Baldwin and Mobile Counties, AL 2015 Orthoimagery Project Report

Submitted: March 23, 2016

Prepared by:

Quantum Spatial, Inc
523 Wellington Way, Suite 375
Lexington, KY 40503
859-277-8700

Contents

List of Figures

List of Tables

List of Appendices

1. Summary / Scope

1.1. Summary

This report contains a summary of the Baldwin and Mobile Counties, AL 2015 Orthoimagery project acquisition task order, issued by Radiance Technologies ordered on December 18, 2015 and modified on January 4, 2016. The task order yielded a project area covering approximately 3,671 square miles over Baldwin and Mobile Counties. The intent of this document is only to provide specific validation information for the data acquisition/collection, processing, and production of deliverables completed as specified in the task order.

1.2. Scope

High resolution 8-bit, 4-band (RGB-IR) digital imagery was acquired and used for digital orthophoto production. Ortho data collection was planned using the specifications listed below in Table 1.

Table 1. Originally Planned Ortho Specifications

Raw GSD	Flight Altitude (AGL)	Min. Sun Angle	Side Overlap	Front Overlap
1 m	27,000 ft	30°	30%	60%

1.3. Coverage

The project boundary covers approximately 2,027 square miles over Baldwin County and approximately 1,644 square miles over Mobile County located in southern Alabama. Project extents are shown in Figure 1 on the following page.

1.4. Duration

Imagery was acquired in nine lifts from January 17, 2016 through February 10, 2016. See "Section: 2.4. Time Period" for more details.

1.5. Issues

There were no issues to report with this project.

