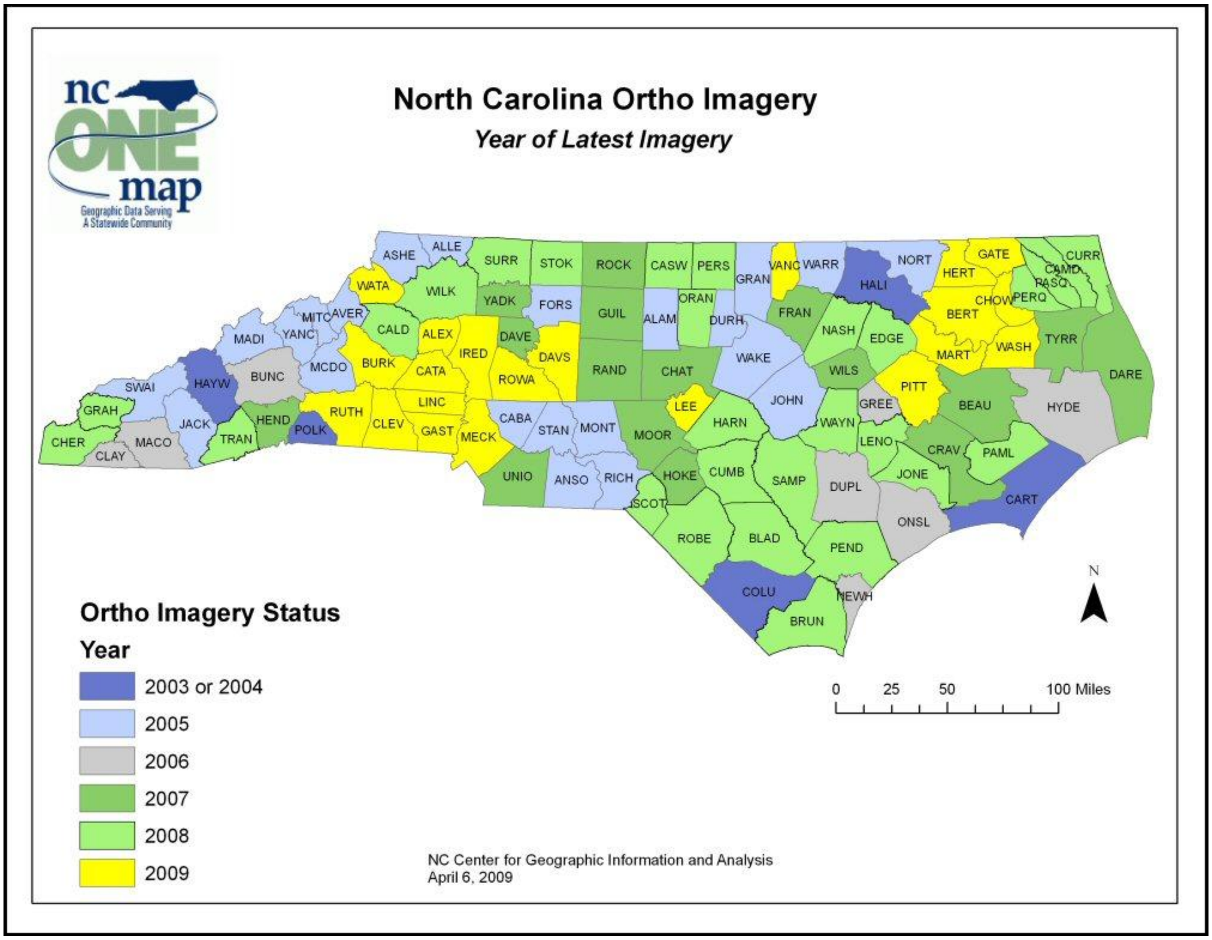

Figure 1. Year of Most Recent Orthoimagery by County, North Carolina.

For purposes of locating 911 calls on the ground as accurately as practical, high-resolution, recently captured imagery like the example from Pamlico County (winter 2010, compressed for display) provides a highly accurate base map upon which county mapping operations edit and add streets and address points, buildings, property boundaries and other map features. See Figure 2.

Figure 2. Example of 6-inch Ground Resolution Imagery from Pamlico County, February 2010.

The typical practice in North Carolina was for individual counties to engage a private contractor to produce orthoimagery every four years, related to a property tax revaluation cycle. Funding for a county project may or may not have included cost-share dollars from the NC OneMap Orthoimagery program or the NC Floodplain Mapping Program depending on annual federal awards and state funding. The expected number of counties flying in a given year would be 25 based on the four-year goal.

In practice, the number of counties contracting for orthoimagery was below par. In 2009, only 21 counties contracted for orthoimagery although another 27 were eligible based on a four-year refresh rate for imagery. In 2010, as few as eight counties appeared likely to be eligible for cost-share and plans for all counties were uncertain because of local budget constraints. This statewide project was timely given the local budget situations and the aging of imagery, particularly in those counties in shades of blue in Figure 1.

In terms of maintenance, the imagery products typically meet local needs for three to four years. The Business Plan for Orthoimagery from the NC Geographic Information Coordinating Council recommends an annual capture of one-fourth of the state as a practical, reliable approach in the coming years. The business plan is available here:
http://ncgicc.net/Portals/3/documents/OrthoImageryBusinessPlan_NC_20101029.pdf

Definitions of terms used in this report and that apply to orthoimagery in general are attached as Appendix A.

2. Achievements

The purpose of the project was to create a statewide image of North Carolina to support accurate, timely and effective placement of 911 calls in correct locations. The objectives were to:

1) Provide all North Carolinians equivalent, up-to-date base imagery that supports detailed mapping of streets and building locations, as well as accurate mapping of property boundaries.
2) Provide comprehensive, consistent, high quality imagery that is seamless across county boundaries and city limits.
3) Give E911 call dispatchers confidence in the images and maps displayed in PSAPs across the state.
4) Create a statewide geospatial building block for the next generation of E911.
5) Realize the full potential of the NC OneMap data clearinghouse for organizing and providing access to statewide, high-resolution imagery.
6) Support employment and income in North Carolina through state-licensed contractors and domestic data processing operations.

2.1. Objectives Achieved

The Statewide Orthoimagery 2010 project achieved all six of project objectives:

1) Produced and distributed complete 2010 orthoimagery to 125 Primary PSAPs across the state by the end of June 2011, and provided public access to imagery services and downloadable files through a new NC OneMap Geospatial Portal on June 2, 2011.
2) The 2010 orthoimagery is comprehensive, consistent, high quality imagery that is seamless across county boundaries and city limits.
3) The imagery is being loaded in computer aided dispatch systems in PSAPs across the state; deliveries included adjacent counties for consistent display beyond PSAP boundaries.
4) The imagery provides a geospatial building block for the next generation of E911.
5) The imagery is the featured dataset in the new NC OneMap Geospatial Portal, providing free public access to statewide, high-resolution imagery (http://data.nconemap.com).
6) The project made a timely contribution to employment and income in North Carolina through state-licensed contractors and domestic data processing operations.

2.2. Deliverables

2.2.1. Products and Services Delivered

a. The Department of Environment and Natural Resources, NC Geodetic Survey established a new validation range for aerial imagery sensors in Surry County to assure sensor quality for capturing imagery.
b. NC Geodetic Survey upgraded the Continuously Operating Reference Station (CORS) network for higher horizontal accuracy and reliability.
c. Contractors managed by the Department of Crime Control and Public Safety, Geospatial and Technology Management Office (GTM), produced some 59,000 tiles in GeoTIFF format to meet project requirements and specifications. The 5,000 by 5,000 foot tiles are true color, leaf-off, 6-inch ground resolution, ortho-rectified, color-balanced, finished images.
d. Fugro EarthData, a private contractor managed by GTM, delivered a portable hard drive for each of 100 counties to CGIA. Each county drive included: county orthoimagery, digital elevation model (if revised from the set available through NC Floodplain Mapping Program), county MrSID tiles and county mosaic, all adjacent counties' MrSID tiles and mosaics, a complete metadata record, and other information including a tile index, aerial triangulation report, and flight lines.
e. NC Geodetic Survey, with the assistance of seven contracted firms, performed horizontal quality control in each of 100 counties.
f. CGIA validated the products, did final quality control, finalized metadata records, and prepared final packaging of digital files. On approval from the NC 911 Board, CGIA distributed one portable drive to each county in regional orientation sessions, distributed one portable drive to each of 25 non-county PSAPs, and maintained a set of portable drives with copies of the county deliverables to store and share with NC OneMap partners including federal and state agencies.
g. CGIA implemented a new NC OneMap Geospatial Portal featuring imagery services, previews and imagery downloads to provide public access to the new imagery. The online application included upgraded software, new servers hosted by NC Office of Information Technology Services, and customized download capability. The NC OneMap Geospatial Portal is the public face of this project and the public access point for viewing and downloading the statewide 2010 imagery. The main web page is captured in Figure 3, featuring a search tool for performing word searches for imagery and other geospatial datasets accessible through NC OneMap (http://data.nconemap.com). For the 2010 imagery, there are options for viewing the imagery directly (as an image service) and for downloading portions of the collection (approximately 20 square miles of imagery per request). An example of a download request (user drew a gray box for the area of interest) is shown in Figure 4. This results in email notification of a compressed file containing imagery, ready for download.
h. CGIA updated the NC OneMap GIS Inventory to reflect the availability of the new datasets.
i. CGIA performed quality assurance with PSAPs and GIS coordinators including a 90-day local review period, issue submittals, and issue resolution.

Figure 3. NC OneMap Geospatial Portal for Public Access to 2010 Imagery

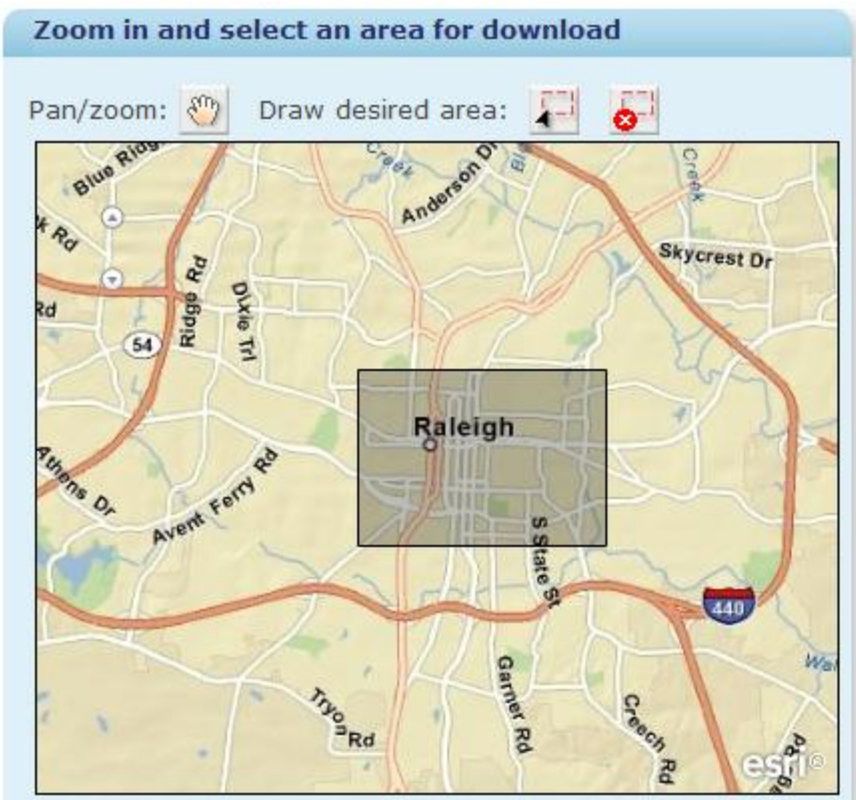

Figure 4. Example of an Area of Interest Defined by a User for Imagery Download, NC OneMap Geospatial Portal

2.2.2. Reports

a. CGIA submitted monthly status reports to the City of Durham and the NC 911 Board summarizing expenditures, task status, progress, and anticipated progress for the following month, including a summary status slide for the NC 911 Board.
b. CGIA and the Project Team prepared monthly budget and task status, detailed spending reports, and progress reports, including assessments of progress from project partners and monitoring of progress of GTM and its contractors by means of the SharePoint project management tool.
c. CGIA prepared a summary of data requests from entities outside of the Project Team.
d. CGIA managed a project webpage on NC OneMap and posted reports and maps to communicate the status of flights, processing, quality control, product delivery, orientation meetings, frequently asked questions, and resources including the orientation presentation, the business plan for orthoimagery, state specifications for orthoimagery, and positional accuracy reports.

3. Schedule and Milestones

The project schedule covered 77 weeks through June 30, 2011, with 13 additional weeks for completing local review and distribution of final quality resolutions. Operation and maintenance of the NC OneMap online access will continue through June 30, 2012. Project Week 1 was January 12-15, 2010. The "Delivery of Imagery to CGIA" phase of the project was completed in February with GTM's contractors delivering all counties in the eastern Piedmont and coastal plain, western Piedmont, and mountains.

The following milestones represent the components of the project. The project team established planned start and finish dates early in the project for these milestones. Actual finish dates were recorded when milestones were completed. While some of the processing milestones were completed later than planned, the key milestones were on target including image acquisition, delivery of portable drives to the counties and public access through NC OneMap.

1. Image Acquisition

	Planned Start	Planned Finish	Actual Finish
A. Image acquisition			
Eastern Piedmont & Coastal	1/15/2010	3/15/2010	3/7/2010
Western Piedmont	1/29/2010	3/27/2010	3/28/2010
Mountain	3/1/2010	4/25/2010	4/11/2010
B. Sample image review	4/12/2010	5/15/2010	6/8/2010

2. Aerial Triangulation

	Planned Start	Planned Finish	Actual Finish
Eastern Piedmont & Coastal	2/15/2010	6/15/2010	9/21/2010
Western Piedmont	2/15/2010	8/30/2010	9/14/2010
Mountain	2/15/2010	9/15/2010	9/14/2010

3. Ortho Processing

	Planned Start	Planned Finish	Actual Finish
Eastern Piedmont & Coastal	3/15/2010	10/20/2010	12/7/2010
Western Piedmont	4/1/2010	11/20/2010	11/23/2010
Mountain	5/24/2010	11/24/2010	12/7/2010

4. Geodetic Control

	Planned Start	Planned Finish	Actual Finish
CORS Upgrades Statewide	3/10/2010	5/14/2010	5/11/2010

5. Delivery of Imagery to CGIA

	Planned Start	Planned Finish	Actual Finish
Eastern Piedmont & Coastal	5/15/2010	12/31/2010	2/8/2011
Western Piedmont	4/21/2010	12/31/2010	2/15/2011
Mountain	7/13/2010	12/31/2010	2/15/2011

6. Data Access

	Planned Start	Planned Finish	Actual Finish
Delivery of imagery to counties (911/GIS)	10/1/2010	4/27/2011	4/28/2011
Follow-up consultation with counties	10/8/2010	4/27/2011	9/30/2011
Planning and design of NC OneMap improvements	2/15/2010	6/15/2010	8/6/2010
Implementation of NC OneMap improvements	6/15/2010	10/28/2010	5/20/2011
Imagery online and accessible to the public	10/28/2010	5/12/2011	6/2/2011

7. 90-Day Review Period

	Planned Start	Planned Finish	Actual Finish
Evaluation of county review comments and re-submittal	5/16/2011	8/1/2011	8/12/2011
Contractors' review and production	5/31/2011	9/1/2011	9/23/2011
Final 90-day resolutions distributed and online	6/1/2011	10/1/2011	10/7/2011

The project team continues to meet on a weekly basis to evaluate progress on final quality control, resolutions, operation and maintenance, and consultations with users.

4. Project Scope and Management

4.1. Responsibilities

This collaborative project took advantage of strategic resources from statewide 911 management and operations, state standards and specifications, state technical services, existing contracts with private service providers, the statewide GIS coordination structure, and ongoing statewide initiatives. Project responsibilities were shared among four parties under a set of three contracts.

