AIRBORNE TOPOGRAPHIC ORTHO REPORT

SAN DIEGO, CA 2014 10 CM ORTHO

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1. Summary / Scope

1.1. Summary

This report contains a summary of the San Diego, CA 2014 10 cm Ortho acquisition task order, issued by the USGS National Geospatial Technical Operations Center (NGTOC), under their Geospatial Product and Services Contract (GPSC) on September 23, 2014 and amended December 12, 2014. The combined task orders yielded study areas covering a portion of San Diego County and Camp Pendleton in California The intent of this document is to only provide specific validation information for the Ortho data acquisition/collection work completed for the USGS NGTOC project.

1.2. Scope

Quantum Spatial acquired high resolution digital aerial imagery and processed digital orthophotography for part of San Diego County. The total imagery project area is estimated at approximately 1,388 square miles resulting in the production and delivery of 6,296 full-image 10 cm 4-band (R.G.B.NIR) 8 bit tiles at a dimension of 2,500 by 2,500 feet in California State Plane Zone VI, survey feet. Project phases included aerial imagery acquisition with airborne GPS/IMU, ground control surveys, aerotriangulation, and orthorectification. The ortho-imagery produced conforms to the specifications as stated in Task # G14PD01045 and Quantum Spatial's Technical Proposal dated September 23, 2014 and amended December 12, 2014.

The aerial data collection was designed with the following specifications listed in Table 1 below.

Table 1. Planned Orthoimagery Specifications

Imagery				
Raw GSD	Flight Altitude (AGL)	Min. Sun Angle	Forward Overlap	Side Overlap
10 cm	6,311 ft	30°	60%	30%
10 cm Urban	6,311 ft	30°	80%	60%

1.3. Location / Coverage

The San Diego, CA 10 cm Ortho project boundaries include the western portion of San Diego County and the Camp Pendleton Marine Corps Base, an area totaling approximately 1,388 square miles, as seen in Figure 1.

Figure 1. San Diego County and Camp Pendleton 10 cm Ortho Project Boundaries

1.4. Duration

The imagery was acquired in nine lifts from October 18, 2014 through January 21, 2015. See Section 2.5 for more details.