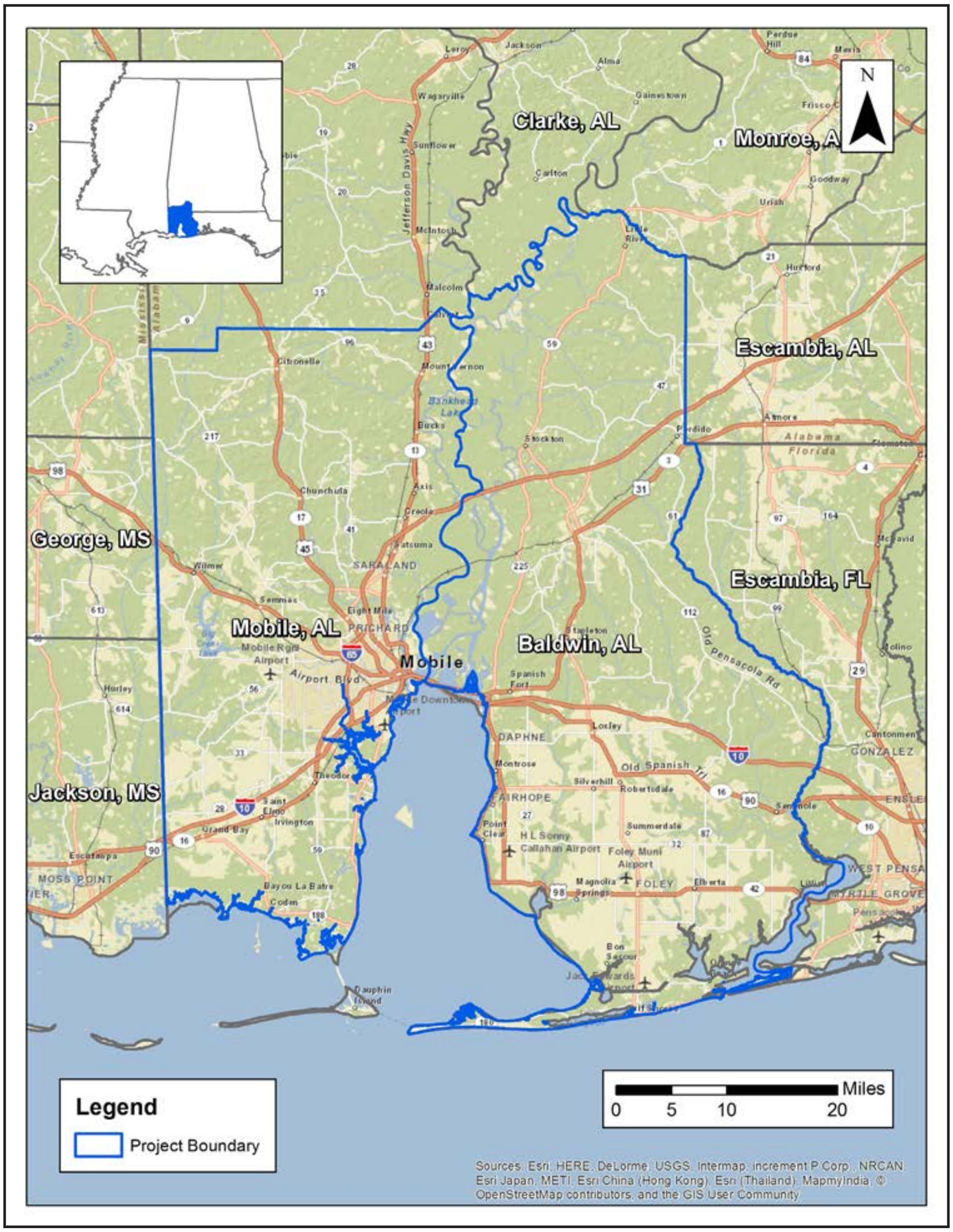
1.6. Deliverables

The following products were produced and delivered:

- Color digital orthophotos in GeoTIFF format
- Project-level metadata in .XML format

All geospatial deliverables were produced in NAD83 UTM Zone 16, meters. All tiled deliverables use a sequential tile index.

Figure 1. Baldwin/Mobile, AL 2015 Orthoimagery Project Boundary



2. Planning / Equipment

2.1. Flight Planning

Flight planning was based on the unique project requirements and characteristics of the project site. The basis of planning included: required accuracies, type of development, amount / type of vegetation within project area, required data posting, and potential altitude restrictions for flights in project vicinity. Please note that certain values in the table below are listed as “Variable” due to the various flight plans used, as described in “Section: 1.5. Issues” of this document.

Detailed project flight planning calculations were performed for the project using Leica MissionPro planning software. The entire target area was comprised of 39 planned flight lines (Figure 2).

2.2. Orthoimagery Camera

Quantum Spatial utilized a Leica ADS 100 (Figure 3), serial number(s) 10552. The Leica ADS 100 system has 4 channel (RGB & IR) multi-spectral capability. The gyro-stabilized mount with adaptive control insures the best possible image collection. A single image is 20,000 pixels.

A brief summary of the aerial acquisition parameters for the project are shown in the Camera System Specifications in Table 2.