NC 911 Board

The North Carolina 911 Board was created by SL 2007-383 (NC General Statute 62A-40) to collect and administer the 911 Fund. The 911 Board awarded a grant to the City of Durham which operates a primary Public Safety Answering Point (PSAP) in the Emergency Communications Center. The grant was the funding source for this project through 2012. The NC 911 Board and the City of Durham executed a contract to begin the project on January 12, 2010. The Board provided project oversight throughout the project period.

City of Durham

The Emergency Communications Center of the City of Durham promotes, preserves, and protects the safety and security of all citizens of Durham by providing 911 communication services. Those services are supported by geospatial datasets, including aerial imagery as a primary base mapping reference. The Center collaborated with the Statewide Mapping Committee's Working Group for Orthophotography Planning to develop a proposal to generate new orthoimagery for all counties in North Carolina. The City of Durham entered into separate agreements with CGIA and the NC Floodplain Mapping Program on January 12, 2010. The City provided project oversight and technical advice throughout the project period.

NC Center for Geographic Information and Analysis (CGIA)
The North Carolina Center for Geographic Information and Analysis in the NC Office of Information Technology Services is the lead organization in the state for geographic information systems (GIS). As part of its services program, CGIA assists public and private organizations with development and use of geographic information systems and data. CGIA was responsible for managing the project for the City of Durham, and for data sharing that leveraged the coordination structure embodied in the North Carolina Geographic Information Coordinating Council and its NC OneMap database. Under the Council, the Statewide Mapping Advisory Committee's Working Group for Orthophotography Planning served as a technical advisory group for the project.

NC Floodplain Mapping Program
The North Carolina Floodplain Mapping Program is located in the Geospatial and Technology Management Office (GTM), Department of Crime Control and Public Safety. For this project, the program was responsible for managing its qualified prime engineering contractors for the statewide acquisition, processing, and quality control of digital orthoimagery. The program was also responsible for managing the NC Geodetic Survey and its horizontal quality control contractors to assure positional accuracy of the orthoimagery products.

4.2. Project Strategy

The project strategy was to leverage North Carolina resources that were in place and operating in support of orthoimagery acquisition and data sharing. CGIA maintains the NC OneMap database and clearinghouse. From 2005-2009, CGIA implemented 62 county cost-share projects under five cooperative agreements with the United States Geological Survey (USGS) in the US Department of the Interior. Those projects included contract administration, quality control, and data distribution to federal, state and local partners. GTM provided full or partial funding for 23 county orthoimagery projects 2004-2009 to support flood insurance rate map maintenance. The program also maintains a statewide database of elevation data used by orthoimagery contractors in processing. The Land Records Management Program in the Secretary of State's Office serves local governments with technical advice and technical specifications while playing a key role in state agency efforts relating to land records and orthoimagery. The NC Geodetic Survey maintains geodetic monuments for surveyors and a network of base stations for Global Positioning System applications. The Geodetic Survey manages a database of ground quality control points available to orthoimagery flight contractors, and specializes in performing horizontal quality control for imagery. In addition, the Statewide Mapping Advisory Committee of the NC Geographic Information Coordinating Council has a Working Group for Orthophotography Planning that brings these players and other agency representatives together on a regular basis.

To leverage these resources, this project (a) established a project team consisting of the CGIA Director, a CGIA Project Manager, a Project Manager from the NC Office of Information Technology Services, the Assistant Director of the Durham Emergency Communications Center, a GIS specialist from the City of Durham, the Executive Director of the NC 911 Board, Legal

Counsel for the NC 911 Board, the Director of GTM, the GIS Manager of GTM, the Director of the NC Geodetic Survey, and the Land Records Manager from the NC Secretary of State's Office; and (b) operated under the technical advice of the Working Group for Orthophotography Planning, chaired by Gary Thompson of the NC Geodetic Survey, with the addition of staff from Durham County GIS to represent the PSAP and the addition of a local government representative.

CGIA served as the overall project manager and contract administrator, and provided technical services under contract to Durham PSAP, including handling of the large volume of data for verification, acceptance, distribution and online access. GTM managed data acquisition under contract to Durham by applying its current Qualifications-Based Selection process under the Mini Brooks Act (GS 163) to engage selected private contractors to produce orthoimagery. Given the volume of data involved in statewide orthoimagery, multiple service providers were involved in flights and image processing as well as third-party quality control. GTM supplied the best available Light Detection And Ranging (LIDAR) datasets for elevation to the private contractors. GTM contracted with the NC Geodetic Survey to upgrade its base stations and camera validation capability, and to manage a process of horizontal quality control involving seven third-party contractors. The project organization is displayed in Figure 5.

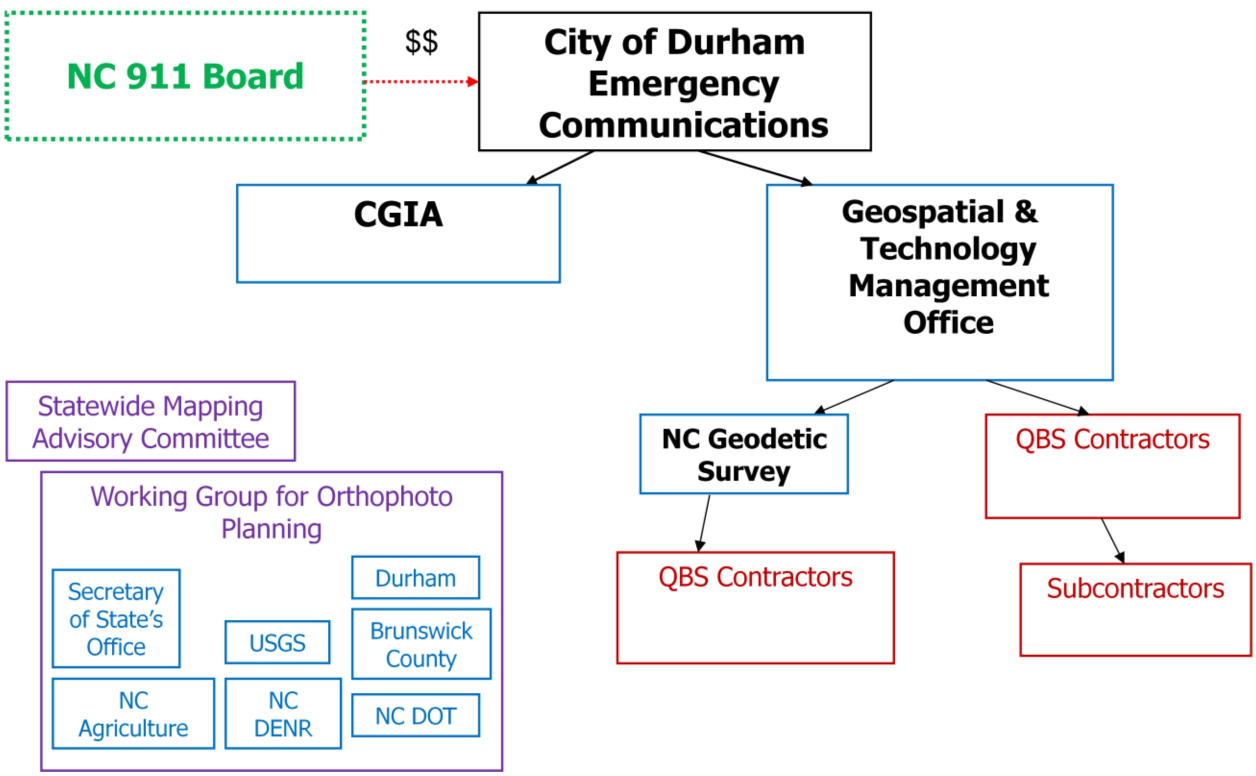

Figure 5. Project Organization

4.3. Tasks by Project Partner

4.3.1. NC Center for Geographic Information and Analysis

A. Planning Phase

1. Specified the detailed requirements for products and services based on NC Technical Specifications for Ortho Imagery and recent imagery projects in the context of the Qualifications-Based Selection process
2. Specified the detailed requirements for information technology upgrades in the NC OneMap framework
3. Communicated with counties and cities, contractors, state agencies, federal partners, and the public to explain the project, products, and benefits
4. Documented the specifications, responsibilities and scopes of work of the project partners

B. Implementation Phase

1. CGIA performed project management tasks to assure project performance and quality, including the following:
   a. Developed and maintained a project website to inform project participants and potential data users in local 911 and GIS operations as well as the public
   b. Implemented information technology upgrades to the NC OneMap image server and disk storage and transfer capacity
   c. In collaboration with the Working Group for Orthophotography Planning, received, reviewed and accepted sample products
   d. Established and implemented payment schedules for the project partners and orthoimagery products; reviewed and approved invoices submitted by GTM on behalf of contractors for payment by NC 911 Board
   e. Evaluated delivered products for completeness of county coverage, visual quality, and metadata compliance
   f. Distributed data to counties on portable drives (uncompressed images for the recipient county plus compressed images for county and adjacent counties)
   g. Shared data with partnering state and federal agencies
   h. Provided public access to imagery products via the NC OneMap Database
   i. Conducted a 90-day quality review with each of 100 counties
   j. Produced a final report including results, project evaluation, lessons learned and recommendations

4.3.2. Geospatial and Technology Management Office

A. Planning Phase

1. GTM verified the detailed requirements for products and services based on NC Technical Specifications for Ortho Imagery.

B. Implementation Phase

1. GTM issued task orders to private contractors available under current Qualifications-Based Selection contracts and managed the contractors to acquire, process, modify based on independent quality control, and deliver to CGIA digital orthoimagery in GeoTIFF and compressed formats for each of 100 counties
    a. The county boundary reference file was be the best available county boundaries from the NC Department of Transportation
    b. The tile index file was a statewide grid of 5,000 by 5,000-foot tiles based on NC State Plane Coordinates, NAD 1983 (NSRS 2007)
2. Issued task orders to private contractors available under current Qualifications-Based Selection to provide independent visual quality control (25 percent of images received detailed inspection)
3. Made digital elevation model datasets revised for this project available for download to the project team and the public
4. Managed the NC Geodetic Survey, under an existing contract, to accomplish the following:
    a. Established an aerial camera validation range
    b. Upgraded the Continuously Operating Reference Station (CORS) network to include statewide coverage with Global Navigation Satellite System (GNSS) receivers and antennas
    c. Engaged an independent team of qualified contractors to perform horizontal quality control for the orthoimagery (NC Geodetic Survey implemented a Qualifications-Based Selection process and selected seven contractors)

A diagram of the major elements of the project is shown in Figure 6.

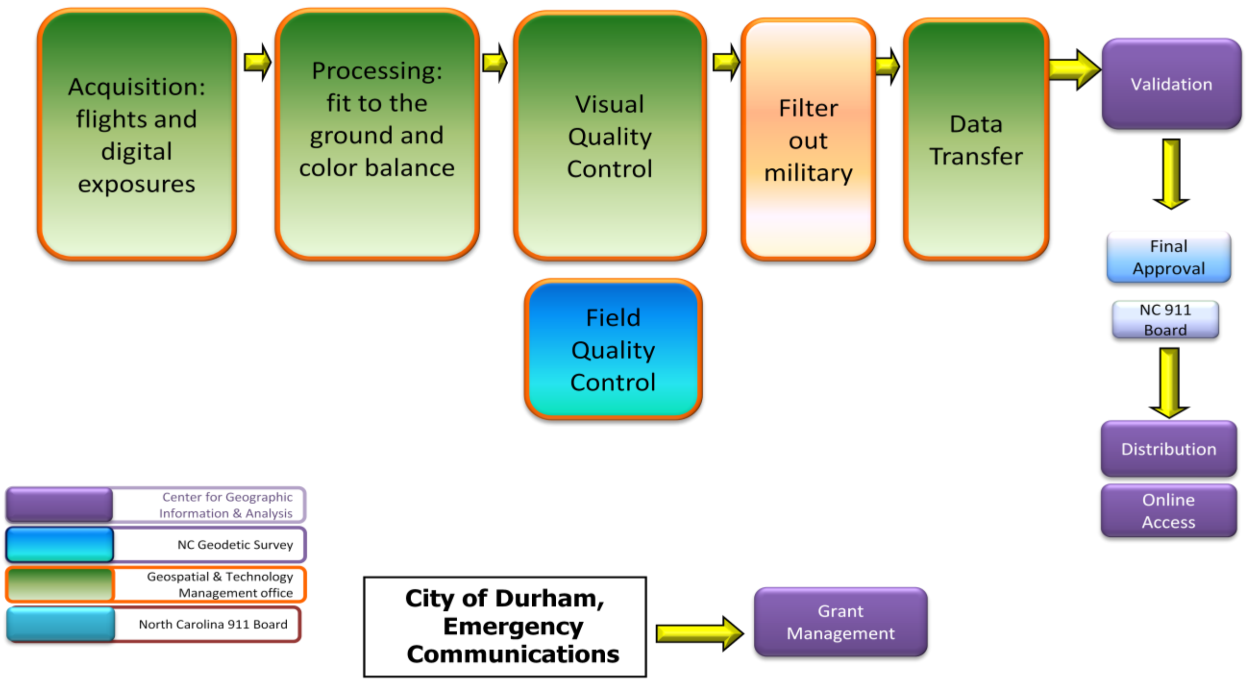

Figure 6. Major Project Elements

4.4. Dependencies

The primary dependency for this project was the limited number of days of suitable conditions for flying and acquiring aerial images. Image acquisition requires clear skies, sun angle not under 33 degrees to limit shadow length, and deciduous trees free of spring foliage. Flights began in mid-January and ended in April in the mountains and by March along the coast. The large flight acquisition team (up to 18 sensors and 26 aircraft) made statewide acquisition achievable for this project.

Timely product delivery depended on image acquisition in the expected timeframe, third-party quality control that had an adequate flow of imagery to review, efficient packaging of datasets for final review and distribution, and preparation of information technology for loading and providing access to new imagery datasets.

A third set of dependencies related to military installations and ranges in eastern North Carolina and special use airspace. The special use airspaces are extensive (see Figure 7) along the coast. The project received permission to fly and acquire imagery over all land (all airspace) in the state with the exception of Harvey Point in Perquimans County. Consequently, contractors captured images over all but a small area. The project received permission from military installations to publish orthoimagery through NC OneMap for imagery up to but not including military bases and ranges. Imagery within the boundaries of military bases was published for Seymour Johnson Air Force Base and the Dare County Bombing Range, and for US Coast Guard properties (the latter at a lower resolution). Imagery within the boundaries of military installations was not published by request of military officials for US Marine Corps and US Army installations.   Imagery adjacent to the installation boundaries was edited (clipped) to include partial tiles on the periphery. Permission to fly and acquire images is a key dependency. Publication, if all areas are flown, can be trimmed strategically to retain as much public information as practical. In the one instance where permission to fly was denied, significant parts of civilian property in Perquimans County were not captured since aircraft cannot fly right to the edge of an installation boundary and therefore were not available for distribution to PSAPs. See Section 11 for recommendations relating to military installations.