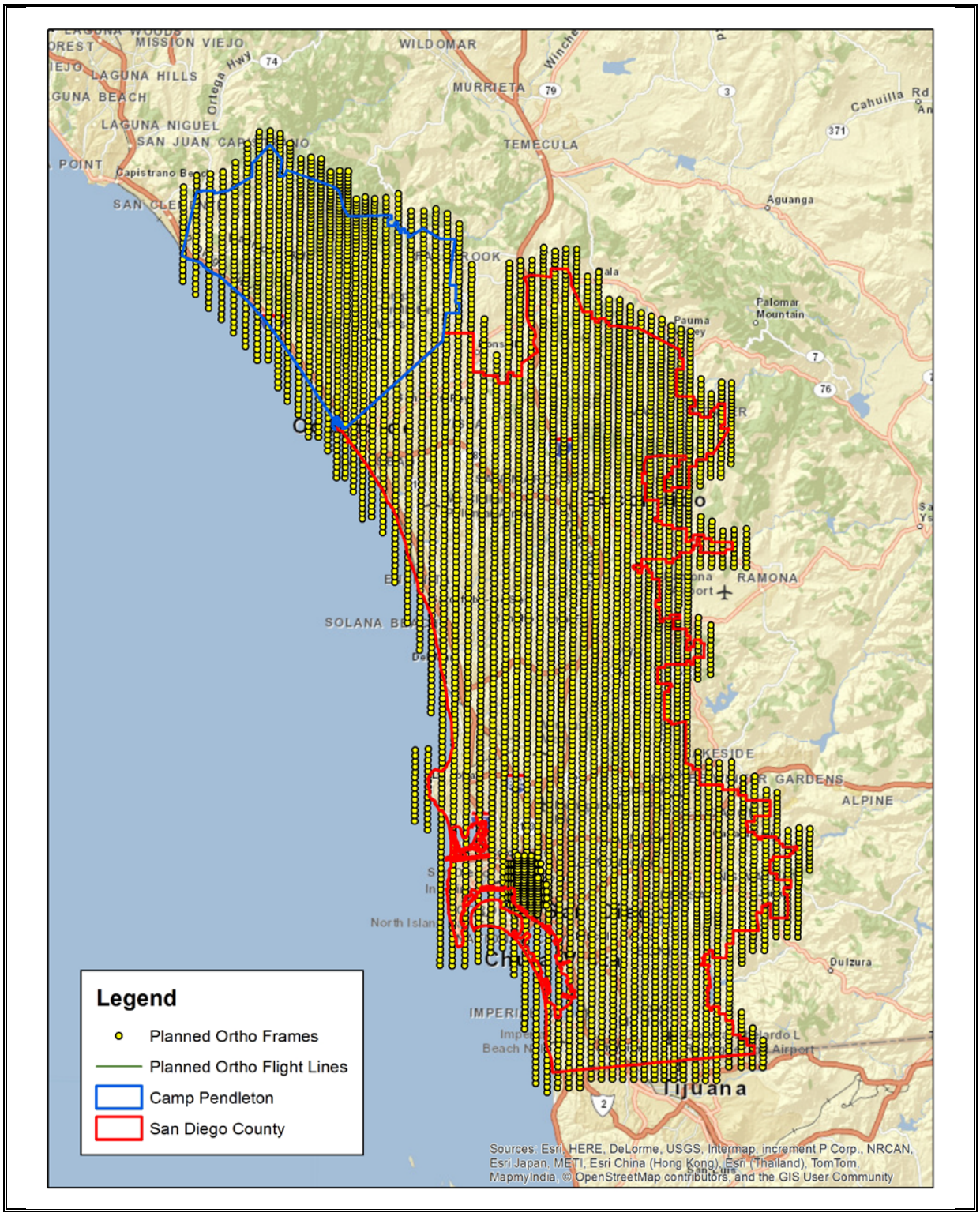
1.5. Issues

Coordination with Mexican airspace was required.

2. Planning / Equipment

The 10 cm Ortho area consisted of approximately 85 planned flight lines and 5,821 planned exposures. Please refer to Figure 2 on the following pages as well as Section 5.

Figure 2. San Diego County and Camp Pendleton 10 cm Ortho Planned Flight Lines



Detailed project flight planning calculations were performed for the San Diego, CA project using UltraNAV with the UltraCam Eagle. 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 of this document. A brief summary of the aerial acquisition parameters for the project are shown in the Camera System Specifications in Table 2 below:

Table 2. Camera System Specifications

Camera System Specifications		10 cm	10 cm Urban
Terrain and Aircraft	Flying Height AGL	6,311 ft	6,311 ft
	Recommended Ground Speed (GS)	150 kts	150 kts
Overlap	Forward Overlap	60%	80%
	Side Overlap	30%	60%
Coverage	Strip Width	2,600 m	2,800 m
Resolution	GSD	10 cm	10 cm

2.1. Equipment: Aircraft

All flights for the Ortho portion of the San Diego, CA project were accomplished through the use of a customized Piper Malibu Mirage (single-piston) (Tail Number: N146ZF). These 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 state-of-the-art Microsoft UltraCam Eagle imagery systems. Some of the operating aircraft can be seen below in Figure 3.

Figure 3. Some of Quantum Spatial's planes

2.2. Orthoimagery Sensor

Quantum Spatial utilized UltraCam Eagle (UCE) sensor during the project. The UCE system has 4 channel (RGB & NIR) multi-spectral capability. The combination of the UCE's Forward Motion Compensation, along with the gyro stabilized mount, insures the best possible image collection. A single full resolution image is 20,010 by 13,080 pixels in size and utilizes a 100mm lens focal distance.