Figure 2. Planned Flight Lines

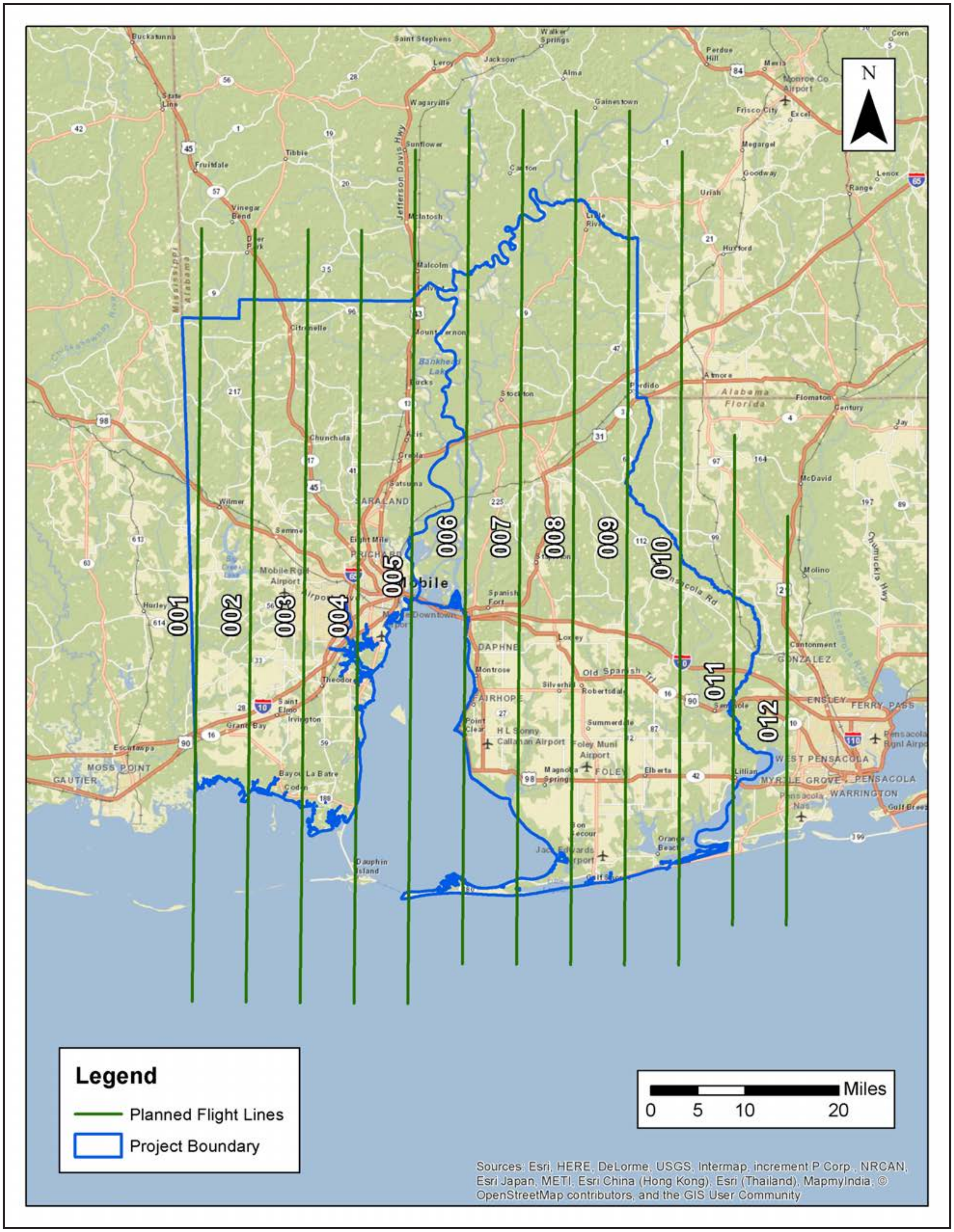


Table 2. Camera System Specifications

Terrain and Aircraft	Flying Height AGL	27,000 ft
	Recommended Ground Speed (GS)	300 kts
Overlap	Forward Overlap	30%
	Side Overlap	60%
Coverage	Strip Width	13,106.66 m
Resolution	GSD	1 m

Figure 3. Leica ADS 100 Camera

2.3. Aircraft

All flights for the project were accomplished through the use of a customized Rockwell turbo Commander 690 (twin-turboprop), serial number 10552. This aircraft provided an ideal, stable aerial base for orthoimagery acquisition. This aerial platform has relatively fast cruise speeds which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds which proved ideal for collection of high-density, consistent data posting using a state-of-the-art Leica ADS 100 imagery system. Some of the operating aircraft can be seen in Figure 4 below.

Figure 4. Some of Quantum Spatial's Planes

2.4. Time Period

Project specific flights were conducted over two months. Nine sorties, or aircraft lifts were completed. Accomplished sorties are listed below.