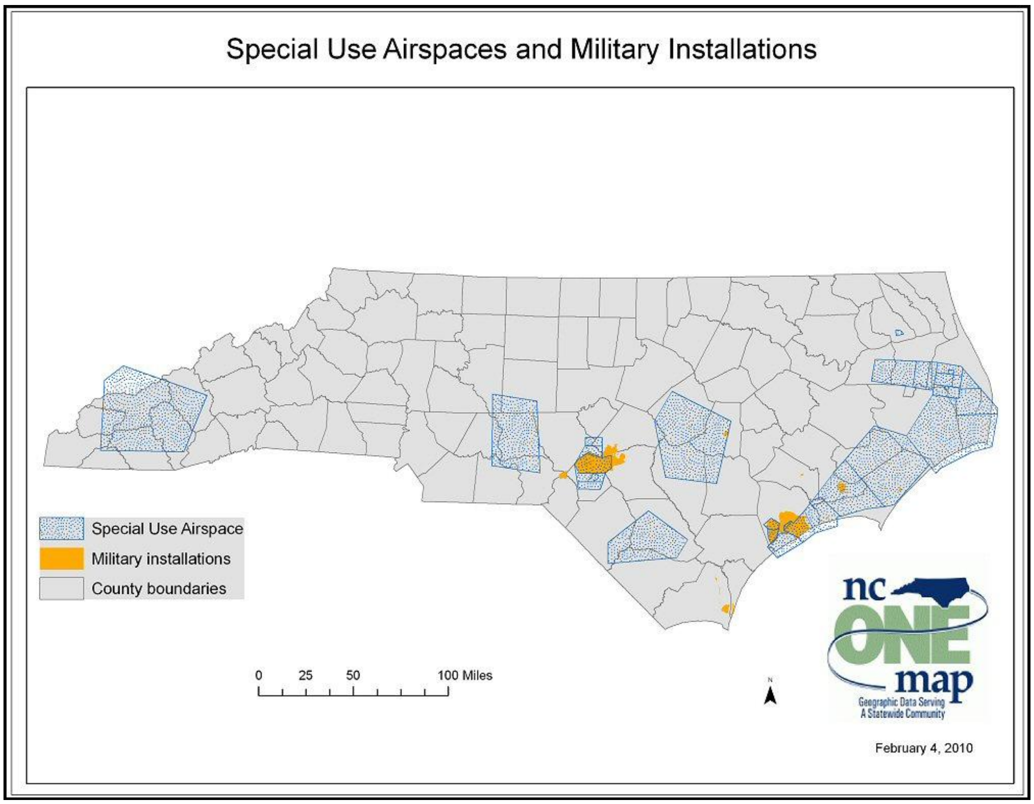

Figure 7. Special Use Airspace and Military Installations in North Carolina

5. Project Budget and Management

Estimated costs were itemized in the grant proposal by the City of Durham. The estimated costs were adjusted at the beginning of the project to account for an inadvertent exclusion of $30,000 for the horizontal quality control to cover NC Geodetic Survey labor plus contractor(s) charges. The project total could not be modified so the estimated costs for verification/ distribution by CGIA and contract administration/project management by CGIA were reduced by $15,000 each as an approximation. The delay in execution of the project (anticipated as early as October 2009 but actually started on January 12, 2010) compressed some of CGIA's labor requirements, but the bulk of the $30,000 reduction for CGIA was recovered by efficiencies over the life of the project.

5.1. Project Budget by Contract

The budget in the contract between the City of Durham and GTM amounted to $11,538,000, covering the cost of contractors for imagery acquisition, orthoimagery production, and quality control. Actual spending was 99 percent of the total. The budget in the contract between the City of Durham and CGIA was $806,000, covering project management, imagery verification, data distribution and public access. It is anticipated that the actual amount will equal the budgeted amount by the end of the contract (June 30, 2012).

Item	Estimated Cost	Actual Cost
GTM: Acquisition and processing by private contractors; visual quality control by private contractors; horizontal quality control by private contractors; validation range and geodetic system upgrades	$11,538,000	$11,530,182.69
CGIA: Verification, handling, distribution, contract administration, project management, NC OneMap IT solutions	$806,000	$806,000*
TOTAL	$12,344,000	$12,336,182.69*

*Estimated; CGIA services to be completed June 30, 2012.

6. Communications

The Project Team followed a communication plan that took advantage of the coordination structure of the NC Geographic Information Coordinating Council (GICC), the NC OneMap website, other technical projects with state partners, and outreach to professional organizations.

6.1. Project Team Meetings

Project Team meetings were scheduled for each Wednesday at CGIA with an optional call-in number. The agenda for each meeting covered these general topics:

a. Outreach
b. Contracts and contractors
c. Financial issues
d. Technical issues
e. Timetable and progress

6.2. GIS Coordination Structure

This project engaged the GIS coordination structure in North Carolina to assure that products and services met the needs of the primary users (local 911 and GIS operations) and added value to the work of a wide range of GIS stakeholders. The coordination structure is well established, and its many members are active, willing and able to offer technical and other advice, communicate preferences, and highlight the benefits of the project.

6.2.1. GICC Committees

The Statewide Mapping Advisory Committee's Working Group for Orthophotography Planning met quarterly and served as a technical advisory group. CGIA serves as staff to this group and coordinated work with the group in support of the City of Durham's grant proposal in the spring of 2009. The City of Durham and the GICC Local Government Committee were represented on the Working Group as were state and federal agencies.

6.2.2. Other Stakeholders

Military officials in eastern North Carolina were consulted for permission to (a) acquire imagery over military installations and restricted flight areas and (b) publish imagery for public use. GTM took the lead in contacting military officials, and Richard Taylor, Executive Director of the 911 Board, organized a session with military officials with the assistance of the Governor's Military Liaison.

The GICC has representation from private businesses, nongovernmental organizations, local governments, state agencies, federal agencies, and universities. The project reported at each quarterly meeting of the GICC and reported to several of the Council's subcommittees including the Statewide Mapping Advisory Committee, the State Government GIS User Committee, the Federal Interagency Committee, the Management and Operations Committee, and the Local Government Committee as requested. The first release of products, to the City of Durham, occurred at the February meeting of the GICC.

Communication with state GIS partners was supplemented through other projects that will be ongoing during this Statewide Orthoimagery Project. The Department of Cultural Resources, State Archives, is directly involved with CGIA in a project (in collaboration with the Library of Congress) to retain orthoimagery through the NC OneMap framework. CGIA and USGS have a cooperative agreement to share orthoimagery data from 2009 and 2010.

6.3. NC OneMap Website

The Project Team maintains a folder and web pages on the www.nconemap.com website. Content includes project overview, detailed description, frequently asked questions, project status, and resources. Links to resources include the positional quality control reports by county for this project, state standards for orthoimagery, the business plan for orthoimagery, and issue papers generated by the project team. CGIA notified local GIS contacts about the establishment of the project pages and about release of the new imagery in the Geospatial Portal. The NC OneMap website also offers data download for GIS datasets and pre-2010 imagery, as well as a web map viewer, a GIS Inventory, and various resources for GIS users.

6.4. Outreach to Professional Organizations and Other Data Users

With the purpose of reaching users of orthoimagery who will benefit from the project, CGIA and the Project Team participated in meetings of professional organizations to convey the scope, approach, and benefits of the project. The team presented project explanations and updates to organizations that included the NC Chapter of the National Emergency Numbering Association, NC Property Mappers Association, Carolina Urban and Regional Information Systems Association, NC Arc User Groups (western and eastern), and the NC State Data Center Annual Meeting. CGIA provided updates during a series of teleconferences for PSAPs by the NC 911 Board. The Land Records Management Program in the Secretary of State's Office held a series of workshops in 2010, including presentations by the project team. Other forums included the NC GIS Conference in February 2011. CGIA also presented a paper on public access to the new imagery to the Esri International User Conference in July 2011.

6.5. Project Reports

The project team was responsible for reporting progress on a regular basis to the Executive Director of the 911 Board and the City of Durham.

6.5.1. Reporting for Submission of Invoices and Project Status to CGIA

The NC Floodplain Mapping Program submitted weekly progress reports and invoices to CGIA. The progress reports included status and percent complete for the following:

1. Validation Range and CORS Upgrades
2. Flight and Ground Control Plan
3. Survey and Ground Control Targets
4. Image Acquisition
5. Aerial Triangulation
6. Image Processing
7. Quality Control
8. Data Transfer

6.5.2. Reporting Project Status and Invoices to City of Durham/911 Board

CGIA submitted a status report monthly to the City of Durham and the 911 Board. The report included the following:

1. Accomplishments for the month
2. Status of major tasks
3. Expenditures for the month and cumulative expenditures and balance for the project
4. Tasks for the next month
5. Technical or financial issues affecting the project timetable

7. Procurement

The magnitude of this project required engagement of private contractors for their expertise and resources. The large amount of data required investment in information technology to support and improve public access to the new imagery.

7.1. Contracted Services

GTM used its Qualifications-Based contractors, already under contract for engineering and technical services, to perform image acquisition, processing and quality control. The Program also used a current contract with the NC Geodetic Survey to implement the horizontal quality control. NC Geodetic Survey conducted a new Qualifications-Based Selection of seven contractors to assist the Geodetic Survey in quality control. All of these services were included in a contract between GTM and the City of Durham.

In addition, the City of Durham contracted with CGIA to manage the project, deliver products to the counties, and provide online access to the imagery datasets.

7.2. CGIA Staffing Supplement

CGIA engaged four ITS supplemental staffing contractors at strategic times to provide technical assistance to staff currently in CGIA's Professional Services Program.

7.3. Portable Drives

The GTM contractor responsible for visual quality control acquired 100 portable drives for transferring datasets to CGIA. In addition, CGIA acquired a second set of 100 portable drives for distribution to counties. After the county deliveries, CGIA acquired additional portable drives to distribute copies to 25 non-county PSAPs and for data sharing with state and federal partners and for temporary back-up purposes. CGIA also purchased a "GeoPortal Jumpstart" from Esri along with 20 hours of technical assistance to take advantage of GeoPortal Server software available under the State of North Carolina Enterprise License Agreement. The services included training, configuration, and customization to enable efficient implementation of a new Geospatial Portal for NC OneMap, featuring the 2010 orthoimagery for public access.

7.4. NC OneMap IT Infrastructure / Hosting Services

CGIA completed a Technical Architecture System Design with the assistance of ITS, and based on the plan, procured new servers hosted by ITS Hosting Services (February 2011) for storing and serving 2010 orthoimagery. The following diagram (Figure 8) shows the hardware in service for the project.

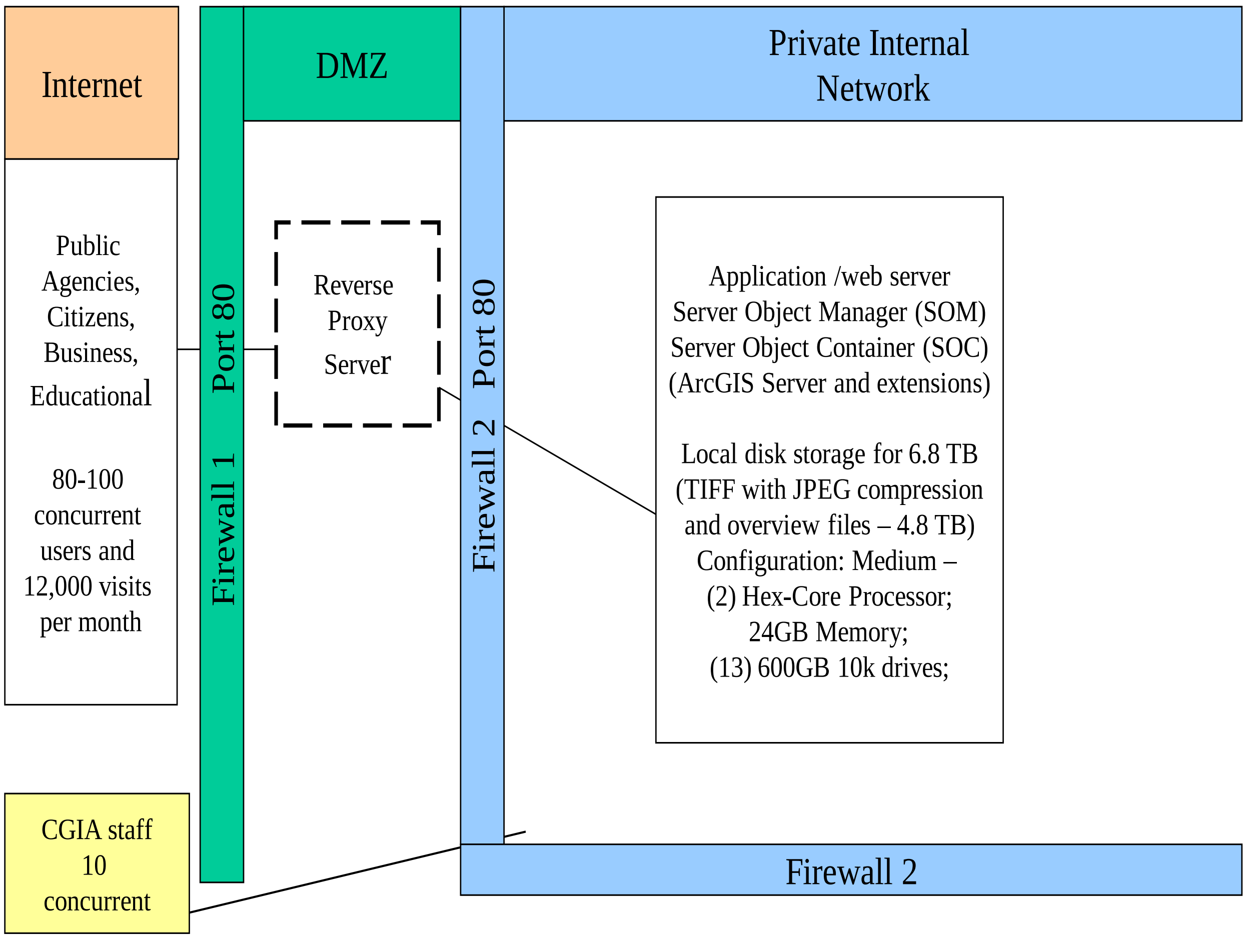

Figure 8. CGIA Servers for the Statewide Orthoimagery 2010, Hosted by ITS

8. Workflow for Product Verification and Distribution

Part of CGIA's role as overall project manager included verification of the deliverables from GTM's contractors and distribution of final datasets to 100 county PSAPs and 25 non-county PSAPs.

8.1. Standard Operating Procedure for Product Verification

CGIA developed a custom standard operating procedure based on the technical plan for quality control for the contractor to GTM and on experience in quality assurances in orthoimagery projects in partnership with the USGS. The procedure was valuable in getting the four ITS contractors trained and ready to verify products. In addition, CGIA built desktop tools for validating file types, file counts, file names, and other aspects of the products.

8.2. Product Verification Workflow Details

The workflow for product verification involved several steps. Each imagery tile (representing 5,000 by 5,000 feet on the ground) was produced in GeoTIFF format by one of the imagery acquisition contractors. Some 59,000 tiles were submitted by the acquisition contractors to a third-party contractor for visual quality control. Quality issues were identified by the third party contractor and resolved by the responsible acquisition contractor in a process managed by GTM.

After acceptance by the third-party contractor and GTM, the third-party contractor compressed the tiles using MrSID software and assembled county packages (each on a portal disk drive supplied by the contractors) using the following steps in this approximate sequence: (1) select GeoTIFF image tiles that intersect the county boundary for the recipient county and copy to a folder; (2) select the compressed (MrSID) image tiles that intersect the county boundary and copy to a folder; (3) create a mosaic (single composite compressed file) of all the selected tiles for the county and copy to a folder; (4) edit and copy metadata records to a folder; (5) copy other files (tile index, flight lines, AT reports) to a folder; (6) identify all counties that are adjacent to the recipient county and select, in turn, select compressed (MrSID) tiles that intersect the selected county boundary and copy to a folder on the recipient county drive; (7) copy the county mosaic for each of the adjacent counties to a folder on the drive; (8) copy respective metadata records for the adjacent counties to the drive; (9) deliver the assembled drive for the recipient county to GTM; and (10) transfer the drive to CGIA for verification and final packaging.

Upon receipt of a county portable drive from GTM, CGIA began its standard operating procedure to verify the drive contents, copy the drive (to be retained by CGIA) to a portable drive destined for the recipient county, verify the contents of the copy, inspect the visual quality of selected tiles, identify quality issues and report issues to GTM, edit metadata records to include CGIA process steps and to provide multiple metadata formats, receive quality resolutions (repaired tiles) from GTM, and finalize the portable drive for delivery to PSAP recipients.

CGIA also conducted a 90-day process for local review of visual quality that included telephone contact, file transfer, and tracking issues (see Section 8.4). For tiles that did not meet visual quality expectations (in both the CGIA inspection and the local review), GTM coordinated the resolution of issues with the acquisition contractors. CGIA was responsible for distributing final resolutions to county recipients and for replacing tiles on the NC OneMap server.

8.3. Distribution of Products to Counties

Each of 100 counties received a portable disk drive with orthoimagery in GeoTiff and MrSID formats, elevation data if modified for the project, metadata, a tile index, county mosaics of compressed imagery, and other information. The recipients were the PSAP contacts. CGIA's county GIS contacts were notified secondarily. The products were distributed in a series of 26 regional meetings across the state between February and April 2011. Each meeting included a cluster of 3-5 counties (see Figure 9). Meetings included an overview, product details, technical notes, and delivery of one portable drive per county. After the meetings, CGIA made and distributed copies of the portable drives to 25 non-county PSAPs for their retention.