Figure 4. Microsoft UltraCam Eagle

2.3. Time Period

Project specific flights were conducted over several months. Nine Ortho sorties, or aircraft lifts were completed. Accomplished sorties are listed below, and the type of acquisition is noted to the side:

Ortho Sorties

- 20141018
- 20141019
- 20141020
- 20141021
- 20141022
- 20141025
- 20141226
- 20141227
- 20150121

3. Processing Summary

3.1. Flight Logs

Flight logs were completed by camera sensor technicians for each mission during acquisition. These logs depict various 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

Within the UltraMap software suite, raw acquired images are radiometrically and geometrically corrected using the camera's calibration files and output as Level 2 images. The resulting radiometry is then manually edited to ensure each image has the appropriate tone, no pixels are clipped, and to blend each image with its neighbors. Once radiometry has been edited, separate RGBI and Panchromatic images are blended together to form single level 3 pan-sharpened 4 band TIFF images.

Image radiometric values were calibrated to specific gain and exposure settings associated with each capture using Microsoft's UltraMap software suite. The calibrated images were saved in TIFF format for input to subsequent processes. Photo position and orientation were calculated by linking the time of image capture, the corresponding aircraft position and attitude, and the smoothed best estimate of trajectory (SBET) data in POSPAC. Adjusted images were then draped upon a ground model and orthorectified. Individual orthorectified tiffs were blended together to remove seams and corrected for any remaining radiometric differences between images using Inpho's OrthoVista.

3.3. Airborne GPS and IMU Post Processing

During the sensor trajectory processing (combining GPS & IMU datasets) certain statistical graphs and tables are generated within the Applanix POSPac processing environment which are commonly used as indicators of processing stability and accuracy. This data for analysis include: Max horizontal / vertical GPS variance, separation plot, altitude plot, PDOP plot, base station baseline length, processing mode, number of satellite vehicles, and mission trajectory. All relevant processing results, plots and graphs produced in the POSPac processing environment for each of the nine sorties are provided in Appendix A.