- Jan 17, 2016-A (N690LN, SN10552)
- Jan 18, 2016-A (N690LN, SN10552)
- Jan 29, 2016-A (N690LN, SN10552)
- Feb 4, 2016-A (N690LN, SN10552)
- Feb 5, 2016-A (N690LN, SN10552)
- Feb 6, 2016-A (N690LN, SN10552)
- Feb 7, 2016-A (N690LN, SN10552)
- Feb 9, 2016-A (N690LN, SN10552)
- Feb 10, 2016-A (N690LN, SN10552)

3. Processing Summary

3.1. Flight Logs

Flight logs were completed by sensor technicians for each mission during acquisition. These logs depict a variety of information, including:

- Job / Project #
- System
- Flight Date / Lift Number
- Flight Line Number
- Flight Line Start Time
- Flight Line Stop Time
- Image Range
- F-Stop Setting
- Shutter Setting

Notes: (Visibility, winds, ride, weather, temperature, dew point, pressure, etc). Project specific flight logs for each sortie are available in Appendix A.

3.2. Imagery Processing Summary

There are several distinct processing steps. First, raw imagery is converted from the raw data collected in flight and post-processed to a "RAW" file that can be incorporated into orthophotography data. Next, Ground Control Points (GCPs) were collected and processed. Then, an additional set of raw data collected in flight from the Airborne GPS systems are processed to create an external orientation file. The processed RAW imagery, ground control and the external orientation file are used to create aerotriangulation data. Finally, the merging of all of these, along with a surface, is done in order to create a digital orthophotograph.

3.3. Raw Data Extraction

Leica Geosystems XPro version 6.2.1 was used to download the raw flight data from the MMU. Raw data for the ADS sensor consists of the un-rectified strip images in TIFF format, commonly referred to as L0 images in ADS workflows, and the raw ABGPS/IMU observables.

3.4. ABGPS/IMU

ABGPS/IMU data was collected on the aircraft during the survey mission, providing sensor position and orientation information for geo-referencing the imagery data. ABGPS observations were collected at a frequency of 2Hz, and IMU observations were collected at a frequency of 200Hz. Precise lever arm measurements from the ABGPS/IMU measurement reference points to the principal point of the ADS focal plane are used in reducing the raw vehicle position/attitude observables to sensor exterior orientation. These lever arm measurements are measured during sensor installation in the survey aircraft.

GPS data was collected using base stations, providing corrections to support differential postprocessing of the ABGPS. Differential correction of the ABGPS data using the ground base station data was performed in NovAtel Inertial Explorer software version 8.6. The NAD83 geodetic coordinates acquired through the CORS network were held as reference during differential correction. Corrected ABGPS data was combined with IMU data in Inertial Explorer through a Kalman filtering algorithm to arrive at a smoothed best estimate of the sensor's trajectory during the collection missions. This trajectory estimate along with precise exposure timing data provide initial EO estimates for the imagery in aero-triangulation.

3.5. Aerotriangulation

Aero-triangulation was performed using Leica Geosystems' XPro software version 6.2.1. XPro's automatic point matching algorithm was used to match image tie points in the side overlap between adjacent image strips. The tie point observations were used in a least squares bundle adjustment to solve for systematic errors in the smoothed best estimate of trajectory, including GPS drift and timing offsets. The bundle adjustment also identifies and eliminates measurement blunders in the tie points.

After solving for systematic navigation errors and removing measurement blunders, ground control points were manually measured in the imagery. Ground control points coordinates used had horizontal reference of NAD83 UTM Zone 16; and vertical reference of NAVD88 ellipsoid heights, meters. AT for the ADS sensor is performed in the ellipsoid vertical reference to avoid systematic errors that geoid undulations cause in the pushbroom sensor model. The ground control point observations are used to solve for any remaining datum transformation required to determine EO in the project datum. Ground control points were assigned statistical weight, equivalent to their estimated accuracy, in the final least squares adjustment to solve for the control datum transformation.