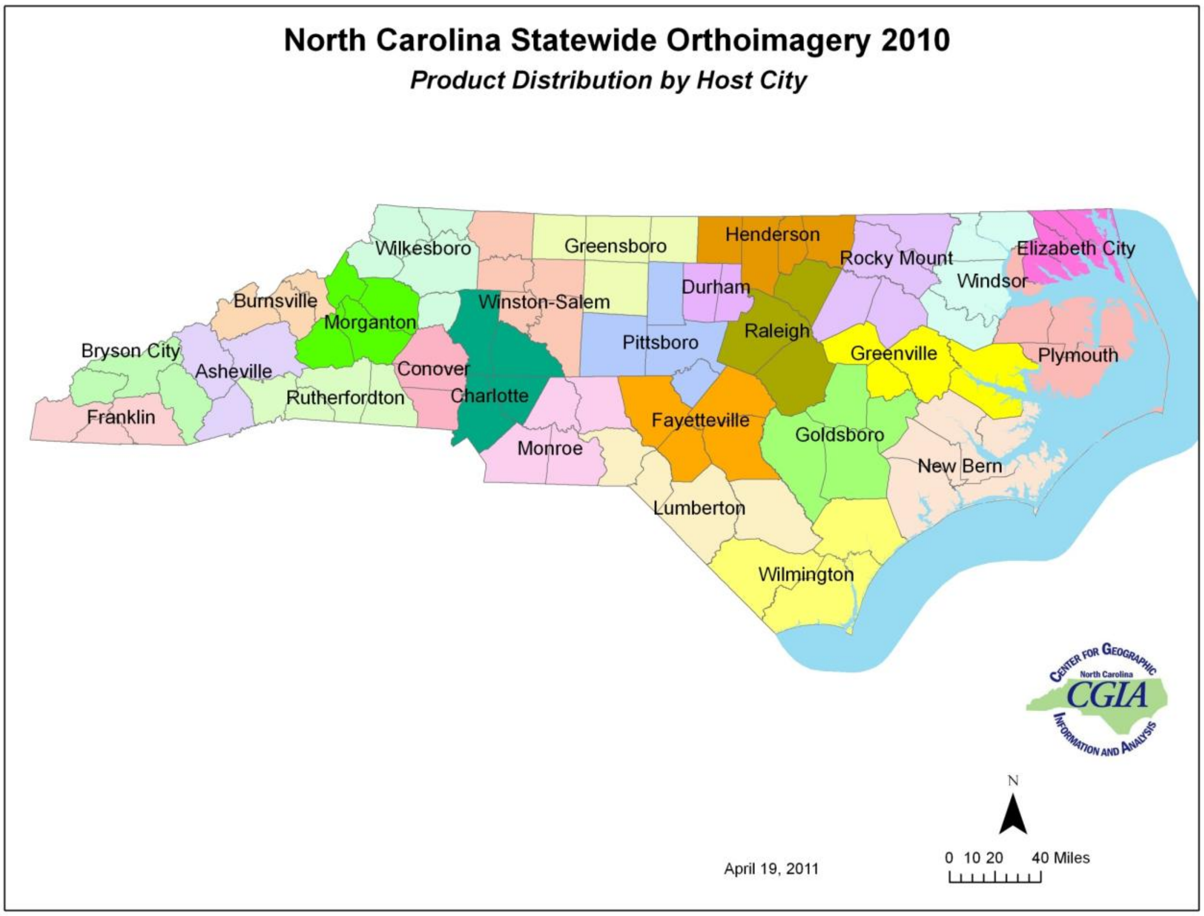

Figure 9. Clusters of Counties and Workshop Locations for Delivery of Orthoimagery to PSAPs, 2011

8.4. Quality Review by PSAPs and Local GIS Operations

CGIA followed up with the data recipients to assure quality. Counties had a 90-day review period for submitting issues and comments to CGIA. The process included review of issues by the Project Team, resolution of issues, and distribution of revised imagery tiles. Counties did a thorough job and discovered a few issues that were not seen in the third-party and CGIA visual quality review processes. Less than 100 resolutions statewide were completed and transferred to the PSAP recipients.

Other comments from data users included confirmation that the imagery was ready to apply in computer aided dispatch (CAD) systems for PSAPs. CGIA learned of two exceptions where (1) a PSAP had unsupported CAD software that was too old to accommodate the version of the compressed imagery and (2) a PSAP with CAD software that was no longer supported by a vendor and could not use the state plane coordinate system. A work-around assisted by CGIA was successful for the first exception, and acquisition of new CAD software was the intended solution for the second exception.

8.5. Sharing Products with State and Federal Partners

The USGS, through its Earth Resources Observation and Science (EROS) Data Center, is the primary federal agency for sharing imagery files (via portable drive) among federal geospatial data users. EROS will accept copies of the 2010 imagery for application in The National Map and for retention in their data storage facilities. During 2011, CGIA shared selected imagery copies with the NC Division of Forest Resources for forest fire response in Dare County and with NCDOT for images of bridges proposed for improvements with federal funds.

8.6. Loading Data into NC OneMap Database/IT Solution

Imagery and related geospatial data were be loaded into the enhanced information technology solution for NC OneMap. The files loaded to the server were TIFF with JPEG compression for the best combination of performance, file size, and versatility. Total disk storage space is approximately 2 TB for the files. The native format (GeoTIFF) tiles totaled 17 TB of disk storage space. They were not loaded on the server, but are retained by CGIA on portable disk drives.

8.7. Implementing Data Download for New Imagery

The compressed imagery files are accessible for download through the NC OneMap Geospatial Portal. A custom download function enables users to download up to 20 tiles per request (or approximately 20 square miles), with email notification and a link to a zipped file containing the requested imagery.

9. Enterprise Project Management

9.1. Project Charter

CGIA prepared and submitted a Project Charter to initiate the Project Portfolio Management process in consultation with the Enterprise Project Management Office (EPMO).

9.2. Monthly Status Reports

CGIA submitted monthly status reports through the Project Portfolio Management tool in consultation with EPMO.

9.3. Approvals for Phases of Project Management

CGIA received approvals for Gate 1 (Planning and Design), Gate 2 (Execution and Build), Gate 3 (Implementation), and Gate 4 (closeout). The operation and maintenance phase began in August 2011. Documents related to Project Portfolio Management included a project plan and a staffing and financial plan.

10. NC OneMap

Implementation of public access to the statewide 2010 imagery was successful and timely. Technical advice from both ITS Hosting Services and the software vendor for image serving software (Esri) was invaluable in achieving expectations for system performance for both image services and data download. On-site technical assistance from Esri was instrumental in achieving the June 2, 2011 milestone for implementation of public access.

CGIA's recommendation for future imagery projects is to update the system in place, add server capacity in a way that will enhance reliability of public access, and explore storage options to support the recommended annual quarter-state acquisition of updated orthoimagery.

The NC OneMap implementation of imagery services for new 2010 orthoimagery is focused on the goal of the NC Statewide Orthoimagery 2010 Project: "to create a statewide image of North Carolina to support accurate, timely and effective placement of 911 calls in correct locations." The fifth of six objectives in the Project Plan guides the implementation strategy: "Realize the full potential of the NC OneMap data clearinghouse for organizing and providing access to statewide, high-resolution imagery." The NC OneMap information technology enhancements were focused on that objective, with priority on free, fast access to imagery services and downloadable files. ITS provisioned a physical server for CGIA to store the 2010 imagery and enable imagery services and file download. The server is a Medium W2K* with 7.2 TB local with this configuration:

> Medium **-** (2) Hex-Core Processor; 24GB Memory; (13) 600GB 10k drives; DVD-RW; (2) Integrated EN Ports; RDP; Server Management; 4-year, 24x7 4-Hr HW Warranty Support, Netbackup 6.8TB

The software for imagery is ArcGIS Server 10. The NC OneMap staff reviewed recommendations from Esri for best practices in serving imagery, considered the project requirements, reviewed performance metrics based on the server model and networks, and carried out the following strategy to best serve users of statewide 2010 imagery.

CGIA converted GeoTIFF imagery county by county to TIFF with JPEG compression to reduce tile size from about 300 MB to about 25 MB each. The advantages of TIFF with JPEG compression when compared to MrSID format are:

- faster performance of imagery services (ArcGIS Server does not uncompress the TIFF tiles for imagery services as it would for MrSID compressed tiles),
- efficient server re-projections and formatting to meet user requests

CGIA did not create a cache, the fastest performing imagery format. The disadvantage of a cache is that it is created in one projection with a predetermined set of scales, thereby dictating rather than responding to, users' needs. Creating a cache of statewide imagery would require about 5 TB of disk storage space (2.5 times that of the source imagery), resulting in an increased cost to the project. The advantage of a cache is speed in rendering for users that require imagery in the set projection. For example, a cache in the Web Mercator Spherical projection would be directly compatible with many popular web applications.

Taking advantage of these gains in flexibility comes at the cost of increased file size. The statewide collection of imagery in the MrSID format is estimated to be approximately 1 TB. Using TIFF with JPEG compression will increase the storage requirement to approximately 2 TB (using the maximum recommended compression rate of 80).

CGIA configured the image service to allow download of up to 20 tiles (equivalent to about 20 square miles) in a user defined area in one request, amounting to a maximum of about 500 MB per request.

For purposes of 911 communications, the image service solution implemented on NC OneMap is a versatile format and it is meeting performance expectations. System performance during the first three months of operation indicated that average processing time was two seconds or less, meeting goals for system transaction times.

11. Recommendations for Future Projects

The purpose of this section is to identify the most valuable tools, techniques and procedures in this project as well offer observations about constraints, dependencies and complicating factors, and make recommendations that will improve future orthoimagery projects. While the project was a successful collaboration that produced the required products on time with high quality and within the project budget, this was the first statewide orthoimagery project in North Carolina and it leaves room for improvement. This section describes several ways to use the knowledge gained on this project to make future projects as efficient, effective and successful as practical.

The first section of this document focuses on specific or common observations and proposed recommendations for planning. Attachment 1 makes some more general conclusions regarding coordination.

11.1. Planning

11.1.1. Standards and Specifications

Imagery, developed for the State Orthoimagery 2010 project, including GeoTIFF and MrSID format, is referenced to North Carolina State Plane Coordinate System, NAD83 (NSRS2007) North American Datum. The *NC Technical Specifications for Digital Orthophoto Base Mapping* from the Land Records Management Program in the Secretary of State's Office (2009) provides detail. Questions regarding this datum were among the most common presented during the course of the project. For that reason, CGIA included explanations and suggestions to PSAPs and GIS coordinators in the delivery and distribution meetings.

The first consideration is the realization that the 2007 datum is not supported by ArcGIS software version 9.3. Therefore, it should be noted that, attempts to re-project other vector data into the same projection as the imagery will not occur because the NSRS2007 North American Datum is unknown, or considered null, by the software. This same principle applies to version 10 with the exception that the projection is included in Esri's library but does not contain transformation parameters. The following is an excerpt from ArcGIS version 10 user documentation that clarifies this point:

> "All existing control points except the CORS stations were updated and are now labeled NAD 1983 (NSRS2007). The official name of the readjustment is National Spatial Reference System (NSRS) of 2007. For most of the United States, the differences between HARN coordinates and NSRS2007 are a few centimeters. *Because of this, no standardized transformations have been calculated and published to convert between NAD 1983 (NSRS2007) and earlier realizations of NAD 1983."*

The nearest equivalent datum to NSRS2007 is North Carolina State Plane Coordinate System, NAD83 (HARN or NSRS2001) North American Datum which is supported by Esri software. The following are worthy to note:

- On average statewide, the difference between the 2001 HARN and NSRS 2007 datum is approximately one/tenth of a foot which is within the acceptable range of the two feet RMS error threshold defined by the North Carolina technical specifications for digital ortho base-mapping.
- To accommodate re-projection "on the fly" within the Esri ArcMap interface, a raster catalog was recommended. A raster catalog, defined by the HARN projection, can be used to assign all GeoTIFFs and/or MrSID images to the catalog, thus creating a known output to facilitate re-projections. The catalog offers the convenience of adding a single source layer to ArcMap as opposed to individual raster layers.
- The catalog is not mandatory; however, it does serve to provide a means for re-projecting existing data and as a tool for convenience. In addition it provides a comparable equivalent datum to NSRS 2007. Finally, it also serves as a method for defining the projection for the GeoTIFF format (see below).

The second is the inability of ArcGIS Version 9.3 to interpret the GeoTIFF projection header. Projection headers are common for storing projection data in raster formats. However, the particular structure utilized for this project and/or defined by the state standards, is not readable by ArcGIS version 9.3. If the end-user runs version 10, there is no issue. It should be noted, in 9.3, in the absence of a catalog and a data frame defined by a projection not equal to North Carolina State Plane Coordinate System, NAD83 and/or units other than feet, overlay and proper alignment of the GeoTIFF imagery will be incorrect. This is not the case for the MrSID format as its header is supported by version 9.3.

11.1.2. Aerotriangulation Block Boundaries

Figure 10 represents the aerotriangulation (AT) blocks boundaries utilized for the project. The boundaries serve two primary functions. One is to assign required study areas to each contractor to facilitate AT quality review (see Attachment 2 for additional documentation). The other is to define the areas that required county deliverables are a subset of. It is the observation that large blocks hamper the schedule for product release per county. AT quality review at the block level dictates multiple counties being released at once. It is the recommendation that block boundaries be further sub-divided to facilitate a more fluid schedule of delivery at the county level. At the same time, it is also a recommendation that the block boundaries align with tiles to insure that a contractor's block requirements align with the required county tiles.

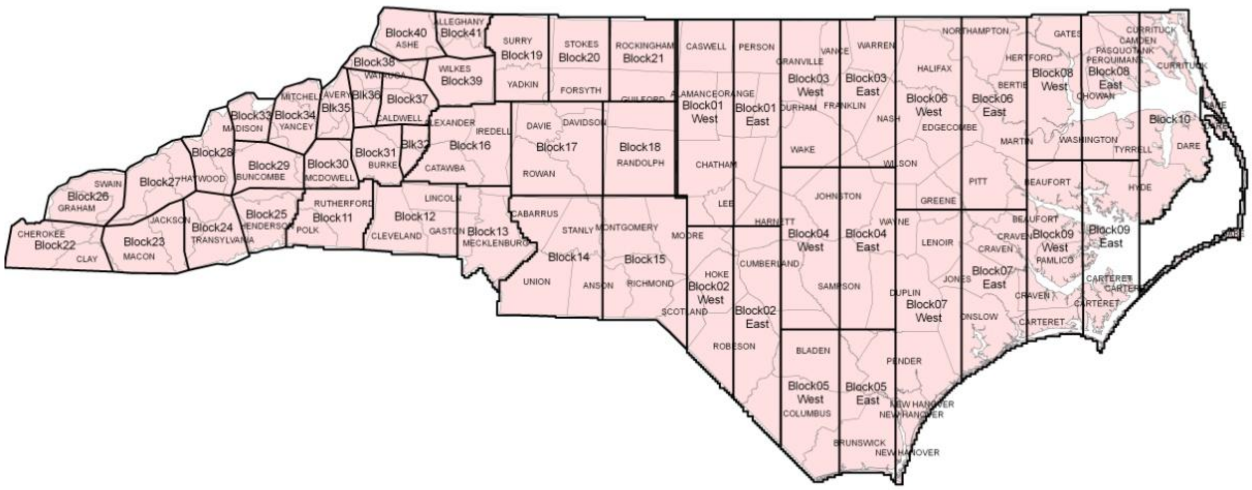

Figure 10: AT Block Boundaries

11.1.3. Validation Range

The new validation range established in Surry County enables systematic validation of digital sensors and processes to assure quality before imagery acquisition. Attachment 3 discusses this topic in detail.