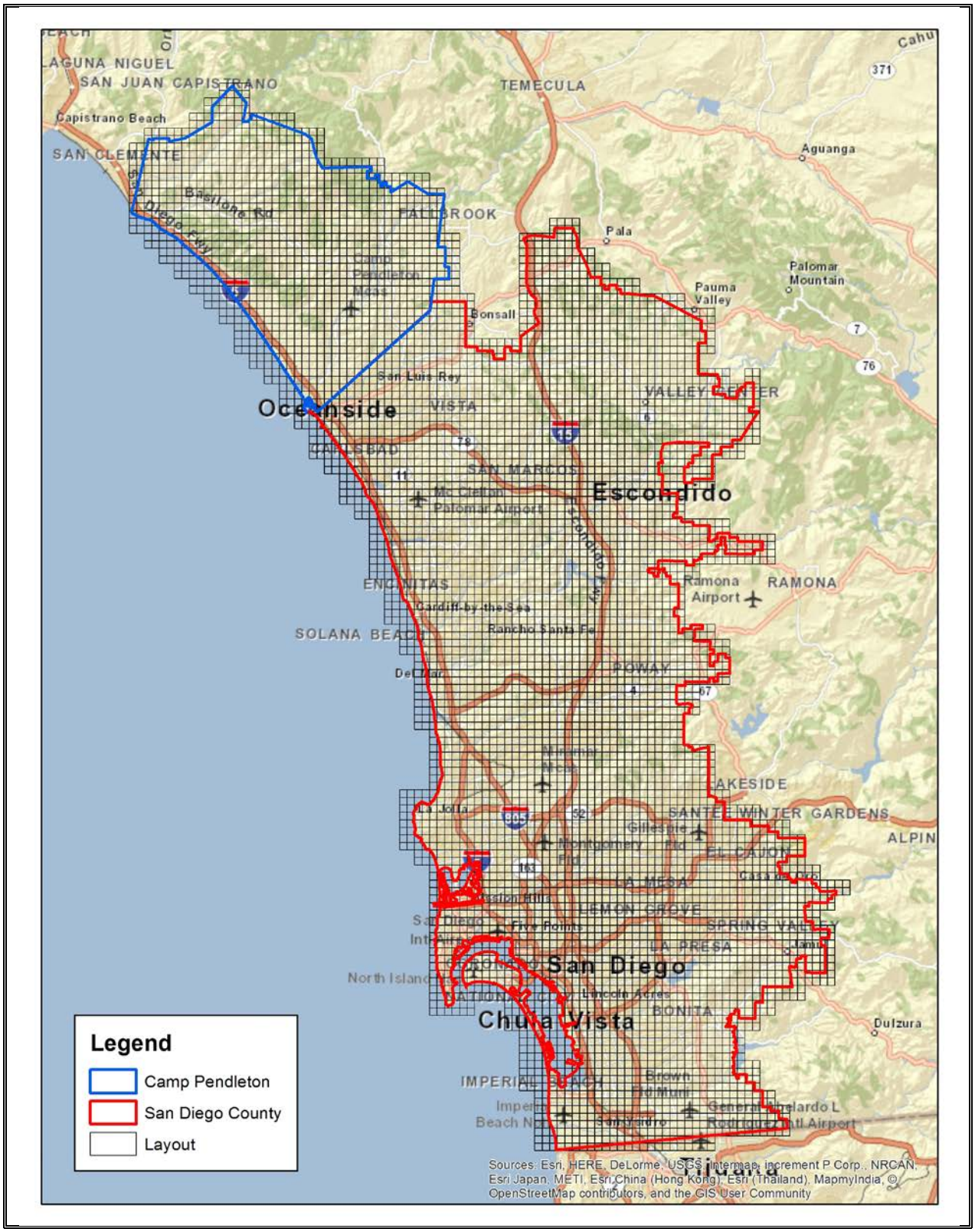
3.4. Aerotriangulation

Using RAW images, Airborne ABGPS/IMU external orientation parameters and ground control data the imagery control solution was further extended and densified using analytical aerotraingualtion adjustment techniques. This adjustment of the measurements was performed using a robust aerotriangulation software package, Image Station Aero Triangulation (ISAT) software, on softcopy photogrammetric workstations. A total of two aerotriangulation blocks were developed for the project, high and low. Each block was mathematically tied to its neighbor to ensure a uniform aerotriangulation solution for the entire area of interest. The final adjustment of these blocks was accomplished by using a rigorous simultaneous least squares bundle adjustment.

3.5. Orthophotography Creation

Digital orthophoto frames are created by using the LiDAR acquired under this task order. They were then combined with processed RAW imagery and aerotriangulation data. Manual Seamlines were drawn in MicroStation on every frame. Then, using the grid created with in-house software a set of "base" mosaicked tiles were created in Intergraph OrthoPro using a bilinear interpolation method on the three data sources (processed RAW imagery, aerotriangulation data and surface data). At this stage a final color balancing is also done to ensure a superior balance across the entire dataset. The first step to the quality control process is to draw circles on areas of concern. Reviewers look for mismatches at seamlines, smears caused by elevation discrepancies (building lean, bridge warping) and radiometric distortions. Then, a different technician edits the circles. Thus, images were thoroughly reviewed by the technician who circled errors as well as the editor, so that each image has been seen by at least three sets of eyes before submitted. There are a total of 6,296 10 cm tiles in GeoTIFF format. Tile layout is shown in Figure 5 on the following page.

Figure 5. San Diego County and Camp Pendleton 10 cm Ortho Tile Layout



4. Deliverables

- Project and tile (file) level metadata in XML format
- Camera calibration/current product characterization report
- Camera station control report with Airborne GPS and IMU data
- Digital stereo pairs (GeoTIFF format)
- MrSID images (15:1 compression rate, Gen 3 format, California State Plane Zone VI, survey feet)
- Aerotriangulation report
- Uncompressed, untiled digital orthorectified images (ArcGIS-readable GeoTIFF format, version 1.8.2)
- Collection, survey, and processing reports
- Project and deliverable level metadata in XML format
- Project report

5. Project Coverage Verification

The San Diego, CA 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.

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 75 of the 85 surveyed blind control points that were established for the project. 10 of the 85 points were not visible on the final orthophotos due to REASON. These points were not used in the production process. The overall RMSEx was measured and computed to be 0.39 ft (0.119 meters), the overall RMSEy was measured and computed to be 0.309 ft (0.094 meters) and the horizontal accuracy at the 95% confidence level was computed to be 0.498 ft (0.152 meters). The complete accuracy report can be found in Appendix B.

Figure 6. San Diego and Camp Pendleton 10 cm Ortho Frame Coverage