For more information, see the Aerotriangulation Report in Appendix B.

3.6. Surface Model Creation

Quantum Spatial generated an elevation model using data from the National Elevation Dataset.

3.7. Orthorectification Process

Orthorectification of imagery was accomplished with the XPro software version 6.2.1 rectification module, which provided a seamless workflow for block bundle adjustment and generation of orthoimages. The XPro rectification module used the block bundle adjustment solution developed in the bundle adjustment module and the L0 images as inputs.

Radiometric correction of the imagery included applying the manufacturer's calibration and a proprietary process to account for atmospheric and lighting effects. Two principal effects were considered in the proprietary correction; atmospheric haze and bi-directional reflectance. Atmospheric haze describes the effect of sunlight reflecting off of aerosols dispersed in the atmosphere, especially in the blue wavelength of the visible light spectrum. Bi-directional reflectance describes the non-uniform brightness of the ground scene in an aerial image caused by varied viewing and illumination angles. Due to the ADS sensor's consistent nadir geometry in the along-track flight direction of the image strip, haze and reflectance only affect the ADS sensor in the across track direction of the image strip. The algorithm works by sampling the pixel values throughout the image strip and calculating an average pixel value for each column of pixels across the sensor track. A polynomial function is used to normalize the samples to remove any anomalies, such as specular reflection on water, from the column averages. Mean brightness of the column averages are calculated, and a correction value determined to adjust the average pixel value of each column in the strip to the mean. The corrections were calculated and applied in the raw 12-bit dynamic range of the ADS sensor, permitting a more accurate correction than one applied after the imagery has been histogram stretched for 8-bit storage and viewing. Correction values were stored in separate files for each multi-spectral image and were applied by the orthorectification module during orthoimage output. The manufacturer's factory calibrated radiometric gain parameters were also applied during orthorectification, modeling the variable sensitivity of each CCD in the ADS sensor to the wavelength of light it is assigned to collect.

The assembled DEM and atmospheric correction files were added to the XPro block definition. The rectification module was used to generate a 4-band orthorectified image strip, commonly referred to as L2 images in ADS workflows. The band order of the L2 was Red in Band 1, Green in Band 2, Blue in Band 3, and Near-Infrared in Band 4. The L2 was stored in 16-bit GeoTIFF file format, and had the atmospheric corrected 12-bit dynamic range of the ADS sensor. The L2 images were validated for relative and absolute horizontal accuracy by visual inspection using the inpho OrthoVista software. Photogrammetric technicians manually measured common features in the sidelap region of adjacent images and photo-identifiable ground control points to validate relative and absolute accuracy of the L2s. The results of the horizontal accuracy assessment are outlined in the table below. With horizontal accuracy requirements validated, the imagery was moved into the mosaic phase.