11.1.4. Military Coordination

Figure 11 represents the 13 areas of military strategic importance recognized by the project. With the exception of Harvey Point in Perquimans County, all areas were flown and data collected. Harvey Point was targeted as a no-fly zone which includes a significant portion of Perquimans County. The project requirements were such that tiles impacted and/or "intersected" by installation boundaries were excluded from delivery. At a follow-up meeting with military officials, approval for release was secured, but with many exceptions:

- Data clipped to the installation boundary:
  - Ft. Bragg and all Marine Corps locations
  - Camp McCall
  - Sunny Point in Brunswick
- Full release covering installation or range:
  - Sunny Point in New Hanover County
  - Dare Bombing Range
  - Seymour Johnson Air Force Base in Wayne County
- Full release with limitations
  - Fourteen Coast Guard strategic locations were allowed at full release delivery to the County PSAP
  - Release was secured on NC OneMap with a request that the fourteen locations be blurred and airplanes and boats removed

The project team observed that the exclusion from publication of whole 5,000 by 5,000-foot tiles that intersect the boundaries of a military installation necessarily leaves out significant portions of civilian property. That has an impact on 911 call answering and response as well as local and regional planning. The solution of trimming tiles to installation boundaries brings the adjacent civilian land into view and is a more beneficial outcome to users. The exclusions, even when trimmed, create a significant amount of work for a project team in change management, follow-up data releases scheduling, logistics, server updates, and potential confusion for users.

It is recommended that the project team secures a senior level point of contact (POC) that represents each branch of the military early in the planning process. Workshops with each POC should be conducted including standard documentation for a consistent method, location, intent, and approval process.

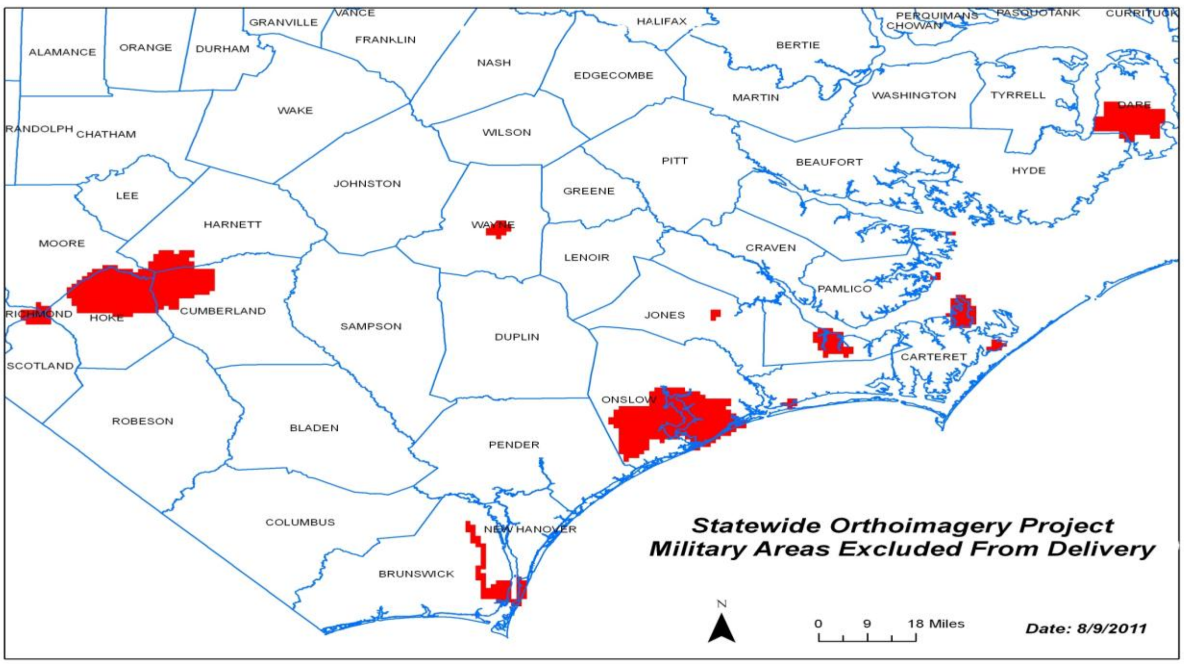

Figure 11: Location of Military Installations

11.1.5. Coordination and Requirements Definitions

A definition of data requirements was a critical component in the success of this statewide project. At a minimum, the following key datasets were valuable to the project team, and county data recipients.

1. NCDOT's 2009 statewide county boundary
2. The statewide ortho tiling scheme
3. Strategic offshore resource locations
4. State boundary
5. County boundary file inconsistencies between local and state sources
6. NOAA imagery resources

Items 4, 5, and 6 represent areas in need of improvement, expansion, or re-evaluation. Regarding Item 4, a 2,000-foot buffer for imagery was set around the state boundary. For technical reasons, mainly those defined by flight lines, the actual distance captured in final tiles and amount of deliverable data varied depending on the location. In addition, a significant number of tiles contained very little "usable" data once again depending on the location. Finally, the state boundary is not precise enough to use for selection of final tiles or clipping of tiles. Border counties are accustomed to some imagery beyond the borders, particularly for 911 communications. It is the recommendation that a wider buffer be established that yields value-added content outside the state.

Regarding Item 5, the consistent comment received during distribution and the 90-day review cycle was that additional tiles should be provided for each county and/or the resulting mosaic. The primary reason for this is that county boundaries used in county GIS operations may differ from those used in a neighboring county and from those compiled statewide by NCDOT. In addition, in some instances, counties maintain jurisdiction over property just outside of the county boundary. Finally, in coastal communities, the method for determination of the tile deliverable was that the 2,000-foot buffer be placed on shoreline data. In several situations, this method was questioned because it was vague, where a "shoreline" terminated and where the county intersection rule would apply. It is the recommendation that a consistent buffer be applied to each county.

Regarding Item 6, the majority of data occupied by the sounds and open water was not flown or provided by the contractors. To supplement this, existing NOAA imagery data was utilized (Figure 12). In the event NOAA data did not exist, an alternative was developed where a NOAA tile would be copied and its coordinate altered to fill in gaps. It is the observation that the value for logistics to acquire large expanses and well as administer the storage capacity (150 GB) does not exceed the benefit which is to display background data for cartographic purposes. It is recommended that a wider buffer be placed on the coastal land that would facilitate coverage in the smaller inlets. It is also recommended that the NOAA data be retained as a supplement for future projects.

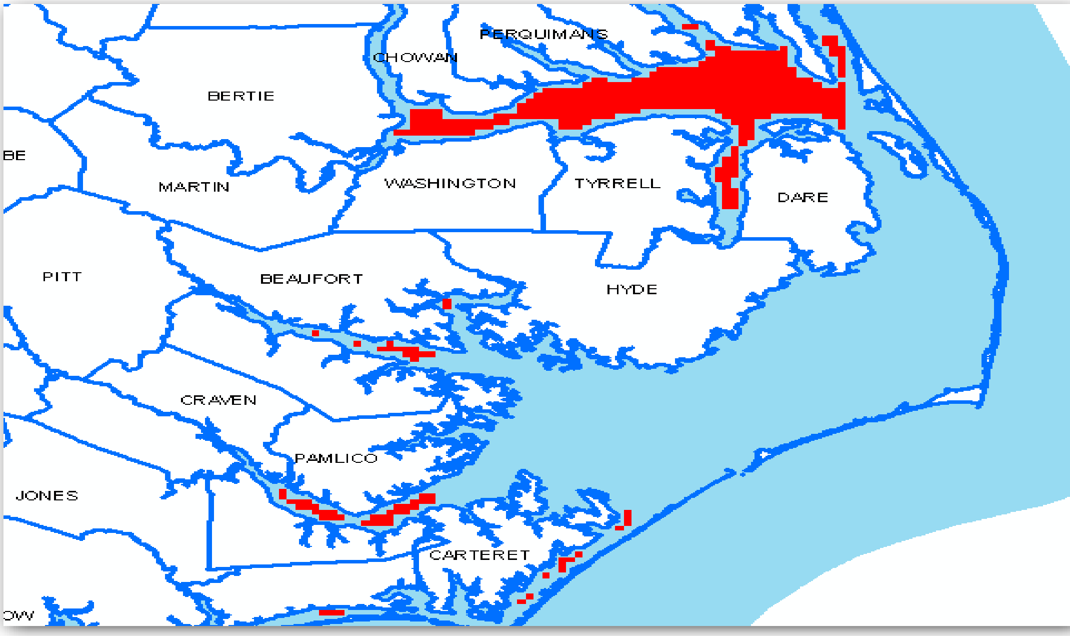

Figure 12: Supplemental NOAA coverage

11.1.6. Communications

Microsoft SharePoint was utilized for weekly status reports and proved to be a streamlined approach for data sharing, project documentation, and a central means of accessibility. This includes the use of the site for posting 90-day issues documentation and as a repository for contractor's documentation for resolutions. It is the observation the site was underutilized until the 90-day review when it was used more intensively. It is the recommendation that a more defined SharePoint structure be developed as a means to provide extended access to data and documentation and as a documented source of data requirements.

11.2. Workflows

11.2.1. Visual Quality Control and Production

The project visual quality review workflow was defined by a linear progression of stages that commenced with initial product delivery by the Vendors. Each stage of review served to satisfy conditions for milestone completion or to focus attention on documented issues to be resolved by the vendors. The following are general descriptions of the review levels:

Upon receipt of the ortho-rectified GeoTIFF product from a contractor, Fugro EarthData (a third-party contractor) inspected and evaluated 25 percent of the tiles applicable to a county. The primary visual quality focus was on seamlines, inconsistencies, and distortions. Attachment 4 provides details of this process as well as recommendations. Following acceptance of the GeoTIFF tiles, Fugro EarthData developed one (1) 20:1 compression of each tile and one (1) 50:1 compression mosaic (all tiles combined) products in MrSID format and assembled files on portable drives for submittal to CGIA.

CGIA performed a visual quality control of five percent of the tiles by county that focused primarily on visual observation, strategic points of interest, color balancing, feature mis-alignment and other guidelines. Issues were submitted to the contractors for remediation. CGIA completed additional quality review of metadata and supporting documents including QC reports and AT reports. Upon acceptance of all products, CGIA performed final packaging, including document and data deliverables, on portable drives for distribution to the 911 PSAP recipients.

In February 2011 the project team implemented an additional level of visual quality review referred to as the 90-day review period. CGIA enlisted the services of points of contact in each of the 100 counties to perform a final quality review within a 90-day period of receipt of their delivery product. To facilitate this, CGIA developed an internal database tracking methodology where a screening review was performed in-house. If issues were deemed to be valid they were submitted to the contractors through a consistent reporting means.

Based on experience in this project, CGIA observed that the following should be considered areas of improvement, expansion, or re-evaluation:

- Prior to release and acceptance, the contractors should be required to perform a macro level quality review to demonstrate adequate seamless color balancing across small scale regional areas. This will reduce the potential for systematic color issues to be sent back to the contractor.
- A number of observations were received across the state about small areas of localized blurriness that were later deemed to be issues related to the sensor used for the project. Investigating workarounds or upgrades to the sensor that could alleviate this issue should be investigated for future projects.
- In a few of the state’s most urbanized city centers there were a few instances of building distortion or lean caused. For highly urbanized areas (i.e., Charlotte, Raleigh) it could be beneficial to have additional or more densely packed flight lines over these areas to minimize off-nadir lean.
- The file format throughout the review process should be limited to GeoTIFF format, and MrSID generation should be held until all review resolutions have been completed. This will avoid multiple instances of file compression and the related file handling.
- An advanced method of product review would reduce file and portable drive handling by the quality review parties. A recommendation is to either (1) load GeoTIFF files directly into an internal image service to facilitate data access for reviewers or (2) stage the GeoTIFFs on an internal image service maintained by the contractors.
- An alternative methodology to reduce “early” packaging should be considered where supporting documents such as reference data, reports, READMEs, metadata, etc., are not packaged on county drives until the primary image products have been

accepted as ready for delivery. An alternative method of centralization is described in section 11.2.3.

Figure 13 displays a work flow including the recommended process improvements. This workflow is defined by the organization of varying levels of visual quality review grouped by different stages.

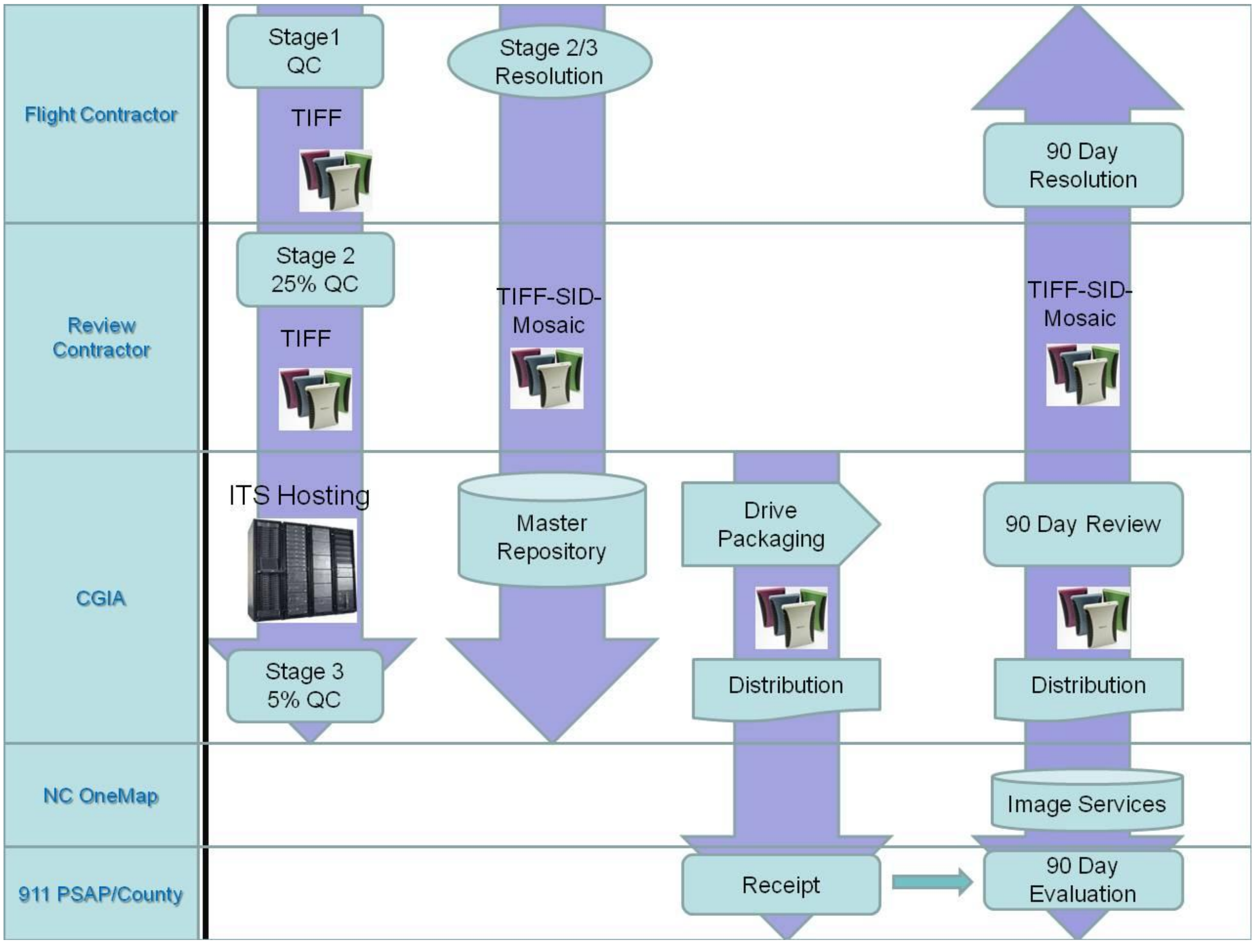

Figure 13: Alternative quality review process flow

In addition, it is worthwhile to note the following recommendations:

- A recurring topic in comments and requests from PSAPs and GIS operations was the value of a 50:1 compression mosaic. It was the consensus, from practicality as well as a means to facilitate mobile 911 applications, to consider a higher compression ratio of 1:100 for a mosaic that requires less disk storage space.
- Finally, a known issue was reported, by the MrSID software vendor Lizardtech, for file compression that addressed a white background/pixel issue that resulted when overlaying multiple mosaics (see Attachment 5). It is the recommendation this issue be re-visited in the future.