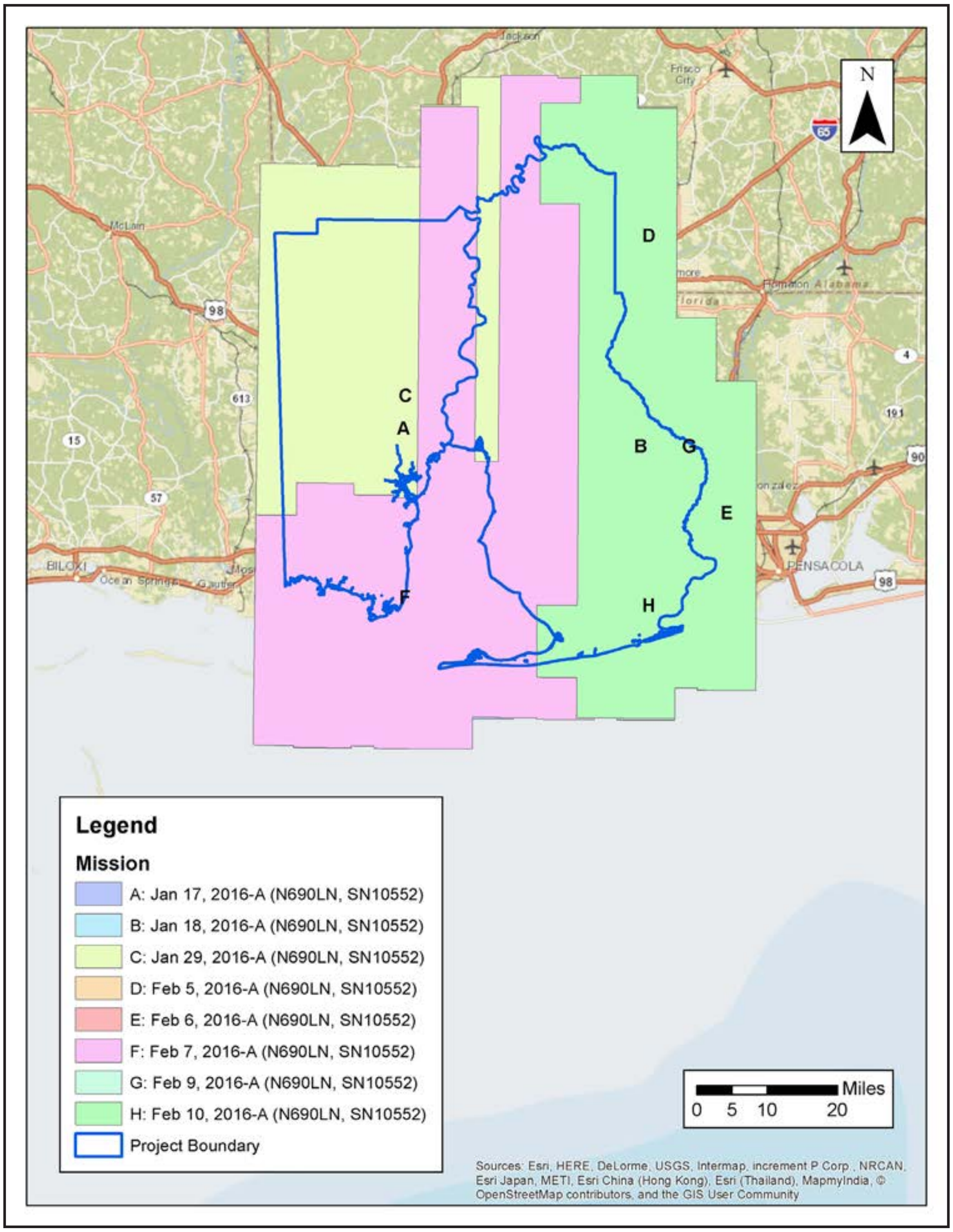
Tile layout is shown in Figure 5.

Figure 5. Ortho Tile Layout

4. Project Coverage Verification

The AOI project area imagery frame coverage (see Figure 6) and content verification was performed and validated by visual review. This action was performed in the field by flight crew during the acquisition phase as well as by imagery QA technicians at our processing center. The ABGPS/IMU and base station data was uploaded to the company FTP site after each flight for the INS processing team in Lexington, Kentucky to verify accuracy of data collected.

Figure 6. Ortho Frame Coverage



5. Ground Control and Check Point Collection

Quantum Spatial utilized a total of 14 blind QA points to perform an independent test of the accuracy of this project. The required accuracy testing was performed on the orthoimagery dataset according to the National Map Accuracy Standards for 1 meter Orthophotos. The locations for all QA points are shown in Figure 7.

5.1. Orthoimagery Testing

Upon completion of all production activities and prior to delivery of the final orthophoto dataset, Quantum Spatial used Accuracy Analyst QC software to compute the overall accuracy of the orthophoto data set using 14 control points. The RMSEr at the 95% confidence level was calculated to be 2.78 meters. Please see the Ortho Accuracy Analyst report in Appendix C for more information.

Figure 7. QA Point Locations