11.2.2. Issue Resolutions

To summarize the quality review process, issues identification, submittal, and resolutions can be grouped into three distinct phases: The 25% inspection, the 5% inspection, and the 90-day review. As the project progressed, CGIA and GTM recognized certain areas of improvements that were implemented during the 90-day and are worth noting:

- A standard document for visual quality issue submittals should be consistent among all parties.
- A single SharePoint repository, used for weekly status reports, should be used also for issues submittals and responses to issues from contractors.
- Embed all requirements for evaluation of issues into the document (e.g., scale, ID, image name, etc.) in the event the snapshot of the issue becomes separated from the description or location.
- Develop a more defined turnaround lag, during production and 90-day review, for delivery of revised imagery tiles that satisfy quality issues. This will help keep product distribution on schedule. Setting required timelines prior to data distribution will eliminate any potential for resolutions to be posted after the delivery. Similarly, instilling tighter restraints on 90-day reviewers will eliminate schedule lag as the project nears completion.
- Develop a more comprehensive tracking methodology for issues approval and rejection, i.e., a more efficient means to determine when and if resolutions get delivered. For example, in some cases, issue resolutions were better postponed until after the 90-day review. In addition, it would be useful to maintain a dynamic shapefile for the locations of resolutions for purposes of status mapping, documentation, and reporting.

11.2.3. Data Packaging

NC Geodetic Survey was responsible for developing horizontal quality reports for each county. Those reports were ultimately stored on a common single source website for download, linked to the project page on NC OneMap. It is the recommendation to develop a similar method for all supporting documentation and data exclusive of the imagery. This data includes reports, supporting shapefiles, metadata, and all other supporting files required for distribution.

11.2.4. Metadata

Finally, it is the observation that the processes for the development and quality review of metadata could be more efficient. Quality and efficiency would be enhanced by use of a common automated interface for validating metadata records by all of the responsible parties. The proposed interface is the USGS Metadata Validation Service: (http://geo-nsdi.er.usgs.gov/validation/.

12. Acknowledgements

This project owes its success to effective collaboration among public agencies and private service providers. The project team would like to recognize the following participants for helping keep the project on task, on time, and within budget to the benefit of all.

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2. NC 911 Board: George Bakolia (Chair), Richard Taylor (Executive Director) and Ron Adams
3. Geospatial and Technology Management Office in the Department of Crime Control and Public Safety: John Dorman, Hope Morgan, and John Lay
4. NC Geodetic Survey in the Department of Environment and Natural Resources: Gary Thompson and Steve Kauffman
5. Land Records Management Program in the Office of the Secretary of State: Tom Morgan
6. NC Attorney General's Office: Richard Bradford
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    - System Architecture and Security: Don Jerman and Doug Banich
    - Procurement and Contracts: Sandra Rosser and Jennie Elias
    - Supplemental Technical Staff: Tom McKay, Nichole Krist, Sarabjeet Kaur, and Smitha Ramakrishnan
8. Statewide Mapping Advisory Committee, Working Group for Orthophotography Planning:

    Anne Payne, Gary Thompson, Keith Johnston, Don Early, Dan Madding, Julia Harrell, Sean McGuire, Tom Morgan, Allan Sandoval, Steve Strader, Steve Randone, Chris Koltyk, Jerry Simmons, Hope Morgan, and Jeff Brown
9. Private service providers included prime contractors (AMEC and ESP Associates), acquisition contractors (PhotoScience, Sanborn, Surdex and Aerometric), quality control contractors (AECOM, Arcadis, Concord Engineering, Joyner Keeny, Stantec, WK Dickson, Withers & Ravenel, and Woolpert), software vendor (Esri), and numerous subcontractors.
10. Finally, thanks to CGIA staff for their persistence and attention to detail: John Derry, Alec Bethune, Sharmila Gogusetti, Brett Spivey, David Giordano, Denise Young, Faye Jones, Tom Tribble, Joe Sewash, Darrin Smith, and Jeff Brown.

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13. Appendix A: Definitions

Aerial Photography

Aerial photography is any photography taken from the air. Typically, aerial photographs are taken with specialized, high-quality, large format cameras that point down vertically from the aircraft to the ground below. Orthophotography is derived from overlapping vertical aerial photography. Digital cameras are becoming more prevalent than film cameras for projects in North Carolina.

Aerial Triangulation

The primary purpose of aerial triangulation (AT) is to compensate for errors in ground positioning of the imagery. GPS positional data is processed against the stationery GPS base stations established throughout the project area. Also, data from the sensor (camera) is processed to provide the continuous orientation and position of the sensor throughout the flight of the aircraft. The orientation and position is used with the raw imagery data to produce a georeferenced image. The triangulation process involves multiple viewing angles and point matching to produce a network of image points. Ground control points are also integrated in the processing to produce imagery that fits the terrain within accuracy specifications.

Color Infrared (CIR)

A "false color" film type which senses information in the green, red, and near-infrared portions of the spectrum. On CIR imagery, near-infrared will appear as red; red will show as green; and green as blue. Blue is not detected. Commonly used for vegetative mapping, natural resource assessment, and environmental analysis. CIR depicts health of vegetation, soil moisture, and other environmental factors as well as impervious surfaces.

Continuously Operating Reference Station (CORS)

The National Geodetic Survey (NGS), an office of the National Oceanic and Atmospheric Administration (NOAA) National Ocean Service, coordinates a network of continuously operating reference stations (CORS). Each CORS site provides Global Navigation Satellite System (GNSS - GPS and GLONASS) carrier phase and code range measurements in support of three-dimensional positioning activities throughout the United States and its territories. Surveyors, GIS/LIS professionals, engineers, scientists, and others can apply CORS data to position points at which GNSS data have been collected. The CORS system enables positioning accuracies that approach a few centimeters relative to the National Spatial Reference System, both horizontally and vertically.

Datum

A set of constants specifying the coordinate system used for geodetic control, i.e., for calculating the coordinates of points on the Earth. This project uses the standard datum for orthoimagery in North Carolina: North America Datum (NAD) 1983 with the readjustment from 2007 (National Spatial Reference System (NSRS) 2007).

Digital Orthoimagery (DOI)

Digital Orthoimagery is a remotely-sensed digital picture, stored in a raster data format. It is a geo-referenced image prepared from a vertical photograph or other remotely-sensed data in which displacement of objects due to sensor orientation and terrain relief have been removed.

Digital Elevation Model (DEM)

Digital Elevation Model is a sample of ground elevations points used to model a land surface. It is a required element in the processing of digital orthoimagery based on the accurate identification of control points in the images whose ground positions are accurately known.

North Carolina has statewide elevation datasets derived from Light Detection and Ranging (LIDAR) technology.

Geographic Registration

Registration is the spatial referencing of an orthoimage to an area on the earth's surface. An image must be geographically registered in order to use it in a GIS as an overlay.

Global Positioning System (GPS)

A system of satellites, computers, and receivers that is able to determine the latitude and longitude of a receiver on Earth by calculating the time difference for signals from different satellites to reach the receiver.

Ground Control Point

Points of accurately known geographic location used to register imagery and other coverage data to ground position. In preparation for flights, white panels are placed in visible locations (ground control points) and their positions are surveyed and recorded. For quality control, aerial imagery contractors compare the geospatial location of the ground control points in the imagery to the recorded locations. Third party horizontal quality control may use the ground control points and other recorded reference points to check the accuracy of visible locations in the imagery.

Ground Sample Distance (GSD)

Ground sample distance is the area on the ground represented by each pixel in a digital orthoimage. The smaller the pixel, the more detail is visible in the image. North Carolina requires pixel of one-foot or smaller, and 6-inch and even 3-inch pixels are prevalent over urban areas. This project uses 6-inch GSD.

High Accuracy Reference Network (HARN)

The HARN is a statewide network of survey monuments measured to an extremely high level of accuracy with respect to, and as part of, a similar nationwide network of high-accuracy points. The positions of these monuments are established using Global Positioning System (GPS) and other sophisticated space-based measuring technologies. HARN is not expressed as part of the datum for this project (NAD 1983, NSRS2007).

Metadata

Metadata is information in standard format about the content, quality, and condition of a dataset. For imagery, metadata includes when and how images were captured from aircraft, processing, extent, contact information, and other items that inform users of the imagery products.

Multi-spectral

Digital orthoimagery collected in multiple bands, with each band corresponding to a portion of the spectrum. Various band combinations may be combined to assist in the identification of specific ground features, via automated image processing techniques.

Natural Color

Natural color is derived from three (red, green, blue) of the four digital bands captured by digital cameras. Commonly used for inventory analysis, cartographic verification, and data verification. Especially useful for showing man-made features, which typically occur in a wider range of colors than natural features.

Orthoimagery

An orthoimage is remotely sensed image data in which displacement of features in the image caused by terrain relief and sensor orientation have been mathematically removed. Orthoimagery combines the image characteristics of a photograph with the geometric qualities of a map. An orthoimage or orthophoto is an aerial photograph (or digital image) geometrically corrected ("orthorectified") such that the scale is uniform: the photo has the same lack of distortion as a map. Unlike an uncorrected aerial photograph, an orthoimage can be used to measure true distances, because it is an accurate representation of the earth's surface, having been adjusted for topographic relief, lens distortion, and camera tilt. Orthoimagery is commonly used in the creation of a Geographic Information System (GIS). Software can display the orthoimage and enable an operator to digitize or place line work, text annotations or geographic symbols (such as hospitals, schools, and fire stations).

Panchromatic

A film type which renders imagery as gray scale. It generally provides the best resolution and least amount of storage space.

Pixel

A pixel is a two-dimensional picture element that is the smallest non-divisible element of a digital image. For this project, a pixel represents 6 inches on the ground, and each 5,000 by 5,000-foot tile has 10 million pixels.

Positional Accuracy

This refers to the variation that can exist between coordinates for a feature on the image to the actual location of that feature on the earth's surface.

Public Safety Answering Point (PSAP)

A public safety answering point is a call center responsible for answering calls to an emergency telephone number for police, firefighting, and ambulance services.

Remote Sensing

The process of collecting data about objects or landscape features without coming into direct physical contact with them.

Scale

Scale is the ratio of distances on a map to those same distances on the earth's surface. Ground resolution relates to mapping scale. For example, a map scale of 1 inch on the map = 200 feet on the ground is equivalent to an image ground resolution of 6 inches (pixel size). A scale of 1-to-400 is equivalent to 1-foot resolution. A scale of 1-to-100 is equivalent to 3-inch ground resolution.

State Plane

A coordinate system (grid) of plane rectangular (x, y) coordinates for pre-determined zones in each of the 50 states. Local governments in North Carolina use state plane with map units in feet.

Tile

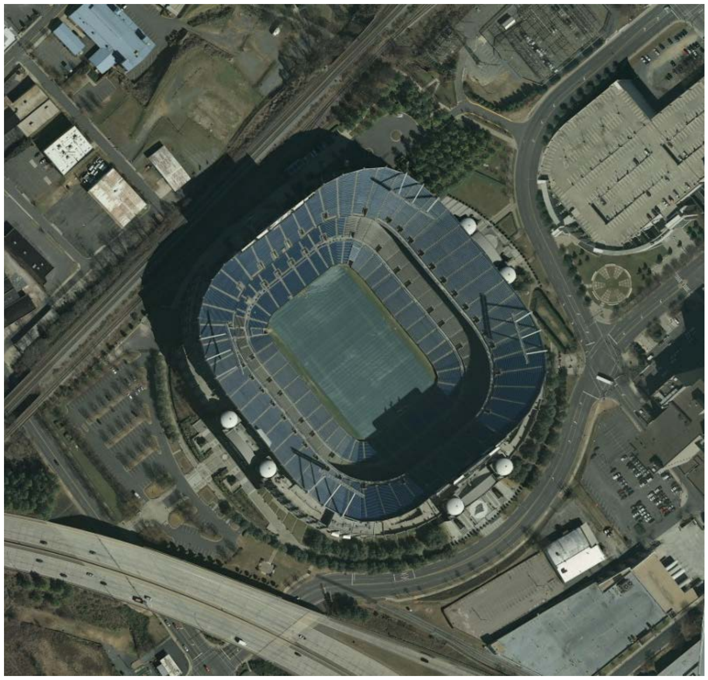
Images are subdivided into smaller units to reduce the physical file size and the amount of computer processing required. Tiles usually cover a regular rectangular grid. The tile size for 6-inch resolution images in North Carolina is 5,000 feet by 5,000 feet.

Sources: NC Center for Geographic Information and Analysis; adapted from New York State Geographic Information System Clearinghouse; the Federal Geographic Data Committee glossary; USGS metadata records, and various project documents.

ATTACHMENTS

Attachment 1: Coordination
Attachment 2: Aerotriangulation Quality Control
Attachment 3: Validation Range
Attachment 4: Orthophotography Review
Attachment 5: MrSID Mosaic

Attachment 1: Coordination



North Carolina Orthophotography Project

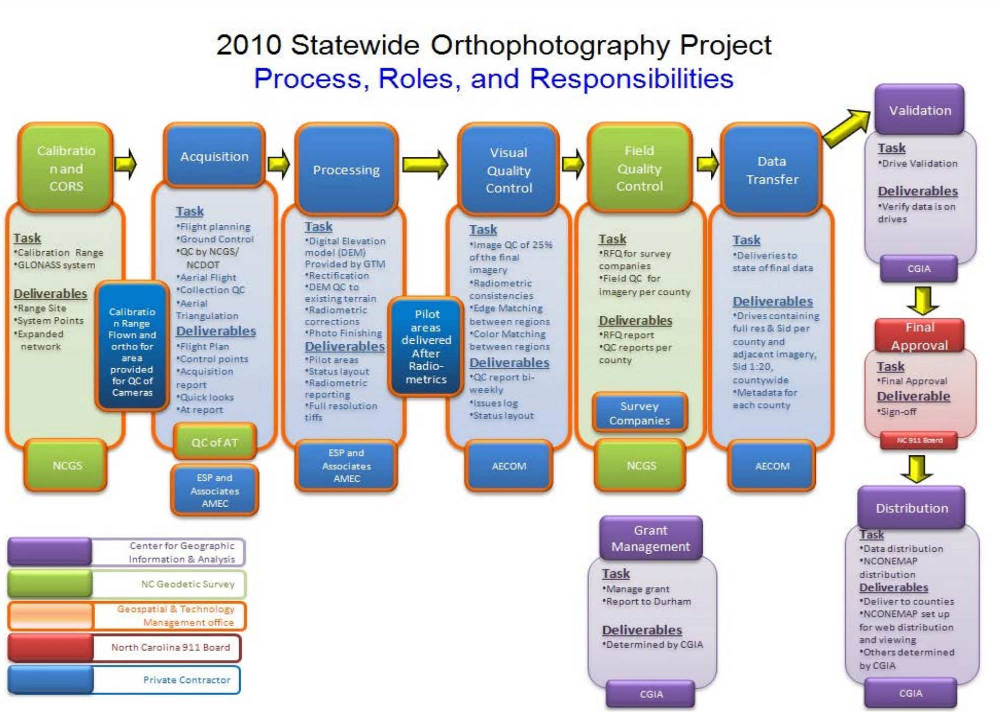
Issue Paper 3: Team Coordination and Cooperation

Background

In 2009, the North Carolina 911 Board awarded a grant of $12.3 million to the City of Durham's Emergency Communications Center for acquisition of statewide ortho imagery. The Durham PSAP concluded that a statewide project would maximize benefits in a timely way. The city of Durham requested help from the North Carolina Orthophotography working group within the State Mapping Advisory Council to assist with managing the collection of this orthophotography. The North Carolina Geospatial & Technology Management Office (GTM) undertook the acquisition management of this project to obtain new natural color digital aerial orthophotography for all 53,819 square miles of North Carolina at a 0.5-foot pixel resolution in one flying season. The primary goal of the North Carolina Orthophotography Project (NCOP) is to fulfill base layer requirements for local, state and federal uses, such as emergency response, floodplain mapping, and tax assessment. Due to the amount of labor required to complete this project, GTM divided the state into four regions. GTM utilized two prime contractors to collect the imagery, assigning each contractor two of the four regions, and the contractors worked with subcontractors to ensure that all of the required aerial orthophotography could be gathered and processed within the tight timeframe. Also included in this project was a validated quality control (QC) process to check the AT, QC for visual aspects of the imagery and QC for horizontal accuracy of the project. The collaboration on this project to deliver a seamless product in a year is a momentous task. Below we will discuss the process for coordinating the contractor teams required to collect this much information in one flying season.

ISSUES-State Role

The first issue was determining the process for collection and who would be responsible for what roles. GTM put forward this plan and suggested responsibilities for each of the roles. This was the process that was selected.



Once the State roles were agreed upon, GTM determined the number of acquisition teams it would take to collect the amount of imagery needed for the state. It was decided that two prime engineering firms and four acquisition teams would be required to collect the imagery. The teams could then decide themselves what the roles of the acquisition teams would responsible for and what amount of information would be collected and processed by each team.

The teams were asked to have additional subcontractors on board for capacity sake. If processing, AT, or finishing could not be completed by the acquisition teams, these other licensed survey companies would be on board to assist with the work load.

We also selected one prime and one acquisition team as the QC for the entire project. Because of the use of multiple contractors and the number of people involved we wanted an unbiased look at the final project deliverables.

GTM also worked ahead of time to determine: Flight requirements, Reporting formats, imagery requirements, Certifications and seals that would need to be provided, media necessary for delivery, file size limitations and drive size needs, etc.... These were important because of their future use for all imagery collection projects within the state.

Expectations

The second issue was to clearly define the expectations for the imagery to be delivered for the state. And to clearly define the roles that each group would be playing.

- Milestones for completion of defined sections
- Clear understanding of responsibilities
- Clear Expectations on what would and would not be corrected
- Consistent and regular communication, both internally among team members and externally between the teams

The Milestones for the project within the acquisition requirements were defined as follows:

1. Calibration and CORS- NC Geodetic Survey
    a. This included the validation range (information provided in IP2),
    b. Continuously Operating Reference Station (CORS),
2. Acquisition-
    a. Flight plans were approved by the state group
    b. Ground control for each section was also approved by the state
    c. Teams determined how best to acquire there section
    d. Communication between teams was expected so that all areas would be covered adequately without duplication of effort
3. AT/AT QC
    a. AT coordinated by the acquisition teams. Either done in house or with the other licensed firms within the contract
4. Processing
    a. There were two pilot areas for each region of the state. The state ortho committee attended meetings to approve the color and visual clarity of each of the pilot areas. This pilot was used to apply the color to the remainder of the region.
    b. Communication was very important between the teams so that the final product would be seamless across the state. The teams worked with one another to provide information so that all teams could provide a tied product
5. Visual QC
    a. All teams provided their products to the QC team. The visual QC team checked 25% of the state with a focus on Major urban, seams between the regions. QC in every county.
6. Field QC- coordinated through NC Geodetic Survey
    a. Survey teams were sent to the field to collect survey for points in each county. The information was then compared to the imagery to check for horizontal accuracies
7. Data Transfer-
    a. Transfer was controlled by the Visual QC team because all of the data was in their hands.
    b. File structure was provided to the team.

Clear Expectations were delivered at the beginning of the project for what corrections would be required. Because of the scope of this project and the timeframe for which the delivery was to be concluded, expectations were defined as such.

Areas of great importance:

- Transportation
- Major Bridges
- Urban areas (to include lean)
- No buildings or large structure pieces cut with seam lines
- Areas of state importance (these areas will be provided)
- color and contrast well balanced at seam edges between contractors and mostly between primes

Areas of least importance

- Limited fixes in highly vegetated areas when all visual components are dense vegetation
- Limited cleaning of color or mosaic line issues in water bodies.
- No expectation of corrections to utility lines above the ground

Vendor Issues

Communication affected a number of technical issues, such as how images tie across the borders, how the teams would share information with each other, and how the teams would divide responsibilities along the common boundary.

To ensure that communication happened regularly and smoothly, the teams established protocols for communication and data sharing at the very beginning of the project, and adhered to these guidelines throughout the project term. Communication was effectively broken into three main phases:

1. Design Phase
2. Planning Phase
3. Execution Phase

Design Phase

Team members were already considering the process of establishing communication protocols prior to the project kickoff meeting, and were thus able to raise these issues for discussion at the project meeting. This early discussion focused on a collective review and understanding of the project specifications, division of labor, and the mechanics of working together.

The teams began the design phase by talking about and exchanging information on the project specifications. They discussed specific, technical issues so that a common baseline understanding for each project requirement existed. Individual team members would raise specific items to ensure that all other team members understood them similarly. Following this process of evaluation of the team's understanding of each technical requirement, the teams sought feedback from the state on any issues for which they felt the need for clarification. Engaging the client where necessary became a means of establishing cooperation and communication.

Once a common understanding of the project requirements had been reached within the team and had been validated by the client, the teams moved on to discussing how best to allocate resources and take ownership of specific project tasks. For example, the AMEC Team was responsible for the Mountain and the Western Piedmont Regions of North Carolina. At the outset of the project, there was a need to clearly understand which of AMEC's two subcontractors was responsible for each geographic region. Through discussion during the design phase of the project, it was determined that the Sanborn Map Company, one of AMEC's two subcontractors, would take responsibility for the Mountain Region because their staff was the most familiar with the challenges of working in the mountains.

Once the work responsibilities had been divided geographically, the two teams discussed how each of their subcontractors would work together along the common border. The key to this process was to establish specific criteria for aerial flight lines to overlap so there would be no gaps in coverage. The teams also communicated during the ground control planning process, so that there would be sufficient control along the border without imposing control by two subcontractors within the same flight strip. The teams requested the state's tiling index from the NCFMP and meticulously reviewed the common border to assign ownership for tile production on a tile by tile basis. Flight lines were not finalized until responsibility for each tile was determined.

In both this phase and the following phase, each team extended its communication process to the other team. As with internal communications, these external communications including sharing information, sharing concepts and designs, achieving consensus on plans and responsibilities, and validating each other's plans. Although the two teams were originally assigned regions of the state based on a number of counties, it became apparent that the two teams could not simply divide responsibility for the state in half based on counties without duplicating flight lines and aerial imagery, because county boundaries at the center of North Carolina do not follow a straight line from north to south but instead zigzag back and forth around the state's longitudinal center line. Dividing the state in half at its center would divide some counties in half. To address these geographical constraints, the two teams agreed to a working border on a tile by tile basis rather than on a county boundary basis. This resulted in a very efficient design and plan. The two teams also established control locations by working together, so as to avoid duplication of efforts.

Planning Phase

The detailed communication and cooperation on the project continued during the project's planning phase. During the planning phase, the teams developed the project documentation, flight and control plans, tile indexes, and communication plans and protocols that were discussed during the design phase. The project plan was born out of the design for flight plans and the tile index where responsibility had been assigned for each tile. During the planning phase, each subcontractor and each team checked each other's flight plans and ground control plans to ensure there was no duplication of effort or any gaps in coverage and control. The planning process was essentially a validation of the design phase. Communication during this phase involved refining procedures related to flight plans and control plans and continuing to exchange information as much as possible.

Execution Phase

The need for regular communication continued throughout the execution phase of the project. This involved weekly reporting on each subcontractor's and each Team's progress, so that the other Team and fellow subcontractors could adjust their work accordingly. This allowed the teams to adjust imagery and to share control ties along borders for each of the four regions, so that the there was a satisfactory level of uniformity in both qualitative and quantitative requirements for the project. The original plan for the execution phase was that whichever subcontractor completed a common border first, the second subcontractor would be required to match their imagery to the imagery of the subcontractor that had already reached that border area. Communication of progress was thus central to an understanding of responsibilities during this phase.

However, while the Teams had used communication throughout the project to establish specific technical responsibilities, neither the Teams nor the NCFMP enjoyed 100 percent success in sharing information and data such that no communication or coordination lapses occurred during the project term. Up front, each Team had agreed to exchanging design and planning documents, but the exchange of information during the execution process was less successful than during the previous phases.

Recommendations

For the NCOP, the quality of the project deliverables was determined by communication and coordination during the project phases. During the planning and design phases of the project, the teams focused almost entirely on the technical aspects of collaboration, making the project technically successful. However, during the execution phase communication on progress was, at times, lacking from one team to another. This project highlighted the need to focus on a more formal infrastructure for establishing communications and milestones and understanding each other's progress. Although each team provided weekly reports, these reports were sometimes lacked the detail necessary to allow team to coordinate work as effectively as possible.

It is recommended that in the future, communication protocols are established for each phase of the project – design, planning and execution – at the very beginning of the project term. While sufficient protocols were in place for the design and planning phases of this project, communication sometimes broke down during the execution phase of the project. These protocols should include established milestones for communicating on each subcontractor's schedule and progress as well as predetermined deadlines for exchanging critical data so that imagery can be tied in appropriately. More attention should be paid to the non-technical aspects of collaboration: communication, reporting and oversight. Additionally, a clear point of contact for each subcontractor should be established, so that each team knows who to contact with questions at any time. The prime contractors for each team should ultimately be held accountable for actively promoting and maintaining consistent and effective levels of coordination and communication between the teams, throughout the life of the project.

The following guidelines are recommended for each phase of the project and should be established during the project kickoff:

1. **Design Phase.** Communicate and collaborate among each team, across teams, and with the NCFMP in order to achieve:
    a. An understanding of the project specifications shared by both project teams, each project subcontractor, and the NCFMP;
    b. A geographic division of responsibilities agreed upon by all parties; and
    c. Specific planning parameters, including established flight lines and assignment of production responsibilities on a tile level basis.

2. **Planning Phase.** Review of the design phase should occur such that:
    a. Each subcontractor on a team evaluates the other subcontractor's flight plans and ground control plans to eliminate any possible duplication of effort and to identify any gaps in coverage or control; and
    b. Each team evaluates the other team's flight plans and ground control plans to eliminate any possible duplication of effort and to identify any gaps in coverage or control.

3. **Execution Phase.** Communication protocols should be established, including:
    a. A single point of contact for each subcontractor and each team who is able to provide details on that party's current progress at all times;
    b. Each subcontractor should provide its team leadership with detailed weekly reporting on number of tiles for which imagery has been collected and processed;
    c. Each team should provide the other team and the NCFMP with detailed weekly reporting on number of tiles for which imagery has been collected and processed;
    d. Deadlines for exchanging information critical to tying in borders among subcontractors on each team as well as among the two teams; and
    e. Deadlines for exchanging information related to schedule and progress updates for each subcontractor.

Date written: 12-30-2010

Contributors:
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Attachment 2: Aerotriangulation Quality Control

1 BACKGROUND

Fugro EarthData (Fugro) was tasked as the Quality Control (QC) manager for the North Carolina statewide orthophotography project under AECOM's North Carolina contract. The main responsibilities covering this task were to do a quality assurance check of the aero triangulation (AT) report, ensure orthophotography tiles were standardized in their delivery, perform a percentage check of tiles for errors, and generate MrSID tiles and mosaics for all accepted data.

2 PROCEDURE

To achieve the quality objectives Fugro designed the following process that was implemented during the AT QC execution. Fugro was not tasked to seal the AT results but to do a quality assurance check of the results.

2.1 Block Integrity Check:

In this step, the actual block layout compared to the executed AT block to ensure that the contractor adhered to the original design of AT blocks and ground control layout. Discrepancies were sent back to the contractor for correction.

2.2 Ground Controls Integrity Check:

This step was performed at the same time as 2.1. The ground control numbers and configuration are examined and any discrepancies were reported for correction or clarification (see figure 1).

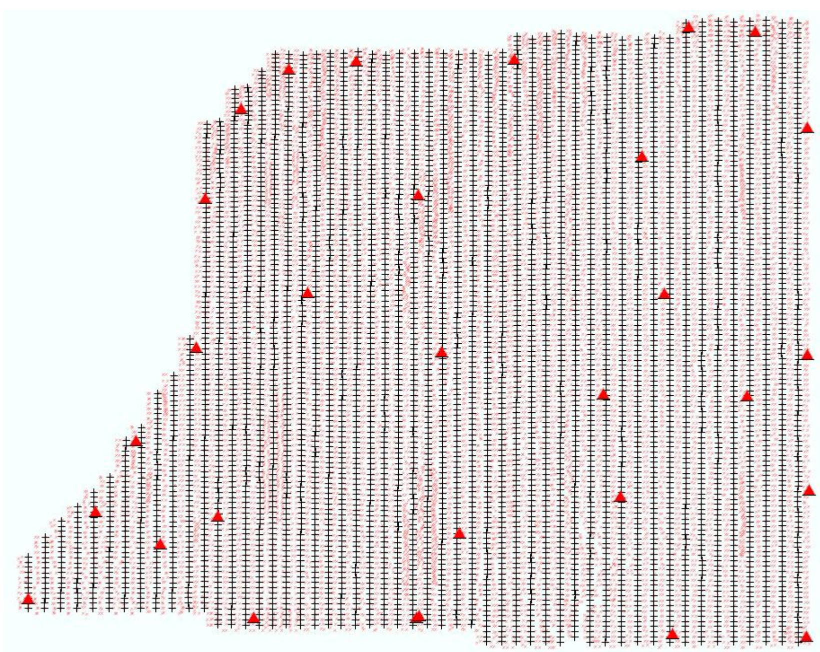

Figure 1 Photo centers, tie/pass, and control layout

2.3 Tie/pass points Integrity Check:

In this step a visual examination of the density and distribution of the tie/pass points was performed (see figure 1) and discrepancies were reported for correction or clarification.

2.4 Bundle Block Adjustment Setup Examination:

In this step, the final report from the bundle block adjustment was examined in order to make sure that the statistics meet the final project accuracy specifications. Final accuracy specifications were developed for the project after the first few blocks were submitted for review and it became clear that vendors needed more guidance on the measure of acceptability (Figure 2). Details of bundle adjustment setup (see figure 3) and weight on the ABGPS and ground control points (see figure 4) are reviewed and discrepancies were reported for correction or clarification.

	Tested Characteristic	Measure of Acceptability
40.	Horizontal accuracy against ground control check points tested in accordance with 10+ points at NSSDA criteria	RMSE = 0.8 ft for imagery with 6" GSD (to support ortho generation according to ASPRS mapping standard class II)
41.	Vertical accuracy against ground control check points tested in accordance with 10+ points at NSSDA criteria	0.8 ft for imagery with 6" GSD (to support ortho generation according to ASPRS mapping standard class II)
42.	Accuracy against image coordinates	RMSE less than or equal to 5 microns is acceptable.
43.	Max. offsets [E, N] to any one blind QA point	3 * RMSE or 2.4 ft
44.	RMSE at airborne GPS residuals in E,N,H	Acceptable RMSE at GPS residuals generally less than 15 cm.

Figure 2 AT accuracy specifications

GCP observations: Enabled
GPS observations: Enabled
IMU observations: Enabled
Error Detection: Disabled
Self-Calibration: Disabled
Precision Computation: Enabled

Figure 3 Block adjustment setup

ID	X	Y	Z	VX	VY	VXY	VZ	Std Dev X	Std Dev Y	Std Dev Z	rx	ry	rz	RMSVX	RMSVY	RMSVZ
652124	1483337.5500	846357.2400	5601.2400	0.1430	-0.0259	0.1453	0.2341	0.1599	0.1702	0.0968	0.22	0.12	0.71	0.0854	0.0624	0.1533
652123	1483339.3600	844907.4900	5605.0500	0.1368	-0.1818	0.2275	0.3451	0.1469	0.1600	0.0817	0.34	0.22	0.80	0.1062	0.0852	0.1618
652122	1483350.4600	843441.6800	5604.3900	0.2439	-0.2686	0.3628	0.2178	0.1444	0.1591	0.0776	0.37	0.23	0.82	0.1096	0.0869	0.1638
652121	1483360.0600	841964.7000	5599.6500	-0.0421	-0.2888	0.2918	0.1812	0.1461	0.1619	0.0784	0.35	0.20	0.81	0.1073	0.0815	0.1634
652120	1483368.6600	840491.9700	5594.8600	0.1492	-0.2969	0.3323	-0.0627	0.1491	0.1625	0.0807	0.32	0.20	0.80	0.1031	0.0803	0.1623
652119	1483366.6800	839017.6800	5597.7800	-0.0071	-0.1864	0.1865	0.0455	0.1466	0.1586	0.0801	0.35	0.23	0.80	0.1066	0.0878	0.1626
652118	1483360.1800	837528.8300	5599.3000	0.1478	-0.2209	0.2658	0.0133	0.1481	0.1602	0.0807	0.33	0.22	0.80	0.1046	0.0849	0.1623

Figure 4 Weight and accuracy of adjusted parameters of the ABGPS

2.5 Bundle Block Adjustment Results Examination:

In this step, the final results of the ground controls fit were examined in order to ensure that it was meeting the contractual specifications (see figure 5)

Parameter	X/Omega	Y/Phi	Z/Kappa	XY
RMS Control	**0.268**	**0.242**	**0.240**	**0.361**
RMS Limits	1.000	1.000	1.000	
Max Ground Residual	0.499	0.649	0.625	
Residual Limits	3.000	3.000	3.000	
Mean Std Dev Object	**0.08471**	**0.07992**	**0.19470**	
RMS Photo Position	0.095	0.177	0.115	
RMS Photo Attitude	0.006599	0.004279	0.021666	
Mean Std Dev Photo Position	0.1527	0.1637	0.0865	

```
 Mean Std Dev Photo Attitude   0.001930 0.001662   0.000975

Current Count

        Control Points Used:   30
        Photos Used:   5104
         Photos Not Used:      0
        Image Points Used:     17089
```

Figure 5 Final accuracy of adjusted block

3 ISSUES ENCOUNTERED

The following issues were observed in various AT reports and communicated back to the vendor and the program manager.

3.1 Blocks design deviated from the original block design:

Some contractors altered the boundary of the blocks due to various legitimate and illegitimate reasons. Among the legitimate reasons were terrain difficulty which made it impossible to collect ground controls as it was laid out in the original design, therefore the blocks were re-aligned to better fit the surveyed ground controls.

3.2 Not enough tie/pass points between adjacent blocks:

Some blocks did not have enough tie points in order to assure accurate transition from one block to another.

3.3 Assigned priority weights were either too loose or too tight:

Some contractors applied unsuitable constraints on the adjusted observations in the AT bundle block adjustment.

4 RESOLUTIONS

Based on the issues encountered three resolutions could be applied to avoid such encounters on future programs.

- AT accuracy specifications should be specified clearly at the RFP or contracting stage so that vendors clearly understand the production expectations. This would also ensure proper AT block design and ground control point (GCP) design.
- Adding blind points at the AT stage would allow vendors and QC firm/s to confirm the quality of the AT solution.
- Ensure that the difficulty of terrain be taken into account during the design of the AT blocks and the GCP layout development.

Date written: 01.24.2011
Contributors:

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Attachment 3: Validation Range

Background

In 2009, the North Carolina 911 Board awarded a grant of $12.3 million to the City of Durham's Emergency Communications Center for acquisition of statewide ortho imagery. The Durham PSAP concluded that a statewide project would maximize benefits in a timely way. The City of Durham requested help from the North Carolina Orthophotography Planning committee to assist with managing the collection of this Orthophotography. The North Carolina Geospatial & Technology Management Office (GTM) undertook the acquisition management of this project to obtain new natural color digital aerial orthophotography of all 53,819 square miles of North Carolina at a 0.5-foot pixel resolution in one flying season. The primary goal of the North Carolina Orthophotography Project (NCOP) is to fulfill base layer requirements for local, state and federal uses, such as emergency response, floodplain mapping, and tax assessment. Due to the amount of labor required to complete this project, GTM divided the state into four regions. GTM utilized two prime contractors to collect the imagery, assigning each contractor two of the four regions, and the contractors worked with subcontractors to ensure that all of the required aerial orthophotography could be gathered and processed within the tight timeframe.

The 2010 North Carolina Orthophotography Project (NCOP) began acquiring data in January of 2010. Because of the scope of the project, the use of digital aerial image sensors was required for image acquisition. In order to meet the project requirements and deliverable time frame, there were up to 26 possible planes that could have been used for the collection of the imagery. In NC it was required that all of the digital sensors meet the same standard criteria and that all acquisition contractors produce a product of the same quality.

Before digital aerial image sensors, film mapping cameras were calibrated and validated to specific standards set forth by USGS (http://calval.cr.usgs.gov/osl/obtaining.php). The existing USGS calibration laboratory could not be used to calibrate digital aerial image sensors because each manufacturer's digital aerial image sensor has its own unique imaging geometry based on its system components. USGS is currently in the process of developing a method to test digital sensors but that is not currently available.

The North Carolina Orthophotography Project (NCOP) was designed to leverage the advantage of the newer digital camera technology which allows for the simultaneous acquisition of both natural color and color infrared imagery. Two project teams were selected to acquire and process the digital imagery for this project; the teams' combined resources included 20 aircraft and digital cameras that could be used for imagery acquisition. In NC it is required that all of the sensors used produce a similar product of the same quality. Therefore, it was determined in the planning phases of the NCOP, that there should be an In Situ Validation Range (ISR) developed in North Carolina to test the sensors in-flight. The purpose of an ISR is to calibrate and/or validate aerial sensor systems and the orthophoto process methodology employed in North Carolina given its existing geospatial resources (LiDAR elevation data and GPS base station distribution). In the NCOP project the North Carolina ISR was used to validate the aerial sensor systems used for aerial acquisition. North Carolina Geodetic Survey (NCGS) and North Carolina Department of Transportation (Photogrammetry Unit) worked together to find an area that fulfilled the requirements posed by USGS to set up a camera calibration site in North Carolina. It was determined that NC did not have the terrain change necessary to fully create a USGS In Situ calibration range. However, based on the needs of aerial collection within the state a validation range would be a great asset for current and future collections from aerial sensors. USGS Digital Aerial Imagery Calibration Range Requirements are available at http://calval.cr.usgs.gov/aerial/digital_qa/ .

It was determined that the best location for the range would be in Surry county. This area was chosen for several reasons: terrain change over a distance, flights would not impede air traffic, and flights would not cause major issues to the local's security concerns. (For the NCOP project it was a required that Surry County be informed when the validation flights would occur so the county would know there would be up to 5 planes flying over their county in a short time frame.)

Recommendation

There is now a range set up in Surry County that has measurements around the airport. In order to produce the best possible validation each sensor should fly the entire area and produce an orthophoto for the tiles that fall within this area. It is the intent that all sensors be used to produce a final product to determine that the vendor follows best practices, utilizes sufficient process quality management techniques and implements comprehensive process change control to ensure that a clear understanding of project deliverables and that the final product meets project specifications. This gives the client a clear idea of what the vendor considers to be an excellent product. The orthophotos are then checked against the ground control measured in advance at the airport. NCGS performs this function for the state and can assist any local government who wishes to internally take on this task.

While the recommendation is to produce complete orthophotos for every sensor to be used in a project, it was not possible during the collection of the NCOP. The time needed for 14+ planes to acquire digital imagery, produce 8 orthophoto tiles for each of those planes and to have them all approved did not fit into the timeframe needed to collect the entire statewide orthophotography in one flying season. There was a compromise made for the NCOP. It was determined that each prime contractor produce a full orthophotography set of tiles. This deliverable would be evaluated to determine that each prime understood the scope of the project and could meet all project deliverable requirements. The remainder of the sensors flew only the eastern most block of tiles. The images were rectified to the NC LiDAR digital elevation model, but not produced to visual standards. These areas were not required to have color and contrast corrections. The major concern for this area was the horizontal accuracy of the collection. These tiles were tested by NC Geodetic for horizontal accuracy within the specifications of the project.

NC Geodetic survey is currently in talks with USGS to provide the Validation range as a national site which could be flown for sensor collections on the east coast.

Date written: 12-30-2010
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Attachment 4: Orthophotography Review

BACKGROUND

Fugro EarthData (Fugro) was tasked as the Quality Control (QC) manager for the North Carolina statewide orthophotography project under AECOM's North Carolina contract. The main responsibilities covering this task were to ensure all orthophotography tiles were standardized in their delivery, had a percent of the tiles checked for errors, and generate MrSID tiles and mosaics for all accepted data.

To achieve the objectives Fugro designed the following process that was implemented during the orthophotography QC execution.

<u>Macro Checks</u>

When a processed delivery block was received the first step was to download all the data from the external hard drive. Next, a series of macro level checks were run against the imagery to ensure that the appropriate standardization criterion was followed. The macro checks performed were as follows:

- Completeness of coverage against expected
- Image size check against expected
- Ensure tfw files were provided
- Geotiff header check
    - Check for 'untiled' versus 'tiled' Geotiff
    - Check that correct datum and projection information were defined correctly
    - Check accuracy of Geotiff coordinates
- Ensure tiles were in Geotiff format and not just Tiff files
- Check to ensure tfw was provided as pixel center file
- Void check to ensure completeness of dataset
- Data completeness check against boundary files

All the macro checks were run as a batched process against the deliverable dataset. The results of the checks were reviewed by a technician to verify the errors reported. Datasets that failed a macro check were rejected, the issue/s identified, and a new dataset with corrections applied was shipped to Fugro EarthData.

<u>Micro Checks</u>

Once a delivery block passed the macro level checks it was ready to begin the micro level checks. Prior to receiving any delivery blocks Fugro pre-selected the tiles that would have a 100% QC performed.

The contractual obligation was for every delivery block to have 25% of their delivery tiles undergo a 100% review. To select the 25% from each delivery block Fugro utilized existing statewide shapefiles that identified features such as bridges, points of interest, urban areas, major highways, rail lines, and universities. These shapefiles represented areas that are most commonly impacted by the orthophotography production process and therefore needed to be included in the QC process. If 25% of the block tiles were not selected after applying the shapefiles then a technician randomly selected tiles until the required percent was achieved.

Fugro utilized ArcMap to do the micro checks. A technician would check out a block of images in ArcMap and do a 100% visual QC of the data. The scanning scale was 1:1000, meaning no issues were flagged if they were not clearly visible at that scale. There were several other criteria that were applied to the review as follows:

- Forest areas were of lesser concern
- Waterbodies were of lesser concern
- Artifacts created by solar reflectance in rural areas were of a lesser concern
- Snow was noted but only for metadata
- Flooding was noted but only for metadata
- Roads should not have separation

As a technician reviewed the imagery any potential issues were flagged and noted using a standardized list of common orthophotography errors. That list of flags was as follows:

- Artifact
- Turbulence
- Smear
- Blurry
- Wavy Feature
- Corrupt Data
- Missing Data
- Trans Obstruction
- Cloud
- Shadow
- Smoke
- Haze
- Snow
- Flooding
- Tile Boundary/Edge Issue
- Seamline
- Sensor Line
- Excessive Tilt
- Radiometry
- Band Registration

A comments field was additionally utilized should the technician require further detail on the flagged call.

After a block completed a full review of the selected QC tiles the flagged calls were reviewed by a senior technician. This review was done to ensure that all flagged calls were valid and within the scope of the QC work.

Once the senior review was completed a QC calls file geodatabase was output that contained all the flagged calls noted during the review. A summary report of the QC calls was prepared and the uploaded along with the geodatabase to the project SharePt site. The appropriate vendor, project PM, and state POC were notified that the blocks QC calls had been posted.

Vendors had two options based on the QC calls, correct the calls and return an updated tile or dispute the call can make a comment as to why the call was being disputed. Corrected tiles once returned were reviewed to ensure the flagged items were corrected and no new calls were introduced. When additional flags were found a second round of QC calls was sent out similar to the first round process.

The QC process continued until all the selected tiles (25% of the delivery block) passed the micro review process. Once a block was accepted the project PM and state POC were notified.

<u>MrSID</u>

As blocks were accepted they entered the MrSID generation phase. For all delivery blocks individual MrSID files were created using a 20:1 compression ratio. All final MrSID tiles were segregated by county. Ultimately there was a folder prepared for every county in the state containing the individual MrSID tiles.

Once a full county was accepted all the tiles were run through a MrSID mosaic process which output a MrSID mosaic with a compression of 50:1.

<u>Final Drives</u>

One final drive was prepared for each county in the state. The drives contained the counties individual Geotiff imagery, individual MrSID imagery, a MrSID county mosaic, metadata, flight lines, and tile index.

ISSUE/S

During the course of the quality control process there were several issues encountered in all phases described above. Below lists some of the more common issues observed.

Macro Check Issues

- The Geotiff header requirements were often wrong with key elements missing in all or a portion of the submitted tiles
- Boundary edge tiles that were partial tiles were often not cut to a smooth boundary but jagged
- There were often void areas in the data, sometimes quite large areas
- Black pixels instead of white pixels as void beyond boundary
- Void white pixels were not all 255
- Geotiffs were tiled instead of untiled
- A few areas of the coverage did not go completely to the boundary
- Extra tiles received in a delivery or tiles missing that were expected
- Incorrect tile extents and file sizes

Micro Check Issues

- There was an abundance of tiles with bad road separation
- Radiometry between blocks was quite noticeable
- Some deliveries had very sharp contrast and others were more blurry
- Harsh seam lines were visible between blocks
- Bridges, railway lines, roads and buildings were at times wavy
- Corrections often returned with the QC call not fixed and more errors introduced
- Incorrect tiles
- Artifacts – green, blue, pink lines
- Smearing
- Harsh lines along tile boundary/edge within blocks and between blocks
- Harsh lines within tiles (not edge or seamlines)
- Bright/blown out glare on roof tops
- Seamlines through buildings
- Seamlines not matching imagery
- Duplication, doubling of features

MrSID Issues

- Larger counties required systems with more memory
- Waiting for blocks to finish before counties can be generated
- Void pixel not always 255 due to compression issue
- Customer changed mosaic compression ratio after mosaics were started

Final Drive Issues

- Initial delivery by block and final delivery by county and dependent on surrounding counties created a bottleneck.
- Potentially using the incorrect county boundary file to define the county tiles.
- Additional rework occurring after some counties sent
- Recycler folder on drive, need to use system's recycle bin to clear out

RECOMMENDATION

The following are some general recommendations taking into account issues encountered and how to reduce the risk of repeating them should another similar project be undertaken.

One recommendation to resolve some of the issues encounter in the QC phase would be to provide a QC expectations document, critical files, and accompanying templates during the project kickoff. The expectations document would clearly list all macro and micro checks that would be performed and the expectation of each delivery. The document could also include screenshots from this year's project of issues that would not be acceptable in a delivery. The critical files should include a geotiff template, the final tile layout, the buffered boundary, and a metadata template.

A pilot submittal of all final deliverables is also recommended as it would serve to indentify issues with the execution of the scope of work early in the project. The pilot would also serve to show the vendors understanding of the project expectations and their ability to the templates.

There were many radiometric differences observed between vendors that could have been resolved by the use of a global histogram. Multiple radiometric pilots over different regions meant that even under the best conditions there would be distinct radiometric transition areas were one histogram segued into another. By defining a single histogram to be applied to all imagery each vendor's data would become unified in its radiometric balancing.

Date written: 02.07.2011
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Attachment 5: MrSID Mosaic

BACKGROUND

Fugro EarthData (Fugro) was tasked as the Quality Control (QC) manager for the North Carolina statewide orthophotography project under AECOM's North Carolina contract. The main responsibilities covering this task were to ensure all orthophotography tiles were standardized in their delivery, had a percent of the tiles checked for errors, and generate MrSID tiles and mosaics for all accepted data.

ISSUE

To achieve the objective of creating a 50:1 MrSID mosaic for each county Fugro utilized Lizardtech's GeoExpress 7. It was observed on certain county MrSID mosaics that the background pixels at locations of transition from imagery to null value areas were not smooth. What should have been a butt matched transition going from the edge of the county imagery to a null value white (255,255,255) shade actually had off white pixel artifacts at the point of transition. This issue was best observed when the null value white pixels were set to transparent then the null pixels that were off white could be seen.

The cause of this issue is the Lizardtech software compression which expresses the issue when counties of a certain shape are mosaiced.

RECOMMENDATION

Fugro contacted Lizardtech regarding the observed artifacts and was informed that the only way for this to be resolved was to create mosaiced images without compression. Being that this project called for 50:1 mosaiced county deliveries there is no resolution for the current deliverables.

Future projects could be impacted by this artifact issue should a compressed mosaic be tasked. New versions of GeoExpress could resolve this issue but it was not known at the time this document was written if Lizardtech planned that update as a part of any future releases.

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